SCADAPack E Series

ISaGRAF User and Reference Manual

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SCADAPack E Series ISaGRAF User and Reference Manual

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Document Revisions

Revision	Date	Modification	Author
1.00	14 Sept, 2005	Initial release of SCADAPack E Series ISaGRAF User and Reference Manual	KN

1 Preface

1.1 Scope

This manual covers in details the SCADAPack E Series RTU[1] ISaGRAF interface.

1.2 Assumed Knowledge

Familiarity with the Microsoft Windows recommended.

1.3 Target Audience

- Systems Engineers
- Commissioning Engineers
- Maintenance Technicians

1.4 References

- E Series Configuration Reference Manual
- ICS Triplex ISaGRAF User Guide
- E Series ISaGRAF ADS Flow Monitor Interface Manual
- E Series ISaGRAF Technical Reference Manual
- E Series ISaGRAF Custom Function Block Reference
- E Series IO Connection Reference
- E Series Configurator Reference

[1] Also simply referred to as RTU in this document

2 Overview

Control Microsystems IEC 61131-3 implementation enables the programming of SCADAPack E Series RTU controller using the IEC 61131-3 programming languages. The programming environment uses the ISaGRAF Workbench to create, load and debug IEC 61131-3 application programs.

2.1 Supported Languages

ISaGRAF Workbench supports the five standard IEC 61131-3 programming languages and a sixth language called Flow Chart. These languages may be mixed and matched within an application to provide an optimum control strategy. The supported programming languages are described below.

Sequential Function Chart (SFC)

The Sequential Function Chart is a graphic language used to describe sequential operations in a process. The process is graphically partitioned into a set of well-defined steps containing actions performed using other languages such as ST, IL, LD and FBD. Steps are linked together with conditional transitions. This language is useful for batch processes and process procedures such as automatic startup and shut down.

Functional Block Diagram (FBD)

The Function Block Diagram is a graphic language used to build complex procedures from a library of functions. Standard library functions such as math and logic may be combined with custom library functions such as dial up modem control, HART Interface, PID controllers and Modbus master and slave protocols to create Function Block Diagram application programs. A class of programs called functions allows the creation of user functions that are not included in the library.

Ladder Diagram (LD)

Ladder Diagram is a graphic language combining contacts and coils to build logical discrete control procedures. This language is identical to the relay ladder logic used by most programmable Logic Controllers. Ladder Diagram contacts and coils may be used in the Function Block Diagram language for discrete control of functions.

Structured Text (ST)

Structured Text is a high-level structured language, similar to Pascal and C, that is used for complex procedures or calculation that cannot be easily implemented using graphic languages. Structured Text is the default language used to describe actions within the steps of the Sequential Function Chart language.

Instruction List (IL)

Instruction List is a low-level programming language, similar to assembly language that is used in small applications that require fast execution. This language is typically used to optimize sections of an application.

Flow Chart (FC)

Flow Chart is a graphic language that is used to describe sequential operations in an application. A Flow Chart diagram is composed of actions to be performed and tests on the actions performed. Actions and tests are connected by oriented links, representing data flow through the Flow Chart. Tests determine the yes or no path of the data flow.

2.2 Custom Functions

The standard ISaGRAF Workbench is enhanced with custom functions to support features provided by the SCADAPack ES controllers. Custom functions provide support for dial up modems, HART Interface modules, Store and Forward messaging, PID controllers and Modbus and DNP master and outstation as well as peer-to-peer communications. Custom functions are integrated into the ISaGRAF Workbench application programming environment.

2.3 Custom I/O Connections

SCADAPack ES, Allen Bradley and Idec modules or other Modbus devices are fully supported by the enhanced ISaGRAF Workbench. The ISaGRAF Workbench I/O connection dialog is used to add selected modules to the I/O connection list. Any combination of I/O modules may be selected up to the maximum number of I/O points supported by the SCADAPack ES controller. Each input or output point on a module is referenced with a variable name and, if required, a Modbus register address. ISaGRAF program variables are updated continuously with data from the external I/O modules.

3 Composition and Layout of this Manual

This manual comprises of the following documents:

- *E Series ISaGRAF Quick Start Guide* provides guides a new user through the creation of an ISaGRAF project and application, compilation of an ISaGRAF program, connecting and downloading the compiled ISaGRAF program to the RTU.
- *E Series ISaGRAF Technical Reference* describes the interface between SCADAPack E Series telemetry processors operating with DNP3 communication protocols and ISaGRAF target software.
- *E Series ISaGRAF Function Block Reference* describes in details all the custom function blocks provided with this ISaGRAF installation.
- *E Series ISaGRAF I/O Connection Reference* describes in details each individual I/O board and equipment provided with this ISaGRAF installation. I/O board and equipments provide ISaGRAF variables access to I/O data.
- *E Series ISaGRAF ADS Flow Reference* details the ADS 3500 Flow Monitor driver implementation for RTU.
- *E Series AGA Function Block Reference* describes ISaGRAF function blocks that are used to calculate the compressibility and the flow rate of a gas (AGA Report 8, AGA Report 3, AGA Report 7, and AGA Report 9).
- *E Series Modbus PLC Interface Manual* describes the RTU's PLC device driver for MODBUS and Open MODBUS/TCP protocols, its interface with ISaGRAF, and using it for communicating with PLC and peripheral devices.
- *E Series DF1 PLC Interface Manual* details the DF1 driver implementation for the RTU. This manual provides a detailed explanation of the DF1 I/O board types referenced in the *I/O Connection Reference Manual*.
- *E Series Idec PLC Interface Manual* details the Idec driver implementation for the RTU. This manual provides a detailed explanation of the Idec I/O board types referenced in the *I/O Connection Reference Manual*.

4 Installation and Licensing

This chapter covers the installation and licensing of the E Series ISaGRAF Workbench development environment.

4.1 System Requirements

The ISaGRAF Workbench can be installed on any personal computer running Microsoft Windows® 98 / NT4 / 2000 or the XP Operating Systems with the following minimum requirements:

- An Intel 80x86 or higher microprocessor.
- 8 Megabytes of conventional memory (16MB recommended)
- 20MB free disk space
- 640x480 VGA (800x600 VGA recommended)
- Mouse (or other pointing device)
- CD-ROM drive
- An RS-232 serial communication port

Note: A USB to RS-232 adapter will be required if PC or laptop is only equipped with a USB port.

4.2 Installation

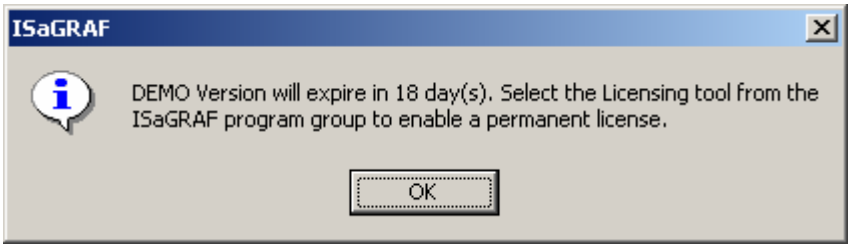
To install the ISaGRAF Workbench

- Insert the ISaGRAF CD into the CD-ROM.
- From your Windows Start menu, select **Run**.
- In the Run dialog, type **d:\setup (if d is your CD-ROM drive)** to run the installation executable. Alternatively, use Windows Explorer to locate the CD-ROM drive, and locate the file setup.exe in the root of the CD-ROM drive. Double click on the file to run the installation.
- Follow the on-screen instructions to complete the Workbench installation.

If all default settings are chosen, the E Series ISaGRAF Workbench is installed in the C:\ISAWIN\ESeries folder.

4.3 Demo Mode

When first installed ISaGRAF will run in the Demo Mode until a permanent license is installed. The Demo version will run for a maximum of 30 days. The following message is displayed when a user attempts to create or edit a project using the Demo version of ISaGRAF.



Note: This dialog also appears when a hardware license is issued but the license key is not connected.

When running in the Demo Mode ISaGRAF does not support the following features:

- Archiving or Restoring projects.
- Exporting IEC 61131 programs to a library.
- Exporting variables.
- Downloading project source code in a target controller.
- Uploading source code from a target controller.

You will need to permanently license your copy of ISaGRAF version 3.5 in order to enable the above license features.

4.4 Licensing

The ISaGRAF Workbench 3.5 provides two types of licenses, a software license and a hardware license. If you are using a Hardware License see the section ***4.6.2 - Install Sentinel Driver and Key*** .

The process of enabling the software license consists of two steps:

- Adding the License Component using the License Manager.
- Activating the License through Control Microsystems via phone or email.

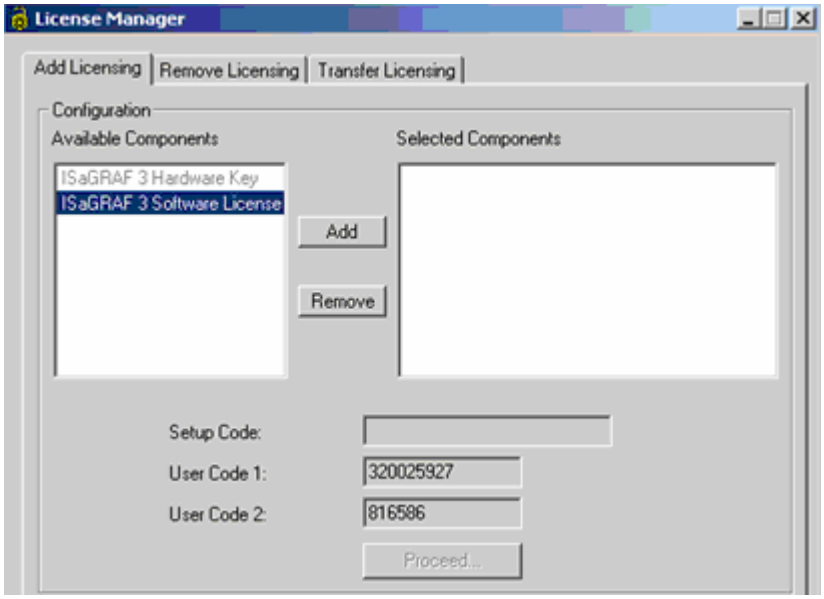
The ISaGRAF License Manager is used to install the ISaGRAF license, thus enabling the I/O variable capacity used in projects and to enable the features not supported in the Demo Mode. The License Manager is also used to:

- Transfer a license from one personal computer to another.
- Remove an ISaGRAF license from a personal computer.

4.5 Activating License

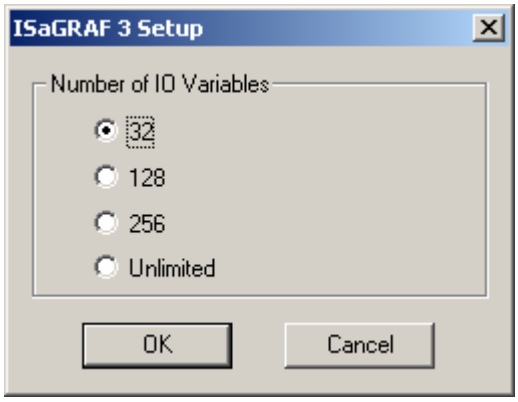
The ISaGRAF License Manager is used to install the license needed for full functionality of the Workbench. The following procedure describes how to permanently license your copy of ISaGRAF 3.5.

- Click on Windows **Start** | **Programs** | **ISaGRAF for E Series** | **Licensing** to launch the License Manager.

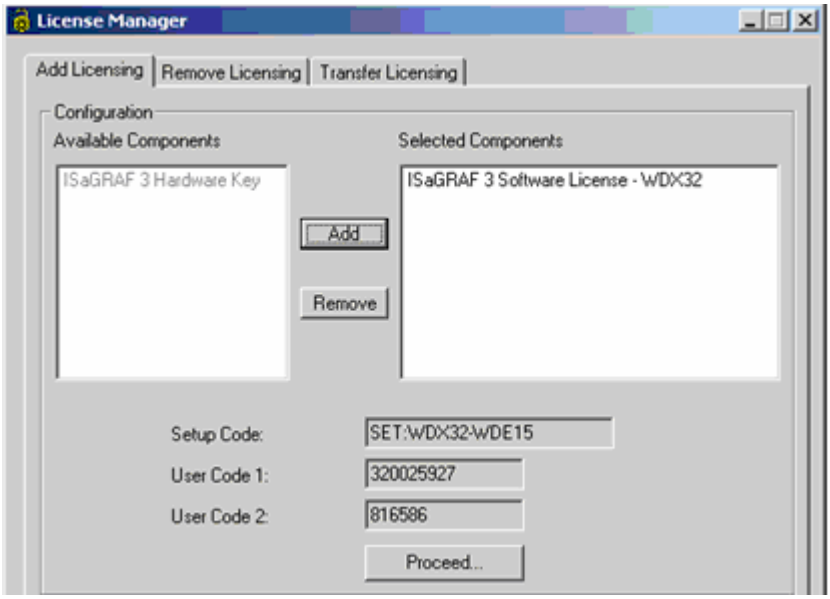


The **Add Licensing** tab displays the dialog necessary to add a permanent ISaGRAF license. In the Configuration area of the dialog the Available Components section displays the licensing formats available.

- From the Available Components window click on **ISaGRAF 3 Software License** and then click the **Add** button to move the selection to the Selected Components window. The following dialog is displayed.

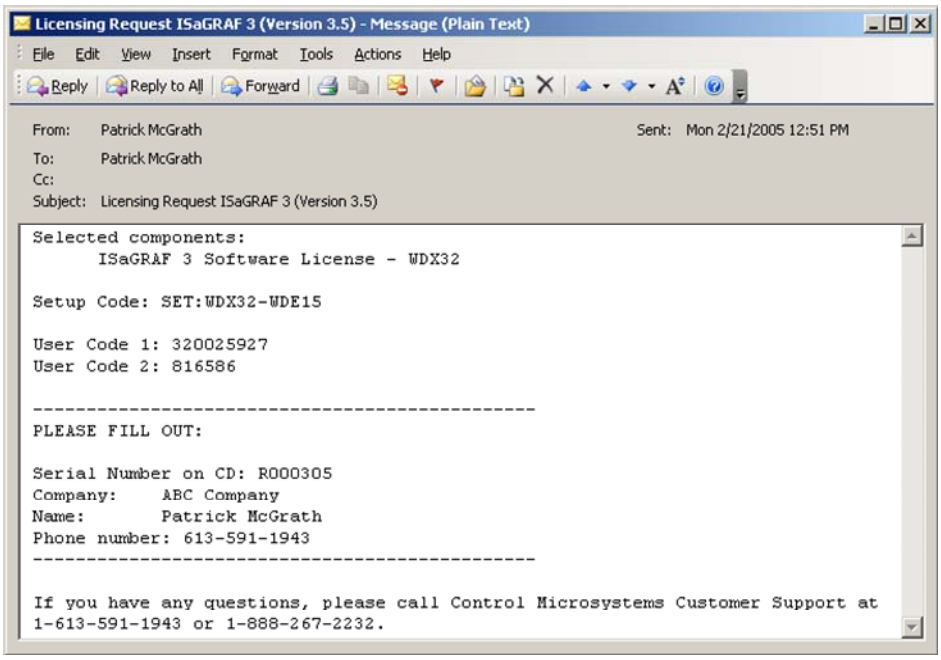


- Select the number of IO variables shown on the ISaGRAF CD jewel case and select the **OK** button. When the dialog closes the licensing window will display the license in the Selected Components column as shown below.



- Click the **Proceed** button. New user codes are created and a prompt to call or email CMI is displayed.

- Click the **Yes** button to automatically generate an License Request email as shown below.



Enter the fields displayed and send the email. If you wish you can phone Customer Support at 888-267-2232 for to complete the license activation over the phone.

If the activation request was sent via email, you will receive a return email containing the registration keys needed to activate your license. There are two sets of four registration keys that need to be entered in the License Manager.

- Enter the first four registration keys in the appropriate entry windows of the **Registration** section of the dialog.

- Click the **Register** button and **OK** on the next dialog prompting to enter the second set of Registration keys
- Enter the second set of registration keys are entered click the **Register** button.

The following dialog is then displayed to indicate the license has been enabled.

- Click the **OK** button to close the Registration Manager.

4.6 Transferring an ISaGRAF License

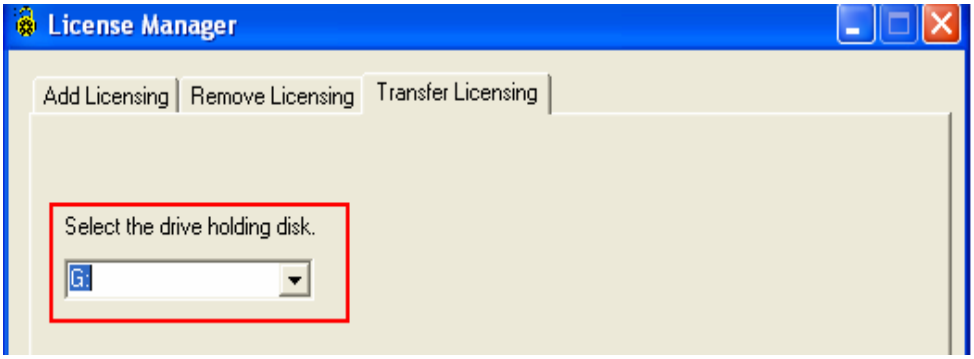
An ISaGRAF license can be transferred from one PC to another. Both PC's must contain an installation of the ISaGRAF workbench. Once the license has been transferred, the ISaGRAF installation on the source PC will continue operating in Demo mode for 30 days after which the application becomes non-functional. On the target PC however, full functionality will be enabled once the license transfer process is complete.

Transferring an ISaGRAF license from one PC to another comprises of three main steps:

- Creating a license transfer disk on the target PC.
- Transferring the ISaGRAF license from the source PC to the transfer disk.
- Installing the ISaGRAF license from the transfer disk to the target PC.

To transfer an ISaGRAF license from one PC to another PC:

1. From the Target PC, prepare the license transfer disk as follows:
   - Select **Start** | **Programs** | **ISaGRAF for E Series** | **Licensing** to launch the License Manager dialog on the target PC.
   - Select the **Transfer Licensing** tab on the License Manger dialog.
   - From the drop down dialog, *select the drive holding* the transfer disk. This drive may be any medium, such as diskette, USB memory stick, or a network disk drive.



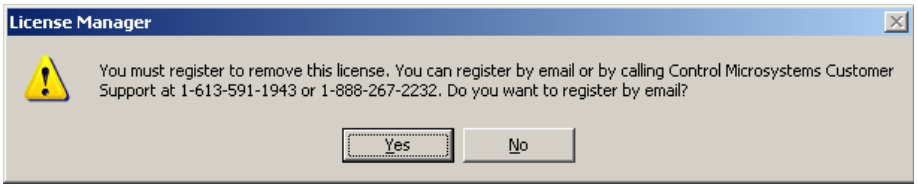
- Click on the **Create Transfer Disk** button. The license disk is created.
- Remove the transfer disk from the target PC.

2. Transfer the license from the source PC (currently licensed computer) to the license transfer disk created in step 1 as follows:
   - Insert the license disk into the source PC's peripheral inlet port.
   - Select **Start** | **Programs** | **ISaGRAF for E Series** | **Licensing** to launch the License Manager dialog on the source PC.
   - Select the **Transfer Licensing** tab on the License Manger dialog.
   - From the drop down dialog, *select the drive holding* the transfer disk created in step 1.
   - Click the **Transfer License to Disk** button. The license is removed from the source PC and copied onto the license transfer disk.
   - Remove the license transfer disk from the source PC.
3. Install the license onto the target PC.
   - Insert the disk containing the ISaGRAF license into the target PC's drive.
   - Select **Start** | **Programs** | **ISaGRAF for E Series** | **Licensing** to launch the License Manager dialog on the target PC.
   - Select the **Transfer Licensing** tab on the License Manger dialog.
   - From the drop down dialog, *select the drive holding* the transfer disk containing the ISaGRAF license copied from step 2.
   - Click on the **Complete Transfer** button to transfer the license onto the target PC.

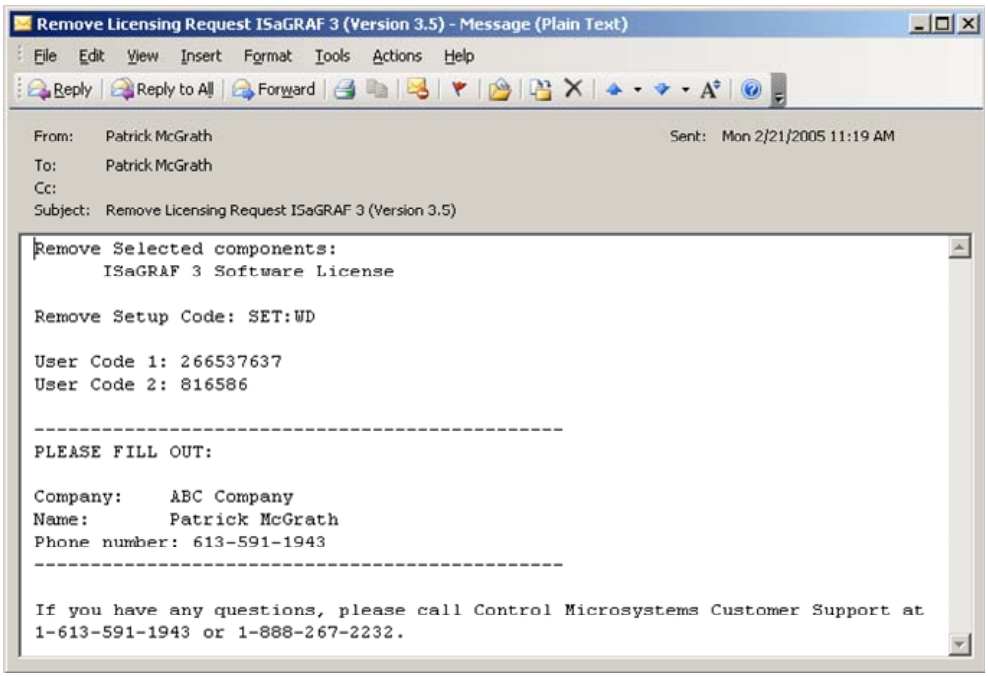
4.6.1 Removing an ISaGRAF License

To permanently remove the ISaGRAF license:

- Select **Start** | **Programs** | **ISaGRAF for E Series** | **Licensing** to launch the License Manager dialog.
- Select the **Removing Licensing** tab on the License Manager
- From the *License Components* box, click on **ISaGRAF 3 Software License (Active)– WDL** and then click the **Add** button to move the selection to the Selected Components window.
- Click the **Proceed** button and the following dialog is displayed.



- Click the **Yes** button to automatically generate an email as shown below.



Enter the fields displayed and send the email. If you wish you can phone Customer Support at 888-267-2232 for to complete the license removal over the phone.

If the license removal request was sent via email, you will receive a return email containing the registration keys needed to remove your license. There are two sets of four registration keys that need to be entered in the License Manager.

There are four registration keys that need to be entered in the License Manager.

- Enter the four registration keys in the appropriate entry windows of the **Registration** section of the dialog.
- Click the **Register** button and the following dialog is displayed indicating the license has been removed.

4.6.2 Install Sentinel Driver and Key

If you are using a hardware key for your license you will need to connect the hardware key to any parallel port on your PC, or a USB port if you have a USB key, and install the Sentinel driver for the key. The following procedure describes the steps required to install the hardware key and Sentinel driver.

- Connect the hardware key to any parallel port, or USB port, on your PC.

- Insert the ISaGRAF CD in your CD-ROM drive.
- From the Windows start menu select **Run**.
- Enter **d: \ISaGRAF Workbench\sentinel\SSD5411-32bit.EXE** (where d is your CD-ROM drive) and click **OK**.
- In the Sentinel Driver Setup Program window click on the Functions menu and select Install Sentinel Driver.

For further information refer to the Readme.txt file in the **d:\sentinel** folder on the CD.

SCADAPack E Series

ISaGRAF Quick Start Guide

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Document Revisions

Revision	Date	Modification	Author
1.00	**20 October 2005**	**Initial release of E Series ISaGRAF Quick Start Guide**	**KN**

1 Preface

1.1 Scope

This document is intended as a quick start guide to help new users create an ISaGRAF application, connect and download the application to a SCADAPack ES or ER controller in a timely fashion. The simple tasks presented in this guide therefore do not include important user information necessary for the control of real life applications. As such, this introductory document should be used in conjunction with the *ISaGRAF Workbench User Guide* and the *E Series ISaGRAF Technical Reference* Manuals.

1.2 Purpose

The purpose of this document is to provide a quick guide for creating an ISaGRAF application, connecting and downloading the application onto a SCADAPack ES controller.

1.3 Assumed Knowledge

Exposure to the ISaGRAF Workbench is recommended.

1.4 Target Audience

- Systems Engineers
- Commissioning Engineers
- Maintenance Technicians

1.5 References

- E Series Configuration Reference Manual
- CJ International ISaGRAF Manuals

2 Overview

This document is intended as a guide to help new users configure, program and operate the SCADAPack ES controller in a timely fashion. It is not meant to be a substitute for the ISaGRAF IEC61131 and SCADAPack ES Controller manuals, but rather as a companion to these manuals. For a thorough treatment of IEC 61131-11 ISaGRAF fundamentals, it is recommended that the user consult the E Series ISaGRAF Technical Reference Manuals and/or the ICS Triplex ISaGRAF User Guide.

In this manual, the user is guided through the task of creating a sample ISaGRAF Function Block Diagram program, compilation of the program, connecting to the SCADAPack ES RTU and downloading the compiled program onto the target kernel.

3 Programming with ISaGRAF

In this section, the user will be guided through creating a simple ISaGRAF application and downloading the compiled program to the RTU target kernel.

The process of creating an ISaGRAF application comprises of the following steps:

- Creating an ISaGRAF application.
- Defining dictionary variables.
- Connecting to external I/O
- Compiling and making the source code available for download to the target controller.
- Connecting and downloading the ISaGRAF application onto the target controller.
- Monitoring the ISaGRAF program variables online.

Each of the above tasks will be covered in the remaining section of this manual.

3.1 Hardware Requirements

The following hardware items are recommended to perform the tasks in this manual:

- CD containing the E Series Configurator Software.
- SCADAPack E Series controller – Make note of nominal operational voltage.
- A 12VDC/1.1A or 24 VDC/0.55A power supply depending on controller requirement.
- RJ-11 to DB-9 crossed cable or CMI part # 297324.
- Windows PC or laptop with the following minimum hardware requirements:
  - Intel (or equivalent) 386 CPU, 33MHz (486 CPU recommended)
  - 16MB RAM (32MB recommended)
  - 4MB free disk space
  - Microsoft Windows® 98 / NT4 / 2000 / XP Operating Systems
  - 640x480 VGA (800x600 VGA recommended)
  - Mouse (or other pointing device)
  - CD-ROM drive
  - One (1) RS-232 serial communication port
  - Ethernet port (optional)

Note:	A USB to RS-232 adapter will be required if PC or laptop is only equipped with a USB port.

3.2 Creating an ISaGRAF Application

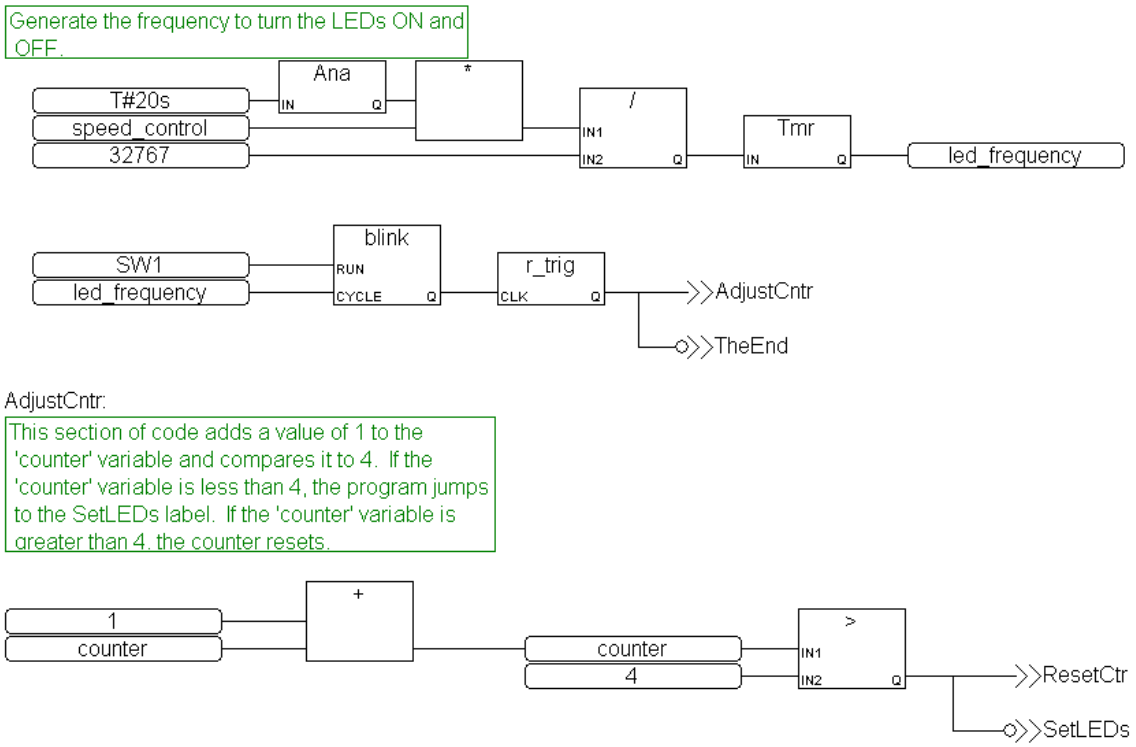
In this section, a sample ISaGRAF application which cycles through the first four digital output channels on the SCADAPack ES at a controlled frequency will be created and downloaded to the controller. The frequency at which the output LEDs are cycled is controlled by a potentiometer attached to one of the analog input ports of the SCADAPack ES.

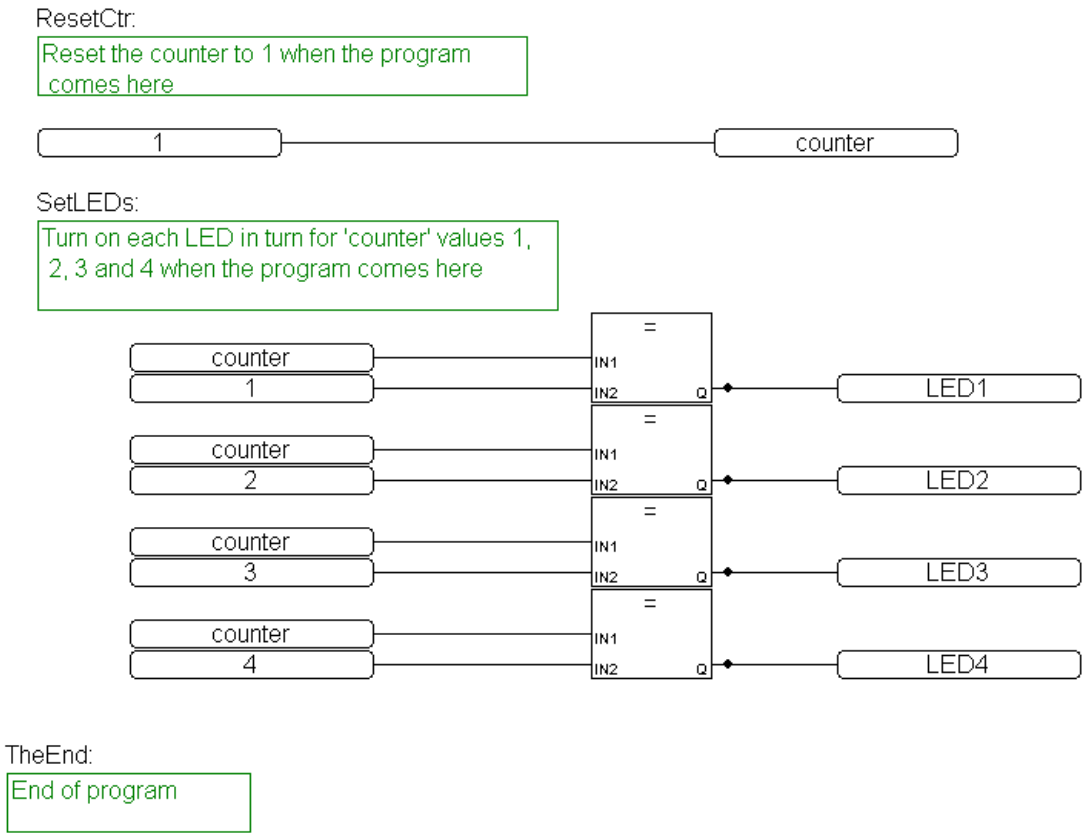
1. Launch the ISaGRAF workbench by clicking on **ISaGRAF for E Series** | **Projects** from the Windows programs menu.
2. Click on **File** | **New** from the Project Management menu bar to create a new application.

3. Enter a project name e.g. Proj1 and click on **OK** to close the dialog.
4. Double click on the project name e.g. Proj1 to open the project's program window.
5. Select **File** | **New** from the program menu bar to create a new program.
6. Specify a program name e.g. prog1 and select **FBD:** Function Block Diagram from the *Language* drop down menu in the New Program dialog. Leave the style parameter at the default **Begin**: Main Program.
7. Click on **OK** to and double click on the newly created program name e.g prog1 to open the FBD/QL editor.

Note:	All subsequent references to this sample program will be done using 'prog1.'

8. Create the sample FBD program exactly as captured in the screen shot below.





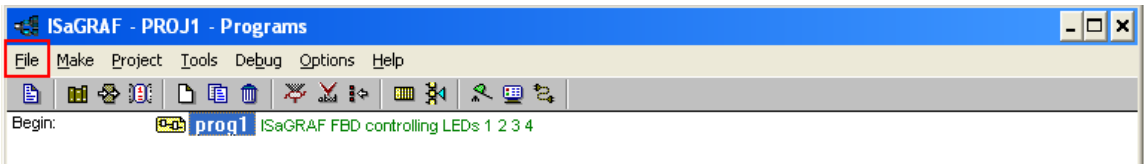
3.3 Defining Dictionary Variables

All variables defined within an ISaGRAF program must exist in the dictionary for the program to compile successfully. The following variables have been used in the above FBD program.

Variable Name	Type	Attribute
speed_control	Integer (Analog)	Input
counter	Integer	Internal
SW1	Boolean	Input
LED1	Boolean	Output
LED2	Boolean	Output
LED3	Boolean	Output
LED4	Boolean	Output
led_frequency	Timer	Internal

To define the above variables in the dictionary do the following:

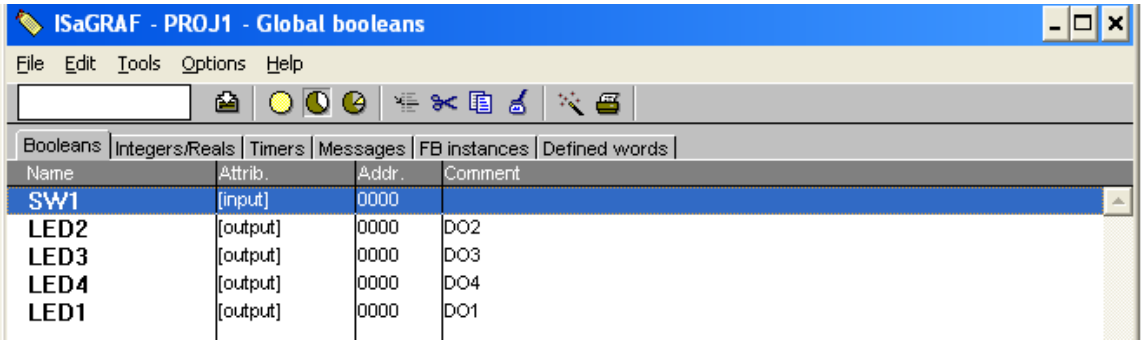
1. From the programs window, select **File** | **Dictionary** or click on the dictionary icon from the toolbar**.**



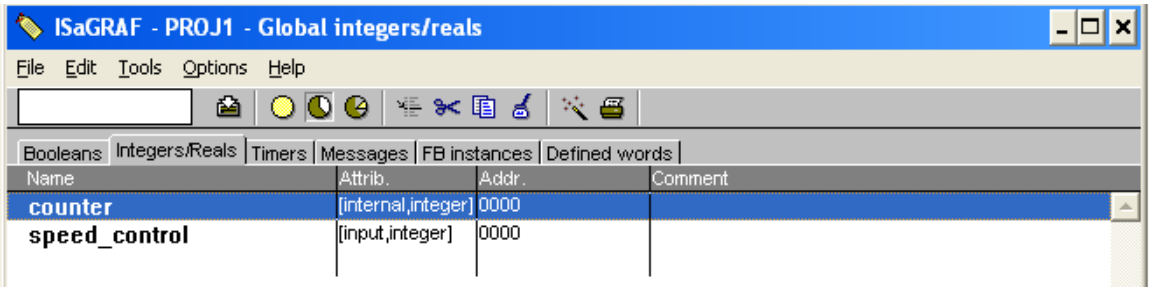
2. Select the Boolean tab.
3. Select **Edit** | **New** and fill out the Boolean Variable dialog as follows:
   - Name: SW1
   - Attribute: Input

Alternatively, you can double click on a blank white space under the Boolean Variable 'page' to open the Boolean Variable dialog.

4. Click on **Store** to add this variable to the dictionary.
5. Re-open the Boolean Variable dialog and add the LED output variables using the following entries.
   - Name: LEDx (x = 1, 2, 3, 4)
   - Attribute: Output
6. After adding all Boolean variables, select **File** | **Save** to save the changes. The completed panel should look like this



7. Select the Integers/Real tab within the dictionary.
8. Add the *speed_control* and *counter* variables, ensuring the correct attribute is selected.
9. Save the changes. The completed panel should look like this



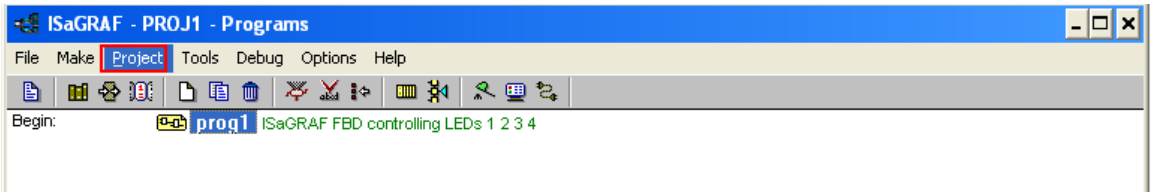
10. Select the Timers tab within the dictionary.

11. Add the *led_frequency* variable also ensuring the correct attribute is selected.
12. Save the changes.
13. After all variables have been entered, close the dictionary.

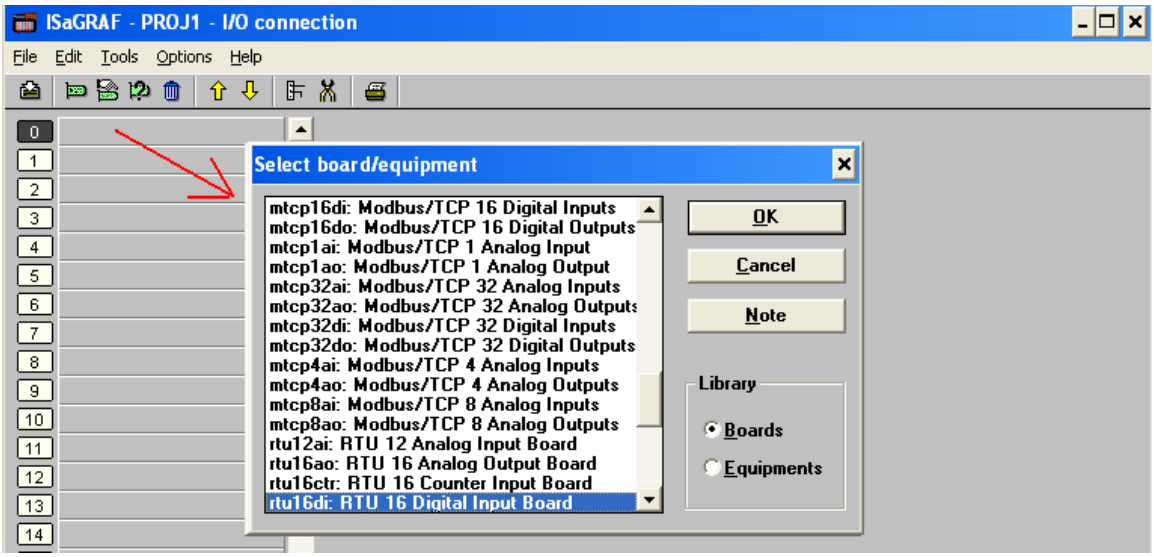
3.4 Connecting Variables to Physical I/O

Before compiling the application, the FBD program variables with input or output type attributes have to be connected to the physical I/O. This is done as follows:

1. Select **Project | I/O Connection** from the project's program menu bar or click on the icon .



2. Double click on the first empty slot 0 in the *I/O connection* window to view the list of available I/O drivers.



3. Select the board /Equipment board type labeled **rtu16di: RTU 16 Digital Input Board** from the list.
4. Click **OK**.

This board type provides and ISaGRAF application access to 16 physical digital inputs.

5. Double on terminal connector 1 directly underneath **board_address = 1** to open the *Connect I/O Channel #* dialog.
6. Select the variable SW1 from the *Free* list and click on the **Connect** button to attach this variable to the digital input channel 1 on the SCADAPack ES controller.
7. Click on **Close** to return to the I/O connection window..

8. Double click on the second empty slot 1 in the *I/O connection* window and select the **rtu16do: RTU 16 Digital Output Board**.
9. Click on **OK**.
10. Double click on terminal connector 1 directly underneath **board_address = 1** to open the *Connect I/O Channel #* dialog.
11. Select the variable LED1 from the *Free* list and click on the **Connect** button to attach this variable to the digital output channel 1 on the SCADAPack ES controller.
12. Click on **Next** and **Connect** to add the remaining digital output variables.
13. Close the dialog.
14. Follow the same procedure above and connect the integer variable *speed_control* to an analog input channel 1 using the **rtu1ai: RTU 1 Analog Input Board** module**.**
15. Click on  from the toolbar to save changes to the dictionary.
16. Close the dictionary.

3.5 Compilation of the Source Code

After completion of the source code (program, dictionary variables and I/O connection), the code is compiled for errors. If no errors are found, the ISaGRAF MAKE utility converts the source code into a form suitable for download onto the selected target controller.

1. Select **Make** | **Compiler** options from PROJ1's program menu bar.
2. Highlight *ISA86M: TIC Code for Inte*l and click on **Select**.
3. Click on **OK** to save the changes.
4. Click on **OK** on the next prompt indicating that all programs will be verified during the next make command. All other parameters can be left at default settings.
5. Select **Make** | **Make application** from PROJ1's program menu or click on  from the toolbar.
6. If no errors are detected, click on **Exit** from the Code Generator dialog. If errors are presented, it may be necessary to verify the source code.

3.6 Downloading the Compiled Program onto the Target RTU

Once the ISaGRAF program has been successfully compiled into a form suitable for download onto the target RTU using the 'Make' command, it then suffices to download the program onto the target RTU for execution. First, a communication link between the ISaGRAF Workbench and the RTU target kernel must be established.

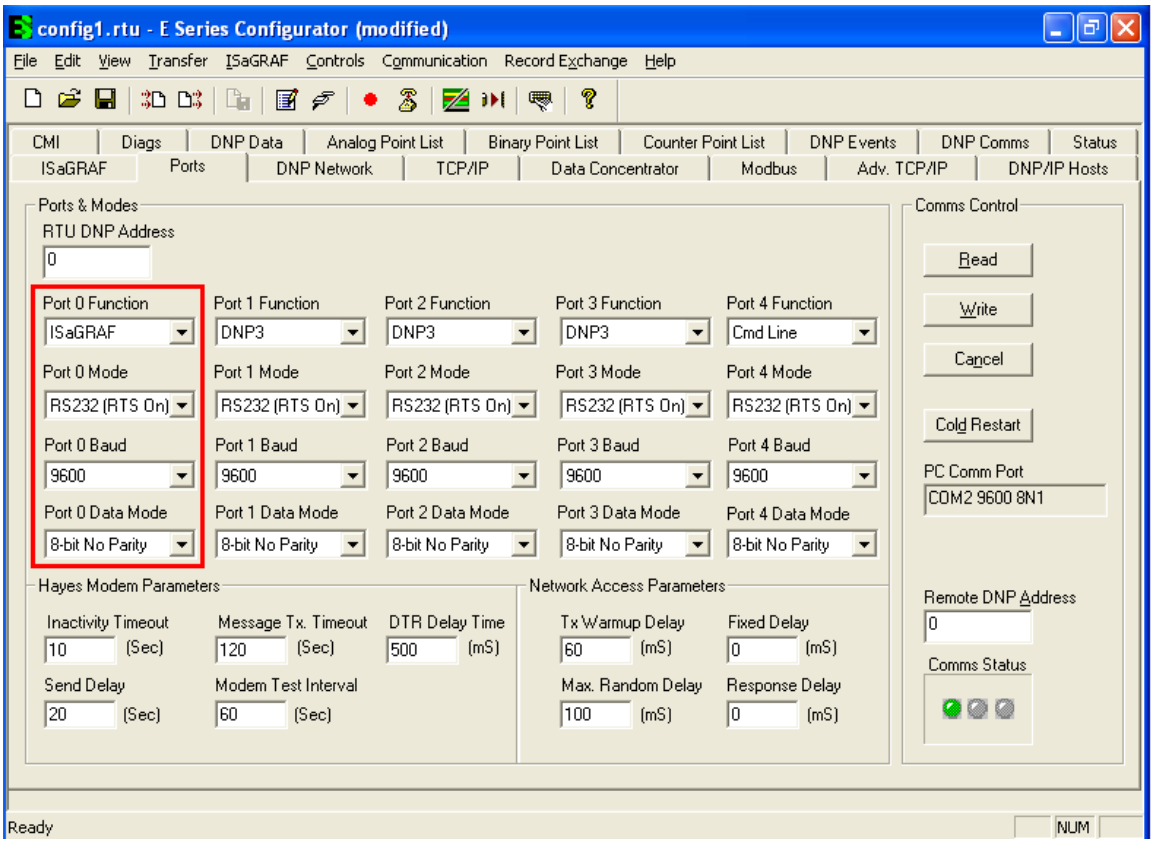
The SCADAPack ES controller supports a serial or Ethernet communication link to the ISaGRAF Workbench. In this project, a serial communication link will be used to enable communication between the ISaGRAF Workbench and the SCADAPack ES RTU.

To connect to the SCADAPack ES via a serial connection, one of the RTU communication ports must be set for "ISaGRAF'.

3.6.1 Configure the SCADAPack ES ISaGRAF Port

1. Select **Start | Programs | Control Microsystems | E Series Configurator | E Series Configurator** to launch this application.
2. Click on **Communication | Communication Device** from the E Series menu bar.
3. Alternatively, click on the icon  from the E Series Configurator toolbar to select the communication device.

4. Ensure that the **RS-232 (Serial) COM port** is selected.
5. Click on **OK** to close the dialog.
6. Select the *Ports* page.
7. Connect the PC to COM port 1 of the RTU.
8. Ensure that the Remote DNP Address in the *Comms Control* panel is correct and click on the Read button.



Note:	If communication problems are encountered at this point, such as if the yellow Comms status light on the bottom right hand corner of the *Ports* page remains lit, please refer to the *E Series Configurator User* Manual or the *SCADAPack ES Quick Start Guide*.

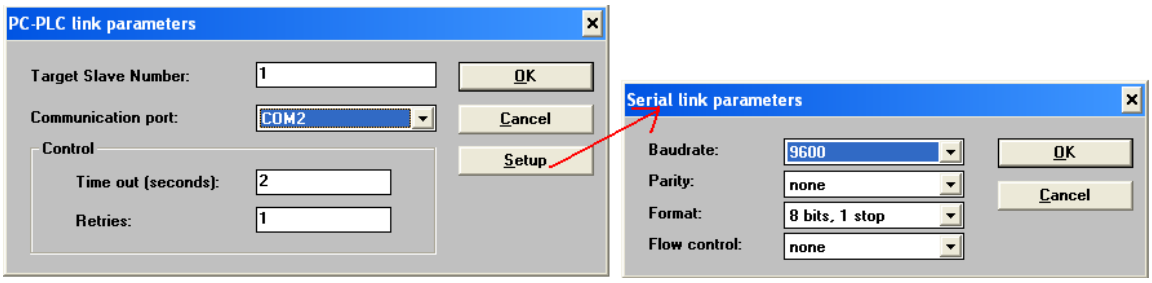
9. Ensure that **Port 0 Function** is set to ISaGRAF as shown in the screen capture above. Also make a note of the Baud Rate and Data Mode parameters.
10. Select **Communications** | **Disconnect** from the E Series Configurator menu bar to free the PC COM port.

Note:	This step is necessary to allow another application, ISaGRAF for example, to share the COM port.

3.6.2 Configure the ISaGRAF PC-PLC Link

1. On the RTU, remove the serial cable from Port 1 and plug it into Port 0, the ISaGRAF port.

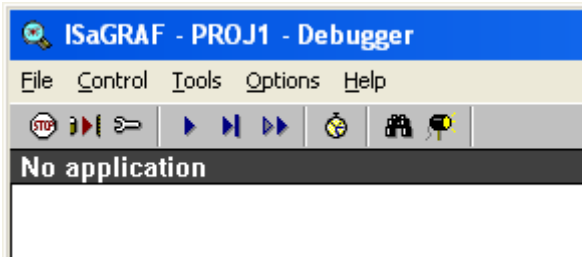
2. Within ISaGRAF click on **Debug** | **Link Setup** from PROJ1's Programs window to launch the PC-PLC link parameters dialog..
3. Alternatively, click on the icon  from the program window toolbar to launch this dialog.
4. Within the *PC-PLC link parameters* dialog,
    1. Select the PC serial port connected to the Port 0 of the RTU from the *Communication Port* drop down menu.
    2. Click on the **Setup** button.
    3. Ensure that baud rate and other link properties match those noted in step 9 above. The baud rate may have to be changed from 19200 to 9600.
    4. In the figure below, the RTU is connected to COM 2 of the PC and the link properties have been set to match those in the figure above.



    5. Click on **OK** on the Serial link parameters dialog to save the changes and close the dialog.
    6. Click on **OK** on the PC-PLC link parameters dialog to save the changes and close the dialog.
5. From PROJ1's program window click on **Debug** | **Debug.**

Alternatively, click on the icon  from the program window toolbar to launch this dialog.

6. The ISaGRAF debugger window will open with the message *No application* as shown below. This indicates that there is currently no application running in the controller.



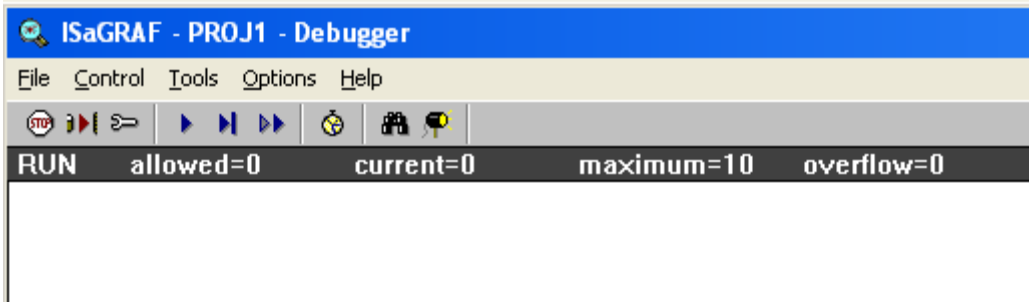
If presented with a different status message such as Disconnected or Logging… Cannot open COM2 communication port, double check the PC-PLC parameters.

7. From the Debugger menu bar, click on **File** | **Download.**

Alternatively, click on the icon  from the program window toolbar to initiate the download process.

8. Ensure that **ISA86M: TIC code for Intel** is selected in the Download dialog and click on **Download**.
9. Observe the download progress on the status bar.

After the download is complete, toggle the switch attached to digital input channel 1 of the SCADAPack ES and observe the LEDs on the controller digital output channels 1- 4 cycle in a round-robin fashion. The Debugger status bar will display RUN while the program executes as shown below.



10. The application variables may now be viewed in real time by opening the dictionary and observing the real time value of one of the variables.
11. Stop the running program by selecting **File | Stop Application** from the Debugger menu bar.

Alternatively, click on the icon  from the program window toolbar to stop the program from running.

12. The LEDs will stop turning on and off in a cyclic fashion.

This completes the exercise. Note that this simple exercise does not exhaust the capabilities of the SCADAPack ES controller. Please refer to the reference manuals that accompany your controller unit for details on the controller operation and capabilities.

SCADAPack E Series

ISaGRAF Technical Reference Manual

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1.10	**19 January 2006**	**Incorporated Dec 19. 2005 changes**	**KN**
1.00	**20 October 2005**	**Initial release of E Series ISaGRAF Technical Reference Manual**	**KN**

1 Preface

1.1 Scope

This document describes the interface between SCADAPack E Series RTU[1]'s processors operating with DNP3 communication protocols and the ISaGRAF target software.

1.2 Purpose

The purpose of this document is to describe in details the interface between SCADAPack E Series RTU's processors operating with DNP3 communication protocols and the ISaGRAF target software. It is assumed that the reader is familiar with the ISaGRAF workbench software. For more information about the ISaGRAF program environment, the see the *ISaGRAF Workbench Users Guide* which contains the *ISaGRAF Language Reference and ISaGRAF Target User's Guide.* Additional programming options specific to the E Series controllers can be found in the *E Series ISaGRAF Function Blocks Reference* manual.

Note that the ISaGRAF Target User's Guide included with the ISaGRAF Workbench manual is not dedicated to any particular ISaGRAF target and describes general concepts. The material covered in this manual together with the E Series *ISaGRAF Function Blocks Reference* manual therefore supplements the *ISaGRAF Target User's Guide* for it deals exclusively with the implementation of the ISaGRAF Target kernel on a Control Microsystems E Series processor.

Specific technical reference information pertaining to ISaGRAF Function Blocks used with SCADAPack E Series RTU's can be found in the *E Series ISaGRAF Function Blocks Reference* manual.

1.3 Assumed Knowledge

Familiarity with the ISaGRAF Workbench is strongly recommended.

1.4 Target Audience

- Systems Engineers
- Commissioning Engineers
- Maintenance Technicians

1.5 References

- E Series Configuration Reference Manual
- CJ International ISaGRAF Manuals

[1] Also referred to simply as 'RTU'

2 Overview

This document describes the interface between SCADAPack E Series RTU operating with DNP3 communication protocols and ISaGRAF target software. The ISaGRAF target kernels execute on the RTU and are built in to the operating system firmware. The ISaGRAF Workbench executes on a PC and provides application generation, transferring and debugging through connection to the target by serial or network communications.

2.1 Terminology

The SCADAPack E Series RTU uses ISaGRAF target software within the RTU's multi-tasking environment. The RTU's have a fixed amount of on-board I/O on the main unit but may be connected to remote I/O units via serial or Ethernet communications.

2.2 ISaGRAF Workbench Software

An ISaGRAF application can be loaded, configured, debugged on the SCADAPack E Series RTU from a standard PC running the ISaGRAF Workbench if there is some physical connection between the PC and the RTU. Serial and Ethernet or TCP/IP communication facilities are provided by the RTU to allow different options of connection from a standard PC.

The ISaGRAF Workbench software is used to create, manage and simulate IEC61131-3 ISaGRAF applications. The ISaGRAF Workbench debugger transfers ISaGRAF application programs to the target and provides application-debugging facilities. ISaGRAF Workbench is compatible with Windows 95/98, NT, 2000 and XP. For more information on the ISaGRAF Workbench, refer to the *ISaGRAF Workbench User's Guide*.

The following sections describe the various connection options that are available between the ISaGRAF Workbench and SCADAPack E Series RTU's.

2.2.1 ISaGRAF Serial Communications

The ISaGRAF Workbench debugger operates with the SCADAPack E Series RTU's on an RTU serial port configured as "ISaGRAF". Operation is supported for RS232, RS422 and RS485.

Note:	A maximum of one RTU serial port may be configured as "ISaGRAF" for local connection to an ISaGRAF Workbench debugger.

An ISaGRAF application previously loaded into the RTU (via Workbench or the E Series Configurator) will execute on the RTU regardless of whether an "ISaGRAF" port is configured.

The "ISaGRAF" port on an RTU can also be used for other purposes:

- ISaGRAF "Diagnosis/Monitoring Tool"
- MODBUS RTU Slave Protocol communications
- RTU Command Line and Diagnostics "Shell"

For more information on MODBUS RTU protocol communications see Section ***8 - ISaGRAF MODBUS Link***.

Operation of the Command Line Shell allows an ASCII terminal to be connected to the RTU "ISaGRAF" port. Entering <Enter> <Enter> <Enter> from the terminal activates the command line shell. Note that the terminal communications settings must match those on the RTU's "ISaGRAF" port. Once activated, the RTU Command Line prompt is displayed, and ISaGRAF Workbench Communications are disabled on this port. RTU diagnostics and all command line facilities are

available. This functionality is the same as that provided by a configured "Cmd Line" port, without re-configuring the RTU.

To return from Command Line Shell back to ISaGRAF Workbench communications, enter the command line "BYE" command and disconnect the ASCII terminal. For more information on the Command Line RTU facilities see the *E Series Operation Reference Manual*.

2.2.2 MODBUS Serial Communications

As described in the previous section, the ISaGRAF Workbench port can be used for MODBUS serial communications. In addition to this, a second serial port can be configured on the SCADAPack E Series RTU to provide separate MODBUS communications. An RTU serial port configured as "ISaGRAF 2" supports the same Modbus operations as the standard 'ISaGRAF' Workbench port but does not support the RTU Command line and Diagnostic shell. Note that the SCADAPack E Series also supports a native MODBUS Slave driver that does NOT require ISaGRAF. Refer to the *E Series Modbus PLC Interface* document for more information.

A maximum of one RTU serial port may be configured in "ISaGRAF" mode. However, both the "ISaGRAF" and "ISaGRAF 2" ports may be used simultaneously, and either port may be used to communicate with either of the E Series RTU ISaGRAF target applications. Operation is supported for RS232, RS422 and RS485. For example, the following scenarios are possible:

- ISaGRAF Workbench on "ISaGRAF" port to Target 1, Modbus master on "ISaGRAF 2" port to Target 1
- Modbus master on "ISaGRAF" port to Target 1, second Modbus master on "ISaGRAF 2" port to Target 1
- Modbus master on "ISaGRAF" port to Target 1, second Modbus master on "ISaGRAF 2" port to Target 2
- Modbus master on "ISaGRAF" port to Target 2, ISaGRAF "Diagnosis/Monitoring Tool" on "ISaGRAF 2" port to Target 2, etc.

An ISaGRAF application previously loaded in the RTU (via the Workbench or the E Series Configurator) maps data to Modbus registers accessible via the "ISaGRAF" or "ISaGRAF 2" port(s).

Note:	The "ISaGRAF 2" port does NOT support RTU Command Line and Diagnostics "Shell" command.

For more information on MODBUS RTU protocol communications see Section ***8 - ISaGRAF MODBUS Link***.

2.2.3 ISaGRAF Remote Access

The SCADAPack E Series RTU provides various remote access facilities for ISaGRAF. These are:

- ISaGRAF application file transfer
- ISaGRAF application file transfer via FTP
- ISaGRAF workbench communication via DNP3
- ISaGRAF workbench communication via TCP/IP

Each of these facilities is further described in Section ***9 - Remote ISaGRAF Access***.

2.3 SCADAPack E Series ISaGRAF Target

The SCADAPack E Series RTU is equipped with ISaGRAF target kernel software. This allows the RTU to perform PLC control functions using the IEC 61131-3 international standard. The control functions provided by ISaGRAF targets are completely autonomous of any supervisory (SCADA Master) system or communications network (e.g. DNP3). The ISaGRAF application operates on the RTU regardless of the state of remote communications. The ISaGRAF target supports ISaGRAF Workbench versions 3.20 and later.

The SCADAPack E Series RTU firmware supports the simultaneous execution of up to two ISaGRAF target kernels on the same RTU. This allows up to two independent ISaGRAF applications to execute simultaneously on the same RTU. The two ISaGRAF targets within the RTU have ISaGRAF Slave addresses of 1 and 2 respectively. The Workbench "Slave Number" communications parameter must be set to match the E Series RTU's ISaGRAF Slave address for the appropriate target kernel prior to connecting the ISaGRAF Workbench debugger to the RTU. Note that both ISaGRAF targets are activated by default, i.e. there is no additional configuration required to activate the second ISaGRAF target.

The status (running or halted) of an ISaGRAF application on each target kernel can be obtained from the E Series Configurator software or via separate *ISaGRAF Application Halted* DNP3 binary points 50100 and 50101. These binary points are part of the DNP3 system points dedicated to providing the status of the RTU. . For more information see the *E Series DNP3 Technical Reference Manual*.

An RTU port selected for 'ISaGRAF' communications mode can also support MODBUS Slave Protocol communications. For more information see Section ***8 - ISaGRAF MODBUS Link***.

The SCADAPack E Series RTUs are based on Intel processors. The ISaGRAF Workbench software generates target independent code (TIC) for Intel, Motorola and PC Simulation. To use ISaGRAF applications with the SCADAPack E Series RTU, ISaGRAF Workbench Make-Compile Options should be selected for "**ISA86M: TIC Code for Intel**".

ISaGRAF Workbench Application Symbols are not required for the SCADAPack E Series RTU.

2.4 Target Scanning Cycle

The ISaGRAF target executes user applications in a cyclic fashion. As such, user applications are also designed to execute in a cyclic fashion. As shown in Figure 2-1, the target cycle has distinct phases. These include obtaining inputs to the ISaGRAF application (via Input Boards), execution of various parts of the ISaGRAF user application, and updating of outputs (via Output Boards).

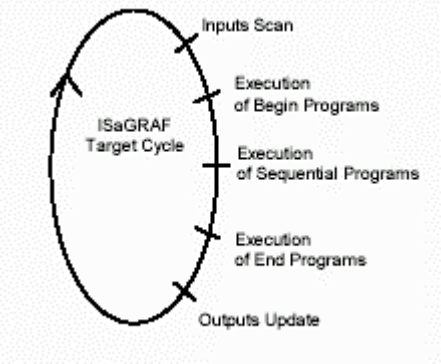


Figure 2-1 Target Scanning Cycle

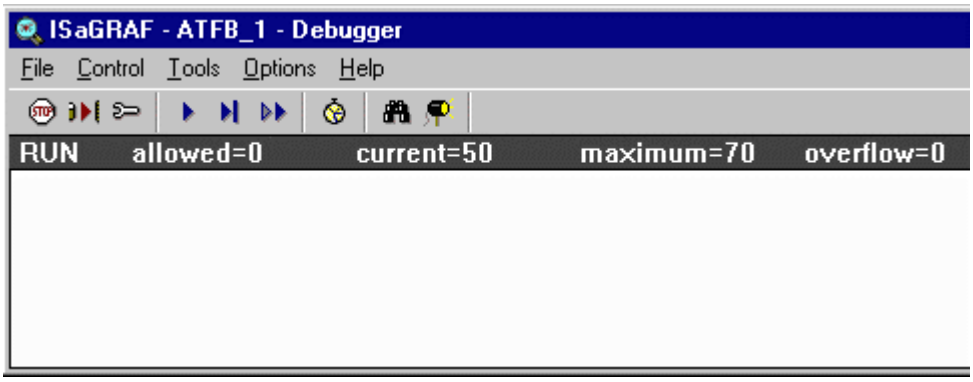
The ISaGRAF target executing on a SCADAPack E Series RTU can be configured to scan in various ways:

- Continuous scanning
- Cycle Timing scanning
- High Priority scanning

2.4.1 Continuous Scanning

This is the default-scanning mode that is used by most ISaGRAF applications. At the end of an ISaGRAF target scan, the target simply restarts the scanning cycle. Typically, the SCADAPack E Series RTU has many bookkeeping activities it must perform in addition to scanning the user's ISaGRAF application. As such, the ISaGRAF application may be interrupted for short periods throughout the scan cycle. This can result in some variations in the time it takes ISaGRAF to perform each scan. If the RTU becomes unusually busy performing these bookkeeping activities, this can result in slower execution of the user's ISaGRAF application.

The ISaGRAF Debugger indicates "allowed=0" for the Continuous Scanning mode of operation.



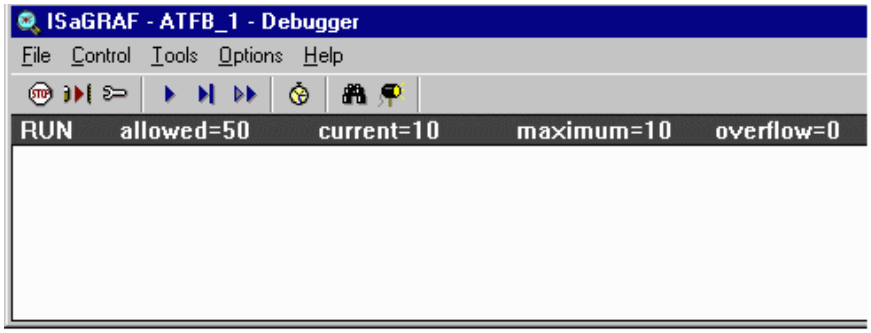
It is recommended that, where possible, ISaGRAF applications use continuous scanning mode and be designed to take into account variations in the timing of the scan rate.

2.4.2 Cycle Time Scanning

This scanning mode can be either permanently set for an ISaGRAF application or temporarily set. Instead of the ISaGRAF target restarting the scanning cycle immediately after updating the outputs, as in the default continuous mode, the scanning process is stopped for a certain time interval. This time interval, which makes up the difference between the actual time of a complete scan and a fixed cycle time, is now available for the RTU to perform activities that previously may have interrupted the scanning cycle. As such, the ISaGRAF application will tend to have more consistent cycle scan times.

Note that the SCADAPack E Series RTU can still schedule other system operations in the middle of an ISaGRAF scan if necessary. This is particularly the case for larger ISaGRAF applications. Smaller ISaGRAF applications will not normally be interrupted by most routine RTU activities.

The ISaGRAF Debugger indicates a non-zero "allowed" time when cycle timing scanning mode is in use as shown in the figure below.

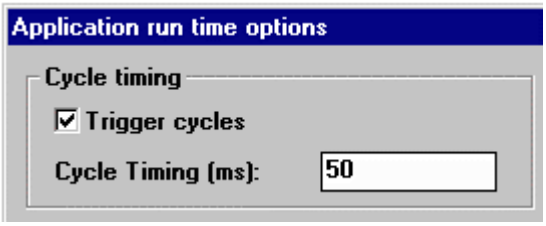


The ISaGRAF Debugger will report "overflow" errors if the time taken to perform an individual scan is higher than the fixed (allowed) time. In this case the fixed cycle time should be increased.

The following sections describe methods for permanently or temporarily setting Cycle Timing scanning for an ISaGRAF application. Note that ISaGRAF also supports changing this mode from within a user application. See the "SYSTEM" function within the *ISaGRAF Language Reference* manual for this implementation. Using this facility overrides both Permanent Cycle Timing and Temporary Cycle Timing as described below.

2.4.2.1 Permanent Cycle Timing

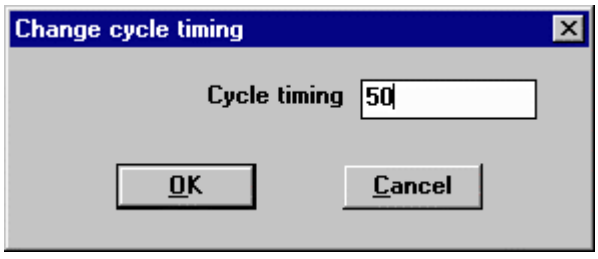
To permanently set an ISaGRAF application cycle time from the Workbench, enable *Trigger Cycles* from the *Application Run Time Option dialog under the Make menu* and enter a value in the *Cycle Timing* field. This must be done before the application is compiled.



To change the ISaGRAF scanning mode from cycle timing back to continuous scanning, disable *Trigger Cycles* and recompile the ISaGRAF user application.

2.4.2.2 Temporary Cycle Timing

To temporarily set or change an ISaGRAF application cycle time, select the ISaGRAF Debugger menu option *Control | Change Cycle Timing* menu or "Set Cycle Timing" i



Note that the Cycle Timing value entered is in milliseconds (mS).

To change the ISaGRAF scanning mode from cycle timing back to continuous scanning, set *Cycle Timing* to zero (0).

WARNING:	If the ISaGRAF application or the SCADAPack E Series RTU is restarted, a temporary cycle timing setting is lost. The cycle time will revert to the setting as compiled by the Workbench.

2.4.3 High Priority Scanning

The SCADAPack E Series RTU supports increasing the priority of ISaGRAF target kernel task(s) in the RTU operating system. This can be achieved by setting the "ISA_TASK_PRI" parameter using the RTUPARAM function block within the ISaGRAF application. In order words, an ISaGRAF application can raise its own priority, subject to the following criteria:

The user ISaGRAF application must be in "Cycle Timing" scanning mode. (See Section ***2.4.2-Cycle Time Scanning*** above), and

Each ISaGRAF application cycle must scan in less time than the fixed *Cycle Timing* setting.

High priority scanning permits the ISaGRAF target kernel task to run at a higher priority than routine RTU operating system tasks. If multiple ISaGRAF target kernels are executing on the same RTU, it is not recommended for more than one of the tasks to operate in high priority scanning mode.

Where high priority scanning is required, it is suggested that user ISaGRAF applications be split into a high priority and low priority component. Two ISaGRAF target kernels could be started to separately execute the low and high priority components in separate tasks. One of the tasks could then use the RTUPARAM function block to increase its priority.

For more information on the RTUPARAM function block see the *E Series ISaGRAF Function Block Reference* manual.

2.5 Target Memory usage

The SCADAPack E Series RTU is equipped with FLASH memory, which contains the RTU operating system, ISaGRAF target kernel engine and telemetry communications software. The RTU is also equipped with battery-backed System Static and Dynamic RAM for storage of user ISaGRAF applications. See section ***3.8-Application Storage*** for details on application storage. RTU system RAM is also available for facilities such as Online ISaGRAF application modification, RTU communication buffer storage, file system support, RTU SCADA event data and historical sample storage, etc. Note that 4K of static RAM is also available for retained variables. See section ***3.11-Retained variables*** for details.

3 RTU PLC Functionality

3.1 Input Scanning

3.1.1 Binary Inputs

The update of physical binary input states to an ISaGRAF application, either from RTU local I/O, remote I/O or other RTU data, is synchronized with the scanning of the ISaGRAF application. ISaGRAF updates its input boards at the start of the scan cycle as described in section ***2.4 - Target Scanning Cycle***. Physical RTU Binary (Digital) inputs are represented as DNP3 Binary Objects in the RTU address space and *Boolean* variables in an ISaGRAF application.

3.1.2 Analog Inputs

The update of physical analog input values to an ISaGRAF application is similar to binary inputs. The process is also synchronized with the scanning of the ISaGRAF application. The SCADAPack E Series RTU supports 16-bit, 32-bit Signed Integers as well as 32-bit Floating-Point DNP3 data objects. Analog variables are represented as 32-bit Signed *Integer* or 32-bit Floating Point *Rea* within the ISaGRAF environment. The RTU supports data conversion between the 16-bit and 32-bit analog data types. For more information see Section ***6 - ISaGRAF Analog I/O Boards / DNP3 Representation & Conversion***.

3.2 Output Updates

3.2.1 Binary Outputs

RTU binary outputs are updated at the end of the scan cycle following changes made by the ISaGRAF application to its Boolean variables. See section ***2.4 - Target Scanning Cycle*** for details. RTU Binary (Digital) inputs are represented as DNP3 Binary Objects in the RTU address space and *Boolean* variables in an ISaGRAF application.

By default an executing ISaGRAF application, with output variables connected to the physical I/O boards, has control of those Physical RTU Binary Outputs (or Derived RTU points), unless a "Remote Interlock" is active for individual binary points. If a remote interlock point is defined, but is not active, changes to the state of the relevant binary output within the ISaGRAF application will be reflected at the physical RTU point. Binary point controls initiated via DNP3, external to the RTU, will not control the physical RTU point in this case. If a remote interlock point is defined and is active, changes to the state of the relevant binary point within the ISaGRAF application will not be reflected at the physical RTU point. Instead changes remotely initiated via DNP3 will be reflected at the physical RTU point.

3.2.2 Analog Outputs

The SCADAPack E Series RTU analog outputs are updated at the end of an ISaGRAF scan similar to Binary Outputs. The RTU supports 16-bit Signed Integer, 32-bit Signed Integer and Floating Point DNP3 data objects. Analog variables are represented as 32-bit Signed *Integer* or 32-bit Floating Point *Rea* within the ISaGRAF environment. The RTU also supports data conversion between the 16-bit and 32-bit analog data types. For more information see Section ***6 - ISaGRAF Analog I/O Boards / DNP3 Representation & Conversion***

By default an executing ISaGRAF application, with analog points on ISaGRAF Output Boards, has control of those Physical RTU Analog Outputs (and Derived RTU points), unless a "Remote Interlock" is active for individual analog points. If a remote interlock point is defined, but is not active, changes made by the ISaGRAF application to the state of the relevant analog point will be

reflected at the physical I/O. Analog output controls initiated via DNP3, external to the RTU, will not control RTU points in this case. If a remote interlock point is defined and is active, changes made by the ISaGRAF application to the state of the relevant binary point will not be reflected at the physical I/O. Instead changes remotely initiated via DNP3 will be reflected at the physical I/O.

3.3 Language Types

The ISaGRAF target kernel tasks on the SCADAPack E Series RTU support all five IEC 61131-3 (1993) international standard sequencing languages. These are:

- SFC - Sequential Function Chart
- FBD - Function Block Diagram
- LD - Ladder Diagram
- ST - Structured Text
- IL - Instruction List

Control applications may be written in ISaGRAF using any combination of the above languages, and can be executed on either, or both, ISaGRAF target kernel tasks. In addition, ISaGRAF Workbench versions 3.30 and above support the 'FC – Flow Chart'.

3.4 Data Types

The SCADAPack E Series RTU supports the following ISaGRAF data types and corresponding DNP3 objects:

Table 3-1: Relationship between ISaGRAF and E Series Data

ISaGRAF Data	DNP3 Object	Data Format
Integer Analog	16-bt or 32-bt analog point	Signed integers
Real Analog	Short floating point analog point	32-bit IEEE-754 standard
Boolean	Binary Points	ON or OFF
Timer		1 ms counts
Message	Octet string points	Up to 255 characters strings

ISaGRAF integer analog variables can correspond to RTU DNP3 16-bit signed integers or 32-bit signed integers. Real ISaGRAF analog variables correspond to DNP3 'short floating point' objects (stored as standard IEEE-754 32-bit single precision floating point values). See Section ***6 - ISaGRAF Analog I/O Boards / DNP3 Representation & Conversion*** for information on data type conversion used by the RTU.

3.5 Operators

ISaGRAF application software supports a comprehensive array of built-in operators including functions for:

Table 3-2: ISaGRAF Supported Built in Operators and Functions

boolean operations	&, =1, >=1, and, or, f_trig, r_trig, rs, sema, sr, xor
analog operations	*, +, -, /, and_mask, ArCreate, ArRead, Arwrite, cmp, limit, max, min, mod, neg, not_mask, odd, or_mask, rand, rol, ror, shl, shr, stackint, xor_mask
data manipulation	1 gain, mux4, mux8, sel
type conversion	ana, ascii, boo, char, msg, real, tmr
comparison	<, <=, <>, =, >, >=
maths	abs, acos, asin, atan, cos, expt, log, pow, sin,sqrt, tan, trunc
string management	cat, day_time, delete, find, insert, left, mid, mlen, replace, right
timer control	tof, ton, tp,
control/signal handling	average, blink, derivate, integral, hyster, lim_alrm, sig_gen
Counting	ctd, ctu, ctud
system access	operate, system

3.6 Conversion Tables

ISaGRAF allows up to 127 look-up Conversion Tables, each containing up to 32 look-up points. An interpolated value is used for points not specifically defined within the lookup table. Conversion Tables can be applied to RTU physical Analog Input channels or derived RTU Analog points. The Conversion Table “curve” must be monotonically increasing or monotonically decreasing.

The SCADAPack E Series RTU allows combinations of integer and floating point values to be applied to conversion tables. The "Electrical" values of the conversion tables apply to the RTU I/O or Derived points, and the "Physical" values apply to internal ISaGRAF variable values.

3.7 On-line Modification

On-line modification allows an ISaGRAF application running on the SCADAPack E Series RTU to be modified, without any discontinuity of execution. Use of this feature is subject to available RAM memory on the RTU and similarity of the new application with the executing application.

On-line application modification is achieved via the following mechanism. Firstly the modified ISaGRAF code is loaded into a new memory area and consistency checking is performed between the new applications data requirements and the original data. On completion of the current scan, control is then handed over to the modified code and execution continues. If further modifications are made, the code is loaded to another new memory area, and execution is handed to the new code on completion of the current scan.

ISaGRAF will only accept a newer version of the running application code if the database is identical. This means that new variables, function block instances and changes to the IO board mapping are not allowed. The applications name can be changed, though the ISaGRAF debugger will not show any information about the renamed application, making it of limited use.

Note: After an RTU restart (e.g. after power outage), the RTU ISaGRAF task will load the ISaGRAF application version it was previously executing.

3.8 Application Storage

The ISaGRAF application(s) loaded into the SCADAPack E Series RTU is stored in a file system partition on the RTU protected from power loss. When power is restored after an outage, for instance, each stored application is validated by the RTU and a separate copy is made in non-volatile memory (NV-RAM) (for execution). If the file system copy is successfully validated, this is copied to the NV-RAM area where execution commences, otherwise the NV-RAM area copy is checked for validity. If the NV-RAM copy is valid, ISaGRAF application copies this application back to the file system, then begins execution of the NV-RAM copy. If both copies are not valid, the ISaGRAF kernel task waits for a new application to be loaded.

Variables, other than those specified as *retained variables*, are stored in volatile (non-saved) memory. ISaGRAF initializes their values when the application restarts.

NOTE: Applications that have undergone on line modification are NOT stored in non-volatile file memory. See section ***3.7 - On-line Modification***.

The ISaGRAF applications are stored in the RTU file system in one or both of two files called isa11 and isa21. These are used for the ***first*** and ***second*** ISaGRAF target kernel tasks, respectively. The configurable "Slave" number of the ISaGRAF target kernel does not impact these file-names.

3.9 I/O Locking

ISaGRAF I/O locking provides the ability to lock inputs and outputs into a certain state, regardless of their true state. This provides a mechanism for freezing I/O in a fixed state, allowing maintenance to be performed while the ISaGRAF application is still executing.

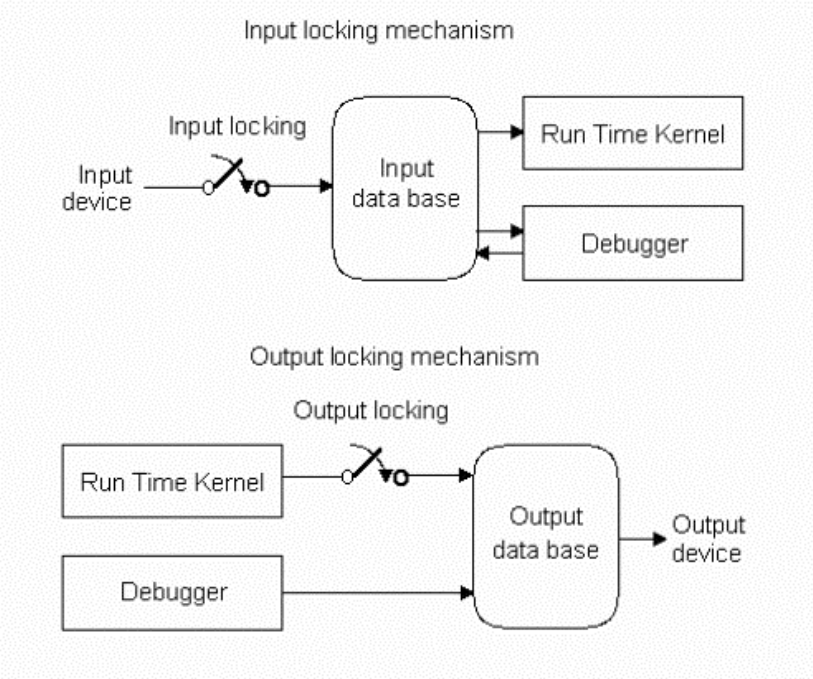


Figure 3-1: Online Modification

shows diagrammatically how inputs and outputs are isolated when locked.

Figure 3-1: Online Modification

3.10 Message variables

Message variables provide a mechanism for manipulating groups of ASCII characters (strings). For example, ASCII characters can be read in from external equipment, processed by an ISaGRAF program, which may then build and output an appropriate ASCII reply. Message variables also interface with the SCADAPack E Series RTU system string points. Message variables are limited to 255 characters in length.

3.11 Retained variables

The SCADAPack E Series RTU provides a facility for storing ISaGRAF application variable values that are required to retain their value when power is lost, or when an ISaGRAF application is restarted. A copy of every ISaGRAF Boolean, analog, timer and message variable with the *retain* attribute is stored by the RTU, at the end of every ISaGRAF application scan (for the two ISaGRAF target kernel tasks), in non-volatile areas of RTU memory. After an ISaGRAF application restarts, all retained variables for that application are refreshed with their last saved value. 4K of RTU system NV-RAM is set aside for retained variables, which must be shared by the four standard variable types. Table 3-3 shows the memory used for each of the standard types.

Table 3-3: Memory used by standard types

Variable Type	Memory Usage
Boolean	1 byte
Analog	4 bytes
Timers	4 bytes
Messages	256 bytes

The amount of memory allocated to each variable type is automatically allocated by the SCADAPack E Series RTU depending on the application requirements and the number of active applications in the RTU. The ISaGRAF Workbench *Application run time options* memory list is not required for the SCADAPack E Series to use retained variables. Non-volatile memory storage for retained variables is allocated at a fixed memory segment within the RTU. The total retained memory space requirements of an application must be less than 12MB or an ISaGRAF startup error will occur (Error 8).

Note: The SCADAPack E Series RTU clears retained variable values when the NV-RAM is cleared. E.g. using hex switch "FC" factory default initialization mode, hex switch “F1” ISaGRAF initialization mode, when an the RTU EPROM is changed or patched, or when using the command line “CLEAR ISAGRAF” command. The ISaGRAF target kernels in the RTU automatically clear retained variables for the appropriate target kernel task when a new ISaGRAF application is loaded.

3.12 Second ISaGRAF Kernel Features

A user ISaGRAF application executing on the RTU's second ISaGRAF kernel may open any RTU points on Input Boards, but cannot open output boards already opened by the First ISaGRAF kernel.

The RTU's ISaGRAF communication task may only communicate with one ISaGRAF Kernel task at a time, but will dynamically switch between them as requests are received from each. The address of the ISaGRAF Kernel to communicate with is configured in the Workbench *Debug Link-setup* menu.

IMPORTANT: It is recommended that if ISaGRAF PLC I/O boards are to be used in both kernels simultaneously, then they should be communicating to PLC devices through different RTU ports. It is possible for both ISaGRAF kernels to use the same port depending on the number of boards attached to each. If there are too many boards in each kernel trying to communicate out a single port then the ISaGRAF communications task may watchdog when starting the applications. A work-around for this is to use DNP to transfer and start the applications. After the application has been restarted, it can be debugged through the Workbench to debugger.

Valid kernel addresses for both ISaGRAF kernels are "1" and "2" for the first and second kernels, respectively.

4 I/O Interfaces

4.1 Physical I/O

All physical inputs and outputs on the SCADAPack E Series RTU can be accessed by the ISaGRAF application via the ISaGRAF I/O Board mechanism. RTU internal data points may also be accessed via I/O boards (or via other C Function Blocks) as will be described later in this section. Each I/O board must be supplied with an address that specifies the RTU DNP3 starting point index or offset when reading from inputs or writing to outputs. This address is entered into the *board_address* field of the particular I/O board within the ISaGRAF Workbench I/O Connections editor.

For information on the SCADAPack E Series RTU DNP3 physical point index mapping see the *E Series DNP3 Technical Reference* manual.

By default, physical RTU output points (Binary & Analog) attached to an ISaGRAF Output Board are under ISaGRAF control while a user ISaGRAF application is executing. A "Remote Interlock" point may be associated with each output point, and if defined but inactive, ISaGRAF retains control of the output point. Communication requests to physical outputs are rejected when ISaGRAF is controlling an output point.

If a "Remote Interlock" point is defined, but is active, then ISaGRAF does not have control of the physical output point. Communication requests to physical outputs are accepted in this case.

4.2 Derived Data

All derived RTU data (e.g. calculations to be sent to a SCADA master, data for peer-to-peer communications, etc.) can be accessed by the ISaGRAF application in exactly the same way as physical I/O, i.e. using the I/O board mechanism (or function block mechanism). All the board types used to access physical I/O may be used for manipulating derived RTU data, by simply specifying an appropriate *board_address*. Derived RTU points can be created using the E Series Configurator. Once created, a user ISaGRAF application can open I/O boards attached to the derived points.

Analog I/O boards can receive data from and send data to ISaGRAF in integer or real (floating point) format from pseudo or physical I/O points (e.g. for SCADA). Floating point RTU data is related to integer data through Raw and Engineering scaling parameters configured for each point. Analog points on I/O boards may also use ISaGRAF Conversion Tables. For more information on data conversion, see Section ***6 - ISaGRAF Analog I/O Boards / DNP3 Representation & Conversion***.

Note: ISaGRAF output boards used for derived outputs *export data* from an ISaGRAF application to the RTU database. This data is then available to the SCADA master system or other peer RTUs. Similarly ISaGRAF input boards used for derived points *import data* from the RTU database into an ISaGRAF application. Control data from a SCADA master, or peer RTU for example is then available to the ISaGRAF application.

ISaGRAF derived outputs = SCADA master inputs, Peer RTU input data

ISaGRAF derived inputs = SCADA master outputs, Peer RTU output data

ISaGRAF input variables attached to input boards from RTU derived data may be initialized to a predefined state via the ISaGRAF *OPERATE* command. See section ***7 - ISaGRAF OPERATE Function*** below. Figure 4-1 shows an example of the ISaGRAF I/O board interface, with inputs attached to the currently selected board (rtu16di) displayed on the right.

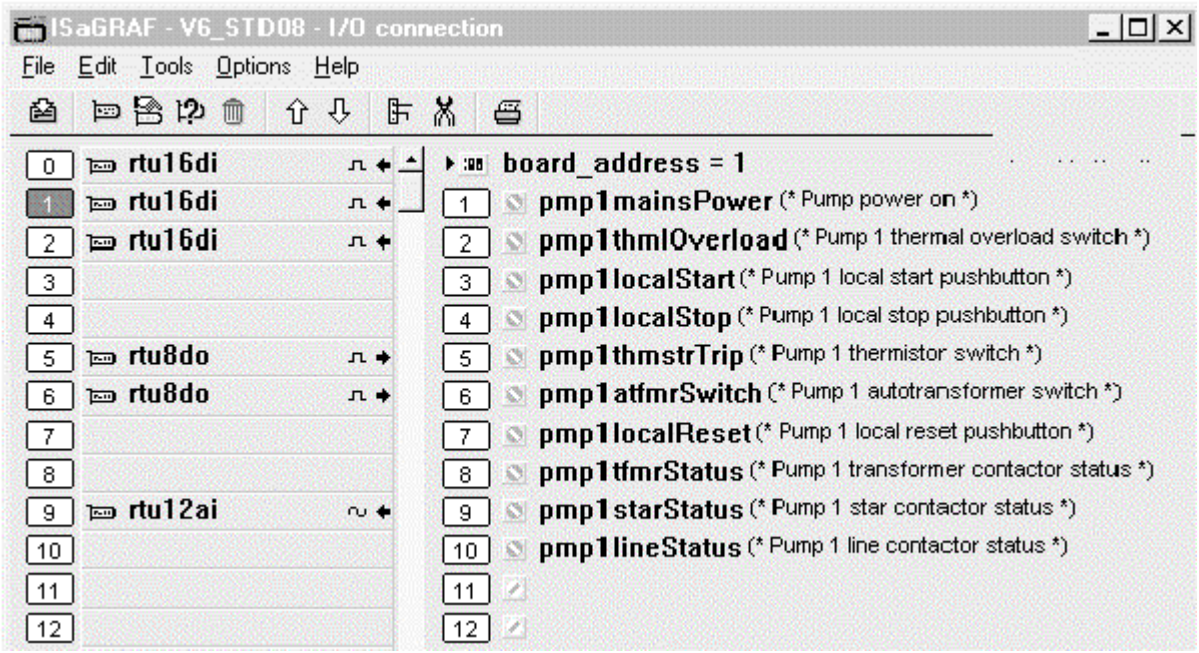


Figure 4-1 ISaGRAF I/O boards

4.3 ISaGRAF I/O Boards

The list below contains the minimum number of I/O Boards available in the Control Microsystems' ISaGRAF library and implemented on the SCADAPack E Series RTU. Note that the ISaGRAF I/O board types access DNP data points configured in the RTU. Both physical I/O points and derived points are accessed using an I/O board. ISaGRAF I/O boards need not necessarily correspond to the RTU I/O card arrangements.

Table 4-1: List of Available I/O Boards

Board Name	ref+	ISaGRAF Data Type	DNP3 Objs supported
rtu16di	0001	16 Boolean Inputs	Physical Input, Derived & System Binary Objects.
rtu32di	0001	32 Boolean Inputs	Physical Input, Derived & System Binary Objects
rtu4do	0002	4 Boolean Outputs	Physical Output, Derived & System Binary Objects
rtu8do	0002	8 Boolean Outputs	Physical Output, Derived & System Binary Objects
Rtu16do	0002	16 Boolean Outputs	Physical Output, Derived & System Binary Objects
rtu8dos	000B	8 Boolean Outputs	Physical Onput, Derived & System Binary Objects with Status
rtu16dos	000B	16 Boolean Outputs	Physical Onput, Derived & System Binary Objects with Status

rtu6ai	0003	6 Analog Inputs*1	Physical Input &, Derived Integer & Floating Point Objects.
rtu2ao	0004	2 Analog Output*1	Physical Output &, Derived Integer & Floating Point Objects
rtu4ao	0004	4 Analog Outputs*1	Physical Output &, Derived Integer & Floating Point Objects
rtu2aos	000C	2 Analog Output*1	Physical Output &, Derived Integer & Floating Point Object with Status
rtu4aos	000C	4 Analog Outputs*1	Physical Output &, Derived Integer & Floating Point Object with Status
rtu16ctr	0005	16 Counter Inputs	Counter Input Objects
rtu32ctr	0005	32 Counter Inputs	Counter Input Objects.

+ For advanced ISaGRAF users: other I/O Boards, I/O Configurations or Complex Equipment types based on these reference numbers shown are possible. Number is shown in HEX format. The E Series RTU has not limit on the number of I/O channels per board for types 0001,0002, 0003, 0004, 000B & 000C.

*1 See Analog Input and Output Board representation and conversion rules in Section ***4.3 - ISaGRAF I/O Boards*** and Section ***6 - ISaGRAF Analog I/O Boards / DNP3 Representation & Conversion***.

4.3.1 Digital Input Boards

Physical RTU digital points may be imported into ISaGRAF through Digital Input (di) boards (ISaGRAF *Boolean Input Board* types). Where an ISaGRAF application attaches a Boolean variable to a Digital Input Board, the *Current State Property* of the digital point will be read into the ISaGRAF variable. If the digital point is a Physical Binary DNP3 I/O address, the physical digital input channel corresponding to that address is read.

4.3.2 Digital Output Boards

Physical RTU digital outputs have two sets of ISaGRAF interfaces. The state of a digital output is controlled through the Digital Output (do) boards (ISaGRAF *Boolean Output Board* types). The feedback status of digital outputs are read through Digital Output Status (dos) boards (ISaGRAF *Digital Input Board* types).

Derived RTU Digital points are controlled through Digital Output (do) boards (ISaGRAF *Boolean Output Board* types). The feedback status of derived digital points is read into Digital Input (di) boards (ISaGRAF *Boolean Input Board* types).

Where an ISaGRAF application attaches a Boolean variable to a Digital Output Board, the *Current State Property* of the digital point will be controlled from the ISaGRAF variable.

4.3.3 Analog Input Boards

Physical RTU Analog points may be imported into ISaGRAF through Analog Input (ai) boards (ISaGRAF *Analog Input Board* types). Where an ISaGRAF application attaches an “Integer” analog variable to an Analog Input Board, the *Current Integer Value* property of the analog point will be read into the ISaGRAF variable. Where an ISaGRAF application attaches a “Real” (floating point) analog variable to an Analog Input Board, the *Current Eng. Value* property of the analog point will

be read into the ISaGRAF variable. Where the analog point is a Physical Analog DNP3 I/O address, the Physical Analog Input channel corresponding to that address is read. See the following section regarding reading the value of a Physical Analog Output channels.

Both "Integer" and "Real" ISaGRAF analog variables may be mixed on the same ISaGRAF Analog Input Board.

ISaGRAF analog integer variables contain signed 32-bit numbers. The value of an "Integer" analog variable will be the physical analog input variable in the range MIN-RAW to MAX-RAW as configured in the point's attributes.

ISaGRAF analog real variables contain 32-bit floating point numbers. For a physical analog input variable, variables will be in the range MIN-ENG to MAX-ENG as configured in the point's attributes.

4.3.4 Analog Output Boards

Physical RTU Analog Outputs have two sets of ISaGRAF interfaces. The value of physical analog outputs is controlled through Analog Output (ao) boards (ISaGRAF *Analog Output Board* types). The feedback status of analog outputs are read into ISaGRAF through Analog Output Status (aos) boards (ISaGRAF *Analog Input Board* types).

Derived RTU Analog points are controlled through Analog Output (ao) boards (ISaGRAF *Analog Output Board* types). The feedback status of derived analog points is read into ISaGRAF through Analog Input (ai) boards (ISaGRAF *Analog Input Board* types).

Where an ISaGRAF application attaches an "Integer" analog variable to an Analog Output Board, the *Current Integer Value* property of the analog point will be controlled from the ISaGRAF variable. The analog point's *Current Integer Value* property, MIN-RAW, MAX-RAW, MIN-ENG & MAX-ENG attributes will be used to automatically calculate the *Current Eng.Value* property of the point.

Where an ISaGRAF application attaches a "Real" (floating point) analog variable to an Analog Output Board, the *Current Eng. Value* property of the analog point will be controlled from the ISaGRAF variable. The analog point's *Current Eng. Value* property MIN-RAW, MAX-RAW, MIN-ENG & MAX-ENG attributes will be used to automatically calculate the *Current Integer Value* property of the analog point.

Both "Integer" and "Real" ISaGRAF analog variables may be mixed on the same ISaGRAF Analog Output Board.

4.3.5 Counter Input Boards

ISaGRAF application *Counter Input Boards* (ctr) support only ISaGRAF "Integer" analog variables. The *Current Integer Value* property of the physical counter input will be read into the ISaGRAF variable.

ISaGRAF analog integer variables contain signed 32-bit numbers, however Counter Inputs are 32-bit unsigned values. For counter values less than 2147483648, the counter value and ISaGRAF variable value are the same. For counter values above 2147483647, the ISaGRAF variable indicates a negative value. The user ISaGRAF application must handle the case where counter input numbers greater than 2147483647 are indicated as negative ISaGRAF numbers. This may be necessary, for example, where a comparison or subtraction of counter values occurs in the user ISaGRAF application. (e.g. Preset counters or reset counter prior to value exceeding 2147483647).

4.3.6 SCADAPack ER I/O Boards

These I/O boards are only supported on the SCADAPack ER RTU's. Applications on the SCADAPack ES that reference these I/O boards will not start.

These SCADAPack ER I/O boards reference physical channels directly, as opposed to referencing a specific I/O channel by DNP point number. The supported SCADAPack ER I/O boards are listed in the following table

Board Name	Board Reference (hex)	ISaGRAF Data Type
Er16ro	0x18	16 Boolean Outputs
er16ai	0x19	16 Analog Inputs *
er32di	0x1A	32 Boolean Inputs

* See Analog conversion rules in Section 6

The SCADAPack ER I/O boards reference the respective physical I/O cards by specifying a *Rack_Num* and *Slot_Num* field. The *Rack_Num* and *Slot_Num* fields are set via user configuration through the I/O board parameters. These are set as part of the ISaGRAF application and are entered into the I/O board parameter fields within the ISaGRAF Workbench I/O Connections editor.

The required fields are described as follows

Rack_Num: specifies the ER rack that the I/O Card is located on.
0 = Local Rack
1 = Expansion Rack, etc.

The default value is 0 (i.e. local rack).

Slot_Num: specifies the I/O card slot on the specified ER rack
1 = I/O Card Slot 1
2 = I/O Card Slot 2, etc.

The default value is 1 (i.e. I/O Card Slot 1).

Note: A valid I/O card configuration must be loaded into the SCADAPack ER RTU prior to loading an ISaGRAF application that references a SCADAPack ER I/O board, otherwise the I/O board can not be opened. This is done using the E Series Configurator tool by assigning an I/O card to a rack on and writing the Configurator file changes onto the RTU. A cold restart is required after these configuration details have been written to the RTU. See the E Series Configurator User manual for details.

4.3.6.1 Digital Output Board: er16ro

The **er16ro** output board references a physical relay output card by specifying a *Rack_Num* and *Slot_Num* field (see Section ***4.3.6 - SCADAPack ER I/O Boards*** for detailed descriptions of these fields). The channel number in the ISaGRAF I/O Connection window corresponds to the physical channel number on the SCADAPack ER I/O card.

Where an ISaGRAF application attaches a Boolean variable to an **er16ro** output board, the state of the corresponding digital relay will be controlled from the ISaGRAF variable. Note that if there is a physical digital output configuration point associated with this physical channel, the *Current State* of this configuration point will be updated after the successful control of the relay output.

Note that controls issued to SCADAPack ER relay output cards resulting from **attached** variables changing state, are issued as complete I/O card controls. This ensures that any simultaneous state

changes at the ISaGRAF output board level, are executed simultaneously at the SCADAPack ER relay output card.

The **er16ro** output board can be opened only if there is valid I/O card configuration loaded into the SCADAPack ER controller. Note that unlike the standard output boards, it is NOT necessary that there are physical digital output configurations points associated with the physical channels referenced by the **er16ro** output board.

4.3.6.2 Analog Input Board: er16ai

The **er16ai** input board references a physical analog input card by specifying a *Rack_Num* and *Slot_Num* field (see Section ***4.3.6 - SCADAPack ER I/O Boards*** for detailed descriptions of these fields). The channel number in the ISaGRAF I/O Connection window corresponds to the physical channel number on the SCADAPack ER I/O card.

Unlike the **er16ro** output board, there must be point database configuration points associated with the physical channels referenced by the **er16ai** input board *Rack_Num* and *Slot_Num* fields for proper operation.

Where an ISaGRAF application attaches an "Integer" analog variable to a **er16ai** input board, the *Current Value Integer Property* of the associated analog point will be read into the ISaGRAF variable. Where an ISaGRAF application attaches a "Real" (floating point) analog variable to an **er16ai** input Board, the *Current Value Engineering Property* of the associated analog point will be read into the ISaGRAF variable. Both "Integer" and "Real" ISaGRAF analog variables may be mixed on the same ISaGRAF **er16ai** input Board.

The **er16ai** input board can be opened only if there is a valid I/O card configuration loaded into the SCADAPack ER controller, and there is at least 1 physical analog input configuration point associated with the given I/O card.

4.3.6.3 Digital Input Board: er32di

The **er32di** input board references a physical binary input card by specifying a *Rack_Num* and *Slot_Num* field (see Section ***4.3.6 - SCADAPack ER I/O Boards*** for detailed descriptions of these fields). The channel number in the ISaGRAF I/O Connection window corresponds to the physical channel number on the SCADAPack ER I/O card.

Unlike the **er16ro** output board, there must be point database configuration points associated with the physical channels referenced by the **er32di** input board *Rack_Num* and *Slot_Num* fields for proper operation.

Where an ISaGRAF application attaches a Boolean variable to a **er32di** input board, the *Current State Property* of the digital point will be read into the ISaGRAF variable. The **er32di** input board may be successfully opened if there is a valid I/O card configuration loaded into the SCADAPack ER controller, and there is at least 1 physical binary input configuration point associated with the given I/O card.

4.4 Slave PLC I/O Boards

As an extension of the data interface provided by the SCADAPack E Series RTU, access by ISaGRAF applications to external PLC or peripheral device data is supported. Standard ISaGRAF I/O boards can continue to access RTU I/O and DNP data exchange areas as usual, with an additional set of ISaGRAF boards provided for the RTU that allow data to be extracted from external PLC device(s). External peripheral data is cached internally by the RTU to maximize ISaGRAF application performance. Access to this cached device data is restricted to ISaGRAF and is termed

Slave PLC data. Direct access to slave PLC data through DNP3 or other mechanisms is not provided.

The Slave PLC device that can be accessed via the ISaGRAF Slave PLC I/O boards depends on the PLC or peripheral device drivers installed in the RTU Operating System firmware.

An LED on the SCADAPack E Series RTU may indicate communication activity with external peripheral device(s). For more information see relevant *E Series Hardware User Manual*.

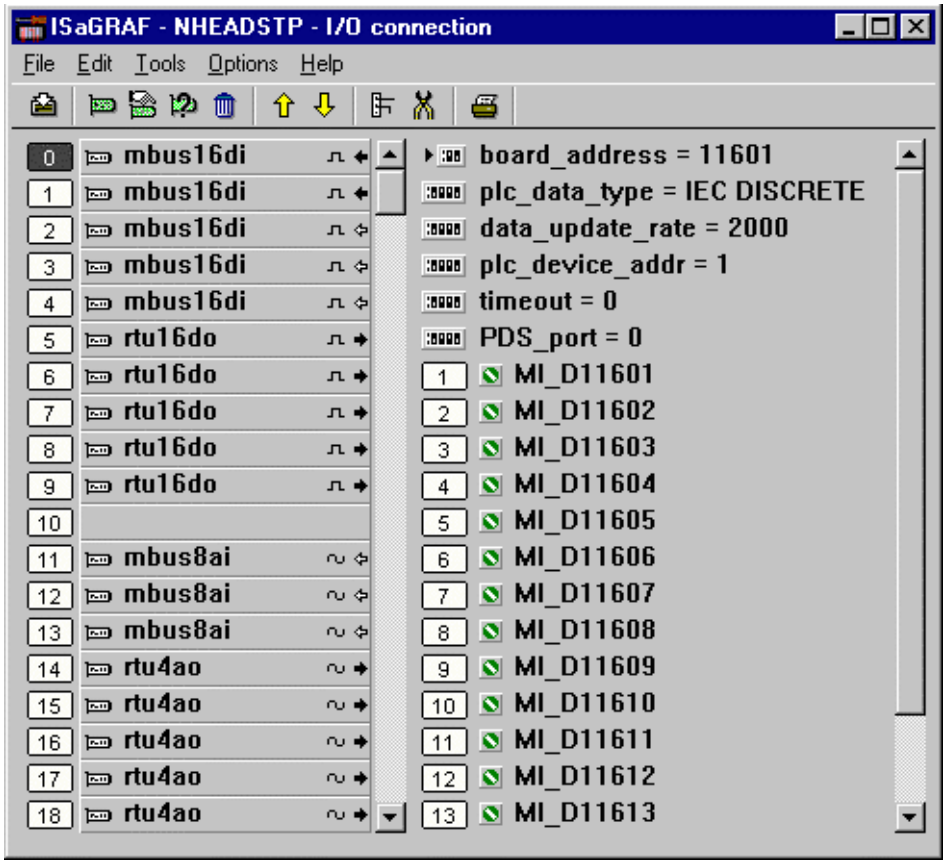


Figure 4-2 Example ISaGRAF Slave PLC I/O boards

Note:	When connecting the ISaGRAF Workbench Debugger to a SCADAPack E Series RTU using Slave PLC I/O boards, the Debugger may indicate "DISCONNECTED" for a period of time, particularly if there a large number of Slave PLC I/O boards, or if a slave PLC is not responding.

Different Slave PLC I/O boards are provided for different types of PLC data. For example: read PLC value registers (analog input board), write PLC coils (boolean output board), read PLC accumulated data (analog input board). The different types of I/O boards available and ranges of PLC data that can be accessed depend on the individual PLC driver. The following section details a summary of the SCADAPack E Series RTU's MODBUS PLC driver. For detailed information on Modbus and other drivers, see the relevant *E Series PLC* Device *Interface* Manual.

ISaGRAF Slave PLC I/O boards access data in the following way:

- a Slave PLC input board corresponds to a read-write access to PLC data

- a Slave PLC output board corresponds to a write-only access to PLC data
- an ISaGRAF OPERATE function call may be performed on an input variable and written to a PLC.
- Serial communication with external devices, such as PLCs, is made through the SCADAPack E Series RTU port(s) configured as “PLC Device”.

Up to a total of 100 Slave PLC I/O boards can be defined in total for all “PLC Device” communication ports and ISaGRAF kernels. Multiple “PLC Device” serial ports, as well as TCP/IP channels, can be used for Slave PLC peripheral communication.

4.4.1 Input Boards

ISaGRAF Slave PLC input boards typically require user configuration through the I/O board parameters. These are set as part of the ISaGRAF application and are entered into the I/O board parameter fields within the ISaGRAF Workbench I/O Connections editor.

The ISaGRAF “OPERATE” function may be used on Slave PLC Input Boards where the PLC register read by the input board is also writeable. This permits PLC registers to be inputs into ISaGRAF, but have them “Presetable” in the PLC by ISaGRAF.

Typical fields are:

board_address: specifies the Slave PLC data registers to access when reading from PLC data into ISaGRAF variables. The PLC data type accessed is specific to the Slave PLC I/O board and board address. This value is usually the PLC’s data (or register) address.

plc_data_type: specifies the PLC data register type. Currently *IEC UINT* type is supported for analog boards and *IEC DISCRETE* type is supported for Boolean boards. Other data types may be supported in the future. See specific PLC driver interface manuals for more information.

data_update_rate: The units for this parameter vary depending on the type of PLC device. For example this may be a setting in milliseconds for a directly connected device, or in minutes for a low power type device (see the *E Series Modbus PLC Interface* manual). As the SCADAPack E Series RTU must extract the data for the I/O board from the PLC or peripheral device, this sets the rate at which the data is extracted. Individual I/O boards may have different data update rates allowing prioritization of data extracted from a slave PLC. Note that the SCADAPack E Series RTU may not be able to read all requested PLC data within the time set by the data update rate depending on the quantity of data to be read, rate of write requests and PLC communication speed. In this case the update rates will be slower.

plc_device_addr: Some PLC device drivers support multi-drop PLC devices on the same communication channel, or have unique addressing identifiers. Where the SCADAPack E Series RTU driver provides multi-drop support, ISaGRAF may access data from any of the locally multi-dropped devices. A separate I/O board will be required for each device.

timeout: PLC device drivers with comprehensive I/O board interfaces may provide a parameter for specifying the communications timeout on an individual I/O board (i.e. the timeout applies to communications associated with that board). Where this value is “0”, the PLC device driver will use a default timeout. The units for this field are dependent upon the PLC device driver. Units may be, for example, milliseconds, seconds, minutes, etc.

port: this parameter may be on a PLC slave I/O board for a device driver. Where present, it defines which of the multiple SCADAPack E Series RTU “PLC Device” ports will be used to communicate with the PLC or peripheral device. ISaGRAF Slave PLC I/O boards that do not include this

parameter can only be used when a single “PLC Device” port is configured on the SCADAPack RTU.

4.4.2 Output Boards

ISaGRAF Slave PLC output boards typically require user configuration through the I/O board parameters. These are set as part of the ISaGRAF application and are entered into the I/O board parameter fields within the ISaGRAF Workbench I/O Connections editor.

Typical fields are:

board_address: specifies the Slave PLC data registers to access when writing from ISaGRAF variables to PLC data. The PLC data type accessed is specific to the Slave PLC I/O board and board address. This value is usually the PLC’s data (or register) address.

plc_data_type: specifies the PLC data register type. Currently *IEC UINT* type is supported for analog boards and *IEC DISCRETE* type is supported for Boolean boards. Other data types may be supported in the future. See specific PLC driver interface manuals for more information.

plc_device_addr: Some PLC device drivers support multi-drop PLC devices on the same communication channel, or have unique addressing identifiers. Where the PDS driver provides multi-drop support, ISaGRAF may access data from any of the locally multi-dropped devices. A separate I/O board will be required for each device.

must_write_rate: The unit for this parameter is driver specific, and configures the rate at which the data for the Output board is written to the PLC. Between “*must_write_rate*” periods, data is written to the PLC only when the ISaGRAF output variable values change. Individual I/O boards may have different must write rates allowing prioritization of data sent to a slave PLC.

timeout: PLC device drivers with comprehensive I/O board interfaces may provide a parameter for specifying the communications timeout on an individual I/O board (i.e. the timeout applies to communications associated with that board). Where this value is “0”, the PLC device driver will use a default timeout. The units for this field are dependent upon the PLC device driver. Units may be, for example, milliseconds, seconds, minutes, etc.

port: this parameter may be on a PLC slave I/O board for a device driver. Where present, it defines which of multiple RTU “PLC Device” ports will be used to communicate with the PLC or peripheral device. If only one “PLC Device” port is configured, this field is ignored. ISaGRAF Slave PLC I/O boards that do not include this parameter can only be used when a single “PLC Device” port is configured on the SCADAPack RTU.

4.4.3 Board Status

The SCADAPack E Series RTU checks for data being written to the PLC by ISaGRAF, before the Slave PLC input board data is retrieved. Communication requests made by the SCADAPack E Series RTU to the PLC are asynchronous to the scanning of the ISaGRAF application, but data within ISaGRAF remains consistent duration of a scan cycle.

To assist with debugging of ISaGRAF Slave PLC I/O board communication, the SCADAPack E Series RTU provides two types of *analog* system points which provide useful information:

1. PLC Communication Status

Status available for the first 60 ISaGRAF Slave PLC I/O Boards used in ISaGRAF kernel 1, and the first 14 ISaGRAF Slave PLC I/O Boards used in ISaGRAF kernel 2.

2. Cache Time (seconds)

- for ISaGRAF Slave PLC Input Boards these system points represents the age of the data since the last update
- these system points are not updated for ISaGRAF Slave PLC Output Boards (always 0)

SCADAPack E Series RTU analog system points 53300 to 53419 are set aside for the Slave PLC communication status information for up to 60 PLC Slave I/O boards in kernel 1. Points 53422 to 53449 are set aside for the Slave PLC communication status information for up to 14 PLC Slave I/O boards in kernel 2. A pair of consecutive points represent the PLC Communication status ('COMMS_STATUS') and the age of the data ('UPDATE_TIME') for each Slave PLC I/O board (refer to Table 4-2 below). Non 'Slave PLC' ISaGRAF I/O boards, including blank ISaGRAF I/O slots, are not included in the consecutive count.

This data is accessible externally to the RTU (via DNP3) or using ISaGRAF (through ***rtu*** input boards or table read/write function blocks to these point addresses). Note that these points are only accessible if Slave PLC functionality is enabled.

Table 4-2 'Comms Status' & 'Cache Time' System Point Numbers for ISaGRAF kernel 1

Consecutive ISaGRAF Slave PLC I/O board	Comms_Status Analog System Point No.	Cache_Time Analog System Point No.
1	53300	53301
2	53302	53303
3	53304	53305
4	53306	53307
5	53308	53309
6	53310	53311
7	53312	53313
8	53314	53315
9	53316	53317
10	53318	53319
11	53320	53321
12	53322	53323
13	53324	53325
14	53326	53327
15	53328	53329
16	53330	53331
17	53332	53333
18	53334	53335
19	53336	53337
20	53338	53339
21	53340	53341
22	53342	53343
23	53344	53345
24	53346	53347
25	53348	53349
26	53350	53351

Consecutive ISaGRAF Slave PLC I/O board	Comms_Status Analog System Point No.	Cache_Time Analog System Point No.
27	53352	53353
28	53354	53355
29	53356	53357
30	53358	53359
31	53360	53361
32	53362	53363
33	53364	53365
34	53366	53367
35	53368	53369
36	53370	53371
37	53372	53373
38	53374	53375
39	53376	53377
40	53378	53379
41	53380	53381
42	53382	53383
43	53384	53385
44	53386	53387
45	53388	53389
46	53390	53391
47	53392	53393
48	53394	53395
49	53396	53397
50	53398	53399
51	53400	53401
52	53402	53403
53	53404	53405
54	53406	53407
55	53408	53409
56	53410	53411
57	53412	53413
58	53414	53415
59	53416	53417
60	53418	53419

Table 4-3 'Comms Status' & 'Cache Time' System Point Numbers for ISaGRAF kernel 2

Consecutive ISaGRAF Slave PLC I/O board	Comms_Status Analog System Point No.	Cache_Time Analog System Point No.
1	53422	53423
2	53424	53425
3	53426	53427

4	53428	53429
5	53430	53431
6	53432	53433
7	53434	53435
8	53436	53437
9	53438	53439
10	53440	53441
11	53442	53443
12	53444	53445
13	53446	53447
14	53448	53449

Note: these system points are only accessible if Slave PLC functionality is enabled through a "PLC Device" port setting or "Modbus/TCP (client)" setting.

Table 4-4 PLC Comms Status values

0	=	No Error
101	=	Unknown device error
102	=	Illegal Data Count
103	=	Illegal Data Address
104	=	Device Timeout
105	=	Read/Write lock failed
106	=	Invalid message
107	=	Device Busy
108	=	Data value out of range

Slave PLC Input Board data is updated by the SCADAPack E Series RTU when it communicates with the Slave PLC device. The PLC communication status is updated if there is an error returned from the PLC or no response from the PLC after a data request by the RTU. Error codes are presented in Table 4-4. The value in each status register is cleared by the RTU upon successful communication sessions. Variables within an ISaGRAF program can be used to log transient errors.

Slave PLC Output Board data is written to the PLC when an ISaGRAF application changes the value of a variable attached to the Output Board. In addition, output board data is written to the PLC under the following conditions:

- When the ISaGRAF application starts, all output board data is written
- If the PLC does not respond to a control, it is resent until it is responded
- Boards with a "must_write_rate" parameter output all data at this rate
- All output board data is rewritten at a background update rate

SCADAPack E Series RTU system point "53420" controls the background update rate of all Slave PLC Output Boards on the RTU. Its default value is 60 seconds. It may be adjusted by the user dynamically or specified in an RTU configuration, and is a non-volatile RTU system point that is retained by the RTU. Note that the background updates are disabled by setting the system point "53420" to 0 (zero). This may be used to optimize the Slave PLC communications bandwidth where background writes are not appropriate or not necessary.

There are individual Slave PLC I/O Boards available in the Control Microsystems ISaGRAF library for different types of PLC devices and different types of data within the same PLC device. Not all

PLC data types for a particular PLC device may be accessible from the Slave PLC I/O boards. For more information see the relevant *E Series PLC* Device *ISaGRAF Interface* manual.

Board Name	ref+	ISaGRAF Data Type
*ddd*16di	0007	16 Boolean Inputs
*ddd*16do	0008	16 Boolean Outputs
*ddd1*ai	0009	1 Analog Input*[1]
*ddd*4ai	0009	4 Analog Inputs*[1]
*ddd*8ai	0009	8 Analog Inputs*[1]
*ddd*1ao	000A	1 Analog Output*[1]
*ddd*4ao	000A	4 Analog Outputs*[1]
*ddd*8ao	000A	8 Analog Outputs *[1]
*pppp*16di	000E	16 Boolean Inputs
*pppp*16do	000F	16 Boolean Outputs
*pppp*32di	000E	32 Boolean Inputs
*pppp*32do	000F	32 Boolean Outputs
*pppp1*ai	0010	1 Analog Input*[1]
*pppp*4ai	0010	4 Analog Inputs*[1]
*pppp*8ai	0010	8 Analog Inputs*[1]
*pppp*16ai	0010	16 Analog Inputs*[1]
*pppp*32ai	0010	32 Analog Inputs*[1]
*pppp*64ai	0010	64 Analog Inputs*[1]
*pppp*1ao	0011	1 Analog Output*[1]
*pppp*4ao	0011	4 Analog Outputs*[1]
*pppp*8ao	0011	8 Analog Outputs *[1]
*pppp*16ao	0011	16 Analog Outputs *[1]
*pppp*32ao	0011	32 Analog Outputs *[1]
*pppp*64ao	0011	64 Analog Outputs *[1]

where:

ddd is the driver type for simpler peripheral device interfaces
pppp is the driver type for more comprehensive peripheral device interfaces

For example *mbus16di* reads 16 Boolean (digital) input points from a Modbus PLC, with settable data type and timeout parameters.

*1 Analog input and output board conversion may be used as described in Section ***6 - ISaGRAF Analog I/O Boards / DNP3 Representation & Conversion***. The OPERATE function may also be used with Analog input boards as described in Section ***7 - ISaGRAF OPERATE Function***

+ For advanced ISaGRAF users: other I/O Boards, I/O Configurations or Complex Equipment types are possible based on the indicated reference numbers (hexadecimal format). Depending on the PDS PLC driver, there is usually an upper limit of 32 I/O channels per digital board and 64 I/O channels per analog board.

A *plc_data_type* user parameter is defined for some comprehensive Slave PLC I/O boards. The value of this parameter field is a string field describing the data type of data being accessed (driver specific) – e.g. “IEC UINT”.

An additional *plc_dev_type* hidden parameter string field value is driver specific, but generally has the form “xyz” where x = plc type, y = communication channel type, and z = special controls. “y” & “z” fields may be optional depending upon the specific driver.

E.g. “M” indicates simple Modbus board (M)

“ms” indicates advanced Modbus board (m), serial comms interface (s);

“mt” indicates advanced Modbus board (m), TCP socket interface (t);

“mtr” indicates advanced Modbus board (m), TCP socket interface (t), reset outputs on ISaGRAF application halted (r).

It is assumed that I/O board’s hidden “*plc_dev_type*” parameter defaults to “Freeze” outputs unless an “r” is explicitly defined as a “special controls” character.

Normally, the SCADAPack E Series RTU’s interface with intelligent PLC equipment would use ‘Freeze’ outputs to internal PLC data, so that a halted RTU ISaGRAF application would leave output data in the last written state. In the case where the SCADAPack E Series RTU interfaces with I/O blocks for purposes of distributed I/O, for example, the “Reset” outputs option may be applicable. Complex equipment types describing I/O blocks, for example, may include an “r” special control field to force outputs to the “Reset” state after an ISaGRAF application is stopped.

5 ISaGRAF Variable / PDS DNP3 Point Interaction

ISaGRAF variables attached to the I/O boards described in Section ***4.3 - ISaGRAF I/O Boards*** read data from or write data to the SCADAPack E Series RTU database points. ISaGRAF *Input* boards read data from the RTU database into ISaGRAF input variables. ISaGRAF *output* boards write data to the RTU database from ISaGRAF output variables.

Each ISaGRAF I/O board is associated with a *board_ address* corresponding to the DNP3 number of the first point on the board. The following configuration concepts and rules apply:

- Variables attached to SCADAPack E Series RTU DNP3 point I/O boards correspond to consecutively numbered DNP3 data points. The ISaGRAF I/O board address may be any valid RTU DNP3 data point index corresponding to physical, derived or RTU system data of a compatible type (see I/O boards information in section ***4.3 ISaGRAF I/O Boards***).
- ISaGRAF Boolean I/O boards (references 0001 & 0002) correspond to consecutive DNP binary data objects starting at the board address of the I/O board. ISaGRAF Boolean Output boards cannot reference "read-only" RTU data points (e.g. physical digital inputs). Boolean I/O Boards support multiple channels.
- ISaGRAF Analog I/O boards (references 0003 & 0004) support multiple channels; each corresponds to an RTU DNP3 analog data object. The RTU DNP object index of the first channel is specified by the board address. Subsequent channels correspond to consecutive RTU DNP3 point indexes. ISaGRAF Analog Output boards cannot reference "read-only" data registers (e.g. physical analog inputs). See Section ***6 - ISaGRAF Analog I/O Boards / DNP3 Representation & Conversion*** below for analog conversion rules.
- ISaGRAF digital and analog output status Input boards (references 000B & 000C) support multiple channels; each corresponds to the status of a DNP3 physical output point.
- ISaGRAF Counter Input boards (reference 000D) map to RTU counter input points or system counter points. SCADAPack E Series RTU counters are managed internally by 32-bit unsigned data types and are presented in 32-bit format to ISaGRAF analog integers. To reset or preset counters use the OPERATE command (see below).

Note: If none of the RTU DNP3 points referenced on the specific I/O board exist in the SCADAPack E Series RTU's database, the ISaGRAF application will NOT start. In order for a given board to be successfully opened, at least one of the RTU DNP3 points referenced must exist.

For this reason, the SCADAPack E Series RTU configuration with defined DNP points must be loaded prior to execution of the user ISaGRAF application(s).

6 ISaGRAF Analog I/O Boards / DNP3 Representation & Conversion

Analog Input and Output Boards can have Integer or Real (floating point) ISaGRAF variables attached. Both integer and real ISaGRAF analog variables are represented in 32-bit format. The SCADAPack E Series RTU data interface to these boards is accomplished via point properties in the RTU point database. In addition to direct variable data mapping, ISaGRAF conversion tables may be attached to any ISaGRAF analog Input/Output variable. Conversion table functions are applied after the following conversion rules are applied:

- An ISaGRAF integer variable attached to an Analog Input board receives a 32-bit signed value from the point's Current Integer Value property. The type of DNP3 object selected for this point does not affect the value presented to ISaGRAF (i.e. An analog point's value may have a conversion applied to a 16-bit DNP3 analog object, but the conversion is not applied to the value reported to ISaGRAF).
- An ISaGRAF real analog (floating point) variable attached to an Analog Input board receives a 32-bit floating point value from the point's Current Engineering Value property. The type of DNP3 object selected for this point does not affect the value presented to ISaGRAF
- An ISaGRAF integer variable attached to an Analog Output board sends a 32-bit signed value to the point's Current Integer Value property. Note that a conversion between integer and engineering value is also carried out according to an integer to engineering conversion formula. The type of DNP3 object selected for this point does not affect the value presented from ISaGRAF
- An ISaGRAF real analog (floating point) variable attached to an Analog Output board sends a 32-bit signed value to the point's Current Engineering Value property. Note that a conversion between engineering and integer value is also carried out according to engineering to integer conversion formula. The type of DNP3 object selected for this point does not affect the value presented from ISaGRAF.
- An ISaGRAF integer variable attached to a Counter Input board receives a 32-bit signed integer value representing the 32-bit unsigned count value of an RTU counter point. As ISaGRAF does not handle unsigned integers, the user's ISaGRAF application must deal with the case of a negative Count value.
- An ISaGRAF real analog (floating point) variable attached to a Counter Input board receives an unsigned numeric value representing the 32-bit unsigned count value of an RTU counter point. The conversion applied may result in a loss of accuracy of the count value as the ISaGRAF single precision (32-bit) floating point value will only provide 6 significant digit resolution.

Due to the arrangement of the SCADAPack E Series RTU data mapping for physical I/O, ISaGRAF input variables attached to physical I/O points on Digital Input and Analog Input I/O boards (e.g. rtuNNdi, rtuNNai where NN represents an integer) read the state or value of the physical Input points. ISaGRAF output variables attached to physical I/O points on Digital Output and Analog Output I/O boards (e.g. rtuNNdo, rtuNNao) control or write to the physical output points. To read the status of physical output points, attach ISaGRAF Input variables to Digital Output Status and Analog Output Status I/O boards (e.g. rtuNNdos, rtuNNaos).

7 ISaGRAF OPERATE Function

ISaGRAF provides a built-in *Operate* Function Block for manipulating I/O variables. Specifically, the SCADAPack E Series RTU provides an interface for initializing values of ISaGRAF Boolean input and analog input variables. This is typically used to load default values, or override variable values that are normally inputs into ISaGRAF from other sources (such as SCADA Master systems). The RTU also uses this mechanism to allow a user application to preset or reset Counter points.

The variable used in an *Operate* Function Block must be of ISaGRAF "Input" variable type, and must be attached to an ISaGRAF Input Board in order to override its value.

Furthermore, the operation simulates an external input change. That is **the input variable value does not update until the next I/O board update at the start of the ISaGRAF scan!** Consequently, access to the input variable after the OPERATE but before the end of scan will reflect the original value of the point (the variables value prior to the OPERATE). The input variable will have the "Operated" value following the start of the next ISaGRAF scan (assuming that the external source for the Input Board has not updated it again in the mean time).

The type of SCADAPack E Series RTU point manipulated by the OPERATE function is implied by the type of ISaGRAF Input Board it is attached to.

The Operate function block parameters are defined as follows:

- For BOOLEAN INPUT variables attached to Digital Input RTU boards:

  Input parameters

IO	name of boolean input variable
Funct	Not Used
Arg	state to initialize: 0=false, 1=true

  Output parameter

Q	1=success, 0=fail

- For INTEGER ANALOG INPUT variables attached to Analog Input boards:

  Input parameters

IO	name of analog input variable
Funct	Not Used
Arg	value to initialize

  Output parameter

Q	1=success, 0=fail

- For INTEGER ANALOG INPUT variables attached to Counter Input boards

  Input parameters

IO	name of counter input variable
Funct	Not Used
Arg	value to initialize

  Output parameter

Q	1=success, 0=fail

- For REAL (FLOATING POINT) ANALOG variables:

  Input parameters

IO	name of real analog input variable
Funct	power for initialize calculation
Arg	value to initialize calculation

  Output parameter

Q	1=success, 0=fail

The Operate Function calculates the initialized value using the following equation:

$$variable\_initalised\_value = Arg / 10^{Funct}$$

For ISaGRAF real analog variables attached to an Analog Input Board, the value derived from the above calculation initializes the 32-bit floating Engineering Value of the RTU DNP point corresponding to the board/channel address to which the variable is connected.

The ISaGRAF Boolean variable must be attached to a Boolean Input Board. The state with which the variable is to be initialized is set in the RTU DNP binary object corresponding board/channel address at which the variable is connected. Similarly, the ISaGRAF integer variable must be attached to an Analog Input Board. The *OPERATE* function argument 'Arg' initializes the Current Value property of the DNP point corresponding to the board/channel address to which the variable is connected. This also applies to ISaGRAF integer analog variables attached to Counter Input Boards. To reset a counter, use 'Arg' with a value of 0. **Figure 7-1** illustrates a sample use of the OPERATE function on a real analog input variable.

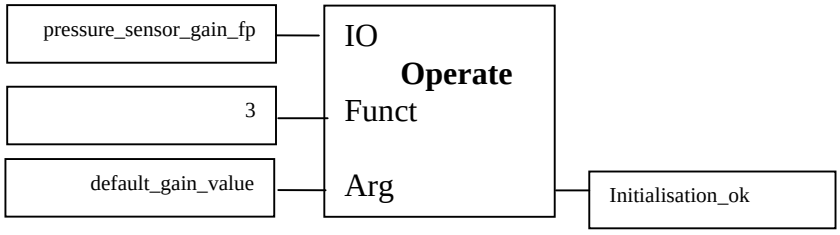


Figure 7-1 Example Operate command

Note:	The *Operate* function block can be used to manipulate RTU ***physical*** input point types providing that the input point is **not** associated with local physical I/O, or remote points that are mapped via the Data Concentrator.

7.1 Using ISaGRAF Operate Functions with Conversion Tables

Care should be taken when using *Operate* function block to set analog input variable values when the ISaGRAF analog variable has a conversion table attached to it.

Note generally that conversion tables cause the value held in the RTU point database, and the ISaGRAF internal value to be different. Conversion tables can be applied to both analog input and analog output variables, but *Operate* functions are only applicable for analog input variables.

The initializing value argument of an *Operate* function, or resulting from the *Operate* function calculation in the case of Real analog input variable types, is the value set in the RTU point. This

value is then applied to a conversion table (if one is attached to the analog) resulting in a different value appearing in the ISaGRAF variable i.e. conversion table value adjustment is performed AFTER the Operate value is loaded into the RTU point.

8 ISaGRAF MODBUS Link

The SCADAPack E Series RTU "ISaGRAF" communication port supports connection to the ISaGRAF Workbench software as well as the MODBUS RTU Slave protocol. The E Series RTU "ISaGRAF 2" communication port also supports MODBUS RTU Slave protocol. This allows ISaGRAF data to be made available to Modbus master devices such as local polling SCADA systems. Auto-detection is performed for both ISaGRAF workbench and MODBUS communications, and no configuration is required to activate Modbus protocol on the "ISaGRAF" port. Note that the SCADAPack E Series RTU also supports a native MODBUS Slave driver that does NOT require ISaGRAF. Refer to the *E Series Modbus PLC Interface* document for more information.

When SCADAPack E Series RTU serial ports are configured appropriately, RS232, RS422 or RS485 operation is supported for ISaGRAF Modbus communications. Once an RTU port is selected for "ISaGRAF" and/or "ISaGRAF 2", ISaGRAF variables can be read/written from a Modbus master. (For ISaGRAF to act as a MODBUS Master, use PLC Slave I/O Boards. See section ***4.4 - Slave PLC I/O Boards***).

Diagnostics for Modbus protocol can be displayed in RTU Diagnostic Display mode using `PLCDIAG` command with `ISAGRAF` and `MODBUS(ISaGRAF)` filters. For more information see the *E Series Operation Reference Manual*.

8.1 MODBUS Operation

A Modbus network contains one Modbus master device only (e.g. a SCADA master) and one or more slaves (e.g. PLCs). ISaGRAF responds to Modbus master requests at a different Modbus Device Address for each SCADAPack E Series RTU ISaGRAF target kernel, i.e. 1 and 2 respectively.

The ISaGRAF slave address of each ISaGRAF target kernel is also the Modbus Device address of the ISaGRAF target kernel, regardless of whether communications are from the RTU "ISaGRAF" port or "ISaGRAF 2" port.

A Modbus master usually sends one request at a time to one slave and waits for the slave to answer before sending the next request.

Where more than one SCADAPack E Series RTU ISaGRAF target kernel is active, they operate independently with respect to MODBUS communications, but share the same RTU communication port i.e. they behave as multi-drop Modbus PLC devices on the same communication link. MODBUS communications is supported with either, or both ISaGRAF target kernels from the same communication port (e.g. "ISaGRAF" port). Simultaneously, MODBUS communications is also supported with either, or both ISaGRAF target kernels from a second communication port (e.g. "ISaGRAF 2" port).

SCADAPack E Series RTU's can be multi-dropped along with other SCADAPack RTU's or other MODBUS devices by using RS485. Both 2-wire and 4-wire RS485 operation is supported by the SCADAPack E Series RTU. Note that the RTU requires software configuration, and correct cabling for multi-drop RS485 operation. For more information see the *E Series Hardware Manual*.

Many multi-drop PLC communications systems use RS485. The most common configurations use 4-wire RS485 connections to PLC devices. Set the SCADAPack E Series RTU serial port modes to "RS485 4w Slave" on the "ISaGRAF" and/or "ISaGRAF 2" ports. Dual RS485 Modbus links are supported by the SCADAPack E Series RTU.

8.2 MODBUS Communication

Each Modbus frame on a serial communication link contains the Modbus slave device address (same as the ISaGRAF target kernel address in the SCADAPack E Series RTU), a request function code, data, and a 16-bit error checking code (CRC). If no answer is received after a timeout period (Modbus master dependant) the request can be repeated a number of times (Modbus master dependant) before the master declares the slave 'disconnected'. These master parameters may need to be adjusted to fit the slave requirements (taking into account communication link speed, topology, etc). If an error occurs in processing a request, the slave may issue an error message instead of the expected answer frame.

The SCADAPack E Series RTU "ISaGRAF" and "ISaGRAF 2" communication ports recognize six MODBUS function codes:

Modbus Function Code	Description
1	read coils (bits)
2	read input discrete (bits)
3	read multiple registers (words)
5	write coil (1 bit)
6	write register (1 word)
16	write multiple registers (words)

The ISaGRAF variable database can be configured to map individual variables to a unique hexadecimal "Network Address". A single linear address space is accessible via Modbus. Each ISaGRAF Kernel Target has a separate and unique Modbus address space. There is no independent Modbus mapping between different MODBUS data types, so every variable's "Network Address" must be unique. Both boolean and analog ISaGRAF variable types can be accessed using any of the Modbus function codes, and may be input, output or internal variables, and local or global variables. Boolean variables can be read as a coil or as a register. Normally analog variables would be read as a register. See section ***8.3 - ISaGRAF / MODBUS Mapping***.

To read an ISaGRAF boolean variable, function codes 1,2 or 3 can be used. If a boolean variable is read as an analog register (using function code 3), the variable TRUE state is read as 65535 (hexadecimal word 0xFFFF), and FALSE is read as 0.

To write a boolean value, function codes 5, 6, or 16 can be used. To write a TRUE value to an ISaGRAF boolean variable, use any non-zero value. Note that the ISaGRAF MODBUS Slave protocol does NOT support Modbus Function Code 15 (force multiple coils).

The Modbus interface to ISaGRAF analog variables uses IEC INT type (signed 16-bit integer in the range –32768 to 32767). To write to an analog ISaGRAF variable, either function 6 or 16 can be used. To read an analog variable, use either function 1 or 3. An ISaGRAF analog variable value less than –32768 is clamped at –32768 when read. Similarly a value greater than 32767 is clamped to 32767 when read. ISaGRAF real analog variable values (floating point) cannot be accessed using ISaGRAF Modbus.

8.3 ISaGRAF / MODBUS Mapping

An ISaGRAF variable can be accessed via MODBUS only if its 'Network address' field has been defined in the workbench dictionary

A variable's 'network address' field in the ISaGRAF database is set in hexadecimal and corresponds to the Modbus protocol's two-byte address 0x0001-0xFFFF (see below for mapping information).

- ISaGRAF Workbench version 3.30 and later has a Modbus mapping interface that aids management of Modbus to ISaGRAF variable mapping.
- 'Network address' field must be unique for each ISaGRAF variable configured
- Modbus Exception Codes such as 'Illegal Function' are not returned by ISaGRAF
- Requests that are not recognized are not answered by ISaGRAF, and responses may not contain all data requested if 'Network Address' variable configurations are not present for all addresses requested. Warning- this may result in unpredictable behavior by the Modbus Master.

The definition of Modbus PLC register addressing as seen by SCADA master systems and Modbus protocol addresses may differ. The Modbus protocol address is associated with two components: 1) Function Code 2) Register Address. PLC register addressing may be represented by a 5-digit or 6-digit address, ranged to inherently include data type and access compatibility with the protocol's Function Code. Examples shown in following table are 5-digit PLC Modbus addresses.

ISaGRAF Variable Type	Example PLC Address (dec)	ISaGRAF 'network address'	MODBUS Codes Read	Function Supported Write
Boolean	00002	0001	1,2	5
	00003	0002	1,2	5
	….	….	….	….
	09999	270E	1,2	5
Analog	40002	0001	3	6,16
	40003	0002	3	6,16
	….	….	….	….
	49999	270E	3	6,16

Note that the 'Network address' value configured for ISaGRAF boolean and analog variables is in the same range. Care should be taken when assigning network addresses to ISaGRAF variables to ensure that addresses are not overlapped or duplicated. Earlier versions of ISaGRAF Workbench contained no uniqueness checking within ISaGRAF. Workbench Versions 3.30 and later contain additional assistance for configuration of Modbus mapping.

Note that the 'Network address' mapping refers to protocol address value not PLC register value. For example, Modbus PLC Coil 2 has a protocol address value of 0001 when using function opcodes 1,2 & 5. Modbus PLC register 40009 has a protocol address value of 0008 when using opcodes 3,6 & 16.

9 Remote ISaGRAF Access

9.1 Application File Transfer

ISaGRAF application TIC code may be loaded from the Workbench workstation's compiled APPLI.X8M files, into the RTU file system. This file transfer may be done using:

- DNP3 protocol. - File transfer
- FTP – TCP/IP File transfer

The APPLI.X8M files can usually be found in the workstation's ISaGRAF workbench application directory tree.

E.g. c:\isawin\apl*appl-name*\appli.x8m

The first and second ISaGRAF Kernel Targets use filenames ISA11 and ISA21 respectively. The APPLI.X8M file(s) must be renamed to ISA11 and/or ISA21 before restarting the ISaGRAF kernel target. For the SCADAPack E Series RTU, the ISaGRAF application files must reside in the root directory of the C drive in order to be executed.

Details of performing this file transfer are provided in the *E Series* O*peration Reference Manual*.

After transferring a new file, the appropriate ISaGRAF Kernel may be restarted through DNP3 commands:

- "RESTART ISAGRAF" - Restarts ISaGRAF Kernels 1 and 2
- "RESTART ISAGRAF 1" - Restarts ISaGRAF Kernel Task 1 only
- "RESTART ISAGRAF 2" - Restarts ISaGRAF Kernel Task 2 only

9.2 DNP3 Communications

The SCADAPack E Series RTU supports remote ISaGRAF Workbench communications via the DNP3 protocol. This is achieved using DNP3 Virtual Terminal objects for transporting ISaGRAF Workbench communications via DNP3. See Figure 9-2 for an illustration of the communication process between an ISaGRAF Workbench running an engineering terminal (e.g. a PC) and a remote RTU.

At the SCADAPack E Series RTU, virtual terminal requests received for the ISaGRAF kernels are re-directed to an ISaGRAF communications task. Responses from the communications task are re-directed to DNP3 virtual terminal objects. Separate ISaGRAF communication tasks provide Local (serial) port and Remote (DNP3 Virtual Terminal) port connections to the ISaGRAF Kernels. The task responsible for handling a remote ISaGRAF communication is always opened even if there is no local RTU serial port configured for ISaGRAF. However, if a local RTU serial port is not configured for ISaGRAF, the ISaGRAF local port communication tasks is not started.

A simultaneous connection from a local and remote ISaGRAF Workbench is possible on the same RTU. Each Workbench may connect to either of the RTU ISaGRAF Kernel tasks or both may connect to the same RTU ISaGRAF Kernel task if required.

The E Series Configurator software allows configuration of the physical communication medium interfaces which must be done prior to commencing workbench communications. E.g. serial communication, modem-dial up, X.29, etc. In the case of PSTN Modem or X.29 communications, the user will have instructed the E Series Configurator to set up the connection to the RTU before launching the Workbench application debug session.

The E Series Configurator software services its inter-task communications interface in order to receive a Workbench packet, encodes it into a DNP Object 112 “Virtual Terminal Output Block” and transmits the request to the remote RTU. Upon receipt of a DNP3 response from the RTU, the application reassembles the message for the Workbench and passes it on to the ISaGRAF task.

A DNP3 communication channel from the ISaGRAF Workbench to the SCADAPack E Series RTU can be established via the E Series Configurator software as follows:

The E Series Configurator initially should be launched and a connection established to the RTU. With an active E Series Configurator to RTU connection established, ISaGRAF should be launched from the E Series Configurator toolbar. This action will initiate the creation of an ISaGRAF Debugger / DNP3 logical link to the E Series Configurator software.

To finalize the communication channel from the ISaGRAF Workbench debugger to the RTU, the “RTUConfig ” option should be selected from the ISaGRAF PC-PLC link parameters dialog as shown in the figure below. Note that no additional setup is required within this dialog.

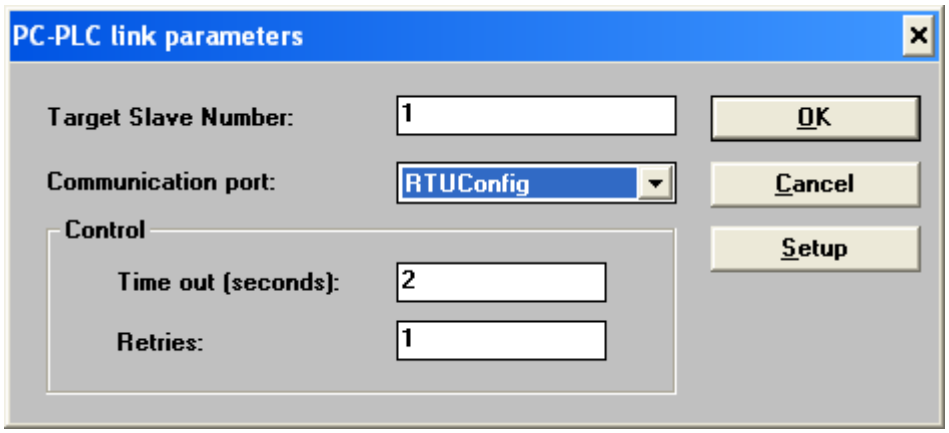


Figure 9-1: RTUConfig PC-PLC Link Option

Launching the ISaGRAF debugger at this point will connect the Workbench to the RTU via the ‘E Series Configurator (RTUConfig) – RTU’ communication channel established earlier.

When a connection is established to a single RTU as a means to communicate with one of many RTUs on an RTU sub-network (i.e. the connected RTU is used as a router), the ISaGRAF Workbench connection uses the currently active ‘ Router RTU - E Series Configurator’ connection. This connection may be reconfigured using the E Series Configurator after the ISaGRAF Workbench debugger has been disconnected. In this case the E Series Configurator does not need to be disconnected from the originally connected RTU prior to establishment of ISaGRAF Workbench communications.

Note: Due to the slower nature of remote ISaGRAF debug communications via Wide Area links (compared with local direct serial connections to an RTU) it may be necessary to increase the Workbench Debugger *Timeout* and *Retries* settings. From the Workbench select “Debug” “Link Setup”. Suggested settings for these parameters are:

- Time out = 20 (seconds)
- Retries = 3

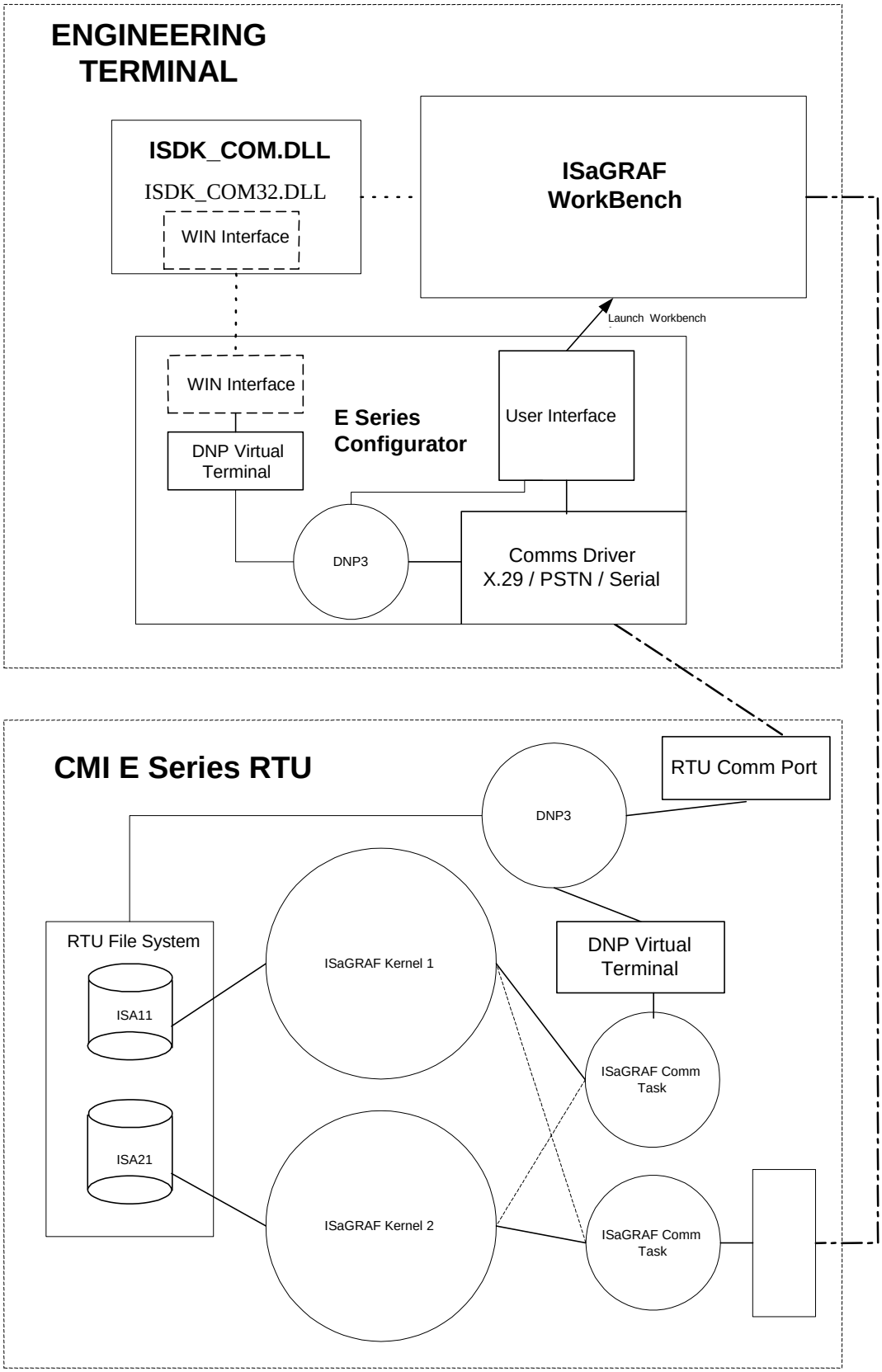


Figure 9-2: Remote ISaGRAF Communication

9.3 TCP/IP Communications

The SCADAPack E Series RTU provides an ISaGRAF Communications Server for TCP/IP. Either the RTU Ethernet or a serial PPP interface may be used for ISaGRAF workbench communications using TCP/IP.

To establish a TCP/IP connection between the ISaGRAF Workbench and the RTU, the ISaGRAF/TCP service on the RTU must be enabled through the *TCP* page on the E Series Configurator software. Refer to the *E Series Configurator User Manual* for details. Furthermore, the ISaGRAF Workbench PC-PLC link parameters must be setup for an Ethernet connection. Setting up the Ethernet connection within the ISaGRAF Workbench is described below.

9.3.1 ISaGRAF Workbench Ethernet Settings

The ISaGRAF Workbench can be configured to connect to the RTU a TCP/IP communications by selecting the "ETHERNET" option from the PC-PLC link parameters dialog and entering the IP address of the remote RTU by selecting the 'Setup' button as shown in the figure below.

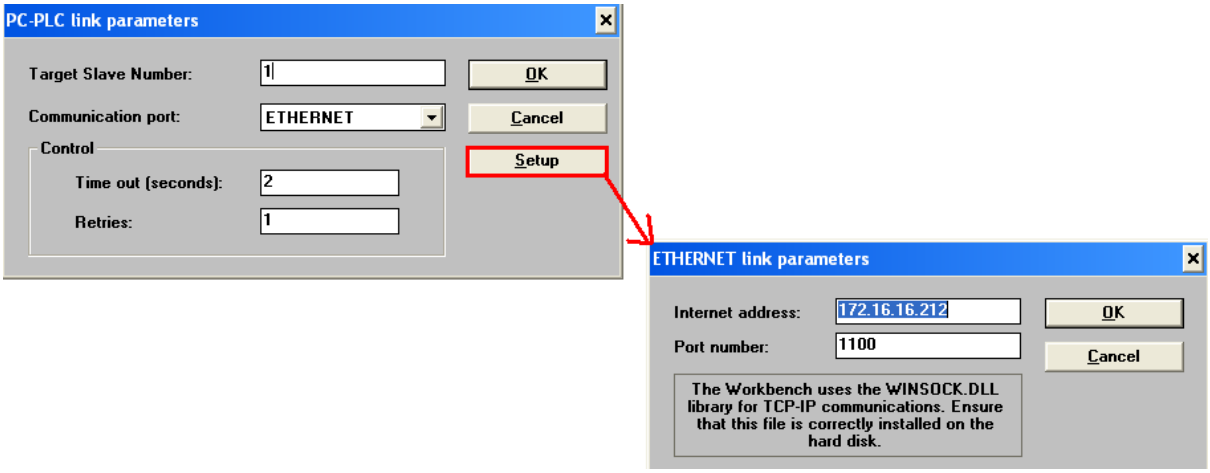


Figure 9-3: ISaGRAF Workbench Ethernet Settings

The function of each field in the ETHERNET link parameters dialog is described below:

*Internet address*IP address or HOST name of the SCADAPack E Series RTU

Port number TCP Port number at which a socket to the ISaGRAF Communications Server will be open on the ISaGRAF host PC.

(The port number for connecting to a SCADAPack E Series RTU is **1100**).

The SCADAPack E Series RTU TCP/IP ISaGRAF Communications Server opens a socket on TCP port number 1100 for ISaGRAF workbench communications, so "Port number" field in the "ETHERNET link parameters" dialog must be set to 1100 for operation with the RTU

At any given time, only a single ISaGRAF Workbench TCP/IP connection is permitted to be opened on the SCADAPack E Series RTU.

9.3.2 ISaGRAF TCP/IP Communications Server

Communications to the SCADAPack E Series RTU's ISaGRAF TCP/IP communications server (TCP ISaGRAF Comm Task shown in **Figure 9-4** below) may be established via the RTU's Ethernet interface or a serial PPP interface.

Only a single ISaGRAF TCP/IP session may be opened at a time regardless of which RTU TCP/IP interface is being used. The ISaGRAF communications server may access either of the RTU's ISaGRAF Targets, set by the "Target Slave Number" as shown above in the "PC-PLC Link Parameters" dialog

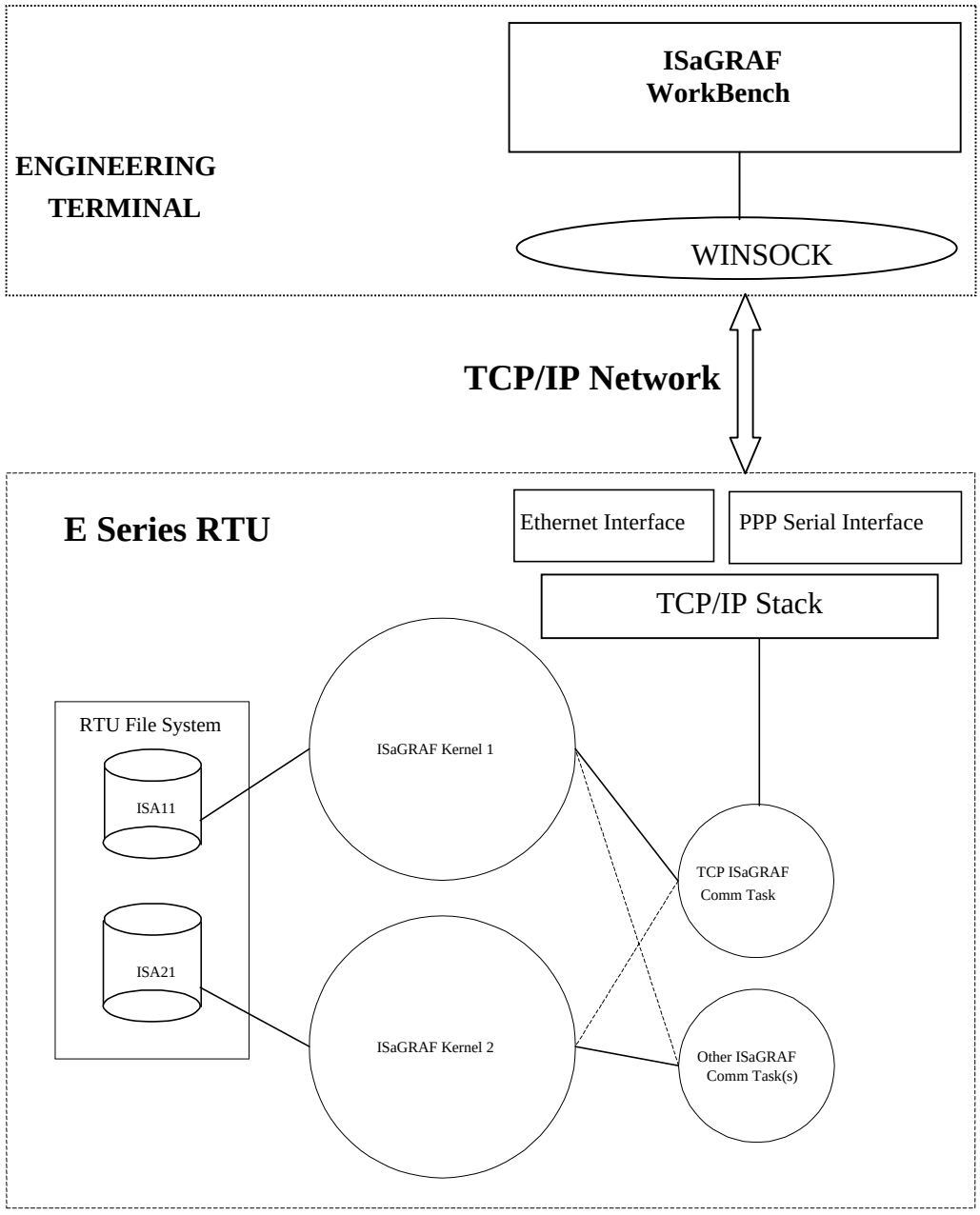


Figure 9-4: TCP/IP ISaGRAF Communication

10 ISaGRAF Troubleshooting & Error Codes

This section describes the different sources of ISaGRAF errors. These errors are accessible from the Workbench debugger or ISaGRAF *SYSTEM* call.

10.1 Error Types

The three different kinds of errors that can be detected by the PDS ISaGRAF target are:

SYSTEM Errors

These problems are probably due to target software or hardware, rather than due to application settings or to program execution. Try a hardware reset of the RTU and try to run other applications. Errors affecting system operation should be reported to Control Microsystems Inc.

APPLICATION Errors

These problems are due to application parameters, size or content. These errors should disappear when loading a known and previously validated application. If the problem still appears, it becomes a system error as listed above.

PROGRAM Errors

These problems are due to a particular sequence of the loaded user application program. These kinds of errors should disappear when the application is started in cycle by cycle mode, or when the offending program is stopped.

Error code and Error argument are sent to the ISaGRAF error routine. The workbench will interpret most errors and display text equivalent to that shown below.

A number or variable may appear in brackets [x] before the error text. Depending on the context of the application the debugger may be able to display the name of the object (variable or program) where the error comes from. In some cases a number may be displayed whose meaning is error dependent.

ISaGRAF target error information is stored and can be accessed later from the workbench debugger or the *SYSTEM* call from within an application.

10.2 Error Summary

Table 10-1 details the ISaGRAF errors that may be reported on SCADAPack E Series RTU's. For more information see the ISaGRAF Target User's Guide.

Table 10-1 ISaGRAF Error List

Code	Message	Type
1	Cannot allocate memory for run time data base	system
2	Incorrect application data base (Motorola / Intel)	application
3	Cannot allocate communication mailbox	system
4	Cannot link kernel data base	system
5	Time-out sending question to kernel	system
6*	Time-out waiting answer from kernel	system
7	Cannot init communication	system
8	Cannot allocate memory for retained variables	application
9*	application stopped	application

Code	Message	Type
10	too many simultaneous N or P actions	application
11	too many simultaneous setting actions	application
12	too many simultaneous resetting actions	application
13	unknown TIC instruction	application
14	invalid type cast	application
16	cannot answer read data request	system
17	cannot answer write data request	system
18	cannot answer debugger session request	system
19	cannot answer modbus request	system
20	cannot answer debugger application request	system
21	cannot answer debugger	system
23	unknown request code	system
24*	Ethernet communication error	system
25*	communication synchro error	system
28	cannot allocate memory for application	application
29	cannot allocate memory for application update	application
30	unknown OEM code	application
31	cannot init Boolean input board	application
32	cannot init analog input board	application
33	cannot init message input board	application
34	cannot init Boolean output board	application
35	cannot init analog output board	application
36	cannot init message output board	application
37	cannot input Boolean board	application
38	cannot input analog board	application
39	cannot input message board	application
40	cannot output Boolean output variable	application
41	cannot output analog output variable	application
42	cannot output message output variable	application
43	cannot operate Boolean variable	application
44	cannot operate analog variable	application
45	cannot operate message variable	application
46	cannot open board	application
47	cannot close board	application
50	cannot overwrite Boolean output variable	program
51	cannot overwrite analog output variable	program
52	cannot overwrite message output variable	program
61	unknown system request code	program
62*	sampling period overflow	program
63	user function not implemented	application
64	integer divided by zero	program
65	conversion function not implemented	application
66	function block not implemented	application

Code	Message	Type
67	standard function not implemented	application
68	real divided by zero	application
69	invalid operate parameters	application
72	application symbols cannot be modified	application
73	cannot update: different set of Boolean variables	application
74	cannot update: different set of analog variables	application
75	cannot update: different set of timer variables	application
76	cannot update: different set of message variables	application
77	cannot update: cannot find new application	application

* These ISaGRAF errors DO NOT generate a PDS RTU System Error Code in system analog point 50020. All other listed ISaGRAF errors DO generate a PDS RTU System Error.

10.3 Error Descriptions

1	**Cannot allocate memory for run time data base**	***system***
	No memory available. Check hardware configuration and application variable memory requirements	
2	**incorrect application data base (Motorola / Intel)**	***application***
	The application file transferred or backed up is not correct. This error appears if the application is generated for MOTOROLA and transferred to a PDS RTU (which uses an INTEL processor)	
3	**cannot allocate communication mailbox**	***system***
	This error is produced by the ISaGRAF communication task if it cannot allocate space for inter task communication	
4	**cannot link kernel data base**	***system***
	This error is produced by the communication task if it cannot find a kernel running with the slave number specified in the comm task startup	
5	**time-out sending question to kernel**	***system***
	The communication task cannot send a request to the ISaGRAF kernel. The kernel is probably not running	
6 *	**time-out waiting answer from kernel**	***system***
	The communication task cannot receive an answer from the ISaGRAF kernel. The kernel is probably not running	
7	**cannot init communication**	***system***
	This warning is produced when the ISaGRAF communication layer cannot initialize the physical link. This does not prevent the ISaGRAF application running, but it cannot communicate	
8	**cannot allocate memory for retained variables**	***application***
	ISaGRAF cannot manage retained variables. The reasons for such a problem may be:	

	- the retained memory string passed as a parameter to the host target is not syntactically correct (not required for PDS RTU) - the size of memory specified for each block is not sufficient. Verify the syntax of the 'retain variable' parameter, or try with a reduced number of Retained variables.	
9 *	**application stopped**	***application***
	This warning is produced every time the application is stopped from the debugger	
10	**too many simultaneous N or P actions**	***application***
	This error occurs if one of the PLC cycles has to execute to many non stored, pulse actions or cyclic blocks. It is possible to locate the trouble in CC mode. The maximum number of simultaneous actions is 2 + 4 per SFC program	
11	**too many simultaneous setting actions**	***application***
	This error occurs if one of the PLC cycles has to execute too many setting actions (executed when an SFC step becomes active). Proceed as for error 10	
12	**too many simultaneous resetting actions**	***application***
	This error occurs if one of the PLC cycles has to execute too many resetting actions (executed when an SFC step is de-activated). Proceed as for error 10	
13	**unknown TIC instruction**	***application***
	The kernel has detected something wrong in the application TIC code (target independent code) of a program. There are two possible explanations: - the target only has a reduced set of instructions, and your application uses a non authorized instruction or variable type- another task has written into application code spare. Try to locate the crash in CC mode & make sure no I/O interface has incorrect parameters	
14	**invalid type cast**	***application***
	The kernel has detected an invalid type casting operation in the application (eg. type casting a Boolean to a Boolean in ST program)	
16	**cannot answer read data request**	***system***
	A communication error is detected answering specific ISaGRAF Modbus request function code 18 (file read). Check connection and system configuration on both target and master sides. Not supported by PDS	
17	**cannot answer write data request**	***system***
	A communication error is detected answering specific ISaGRAF Modbus request function code 17 (file write). Check connection and system configuration on both target and master sides. Not supported by PDS	
18	**cannot answer debugger session request**	***system***
	A communication error is detected answering a debugged request. Check	

	connection and system configuration on both target and master sides	
19	**cannot answer Modbus request**	***system***
	A communication error is detected answering a Modbus request. Check connection and system configuration on both target and master sides	
20	**cannot answer debugger application request**	***system***
	A communication error is detected answering a debugger request. Check connection and system configuration on both target and master sides	
21	**cannot answer debugger**	***system***
	A communication error is detected answering a debugger request. Check connection and system configuration on both target and master sides	
23	**unknown request code**	***system***
24 *	**Ethernet communication error**	***system***
	This appears each time a debugger TCP/IP connection is closed. In this case the system is working OK. Otherwise it means an Ethernet communication error is detected. Check connection and system configuration on both target and master sides. The following errors may be given: 024:001 = error while sending or receiving 024:002 = error creating the socket 024:003 = error binding or listening on the socket 024:004 = error while accepting a new client	
25 *	**Communication synchro error**	***system***
	A synchronization error is detected framing a debugger communication request, possibly due to missing bytes or CRC error. Check connection and system configuration on both target and master sides.	
28	**Cannot allocate memory for application**	***Application***
	No application memory available. Check the hardware memory configuration and size of the application	
29	**Cannot allocate memory for application update**	***application***
	No working memory available. Check the hardware memory configuration and size of the application. Large applications may prohibit the use of on-line updating	
30	**Unknown OEM code**	***application***
	The application is using a board whose manufacturer code is not recognized by the target. CMI's OEM code for the SCADAPack E Series RTU is 90 (5A hex). Check the I/O connection in the workbench and use 'VIRTUAL' board attribute to locate the incorrect board. The workbench library may not correspond to the target versions	
31	**Cannot init Boolean input board**	***application***
	A Boolean input board init has failed. Check the I/O connection in the	

	workbench and the parameter settings of the boards	
32	**Cannot init analog input board**	***application***
	An analog input board init has failed. Check the I/O connection in the workbench and the parameter settings of the boards	
33	**cannot init message input board**	***application***
	A message input board init has failed. Check the I/O connection in the workbench and the parameter settings of the boards	
34	**cannot init Boolean output board**	***application***
	A Boolean output board init has failed. Check the I/O connection in the workbench and the parameter settings of the boards	
35	**cannot init analog output board**	***application***
	An analog output board init has failed. Check the I/O connection in the workbench and the parameter settings of the boards	
36	**cannot init message output board**	***application***
	A message output board init has failed. Check the I/O connection in the workbench and the parameter settings of the boards	

37	**cannot input Boolean board**	***application***
	An error has been detected while refreshing a Boolean input board. Check the I/O connection in the workbench and board parameters	
38	**cannot input analog board**	***application***
	An error has been detected while refreshing an analog input board. Check the I/O connection in the workbench and board parameters	
39	**cannot input message board**	***application***
	An error has been detected while refreshing a message input board. Check the I/O connection in the workbench and board parameters	
40	**cannot output boolean output variable**	***application***
	An error has been detected while updating an output Boolean variable. Check the I/O connection in the workbench and board parameters	
41	**cannot output analog output variable**	***application***
	An error has been detected while updating an output analog variable. Check the I/O connection in the workbench and board parameters	
42	**cannot output message output variable**	***application***
	An error has been detected while updating an output message variable. Check the I/O connection in the workbench and board parameters	
43	**cannot operate Boolean variable**	***application***
	An error has been detected executing an OPERATE call to a Boolean variable. Verify the OPERATE parameters and I/O board user's note. PDS supports operate calls to Boolean input variables only	
44	**cannot operate analog variable**	***application***
	An error has been detected executing an OPERATE call to an analog	

	variable. Verify the OPERATE parameters and I/O board user's note PDS supports operate calls to analog input variables only	
45	**cannot operate message variable**	***application***
	An error has been detected executing an OPERATE call to a message variable. Verify the OPERATE parameters and I/O board user's note PDS does not support operates to message variables	
46	**cannot open board**	***application***
	The application is using a board reference which is unknown in the target. Check the I/O connection in the workbench. The workbench library may not correspond to the target version	
47	**cannot close board**	***application***
	The application is closing a board reference which is unknown in the target Check the I/O connection in the workbench	
50	**cannot overwrite Boolean output variable**	***program***
	Two SFC sequences are writing to the same Boolean output variable in the same PLC cycle. This should be avoided to prevent hazardous behavior of the I/O. In case of such a conflict, the priority is given to the highest program in the hierarchy. If the two SFC programs are located at the same level, the result is unpredictable	
51	**cannot overwrite analog output variable**	***program***
	Two SFC programs are writing the same analog output variable in the same PLC cycle. See error 50 comments	

52	**cannot overwrite message output variable**	***program***
	Two SFC programs are writing the same message output variable in the same PLC cycle. See error 50 comments	
61	**unknown system request code**	***program***
	A program is using the SYSTEM call with an invalid order code	
62 *	**sampling period overflow**	***program***
	The PLC cycle is longer than specified in the workbench menu. As the RTU has a multitasking operating system, this means there is not enough CPU time to execute a cycle even if the 'current cycle duration' is less than the specified period. There are many possible ways to remove this warning: reduce the number of operations performed at the instant where the warning is detected: reduce number of tokens, of valid transitions, optimize complex processing, etc. - reduce communication traffic to give more time to ISaGRAF use dynamic cycle duration modification to adapt the cycle duration to different process stages - set cycle duration to ZERO to let the ISaGRAF kernel run as fast as possible without any overflow checking	
63	**user function not implemented**	***application***

	A program is using a C function which is unknown in the target. The workbench library may not correspond to the target version	
64	**integer divided by zero**	***program***
	A program is trying to divide an integer analog by zero. The application should prevent such an event which may have unpredictable effects. When this occurs, ISaGRAF places the maximum analog value as the result. When the operand is negative, the result is inverted	
65	**conversion function not implemented**	***application***
	A program is using a conversion function which is unknown in the target. The workbench library may not correspond with the target version. When this occurs, ISaGRAF does not convert the value	
66	**function block not implemented**	***application***
	A program is using a function block which is unknown in the target. The workbench may not correspond to the target version.	
67	**standard function not implemented**	***application***
	A program is using a function block which is unknown in the target although it is supposed to be available on most target implementations. Contact Control Microsystems.	
68	**real divided by zero**	***application***
	A program is trying to divide a real analog by zero. The application should prevent such an event.	
69	**invalid operate parameters**	***application***
	A program is passing invalid parameters in an OPERATE call. Check application calling parameters and see I/O Board technical note.	
72	**application symbols cannot be modified**	***application***
	Trying to make an application update, the modified application cannot be started because the symbols are different. One or more variables or instances of function blocks may have been added, removed or modified, compared to the current application.	
73	**cannot update: different set of boolean variables**	***application***
	The modified application cannot be started because some boolean variables have been added or removed, compared to the current application	
74	**cannot update: different set of analog variables**	***application***
	The modified application cannot be started because some analog variables have been added or removed, compared to the current application	
75	**cannot update: different set of timer variables**	***application***
	The modified application cannot be started because some timer variables have been added or removed, compared to the current application	
76	**cannot update: different set of message variables**	***application***
	The modified application cannot be started because some message variables have been added or removed, compared to the current	

	application	
77	**cannot update: cannot find new application**	***application***
	The modified application cannot be found in memory, something may have gone wrong during the transfer to the target	

* These ISaGRAF errors DO NOT generate RTU System Error Code in system analog point 50020. All other listed ISaGRAF errors DO generate a PDS RTU System Error.

11 ISaGRAF Unsupported Features

This section outlines the features that are documented in the ISaGRAF Workbench User's Guide or ISaGRAF Target User's Guide that are *not* currently implemented in the SCADAPack E Series RTU ISaGRAF Target. Most other major ISaGRAF features are implemented. An ISaGRAF target error will usually be produced if an ISaGRAF application or ISaGRAF Workbench accesses an unimplemented feature.

- Modbus protocol File extensions (standard Modbus protocol is supported)
- Mailbox, Task & Keyboard management
- File read/write support
- ISaGRAF project Upload from Target

SCADAPack E Series

ISaGRAF Function Block Reference

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Document Revisions

Revision	Date	Modification	Author
1.10	19 January 2006	Incorporated Dec 19, 2005 changes	KN
1.00	11 October 2005	Initial release of SCADAPack E Series ISaGRAF Function Block Reference	KN

1 Preface

1.1 Scope

This manual describes in details all the custom function blocks provided with the SCADAPack E Series RTU ISaGRAF installation.

1.2 Purpose

The purpose of this document is to describe the custom function blocks provided with the E Series ISaGRAF installation. This manual is intended to be used alongside with the E Series ISaGRAF Technical Reference and E Series ISaGRAF IO Connection Reference manuals.

1.3 Assumed Knowledge

Familiarity with the ISaGRAF Workbench is strongly recommended.

1.4 Target Audience

- Systems Engineers
- Commissioning Engineers
- Maintenance Technicians

1.5 References

- E Series Configuration Reference Manual
- CJ International ISaGRAF Manuals
- E Series ISaGRAF ADS Flow Manual
- E Series ISaGRAF Reference Manual
- E Series IO Connection Reference Manual

2 Overview

Physical and user DNP points within the SCADAPack E Series RTU (and some system points) have both **Property** and **Attribute** fields associated with them. The distinction between these field types within a point is particularly important for point processing.

A "**Property**" field of a point represents a physical or derived quantity, describing a particular aspect of the real time condition of a point.

An "**Attribute**" field of a point dictates how the SCADAPack E Series RTU should manipulate or present a particular aspect of a point. In terms of data processing, some attributes describe how some point properties are derived. Multiple point attributes may impact a point property. Similarly, multiple point properties may be impacted by a single attribute. For more information on point properties and attributes, consult the *E Series Configuration Technical Reference* manual.

This document describes Function Blocks and Functions supported by the SCADAPack E Series RTU[1] processors when using the ISaGRAF IEC61131-3 environment. These function blocks or functions provide an ISaGRAF application access to RTU configuration and I/O data in the form of DNP point properties and attributes, access to RTU facilities such as serial ports, DNP3 data objects, peer-to-peer DNP3 communication, real time clock and additional control functions.

All functions can be implemented using the IEC-61131 Function Block Diagram or Structured Text languages.

The manual is arranged as follows:

- Section ***3 3- Using the ISaGRAF Pre-Processor*** describes the RTU's ISaGRAF pre-processor. The ISaGRAF pre-processor maps a named variable within an ISaGRAF application to a DNP point number where applicable. This feature becomes useful for the function blocks require a DNP point number as an input parameter.
- Section ***4- E Series Function Blocks*** is sub-divided as follows:
  - Section ***4.1 Point Attribute function blocks*** presents the function blocks that can be used to return or set RTU DNP point properties
  - Section ***4.2 - Real Time Clock function blocks*** describes function blocks which provide an ISaGRAF application access to the RTU's real time clock.
  - Section ***4.3 - DNP3 Communication function blocks*** describes ISaGRAF function blocks that interface with the SCADAPack E Series RTU's peer-to-peer communication facilities. These function blocks transfer data between an ISaGRAF variable and a remote RTU point database.
  - Section ***4.4 - DNP3 Queued Communication function blocks*** describes ISaGRAF function blocks that interface with the SCADAPack E Series RTU's peer-to-peer communication facilities. Queued peer function blocks transfer data directly between the point databases of two peer RTUs.
  - Section ***4.5 - Serial Port User Communication functions*** describes ISaGRAF function blocks which can be used to set or retrieve serial port properties on the E Series RTU.
  - Section ***4.6 - Miscellaneous function blocks*** describes several miscellaneous function blocks including the PID_AL function block that provides PID control with output limiting and anti-integral windup protection.

[1] Also referred to simply as RTU

- Section *4.7 - TCP/IP Interface functions* describes function blocks that provide interfaces to RTU TCP/IP communication and configuration services.
- Section *4.8 - Alarm Group Functions & Function Block* describes the ISaGRAF 'Summary Alarm' functions and function blocks. These provide a mechanism for grouping individual RTU Digital point states (alarms) in to a named alarm group, and configuring an alarm output if any of the points in the group change to the alarm state.

2.1 C Functions and Function Blocks

A summary of function and function blocks is given below.

"C" Function Blocks include:

TIMEDATE Read the current date and time from the PDS real-time clock – adjusted for local time & Summer (daylight savings) Time when selected

PDS_TIME Current Time of day (milliseconds since midnight Timer variable format) adjusted for local time & Summer (daylight savings) Time when selected

OS_TIME Read the PDS operating system time (unadjusted UTC / standard time)

RD1BIN Read 1 binary object from local or peer DNP3 data

RD1ANA Read 1 analog object from local or peer DNP3 data

RD1FLT Read 1 floating point analog from local or peer DNP3 data

RD4BIN Read 4 binary objects from local or peer DNP3 data

RD4ANA Read 4 analog objects from local or peer DNP3 data

RD4FLT Read 4 floating point analogs from local or peer DNP3 data

RD8BIN Read 8 binary objects from local or peer DNP3 data

RD8ANA Read 8 analog objects from local or peer DNP3 data

RD8FLT Read 8 floating point analogs from local or peer DNP3 data

RD16BIN Read 16 binary objects from local or peer DNP3 data

RD16ANA Read 16 analog objects from local or peer DNP3 data

RDFLD_I Reads Integer Attributes from the RTU point database

RDFLD_R Reads Floating Point Attributes from the point database

RDREC Reads the most common attributes for point types

RDREC_DG Reads attributes for digital points from the point database

RDREC_CN Reads attributes for counter points from the point database

RDREC_AN Reads attributes for analog points from the point database

RDSTRING Read a string point from the RTU system string map

RD_TC_AD Read TC Addresses from a given TC Id Number

WR1BIN Write 1 binary object to local or peer DNP3 data

WR1ANA Write 1 analog object to local or peer DNP3 data

WR1FLT	Write 1 floating point analog to local or peer DNP3 data
WR4BIN	Write 4 binary objects to local or peer DNP3 data
WR4ANA	Write 4 analog objects to local or peer DNP3 data
WR4FLT	Write 4 floating point objects to local or peer DNP3 data
WR8BIN	Write 8 binary objects to local or peer DNP3 data
WR8ANA	Write 8 analog objects to local or peer DNP3 data
WR8ANA	Write 8 floating point analogs to local or peer DNP3 data
WR16BIN	Write 16 binary objects to local or peer DNP3 data
WR16ANA	Write 16 analog objects to local or peer DNP3 data
PEER_RDX	Execute a queued DNP Read Request
PEER_WRX	Execute a queued DNP Write Request
SETATR_I	Sets Integer Attribute Values to the point database
SETATR_R	Sets Floating Point Attribute Values to the point database
RTUPULSE	Pulse a digital output point
PID_AL	PID controller with output limiting
RTUPARAM	modify RTU system parameters
CHGROUTE	modify DNP3 routing table entry
CHGRTPRT	modify DNP3 routing table destination port
CHGRTNUM	modify DNP3 routing table connect id string
ANA_TIME	high speed Analog Input with time-stamping
ALMPROC	Process Alarm Group points
GEN_EVT	Force a DNP Event on a configured DNP point
GETPORT	Reads a serial port hardware line state for a DNP3 serial port
SETPORT	Sets a serial port hardware line state for a DNP3 serial port
DC_POLL	Force the Data Concentrator to issue a Class 0 poll to all IED’s
FINDFILE	Search file system for specific file,
DIR_INFO	Provides files system directory / drive information

“C” Functions include**:**

COMOPEN	open an ISaGRAF User (ASCII) serial port
COMCLOSE	close an ISaGRAF User (ASCII) serial port
COMSETUP	set communication parameters on a serial port
COMTX	send a user message to the serial port
COMRX	read a user message from the serial port

COMRXCLR	clear the serial port receive buffer
REA_MSG*	Convert real (float) values to messages
PEER_RDQ	Adds a DNP Read Request to a named queue
PEER_WRQ	Adds a DNP Write Request to a named queue
PEER_RDC	Clears all entries in a named DNP Read request queue
PEER_WRC	Clears all entries in a named DNP Read request queue
ALMADD	create and/or Add points to an Alarm Group
ALMLOAD	Load Alarm Group mask
ALMCLR	Clear Alarm Group

F_DEL	Deletes file from RTU file system
F_DELTRE	Deletes directory (including contents) from RTU file system
F_COPY	Copies file in RTU file system
F_JOIN	Appends file to end of another in RTU file system
F_REN	Renames a file in the RTU file system
F_MKDIR	Creates a directory in the RTU file system
F_RMDIR	Removes a directory in the RTU file system
F_CD	Changes working directory in the RTU file system
F_DSKSEL	Changes working drive in the RTU file system
F_PWD	Reports current working directory in the RTU file system
F_WOPEN	Opens file for WRITE access in RTU file system
F_ROPEN	Opens file for READ access in RTU file system
F_CLOSE	Closes file in RTU file system
F_EOF	Tests for end of file
FA_READ	Reads analog (binary data) from open file
FA_WRITE	Writes analog (binary data) to open file
FM_READ	Reads message (string) from open file
FM_WRITE	Writes message (string) to open file

* This function is provided as an alternative to the standard ISaGRAF library *MSG* conversion function when converting from a real (floating point) analog to a message string. See section ***4.6.6 - rea_msg***.

These function blocks and functions provided by Control Microsystems are extensions to the ISaGRAF workbench library, and may be used in SCADAPack E Series RTU ISaGRAF applications as detailed in the following sections.

3 The ISaGRAF Preprocessor

3.1 General

A pre-processor is provided for the ISaGRAF Workbench to assist in defining constants for use with the SCADAPack E Series RTU.

The Control Microsystems ISaGRAF Pre-Processor allows the use of a string “define” in place of a DNP Point Number as an input parameter to some ISaGRAF function blocks. It is useful for the following function blocks:

- “SETATR_I”
- “SETATR_R”
- “RDFLD_I”
- “RDFLD_R”.

3.2 Description

The ISaGRAF target does not provide any run-time correspondence between I/O board point addresses and variables used within ISaGRAF logic. Further to this, when a variable name is used within an ISaGRAF program, the variable’s “VALUE” is used at run-time by the target (inside the SCADAPack E Series RTU) and there is no connection with its NAME. This architecture is common to most programming languages where use of a variable name implies its value. Because of this issue, parameters passed to ISaGRAF “C Function Blocks” (through variable names in source code) are passed as values only. In all scenarios, the above ISaGRAF function blocks require the DNP address of the point to be passed as a value. Internally, ISaGRAF does not provide a mechanism for obtaining the “Address” of a variable. The DNP “Address” of a variable is relevant only when a variable is attached to an CMI I/O Board that provides a logical connection to an RTU point via a DNP3 point address.

To solve the problem of relating a Named Value with a DNP Point Address, there needs to be a mechanism to resolve the correspondence between I/O board channel address, and the ISaGRAF variable name. This correspondence can be made from the ISaGRAF Workbench application database. To provide a solution, the ISaGRAF workbench compiler, during a MAKE cycle, automatically invokes a pre-processor phase that allows substitution of pre-defined names with corresponding values.

In the standard ISaGRAF workbench environment, the application programmer can make use of *defines* at Common, Global and Local levels. The Control Microsystems ISaGRAF Pre-Processor uses *defines*, in a standard manner Global to an application, to denote the DNP “address” for any ISaGRAF variable connected to an I/O board channel.

For example, an ISaGRAF variable called FRED is created and connected to a I/O board channel, whose board address is at DNP address 10000. An ISaGRAF application programmer wishes to use the function block "RDFLD_I” to obtain an attribute of this point. He would create an instance of the function block and call the function block with a POINT parameter “Z_FRED”.

The pre-pended string or operator “Z_” as described in this example implies the “DNP Point Address of” the ISaGRAF Variable. The “Address of” operator string and whether the string is appended or prepended to the variable name is user definable.

Of course it is possible for the ISaGRAF programmer to manually create these *defines* through the Workbench (i.e. define Z_FRED = 10000). The problem, of course, with this manual method is that

a change to the I/O board address would not be automatically reflected in the *define* value for each point on the I/O board.

3.3 Using the ISaGRAF Pre-Processor

Control Microsystems ISaGRAF pre-processor stage automates the process of creating *defines* for each ISaGRAF variable connected to a "Real" I/O board. (ie. not a "Virtual" ISaGRAF I/O board). The pre-processor is invoked automatically during each ISaGRAF "Make". It examines the ISaGRAF project database for I/O board variables, calculates the DNP address, and creates or replaces a *define* for each I/O board variable. The use of ISaGRAF *defines* is still available to the application programmer, without interference.

The ISaGRAF application programmer need only be aware of specifying the *variable name* (as normal) where the VALUE is to be used (eg. FRED), and the *define* name where the DNP point address is to be used (eg. Z_FRED). Upon a change in the board I/O address, or movement of a variable within an I/O board or to a new I/O board, the corresponding *define* is automatically updated at the next ISaGRAF "Make".

The ISaGRAF application programmer should be aware that the maximum variable name or define name length is 16 characters. Hence by using the "Z_" (or similar) prepend facility, I/O board variable names are limited to 14 characters.

The "Address of" variable name is derived from the variable name by stripping all underscore characters from the variable name and prepending or appending the operator string to the variable name. If the resulting string is greater than the ISaGRAF 16 character limit, the pre-processor will truncate the variable name.

In some cases, the resulting *define* name may not be unique. In these cases, the pre-processor will raise an error dialog box and will not allow the ISaGRAF compiler to run. If this occurs, one of the offending variable names needs to be modified in order to guarantee uniqueness.

Examples of *define*s corresponding to variable names are as follows:

Variable name	Define name	Comment
ww1surchPump12	Z_ww1surchPump12	Variable name used intact as it's 14 characters or less and has no underscores.
ww1_surch_Pump12	Z_ww1surchPump12	Variable name (with no underscores) is less than 14 chars.
ww1surchPump_Def	Z_ww1surchPumpDe	Variable name is greater than 14 characters with underscores stripped, so variable name is truncated.

The "defines" that have been created by the pre-processor can be viewed within the ISaGRAF workbench by opening the project, selecting "**Dictionary**" then selecting the "**Defined Words**" tab. Select the "**Global objects**" toolbar button to view the project "defines".

The ISaGRAF Pro-Processor is automatically installed with the Workbench with the following default settings:

[SERCK]

PREPEND=1

STR_PREPEND=Z_

The “PREPEND” key defaults to “true” and tells the pre-processor to prepend the “Address of” string. Set to “PREPEND=0” to append the “Address of” string.

The “STR_PREPEND” key defaults to “Z_” and allows the user to customize the “Address of” operator string. The user value may be any legal ISaGRAF character string up to five characters in length.

Once the files have been installed as described above, and the INI parameters are set, you are ready to use the ISaGRAF Pre-Processor. The pre-processor is automatically started, when necessary, prior to the ISaGRAF Compiler’s normal operation, such as during an ISaGRAF Workbench MAKE cycle.

Note: The Control Microsystems ISaGRAF pre-processor is implemented as a Win32 application and will only run on Windows 9x or Windows NT operating systems.

4 E Series Function Blocks

4.1 Point Attribute function blocks

These function blocks set or return the property or attribute of a DNP point stored in the RTU database. All DNP point properties or attributes that can be set or retrieved using the E Series Configurator can also be accessed using the function blocks presented in this subsection of the manual. Further information on point properties and attributes can be found in the *E Series Configuration Technical Reference* manual.

4.1.1 rdfld_i

Read DNP point attribute of type integer

Description

The rdfld_i function reads a DNP point attribute or property and returns the value in a 32 bit integer variable.

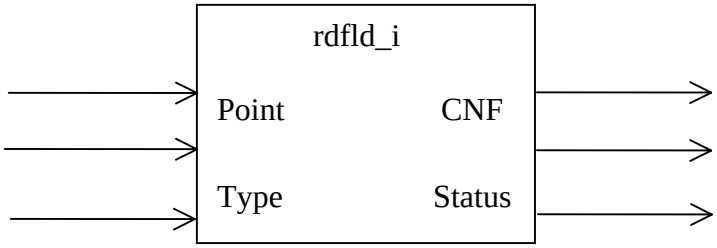


Figure 4-1: rdfld_i function block

INPUTS	TYPE	DESCRIPTION
Point	Integer	RTU DNP Point Address. Can be a dictionary variable containing the DNP point address, see section ***3 - The ISaGRAF Preprocessor***. Can also be numeric DNP point address.
Type	Integer	RTU DNP Point data type. Argument can be one of the ISaGRAF reserved keywords below or an integer value corresponding to the data type. **ISaGRAF Keyword** / **Equivalent Numeric Value** / **Comment** DIN / 1 / Digital input point DOUT / 2 / Digital output point AIN / 3 / Analog input point AOUT / 4 / Analog output point CIN / 5 / Counter input point
Attrib	Integer	Desired point attribute (property). Argument can be an ISaGRAF reserved keyword or an integer value corresponding to the attribute. See Table 4-1 to Table 4-4 for keywords and their corresponding numeric values.

OUTPUTS	TYPE	DESCRIPTION
CNF	Boolean	Confirm valid or invalid status **Possible Values** / **Meaning** TRUE / Confirm Valid Status FALSE
Status	Integer	Status of Read Request **Possible Values** / **Meaning** -1 / Unknown Return Error

OUTPUTS	TYPE	DESCRIPTION	
		0	Success
		1	Point does not exist
		2	Bad point type
		3	Unknown attribute for this point
		4	Bad value for this attribute
		5	Invalid attribute for this function block
		8	Point is locked
		12	Database is locked
		18	I/O Processor Unavailable
Value	Integer	Depends on 'Attrib' input parameter	

Table 4-1 rdfld_i function attributes (attrib) for point properties

Attrib (ISaGRAF Keyword)	Equivalent Numeric Value	Description
Qlty	100	Point Quality
Fail	101	Point Failed
IOF[1]	102	IO Not Responding
ISA[1]	103	ISaGRAF Controlled
Ilock[2]	104	Remote Control Interlock Enabled
State	105	Current State
Alarm	106	Point is in Alarm
A4H	114	Alarm Limit Transgress 4H
A3H	113	Alarm Limit Transgress 3H
A2H	112	Alarm Limit Transgress 2H
A1H	111	Alarm Limit Transgress 1H
A1L	110	Alarm Limit Transgress 1l
A2L	109	Alarm Limit Transgress 2l
A3L	108	Alarm Limit Transgress 3l
A4L	107	Alarm Limit Transgress 4l
Raw	115	Current Integer Value
RoRise	117	Rate Of Rise Exceeded
RoFall	118	Rate of Fall Exceeded
NC	119	No Change Detected
ORange	120	Over Range
URange	121	Under Range
ADF	122	Ad Reference Check
HI[1]	123	High Limit Exceeded
CntRZ	53	Counter Reset to Zero on Power Up
PObj	3	DNP Static Object Type

Table 4-2 rdfld_i function attributes (attrib) for Integer (analog) points.

Attrib (ISaGRAF Keyword)	Equivalent Numeric Value	Description
RoRPN	17	Rate Of Rise Point Number
RoFPN	18	Rate Of Fall Point Number
NCPN	19	No Change Point Number
CexPN	20	Counter Exceeded Point Number
Rmin	29	Raw Min
Rmax	30	Raw Max
RoCTm	38	Rate Of Change Time
NCTm	39	No Change Time
Ev4H	49	Limit Event Enable 4h
Ev3H	48	Limit Event Enable 3h
Ev2H	47	Limit Event Enable 2h
Ev1H	46	Limit Event Enable 1h
Ev1L	45	Limit Event Enable 1l
Ev2L	44	Limit Event Enable 2l
Ev3L	43	Limit Event Enable 3l
Ev4L	42	Limit Event Enable 4l
LimHi	51	Counter High Limit
CntDev	52	Counter Change Deviation

Table 4-3 rdfld_i function attributes (attrib) for Digital (Boolean) points

Attrib (ISaGRAF Keyword)	Equivalent Numeric Value	Description
Inv[1]	11	Invert Point State
AState	12	Alarm Active State
AClrTm[3]	14	Alarm Clear Time Deadband
PTm	15	Output Pulse Time
DebTm	16	Debounce Time
DblStPt	54	Double Status Point Number

Table 4-4 rdfld_i function attributes (attrib)

Attrib (ISaGRAF Keyword)	Equivalent Numeric Value	Description
AInh[1]	7	Alarm Inhibit
ATm	10	Alarm Time Deadband
Bad	6	Point Is Bad

IlockPN[2]	4	Remote Control Interlock Point
IlockTm	5	Interlock Alarm Timeout
PClass	2	Point Data Class
PrId[2]	9	Profile Id
Prior	13	Point Priority
TInh[1]	8	Trend Inhibit

1 Upper case of i (I)
2 Upper case of i (I), lower case L (l)
3 Lower case L (l)

Note: The keywords in Table 4-1 to

Note: Table 4-4 are reserved and should be used exclusively to retrieve point properties using the function block. User defined variables which duplicate these keywords but are not being used in the same context will generate errors during the compilation.

An IEC61131-3 Function Block Diagram example of RDFLD_I is illustrated in Figure 4-2 below. The current integer value (Attrib = Raw) of analog input point labeled z_speedcontrol (analog input point 1) has been obtained.

Note that the preprocessor has been configured to create a dictionary variable z_speedcontrol of type 'defined word. The variable z_speedcontrol contains the DNP address of analog input point labeled 'speedcontrol'. Alternatively, the numeric DNP address of the analog input can also be used.

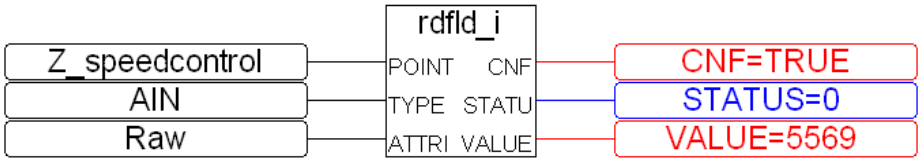


Figure 4-2 RDFLD_I function block diagram example

IEC61131-3 Structured Text prototypes take on the following form:

prototype: rdfld_i_inst (POINT, TYPE, ATTRIB)
complete_confirm := rdfld_i_inst.CNF
return_status := rdfld_i_inst.STATUS
return_value := rdfld_i_inst.VALUE
where rdfld_i_inst is an FB instance of the function block rdfld_ defined in the program dictionary.

An equivalent Structured Text implementation of the function block diagram in Figure 4-2 is listed below. This code will store the outputs of the function block rdfld_i in the variables CNF, STATUS and VALUE.

```
(*          Code Begins Here                                    *)
(* Ensure dictionary has the following variables defined:      *)
(* Boolean              CNF                                    *)
(* integer              STATUS                                 *)
(* Real                       Value                            *)
(* FB instances               rdfld_i_inst                     *)
```

```
rdfld_i_inst(z_speedcontrol, AIN, Raw);
if (rdfld_i_inst.CNF) then
      CNF := rdfld_i_inst.CNF;
      STATUS := rdfld_i_inst.status;
      VALUE := rdfld_i_inst.value;
end_if;
(* Code Ends Here *)
```

4.1.2 rdfld_r

Read DNP point attribute of type real

Description

Point database attributes and property fields that return real (float) values may be read by ISaGRAF application using the function block “RDFLD_R”.

Attributes and properties may be read from the point database. The format of this function block is the same as “RDFLD_I” except that the “Value” field in the case of “RDFLD_R” is a Real (float) value, and in the case of “RDFLD_I” is an Integer value. The description below illustrates the purpose, inputs and outputs of the RDFLD_R function block. Each time the function block is called, the RTU updates the ISaGRAF value variable from the specified point database field for the specified RTU point and point type.

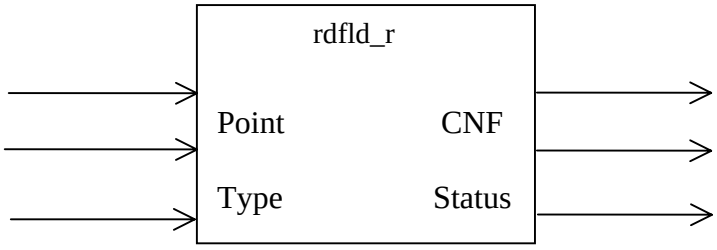


Figure 4-3: rdfld_r function block

INPUTS	TYPE	DESCRIPTION
Point	Integer	RTU DNP Point Address. Can be a dictionary variable containing the DNP point address, see section ***3 - The ISaGRAF Preprocessor***. Can also be numeric DNP point address.
Type	Integer	RTU DNP Point data type. Argument can be one of the ISaGRAF reserved keywords below or an integer value corresponding to the data type. **ISaGRAF Keyword** / **Equivalent Numeric Value** / **Comment** DIN / 1 / Digital input point DOUT / 2 / Digital output point AIN / 3 / Analog input point AOUT / 4 / Analog output point CIN / 5 / Counter input point
Attrib	Integer	Desired point attribute (property). Argument can be an ISaGRAF reserved keyword or an integer value corresponding to the attribute. See Table 4-5 for keywords and their corresponding numeric values.

OUTPUTS	TYPE	DESCRIPTION
CNF	Boolean	Confirm valid or invalid status Possible Values Meaning

		TRUE	Confirm Valid Status
		FALSE	Have not been able to get a false
Status	Integer	Status of Read Request	
		Possible Values	**Meaning**
		-1	Unknown Return Error
		0	Success
		1	Point does not exist
		2	Bad point type
		3	Unknown attribute for this point
		4	Bad value for this attribute
		5	Invalid attribute for this function block
		8	Point is locked
		12	Database is locked
		18	I/O Processor Unavailable
Value	Real	Depends on 'Attrib' input parameter	

Table 4-5 rdfld_r function attributes (attrib)

Attrib (ISaGRAF Keyword)	**Equivalent Numeric Value**	**Description**
Emin	31	Engineering Min
Emax	32	Engineering Max
Eng	116	Current Engineering Value
Lim4H	28	Engineering Limit 4H
Lim3H	27	Engineering Limit 3H
Lim2H	26	Engineering Limit 2H
Lim1H	25	Engineering Limit 1H
Lim1L	24	Engineering Limit 1L
Lim2L	23	Engineering Limit 2L
Lim3L	22	Engineering Limit 3L
Lim4L	21	Engineering Limit 4L
LimRise	35	Rate Of Rise
LimFall	36	Rate Of Fall
LimNC	37	No Change
AclrVal [3]	40	Alarm Clear Value Deadband
LimZero	41	Zero Threshold Limit
EvDev	50	Even _Deviation
LimOR	33	Over Range Limit
LimUR	34	Under Range Limit

1 Upper case of i (I)

2 Upper case of i (I), lower case L (l)

3 Lower case L (l)

Note:	The keywords in Table 4-5 are reserved and should be used exclusively to retrieve point properties using the function block. User defined variables which duplicate these keywords but are not being used in the same context will generate errors during the compilation.

An IEC61131-3 Function Block Diagram example of RDFLD_R is illustrated in Figure 4-4 below. The current floating point or real value of analog input point labeled z_speedcontrol (analog input pont 1) has been obtained.

Note that the preprocessor has been configured to create a dictionary variable z_speedcontrol of type ‘defined word. The variable z_speedcontrol contains the DNP address of analog input point labeled ‘speedcontrol’. Alternatively, the numeric DNP address of the analog input can also be used.

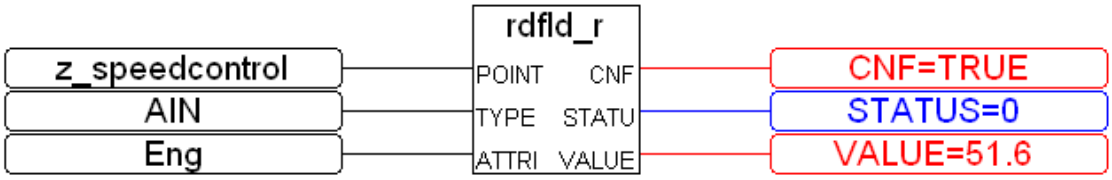


Figure 4-4 rdfld_r function block diagram example

IEC61131-3 Structured Text prototypes take on the following form:

prototype: rdfld_r _inst (POINT, TYPE, ATTRIB)
complete_confirm := rdfld_r_inst.CNF
return_status := rdfld_r_inst.STATUS
return_value := rdfld_r_inst.VALUE

where rdfld_r_inst is an instance of the function block rdfld_r defined in the program dictionary.

An equivalent Structured Text implementation of the function block diagram in Figure 4-4 is listed below. This code will store the outputs of the function block rdfld_r in the variables CNF, STATUS and VALUE.

```
 (*         Code Begins Here                                  *)
(* Ensure dictionary has the following variables defined:    *)
(* Boolean              CNF                                  *)
(* integer              STATUS                               *)
(* Real                       Value                          *)
(* FB instances               rdfld_r_inst                   *)
rdfld_r_inst(z_speedcontrol, AIN, Eng);
if (rdfld_r_inst.CNF) then
      CNF := rdfld_r_inst.CNF;
      STATUS := rdfld_r_inst.STATUS;
      VALUE := rdfld_r_inst.VALUE;
end_if;
(* Code Ends Here *)
```

4.1.3 rdrec

Read DNP point attribute of type real

Description

The RDREC function block reads the most common attributes for point types. If an attribute is not defined for the DNP point in question, a value of zero is returned.

The description below illustrates the purpose, inputs and outputs of the RDREC function block.

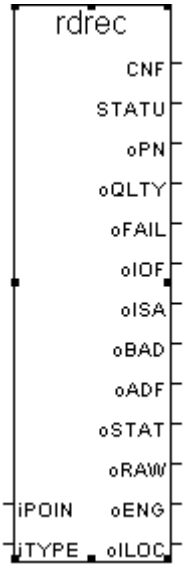


Figure 4-5: rdrec function block

INPUTS	TYPE	DESCRIPTION
iPOIN	Integer	RTU DNP Point Address. Can be a dictionary variable containing the DNP point address, see section ***3 - The ISaGRAF Preprocessor***. Can also be numeric DNP point address.
iTYPE	Integer	RTU DNP Point data type. Argument can be one of the ISaGRAF reserved keywords below or an integer value corresponding to the data type. **ISaGRAF Keyword** / **Equivalent Numeric Value** / **Comment** DIN / 1 / Digital input point DOUT / 2 / Digital output point AIN / 3 / Analog input point AOUT / 4 / Analog output point CIN / 5 / Counter input point

OUTPUTS	TYPE	DESCRIPTION
CNF	Boolean	Confirm valid or invalid status **Possible Values** **Meaning**

		TRUE Confirm Valid Status FALSE
Status	Integer	Status of Read Request **Possible Values** **Meaning** -1 Unknown Return Error 0 Success 1 Point does not exist 2 Bad point type 3 Unknown attribute for this point 4 Bad value for this attribute 5 Invalid attribute for this function block 8 Point is locked 12 Database is locked 18 I/O Processor Unavailable
oPN	Integer	Point Number
oQlty	Integer	Point Quality
oFail	Boolean	Point Failed
oIOF	Boolean	ISaGRAF Controlled
oBAD	Boolean	Point is Bad
oADF	Boolean	A/D Reference Error
oSTATE	Boolean	Point State
oRAW	Integer	Raw Point Value
oENG	Real	Engineering (Real) Value
oILOC	Boolean	Control Interlock Active

An IEC61131-3 Function Block Diagram example of RDFLD_R is illustrated in below.

Note that the preprocessor has been configured to create a dictionary variable z_speedcontrol of type ‘defined word. The variable z_speedcontrol contains the DNP address of analog input point labeled ‘speedcontrol’. Alternatively, the numeric DNP address of the analog input can also be used.

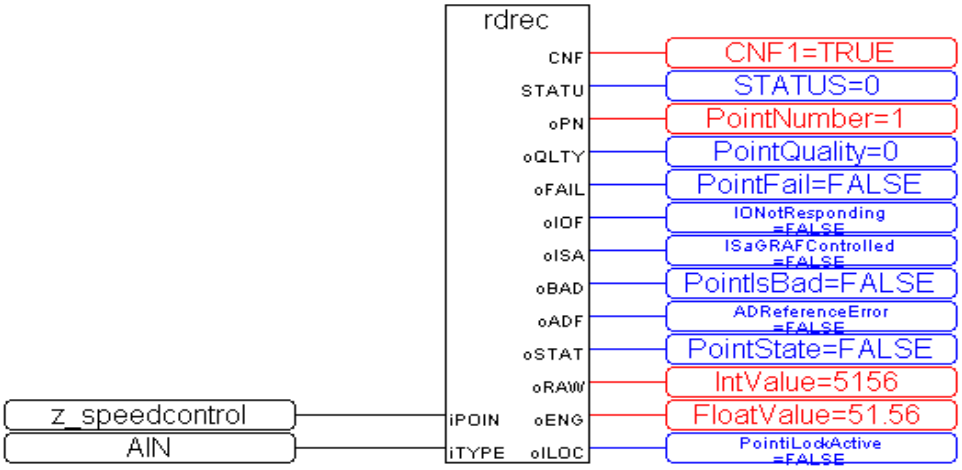


Figure 4-6: rdrec function block example

IEC61131-3 Structured Text prototypes take on the following form:

```
prototype:  rdrec_inst (POINT, TYPE)
            complete_confirm :=  rdrec_inst.CNF
            return_status := rdrec_inst.STATUS
            Point_number := rdrec_inst.oPN …….
```

where rdrec_inst is an instance of the function block rdrec defined in the program dictionary.

An equivalent Structured Text implementation of the function block diagram in Figure 4-6 listed below. This code will store the outputs of the function block rdrec in the variables CNF, STATUS, PointNumber, PointQuality, etc…

```
(*   Code Snippet Begins Here                                    *)
(* Ensure dictionary has the following variables defined:       *)
(* Boolean              CNF                                     *)
(* Boolean              PointFailed                             *)
(* integer              STATUS                                  *)
(* Integer              PointNumber                             *)
(* Integer              PointQuality                            *)
(* Integer              IntValue                                *)
(* Real                       FloatValue                        *)
(* FB instances   rdfld_inst                                    *)
rdrec_inst(z_speedcontrol, AIN);
if (rdrec_inst.CNF) then
      CNF := rdrec_inst.CNF;
      STATUS := rdrec_inst.status;
      PointNumber := rdrec_inst.oPN;
      PointQuality := rdrec_inst.oQlty;
      PointFailed := rdrec_inst.oFail;
      IntValue := rdrec_inst.oRaw;
      FloatValue := rdrec_inst.oEng;
end_if;
(* Code Ends Here *)
```

4.1.4 rdrec_dg

Read attributes for digital DNP points

Description

The rdrec_dg function block reads attributes for digital points. Return Values that do not exist for a point type will return 0.

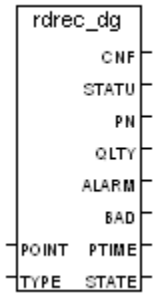


Figure 4-7 rdrec_dg function block

INPUTS	TYPE	DESCRIPTION
iPOINT	Integer	RTU DNP Point Address. Can be a dictionary variable containing the DNP point address, see section ***3 - The ISaGRAF Preprocessor***. Can also be numeric DNP point address.
iTYPE	Integer	RTU DNP Point data type. Argument can be one of the ISaGRAF reserved keywords below or an integer value corresponding to the data type. **ISaGRAF Keyword** / **Equivalent Numeric Value** / **Comment** DIN / 1 / Digital input point DOUT / 2 / Digital output point AIN / 3 / Analog input point AOUT / 4 / Analog output point CIN / 5 / Counter input point

OUTPUTS	TYPE	DESCRIPTION
oCnf	Boolean	Confirm valid or invalid status **Possible Values** / **Meaning** TRUE / Confirm Valid Status FALSE
oStatus	Integer	Status of Read Request **Possible Values** / **Meaning** -1 / Unknown Return Error 0 / Success 1 / Point does not exist 2 / Bad point type 3 / Unknown attribute for this point

		4	Bad value for this attribute
		5	Invalid attribute for this function block
		8	Point is locked
		12	Database is locked
		18	I/O Processor Unavailable
oPn	Integer	Point Number	
oQlty	Integer	Point Quality	
oAlarm	Boolean	Point Failed	
oBad	Boolean	Point is Bad	
oPtime	Timer	Output pulse time	
ostate	Boolean	Point State	

An IEC61131-3 Function Block Diagram example of rdrec_dg is illustrated in below.

Note that the preprocessor has been configured to create a dictionary variable z_DIN1 of type ‘defined word. The variable z_DIN1 contains the DNP address of digital input point labeled ‘DIN1’. Alternatively, the numeric DNP address of the digital input can also be used.

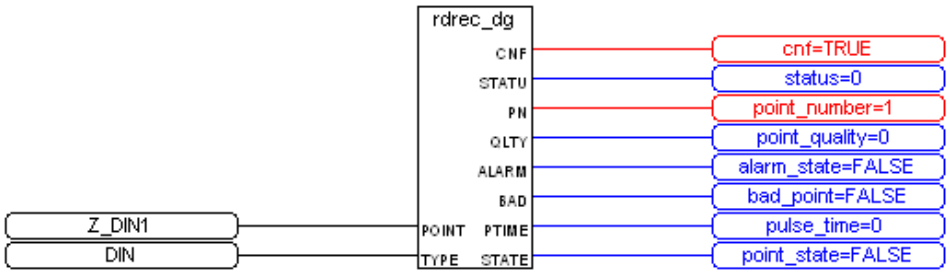


Figure 4-8 rdrec_dg function block example

IEC61131-3 Structured Text prototypes take on the following form:

```
Prototype:        rdrec_dg_inst (point, type)
                  complete_confirm :=  rdrec_dg_inst.cnf
                  return_status := rdrec_dg_inst.status
                  Point_number := rdrec_dg_inst.PN …….
```

where rdrec_dg_inst is an instance of the function block rdrec_dg defined in the program dictionary.

An equivalent Structured Text implementation of the function block diagram in Figure 4-8 is listed below.

```
(*   Code Snippet Begins Here                                  *)
(* Ensure dictionary has the following variables defined:     *)
(* Boolean              cnf                                   *)
(* integer              status                                *)
(* Integer              point_number                          *)
(* Integer              point_quality                         *)
(* Boolean              alarm_state                           *)
(* Boolean              bad_point                             *)
(* Integer              pulse_tme                             *)
(* Boolean              point_state                           *)
(* FB instances   rdrec_dg_inst                               *)
```

```
rdrec_dg_inst(z_DIN1, DIN);
if (rdrec_dg_inst.ocnf) then
      cnf := rdrec_dg_inst.ocnf;
      status := rdrec_dg_inst.ostatus;
      point_number :=  rdrec_dg_inst.opn;
      point_quality := rdrec_dg_inst.oqlty;
      alarm_state := rdrec_dg_inst.oalarm;
      bad_point := rdrec_dg_inst.obad;
      pulse_time := rdrec_dg_inst.optime;
      point_state := redrec_dg_inst.ostate;
end_if;
(* Code ends here *)
```

4.1.5 rdrec_cn

Read attributes for counter DNP points

Description

The rdrec_cn function block reads attributes for counter points. The return value for a point type that does not exist is 0.

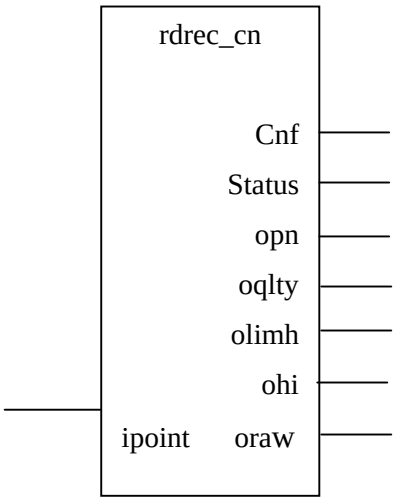


Figure 4-9: rdrec_cn function block

INPUTS	TYPE	DESCRIPTION
ipoint	Integer	RTU DNP Point Address. Can be a dictionary variable containing the DNP point address, see section ***3 - The ISaGRAF Preprocessor***. Can also be numeric DNP point address.
type	Integer	RTU DNP Point data type. Argument can be one of the ISaGRAF reserved keywords below or an integer value corresponding to the data type.

ISaGRAF Keyword	Equivalent Numeric Value	Comment
DIN	1	Digital input point
DOUT	2	Digital output point
AIN	3	Analog input point
AOUT	4	Analog output point
CIN	5	Counter input point

OUTPUTS	TYPE	DESCRIPTION
Cnf	Boolean	Confirm valid or invalid status **Possible Values** **Meaning** TRUE Confirm Valid Status FALSE
Status	Integer	Status of Read Request **Possible Values** **Meaning** -1 Unknown Return Error 0 Success 1 Point does not exist 2 Bad point type 3 Unknown attribute for this point 4 Bad value for this attribute 5 Invalid attribute for this function block 8 Point is locked 12 Database is locked 18 I/O Processor Unavailable
opn	Integer	Point Number
oqlty	Integer	Point Quality
olim1h	Real	Counter high limit
ohi	Boolean	Counter limit exceeded
oraw	integer	Raw value

o is lower case O
l is lower case L

IEC61131-3 Structured Text prototypes take on the following form:

```
Prototype:  rdrec_cn_inst (point, type)
            complete_confirm :=  rdrec_cn_inst.cnf
            return_status := rdrec_cn_inst.status
            Point_number := rdrec_cn_inst.opn
            Point_quality  := rdrec_cn_inst.opn
```

where rdrec_dg_inst is an instance of the function block rdrec_cn defined in the program dictionary.

4.1.6 rdrec_an

Read attributes for analog (integer) DNP input points

Description

The RDREC_AN function block reads attributes for analogue points. The return value for a point type that does not exist is 0.

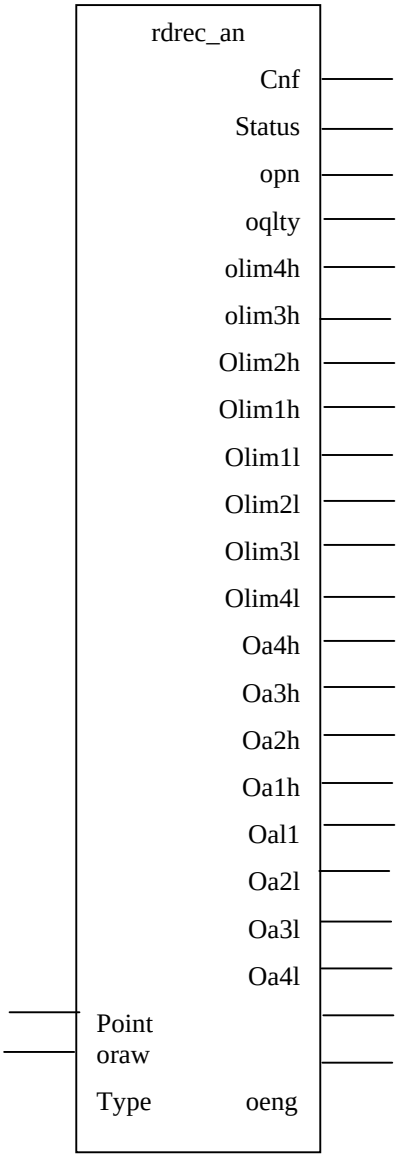


Figure 4-10: rdrec_an function block

INPUTS	TYPE	DESCRIPTION
POINT	Integer	RTU DNP Point Address. Can be a dictionary variable containing the DNP point address, see section ***3 - The ISaGRAF Preprocessor***. Can also be numeric DNP point address.

INPUTS	TYPE	DESCRIPTION
TYPE	Integer	RTU DNP Point data type. Argument can be one of the ISaGRAF reserved keywords below or an integer value corresponding to the data type. **ISaGRAF Keyword** / **Equivalent Numeric Value** / **Comment** DIN / 1 / Digital input point DOUT / 2 / Digital output point AIN / 3 / Analog input point AOUT / 4 / Analog output point CIN / 5 / Counter input point

OUTPUTS	TYPE	DESCRIPTION
Cnf	Boolean	Confirm valid or invalid status **Possible Values** / **Meaning** TRUE / Confirm Valid Status FALSE
Status	Integer	Status of Read Request **Possible Values** / **Meaning** -1 / Unknown Return Error 0 / Success 1 / Point does not exist 2 / Bad point type 3 / Unknown attribute for this point 4 / Bad value for this attribute 5 / Invalid attribute for this function block 8 / Point is locked 12 / Database is locked 18 / I/O Processor Unavailable
opn	Integer	Point Number
oqlty	Integer	Point Quality
olim4h	Real	Engineering Limit 4H
olim3h	Real	Engineering Limit 3H
olim2h	Real	Engineering Limit 2H
olim1h	Real	Engineering Limit 1H
olim1l	Real	Engineering Limit 1L
olim2l	Real	Engineering Limit 2L
olim3l	Real	Engineering Limit 3L
olim4l	Real	Engineering Limit 4L
oa4h	Boolean	Alarm Limit Transgress 4H
oa3h	Boolean	Alarm Limit Transgress 3H
oa2h	Boolean	Alarm Limit Transgress 2H
oa1h	Boolean	Alarm Limit Transgress 1H

oa1l	Boolean	Alarm Limit Transgress 1L
oa2l	Boolean	Alarm Limit Transgress 2L
oa3l	Boolean	Alarm Limit Transgress 3L
oa4l	Boolean	Alarm Limit Transgress 4L
oraw	integer	Raw value
oeng	Real	Floating point value

o is lower case
l is lower case

An IEC61131-3 Function Block Diagram example of rdrec_an is illustrated in below.

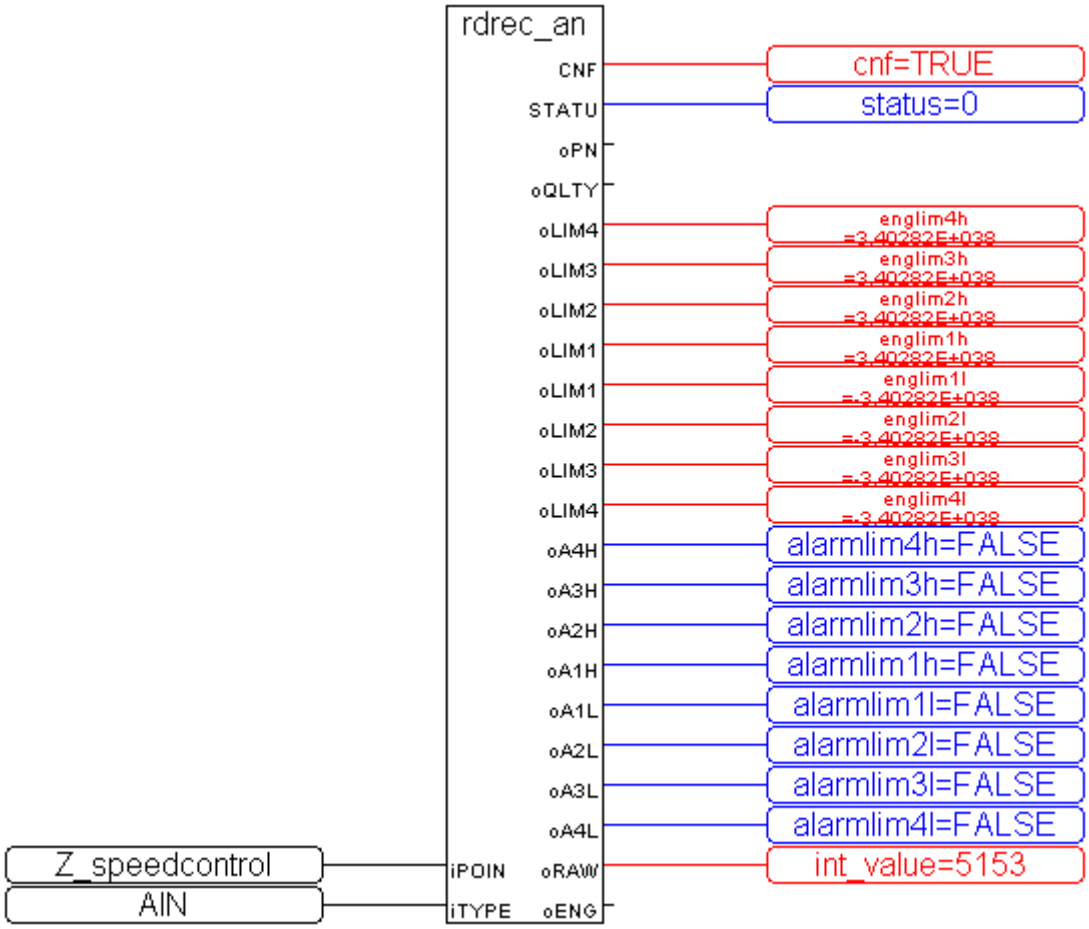


Figure 4-11: rdrec_an function block example

IEC61131-3 Structured Text prototypes take on the following form:

```
prototype:  rdrec_an_inst (point, type)
            complete_confirm :=  rdrec_an_inst.cnf
            return_status := rdrec_an_inst.status
            Point_number := rdrec_an_inst.pn …….
```

where rdrec_an_inst is an instance of the function block rdrec_an defined in the program dictionary. An Structured Text sample implementation of the rdrec_an function block in Figure 4-10 is listed below.

```
(*   Code Snippet Begins Here                                  *)
(* Ensure dictionary has the following variables defined:     *)
(* Boolean              cnf                                   *)
(* integer              status                                *)
(* Integer              point_number                          *)
(* Integer              point_quality                         *)
(* Real                       eng_limit_4H                    *)
(* Real                       eng_limit_1L                    *)
(* Boolean              alarm_limit_tran_4H                   *)
(* Boolean              alarm_limit_tran_1L                   *)
(* Integer              current_int_value                     *)
(* Real                       current_real_value              *)
rdrec_an_inst(z_speedcontrol, AIN);
if (rdrec_an_inst.cnf) then
      cnf := rdrec_an_inst.cnf;
      status := rdrec_an_inst.status;
      point_number :=  rdrec_an_inst.opn;
      point_quality := rdrec_an_inst.oqlty;
      eng_limit_4H := rdrec_an_inst.olim4h;
      eng_limit_1L := rdrec_an_inst.olim1l;
      alarm_limit_tran_4H := rdrec_an_inst.oa4H;
      alarm_limit_tran_1L := rdrec_an_inst.oa1L;
      current_int_value  := rdrec_an_inst.oraw;
      current_real_value  := rdrec_an_inst.oeng;
end_if;
(* code ends here *)
```

4.1.7 rdstring

Read a string point

Description

Reads a string point or message from the RTU system string map. The return value for a point that does not exist is 0.

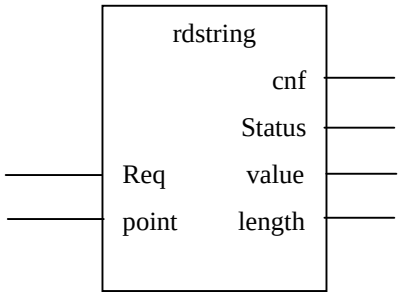


Figure 4-12: rdstring function block

INPUTS	TYPE	DESCRIPTION
point	Integer	RTU DNP Point Address that holds a string value. Can be a dictionary variable containing the DNP point address, see section ***3 - The ISaGRAF Preprocessor***. Can also be numeric DNP point address. **Possible Values** — **Description** 50100 — ISaGRAF Target 1 Application Name 50101 — ISaGRAF Target 2 Application Name
req	boolean	Request to read a point **Possible Values** — **Meaning** TRUE — Read point enabled FALSE — Read point function disabled

OUTPUTS	TYPE	DESCRIPTION
Cnf	Boolean	Confirm valid or invalid status **Possible Values** — **Meaning** TRUE — Confirm Valid Status FALSE
Status	Integer	Status of Read Request **Possible Values** — **Meaning** -1 — Unknown Return Error 0 — Success 1 — Point does not exist
Value	Msg	Return string message
Length	Integer	Maximum string length allowed for a point

A sample function block implementation of rdstring is illustrated below;

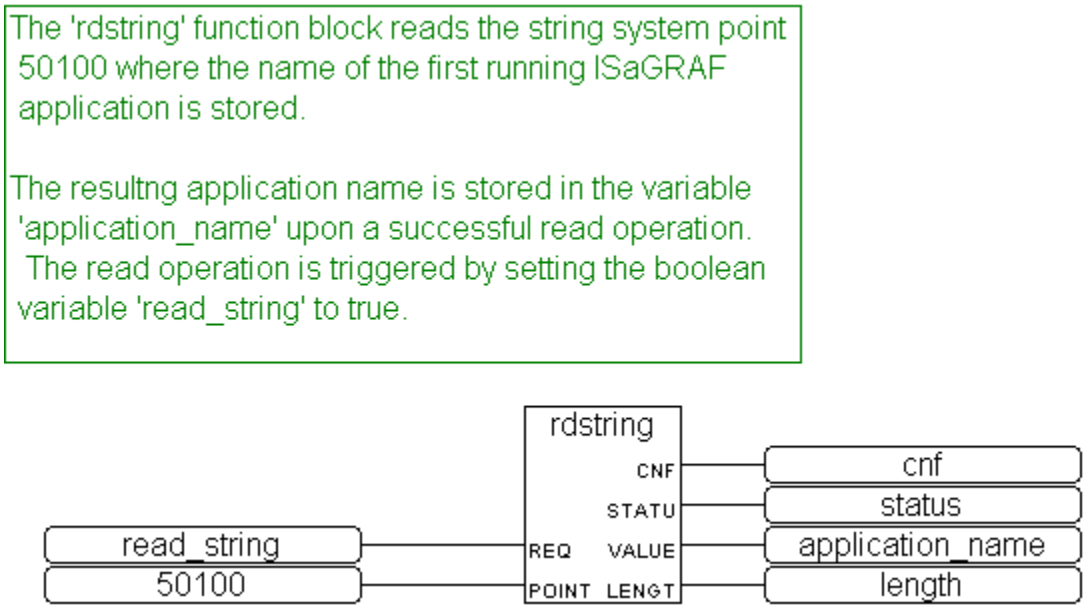


Figure 4-13 rdstring function block example

A structured text implementation of rdstring is listed below. In this example, variable ISaGRAF_APP_1 contains the DNP address of the ISaGRAF application name running on kernel 1. This is the system point number for the first ISaGRAF application name.

```
Read_String := TRUE;
ISaGRAF_APP_1 := 50100;
r_string(Read_String, ISaGRAF_APP_1);
IF(r_string.CNF) THEN
      Read_String := FALSE;
      IF(r_string.STATUS = SUCCESS) THEN
            ReadStringValue := r_string.VALUE;
            valid_string := TRUE;
      ELSE
            valid_string := FALSE;
      END_IF;
END_IF;
```

4.1.8 rd_tc_ad

Return Telemetry computer address information for X.25 and PSTN terminals

Description

This function block returns RTU configuration information for Telemetry Computer (TC) systems, specifically X.25 address and PSTN number details. It provides specific connection information suitable for backup communication processing.

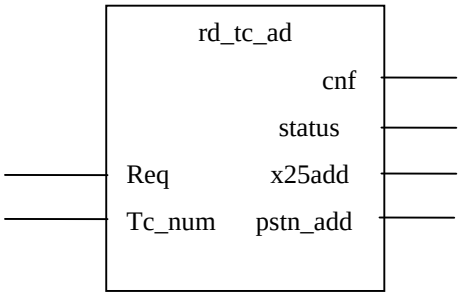


Figure 4-14: rd_tc_ad function block

INPUTS	TYPE	DESCRIPTION
tc_num	Integer	Telemetry computer number.
req	boolean	Request to read a point **Possible Values** — **Meaning** TRUE — Read point enabled FALSE — Read point function disabled

OUTPUTS	TYPE	DESCRIPTION
Cnf	Boolean	Confirm valid or invalid status **Possible Values** — **Meaning** TRUE — Confirm Valid Status FALSE
Status	Integer	Status of Read Request **Possible Values** — **Meaning** -1 — Unknown Return Error 0 — Success 1 — Information not found
x25add	Msd	X25 address string
Pstn_add	msg	PSTN phone number string

A sample implementation of rd_tc_ad is presented below:

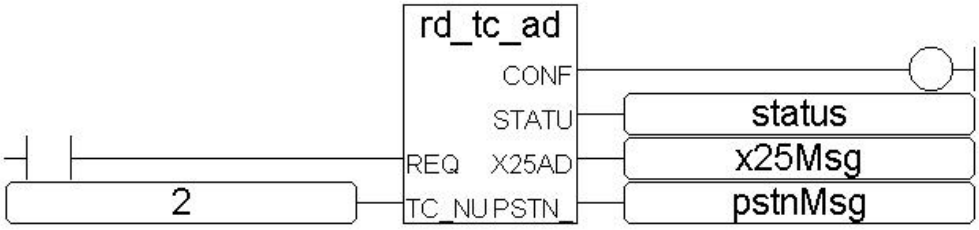


Figure 4-15 rd_tc_ad function block example

4.1.9 rtupulse and rtupuls2

Generate a pulse on a digital output

Description

Digital output points on the SCADAPack E Series RTU can be activated for a predetermined length of time. There are two mechanisms for creating pulses on the digital output ports under control of the ISaGRAF application.

- An ISaGRAF application may choose to switch a *Boolean Output* variable on and off.
- The RTU's ISaGRAF "*RTUPULSE*" or "*RTUPULS2*" function block may be activated by the ISaGRAF application.

4.1.9.1 rtupulse

The function block 'rtupulse' turns on the RTU digital outputs for a predetermined length of time. There must NOT be an ISaGRAF Boolean Output Board connection for the physical digital output being controlled (i.e. No attached ISaGRAF output board variable). When this function block is executed, the RTU turns ON the output point for the duration of the "ptime" parameter of the "rtupulse" function block.

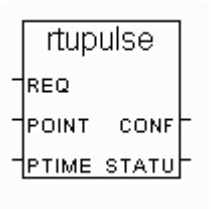


Figure 4-16: rtupulse function block

If "ptime" is zero, the output point is turned ON for the time duration configured in the point's "Output Pulse Time" attribute. This field may initially have been configured through an ISaGRAF application using the setatr_i function block with the attribute set to Ptm. The function block will execute when the 'req' input value goes from FALSE to TRUE. 'req' must be set to FALSE before each subsequent pulse execution from this instance of the function block.

SCADAPack ER physical digital outputs return CNF status at the initiation of the pulse or pulse train rather than the completion of the pulse or pulse train.

The RTU will not pulse the digital point as instructed by this ISaGRAF function block if the digital point was not found, was read-only (eg. physical input point), if a remote control interlock point was active for this point, or if a pulse is currently being executed on this point.

This function block causes the RTU to control digital outputs in a similar fashion to the DNP3 CROB object. The main differences are:

- The pulse duration time is specified by the ISaGRAF application, or is preset in a point attribute if ISaGRAF specifies a time of zero.
- Only a single pulse is generated. Once initiated by ISaGRAF, the digital output pulse is controlled by the RTU's I/O Processor Task and is independent of the ISaGRAF application cycle time.

Note: The ISaGRAF User Application may read the output point's "Output Pulse Time" attribute using the "rdfld_i" function block and use this to derive the "rtupulse" function block's "ptime" parameter. For example, on a valve, the minimum useful pulse width is likely to be that specified in the "Output Pulse Time" point attribute.

INPUTS	TYPE	DESCRIPTION
req	boolean	Request to read a point **Possible Values** — **Meaning** TRUE — Read point enabled FALSE — Read point function disabled
point	Integer	RTU DNP digital output point Can be a dictionary variable containing the DNP point address, see section ***3 - The ISaGRAF Preprocessor***.
Ptime	Timer	Pulse duration (ms timer format)

OUTPUTS	TYPE	DESCRIPTION
conf	Boolean	Confirm status ready to write **Possible Values** — **Meaning** TRUE — Pulse has completed or pulse request failed. TRUE indicates the status is ready to read. FALSE — Pulse has not been completed or REQ = false
Status	Integer	Status of Read Request **Possible Values** — **Meaning** 0 — Output pulse has completed executing 1 — Error: digital point not found or pulse not yet completed. (in a sample application, this value is 1 before the pulse is generated and changes to 0 after the pulse has been generated). 2 — Failed: remote interlock active 3 — Failed: pulse already executing

In the sample function block diagram below, DNP digital output point 5 has been programmed to stay ON for 5 seconds when SW1 is TRUE.

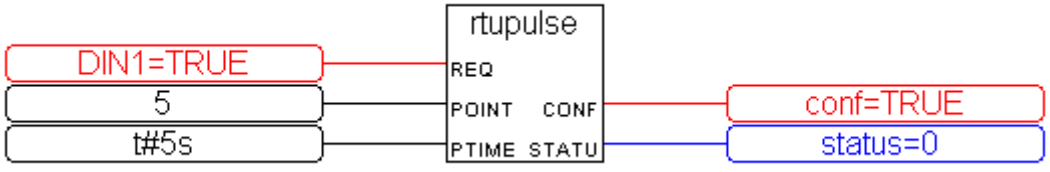


Figure 4-17: rtupulse function block example

In the Structured text sample below, digital output point 6 has been programmed to stay ON for 10 seconds when SW2 is TRUE. Note that the variables SW2, conf and status have to be defined in the program dictionary.

```
(* Code starts here *)
rtupulse_inst(SW2, 6, t#10s);
if (rtupulse_inst.conf) then
conf := rtupulse_inst.conf;
status := rtupulse_inst.status;
end_if;
```

4.1.9.2 rtupuls2

The RTUPULS2 function block is similar in function with some additional parameters and functionality. The above details about the RTUPULSE function block also apply to the RTUPULS2 function block except where overridden below.

This function block causes the RTU to control digital outputs in a similar fashion to the DNP3 CROB object. The main differences are:

- The pulse on duration time is specified by the ISaGRAF application, or is preset in a point attribute if ISaGRAF specifies a time of zero.
- The pulse off duration time is specified by the ISaGRAF application, or is 10 ms by default.
- The number of pulses generated is determined by the count value. Once initiated by ISaGRAF, the digital output pulse is controlled by the RTU's I/O Processor Task and is independent of the ISaGRAF application cycle time.

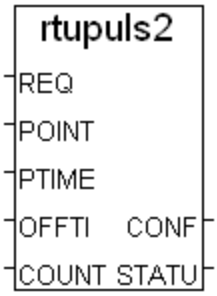


Figure 4-18: rtupulse function block

INPUTS	TYPE	DESCRIPTION
req	boolean	Request to read a point **Possible Values** — **Meaning** TRUE — Read point enabled FALSE — Read point function disabled
point	Integer	RTU DNP digital output point Can be a dictionary variable containing the DNP point address, see section ***3 - The ISaGRAF Preprocessor***.
Ptime	Timer	Pulse on duration (mS timer format)
offtime	Timer	Pulse off duration (mS timer format)

Count	Integer	Number of pulse cycles in the pulse train

OUTPUTS	TYPE	DESCRIPTION
conf	Boolean	Confirm status ready to write **Possible Values** — **Meaning** TRUE — Pulse has completed or pulse request failed. TRUE indicates the status is ready to read. FALSE — Pulse has not been completed or REQ = false
Status	Integer	Status of Read Request **Possible Values** — **Meaning** 0 — Output pulse has completed executing 1 — Error: digital point not found or pulse not yet completed. (in a sample application, this value is 1 before the pulse is generated and changes to 0 after the pulse has been generated). 2 — Failed: remote interlock active 3 — Failed: pulse already executing

prototype: RTUPULSE(REQ, POINT,PTIME, OFFTIME, COUNT);

4.1.10 setatr_i

Set integer DNP point attributes

Description

RTU point database attributes represented by integer values may be set by an ISaGRAF application using ISaGRAF function block “setatr_i”.

The tables below describe the inputs and outputs of the setatr_i function block. Each time the function block is called, the RTU updates the specified point database field for the specified RTU point number and point type from the value of an ISaGRAF variable.

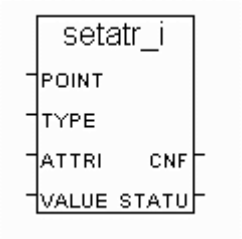


Figure 4-19 setatr_i function block

INPUTS	TYPE	DESCRIPTION
Point	Integer	RTU DNP Point Address. Can be a dictionary variable containing the DNP point address, see section ***3 - The ISaGRAF Preprocessor***. Can also be numeric DNP point address.
Type	Integer	RTU DNP Point data type. Argument can be one of the ISaGRAF reserved keywords below or an integer value corresponding to the data type. **ISaGRAF Keyword** / **Equivalent Numeric Value** / **Comment** DIN / 1 / Digital input point DOUT / 2 / Digital output point AIN / 3 / Analog input point AOUT / 4 / Analog output point CIN / 5 / Counter input point
Attrib	Integer	Desired point attribute (property). Argument can be an ISaGRAF reserved keyword or an integer value corresponding to the attribute. See Table 4-6.
Value	Integer	Desired field value

OUTPUTS	TYPE	DESCRIPTION
Cnf	Boolean	Confirm valid or invalid status **Possible Values** / **Meaning** TRUE / Confirm Valid Status FALSE
Status	Integer	Status of Read Request

		Possible Values	Meaning
		-1	Unknown Return Error
		0	Success
		1	Information not found
		2	Bad Point type
		3	Unknown attribute for this point
		4	Bad value for this attribute
		5	Invalid attribute for this point

Structured text prototypes take on the following format:

```
SETATR_I _INST(POINT, TYPE, ATTRIB,VALUE)
complete_confirm :=  SETATR_I_NST.CNF
return_status := SETATR_I_INST.STATUS
```

Table 4-6: Valid attributes (attrib) for setatr_i function block

Attrib (ISaGRAF Keyword)	**Equivalent Numeric Value**	**Description**	**Point Type where Applicable**
PClass	2	Point Data Class	All
PObj	3	DNP Static Object Type	All
IlockPN	4	Remote Interlock Point	Output points only
IlockTm	5	Interlock Alarm timeout	Output points only
Bad	6	Point is bad	All
AInh[1]	7	Alarm Inhibit 0 = alarm enable 1 = alarm disable	All
TInh[1]	8	Trend Inhibit 0 = trend enable 1 = trend disable	All
PrId[2]	9	Profile Id	All
ATm	10	Alarm Time Deadband	All
Inv[1]	11	Invert Point State	Digital points only
AState	12	Alarm Active State	Digital points only
Prior	13	Point Priority	All
AClrTm[3]	14	Alarm Clear Time Deadband	all
PTm	15	Output Pulse Time	Digital output only
DebTm	16	Debounce Time	Digital input only
RoRPN	17	Rate Of Rise Point Number	Analog
RoFPN	18	Rate Of Fall Point Number	Analog
NCPN	19	No Change Point Number	Analog
CexPN	20	Counter Exceeded Point Number	Counter
CntRZ		Counter Reset to Zero on power up 0 = retain previous value 1 = Reset to zero	Counter

Attrib (ISaGRAF Keyword)	Equivalent Numeric Value	Description	Point Type where Applicable
Rmin	29	Raw Min	Analog
Rmax	30	Raw Max	Analog
RoCTm	38	Rate Of Change Time	Analog
NCTm	39	No Change Time	Analog
Ev4H	49	Limit Event Enable 4h 0 = event disabled 1 = event enabled	Analog
Ev3H	48	Limit Event Enable 3h 0 = event disabled 1 = event enabled	Analog
Ev2H	47	Limit Event Enable 2h 0 = event disabled 1 = event enabled	Analog
Ev1H	46	Limit Event Enable 1h 0 = event disabled 1 = event enabled	Analog
Ev1L	45	Limit Event Enable 1l 0 = event disabled 1 = event enabled	Analog
Ev2L	44	Limit Event Enable 2l 0 = event disabled 1 = event enabled	Analog
Ev3L	43	Limit Event Enable 3l 0 = event disabled 1 = event enabled	Analog
Ev4L	42	Limit Event Enable 4l 0 = event disabled 1 = event enabled	Analog
LimHi	51	Counter High Limit	Counter
CntDev	52	Counter Change Deviation	Counter
AclrVal [3]	40	Alarm Clear Value Deadband	Analog
LimZero	41	Zero Threshold Limit	Analog
LimOR	33	Over Range Limit	Analog
LimUR	34	Under Range Limit	Analog

4.1.11 setatr_r

Set real DNP point attributes

Description

RTU point database attributes represented by real (floating point) values may be set by an ISaGRAF application using ISaGRAF function block “setatr_r”.

The table below describes the inputs and outputs of the setatr_r function block. Each time the function block is called, the RTU updates the specified point database field for the specified RTU point number and point type from the value of an ISaGRAF variable.

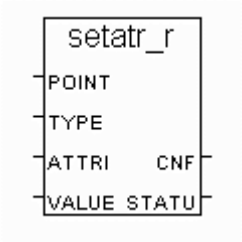


Figure 4-20 setatr_r function block

INPUTS	TYPE	DESCRIPTION
Point	Integer	RTU DNP Point Address. Can be a dictionary variable containing the DNP point address, see section ***3 - The ISaGRAF Preprocessor***. Can also be numeric DNP point address.
Type	Integer	RTU DNP Point data type. Argument can be one of the ISaGRAF reserved keywords below or an integer value corresponding to the data type. **ISaGRAF Keyword** / **Equivalent Numeric Value** / **Comment** DIN / 1 / Digital input point DOUT / 2 / Digital output point AIN / 3 / Analog input point AOUT / 4 / Analog output point CIN / 5 / Counter input point
Attrib	Integer	Desired point attribute (property). Argument can be an ISaGRAF reserved keyword or an integer value corresponding to the attribute. See Table 4-7
Value	Real	Desired field value

OUTPUTS	TYPE	DESCRIPTION
Cnf	Boolean	Confirm valid or invalid status **Possible Values** / **Meaning** TRUE / Confirm Valid Status FALSE
Status	Integer	Status of Read Request

		Possible Values	Meaning
		-1	Unknown Return Error
		0	Success
		1	Information not found
		2	Bad Point type
		3	Unknown attribute for this point
		4	Bad value for this attribute
		5	Invalid attribute for this point

Table 4-7 valid attribute (attrib) values for setatr_r

Attrib (ISaGRAF Keyword)	Equivalent Numeric Value	Description	Point Type where Applicable
Emin	31	Engineering Min	Analog
Emax	32	Engineering Max	Analog
Lim4H	28	Engineering Limit 4H	Analog
Lim3H	27	Engineering Limit 3H	Analog
Lim2H	26	Engineering Limit 2H	Analog
Lim1H	25	Engineering Limit 1H	Analog
Lim1L	24	Engineering Limit 1L	Analog
Lim2L	23	Engineering Limit 2L	Analog
Lim3L	22	Engineering Limit 3L	Analog
Lim4L	21	Engineering Limit 4L	Analog
LimRise	35	Rate Of Rise	Analog
LimFall	36	Rate Of Fall	Analog
LimNC	37	No Change	Analog
EvDev	50	Even _Deviation	Analog

4.2 Real Time Clock function blocks

The following function blocks provide an ISaGRAF application access to the SCADAPack E Series RTU real time clock.

In addition to these functions, the SCADAPack E Series RTU supports ISaGRAF's standard "day_time" function returning the RTU clock in several string formats. For more information on this standard function, see the *ISaGRAF Workbench Language Reference* manual. Note that the "day_time" function returns the local RTU time, adjusted for Summer Time (see TIMEDATE description of the time-zone modifier for more information).

4.2.1 os_time

Return RTU local time in seconds since 00:00:00, 1st Jan 1970

Description

This function block returns the current time (Standard Time) as used by the PDS RTU operating system. The return parameter is an integer analog variable, in 'Seconds since 00:00:00, 1st Jan 1970. This function block does not adjust for UTC offsets or daylight saving time. I.e. it returns standard RTU time from the RTU's real time clock.

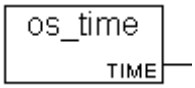


Figure 4-21 os_time function block

OUTPUT	TYPE	DESCRIPTION
Time	Integer	RTU operating system time in seconds since 00:00:00, 1970

4.2.2 pds_time

Return RTU local time since midnight, in milliseconds

Description

This function block returns the RTU local time. If the RTU's real time clock is operating in UTC mode, the RTU's *LOCAL TIME OFFSET FROM UTC* system point is applied prior to returning the data. In addition, the RTU examines a system point called *TIME ZONE MODIFIER* – binary system point 50302, and adjusts for summer time by adding 1 hour (if the point is set) prior to presenting the time to the user. The return parameter is a timer variable in "mS since midnight" ISaGRAF timer format (e.g.. t#23h59m59s999mS).

Figure 4-22: pds_time function block

OUTPUTS	TYPE	DESCRIPTION
Time	Timer	RTU time in milliseconds since midnight

4.2.3 timedate

Return RTU local time and date

Description

This function block returns the RTU local time and date. All return parameters are of type integer. If the RTU's real time clock is operating in UTC mode, the RTU's *LOCAL TIME OFFSET FROM UTC* system point is applied prior to returning the data. In addition, the RTU examines a system point called *TIME ZONE MODIFIER* – binary system point 50302, and adjusts for summer time by adding 1 hour (if the point is set) prior to presenting the time to the user.

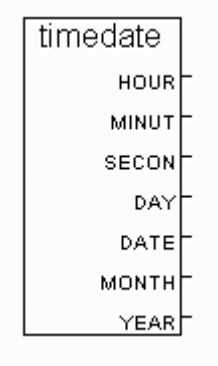


Figure 4-23 timedate function block

OUTPUTS	TYPE	DESCRIPTION
Hour	Integer	Current hour in 24 hour format (0-23)
Minute	Integer	Current minute (0-59)
Second	Integer	Current second (0-59)
Day	Integer	Current day (1-7 where 1 = Sunday)
Date	Integer	Current date (1-31)
month	Integer	Current month (1-12)
Year	Integer	Current year (2000-2099)

4.3 DNP3 Communication function blocks

The following section details ISaGRAF function blocks that interface with the SCADAPack E Series RTU Peer-to-Peer communication facilities. Communication between RTU devices uses DNP3 protocol. This section details function blocks for transfer of simple data types for ISaGRAF variables and DNP3 points. Section ***4.4 - DNP3 Queued Communication function blocks*** details queued communication function blocks for RTU database point data between RTU devices.

Each DNP3 Communication Function Block described in this section is implemented for one of two broad communication types:

RD data read

WR (SET) data write

These operate on three classes of DNP objects and corresponding ISaGRAF variable types:

BIN binary objects (corresponding to ISaGRAF Boolean variables)

ANA analog objects (corresponding to ISaGRAF Integer variables)

FLT floating point objects (corresponding to ISaGRAF Real variables)

The function blocks perform data transfer in one of two ways, depending on the value of the ObjectType parameter (see below).

- Local RTU data access (current point state or value in this RTU)
- DNP data communications with Peer RTU node

The RTU processing of user requests from a DNP3 ISaGRAF communication function block is limited to around 20 simultaneous requests. It is recommended that no more than this number of requests from an ISaGRAF application is generated within a single ISaGRAF scan. This allows the DNP3 driver to process the queued ISaGRAF requests.

Decreasing the rate of the DNP3 ISaGRAF communication block requests to fit these constraints should have little affect on the performance of the requested communications, particularly communication with peer DNP3 devices. The SCADAPack E Series RTU will process only a single outstanding communication request per DNP3 RTU port. Other DNP3 requests made at around the same time are processed in order, when each previous request is completed on that channel.

The DNP communication function blocks take the following general parameters

Calling (Input) Parameters

REQ (boo)	Data transfer communication request is initiated on the rising edge of this input. This user should keep this input asserted until the CNF output parameter is asserted (see below)
DNPnode (ana)	DNP peer node with which communication occurs (only applicable for DNP peer communications. Set value to *0* when doing Local RTU data access)
ObjectType (ana)	DNP3 data object requested from peer RTU node, or *Local_RTU_Data* for access to PDS RTU data
Index (ana)	Data index of first DNP data object accessed by this block

DT (timer) — Transaction time-out time in ISaGRAF timer format when communicating with peer DNP node (not applicable when doing Local RTU data access. Should be set to *0*)

SDx — Send data parameters (only present on Write function blocks) transferred by this function block when the REQ line is asserted (rising edge). The number of parameters (and hence the number of data objects transferred) depends on the number fixed for the function block (e.g. WR8ANA has parameters SD0..SD7 and writes 8 analog objects)

Return (Output) Parameters

CNF (boo) — Data transfer completion confirm: asserted by the function block to indicate completion of the request

RDY (boo) — Data ready asserted by the function block in conjunction with CNF to indicate successful completion of the transfer operation. RDx parameters (if any) will be valid at the time of the rising edge of RDY. If CNF is activated and RDY is not activated, the data transfer was unsuccessful

STATUS (ana) — Data transfer status: when CNF is active and RDY inactive this output parameter indicates a status code for the unsuccessful data transfer. Status = 255 while there is an outstanding DNP request. See Appendix A in the *E Series DNP RTU Technical Manual* for more information.

RDx — Read data parameters (only present of Read function blocks), are valid when the RDY parameter is active. The quantity of RDx parameters depends on the function block type (e.g. RD16BIN has Boolean parameters RD0…RD15 when 16 data objects are read)

The following tables describe the allowed Object Types for each of the communication function blocks. Note – CMI's '**common.eqv**' file contains definitions for these parameters.

Table 4-8 Read Function Block Object Types

Function Block	RDnnBIN	RdnnANA	RDnnFLT
Object Types Supported	Local_RTU_Data BinaryInput BinInput_Status BinOutput_Stat	Local_RTU_Data AnalogIn_32 AnalogIn_16 AnaIn_32_NoFlag AnaIn_16_NoFlag AnaOut_32_Stat AnaOut_16_Stat ReadTimeAndDate BinCounter_32 BinCounter_16 BinCtr_32_NoFlag BinCtr_16_NoFlag FrozCounter_32 FrozCounter_16 FrzCtr_32_NoFlag FrzCtr_16_NoFlag	Local_RTU_Data AnalogIn_Float AnOut_Float_Stat
ISaGRAF Variable	BOOLEAN	INTEGER	REAL

Table 4-9 Write Function Block Object Types

Function Block	WRnnBIN	WRnnANA	WRnnFLT
Object Types Supported	Local_RTU_Data CROB_DirOp CROB_SelOp CROB_DONA	Local_RTU_Data AnaOut_32_DirOp AnaOut_32_SelOp AnaOut_32_DONA AnaOut_16_DirOp AnaOut_16_SelOp AnaOut_16_DONA WriteTimeAndDate	Local_RTU_Data AnOutFloat_DirOp AnOutFloat_SelOp AnOutFloat_DONA
ISaGRAF Variable	BOOLEAN	INTEGER	REAL

4.3.1 rdxxbin

Read DNP3 digital points from the local or peer RTU address map

Description

This series of function blocks reads current value data from local RTU DNP binary points, or generates a DNP3 read request to a peer node for DNP3 binary objects. *xx* in the function block name refers to the number of objects to read and can be either 4, 8 or 16. The valid DNP object indexes that can be read from a peer DNP device are dependent on the peer device. The SCADAPack E Series RTU generates DNP3 start/stop range qualifiers (00 & 01) in requests to peer devices. Consult the DNP3 device manufacturer's device profile for more information.

Note:	Peer Read function blocks perform Application Layer retries as configured in the E Series Configurator 'Appl. Layer Attempts' field (default = 2). This means that for a single trigger of this function block, subsequent attempts could be made if the requests are failing. If each of the attempts fail, then the output parameters (CNF, RDY, and STATUS) will only be updated with failure status after all Application Layer Attempts have been performed (i.e. attempts x DT (timeout)).

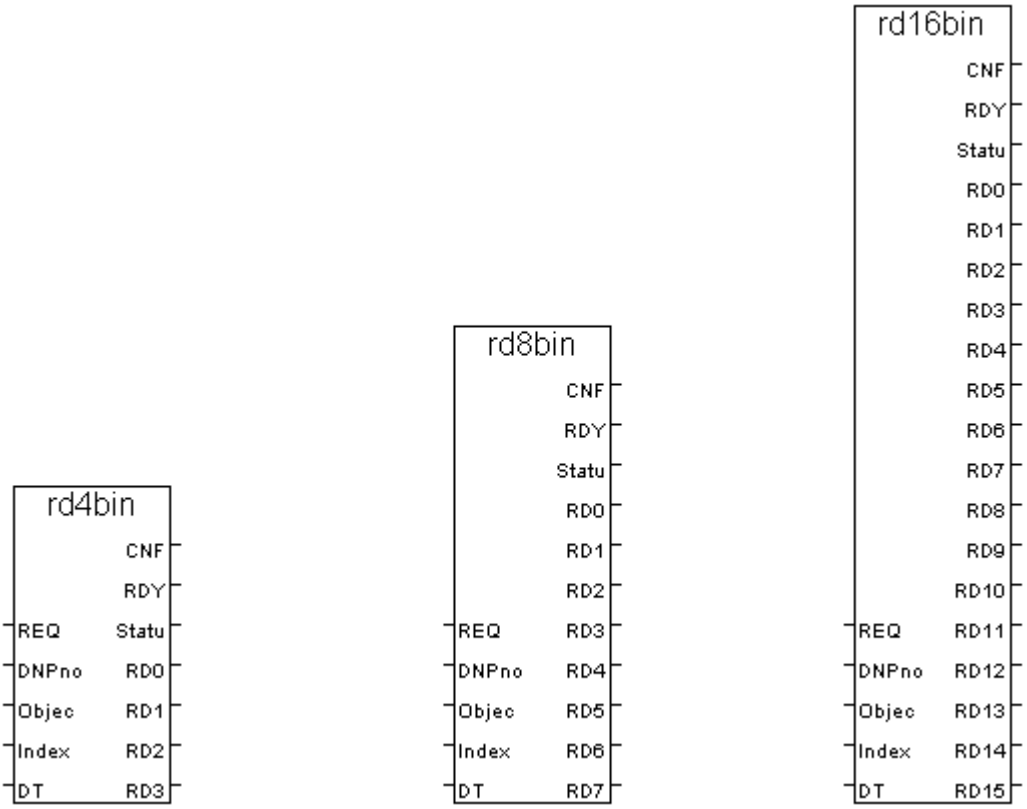


Figure 4-24 rdxxbin function blocks

INPUTS	TYPE	DESCRIPTION
Req	boolean	Data Transfer Request. Initiate data transfer request on rising edge
DNPnode	Integer	DNP Node address (peer RTU request only). Set value to 0 when doing Local RTU data access.
ObjectType	Integer	Local_RTU_Data or DNP data object to read from peer RTU. For peer RTU read, the following values are valid for this function block: BinaryInput BinInput_Status BinOuput_Sta
Index	Integer	Starting index of DNP data object to read (consecutive data objects will be read starting with this one)
dt	Integer	Transaction time-out (peer RTU request only.

OUTPUTS	TYPE	DESCRIPTION
Cnf	boolean	Data transfer confirm: indicates completion of request TRUE => Request Completed FALSE => Request not completed
Rdy	Integer	Data ready TRUE => Data Ready FALSE => Data Not Ready
Status	Integer	When CNF is TRUE and RDY is FALSE this indicates a table data access problem (status code) Status = 0 indicates a successful read Status = 255 indicates an outstanding DNP request See Appendix A for all other status codes
RDx x = 0-nn	Boolean	Binary data. Outputs are valid when CNF and RDY are TRUE. Quantity of RDi parameters depends on function

4.3.2 rdxxana

Read DNP3 analog points from the local or peer RTU address map

Description

This series of function blocks reads current integer value data from local RTU DNP analog points, or generates a DNP3 read request to a peer node for DNP3 integer analog objects. *xx* refers to the number of objects to read. The valid DNP object indexes that can be read from a peer DNP device are dependent on the peer device. The RTU generates DNP3 start/stop range qualifiers (00 & 01) in requests to peer devices. Consult the DNP3 device manufacturer's device profile for more information.

Note:	Peer Read function blocks perform Application Layer retries as configured in the E Series Configurator 'Appl. Layer Attempts' field (default = 2). This means that for a single trigger of this function block, subsequent attempts could be made if the requests are failing. If each of the attempts fail, then the output parameters (CNF, RDY, and STATUS) will only be updated with failure status after all Application Layer Attempts have been performed (i.e. attempts x DT (timeout)).

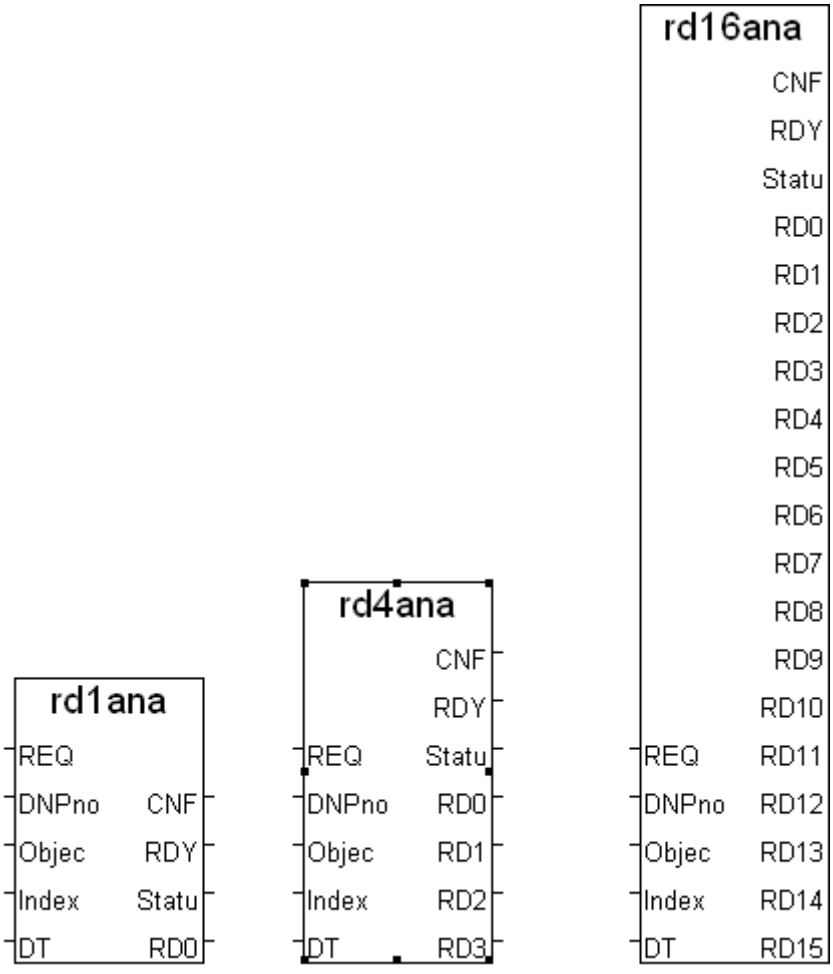


Figure 4-25 rdxxana function block

INPUTS	TYPE	DESCRIPTION
Req	boolean	Data Transfer Request. Initiate data transfer request on rising edge
DNPnode	Integer	DNP Node address (peer RTU request only). Set value to 0 when doing Local RTU data access.
ObjectType	Integer	Local_RTU_Data or DNP data object to read from peer RTU. For peer RTU read, the following values are valid for this function block: AnalogIn_32 BinCounter_16 AnalogIn_16 BinCtr_32_NoFlag AnaIn_32_NoFlag BinCtr_16_NoFlag AnaIn_16_NoFlag FrozCounter_32 AnaOut_32_Stat FrozCounter_16 AnaOut_16_Stat FrzCtr_32_NoFlag ReadTimeAndDate FrzCtr_16_NoFlag BinCounter_32
Index	Integer	Starting index of DNP data object to read (consecutive data objects will be read starting with this one)
dt	Integer	Transaction time-out (peer RTU request only.

OUTPUTS	TYPE	DESCRIPTION
Cnf	boolean	Data transfer confirm: indicates completion of request TRUE => Request Completed FALSE => Request not completed
Rdy	Integer	Data ready TRUE => Data Ready FALSE => Data Not Ready
Satus	Integer	When CNF is TRUE and RDY is FALSE, this indicates a table data access problem (status code) Status = 0 indicates a successful read Status = 255 indicates an outstanding DNP request See Appendix A for all other status codes
RDx x= 0-NN	Integer	Analog data. Outputs are valid when CNF and RDY are TRUE. Quantity of RDxx parameters depends on function

Reads may be performed using 16-bit or 32-bit analog objects. Note that *ReadTimeAndDate* ObjectType does not return data into the RDi parameters. Rather, a returned response from a peer RTU (being the peer RTU time) is updated in the local SCADAPack E Series RTU's real time clock. CNF, RDY & STATUS parameters indicate completion of operation as normal.

4.3.3 rdxxflt

Read DNP3 floating points from the local or peer RTU address map

Description

This series of function blocks reads current floating point value data from local SCADAPack E Series RTU analog points, or generates a DNP3 read request to a peer node for DNP3 floating point analog objects. *xx* refers to the number of objects to read. The valid DNP object indexes that can be read from a peer DNP device are dependent on the peer device. The RTU generates DNP3 start/stop range qualifiers (00 & 01) in requests to peer devices. Consult the DNP3 device manufacturer's device profile for more information.

Note: Peer Read function blocks perform Application Layer retries as configured in the E Series Configurator 'Appl. Layer Attempts' field (default = 2). This means that for a single trigger of this function block, subsequent attempts could be made if the requests are failing. If each of the attempts fail, then the output parameters (CNF, RDY, and STATUS) will only be updated with failure status after all Application Layer Attempts have been performed (i.e. attempts x DT (timeout)).

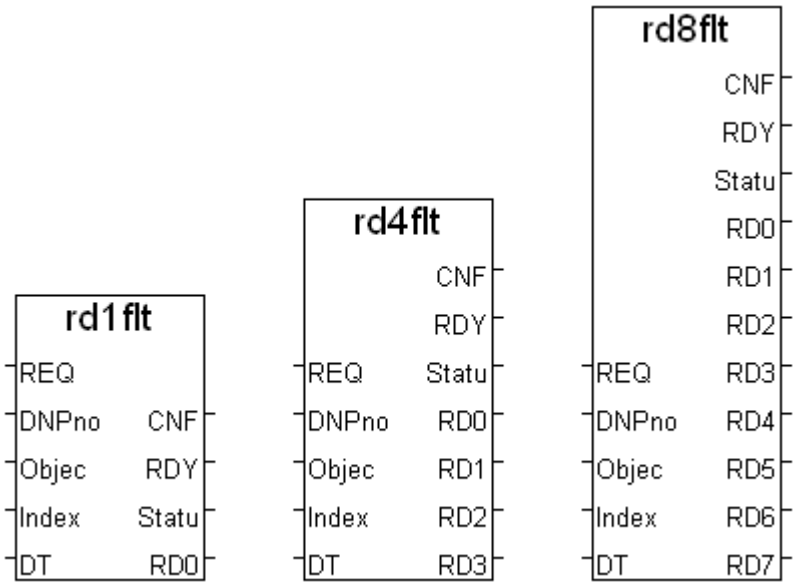


Figure 4-26 rdxxflt function block

INPUTS	TYPE	DESCRIPTION
Req	boolean	Data Transfer Request. Initiate data transfer request on rising edge
DNPnode	Integer	DNP Node address (peer RTU request only). Set value to 0 when doing Local RTU data access.
ObjectType	Integer	Local_RTU_Data or DNP data object to read from peer RTU. For peer RTU read requests, the following values are valid for this function block: AnalogIn_Float AnOut_Float_Stat
Index	Integer	Starting index of DNP data object to read (consecutive data objects will be read starting with this one)

INPUTS	TYPE	DESCRIPTION
		be read starting with this one)
dt	Integer	Transaction time-out (peer RTU request only.

OUTPUTS	TYPE	DESCRIPTION
Cnf	boolean	Data transfer confirm: indicates completion of request TRUE => Request Completed FALSE => Request not completed
Rdy	Integer	Data ready TRUE => Data Ready FALSE => Data Not Ready
Satus	Integer	When CNF is TRUE and RDY is FALSE this indicates a table data access problem (status code) Status = 0 indicates a successful read Status = 255 indicates an outstanding DNP request See Appendix A for all other status codes
RDx x= 0-NN	Integer	Analog data. Outputs are valid when CNF and RDY are TRUE. Quantity of RDxx parameters depends on function

4.3.4 wrxxbin

Write DNP3 binary data to local or peer RTU address space

Description

This series of function blocks writes current value data into local SCADAPack E Series RTU DNP binary points, or generates a DNP3 operate or write request to a peer node for DNP3 binary objects. xx in the function block name refers to the number of objects to send (fixed combinations available). The valid DNP object indexes that can be written to a peer DNP device are dependent on the peer device. For other DNP3 devices consult the device manufacturer's documentation.

Note:	No Application Layer retries are performed on peer write function blocks. If the user requires retries then either configure Data Link retries (with 'always' mode), or implement the retries in the ISaGRAF application.

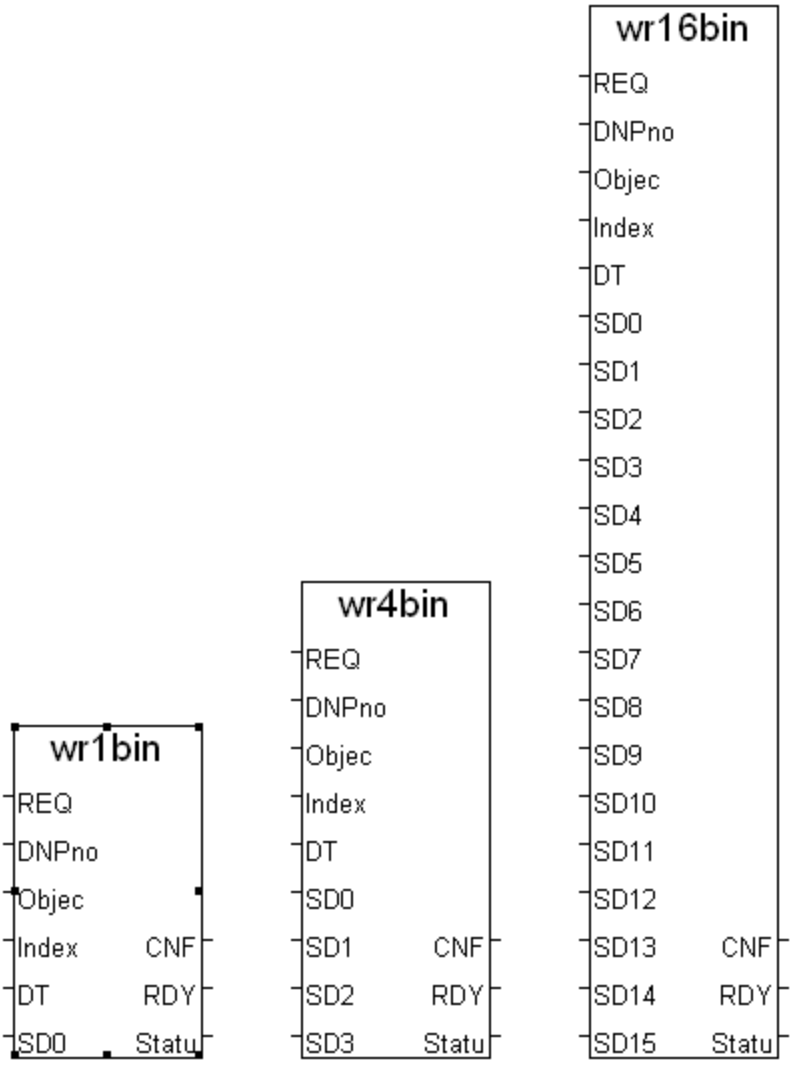


Figure 4-27 wrxxbin function block

INPUTS	TYPE	DESCRIPTION
Req	boolean	Data Transfer Request. Initiate data transfer request on rising edge
DNPnode	Integer	DNP Node address (peer RTU request only). Set value to 0 when doing Local RTU data access.
ObjectType	Integer	Local_RTU_Data or DNP data object to write to peer RTU. For peer RTU write requests, the following values are valid for this function block: BinaryOutput CROB_DirOp CROB_SelOp CROB_DONA
Index	Integer	Starting index of DNP data object to send (consecutive data objects will be sent starting with this one)
dt	Integer	Transaction time-out (peer RTU request only.
SDx x = 1-NN		Send data parameters, valid when RDY is TRUE. Quantity of SDx parameters depends on function block type wrNNbin. SDx data is sent when REQ is activated (rising edge).

OUTPUTS	TYPE	DESCRIPTION
Cnf	boolean	Data transfer confirm: indicates completion of request TRUE => Request Completed FALSE => Request not completed
Rdy	Integer	Status of data transfer TRUE => Data transfer successful FALSE => Data transfer unsuccessful
Satus	Integer	When CNF is TRUE and RDY is FALSE this indicates a table data access problem (status code) Status = 0 indicates a successful write Status = 255 indicates an outstanding DNP request See Appendix A for all other status codes

BinaryOutput ObjectType uses DNP3 *Write* function and provides an efficient method of changing remote binary data. This operation does not provide any direct feedback of the write operation result from the remote node, and is not an implementation required by the DNP3 Subset Definitions.

CROB_DirOp (Control Relay Output Block) uses DNP3 *Direct Operate* function which provides more secure control and feedback of the result at the remote node. It is a requirement of the DNP3 Subset Definition, but is much less efficient than a *Binary Output Write.* Direct Operate is single phase (request/response).

CROB_SelOp (Control Relay Output Block) uses DNP3 *Select* and *Operate* functions which provide the most secure control and feedback available in DNP3 but is much less efficient than a *Binary Output Write*. Select Operate is dual phase (select request/select response, operate request/operate response).

CROB_DONA (Control Relay Output Block) uses DNP3 *Direct Operate No Acknowledge* function. This is an insecure control operation as there is no feedback or confirmation from the remote node. Although required by the DNP3 Subset Definitions, **the use of Direct Operate No Acknowledge (DONA) is not recommended for peer communication.**

4.3.5 wrxxana

Write DNP3 analog data to local or peer RTU address space

Description

This series of function blocks writes current value integer data into local SCADAPack E Series RTU DNP analog points, or generates a DNP3 operate or write request to a peer node for DNP3 integer analog objects. *NN* refers to the number of objects sent. The valid DNP object indexes that can be written to a peer DNP device are dependent on the peer device. For other DNP3 devices consult the device manufacturer's documentation.

Note:	No Application Layer retries are performed on peer write function blocks. If the user requires retries then either configure Data Link retries (with 'always' mode), or implement the retries in the ISaGRAF application.

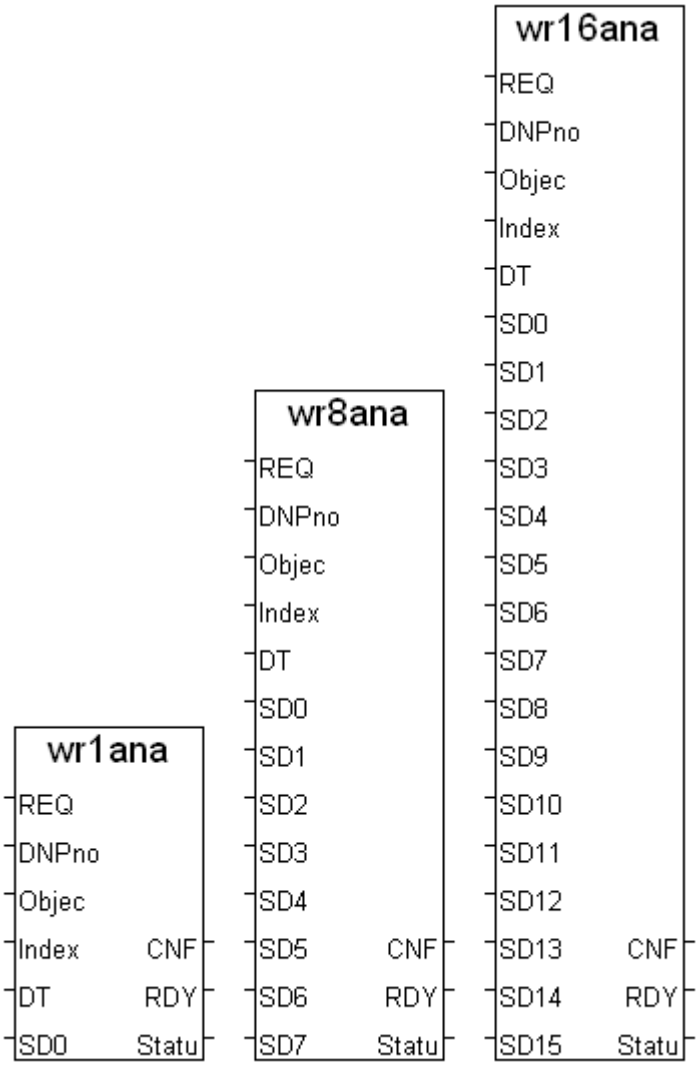


Figure 4-28 wrxxana function block

INPUTS	TYPE	DESCRIPTION
Req	boolean	Data Transfer Request. Initiate data transfer request on rising edge
DNPnode	Integer	DNP Node address (peer RTU request only). Set value to 0 when doing Local RTU data access.
ObjectType	Integer	Local_RTU_Data or DNP data object to write to peer RTU. For peer RTU write requests, the following values are valid for this function block: AnaOut_32_DirOp AnaOut_16_DirOp AnaOut_32_SelOp AnaOut_16_SelOp AnaOut_32_DONA AnaOut_16_DONA WriteTimeAndDate
Index	Integer	Starting index of DNP data object to send (consecutive data objects will be sent starting with this one)
dt	Integer	Transaction time-out (peer RTU request only.
SDx x = 1-NN		Send data parameters, valid when RDY is TRUE. Quantity of SDx parameters depends on function block type wrxxbin. SDx data is sent when REQ is activated (rising edge).

OUTPUTS	TYPE	DESCRIPTION
Cnf	boolean	Data transfer confirm: indicates completion of request TRUE => Request Completed FALSE => Request not completed
Rdy	Integer	Status of data transfer TRUE => Data transfer successful FALSE => Data transfer unsuccessful
Satus	Integer	When CNF is TRUE and RDY is FALSE this indicates a table data access problem (status code) Status = 0 indicates a successful write Status = 255 indicates an outstanding DNP request See Appendix A for all other status codes

Note that *WriteTimeAndDate* ObjectType ignores data presented in the SDx parameters. Rather, the PDS RTU real time clock is sent to the peer RTU. CNF, RDY & STATUS parameters indicate completion of operation as normal.

DNP3 *Direct Operate* functions provides secure control and feedback of the result at the remote node. Direct Operate is single phase (request/response).

DNP3 *Select* and *Operate* functions provide the most secure control and feedback available in DNP3. Select Operate is dual phase (select request/select response, operate request/operate response).

DNP3 *Direct Operate No Acknowledge* function is an insecure control operation as there is no feedback or confirmation from the remote node. Although required by the DNP3 Subset Definitions, **the use of Direct Operate No Acknowledge (DONA) is not recommended for peer communication.**

4.3.6 wrxxflt

Write DNP3 floating point data into local or peer RTU address space

Description

This series of function blocks writes current value floating point data into local SCADAPack E Series RTU DNP analog points, or generates a DNP3 operate or write request to a peer node for DNP3 floating point analog objects. *NN* refers to the number of objects sent. The valid DNP object indexes that can be read from a peer DNP device are dependent on the peer device. For other DNP3 devices consult the device manufacturer's documentation.

No Application Layer retries are performed on peer write function blocks. (Firmware versions previous to this use the E Series Configurator 'Appl. Layer Attempts' field to determine how many times to retry at the Application Layer). If the user requires retries then either configure Data Link retries (with 'always' mode), or implement the retries in the ISaGRAF application.

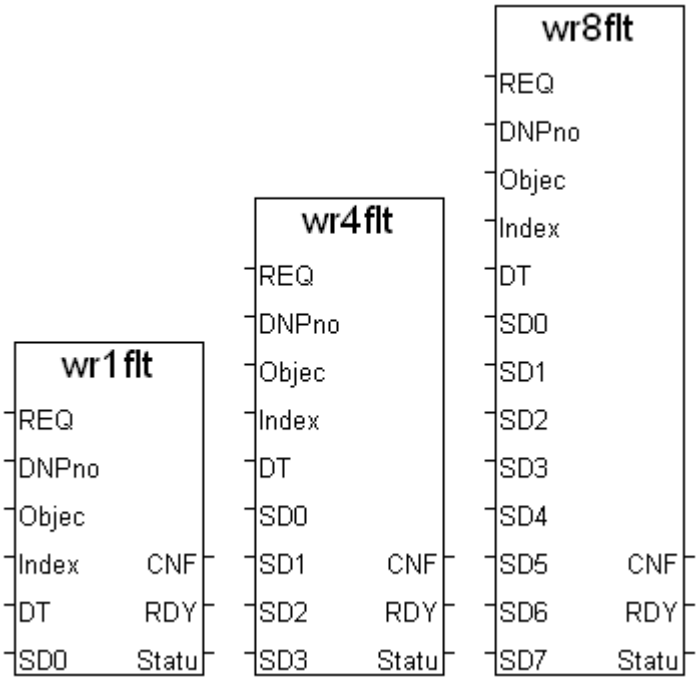


Figure 4-29 wrxxflt function block

INPUTS	TYPE	DESCRIPTION
Req	boolean	Data Transfer Request. Initiate data transfer request on rising edge
DNPnode	Integer	DNP Node address (peer RTU request only). Set value to 0 when doing Local RTU data access.
ObjectType	Integer	Local_RTU_Data or DNP data object to write to peer RTU. For peer RTU write requests, the following values are valid for this function block: AnOutFloat_DirOp AnOutFloat_SelOp AnOutFloat_DONA

Index	Integer	Starting index of DNP data object to send (consecutive data objects will be sent starting with this one)
dt	Integer	Transaction time-out (peer RTU request only.
SDx x = 1-NN		Send data parameters, valid when RDY is TRUE. Quantity of SDx parameters depends on function block type wrxxbin. SDx data is sent when REQ is activated (rising edge).

OUTPUTS	**TYPE**	**DESCRIPTION**
Cnf	boolean	Data transfer confirm: indicates completion of request TRUE => Request Completed FALSE => Request not completed
Rdy	Integer	Status of data transfer TRUE => Data transfer successful FALSE => Data transfer unsuccessful
Status	Integer	When CNF is TRUE and RDY is FALSE this indicates a table data access problem (status code) Status = 0 indicates a successful write Status = 255 indicates an outstanding DNP request. See Appendix A for all other status codes

DNP3 *Direct Operate* functions provides secure control and feedback of the result at the remote node. Direct Operate is single phase (request/response).

DNP3 *Select* and *Operate* functions provide the most secure control and feedback available in DNP3. Select Operate is dual phase (select request/select response, operate request/operate response).

DNP3 *Direct Operate No Acknowledge* function is an insecure control operation as there is no feedback or confirmation from the remote node. Although required by the DNP3 Subset Definitions, **the use of Direct Operate No Acknowledge (DONA) is not recommended for peer communication.**

4.3.7 dc_poll

Force a class 0 poll to all configured IED's

Description

The ISaGRAF application needs to be able to force the Data Concentrator or master RTU to issue a Class 0 poll to all configured IED's in order to update the local database with a current image of IED point values. The DC_POLL Function Block is used to issue this request:

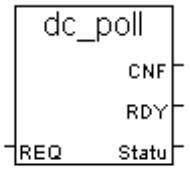


Figure 4-30 DC_POLL Function Block

INPUTS	TYPE	DESCRIPTION
Req	boolean	Data Transfer Request. Initiate data transfer request on rising edge

OUTPUTS	TYPE	DESCRIPTION
Cnf	boolean	Data transfer confirm: indicates completion of request TRUE => Request Completed FALSE => Request not completed
Rdy	Integer	Status of data TRUE => Data ready FALSE => Data not ready
Satus	Integer	When CNF is TRUE and RDY is FALSE this indicates a table data access problem (status code) Status = 0 indicates a successful poll Status = 255 indicates an outstanding DNP request See Appendix A for all other status codes

The function block operates regardless if the DCons. is currently disabled or not. The dc_poll function block will raise its CNF output when all the IED's polled have responded or timed out.

If the dc_poll request is issued while the DCons. is disabled, IED responses will **not** generate local events in the DCons.

4.4 DNP3 Queued Communication function blocks

A second series of ISaGRAF DNP3 Peer function blocks can be used for more sophisticated communication regimes than the transfer of simple data types as described in the function blocks in section ***4.3 - DNP3 Communication function blocks***. Whereas the simpler peer function blocks transferred data between ISaGRAF variables and remote RTU DNP points, the Queued Peer function blocks transfer data directly between the point databases of two peer RTUs. These queued function blocks provide enhanced functionality. For example:

- If the application programmer has six Integer Analog, one Floating Point Analog and two Binary states to read from a Peer RTU, he may use as many as four simple data type function blocks to achieve this. These four function blocks, if triggered at the same time, would cause four DNP Read request fragments to be generated and queued for transmission. As the second and subsequent fragments are not be sent until the target RTU has processed and responded to the previous fragment, delays due to network latencies are four times longer than if the request could have been combined into one DNP fragment.
- The simple "rdxxana" function blocks allow the application programmer to read 1, 4, 8 or 16 consecutive analog points from the target, depending on which block he chooses. This tends to either force the application programmer to be conscious of either "packing" his target point numbers close together or of having to use more Peer function blocks if they are not close together. This may not be a problem for new applications, but could be inefficient if adding extra Peer points to an existing application.
- The simple "rdXY" function blocks do not transfer any point quality data from the target RTU to the ISaGRAF application. This quality data is returned in the "Flag" octet of certain DNP Object types and gives additional information such as "Over-Range" and "A/D Reference error" for example. It is useful to be able to make this quality information available to ISaGRAF programmers.

The Queued Peer function blocks operate in quite a different manner than the simpler peer function blocks in that Peer Read or Write point requests will be queued by the functions "peer_rdq" and "peer_wrq", but executed by the functions "peer_rdx" and "peer_wrx". I.e. a request built up using one or more "peer_rdq" calls to the same queue is sent to the target RTU (or Executed) by the function block "peer_rdx" using that queue. A request built up using one or more "peer_wrq" calls to the same queue is sent to the target RTU (or Executed) by the function block "peer_wrx" using that queue.

Two "queue lists" are created for each ISaGRAF target kernel application, one for Read request and the other for Write requests. These queue lists hold any number of named "point request queues". For example, an application programmer may use an instance of the "peer_rdq" function to send 'Read' requests into a queue named "Lane Cove West A" and another instance of "peer_rdq" to send 'Read' requests into another queue named of "North Head STP". Two separate queues would be created, each of which are executed independently.

The queues and "queue lists" persist while the ISaGRAF application is running, but will be cleared when the ISaGRAF application is stopped or the RTU is Cold Reset. I.e. Points queued using "peer_rdq" need not be re-queued unless the ISaGRAF application is stopped.

4.4.1 peer_rdq

Adds a range of remote DNP points into a named Read Request queue

Description

This ISaGRAF function adds a specified number of DNP points, to be read from a remote peer and written to a local RTU, into a queue for later execution. The DNP point numbers will be added to a specified queue if present or a new queue will be created with the given name. The final *Read* request is executed by the peer_rdx function block, see Section ***4.4.3 - peer_rdx***. The "peer_rdq" function would be typically executed only at application startup.

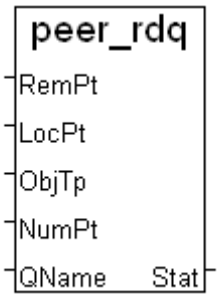


Figure 4-31 "peer_rdq" function

INPUTS	TYPE	DESCRIPTION
RemPt	Integer	DNP point number in the target RTU device to read from. Valid values are 0-65534.
LocPt	Integer	DNP point number in the local RTU to write to. Must be a valid physical output or derived point.
ObjTp	Integer	DNP data object to read from peer RTU. The following values are valid for this function: BinaryInput, BinInput_Status, BinOutput_Stat, BinCounter_32, BinCounter_16, BinCtr_32_NoFlag, BinCtr_16_NoFlag, AnalogIn_32, AnalogIn_16, AnaIn_32_NoFlag, AnaIn_16_NoFlag, AnalogIn_Float, AnaOut_32_Stat, AnaOut_16_Stat, AnaOutFloat_Stat
NumPt	Integer	Number of consecutive points to add to queue. Valid entries are 1-65534.
Qname	Message	String name of queue, max 50 characters, spaces OK.

Note that the "LocPt" or Local Point parameter should refer to a DIGITAL_OUT_TYPE, ANALOG_OUT_TYPE or COUNTER_TYPE point type, depending on which "ObjTp" DNP Object Type is specified.

OUTPUTS	TYPE	DESCRIPTION
Stat	Boolean	TRUE for success FALSE for failure

4.4.2 peer_wrq

Adds a range of DNP points on the local RTU into a named Write queue

Description

This ISaGRAF function adds a specified number of DNP points, to be copied from the local RTU onto a Remote RTU, into a queue for later execution. The DNP point numbers will be added to a specified queue if present or a new queue will be created with the given name. The final *Write* request is executed by the peer_wrx function block, See ***4.4.4 - peer_wrx***. The "peer_wrq" function would be typically executed only at application startup.

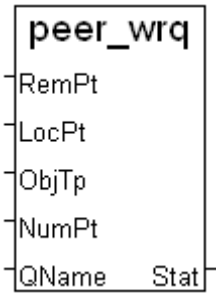


Figure 4-32 "peer_wrq" function

INPUTS	TYPE	DESCRIPTION
RemPt	Integer	DNP point number in the target RTU to write to. Valid values are 0-65534.
LocPt	Integer	DNP point number in the local RTU where the current value or state is read from. Must be a valid RTU input point type.
ObjTp	Integer	DNP data object to read from peer RTU. The following values are valid for this function: BinaryInput, BinInput_Status, BinOutput_Stat, BinCounter_32, BinCounter_16, BinCtr_32_NoFlag, BinCtr_16_NoFlag, AnalogIn_32, AnalogIn_16, AnaIn_32_NoFlag, AnaIn_16_NoFlag, AnalogIn_Float, AnaOut_32_Stat, AnaOut_16_Stat, AnaOutFloat_Stat
NumPt	Integer	Number of consecutive points to add to queue. Valid entries are 1-65534.
Qname	Message	String name of queue, max 50 characters, spaces OK.

Note that the "LocPt" or Local Point parameter should refer to a DIGITAL_IN_TYPE or ANALOG_IN_TYPE point type, depending on which "ObjTp" DNP Object Type is specified.

OUTPUTS	TYPE	DESCRIPTION
Satus	Boolean	TRUE for success FALSE for failure

4.4.3 peer_rdx

Execute queued DNP Read requests

Description

The interface for this ISaGRAF function block is similar to the simple "rd*xx*" family of function blocks. When triggered with a rising edge on the REQ input, the function block will look for a matching queue name with the one supplied by the user. If found, it will iterate the queue in order to build up one or more DNP request fragments. Consecutive point numbers will be packed into the DNP request fragment in an efficient manner.

Unlike the simple ISaGRAF Peer function blocks (which read into ISaGRAF variables), the returned values or states of the remote points are written directly to the local RTU points specified when the point request was queued with "peer_rdq". Where the user has queued a point request using a DNP Object type that supports status flags, the response status flags will be written to the local RTU points.

The local points will contain valid data (and flags) when CNF & RDY are TRUE. The Analog "*Stat*" output variable will contain Zero if the transaction was successful, otherwise an error code. See Table 4-10 for error codes.

Note: Should the DNP request fail, the ISaGRAF application programmer may choose to set the "Point is Bad" property on all local RTU points in that named Read queue. This will cause the RTU's IO Processor to also set each point's "Point is Failed" property. A subsequent successful transaction could clear the "Point is Bad" property.

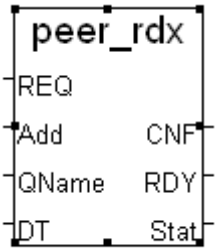


Figure 4-33 "peer_rdx" Function Block

INPUTS	TYPE	DESCRIPTION
Req	Boolean	Data Transfer Request. Initiate data transfer request on rising edge
Add	Integer	DNP target device address. Valid range is 0-65534.
QName	Message	String name of the queue, max 50 characters, spaces OK.
dt	Timer	Transaction time-out (peer RTU request only.

OUTPUTS	TYPE	DESCRIPTION
Cnf	Boolean	Data transfer confirm. TRUE indicates completion of request. FALSE, otherwise.
Rdy	Boolean	Data is ready

Sat	Integer	0 for success, otherwise see error code in Table 4-10.

Table 4-10 Status codes returned by the “peer_rdx” and “peer_wrx” function blocks

DNP STATUS CODE	DESCRIPTION
0	Operation successful
8	DNP timeout
9	Bad Read
10	Bad Operate
50	Bad Function IIN set
51	Object Unknown IIN set
52	Out of Range IIN set
63	CROB formatting error
64	CROB operation not supported
65	CROB queue full
66	CROB hardware problem
127	Request failed to queue

4.4.4 peer_wrx

Execute queued DNP Write requests

Description

The operation of this function block is very similar to the "peer_rdx" function block. It triggers a DNP "Direct Operate" control for the points queued using the "peer_wrq" function. The local RTU points in the Write queue will **not** have any properties changed.

The interface for this ISaGRAF function block is similar to the simple "wr*xx*" family of function blocks. When triggered with a rising edge on the REQ input, the function block will look for a matching queue name with the one supplied by the user. If found, it will iterate the queue in order to build up one or more DNP request fragments. Consecutive point numbers will be packed into the DNP request fragment in an efficient manner.

Unlike the simple ISaGRAF Peer function blocks (which write from ISaGRAF variables), the returned values or states of the remote points are written directly to the local RTU points specified when the point request was queued with "peer_wrq". Where the user has queued a point request using a DNP Object type that supports status flags, the response status flags will be written to the remote RTU points.

The remote points will contain valid data (and flags) when CNF & RDY are TRUE. The Analog "*Stat*" output variable will contain Zero if the transaction was successful, otherwise an error code. See Table 4-10 for error codes.

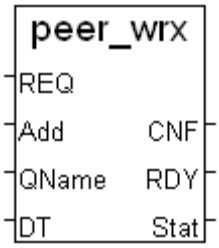


Figure 4-34 "peer_wrx" Function Block

INPUTS	TYPE	DESCRIPTION
Req	Boolean	Data Transfer Request. Initiate data transfer request on rising edge
Add	Integer	DNP target device address. Valid range is 0-65534.
QName	Message	String name of the queue, max 50 characters, spaces OK.
dt	Timer	Transaction time-out (peer RTU request only).

OUTPUTS	TYPE	DESCRIPTION
Cnf	Boolean	Data transfer confirm. TRUE indicates completion of request. FALSE, otherwise.
Rdy	Boolean	Data is ready
Sat	Integer	0 for success, otherwise see error code in Table 4-10.

4.4.5 peer_rdc

Clear a Read request queue

Description

The “peer_rdc” ISaGRAF functions allow the application programmer to clear all points in a named queue. The functions will return TRUE if the specified queue is found and its points are removed successfully.

Figure 4-35 "peer_rdc" function

INPUTS	TYPE	DESCRIPTION
QName	Message	String name of the queue, max 50 characters, spaces OK.

OUTPUTS	TYPE	DESCRIPTION
Sat	Boolean	TRUE for success otherwise FALSE.

4.4.6 peer_wrc

Clear a Write request queue

Description

The “peer_wrc” ISaGRAF functions allow the application programmer to clear all points in a named queue. The functions will return TRUE if the specified queue is found and its points are removed successfully.

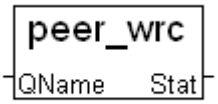
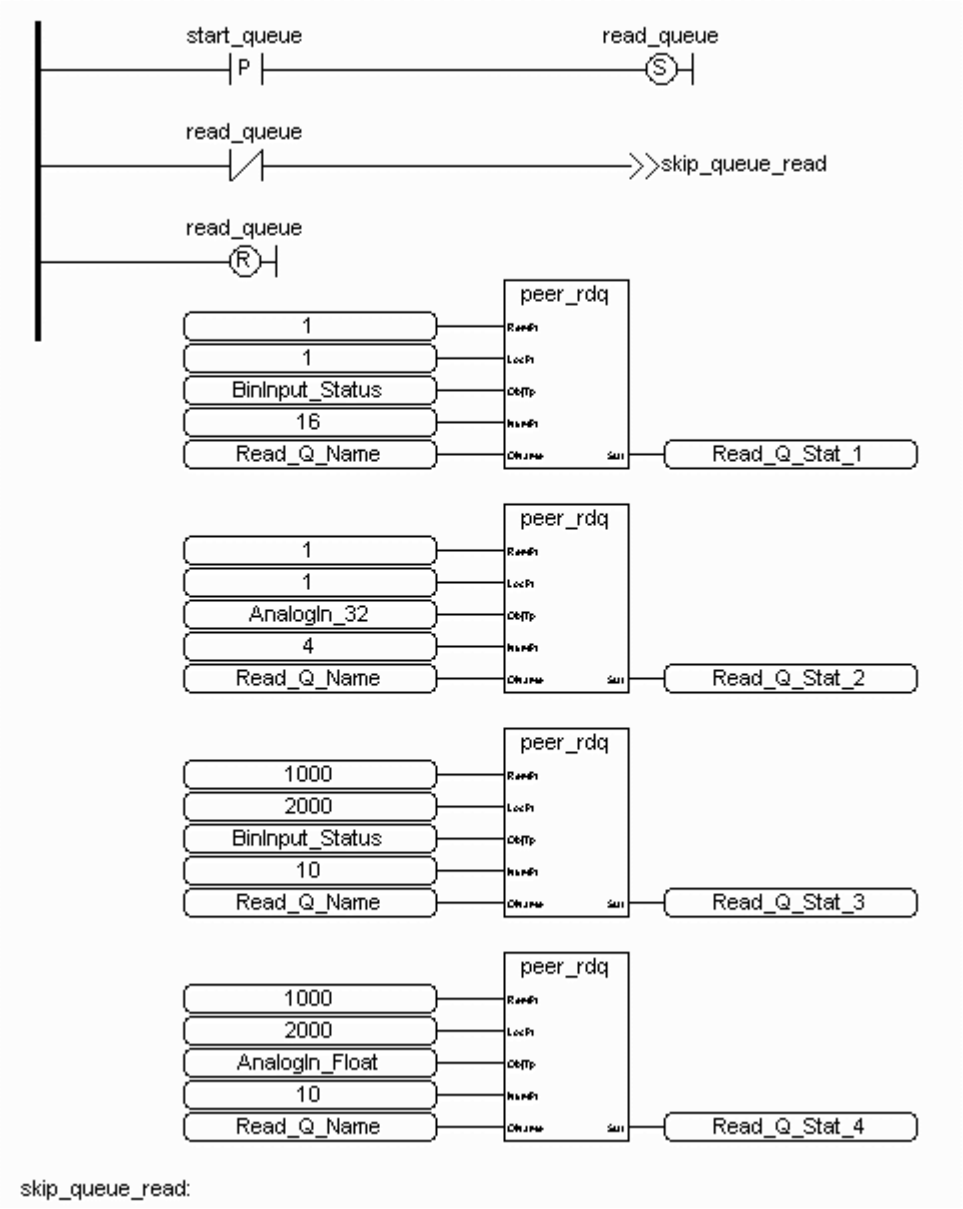


Figure 4-36 "peer_wrc" function

INPUTS	TYPE	DESCRIPTION
QName	Message	String name of the queue, max 50 characters, spaces OK.

OUTPUTS	TYPE	DESCRIPTION
Sat	Boolean	TRUE for success, otherwise FALSE.

4.4.7 Queued Peer Read Example



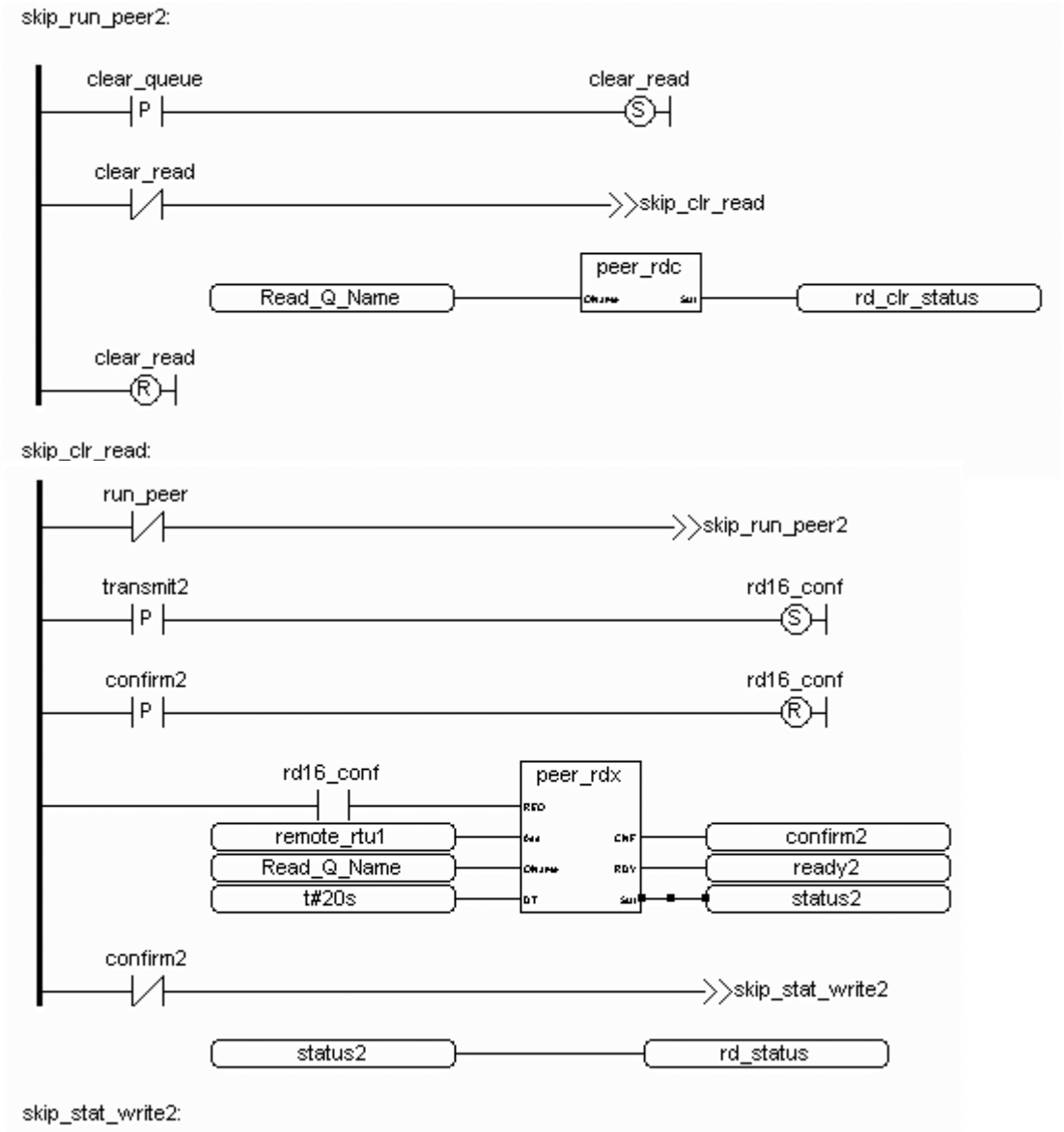


Figure 4-37 Example Peer Queued Read

Figure 4-37 shows an example of how a Peer Queued Read test program might be implemented. Setting the boolean variable “start queue” TRUE causes four Read Queue functions to be executed once only. Following that, setting the “run_peer” variable TRUE will cause the “peer_rdx” to issue a DNP Peer read request. The “peer_rdx” function block will be re-triggered by its Confirm (CNF) line going TRUE to indicate completion. This cycle will continue until “run_peer” is set FALSE.

Setting the “clear_queue” Boolean variable TRUE causes the “peer_rdc” function to execute once. This will clear all Read requests in the named queue.

4.5 Serial Port User Communication functions

These function blocks provide an interface to setup serial port parameters on the E Series RTU via an ISaGRAF application.

4.5.1 comopen

Open a serial port for use

Description

This function is used to open an RTU serial port for use within an ISaGRAF program. The function returns a positive integer ID for the opened port if successful, or a zero if not successful. The ID is used by the *comsetup, comrx, comtx, comclose* and *comrxclr* functions to identify which port to act upon, as more than one serial port may be in use. The RTU port "Function" configuration must be set to "ISaGRAF-User" using the E Series Configurator before the port can be used within an ISaGRAF program. Multiple ports may be configured for ISaGRAF-User and opened for User access by the ISaGRAF applications.

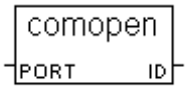


Figure 4-38 COMOPEN function

INPUTS	TYPE	DESCRIPTION
Port	Message	Serial Port to control Valid values are: PORT 0 PORT 1 PORT 2 PORT 3 DIAG PORT is case insensitive (upper and lower case allowed), and a space before the port digit is optional (e.g. "PORT0" & "PORT 0" allowed).

OUTPUTS	TYPE	DESCRIPTION
Id	Integer	Id of serial port. Return value is 0 if port could not be opened.

4.5.2 comclose

Close a serial port

Description

This function is used to close an RTU serial port currently in use by an ISaGRAF program (ie. A port previous opened using the comopen function). The figure below shows the function with the following calling and return parameters:

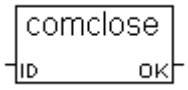


Figure 4-39 COMCLOSE function

INPUTS	TYPE	DESCRIPTION
Id	Integer	ID of serial port to close (ID from previous comopen)

OUTPUTS	TYPE	DESCRIPTION
OK	Boolean	TRUE if operation is successful. Else FALSE.

4.5.3 comrx

Read characters from a serial port

Description

This function receives a string of ASCII characters from an open RTU serial port. Either a string length or a terminating character can be specified to indicate when to stop reading characters. The figure below shows the function with the following calling and return parameters:

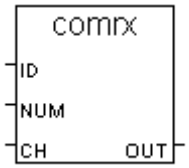


Figure 4-40 COMRX function

INPUTS	TYPE	DESCRIPTION
Id	Integer	ID of serial port to close (ID from previous comopen)
Num	Integer	Number of characters to be read (0 = no minimum length to be read)
Ch	Integer	Watch for this character to terminate string (non–valid ASCII character >=256 disables a terminating character)

OUTPUTS	TYPE	DESCRIPTION
Out	Message	Character string read from serial port

4.5.4 comrxb

Read binary characters from serial port and display in ASCII

Description

This function receives an array of binary characters from an open RTU serial port and displays it as an ASCII string. This function is used for receiving binary protocols. Either an array length or a terminating character can be specified to indicate when to stop reading characters. The array length should be set as twice the number of binary characters that you wish to receive. For example, to receive the binary characters 0x32 0xF4 0x5D, you would set NumChars to be 6, and the received msg would be the string '32F45D' (which has 6 characters). Figure 3.12 shows the function with the following calling and return parameters:

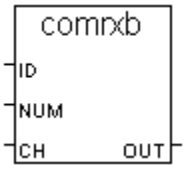


Figure 4-41 COMRXB function

INPUTS	TYPE	DESCRIPTION
Id	Integer	ID of serial port to close (ID from previous comopen)
Num	Integer	2 * Number of characters to be read (0 = no minimum length to be read)
Ch	Integer	Watch for this character to terminate string (non–valid ASCII character >=256 disables a terminating character)

OUTPUTS	TYPE	DESCRIPTION
Out	Message	character string representation of the binary protocol from serial port

4.5.5 comrxclr

Clear serial port receive (RX) buffer

Description

This function is used to clear an RTU's serial port receive buffer. It requires that the serial port has been opened using the comopen function.

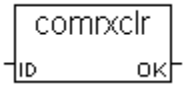


Figure 4-42 COMRXCLR function

INPUTS	TYPE	DESCRIPTION
Id	Integer	ID of serial port to close (ID from previous comopen)

OUTPUTS	TYPE	DESCRIPTION
OK	Boolean	TRUE if operation is successful. Else FALSE.

4.5.6 comsetup

Setup the E Series RTU serial port parameters

Description

This function is used to setup the serial port parameters of the E Series RTU. Note that the port must already have been opened using *comopen* command.

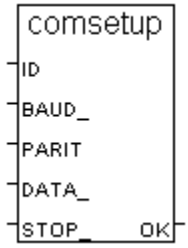


Figure 4-43 COMSETUP function

INPUTS	TYPE	DESCRIPTION
Id	Integer	ID of serial port to close (ID from previous comopen)
Baud_Rate	Integer	Baud rate of serial port. Possible values are: 300, 1200, 2400, 4800, 9600, 19200, 38400 (depending on serial port support).
Party	Message	Parity bit. Possible values are: even, odd and none.
Data_Bits	Integer	Number of data bits. Possible values are: 7 or 8
Stop_Bits	Integer	Number of stop bits. Possible values are 1 or 2.

OUTPUTS	TYPE	DESCRIPTION
OK	Boolean	TRUE if operation successful.

4.5.7 comtx

Write characters to a serial port

Description

This function writes a string of ASCII characters to an open RTU serial port.

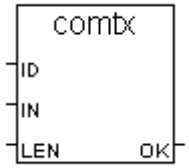


Figure 4-44 comtx function

INPUTS	TYPE	DESCRIPTION
Id	Integer	ID of serial port to close (ID from previous comopen)
In	Message	character string to write to the serial port
Len	Integer	Number of characters to write. The LEN parameter also allows for the transmission of the NUL (ASCII 0) character, which is generally used to terminate a string of characters.

OUTPUTS	TYPE	DESCRIPTION
OK	Boolean	TRUE if operation successful.

4.5.8 comtxb

Convert a string of ASCII characters to binary and write to serial port

Description

This function converts a string of ASCII characters to binary and writes them out an open RTU serial port. The NumChars variable should be set to the number of ASCII characters to transmit (i.e. twice the number of binary characters that will be transmitted). That is, to transmit the binary characters 0x02 0xFD 0x6A then you would set TxMsg as '02FD6A' and NumChars as 6. Figure 3.13 shows the function with the following calling and return parameters:

Figure 4-45 COMTX function

INPUTS	TYPE	DESCRIPTION
Id	Integer	ID of serial port to close (ID from previous comopen)
In	Message	character string to convert to binary and write to serial port
Len	Integer	Number of characters to write. (2* the number of binary characters to write).

OUTPUTS	TYPE	DESCRIPTION
OK	Boolean	TRUE if operation successful.

4.6 Miscellaneous function blocks

The application programmer can use these miscellaneous function blocks to further enhance the capability of an ISaGRAF application.

4.6.1 pid_al

PID regulator with output limiting and integral wind-up prevention

Description

This function block provides PID (Proportional-Integral-Derivative) control to ISaGRAF with output limiting and integral wind-up prevention. The figure below shows the function block with the following calling and return parameters:

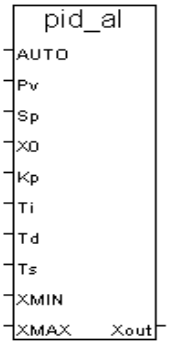


Figure 4-46 pid_al Function Block

INPUTS	TYPE	DESCRIPTION
Auto	Boolean	PID Automatic mode when TRUE PID manual mode when FALSE **NOTE: AUTO mode must be set to FALSE at initialization** In Manual mode, the following occurs: Xout = X0 Integral = (X0*Ti)/Kp; where Ti and Kp and Integral Time constants and Proportional constants respectively.
PV	Real	Process Variable –output value from process
SP	Real	Set Point –desired value of process variable
X0	Real	Manual mode output adjustment value
Kp	Real	Proportionality constant
Ti	Real	Integral Time constant
Td	Real	Derivative Time Constant
Ts	Timer	Sampling period in mS. This value must be greater than the ISaGRAF target scan rate.
Xmin	Real	Minimum limit on process output command value
Xmax	Real	Maximum limit on process output command value. Should be greater than Xmin

		than Xmin.

OUTPUTS	TYPE	DESCRIPTION
Xout	Real	Process command value. Xout is limited within Xmin and Xmax. The Integral term is held constant when Xout reaches Xmin or Xmax. Xout = X0 in manual mode.

4.6.2 rtuparam

Modify a specific RTU parameter

Description

This function block provides an ISaGRAF application with the ability to modify RTU operational parameters. The RTUPARAM function block operates in a similar way to the ISaGRAF peer communication function blocks described above, with respect to the REQ, CNF, RDY and STATUS parameters. Note that changes to these parameters are not permanently stored in the E Series RTUs Non-Volatile memory (NV-RAM). When the E Series RTU is reset, the parameter values revert to their previously configured value that is stored in NV-RAM in the E Series RTU.

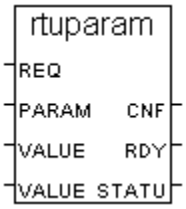


Figure 4-47 rtuparam Function Block

INPUTS	TYPE	DESCRIPTION
Req	Boolean	Data transfer request initiated on rising edge.
Param	Integer	Name of parameter to modify
Value1	Integer	Parameter dependent value. See Table 4-11
Value2	Integer	Parameter dependent value. See Table 4-11

OUTPUTS	TYPE	DESCRIPTION
Cnf	Boolean	Data transfer confirm. TRUE indicates completion of request. FALSE, otherwise.
Rdy	Boolean	Data transferred successfully.
Sat	Integer	0 for success when Cnf and Rdy are TRUE. Otherwise see error code in Table 4-10.

Table 4-11 - Valid PARAM and VALUE fields for RTUPARAM

PARAM	Value*	Value1+	Value2	Comment
MASTER_COMPORT	1	0 = Port0 1 = Port1 2 = Port2 3 = Port3 / FSK	0 = Master1 1 = Master 1 2 = Master 2 3 = Master 3	Changes RTU communication port to which unsolicited messages, to a DNP3 Master station, are directed

PARAM	Value*	Value1+	Value2	Comment
		4 = Port 4 5 = Ethernet 1 6 = Ethernet 2		Port 3 available only where "Additional Serial Port" option fitted. Ethernet only available for PDS v7 series Telemetry
UNSOL_TX_DELAY	2	Secs	0 = Master1 1 = Master 1 2 = Master 2 3 = Master 3	Changes Unsolicited transmission delay to the appropriate DNP3 Master session.
APPL_TO	3	Secs	0	Changes DNP application layer timeout
COLD_RESTART	4	0	0	Restarts the PDS RTU
APPL_EVENT_TO	5	Secs	0 = Master1 1 = Master 1 2 = Master 2 3 = Master 3	Changes DNP event confirm timeout to the appropriate DNP3 Master session.
MY_DNP_ADDRESS	6	New DNP Address = 0 to 65534		Changes the RTU's DNP address "on-line" without a Warm or Cold restart.
ETH_IP_ADDRESS_1	7	Numeric value of the new TCP/IP address.**		Changes the TCP/IP address for Ethernet Port 1 "on-line" without a Warm or Cold restart.
ETH_IP_ADDRESS_2	8	Numeric value of the new TCP/IP address.**		Changes the TCP/IP address for Ethernet Port 2 "on-line" without a Warm or Cold restart.
UNSOL_CLASSES	9	No Classes = 0 Class 1,2,3 = 14 Class 1 = 2 Class 2 = 4 Class 3 = 8 Class 1,2 = 6 Class 1,3 = 10 Class 2,3 = 12	0 = Master1 1 = Master 1 2 = Master 2 3 = Master 3	Changes the RTU's DNP enabled Unsolicited Event Classes "on-line" without a restart. This functionality may be useful in a dual-redundancy change-over situation.
SYS_ERR_CODE	10	100-999	0	User error code number sent to PDS Error Code system analog point 50020
ISA_TASK_PRI	11	0 = Normal_Priority 1 = High_Priority	0	Increases this ISaGRAF Kernel task's priority in the PDS RTU operating system. Requires application fixed Cycle Timing with ISaGRAF actually scanning faster than the fixed cycle time.
DISCONNECT_PORT	12	0 = Port0 1 = Port1 2 = Port2 3 = Port3 / FSK 4 = Port 4	0	Requests that the DNP3 serial port driver task associated with the supplied port no. Breaks its current connection (if it has one). Valid for PPP/GPRS, X.29 and Hayes Modem port modes.
UNSOL_ALLOWED	13	0 = No Unsol Allowed. 1 = Unsol. Allowed.	0 = Master1 1 = Master 1 2 = Master 2 3 = Master 3	Controls Unsolicited Response transmissions to the appropriate DNP3 Master session.
DISABLE_MASTER	14	0 = Master session enabled.	0 = Master1 1 = Master 1	A disabled Master session does not respond to any DNP3 message sent to it or

PARAM	Value*	Value1+	Value2	Comment
		1 = Master session disabled.	2 = Master 2 3 = Master 3	DNP3 message sent to it or generate any Unsol. Responses until it is enabled by the ISaGRAF application.
DISABLE_DCONS	15	0 = DCons. enabled. 1 = DCons. disabled. #	0	When disabled, the DNP3 Data Concentrator does not generate any periodic polls (forced polls are ok) or confirm any Unsolicited responses from IED's.
PORT_CONF_MODE	16	0=Never 1=Sometimes 2=Always	0 = Port0 1 = Port1 2 = Port2 3 = Port3 4 = Port4 5 = Ethernet 1 6 = Ethernet 2	Changes the link layer confirm mode of a serial or Ethernet port to the mode specified. See the DNP# technical reference for a description of these modes.
RESTART_SERVICE	17	1 = History	Optional. If non-zero, Value2 specifies the maximum size for the history file ++	Appends trend sampler files to file called history. Refer to the v7 Trend Sampler Manual for more information on "restart history".
		2 = Sampler	Not Used.	Restarts Sampler task. Refer to the v7 Trend Sampler Manual for more information on "restart sampler".
		3 = Profile		Restarts the Profile task
		4 = TCP_Service		Restarts the TCP Service task.
		5 = Mask		Clears the system error code, reset reasons, and task watchdog system points

*The PARAM name values (global defines) are defined in CMI's ***common.eqv*** file.

** The numeric value of a TCP/IP address may be obtained from the E Series ISaGRAF Function, "MSG_IP". See Section ***4.7.5 - msg_ip***.

+ A value of "USE_DNP_DEFAULT" (-1) may be used in Value1 to restore the RTU's configured (default) value.

If the Data Concentrator becomes disabled due to an ISaGRAF RTUPARAM request, local mapped points are not marked as "IO Not responding", as would normally be the case for points mapped to a non-responding IED. The "Data Concentrator Ready" point state is False.

When the Data Concentrator is re-enabled by ISaGRAF request, all IED's are marked internally as IED_NOT_FOUND. Their state will then be changed to IED_RUNNING or IED_COMMS_FAILED depending upon a successful poll response.

When the DCons. restart is complete, the "Data Concentrator Ready" point state will change to True.

4.6.3 chgroute

Modify entries in the E Series RTU DNP3 Routing Table

Description

This function block provides an ISaGRAF application with the ability to modify entries in the E Series RTU DNP3 Routing Table. The *chgroute* function block operates in a similar way to the ISaGRAF peer communication function blocks described above, though the parameters that are modified are in the local PDS RTU. The parameter meanings are as follows:

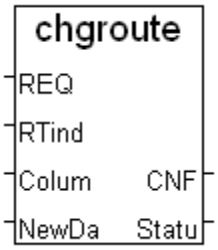


Figure 4-48 chgroute Function Block

INPUTS	TYPE	DESCRIPTION
Req	Boolean	Data transfer request initiated on rising edge.
RTindex	Integer	Route Table Row Index (0-49). The RTindex parameter defines the Route Table row in which the parameter is to be changed. The route table rows are configured by E Series Configurator and are indicated as Rows 1 to 50. Corresponding values for Rtindex are 0-49.
Column	Integer	Route Table Column number (0-7). See Table 4-12
NewData	Integer	New value for route table entry.

OUTPUTS	TYPE	DESCRIPTION
Cnf	Boolean	Data transfer confirm. TRUE indicates completion of request. FALSE, otherwise.
Sat	Integer	0 for success when Cnf is TRUE. Otherwise see error code in Table 4-10.

Table 4-12 – Valid Column parameters for chgroute

COLUMN VALUE	DNP ROUTE TABLE COLUMN	VALID COLUMN VALUES	COMMENT
0	Source Port	0 = Port0 1 = Port1 2 = Port2 3 = Port3 / FSK (radio/ll) 4 = Port 4	Source port of DNP3 message to be routed

COLUMN VALUE	DNP ROUTE TABLE COLUMN	VALID COLUMN VALUES	COMMENT
		5 = Ethernet 254 = Any 255 = Table End	
1	Source Start	0-65535	Source DNP node Address Range
2	Source End	0-65535	
3	Dest Start	0-65535	Destination DNP node Address Range
4	Dest End	0-65535	
5	Dest Port	0 = Port0 1 = Port1 2 = Port2 3 = Port 3 / FSK (radio/ll) 4 = Port 4 5 = Ethernet 8 = Pool	Destination port to route DNP3 message to.
6	Status	0 = Offline Static 1 = Online Static 256 = Offline Dynamic 257 = Online Dynamic 512 = Offline Fixed 513 = Online Fixed	Route Type
7	Lifetime	0-32767 secs	Lifetime of Dynamic Route for Online->Offline

4.6.4 chgrtnum

Change DNP3 Routing Table dial string

Description

This function block provides an ISaGRAF application with the ability to modify the "Connect No." string in the DNP3 Routing Table of the SCADAPack E Series RTU. The *chgrtnum* function block operates in a similar way to the ISaGRAF *chgroute* function block described above. This function block, though, takes a DNP Destination address as a parameter, and searches the route table for an entry whose destination address range includes the function block parameter value. The first matching entry that is found has its *Connect No.* field updated by the function block DIAL parameter value (string).

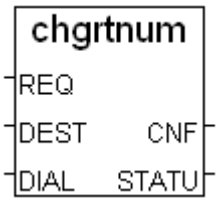


Figure 4-49 CHGRTNUM Function Block

INPUTS	TYPE	DESCRIPTION
Req	Boolean	Data transfer request initiated on rising edge.
Dest	Integer	Destination DNP node address to search (0-65535)
Dial	Message	Connect No. (message string) to transfer to the matching route entry. E.g. Dial number, IP address

OUTPUTS	TYPE	DESCRIPTION
Cnf	Boolean	Data transfer confirm. TRUE indicates completion of request. FALSE, otherwise.
Sat	Integer	0 for success when Cnf is TRUE. Otherwise see error code in Table 4-10.

4.6.5 chgrtprt

Change DNP3 Routing Table port number

Description

This function block provides an ISaGRAF application with the ability to modify the destination port number in a E Series RTU DNP3 Routing Table. The CHGRTPRT function block operates in a similar way to the ISaGRAF CHGROUTE function block described above. This function block, though, takes a DNP Destination address as a parameter, and searches the route table for an entry whose destination address range includes the function block parameter value. The first matching entry that is found has its *Destination Port* updated by the function block PORT parameter value (integer analog).

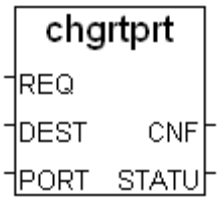


Figure 4-50 CHGRTPRT Function Block

INPUTS	TYPE	DESCRIPTION
Req	Boolean	Data transfer request initiated on rising edge.
Dest	Integer	Destination DNP node address to search (0-65535)
Port	Message	Destination Port number to transfer to the matching route entry. Port number values for E Series RTUs are: 0=Port0, 1=Port1, 2=Port2, 3=Port3/FSK, 4= Port4, 5=Ethernet, 8=Pool Also see Table 4-12 above.

OUTPUTS	TYPE	DESCRIPTION
Cnf	Boolean	Data transfer confirm. TRUE indicates completion of request. FALSE, otherwise.
Status	Integer	0 for success when Cnf is TRUE. Otherwise see error code in Table 4-10.

4.6.6 rea_msg

Convert a Real variable to a Message variable

Description

The standard ISaGRAF library provides a “MSG” conversion function for converting between ISaGRAF variable types. The standard function, however, truncates real (float) values before converting to a message string. I.e. only the integer portion is converted to a message string. Control Microsystems’s *rea_msg* function converts the integer and fractional portions of the real (float) value to a message string.

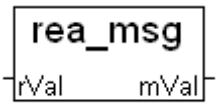


Figure 4-51 rea_msg function

INPUTS	TYPE	DESCRIPTION
rVal	Integer	Read (floating point) value

OUTPUTS	TYPE	DESCRIPTION
mVal	Message	Message string containing converted value

4.6.7 ana_time

Read float value with timestamp

Description

This function block provides an analog point's current engineering value, and the most relevant timestamp corresponding to the reported value. In order to provide an accurate timestamp for the point, the RTU can record a value and timestamp for a point when a DNP3 event is generated. This information is then available to ISaGRAF through this function block.

The function block can be operated in one of 2 modes. The first mode ignores DNP3 events and presents current values and current time, whereas the second mode uses DNP3 float events to obtain greater accuracy timestamps. This second mode requires that the point in question be appropriately configured to generate DNP3 float events for any change of value as described at the end of this subsection.

If multiple DNP3 events are generated between ISaGRAF scans, only the most recent value and timestamp will be available to the ISaGRAF function block. If the point is not configured as detailed below, the timestamp presented shall be the time at which the function block outputs are updated.

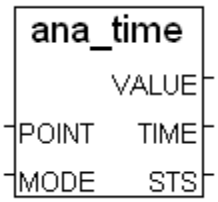


Figure 4-52 ana_time function

INPUTS	TYPE	DESCRIPTION
Point	Integer	specifies the RTU point number of the analog point.
Mode	Integer	0 = MODE_RTC: The timestamps presented represent the time at which the function block outputs are updated. Using this mode along with the elevated ISaGRAF task priority (see Section *4.6.2 - rtuparam*) can result in relatively constant time intervals between timestamps. Note that DNP3 events are not used to derive timestamps in this mode. 1 = MODE_EVT: DNP3 float event timestamps are used to update the function block timestamp output. In the absence of any DNP3 events, the timestamp presented, is the time at which the function block outputs are updated (same as for mode MODE_RTC). This mode produces timestamps of greater accuracy though the interval between timestamps can vary significantly.

OUTPUTS	TYPE	DESCRIPTION
Value	Real	The engineering value of the point. ISaGRAF checks to see if any DNP3 events for the point have been generated since the last scan, and if so the most recent event will provide the value to the function block output. If no events

OUTPUTS	TYPE	DESCRIPTION
		have generated since the last scan, the current value will be retrieved from the RTU point database using the points CURRENT ENGINEERING VALUE property.Message string containing converted value
Time	Timer	The time-stamp at which the *current value* occurred (milliseconds since midnight). ISaGRAF checks to see if any DNP3 events for the point have been generated since the last scan, and if so the most recent event will provide the timestamp to the function block output. If no events have generated since the last scan, the current time (as milliseconds since midnight) will be presented as the function block timestamp output. Note that the time is presented as Standard Time without local time or daylight savings correction.
Sts	Integer	Function block status values are indicated as follows: 0 = Success 1 = Point does not exist 6 = Invalid argument to function block (e.g. incorrect mode) -1 = Unknown error

NOTE:
In order for the ANA_TIME function block to provide accurate time stamping in MODE_EVT mode, it is necessary that the analog point be correctly configured to generate DNP3 events as follows: Refer to the *E Series Configurator Technical Reference* manual for further details.

- **Point Data Class:** Set this attribute to Class 1, Class 2 or Class 3.
- **DNP Static Object Type**: Set this attribute to Object 30 variation 5 or Object 40 variation 3.
- **Event Deviation** : Set to 0% to ensures that an event is generated for ANY value change
- **Alarm Inhibit**: Set to NO.

4.6.8 gen_evt

Generate a DNP event for a given point

Description

This function block provides a mechanism to force DNP3 events on appropriately configured configuration points. Typically DNP3 events are generated for points on significant value changes, with the associated timestamp reporting the actual time of the value change. This mechanism allows DNP3 events to be generated (forced) on the specified points as required. The value included in the forced DNP3 event will be the current point database value of the point in question.

The *gen_evt* function block includes a *time* input parameter which allows a timestamp to be included in the forced DNP3 event. Note that *time* input parameter represents the "*number of seconds since 1970*". This *time* input parameter must coincide with how the RTU's real time clock is set, i.e. either UTC or Standard Time format. (**Note**: This value can be obtained from the *os_time* function block as detailed in Section ***4.2.1 - os_time***). If a zero value is entered for the *time* input parameter, the RTU's operating system will timestamp the forced DNP3 event.

Note that DNP3 events generated using the *gen_evt* function blocks are inserted into the DNP3 event buffer as ***Buffered*** events.

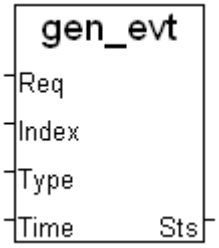


Figure 4-53 gen_evt function block

HINT: If ISaGRAF is to be used to write value changes to the specified point **before** forcing the DNP3 event, ensure that these point value updates are carried out using the DNP3 communication function blocks (where the *ObjectType* input is set to *Local_RTU_Data*), as opposed to using ISaGRAF output boards. This ensures that the operating system will process the value update **before** the "*force DNP3 event*" request.

INPUTS	TYPE	DESCRIPTION
Req	Boolean	Force DNP3 events request. This invokes a request to force a DNP3 event on the specified point when asserted (rising edge).
Index	Integer	This input specifies the DNP point number of the configuration point.
Type	Integer	This input specifies the point type of the configuration point. Valid values for the **Type** input are listed as follows DIN or 1 (Digital Input) AIN or 3 (Analog Input) CIN or 5 (Counter Input)
Time	Integer	This input specifies the timestamp to be used in the forced DNP3 event. Note that this input represents the number of seconds since January 1st, 1970 and must be specified as UTC time. Note that if a 0 value is entered, the RTU's operating system will timestamp the event with the current RTU time.

OUTPUTS	TYPE	DESCRIPTION
Sts	Integer	Function block status values are indicated as follows: 0 = Success 1 = Point does not exist 2 = Bad Point Type -1 = Unknown error

NOTE:

In order for the *gen_evt* function block to successfully force DNP3 events on the specified point (i.e. the configuration point specified by the ***Index*** and ***Type*** input parameters), the ***Point Data Class*** attribute of the configuration point must be configured as follows.

- Point Data Class : Set this attribute to Class 1, Class 2 or Class 3.
- Alarm Inhibit: The DNP3 event will be forced on the point irrespective of the state of the *Alarm Inhibit* attribute. Therefore if DNP3 events are only to be generated on the specified point using the *gen_evt* function block, then set the *Alarm Inhibit* attribute to YES which will prevent normal value changes from generating DNP3 events on the specified point.

4.6.9 getport

Read a DNP3 RS-232 line state

Description

The GETPORT ISaGRAF function block reads a serial port hardware line state for a DNP3 serial port only. Non-DNP3 ports or DNP3 driver ports (PPP, GPRS, Hayes Modem, FSK) are also not supported.

Figure 4-54 getport Function Block

INPUTS	TYPE	DESCRIPTION
Req	Boolean	Data Read request: initiate data transfer when asserted (rising edge)
Port	Integer	DNP3 E Series serial port number.
Param	Integer	Which DNP serial port hardware line to read. Valid value are: CTS DCD DSR (defined in the “common.eqv” file).

OUTPUTS	TYPE	DESCRIPTION
Cnf	Boolean	Data transfer confirm. TRUE indicates completion of request. FALSE, otherwise.
Status	Integer	Transaction status value: 0 = Success 1 = Invalid Port 2 = Invalid Parameter
Lstate	Boolean	The state of the serial port hardware line. True if the hardware line is asserted.

4.6.10 setport

Set a DNP3 RS-232 line state

Description

The setport ISaGRAF function block sets a serial port hardware line state for a DNP3 serial port only. Non-DNP3 ports or DNP3 driver ports (PPP, GPRS, Hayes Modem, FSK) are also not supported.

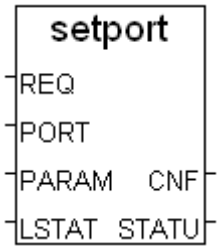


Figure 4-55 setport Function Block

INPUTS	TYPE	DESCRIPTION
Req	Boolean	Data Read request: initiate data transfer when asserted (rising edge)
Port	Integer	DNP3 E Series serial port number.
Param	Integer	Which DNP serial port hardware line to read. Valid value are: RTS DTR (defined in the “common.eqv” file).
Lstate	Boolean	The new state of the serial port hardware line. TRUE if the hardware line is to be asserted.

OUTPUTS	TYPE	DESCRIPTION
Cnf	Boolean	Data transfer confirm. TRUE indicates completion of request. FALSE, otherwise.
Status	Integer	Transaction status value: 0 = Success 1 = Invalid Port 2 = Invalid Parameter

4.7 TCP/IP Interface functions

These function blocks provide interfaces to RTU TCP/IP communication and configuration services. For more information on IP routing with the SCADAPack E Series RTU, see the *E Series TCP/IP Technical Reference* Manual.

4.7.1 ip_add

Add an IP Routing table entry

Description

This function interfaces to the TCP/IP facilities in the SCADAPack E Series RTU for adding an entry to the IP Routing Table. The *ip_add* function adds a routing entry to the IP Routing Table. A route entry access counter is incremented each time that the function is executed for this route. An *ip_del* function decrements the access counter and removes the route entry when the access counter reaches 0. It is advised to execute the function only when the route is first added. Depending upon the input parameter settings, one of the following route entry types may be added:

- HOST Route
- NETWORK Route
- GATEWAY Route
- DEFAULT GATEWAY Route

Note: Route entries added using this function are not preserved in NV RAM so are not retained if an RTU is restarted or powered off.

Figure 4-56 IP_ADD Function

INPUTS	TYPE	DESCRIPTION
Ip_dest	Message	Destination IP Address for route
Mask	Message	Destination Subnet Mask for route
IP_gw	Message	Gateway host IP Address for route
Metric	Integer	route metric (cost) for added route. (0 = use default interface metric)
TTL	Timer	Time to Live route entry. (t#0 = static route: no lifetime)
Interface	Integer	Number of IP interface (E.g. 0=Port0, 1=Port1, etc.).

OUTPUTS	TYPE	DESCRIPTION
Status	Integer	Indicates status or error code when adding to IP Table. 0 = success, otherwise see Table 4-10

4.7.2 ip_del

Delete an IP Routing table entry

Description

This function interfaces to the TCP/IP facilities in the SCADAPack E Series RTU for deleting an entry to the IP Routing Table. The IP_DEL function removes a routing entry to the IP Routing Table. The route entry's access counter is decremented each time that the function is executed and the route entry is deleted when the access counter reaches 0. It is advised to execute the function only when it is required to delete a route.

The specified IP address and mask information must match those used to previously to add an entry to the route table. I.e. via static routes in the RTU's configuration, command line ROUTE ADD command or ISaGRAF's ip_add function.

Note: Configured static route entries previously preserved in NV RAM are not permanently removed by the *ip_del* function. The permanent route entries will be restored upon an RTU restart or power on.

Figure 4-57 IP_DEL Function

INPUTS	TYPE	DESCRIPTION
Ip_dest	Message	Destination IP Address for route
Mask	Message	Destination Subnet Mask for route

OUTPUTS	TYPE	DESCRIPTION
Status	Integer	Indicates status or error code when adding to IP Table. 0 = success

4.7.3 ip_cycgw

Cycle default IP gateway route

Description

This function interfaces to the TCP/IP facilities in the SCADAPack E Series RTU for cycling default gateway entries in the IP Routing Table. The IP_CYCGW function cycles between DEFAULT GATEWAY route entries in the IP Routing Table. This is only applicable where multiple DEFAULT GATEWAY entries have been added to the IP Routing Table.

This operation of this function has no effect if there are no DEFAULT GATEWAY entries in the IP Routing Table, or if there is only a single DEFAULT GATEWAY entry.

Note:	The first DEFAULT GATEWAY entry found in the routing table is the active default gateway. This entry will always be the initial active default gateway whenever the RTU is restarted or powered on.

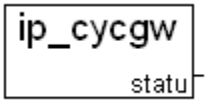


Figure 4-58 IP_CYCGW Function

OUTPUTS	TYPE	DESCRIPTION
Status	Interger	Indicates status or error code when cycling between default gateway IP routes. 0 = success

4.7.4 ip_ping

Ping a remote IP node

Description

This function block interfaces to the TCP/IP PING Client facilities in the E Series RTU. The *ip_ping* function block sends an ICMP ECHO request to the IP host specified by the *ip_dest* parameter. This tests IP (Network Layer) operations on the remote host.

It is suggested that the i*p_ping* function block could be used by an application executing in the second ISaGRAF Target Kernel, so as not to degrade the performance of a main control application executing in the first ISaGRAF Target Kernel.

WARNING:	This function block executes synchronously with the ISaGRAF execution scan, and may significantly increase the ISaGRAF application scan rate, particularly if the remote IP host does not reply to the PING request.

Figure 4-59 IP_PING Function Block

INPUTS	TYPE	DESCRIPTION
Ip_dest	Message	Destination IP address of remote host
Len	Integer	Number of bytes to send in ping request. (must be less than 1500)
TTL	Timer	Time To Live for ping packet on IP network. (t#0 = default TTL)
Timeout	Tmer	Time to wait for remote IP host to respond

OUTPUTS	TYPE	DESCRIPTION
Status	Integer	Indicates status or error code for Ping request. 0 = success
Elapsed	Timer	Elapsed time between Ping Response and Ping Request. Valid when STATUS = 0

4.7.5 msg_ip

Covert a message type string to an IP address

Description

This function converts an ISaGRAF Message type containing a TCP/IP address in dotted decimal format into a numeric value.

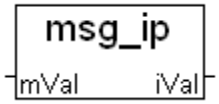


Figure 4-60 MSG_IP Function

INPUTS	TYPE	DESCRIPTION
mVal	Message	TCP/IP address as a string in dotted decimal format.

OUTPUTS	TYPE	DESCRIPTION
iVal	Integer	TCP/IP address as an integer value.

Structured text example:

```
rtuparam_2 (FALSE, ETH_IP_ADDRESS_1, 0, 0);
IF (r_trig2.Q = TRUE) THEN
    rtuparam_2 (TRUE, ETH_IP_ADDRESS_1, msg_ip ('192.168.0.218'),
    0);
END_IF;
```

4.7.6 ppp_echo

Ping a remote IP node

Description

This function interfaces to the TCP/IP facilities for querying the status of a PPP link on a SCADAPack E Series RTU. The *ppp_echo* function sends an LCP ECHO command to the nominated PPP interface on an E Series RTU.

A successful status (0) indicates PPP link "UP" state on the serial interface.

Note: PPP_ECHO may return a timed-out error (Status = 2040) on a busy PPP link. Therefore it is advisable to check the link a few times after a timeout before being sure that connection on the PPP link is lost.

For more information on using PPP with the SCADAPack E Series RTU, see the *E Series TCP/IP Technical Reference* Manual.

WARNING: This function executes synchronously with the ISaGRAF execution scan, and may significantly increase the ISaGRAF application scan rate, particularly if the peer PPP device does not reply to the LCP ECHO request.

It is suggested that the *ppp_echo* function could be used by an application executing in the second ISaGRAF Target Kernel, so as not to degrade the performance of a main control application executing in the first ISaGRAF Target Kernel.

Figure 4-61 ppp_echo Function

INPUTS	TYPE	DESCRIPTION
Interface	Integer	Number of PPP port IP interface. (E.g. 0=Port0, 1=Port1, etc.)
Len	Integer	Number of bytes to send in LCP Echo. Must be less than 500.
Timeout	Timer	Time to wait for the peer PPP device to respond

OUTPUTS	TYPE	DESCRIPTION
Status	Integer	Indicates status or error code for PPP ECHO operation. 0 = success

4.8 Alarm Group Functions & Function Block

The ISaGRAF 'Summary Alarm' functions and function blocks available in the SCADAPack E Series RTU provide a mechanism for grouping individual RTU Digital point states (alarms) in to a named alarm group, then provide a summary alarm output if any of the points in the group transition in to an alarm state. There are three aspects of the summary alarm functions that are provided through user interfaces:

- Configuration of points within a named alarm group
- Processing of the alarm group
- Transferring and loading the point "mask" values externally through DNP3 points.

These interfaces are handled through independent ISaGRAF functions and function blocks. As detailed below, the point numbers registered for alarm summaries do not necessarily have to be imported in to the ISaGRAF application through an input board. However, if they are attached to I/O boards as ISaGRAF input variables, translation to the DNP3 point number can be provided for the point in the RTU database. The Control Microsystems ISaGRAF pre-processor can automatically build an ISaGRAF "Defines" list based on variables attached to DNP3 point I/O boards. These defines can then be used as named DNP3 point numbers. See section ***3 - The ISaGRAF Preprocessor*** for details.

The I/O Processor sub-system within the RTU supports the concept of point alarms, as a standard feature. Each binary point within the RTU database has a "Point-In-Alarm" property which is processed through these Summary Alarm interfaces.

For information on RTU alarm processing see the *E Series Data Processing Technical Reference Manual*.

4.8.1 almadd

Add a point to an alarm group

Description

Creating and configuring the Alarm Group is performed by a call from ISaGRAF User Application code to the RTU ISaGRAF *almadd* Function.

Typically the ISaGRAF function calls to configure an alarm group are executed during the start-up phase of an ISaGRAF application. Once executed at ISaGRAF application startup, this code no longer needs to be executed while the ISaGRAF application is running. Where an alarm group identified by the string passed to GRPNAME does not exist, it will be created by the *almadd* function and the specified Point number will be added to the alarm group. A subsequent call to the *almadd* function whose GRPNAME has been previously created, will add the new point to the existing alarm group.

The function Output is used to indicate the success (or otherwise) of the creation of a named alarm group, and/or the successful (or otherwise) addition of the point to the named alarm group.

Attempting to add the same DNP Point number twice to the same Alarm Group name will result in the *almadd* function returning an error code 3.

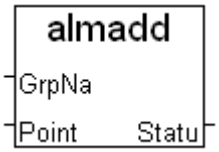


Figure 4-62: almadd Function

INPUTS	TYPE	DESCRIPTION
GrpName	Message	INPUTS of alarm group (a string)
Pont	Integer	RTU DNP Digital Input or User Point number.

OUTPUTS	TYPE	DESCRIPTION
Status	Integer	Indicates status or error code. Status: -1 = Internal Error 0 = Success 1 = Point does not exist 2 = Invalid Group 3 = Point already exists in Group

Structured Text Example:

```
IF (almadd('ProtectionFault', Z_P_PHA_TRIP) = 0) THEN
  Status1 := almadd('ProtectionFault',Z_P_PHB_TRIP);
  Status2 := almadd('ProtectionFault',Z_P_PH _TRIP);
END_IF;
```

Note the use of a point number "Z_…". This could be a numeric value, or an ISaGRAF define generated by the Control Microsystems ISaGRAF Pre-Processor. This ISaGRAF function dynamically creates an alarm group and dynamically adds points to the alarm groups. Apart from upper memory limitations of the RTU's CPU, there is no design limit to the number of alarm groups that can be created using this function block. Similarly there is no design limit to the number of points that can be added to an alarm group.

4.8.2 almproc

Process a summary alarm group

Description

Processing (execution) of the Alarm Group is performed by a call from ISaGRAF user application code to the ALMPROC Function Block.

Once configured in a one-off execution of ISaGRAF code using calls to the *almadd* function block instance (as described in section ***4.8.1 - almadd*** above), a call to an *almproc* function block would typically occur each ISaGRAF scan. The rate of execution could be controlled through additional logic if required, but optimal responsiveness is achieved through execution each ISaGRAF scan.

The *almproc* function block takes as an input an alarm group name (as created and configured by calls to the ALMADD function block). The *almproc* function block summarizes the alarm states of the given alarms and asserts its *alm_out* output parameter when one of the input points is in alarm. In addition, an ACCEPT input masks the active alarms and clears the *alm_out* output parameter. An alarm condition that is cleared on a point (i.e. a point that goes out of the alarm state) automatically clears the mask for that alarm on the next ISaGRAF scan of the *almproc* function. A recurrence of the alarm, or occurrence of another new alarm, again sets the *alm_out* output parameter. An ACCEPT masks the active alarms and clears the *alm_out* output parameter.

An RTU restart or ISaGRAF application restart clears the internal alarm mask. If an *almload* function is not used prior to using *almproc* active alarms on the Alarm Group will cause regeneration of the *alm_out* condition. *almload* can be used to restore an alarm mask, thereby preserving the alarm mask and preventing regeneration of the group alarm. See section ***4.8.3 - almload*** below.

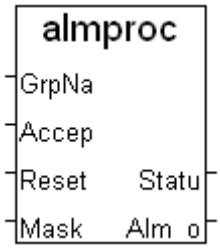


Figure 4-63: almproc Function Block

INPUTS	TYPE	DESCRIPTION
GrpName	Message	String value identifying alarm group.
Accept	Boolean	OFF to ON transition (rising edge) of this point accepts current alarms.
Reset	Boolean	OFF to ON (rising edge) transition of this point clears internal alarm masks and generates the ALARM output if required.
Mask_pt	Integer	RTU DNP digital user point number. 0 = No mask point

OUTPUTS	TYPE	DESCRIPTION
Status	Integer	Indicates status or error code. Status: -1 = Internal Error

OUTPUTS	TYPE	DESCRIPTION
		0 = Success 1 = Point does not exist 2 = Invalid Group 4 = Mask point does not exist
Alm_out	Boolean	Unaccepted new alarm has occurred. Activating the ACCEPT input masks the current alarms and clears the ALARM output point

RTU point database attributes are applied to the logic associated with Alarm activation as shown in the following table. See the *E Series Data Processing Technical Manual* for more information.

Table 4-13: RTU Alarm point attributes and descriptions

Point Attribute	Description	Effect on ALARM activation
Invert State (Physical digital inputs)	When OFF, the physical input in an Energized state represents "ON" (active) state in the database. When ON, the physical input in an Energized state represents "OFF" (active) state in the database	No direct effect (see Alarm Active State below)
Debounce Time (Physical digital inputs)	Duration (in mS) that the input must stay active before it is registered as being ON in the database	Delays updating point state in the RTU Database after the input is active
Alarm Active State	Indicates which state in the point database represents the "alarm" state of the point. When this attribute value = ON, the database point state being ON is the alarm condition	Determines which point state causes activation of the "Point-in-Alarm" property
Alarm Time Deadband	Duration (in Seconds) that the point must stay in the alarm state before the "Point-in-Alarm" property is activate	Delays activation of the alarm property of the point
Alarm Clear Time Deadband	Duration (in Seconds) that the point must stay out the alarm state before the "Point-in-Alarm" property is de-activated	Delays clearing of the alarm property of the point
Alarm Inhibit	Inhibits the "Point-in-Alarm" property being activated, regardless of the input condition	Prevents the point going in to the alarm state

Transition of the RESET input parameter (from OFF to ON state) causes the alarm mask (internal for that alarm group) to be reset. Following clearing of the mask, any active alarm states previously masked will reactivate the ALM_OUT output.

Note that ‘fleeting alarms’ of very short duration may not annunciate via the ALM_OUT output if the ISaGRAF scan rate (or call rate to the ALMPROC function block) exceeds the duration of the alarm condition.

A short duration alarm that exceeds a point’s alarm time deadband (configured in the RTU point database) and the ISaGRAF scan rate will activate the ALM_OUT output. The ALM_OUT output will remain active (until ACCEPTed) even if the input point alarm condition is no longer active.

The MASK_PT input parameter is used to allow the internal Function Block mask to be written out into consecutive RTU Digital User points. These User points can be read later by the **ALMLOAD** Function in order to load a new internal mask. This may be used to make the internal mask non-volatile or to transfer the internal mask values to another RTU via DNP3 Peer Function Blocks for redundancy purposes, for example. If the MASK_PT input is zero, this functionality is disabled. If the DNP point supplied to the MASK_PT input does not exist for one or more points in the Alarm Group, the STATUS value will be set to an error code of 4. However, this does not otherwise affect processing of the Alarm Group.

The STATUS output parameter is used to indicate the success (or otherwise) of the processing of a named alarm group. The ALM_OUT output indicates the presence of a new alarm that has not yet been accepted.

A typical structured text example could be:

```
SumAlm_ProtFault('ProtectionFault', Oper_ACCEPT, Oper_RESET);
IF (SumAlm_ProtFault.Status = 0) THEN
  ProtFault_Alarm := SumAlm_ProtFault.ALM_OUT;
  OPERATE(Oper_ACCEPT, 0);
  OPERATE(Oper_RESET, 0);
END_IF;
```

where “SumAlm_ProtFault” is an Instance of an “ALMPROC” function block. “Oper_ACCEPT” is a Boolean variable being the operator ‘Accept’ input and “Oper_RESET” is a Boolean variable to clear the summary alarm mask. “ProtFault_Alarm” could be an ISaGRAF Boolean Output variable that updates a DNP3 point in the RTU point database. In this example it is assumed that the Oper_ACCEPT and Oper_RESET inputs are latched variables on ISaGRAF input boards from RTU database points. The OPERATE function clears the variables and their point source in the database. If pulse points were to be used instead of latch points, the OPERATE function calls would be unnecessary. However, when using Pulse Points, the pulse duration of ACCEPT and RESET points must be long enough to significantly exceed the length of the ISaGRAF scan.

4.8.3 almload

Load a mask to an alarm group

Description

Loading of the Alarm Group internal mask from an external source can be performed by a call from ISaGRAF User Application code using the *almload* ISaGRAF Function.

The *almload* function takes as an input an alarm group name (as created and configured by calls to the ALMADD function block) and an RTU User Digital point number. When used for restoring the alarm mask state, this Digital point number is normally the same number that was supplied as the MASK_PT input parameter to the ALMPROC function block for the same alarm group name.

The MASK_PT input parameter is used to allow the internal *almproc* Function Block mask to be loaded by reading consecutive RTU Digital User points. If the MASK_PT input is zero, an error code is returned. The number of RTU digital points read corresponds to the number of alarms in the Alarm Group.

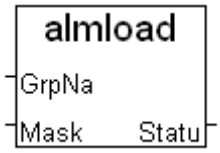


Figure 4-64: almload Function

INPUTS	TYPE	DESCRIPTION
GrpName	Message	String value identifying alarm group.
Mask_pt	Integer	RTU DNP digital user point number. 0 = No mask point

OUTPUTS	TYPE	DESCRIPTION
Status	Integer	-1 = Internal Error 0 = Success 1 = Point does not exist 2 = Invalid Group

4.8.4 almclr

Destroy an alarm group

Description

A previously created Alarm Group can be removed using the ALMCLR ISaGRAF function. Calling this function frees RTU system resources associated with the named Alarm Group. After this function is called, the named alarm group no longer exists and does not perform alarm group functions. ISaGRAF alarm group functions and function blocks referencing this alarm group after an ALMCLR will result in status error codes.

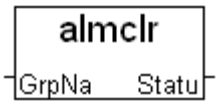


Figure 4-65: almclr Function

INPUTS	TYPE	DESCRIPTION
GrpName	Message	String value identifying alarm group.

OUTPUTS	TYPE	DESCRIPTION
Status	Integer	-1 = Internal Error 0 = Success 2 = Invalid Group

4.9 RTU File System Interface Functions and Function Blocks

This section describes all of the functions and function blocks that support access to the RTU file system. Many of the functions and function blocks detailed in this section return an analog status value. Refer to Section ***4.9.1 - File System Access Error Codes*** for a list of file system status error codes. The standard functions that provide similar functionality to the command line interface for file system access are detailed in Section ***4.9.2-Standard File System Access Functions***. The directory / drive information function blocks are detailed in Section ***4.9.3 - Directory Information Function Blocks*** and the file read / write functions are detailed in Section ***4.9.4 - ISaGRAF File Read / Write Functions.***

4.9.1 File System Access Error Codes

Many of the RTU file system functions and function blocks return an integer status / error code. The possible status / error code values are detailed in the following table.

Table 4-14: File System Status / Error Codes

Status Value	Description
0	Success
-1	Unknown Error
-1000	Source name is illegal
-1001	Source file is in use
-1002	Source file does not exist
-1003	Invalid file pointer
-1004	Illegal position
-1005	Illegal destination name
-1006	Source file name in use
-1007	Invalid query structure
-1008	Destination file name in use
-1009	Error creating working buffer
-1010	Error writing to file
-1011	Could not create file
-1012	New file would exceed the maximum file size
-1013	Requested operation not supported
-1014	Directory in use
-1015	File or Directory does not exist
-1016	Invalid Path
-1017	File or Directory already exists

4.9.2 Standard File System Access Functions

This section details the proposed functions that will provide equivalent functionality to the following command line commands

- Del (identified as **F_DEL** in ISaGRAF)
- Deltree (identified as **F_DELTRE** in ISaGRAF)
- Copy (identified as **F_COPY** in ISaGRAF)
- Join or Append (identified as **F_JOIN** in ISaGRAF)
- Rename (identified as **F_REN** in ISaGRAF)
- MD (identified as **F_MKDIR** in ISaGRAF)
- RMDIR (identified as **F_RMDIR** in ISaGRAF)
- CD (identified as **F_CD** in ISaGRAF)
- DSKSEL (identified as **F_DSKSEL** in ISaGRAF)

4.9.2.1 F_DEL

The F_DEL function is used to delete the specified file from the RTU file system from within an ISaGRAF program. The figure below shows the function with the following calling and return parameters:

INPUTS	TYPE	DESCRIPTION
iFile	Message	Filename to delete (including path)
OUTPUTS	**TYPE**	**DESCRIPTION**
oSts	Integer	Status of Delete Request

The **iFile** argument specifies the filename to delete, and is case insensitive (upper and lower case allowed). The maximum number of characters allowed for the **iFile** argument is 255.

The **iFile** argument and a may include the full path, e.g. “C:\sample.txt”. Note that if only the filename is specified, the current working directory will be used to determine the full path. The current working directory can be changed in ISaGRAF using **F_CD** function (see Section *4.9.2.8 - F_CD Function*).

The function returns a 0 if the delete request was successful. If an error was detected, a negative integer value is returned. Refer to Section *4.9.1 - File System Access Error Codes* for the range of possible error codes and their descriptions.

4.9.2.2 F_DELTRE

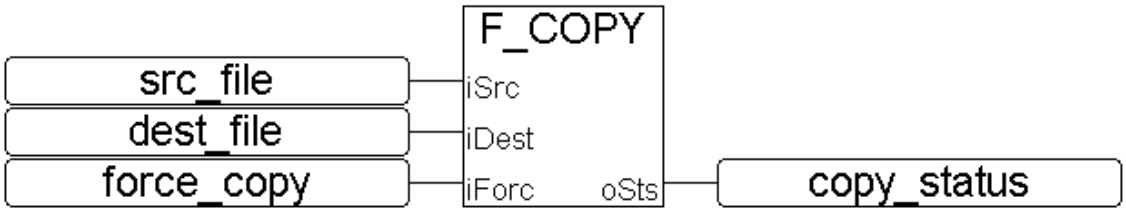
The F_DELTRE function is used to remove the specified directory and all files in that directory. Note also that all subdirectories and files below the specified directory are also deleted. The figure below shows the function with the following calling and return parameters:

INPUTS	TYPE	DESCRIPTION
iDir	Message	Directory to delete
OUTPUTS	**TYPE**	**DESCRIPTION**
oSts	Integer	Status of Delete Request

iDir is case insensitive (upper and lower case allowed). The maximum number of characters allowed for the **iDir** argument is 255. The function returns a 0 if the request was successful. If an error was detected, a negative integer value is returned. Refer to Section ***4.9.1 - File System Access Error Codes*** for the range of possible error codes and their descriptions.

4.9.2.3 F_COPY

The F_COPY function is used to copy the specified source file to a new file in the RTU file system whose name is specified as the destination filename. The figure below shows the function with the following calling and return parameters:



INPUTS	TYPE	DESCRIPTION
iSrc	Message	Source file to be copied
iDest	Message	Filename for the new copied file
Force_copy	Message	Forces copy over existing files
OUTPUTS	**TYPE**	**DESCRIPTION**
oSts	Integer	Status of Delete Request

The **iSrc** argument specifies the filename of the file to be copied, and the **iDest** argument specifies the filename for the new copied file. Note that both of these arguments are case insensitive (upper and lower case allowed). The maximum number of characters allowed for the **iSrc** and **iDest** arguments is 255. The **iForce** argument allows existing destination files to be overwritten.

The **iSrc** and **iDest** arguments may include the full path, e.g. “C:\sample.txt”. Note that if only the filename is specified, the current working directory will be used to determine the full path. The current working directory can be changed in ISaGRAF using **F_CD** function (see Section ***4.9.2.8 - F_CD Function***).

The function returns a 0 if the delete request was successful. If an error was detected, a negative integer value is returned. Refer to Section ***4.9.1 - File System Access Error Codes*** for the range of possible error codes and their descriptions.

4.9.2.4 F_JOIN Function

The F_JOIN function is used to append the specified source file to the specified destination file. The third argument to this function block allows the programmer to “optionally” specify a maximum size (in bytes) for the destination file. The figure below shows the function with the following calling and return parameters:

INPUTS	TYPE	DESCRIPTION
iSrc	Message	Source file to be copied
iDest	Message	Filename for the new copied file
iLimit	Integer	‘Optional’ maximum size for the destination file (0 = no limit)
OUTPUTS	**TYPE**	**DESCRIPTION**
oSts	Integer	Status of Request

The **iSrc** argument specifies the filename of the file(s) to be appended, and the **iDest** argument specifies the filename to which the source file is appended to. Note that both of these arguments are case insensitive (upper and lower case allowed). The maximum number of characters allowed for the **iSrc** and **iDest** arguments is 255.

The **iLimit** argument specifies the maximum size of the destination file. If this argument is zero, the source file(s) will be unconditionally appended to the destination file.

The **iSrc** and **iDest** arguments may include the full path, e.g. “C:\sample.txt”. Note that if only the filename is specified, the current working directory will be used to determine the full path. The current working directory can be changed in ISaGRAF using **F_CD** function (see ***4.9.2.8 - F_CD Function***).

The function returns a 0 if the join request was successful. If an error was detected, a negative integer value is returned. Refer to ***4.9.1 - File System Access Error Codes*** for the range of possible error codes and their descriptions.

4.9.2.5 F_REN Function

The F_REN function is used to rename a specified file to a new filename in the RTU file system. The figure below shows the function with the following calling and return parameters:

INPUTS	TYPE	DESCRIPTION
iOld	Message	Existing filename
iNew	Message	New filename
OUTPUTS	**TYPE**	**DESCRIPTION**
oSts	Integer	Status of Request

The **iOld** argument specifies the existing filename of the specified file, and the **iNew** argument specifies the new filename for the specified file. Note that both of these arguments are case insensitive (upper and lower case allowed). The maximum number of characters allowed for the **iOld** and **iNew** arguments is 255.

The **iSrc** and **iDest** arguments may include the full path, e.g. “C:\sample.txt”. Note that if only the filename is specified, the current working directory will be used to determine the full path. The current working directory can be changed in ISaGRAF using **F_CD** function (see ***4.9.2.8 - F_CD Function***).

The function returns a 0 if the join request was successful. If an error was detected, a negative integer value is returned. Refer to ***4.9.1 - File System Access Error Codes*** for the range of possible error codes and their descriptions.

4.9.2.6 F_MKDIR Function

The F_MKDIR function is used to create directories, and requires a single argument which specifies the directory name (or full path) to be created. If the directory name alone is specified, the directory is created as a subdirectory of the current working directory. A full path specification allows directories to be created wherever required. The current working directory can be changed in ISaGRAF using **F_CD** function (see *4.9.2.8 - F_CD Function*). Note that the F_MKDIR function supports creation of directories on other drives, i.e. different to the current drive.

The figure below shows the function with the following calling and return parameters:

INPUTS	TYPE	DESCRIPTION
iDir	Message	Directory to create
OUTPUTS	**TYPE**	**DESCRIPTION**
oSts	Integer	Status of Request

iDir is case insensitive (upper and lower case allowed). The maximum number of characters allowed for the **iDir** argument is 255.

The function returns a 0 if the join request was successful. If an error was detected, a negative integer value is returned. Refer to *4.9.1 - File System Access Error Codes* for the range of possible error codes and their descriptions.

4.9.2.7 F_RMDIR Function

The F_RMDIR function is used to remove directories, and requires a single argument which specifies the directory name (or full path) to be removed. If the directory name alone is specified, the directory must exist as a subdirectory of the current working directory. A full path specification allows directories to be removed wherever required. The current working directory can be changed in ISaGRAF using **F_CD** function (see ***4.9.2.8 - F_CD Function***). Note that the F_RMDIR function supports removal of directories on other drives, i.e. different to the current drive.

The figure below shows the function with the following calling and return parameters:

INPUTS	TYPE	DESCRIPTION
iDir	Message	Directory to remove
OUTPUTS	**TYPE**	**DESCRIPTION**
oSts	Integer	Status of Request

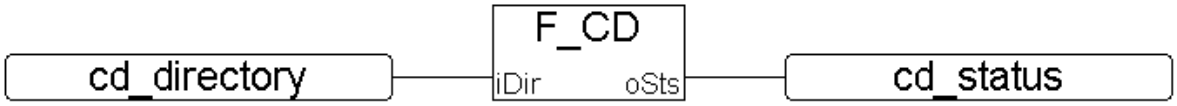
iDir is case insensitive (upper and lower case allowed). The maximum number of characters allowed for the **iDir** argument is 255.

The function returns a 0 if the request was successful. If an error was detected, a negative integer value is returned. Refer to ***4.9.1 - File System Access Error Codes*** for the range of possible error codes and their descriptions.

4.9.2.8 F_CD Function

The F_CD function is used to change the working directory within a given drive. If the target directory is directly below the current working directory, only the directory name is required, otherwise the full path is required. An **iDIR** argument of "**..**" will change the working directory to one level above the current working directory.

The figure below shows the function with the following calling and return parameters:



INPUTS	TYPE	DESCRIPTION
iDir	**Message**	**Target Directory**
OUTPUTS	**TYPE**	**DESCRIPTION**
oSts	Integer	Status of Request

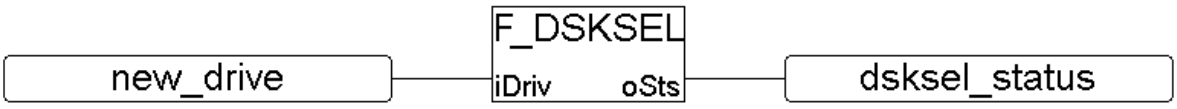
iDir is case insensitive (upper and lower case allowed). The maximum number of characters allowed for the **iDir** argument is 255.

The function returns a 0 if the request was successful. If an error was detected, a negative integer value is returned. Refer to ***4.9.1 - File System Access Error Codes*** for the range of possible error codes and their descriptions.

4.9.2.9 F_DSKSEL Function

The F_DSKSEL function is used to change the between working drives on the RTU file system. After executing this function, the current working directory on the target drive will be selected, e.g. if the current working directory is currently “C:\testdir”, and the last specified working directory on the “D drive” was “D:\targetdir”, the F_DSKSEL function with the argument “**D:**” would then result with “D:\targetdir” as the current working directory. Calling the F_DSKSEL function with the argument “**C:**” would then result with “C:\testdir” as the current working directory.

The figure below shows the function with the following calling and return parameters:



INPUTS	TYPE	DESCRIPTION
iDrive	Message	Target Drive
OUTPUTS	**TYPE**	**DESCRIPTION**
oSts	Integer	Status of Request

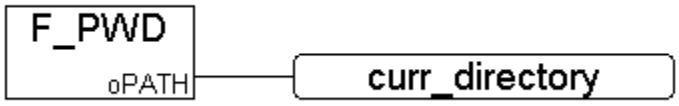
iDrive is case insensitive (upper and lower case allowed). The maximum number of characters allowed for the **iDrive** argument is 10.

The function returns a 0 if the request was successful. If an error was detected, a negative integer value is returned. Refer to ***4.9.1 - File System Access Error Codes*** for the range of possible error codes and their descriptions.

4.9.2.10 F_PWD Function

The F_PWD function is used to display the current working directory for the ISaGRAF kernel task in which the function is called.

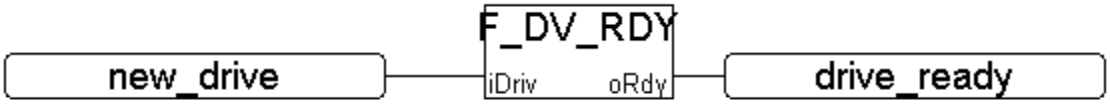
The figure below shows the function with the following return parameters. Note that there are no calling parameters.



OUTPUTS	TYPE	DESCRIPTION
oPATH	Message	Current Working Directory.

4.9.2.11 F_DV_RDY Function

The F_DV_RDY function is used to determine whether or not the specified drive is mounted and ready. The figure below shows the function with the following calling and return parameters:



INPUTS	TYPE	DESCRIPTION
iDrive	Message	Target Drive to be checked
OUTPUTS	**TYPE**	**DESCRIPTION**
oRdy	Boolean	Status of Request

iDrive is case insensitive (upper and lower case allowed). The maximum number of characters allowed for the **iDrive** argument is 10.

The function returns TRUE if the specified drive is mounted and ready for use, otherwise FALSE in returned.

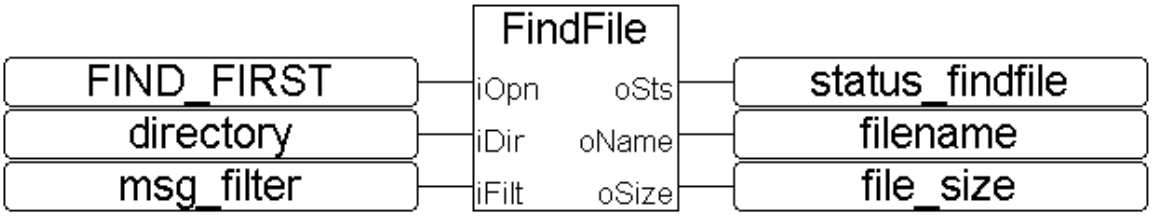
4.9.3 Directory Information Function Blocks

The functionality of the command line **DIR** command will be provided by the following ISaGRAF function blocks

- FindFile
- DirInfo

4.9.3.1 FINDFILE Function Block

The **FINDFILE** function block allows the programmer to search a given directory for a specific file. The specific filename and size to be returned are determined by the specified file operation, i.e. “first file”, “next file”, or the “oldest file”. The function block also allows the programmer to specify the directory to search, and a filter as the search criteria, which is only required when searching for the “first file”. In addition to the retrieved filename, this function block also returns size of the file in bytes.



4.9.3.1.1 Function Block Parameters

The inputs to the **FINDFILE** function block are as follows

iOpn (ANA) - specifies which file operation to be carried out. The possible values are listed as follows:

0 = FIND_FIRST:	This instructs the FindFile function block to search for the first file in the specified directory (defined in common.eqv as FIND_FIRST)
1 = FIND_NEXT:	This instructs the FindFile function block to search for the next file in the specified directory. The filter for the search would have been specified in the previous “FIND_FIRST” call. (defined in common.eqv as FIND_NEXT).
2 = FIND_OLDEST:	This instructs the FindFile function block to search for the oldest file in the specified directory. The filter for the “oldest” file search is specified by the Dir input parameter. defined in common.eqv as FIND_OLDEST).

iDir (MSG) – specifies the directory for the file search. This argument is case insensitive (upper and lower case allowed) and the maximum number of characters allowed is 255. If no directory is specified, the current working directory will be referenced for the search.

iFilt (MSG) – specifies the filter for the search criteria, e.g. “*” to search all files. This is not required for the FIND_NEXT calls as this would have been specified in the FIND_FIRST call. This

argument is case insensitive (upper and lower case allowed) and the maximum number of characters allowed is 255. If no filter is specified then "*" will be used.

The outputs to the **FINDFILE** function block are as follows:

oSts (ANA) - specifies which status of the requested file operation. The function block **oSts** value returns 0 if the search was successful (according the specified search criteria). If an error was detected, a negative integer value is returned. Refer to ***4.9.1 - File System Access Error Codes*** for the range of possible error codes and their descriptions.

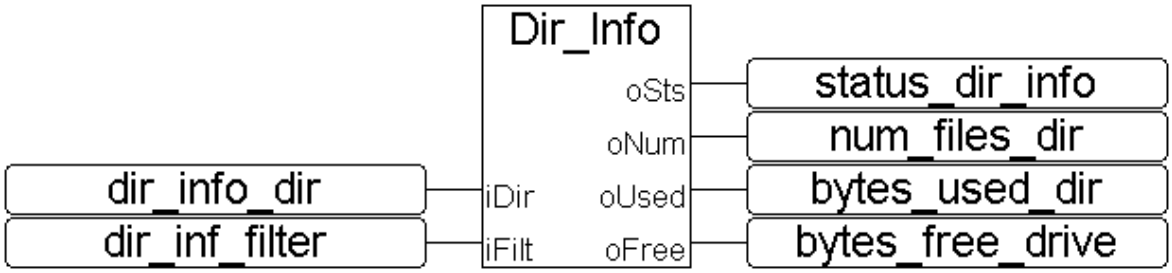
oName (MSG) – specifies the file name retrieved and is only valid if the **oSts** output indicates success, i.e. 0. The maximum number of characters allowed for the **oName** output is 255.

oSize (ANA) – specifies the size of the detected file in bytes and is only valid if the **oSts** output indicates success, i.e. 0.

4.9.3.2 DIR_INFO Function Block

The **DIR_INFO** function block allows the programmer to determine the following information for a given directory

- number of files in the directory
- total bytes used in directory (according to specified filter)
- bytes available in the current working drive



4.9.3.2.1 Function Block Parameters

The inputs to the **DIR_INFO** function block are as follows

iDir (MSG) – specifies the directory for the information search. This argument is case insensitive (upper and lower case allowed) and the maximum number of characters allowed is 255. If no directory is specified, the current working directory will be referenced for the directory information search.

iFiltr (MSG) – specifies the filter for the **DIR_INFO** information search, e.g. "*" to include all files. This argument is case insensitive (upper and lower case allowed) and the maximum number of characters allowed is 255. If no filter is specified then "*" will be used.

The outputs to the **DIR_INFO** function block are as follows

- oSts (ANA) - specifies which status of the directory information search. The function block oSts value returns 0 if the information search was successful. If an error was detected, a negative integer value is returned. Refer to ***4.9.1 - File System Access Error Codes*** for the range of possible error codes and their descriptions.
- oNum (ANA) – specifies the number of files in the directory according to the search criteria, i.e. the iFiltr input. The presented value is only valid if the oSts output indicates success.
- oUsed (ANA) – specifies the total number of bytes used by files in the directory that satisfy the search criteria, i.e. the iFiltr input. The presented value is only valid if the oSts output indicates success.
- oFree (ANA) – specifies the total number of bytes available in the RTU file system. The presented value is only valid if the oSts output indicates success.

4.9.4 ISaGRAF File Read / Write Functions

This section describes the functions that provide both read and write access to files in the RTU file system and allow for transfer of both ASCII and binary data. Note that these functions are already included in the standard ISaGRAF help files, though there is currently no firmware implementation for these functions. They have been documented here in order to clarify the standard interface to the RTU file system for file read and write access.

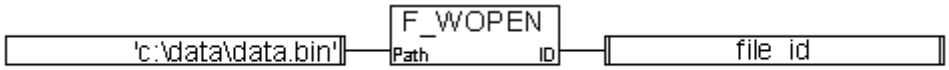
The functions detailed in this section are listed as follows

- F_WOPEN
- F_ROPEN
- F_CLOSE
- F_EOF
- FA_READ
- FA_WRITE
- FM_READ
- FM_WRITE.

4.9.4.1 F_WOPEN Function

The F_WOPEN function opens the specified file in write mode. It is to be used with the FA_WRITE, FM_WRITE, and F_CLOSE functions.

The figure below shows the function with the following calling and return parameters:



INPUTS	TYPE	DESCRIPTION
Path	Message	Filename to open in write mode (may include path)
OUTPUTS	**TYPE**	**DESCRIPTION**
ID	Integer	File ID (file handle)

The **PATH** argument specifies the filename to open in write mode. For 586 models, this argument may include the full path, otherwise the current working directory shall be used to determine the full patch for the specified file. This argument is case insensitive (upper and lower case allowed), and the maximum number of characters allowed is 255.

The **ID** return parameter presents a file handle to be used for subsequent file accesses. A returned value of 0 indicates a failure, i.e. the specified file could not be opened in write mode.

4.9.4.2 F_ROPEN Function

The F_ROPEN function opens the specified file in read mode. It is to be used with the FA_READ, FM_READ, and F_CLOSE functions.

The figure below shows the function with the following calling and return parameters:

INPUTS	TYPE	DESCRIPTION
Path	Message	Filename to open in read mode (may include path)
OUTPUTS	**TYPE**	**DESCRIPTION**
ID	Integer	File ID (file handle)

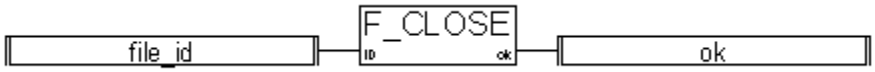
The **PATH** argument specifies the filename to open in read mode. For 586 models, this argument may include the full path, otherwise the current working directory shall be used to determine the full patch for the specified file. This argument is case insensitive (upper and lower case allowed), and the maximum number of characters allowed is 255.

The **ID** return parameter presents a file handle to be used for subsequent file accesses. A returned value of 0 indicates a failure, i.e. the specified file could not be opened in read mode.

4.9.4.3 F_CLOSE Function

The F_CLOSE function closes files that have been opened with F_WOPEN or F_ROPEN.

The figure below shows the function with the following calling and return parameters:



INPUTS	TYPE	DESCRIPTION
ID	Integer	File ID (file handle)
OUTPUTS	**TYPE**	**DESCRIPTION**
OK	Boolean	Status of file close request

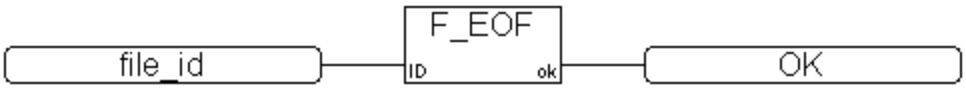
The **ID** argument specifies the file handle that was returned in calls to either F_WOPEN or F_ROPEN. A valid ID value for a currently open file is non-zero.

The **OK** return parameter presents a boolean status for the file close request. TRUE is returned is the file close is OK, otherwise FALSE is returned.

4.9.4.4 F_EOF Function

The F_EOF function tests whether the end of file has been reached.

The figure below shows the function with the following calling and return parameters:



INPUTS	TYPE	DESCRIPTION
ID	Integer	File ID (file handle)
OUTPUTS	**TYPE**	**DESCRIPTION**
OK	Boolean	Status of request

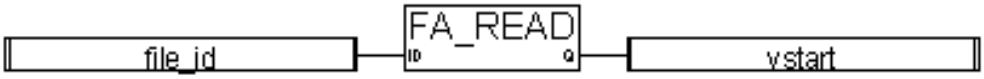
The **ID** argument specifies the file handle that was returned in calls to either F_WOPEN or F_ROPEN. A valid ID value for a currently open file is non-zero.

The **OK** return parameter presents a boolean status for the end of file test. TRUE is returned is the end of file has been reached in the last read or write procedure call, otherwise FALSE is returned.

4.9.4.5 FA_READ Function

The FA_READ function reads analog values from a binary file. It is to be used with the F_ROPEN and F_CLOSE functions. This function makes a sequential access to the file from the previous position. The first call after F_ROPEN reads the first 4 bytes of the file. Each call pushes the “read” pointer. To check whether the end of file is reached, the F_EOF function is used.

The figure below shows the function with the following calling and return parameters:



INPUTS	TYPE	DESCRIPTION
ID	Integer	File ID (file handle)
OUTPUTS	**TYPE**	**DESCRIPTION**
q	Integer	Integer value read from file

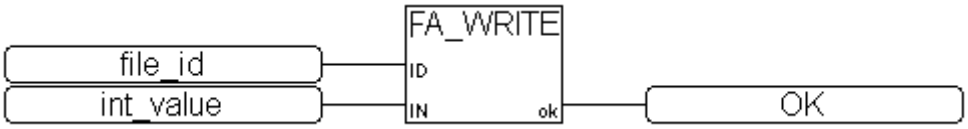
The **ID** argument specifies the file handle that was returned in the call to F_ROPEN. A valid ID value for a currently open file is non-zero.

The **Q** return parameter returns the integer analog value read from the file.

4.9.4.6 FA_WRITE Function

The FA_WRITE function writes analog values to a binary file. It is to be used with the F_WOPEN and F_CLOSE functions. This function makes a sequential access to the file from the previous position. The first call after F_WOPEN writes the first 4 bytes of the file. Each call pushes the "write" pointer.

The figure below shows the function with the following calling and return parameters:



INPUTS	TYPE	DESCRIPTION
ID	Integer	File ID (file handle)
IN	Integer	Integer value to be written to file
OUTPUTS	**TYPE**	**DESCRIPTION**
q	Integer	Status of file write request

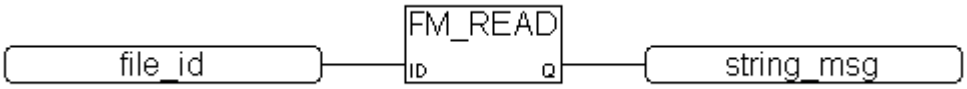
The **ID** argument specifies the file handle that was returned in the call to F_WOPEN. A valid ID value for a currently open file is non-zero. The **IN** argument represents the actual value that will be written (in 4 bytes) to the specified file.

The **OK** return parameter returns the status of the file write request. TRUE is returned if the file write was successful, otherwise FALSE is returned.

4.9.4.7 FM_READ Function

The FM_READ function reads MESSAGE values from a binary file. It is to be used with the F_ROPEN and F_CLOSE functions. This function makes a sequential access to the file from the previous position. The first call after F_ROPEN reads the first string of the file. Each call pushes the "read" pointer. A string is terminated by null (0), end of line ('\n') or return ('\r'). To check whether the end of file is reached, the F_EOF function is used.

The figure below shows the function with the following calling and return parameters:



INPUTS	TYPE	DESCRIPTION
ID	Integer	File ID (file handle)
OUTPUTS	**TYPE**	**DESCRIPTION**
q	Integer	Message variable read from file

The **ID** argument specifies the file handle that was returned in the call to F_ROPEN. A valid ID value for a currently open file is non-zero.

The **Q** return parameter returns the string read from the file.

4.9.4.8 FM_WRITE Function

The FM_WRITE function writes a message variable to a binary file as a null terminated string. It is to be used with the F_WOPEN and F_CLOSE functions. This function makes a sequential access to the file from the previous position. The first call after F_WOPEN writes the first string to the file. Each call pushes the “write” pointer.

The figure below shows the function with the following calling and return parameters:

INPUTS	TYPE	DESCRIPTION
ID	Integer	File ID (file handle)
IN	Message	Message variable to be written to file
OUTPUTS	**TYPE**	**DESCRIPTION**
q	Integer	Status of file write request

The **ID** argument specifies the file handle that was returned in the call to F_WOPEN. A valid ID value for a currently open file is non-zero. The **IN** argument represents the actual string that will be written to the specified file.

The **OK** return parameter returns the status of the file write request. TRUE is returned if the file write was successful, otherwise FALSE is returned.

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ISaGRAF IO Connection Reference

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Document Revisions

Revision	Date	Modification	Author
1.00	19 October 2005	Initial release of SCADAPack E Series ISaGRAF I/O Connection Technical Reference	KN

1 Preface

1.1 Scope

This manual describes in details each I/O board and equipments provided with the SCADAPack E Series ISaGRAF installation. The SCADAPack E Series RTU[1] provides onboard I/O channels and cam be used to interface with other third party RTU's such as the Allen Bradley and Idec PLC's. As such, the I/O boards provided with the E Series ISaGRAF installation allow an ISaGRAF application access to onboard or remote (third party) I/O data. Sufficient information is provided for all I/O boards installed with the SCADAPack E Series ISaGRAF installation. However, a detailed implementation of the I/O board drivers for the Allen Bradley, Idec and other third party Modbus devices is available in the *E Series DF1 Interface*, *E Series Idec* and *E Series Modbus PLC Interface* manuals.

1.2 Purpose

The purpose of this document is to describe the custom I/O board and equipments provided with the E Series ISaGRAF installation.

1.3 Assumed Knowledge

Familiarity with the ISaGRAF Workbench is strongly recommended.

1.4 Target Audience

- Systems Engineers
- Commissioning Engineers
- Maintenance Technicians

1.5 References

- E Series Configuration Reference Manual
- CJ International ISaGRAF Manuals
- E Series Modbus PLC Interface
- E Series Idec PLC Interface
- E Series DF1 Interface
- E Series ISaGRAF ADS Flow Manual
- E Series ISaGRAF Reference Manual

[1] Referred to simply as RTU hereafter

2 Overview

This manual describes in details each I/O board and equipments provided with the SCADAPack E Series ISaGRAF installation. This manual is intended to be used alongside with the E Series ISaGRAF Technical Reference. Sufficient information is provided for the I/O interfaces to Idec, Allen-Bradley and Schneider Automation TSX Momentum PLC's from the SCADAPack E Series RTU. For additional information on how to configure these units however, the user will have to consult with their respective manuals.

The ISaGRAF I/O connection library provides three major types of I/O connection to the SCADAPack E Series RTU data.

- I/O boards with the ***rtu*** prefix, presented in section ***4.1 - Standard ISaGRAF I/O Boards*** - are used to access to E Series RTU DNP3 data such as physical I/O or derived points.
- I/O board with the ***mbus*** or ***mtcp*** prefix presented in sections ***4.2 - Serial Modbus Master I/O Boards*** and ***4.3 - Modbus TCP Client I/O Boards*** are used to access to Modbus data on a peripheral PLC devices connected to the E Series RTU via a serial or TCP connection. This section of the manual may be used in conjunction with the *E Series Modbus PLC Interface* manual.
- I/O boards with the ***idec*** prefix presented in section ***4.4 - Idec PLC I/O Boards*** are used to access to data on the Idec type PLC. This section of the manual may be used in conjunction with the *E Series Idec PLC Interface* manual. Idec PLC's supported include:
  - FA-1 and FA-1J series (Theses PLC's don't support expansion areas and data registers)
  - FA-2 and FA2J series
- I/O boards with the ***df1*** prefix presented in section ***4.5 - Allen Bradley PLC I/O Boards*** are used to access to data on the Allen- Bradley family of PLC's. This section of the manual can be used in conjunction with the *E Series DF1PLC Interface* manual. AB PLC's supported include:
  - SLC 500 Series
  - PLC 5 Series
  - DF1 Generic PLC's

The listed I/O complex equipments, presented in chapter ***5-I/O Complex Equipment*** are used to access data on Schneider Automation TSX Momentum brand of PLC's.

3 ISaGRAF Variable / RTU DNP3 Point Interaction

ISaGRAF variables attached to the I/O boards that are presented throughout this manual read data from or write data to the SCADAPack E Series RTU database points. ISaGRAF *Input* boards read data from the RTU database into ISaGRAF input variables. ISaGRAF *output* boards write data to the RTU database from ISaGRAF output variables.

Each ISaGRAF I/O board is associated with a *board_ address* corresponding to the DNP3 number of the first point on the board or the Modbus register of the first point of the board. The following configuration concepts and rules apply:

- Variables attached to RTU DNP3 point I/O boards correspond to consecutively numbered DNP3 data points or Modbus registers. The ISaGRAF I/O board address may be any valid RTU DNP3 data point index corresponding to physical, derived or RTU system data of a compatible type. If reading data from a peripheral Modbus type PLC, The ISaGRAF I/O board address may be any valid Modbus register corresponding to physical I/O.
- ISaGRAF Boolean I/O boards (references 0001 & 0002) correspond to consecutive DNP binary data objects starting at the board address of the I/O board. ISaGRAF Boolean Output boards cannot reference "read-only" RTU data points (e.g. physical digital inputs). Boolean I/O Boards support multiple channels.
- ISaGRAF Analog I/O boards (references 0003 & 0004) support multiple channels; each corresponds to an RTU DNP3 analog data object. The RTU DNP object index of the first channel is specified by the board address. Subsequent channels correspond to consecutive RTU DNP3 point indexes. ISaGRAF Analog Output boards cannot reference "read-only" data registers (e.g. physical analog inputs).
- ISaGRAF digital and analog output status Input boards (references 000B & 000C) support multiple channels; each corresponds to the status of a DNP3 physical output point.
- ISaGRAF Counter Input boards (reference 000D) map to RTU counter input points or system counter points. RTU counters are managed internally by 32-bit unsigned data types and are presented in 32-bit format to ISaGRAF analog integers. To reset or preset counters use the Operate command (see below).

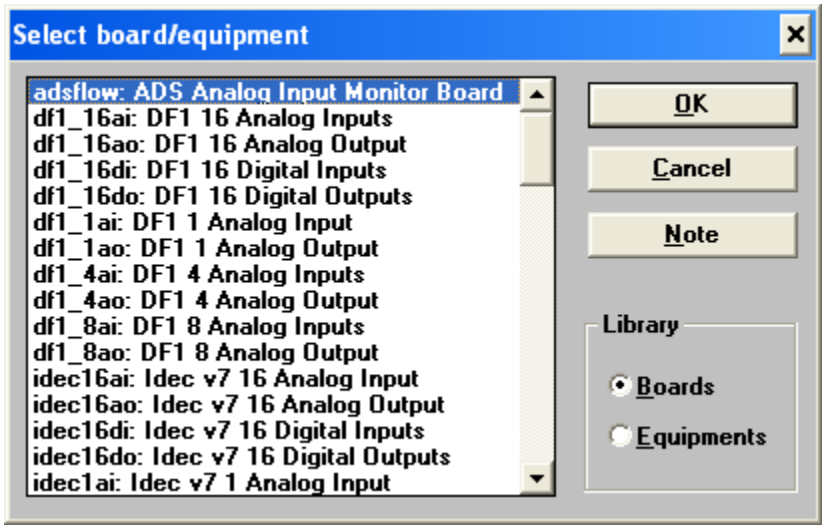
Note: An ISaGRAF application will NOT start if none of the RTU DNP3 points referenced on the specific I/O board exist in the RTU's database. In order for a given board to be successfully opened, at least one of the RTU DNP3 points referenced must exist.

For this reason, the E Series RTU configuration must be loaded with defined DNP points prior to execution of the user ISaGRAF application(s).

Note: For advanced ISaGRAF users: other I/O Boards, I/O Configurations or Complex Equipment types based on these reference numbers shown are possible. Number is shown in HEX format. The SCADAPack E Series RTU has no limit on the number of I/O channels per board for types 0001,0002, 0003, 0004, 000B & 000C.

4 I/O Boards

All physical inputs and outputs on the E Series RTU can be accessed by the ISaGRAF application via the ISaGRAF I/O Board mechanism. E Series RTU internal data points may also be accessed via I/O boards (or via other C Function Blocks). Each I/O board must be supplied with an address that specifies the RTU DNP3 starting point index or offset when reading from inputs or writing to outputs. This address is entered into the *board_address* field of the particular I/O board within the ISaGRAF Workbench I/O Connections editor. I/O boards are accessible within a project by clicking on **Project** | **I/O connection** from the programs window menu bar.



4.1 Standard ISaGRAF I/O Boards

This section presents the Standard ISaGRAF I/O board used to access DNP data points configured in the SCADAPack E Series RTU. Both physical I/O points and derived points may be accessed from an I/O board. ISaGRAF I/O boards need not necessarily correspond to the RTU I/O card arrangements. These I/O board are listed in the I/O connection library with the ***rtu*** prefix.

4.1.1 ISaGRAF Analog I/O Boards / DNP3 Representation & Conversion

Analog Input and Output Boards can have Integer or Real (floating point) ISaGRAF variables attached. Both integer and real ISaGRAF analog variables are represented in 32-bit format. The RTU data interface to these boards is accomplished via point properties in the RTU point database. In addition to direct variable data mapping, ISaGRAF conversion tables may be attached to any ISaGRAF analog Input/Output variable. Conversion table functions are applied after the following conversion rules are applied:

- An ISaGRAF integer variable attached to an Analog Input board receives a 32-bit signed value from the point's Current Integer Value property. The type of DNP3 object selected for this point does not affect the value presented to ISaGRAF (i.e. An analog point's value may have a conversion applied to a 16-bit DNP3 analog object, but the conversion is not applied to the value reported to ISaGRAF).
- An ISaGRAF real analog (floating point) variable attached to an Analog Input board receives a 32-bit floating point value from the point's Current Engineering Value property. The type of DNP3 object selected for this point does not affect the value presented to ISaGRAF

- An ISaGRAF integer variable attached to an Analog Output board sends a 32-bit signed value to the point's Current Integer Value property. Note that a conversion between integer and engineering value is also carried out according to an integer to engineering conversion formula. The type of DNP3 object selected for this point does not affect the value presented from ISaGRAF
- An ISaGRAF real analog (floating point) variable attached to an Analog Output board sends a 32-bit signed value to the point's Current Engineering Value property. Note that a conversion between engineering and integer value is also carried out according to engineering to integer conversion formula. The type of DNP3 object selected for this point does not affect the value presented from ISaGRAF.
- An ISaGRAF integer variable attached to a Counter Input board receives a 32-bit signed integer value representing the 32-bit unsigned count value of an RTU counter point. As ISaGRAF does not handle unsigned integers, the user's ISaGRAF application must deal with the case of a negative Count value.
- An ISaGRAF real analog (floating point) variable attached to a Counter Input board receives an unsigned numeric value representing the 32-bit unsigned count value of an RTU counter point. The conversion applied may result in a loss of accuracy of the count value as the ISaGRAF single precision (32-bit) floating point value will only provide 6 significant digit resolution.

Due to the arrangement of RTU data mapping for physical I/O, ISaGRAF input variables attached to physical I/O points on Digital Input and Analog Input I/O boards (e.g. rtuNNdi, rtuNNai where NN represents an integer) read the state or value of the physical Input points. ISaGRAF output variables attached to physical I/O points on Digital Output and Analog Output I/O boards (e.g. rtuNNdo, rtuNNao) control or write to the physical output points. To read the status of physical output points, attach ISaGRAF Input variables to Digital Output Status and Analog Output Status I/O boards (e.g. rtuNNdos, rtuNNaos).

4.1.2 Digital Input Boards

RTU digital points may be imported into ISaGRAF through Digital Input (di) boards (ISaGRAF *Boolean Input Board* types). Where an ISaGRAF application attaches a Boolean variable to a Digital Input Board, the *Current State* property of the digital point will be read into the ISaGRAF variable. If the digital point is a Physical Binary DNP3 I/O address, the physical digital input channel corresponding to that address is read.

4.1.2.1 rtu16di

RTU 16 channel digital input board

The **rtu16di** I/O board provides sixteen digital input channels which can be connected to Boolean variables within an ISaGRAF application. RTU DNP3 objects supported include Physical Inputs, Derived & System Binary Objects. Connected ISaGRAF variables are updated continuously with the *Current State* property of the digital point from the RTU point database.

Board Reference (hex)	0001
Library type	IO board
Data type	Digital (Boolean)
Channel type	Input
Number of channels	16

4.1.2.2 rtu32di

RTU 32 channel digital input board

The **rtu32di** I/O board provides thirty two digital input channels which can be connected to Boolean variables within an ISaGRAF application. RTU DNP3 objects supported include Physical Inputs, Derived & System Binary Objects. Connected ISaGRAF variables are updated continuously with the *Current State* property of the digital point from the RTU point database.

Board Reference (hex)	0001
Library type	IO board
Data type	Digital (Boolean)
Channel type	Input
Number of channels	32

4.1.3 Digital Output Boards

Physical RTU digital outputs have two sets of ISaGRAF interfaces. The state of a digital output is controlled through the Digital Output (do) boards (ISaGRAF *Boolean Output Board* types). The feedback status of a digital output is read through Digital Output Status (dos) boards (ISaGRAF *Digital Input Board* types).

Derived RTU Digital points are controlled through Digital Output (do) boards (ISaGRAF *Boolean Output Board* types). The feedback status of derived digital points is read into Digital Input (di) boards (ISaGRAF *Boolean Input Board* types).

Where an ISaGRAF application attaches a Boolean variable to a Digital Output Board, the *Current State* property of the digital point will be controlled from the ISaGRAF variable.

4.1.3.1 rtu4do

RTU 4 channel digital output board

The **rtu4do I/O** board provides four digital output channels which can be connected to Boolean variables within an ISaGRAF application. E Series RTU DNP3 objects supported include Physical outputs, Derived & System Binary Objects. The *Current State* property of the digital output points are updated continuously with data from the ISaGRAF variables.

Board Reference (hex)	0002
Library type	IO board
Data type	Digital (Boolean)
Channel type	Output
Number of channels	4

4.1.3.2 rtu8do

RTU 4 channel digital output board

The **rtu8do** I/O board provides eight digital output channels which can be connected to Boolean variables within an ISaGRAF application. RTU DNP3 objects supported include Physical outputs, Derived & System Binary Objects. The *Current State* property of the digital output points are updated continuously with data from the ISaGRAF variables.

Board Reference (hex)	0002
Library type	IO board
Data type	Digital (Boolean)
Channel type	Output
Number of channels	8

4.1.3.3 rtu16do

RTU 4 channel digital output board

The **rtu16do** I/O board provides sixteen digital output channels which can be connected to Boolean variables within an ISaGRAF application. RTU DNP3 objects supported include Physical outputs, Derived & System Binary Objects. The *Current State* property of the digital output points are updated continuously with data from the ISaGRAF variables.

Board Reference (hex)	0002
Library type	IO board
Data type	Digital (Boolean)
Channel type	Input
Number of channels	16

4.1.3.4 rtu8dos

RTU 8 channel digital output feedback board

The **rtu8dos** I/O board provides eight digital input channels which can be connected to Boolean variables within an ISaGRAF application. RTU DNP3 objects supported include Physical outputs, Derived & System Binary Objects. Connected ISaGRAF variables are updated continuously with the *Current State* property of the digital output point fed back from the SCADAPack E Series RTU.

There is a one to one mapping between the channels on the digital output board and the digital output feedback board. In order words, channel 1 on the digital output feedback board will return the fed back *Current State* property of channel 1 on the digital output board; The *Current State* property of channel 7 on the digital output board will be feedback on channel 7 of the digital output feedback board. As a result, the digital output feedback boards pass input data based on the status of the digital output back into an ISaGRAF application. This feature can be used to track a discrepancy between an ISaGRAF application output and the current state of the actual digital output being controlled by the variable.

Board Reference (hex)	000B
Library type	IO board
Data type	Digital (Boolean)
Channel type	Input
Number of channels	8

4.1.3.5 rtu16dos

RTU 16 channel digital output feedback board

The **rtu16dos** I/O board provides sixteen digital input channels which can be connected to Boolean variables within an ISaGRAF application. RTU DNP3 objects supported include Physical outputs, Derived & System Binary Objects. Connected ISaGRAF variables are updated continuously with the *Current State* property of the digital output point fed back from the RTU.

Board Reference (hex)	000B
Library type	IO board
Data type	Digital (Boolean)
Channel type	Input
Number of channels	16

4.1.4 Analog Input Boards

RTU Analog points may be imported into ISaGRAF through Analog Input (ai) boards (ISaGRAF *Analog Input Board* types). Where an ISaGRAF application attaches an "Integer" analog variable to an Analog Input Board, the *Current Integer Value* property of the analog point will be read into the ISaGRAF variable. Where an ISaGRAF application attaches a "Real" (floating point) analog variable to an Analog Input Board, the *Current Eng.Value* property of the analog point will be read into the ISaGRAF variable. Where the analog point is a Physical Analog DNP3 I/O address, the Physical Analog Input channel corresponding to that address is read. See the following section regarding reading the value of a Physical Analog Output channels.

Both "Integer" and "Real" ISaGRAF analog variables may be mixed on the same ISaGRAF Analog Input Board.

ISaGRAF analog integer variables contain signed 32-bit numbers. The value of an "Integer" analog variable will be the physical analog input variable in the range MIN-RAW to MAX-RAW as configured in the point's attributes.

ISaGRAF analog real variables contain 32-bit floating point numbers. For a physical analog input variable, variables will be in the range MIN-ENG to MAX-ENG as configured in the point's attributes.

4.1.4.1 rtuxxai

1,6 or 12 channel RTU Analog Input Board

The **rtu*xx*ai** I/O board provides 1, 6 or 12 analog input channels which can be connected to Integer or Real variables within an ISaGRAF application. RTU DNP3 objects supported include Physical inputs, Derived Integer and Floating Point objects. ISaGRAF variables of type Integer are continuously updated with the *Current Integer Value* property whereas variables of type real are updated with the *Current Eng Value* property from the RTU point database.

Board Reference (hex)	0003
Library type	IO board
Data type	Analog (Integer or Real)
Channel type	Input
Number of channels	1, 6 or 12

4.1.5 Analog Output Boards

Physical RTU Analog Outputs have two sets of ISaGRAF interfaces. The value of physical analog outputs is controlled through Analog Output (ao) boards (ISaGRAF *Analog Output Board* types). The feedback status of an analog output is read into ISaGRAF through Analog Output Status (aos) boards (ISaGRAF *Analog Input Board* types).

Derived RTU Analog points are controlled through Analog Output (ao) boards (ISaGRAF *Analog Output Board* types). The feedback status of derived analog points is read into ISaGRAF through Analog Input (ai) boards (ISaGRAF *Analog Input Board* types).

Where an ISaGRAF application attaches an "Integer" analog variable to an Analog Output Board, the *Current Integer Value* property of the analog point will be controlled from the ISaGRAF variable. The analog point's *Current Integer Value* property, MIN-RAW, MAX-RAW, MIN-ENG & MAX-ENG attributes will be used to automatically calculate the *Current Eng.Value* property of the point.

Where an ISaGRAF application attaches a "Real" (floating point) analog variable to an Analog Output Board, the *Current Eng. Value* property of the analog point will be controlled from the ISaGRAF variable. The analog point's *Current Eng. Value* property MIN-RAW, MAX-RAW, MIN-ENG & MAX-ENG attributes will be used to automatically calculate the *Current Integer Value* property of the analog point.

Both "Integer" and "Real" ISaGRAF analog variables may be mixed on the same ISaGRAF Analog Output Board.

4.1.5.1 rtuxxao

2, 4 or 16 Channel RTU Analog Output Board

The **rtu*xx*ao** I/O board provides 2, 4 or 16 analog output channels which can be connected to Integer or Real variables within an ISaGRAF application. RTU DNP3 objects supported include Physical outputs, Derived Integer and Floating Point objects. The *Current Integer Value* property of the point is continuously updated by the attached ISaGRAF Integer variable. Whereas, the *Current Eng. Value* property of the point is continuously updated by the attached ISaGRAF Real variable.

Both "Integer" and "Real" ISaGRAF analog variables may be mixed on the same ISaGRAF Analog Output Board.

Board Reference (hex)	0004
Library type	IO board
Data type	Analog (Integer or Real)
Channel type	Output
Number of channels	2, 4 or 16

4.1.5.2 rtu2aos

RTU 2 channel analog output feedback status board

The **rtu2aos** I/O board provides two analog input channels which can be connected to Integer or Real variables within an ISaGRAF application. RTU DNP3 objects supported include Physical outputs, Derived Integer and Floating Point objects. The feedback *Current Eng Value* or *Current Integer Value* property status of analog outputs are read into ISaGRAF through Analog Output Status (aos) boards (ISaGRAF *Analog Input Board* types).

There is a one to one mapping between the channels on the analog output board and the analog output feedback board. In order words, channel 1 on the analog output feedback board will return the fed back *Current Integer* or *Eng Value* property of channel 1 on the analog output board. As a result, the analog output feedback board passes input data, based on the feedback status of the analog output, back into an ISaGRAF application. This feature can be used to track a discrepancy between an ISaGRAF application output and the current state of the actual digital output being controlled by the variable.

Board Reference (hex)	000C
Library type	IO board
Data type	Analog (Integer or Real)
Channel type	Input
Number of channels	2

4.1.5.3 rtu4aos

RTU 4 channel analog output feedback status board

The **rtu4aos** I/O board provides four analog input channels which can be connected to Integer or Real variables within an ISaGRAF application. RTU DNP3 objects supported include Physical outputs, Derived Integer and Floating Point objects. The feedback *Current Eng Value* or *Current Integer Value* property status of analog outputs are read into ISaGRAF through Analog Output Status (aos) boards (ISaGRAF *Analog Input Board* types).

There is a one to one mapping between the channels on the analog output board and the analog output feedback board. In order words, channel 1 on the analog output feedback board will return the fed back *Current Integer* or *Eng Value* property of channel 1 on the analog output board. As a result, the analog output feedback board passes input data, based on the feedback status of the analog output, back into an ISaGRAF application. This feature can be used to track a discrepancy between an ISaGRAF application output and the current state of the actual digital output being controlled by the variable.

Board Reference (hex)	000C
Library type	IO board
Data type	Analog (Integer or Real)
Channel type	Input
Number of channels	4

4.1.6 Counter Input Boards

ISaGRAF application *Counter Input Boards* (ctr) support only ISaGRAF "Integer" analog variables. The *Current Integer Value* property of the physical counter input will be read into the ISaGRAF variable.

ISaGRAF analog integer variables contain signed 32-bit numbers, however Counter Inputs are 32-bit unsigned values. For counter values less than 2147483648, the counter value and ISaGRAF variable value are the same. For counter values above 2147483647, the ISaGRAF variable indicates a negative value. The user ISaGRAF application must handle the case where counter input numbers greater than 2147483647 are indicated as negative ISaGRAF numbers. This may be necessary, for example, where a comparison or subtraction of counter values occurs in the user ISaGRAF application. (e.g. Preset counter or reset counter prior to value exceeding 2147483647).

4.1.6.1 rtu16ctr

RTU 32 channel counter input board

The **rtu16ctr** I/O board provides sixteen counter input channels which can only be connected to Integer variables within an ISaGRAF application. RTU DNP3 objects supported include Counter Inputs objects. ISaGRAF variables of type Integer are continuously updated with the *Current Integer Value* property from the RTU point database.

Board Reference (hex)	0005
Library type	IO board
Data type	Counter (Integer)
Channel type	Input
Number of channels	16

4.1.6.2 rtu32ctr

RTU 32 channel counter input board

The **rtu32ctr** I/O board provides thirty two counter input channels which can only be connected to Integer variables within an ISaGRAF application. RTU DNP3 objects supported include Counter Inputs objects. ISaGRAF variables of type Integer are continuously updated with the *Current Integer Value* property from the RTU point database.

Board Reference (hex)	0005
Library type	IO board
Data type	Counter (Integer)
Channel type	Input
Number of channels	32

4.1.7 String Output Boards

4.1.7.1 rtu1sto

RTU 1 channel string output board

The **rtu1str** I/O board provides 1 string output channel which can be connected to a 'Message' variable within an ISaGRAF application.

Board Reference (hex)	0013
Library type	IO board
Data type	Message (string)
Channel type	Input
Number of channels	1

4.1.8 SCADAPack ER I/O Boards

These I/O boards are only supported on the SCADAPack ER RTUs. Applications on the SCADAPack ES that reference these I/O boards will not start.

These SCADAPack ER I/O boards reference physical channels directly, as opposed to referencing a specific I/O channel by DNP point number. The supported SCADAPack ER I/O boards are listed in the following table

Board Name	Board Reference (hex)	ISaGRAF Data Type
ER16RO	0x18	16 Boolean Outputs
ER16AI	0x19	16 Analog Inputs *
ER32D	0x1A	32 Boolean Inputs

* See Analog conversion rules in Section ***4.1.1 - ISaGRAF Analog I/O Boards / DNP3 Representation & Conversion***

The SCADAPack ER I/O boards reference the respective physical I/O cards by specifying a *Rack_Num* and *Slot_Num* field. The *Rack_Num* and *Slot_Num* fields are set via user configuration through the I/O board parameters. These are set as part of the ISaGRAF application and are entered into the I/O board parameter fields within the ISaGRAF Workbench I/O Connections editor.

The required fields are described as follows

Rack_Num: specifies the ER rack that the I/O Card is located on.

0 = Local Rack

1 = Expansion Rack, etc.

The default value is 0 (i.e. local rack).

Slot_Num: specifies the I/O card slot on the specified ER rack

1 = I/O Card Slot 1

2 = I/O Card Slot 2, etc..

The default value is 1 (i.e. I/O Card Slot 1).

Note: A valid I/O card configuration must be loaded into the SCADAPack ER RTU prior to loading an ISaGRAF application that references a SCADAPack ER I/O board, otherwise the I/O board can not be opened. This is done using the E Series Configurator tool by assigning an I/O card to a rack on and writing the Configurator file changes onto the RTU. A cold restart is required after these configuration details have been written to the RTU. See the E Series Configurator User manual for details.

4.1.8.1 er16ro

Open Modbus TCP/PLC 16 channel analog input board

The **er16ro** output board references a physical relay output card by specifying a *Rack_Num* and *Slot_Num* field (see Section ***4.1.8- SCADAPack ER I/O Boards*** for detailed descriptions of these fields). The channel number in the ISaGRAF I/O Connection window corresponds to the physical channel number on the SCADAPack ER I/O card.

Where an ISaGRAF application attaches a Boolean variable to an **er16ro** output board, the state of the corresponding digital relay will be controlled from the ISaGRAF variable. Note that if there is a physical digital output configuration point associated with this physical channel, the *Current State* of this configuration point will be updated after the successful control of the relay output.

Note that controls issued to SCADAPack ER relay output cards resulting from **attached** variables changing state, are issued as complete I/O card controls. This ensures that any simultaneous state changes at the ISaGRAF output board level, are executed simultaneously at the SCADAPack ER relay output card.

The **er16ro** output board may be successfully opened if there is valid I/O card configuration loaded into the SCADAPack ER controller. Note that unlike the standard output boards, it is NOT necessary that there are physical digital output configurations points associated with the physical channels referenced by the **er16ro** output board.

Board Reference (hex)	0x18
Library type	IO board
Data type	Digital (Boolean)
Channel type	Output
Number of channels	16

Note: A valid I/O card configuration must be loaded into the SCADAPack ER RTU prior to loading an ISaGRAF application that references a SCADAPack ER I/O board, otherwise the I/O board can not be opened. This is done using the E Series Configurator tool by assigning an I/O card to a rack on and writing the Configurator file changes onto the RTU. A cold restart is required after these configuration details have been written to the RTU. See the E Series Configurator User manual for details.

4.1.8.2 er16ai

SCADAPack ER 16 channel analog input board

The **er16ai** input board references a physical analog input card by specifying a *Rack_Num* and *Slot_Num* field (see Section ***4.1.8 - SCADAPack ER I/O Boards*** for detailed descriptions of these fields). The channel number in the ISaGRAF I/O Connection window corresponds to the physical channel number on the SCADAPack ER I/O card.

Unlike the **er16ro** output board, there must be point database configuration points associated with the physical channels referenced by the **er16ai** input board *Rack_Num* and *Slot_Num* fields for proper operation.

Where an ISaGRAF application attaches an "Integer" analog variable to an **er16ai** input board, the *Current Integer Value* property of the associated analog point will be read into the ISaGRAF variable. Where an ISaGRAF application attaches a "Real" (floating point) analog variable to an **er16ai** input Board, the *Current Eng Value* property of the associated analog point will be read into the ISaGRAF variable. Both "Integer" and "Real" ISaGRAF analog variables may be mixed on the same ISaGRAF **er16ai** input Board.

The **er16ai** input board may be successfully opened if there is a valid I/O card configuration loaded into the SCADAPack ER controller, and there is at least 1 physical analog input configuration point associated with the given I/O card.

Board Reference (hex)	0x19
Library type	IO board
Data type	Analog (Integer or Real)
Channel type	Input
Number of channels	16

Note: A valid I/O card configuration must be loaded into the SCADAPack ER RTU prior to loading an ISaGRAF application that references a SCADAPack ER I/O board, otherwise the I/O board can not be opened. This is done using the E Series Configurator tool by assigning an I/O card to a rack on and writing the Configurator file changes onto the RTU. A cold restart is required after these configuration details have been written to the RTU. See the E Series Configurator User manual for details.

4.1.8.3 er32di

SCADAPack ER 32 channel digital input board

The **er32di** input board references a physical binary input card by specifying a *Rack_Num* and *Slot_Num* field (see Section ***4.1.8 - SCADAPack ER I/O Boards*** for detailed descriptions of these fields). The channel number in the ISaGRAF I/O Connection window corresponds to the physical channel number on the SCADAPack ER I/O card.

Unlike the **er16ro** output board, there must be point database configuration points associated with the physical channels referenced by the **er32di** input board *Rack_Num* and *Slot_Num* fields for proper operation.

Where an ISaGRAF application attaches a Boolean variable to an **er32di** input board, the *Current State Property* of the digital point will be read into the ISaGRAF variable. The **er32di** input board may be successfully opened if there is a valid I/O card configuration loaded into the SCADAPack ER controller, and there is at least 1 physical binary input configuration point associated with the given I/O card.

Board Reference (hex)	0x1A
Library type	IO board
Data type	Digital (Boolean)
Channel type	Input
Number of channels	32

Note: A valid I/O card configuration must be loaded into the SCADAPack ER RTU prior to loading an ISaGRAF application that references a SCADAPack ER I/O board, otherwise the I/O board can not be opened. This is done using the E Series Configurator tool by assigning an I/O card to a rack on and writing the Configurator file changes onto the RTU. A cold restart is required after these configuration details have been written to the RTU. See the E Series Configurator User manual for details.

4.2 Serial Modbus Master I/O Boards

4.2.1 Overview

PLC and peripheral devices may communicate with the Control Microsystems SCADAPack E Series RTU using ISaGRAF **Slave** I/O boards. PLC or peripheral device elements are read and the return values cached in the RTU for access through an ISaGRAF input board. Similarly, ISaGRAF output board data can be transferred to the PLC or peripheral device. The RTU's interface with ISaGRAF is described in detail in the *E Series ISaGRAF Technical Reference Manual*. The status of the data read from the PLC or peripheral device is present in RTU system points that can be accessed using ISaGRAF variables or external to the RTU.

When using ISaGRAF Modbus PLC I/O boards for communication with a Modbus peripheral device, or devices, the SCADAPack E Series RTU is a **Modbus Master**. The peripheral device(s) must be Modbus Slave(s).

When using ISaGRAF Modbus/TCP I/O boards for communication with Modbus/TCP peripheral devices, the SCADAPack E Series RTU is an **Open Modbus/TCP Client**. The peripheral device(s) must be Open Modbus/TCP **Server**(s) (e.g. Ethernet PLC). Open Modbus/TCP protocol is also known as MBAP protocol, but is referred to as Open Modbus/TCP protocol throughout this manual.

4.2.2 I/O Board Types

Where a SCADAPack E Series RTU has one or more of its serial ports configured as '*PLC Device*' and ***mbus..*** or ***mod..*** ISaGRAF I/O boards are used, the RTU communicates using serial "MODBUS RTU" protocol. Note that the RTU does not support "MODBUS ASCII" protocol. Settings of the RTU communication port such as baud rates and parity format, configured using the E Series Configurator, are used by the RTU's Modbus PLC device driver. RS232, RS422 and RS485 communications are supported.

Note that ***mbus..*** ISaGRAF I/O boards generally supersede ***mod..*** I/O boards. Whilst the SCADAPack E Series RTU maintains compatibility with the older ***mod..*** I/O boards, it is recommended that ***mbus..*** I/O boards are used instead. An exception to this may be where a ***mod..*** I/O board uses a Modbus function code not available on ***mbus..*** I/O board.

mod.. ISaGRAF I/O boards can not be used when multiple communication ports are configured for PLC peripheral device communications due to the requirement to specify which of these ports connects to the device. Use only ***mbus..*** and/or ***mtcp..*** I/O boards in this situation.

For SCADAPack E Series RTU's when the *Modbus/TCP(client)* IP service is enabled, and when using ***mtcp..*** ISaGRAF I/O boards, the RTU communicates using Open Modbus/TCP communication protocol. The protocol connects TCP socket(s) between the RTU (Client) and the peripheral device(s) (Servers). TCP/IP over Ethernet and PPP communications from the SCADAPack E Series RTU are supported.

The SCADAPack E Series RTU supports simultaneous communication using serial Modbus and Open Modbus/TCP protocols. I.e. ***mbus..*** I/O boards can communicate with Modbus peripherals on one or more RTU serial ports, and at the same time, ***mtcp..*** I/O boards can communicate with Modbus/TCP peripherals on the RTU TCP/IP interface (e.g. Ethernet).

As an extension of the data interface provided by the SCADAPack E Series RTU, access by ISaGRAF applications to external PLC or peripheral device data is supported. Standard ISaGRAF I/O boards can continue to access I/O and DNP data exchange areas as usual, with an additional set of ISaGRAF boards provided for the RTU that allow data to be extracted from external PLC device(s). External peripheral data is cached internally by the E Series RTU to maximize ISaGRAF

application performance. Access to this cached device data is restricted to ISaGRAF and is termed Slave PLC data. Direct access to slave PLC data through DNP3 or other mechanisms is not provided by this family of RTUs.

The Slave PLC device that can be accessed via the ISaGRAF Slave PLC I/O boards depends on the PLC or peripheral device drivers installed in the SCADAPack E Series Operating System firmware. An LED on the RTU may indicate communication activity with external peripheral device(s). For more information see relevant E Series Hardware User Manual.

Note: When connecting ISaGRAF Workbench Debugger to a SCADAPack E Series RTU using Slave PLC I/O boards, the Debugger may indicate "DISCONNECTED" for a period of time, particularly if there a large number of Slave PLC I/O boards, or if a slave PLC is not responding.

Different Slave PLC I/O boards are provided for different types of PLC data. For example: analog input boards are provided to read PLC value registers, Boolean output boards for writing to PLC coils and analog input boards to read PLC accumulated data. The different types of I/O boards available and ranges of PLC data that can be accessed depend on the individual PLC driver. The following section details a summary of the RTU's MODBUS PLC driver. For detailed information on Modbus and other drivers, see the relevant *E Series PLC* Device *Interface* Manuals.

ISaGRAF Slave PLC I/O boards access data in the following way:

- a Slave PLC input board corresponds to a *read-write* access to PLC data
- a Slave PLC output board corresponds to a *write-only* access to PLC data
- an ISaGRAF OPERATE function call may be performed on an input variable and written to a PLC.
- Serial communication with external devices, such as PLC's, is made through the RTU port(s) configured as "PLC Device".

Up to a total of 100 Slave PLC I/O boards can be defined in total for all "PLC Device" communication ports and ISaGRAF kernels. Multiple SCADAPack E Series "PLC Device" serial ports, as well as TCP/IP channels, can be used for Slave PLC peripheral communication.

4.2.3 Input Boards

ISaGRAF Slave PLC input boards typically require user configuration through the I/O board parameters. These are set as part of the ISaGRAF application and are entered into the I/O board parameter fields within the ISaGRAF Workbench I/O Connections editor.

The ISaGRAF "OPERATE" function may be used on Slave PLC Input Boards where the PLC register read by the input board is also writeable. This permits PLC registers to be inputs into ISaGRAF, but have them "Presetable" in the PLC by ISaGRAF.

Typical fields are:

board_address: specifies the Slave PLC data registers to access when reading PLC data into ISaGRAF variables. The PLC data type accessed is specific to the Slave PLC I/O board and board address. This value is usually the PLC's data (or register) address.

plc_data_type: specifies the PLC data register type. Currently *IEC UINT* type is supported for analog boards and *IEC DISCRETE* type is supported for Boolean boards. Other data types may be supported in the future. See specific PLC driver interface manuals for more information.

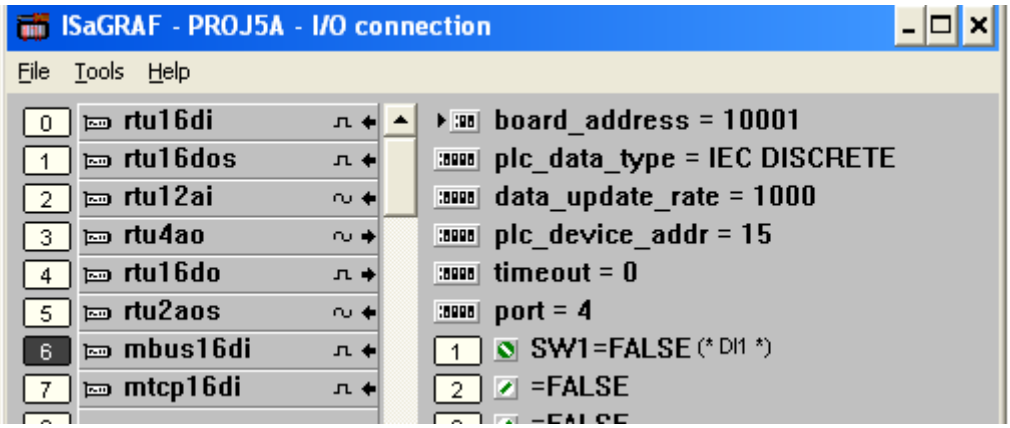
data_update_rate: The units for this parameter vary depending on the type of PLC device. For example this may be a setting in milliseconds for a directly connected device, or in minutes for a low power type device (see the *E Series Modbus PLC Interface* manual). As the SCADAPack E Series RTU must extract the data for the I/O board from the PLC or peripheral device, this sets the rate at which the data is extracted. Individual I/O boards may have different data update rates allowing prioritization of data extracted from a slave PLC. Note that the RTU may not be able to read all requested PLC data within the time set by the data update rate depending on the quantity of data to be read, rate of write requests and PLC communication speed. In this case the update rates will be slower. For ***mtcp*** board types, the time specified in this field is in mS.

plc_device_addr: This parameter specified the PLC device address. Some PLC device drivers support multi-drop PLC devices on the same communication channel, or have unique addressing identifiers. Where the RTU driver provides multi-drop support, ISaGRAF may access data from any of the locally multi-dropped devices. A separate I/O board will be required for each device.

timeout: PLC device drivers with comprehensive I/O board interfaces may provide a parameter for specifying the communications timeout on an individual I/O board (i.e. the timeout applies to communications associated with that board). Where this value is "0", the PLC device driver will use a default timeout of 1200mS. The units for this field are dependent upon the PLC device driver. Units may be, for example, milliseconds, seconds, minutes, etc. For ***mtcp*** board types, the unit of this field is in mS.

The next two fields depend on the I/O board type selected given that the SCADAPack E Series RTU can communicate with Modbus PLC peripheral devices via the serial 'MODBUS RTU' or Open Modbus/TCP protocols. For serial Modbus connections to the peripheral PLC device, the I/O board types with prefix ***mbus*** should be used. For Open Modbus/TCP connections to the peripheral device, the I/O board types with prefix ***mtcp*** should be used.

Port: This parameter is only available on the serial Modbus I/O board driver with the ***mbus*** prefix. Where present, it defines which of multiple RTU "PLC Device" ports will be used to communicate with the PLC or peripheral device. ISaGRAF Slave PLC I/O boards that do not include this parameter can only be used when a single "PLC Device" port is configured on the E Series RTU.



4.2.3.1 mbus16di

Serial Modbus PLC 16 digital input board

Description

The **mbus16di** I/O board provides sixteen digital input channels for a SCADAPack E Series RTU to communicate with a Modbus PLC peripheral device via a serial connection. PLC data supported include coil, digital input status and holding registers. Connected ISaGRAF variables are updated continuously with the *Current State* of the digital point. This information is cache internally by the E Series RTU and made available to the ISaGRAF application.

I/O Connection

Board Reference (hex)	000E
Library type	IO board
Data type	Digital (Boolean)
Channel type	Input
Number of channels	16

Board Configuration

board_address	Enter address	To…
	1-9999	**Read Coils –Modbus Function Code 1**
	10001-19999	**Read Input Status – Modbus Function Code 2**
	40001-65535	**Read Holding Register – Modbus Function Code 3**
plc_data_type	IEC DISCRETE, 984 DISCRETE	
data_update_rate	Unit in mS	
plc_device_addr	Modbus slave address (1-254)	
Timeout	Unit in mS	
Port	0-3 = Port 0-3 on ES RTU, 4 = Diag Port	

4.2.3.2 mbus32di

Serial Modbus PLC 32 digital input board

Description

The **mbus32di** I/O board provides thirty two digital input channels for a SCADAPack E Series RTU to communicate with a Modbus PLC peripheral I/O device via a serial connection. The digital channels can be connected to Boolean variables within an ISaGRAF application. PLC data supported include coil, digital input status and holding registers.. Connected ISaGRAF variables are updated continuously with the *Current State* of the digital point. This information is cache internally by the E Series RTU and made available to the ISaGRAF application.

I/O Connection

Board Reference (hex)	000E
Library type	IO board
Data type	Digital (Boolean)
Channel type	Input
Number of channels	32

Board Configuration

board_address	Enter address	To…
	1-9999	**Read Coils –Modbus Function Code 1**
	10001-19999	**Read Input Status – Modbus Function Code 2**
	40001-65535	**Read Holding Register – Modbus Function Code 3**
plc_data_type	IEC DISCRETE, 984 DISCRETE	
data_update_rate	Unit in mS	
plc_device_addr	Modbus slave address (1-254)	
Timeout	Unit in mS	
Port	0-3 = Port 0-3 on ES RTU, 4 = Diag Port	

4.2.3.3 mbusxxai

1, 4, 8, 16, 32 or 64 Channel Serial Modbus PLC Analog Input Board

Description

The **mbus*xx*ai** I/O board provides 1, 4, 8, 16, 32 or 64 analog input channels for a SCADAPack E Series RTU to communicate with a Modbus PLC peripheral device /O device for serial connection. The analog input channels can be tied to an Integer or Real variable within an ISaGRAF application. PLC data supported include inputs, and holding registers. Connected ISaGRAF variables are updated continuously with the *Current Value* of the I/O point. This information is cache internally by the E Series RTU and made available to the ISaGRAF application.

I/O Connection

Board Reference (hex)	0010
Library type	IO board
Data type	Analog (Integer)
Channel type	Input
Number of channels	1, 4, 8, 16, 32, 64

Board Configuration

board_address	Enter address	To…
	30001- 39999	**Read Input Register – Modbus Function Code 4**
	40001- 65535	**Read Holding Register – Modbus Function Code 3**
plc_data_type	IEC UINT, IEC INT, IEC DINT, IEC REAL	
data_update_rate	Unit in mS	
plc_device_addr	Modbus slave address (1-254)	
Timeout	Unit in mS	
Port	0-3 = Port 0-3 on ES RTU, 4 = Diag Port	

4.2.4 Output Boards

ISaGRAF Slave PLC output boards typically require user configuration through the I/O board parameters. These are set as part of the ISaGRAF application and are entered into the I/O board parameter fields within the ISaGRAF Workbench I/O Connections editor.

Typical fields are:

board_address: specifies the Slave PLC data registers to access when writing from ISaGRAF variables to PLC data. The PLC data type accessed is specific to the Slave PLC I/O board and board address. This value is usually the PLC's data (or register) address.

plc_data_type: specifies the PLC data register type. Currently *IEC UINT* type is supported for analog boards and *IEC DISCRETE* type is supported for Boolean boards. Other data types may be supported in the future. See specific PLC driver interface manuals for more information.

plc_device_addr: Some PLC device drivers support multi-drop PLC devices on the same communication channel, or have unique addressing identifiers. Where the RTU driver provides multi-drop support, ISaGRAF may access data from any of the locally multi-dropped devices. A separate I/O board will be required for each device.

must_write_rate: The unit for this parameter is driver specific, and configures the rate at which the data for the Output board is written to the PLC. Between "*must_write_rate*" periods, data is written to the PLC only when the ISaGRAF output variable values change. Individual I/O boards may have different must write rates allowing prioritization of data sent to a slave PLC.

timeout: PLC device drivers with comprehensive I/O board interfaces may provide a parameter for specifying the communications timeout on an individual I/O board (i.e. the timeout applies to communications associated with that board). Where this value is "0", the PLC device driver will use a default timeout. The units for this field are dependent upon the PLC device driver. Units may be, for example, milliseconds, seconds, minutes, etc.

port: this parameter may be on a PLC slave I/O board for a device driver. Where present, it defines which of multiple RTU "PLC Device" ports will be used to communicate with the PLC or peripheral device. If only one "PLC Device" port is configured, this field is ignored. ISaGRAF Slave PLC I/O boards that do not include this parameter can only be used when a single "PLC Device" port is configured on the E Series RTU.

4.2.4.1 mbus16do

Serial Modbus PLC 16 Digital Output Board

Description

The **mbus16do** I/O board provides sixteen digital output channels for a SCADAPack E Series RTU to communicate with a Modbus PLC peripheral I/O device. The digital output channel can be tied to Boolean variables within an ISaGRAF application. PLC data supported include relays coils and holding registers. The connected I/O points are updated continuously with the *Current State* of the ISaGRAF variables. This information is cache internally by the RTU and made available to the I/O points.

I/O Connection

Board Reference (hex)	000F
Library type	IO board
Data type	Digital (Boolean)
Channel type	Output
Number of channels	16

Board Configuration

board_address	Enter address	To…
	1-9999	**Write Coil – Modbus Function Code 5**
	40001-65535	**Write Holding Register – Modbus Function Code 16**
plc_data_type	IEC DISCRETE, 984 DISCRETE	
data_update_rate	Unit in mS	
plc_device_addr	Modbus slave address (1-254)	
Timeout	Unit in mS	
Port	0-3 = Port 0-3 on ES RTU, 4 = Diag Port	

4.2.4.2 mbus32do

Serial Modbus PLC 32 Digital Output Board

Description

The **mbus32do** I/O board provides thirty two digital output channels for a SCADAPack E Series RTU to communicate with a Modbus PLC I/O device. The digital output channel can be tied to Boolean variables within an ISaGRAF application. PLC data supported include relays coils and holding registers. The connected I/O points are updated continuously with the *Current State* of the ISaGRAF variables. This information is cache internally by the RTU and made available to the I/O points.

I/O Connection

Board Reference (hex)	000F
Library type	IO board
Data type	Digital (Boolean)
Channel type	Output
Number of channels	32

Board Configuration

board_address	Enter address	To…
	1-9999	**Write Coil – Modbus Function Code 5**
	40001-65535	**Write Holding Register – Modbus Function Code 16**
plc_data_type	IEC DISCRETE, 984 DISCRETE	
data_update_rate	Unit in mS	
plc_device_addr	Modbus slave address (1-254)	
Timeout	Unit in mS	
Port	0-3 = Port 0-3 on ES RTU, 4 = Diag Port	

4.2.4.3 mbusxxao

1, 4, 8, 16, 32 or 64 Channel Serial Modbus PLC Analog Output Board

Description

The **mbus*xx*ao** I/O board provides 1, 4, 8, 16, 32 or 64 analog output channels for a SCADAPack E Series RT U to communicate with a Modbus PLC peripheral device via a serial connection. The analog output channels can be tied to Integer or Real variables within an ISaGRAF application. PLC data supported include outputs and holding registers. The connected I/O points are updated continuously with the *Current Value* of the ISaGRAF variables. This information is cache internally by the RTU and made available to the I/O points.

I/O Connection

Board Reference (hex)	0011
Library type	IO board
Data type	Analog (Integer or Real)
Channel type	Output
Number of channels	1, 4, 8, 16, 32, or 64

Board Configuration

board_address	Enter address	To…
	40001-65535	**Write Holding Register – Modbus Function Code 16**
plc_data_type	IEC UINT, IEC INT, IEC DINT, IEC REAL	
data_update_rate	Unit in mS	
plc_device_addr	Modbus slave address (1-254)	
Timeout	Unit in mS	
Port	0-3 = Port 0-3 on ES RTU, 4 = Diag Port	

4.2.4.4 modxxao

Serial Modbus PLC1 or 4 Analog Output Board

Description

The **mod*xx*ao** I/O board provides 1 or 4 analog output channels for a SCADAPack E Series RTU to communicate with a Modbus PLC peripheral device via a serial connection. The analog output channels can be tied to Integer or Real variables within an ISaGRAF application. PLC data supported include outputs and holding registers. The connected I/O points are updated continuously with the *Current Value* of the ISaGRAF variables. This information is cache internally by the SCADAPack E Series RTU and made available to the I/O points.

I/O Connection

Board Reference (hex)	000A
Library type	IO board
Data type	Analog (Integer or Real)
Channel type	Output
Number of channel	1

Board Configuration

board_address	Enter address	To…
	40001-49999	**Write Holding Register – Modbus Function Code 6**
plc_data_type	IEC UINT, IEC INT, IEC DINT, IEC REAL	
plc_device_addr	Modbus slave address (1-254)	

4.3 Modbus TCP Client I/O Boards

The ***mtcp..*** ISaGRAF boards can be used with E Series telemetry only. Ethernet or PPP serial interfaces can be used by a n E Series RTU to communicate with Open Modbus/TCP protocol peripheral devices (herein described as PLC's).

Note:	Each the ISaGRAF application's PLC I/O boards use a separate Modbus/TCP request to read or write its data. Improved Modbus communication efficiency can be achieved by grouping Modbus registers together and using less I/O boards with a larger number of channels (e.g. Mtcp64ai), rather than more I/O boards with a smaller number of channels.

A maximum of 100 Modbus/TCP Slave I/O Boards may be configured in total across both RTU ISaGRAF Applications.

ISaGRAF "Complex Equipment" types are comprised of configurations similar to I/O boards. Where a Complex Equipment type includes slave PLC I/O board configurations, each such I/O board configuration within the Complex Equipment type counts towards the limit of 100 Slave I/O boards.

Modbus/TCP boards utilize default IEC data types. Where applicable, the data type may be available for the user to choose.

4.3.1 Modbus/TCP Input Boards

Modbus/TCP PLC Input Board variables are updated at the start of an ISaGRAF application scan. The value presented to the ISaGRAF variables is the value returned by the PLC to the previous read request. This read may have occurred during previous ISaGRAF application scans. The "data update rate" parameter on the I/O board sets the "scan" rate of the PLC data. The PLC communication status is updated if there is an error returned from the PLC, or no response from the PLC after a data request by the SCADAPack E Series RTU. The status is cleared by the RTU upon successful communications. To catch transient errors you can use ISaGRAF code to store non-zero values.

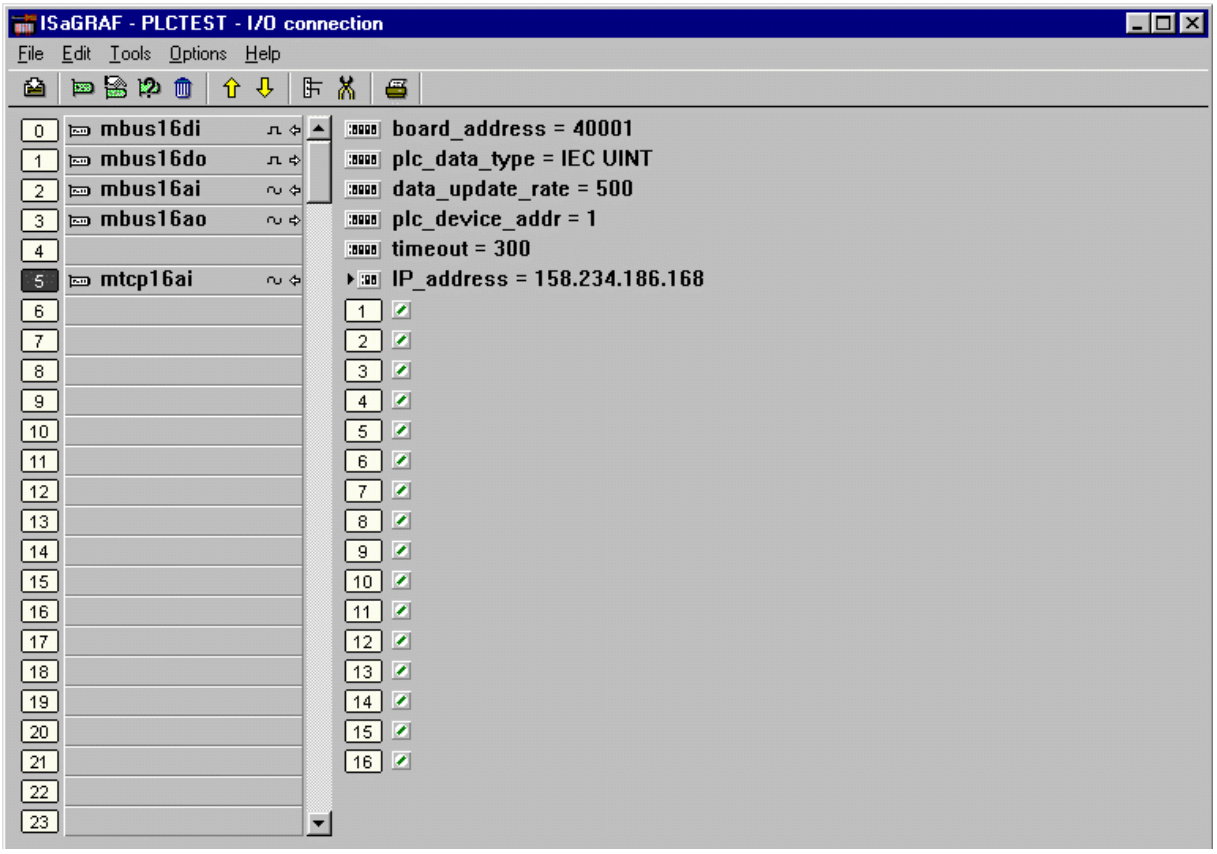


Figure 4-1: ISaGRAF Modbus/TCP board

❖ Input Board Parameters

board_address: specifies the Modbus/TCP PLC data registers to access when reading from PLC data into ISaGRAF variables. The PLC data type accessed is the same as Modbus Slave PLC I/O boards detailed in section ***4.2 - Serial Modbus Master I/O Boards***

plc_data_type: specifies the Modbus/TCP PLC data register type. The various types supported include IEC DISCRETE, 984 DISCETE, IEC UINT, IEC INT, IEC DINT, IEC REAL and SWAP REAL

data_update_rate: The units for this parameter are set in Milliseconds, and specify the rate at which the data for the Input board is extracted from the PLC. Individual I/O boards may have different data update rates allowing prioritization of data extracted from a slave PLC. Note that the E Series RTU may not be able to read all requested PLC data within the time set by the data update rate depending on the quantity of data to be read, rate of write requests and PLC communication speed. In this case the update rates will be slower.

plc_device_address: This parameter specifies the PLC device (unit) address. All Modbus PLC devices accessed at the same IP address (e.g. via a Modbus bridge) must have a unique Unit address in order to be identified. ISaGRAF may access data from different units on the same IP address or at different IP addresses. In all these cases a separate I/O board will be required for each device.

timeout: The Modbus/TCP PLC device driver provides a parameter for specifying the communications timeout on an individual I/O board (i.e. the timeout applies to communications

associated with that board). Where this value is “0”, the PLC device driver will use the default timeout (1200mS). Units for this field are in milliseconds.

IP_address: This parameter specifies the IP network address that the SCADAPack E Series RTU connects to for communication with the PLC for this I/O board. Enter the IP address of the Modbus/TCP PLC, or Modbus Bridge if applicable.

❖ “OPERATE” on Input Boards

The ISaGRAF “OPERATE” function may be used on Modbus/TCP Input Boards where the register read by the input board is also writeable. E.g. COILS or HOLDING REGISTERS. This permits registers to be inputs into ISaGRAF, but have them “Preset” in the PLC by ISaGRAF.

For more information see the *E Series ISaGRAF Technical Reference* manual.

4.3.1.1 mtcp16di

Open Modbus/TCP PLC 16 digital input board

Description

The **mtcp16di** I/O board provides sixteen digital input channels for a SCADAPack E Series RTU to communicate with a Modbus PLC peripheral I/O device via a TCP/IP connection. The digital channels can be connected to Boolean variables within an ISaGRAF application. PLC data supported include coils, digital input status and holding registers. Connected ISaGRAF variables are updated continuously with the *Current State* of the digital point. This information is cache internally by the RTU and made available to the ISaGRAF application.

I/O Connection

Board Reference (hex)	000E
Library type	IO board
Data type	Digital (Boolean)
Channel type	Input
Number of channels	16

Board Configuration

board_address	Enter address	To…
	1-9999	**Read Coils –Modbus Function Code 1**
	10001-19999	**Read Input Status – Modbus Function Code 2**
	40001-65535	**Read Holding Register – Modbus Function Code 3**
plc_data_type	IEC DISCRETE, 984 DISCRETE	
data_update_rate	Unit in mS	
plc_device_addr	Modbus slave address (1-254)	
Timeout	Unit in mS	
ip_address	IP address of the peripheral PLC device (111.222.333.444)	

4.3.1.2 mtcp32di

Open Modbus/TCP PLC 32 Digital Input Board

Description

The **mtcp32di** I/O board provides thirty two digital input channels for a SCADAPack E Series RTU to communicate with a Modbus PLC peripheral I/O device via a TCP/IP connection. The digital channels can be connected to Boolean variables within an ISaGRAF application. PLC data supported include coil registers, digital input status and holding registers. Connected ISaGRAF variables are updated continuously with the *Current State* of the digital point. This information is cache internally by the RTU and made available to the ISaGRAF application.

I/O Connection

Board Reference (hex)	000E
Library type	IO board
Data type	Digital (Boolean)
Channel type	Input
Number of channels	32

Board Configuration

board_address	Enter address	To…
	1-9999	**Read Coils –Modbus Function Code 1**
	10001-19999	**Read Input Status – Modbus Function Code 2**
	40001-65535	**Read Holding Register – Modbus Function Code 3**
plc_data_type	IEC DISCRETE, 984 DISCRETE	
data_update_rate	Unit in mS	
plc_device_addr	Modbus slave address (1-254)	
Timeout	Unit in mS	
Port	0-3 = Port 0-3 on ES RTU, 4 = Diag Port	

4.3.1.3 mtcpxxai

1, 4, 8, 16 or 32 Channel Open Modbus/TCP PLC Analog Input Board

Description

The **mtcp*xx*ai** I/O board provides 1, 4, 8, 16, 32 analog input channels for a SCADAPack E Series RTU to communicate with a Modbus PLC peripheral I/O device via a TCP/IP connection. The analog input channels can be tied to Integer or Real variables within an ISaGRAF application. PLC data supported include inputs, and holding registers. Connected ISaGRAF variables are updated continuously with the *Current Value* of the I/O points. This information is cache internally by the E Series RTU and made available to the ISaGRAF application.

I/O Connection

Board Reference (hex)	0010
Library type	IO board
Data type	Analog (Integer or Real)
Channel type	Input
Number of channels	1, 4, 8, 16 or 32

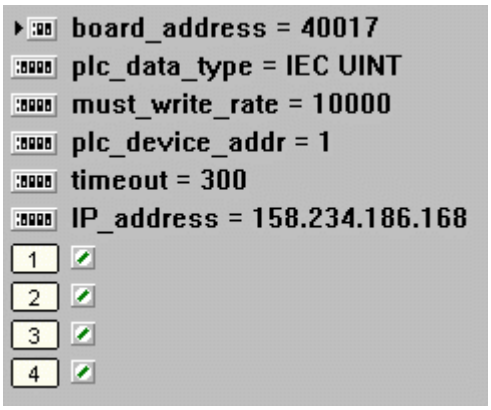
Board Configuration

board_address	Enter address	To…
	30001- 39999	**Read Input Register – Modbus Function Code 4**
	40001- 65535	**Read Holding Register – Modbus Function Code 3**
plc_data_type	IEC UINT, IEC INT, IEC DINT, IEC REAL	
data_update_rate	Unit in mS	
plc_device_addr	Modbus slave address (1-254)	
Timeout	Unit in mS	
ip_address	IP address of remote PLC device (111.222.333.444 format)	

4.3.2 Modbus/TCP Output Boards

Modbus/TCP PLC Output Board data is updated to the PLC when an ISaGRAF application changes the value of a variable attached to the Output Board. In addition, output board data is updated to the PLC under the following conditions:

- When the ISaGRAF application starts, all output board data is written
- If the PLC does not respond to a control, it is re-sent until it is responded
- All output board data is rewritten at a background update rate



❖ Output Board Parameters

board_address: specifies the Modbus/TCP PLC data registers to access when reading from PLC data into ISaGRAF variables. The PLC data type accessed is the same as Modbus Slave PLC I/O boards detailed in section ***4.2.4 - Output Boards***.

plc_data_type: specifies the Modbus/TCP PLC data register type.

plc_device_address: This parameter specifies the PLC device (unit) address. All Modbus PLC devices accessed at the same IP address (e.g. via a Modbus bridge) must have a unique unit address in order to be identified. ISaGRAF may access data from different units on the same IP address or at different IP addresses. In all these cases a separate I/O board will be required for each device.

must_write_rate: The unit for this parameter is set in Milliseconds, and specifies the rate at which the data for the Output board is written to the PLC. Between "*must_write_rate*" periods, data is only written to the PLC when the ISaGRAF output variable values change. Individual I/O boards may have different must write rates allowing prioritization of data sent to slave PLC(s).

timeout: The Modbus/TCP PLC device driver provides a parameter for specifying the communications timeout on an individual I/O board (i.e. the timeout applies to communications associated with that board). Where this value is "0", the PLC device driver will use the default timeout (1200mS). Units for this field are in milliseconds.

IP_address: This parameter specifies the IP network address that the PDS RTU connects to for communication with the PLC for this I/O board. Enter the IP address of the Modbus/TCP PLC, or Modbus Gateway or Modbus Bridge, as applicable.

4.3.2.1 mtcp16do

Open Modbus/TCP PLC 16 Digital Output Board

Description

The **mtcp16do** I/O board provides sixteen digital output channels for a SCADAPack E Series RTU to communicate with a Modbus PLC peripheral I/O device via TCP/IP. The digital output channel can be tied to Boolean variables within an ISaGRAF application. PLC data supported include relays coils and holding registers. The connected I/O points are updated continuously with the *Current State* of the ISaGRAF variables. This information is cache internally by the RTU and made available to the I/O points.

I/O Connection

Board Reference (hex)	000F
Library type	IO board
Data type	Digital (Boolean)
Channel type	Output
Number of channels	16

Board Configuration

board_address	Enter address	To…
	1-9999	**Write Coil – Modbus Function Code 5**
	40001-65535	**Write Holding Register – Modbus Function Code 16**
plc_data_type	IEC DISCRETE, 984 DISCRETE	
data_update_rate	Unit in mS	
plc_device_addr	Modbus slave address (1-254)	
Timeout	Unit in mS	
ip_address	IP address of PLC device (111.222.333.444 format)	

4.3.2.2 mtcp32do

Open Modbus/TCP PLC 32 Digital Output Board

Description

The **mtcp32do** I/O board provides thirty two digital output channels for a SCADAPack E Series RTU to communicate with a Modbus PLC peripheral I/O device via a TCP/IP connection. The digital output channel can be tied to Boolean variables within an ISaGRAF application. PLC data supported include relays coils and holding registers. The connected I/O points are updated continuously with the *Current State* of the ISaGRAF variables. This information is cache internally by the RTU and made available to the I/O points.

I/O Connection

Board Reference (hex)	000F
Library type	IO board
Data type	Digital (Boolean)
Channel type	Output
Number of channels	32

Board Configuration

board_address	Enter address	To…
	1-9999	**Write Coil – Modbus Function Code 5**
	40001-65535	**Write Holding Register – Modbus Function Code 16**
plc_data_type	IEC DISCRETE, 984 DISCRETE	
data_update_rate	Unit in mS	
plc_device_addr	Modbus slave address (1-254)	
Timeout	Unit in mS	
ip_address	IP address of PLC device (111.222.333.444 format)	

4.3.2.3 mtcpxxao

1, 4, 8, 16 or 32 Channel Open Modbus/TCP PLC Analog Output Board

Description

The **mtcp*xx*ao** I/O board provides 1, 4, 8, 16 or 32 analog output channels for a SCADAPack E Series RTU to communicate with a Modbus PLC peripheral I/O device via TCP/IP. The analog output channels can be tied to Integer or Real variables within an ISaGRAF application. PLC data supported include analog outputs and holding registers. The connected I/O points are updated continuously with the *Current Value* of the ISaGRAF variables. This information is cache internally by the RTU and made available to the I/O points.

I/O Connection

Board Reference (hex)	0011
Library type	IO board
Data type	Analog (Integer or Real)
Channel type	Output
Number of channel	1, 4, 8, 16 or 32

Board Configuration

board_address	Enter address	To…
	40001-65535	**Write Holding Register – Modbus Function Code 16**
plc_data_type	IEC UINT, IEC INT, IEC DINT, IEC REAL	
data_update_rate	Unit in mS	
plc_device_addr	Modbus slave address (1-254)	
Timeout	Unit in mS	
ip_address	IP address of PLC device (111.222.333.444 format)	

4.4 Idec PLC I/O Boards

The Idec FA-2J PLC communicates with the SCADAPack E Series RTU using an ISaGRAF **idecxxx** I/O board through an RTU '*PLC Device*' port. The Idec registers are read and the return values cached in the RTU for access through an ISaGRAF input board. Outputs are written from the SCADAPack RTU's output cache to the Idec PLC. The RTU's handling of the communications is the same as other PLC driver communications. The age and status of the data read from the Idec PLC is present in RTU system points that can be accessed from within ISaGRAF or external to the RTU.

The Idec Driver supports communications to the following Idec PLC's:

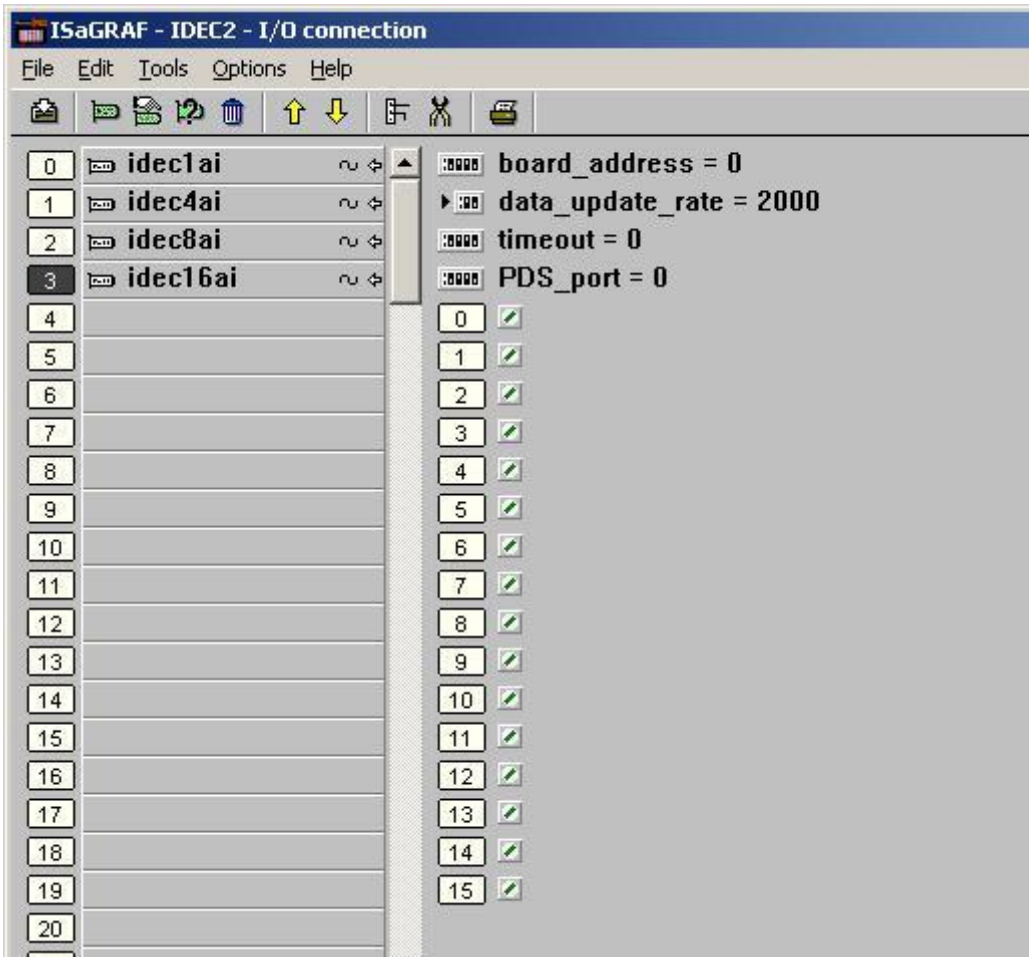
- FA-1 and FA-1J series (Theses PLC's don't support expansion areas and data registers)
- FA-2 and FA2J series

4.4.1 Input Boards

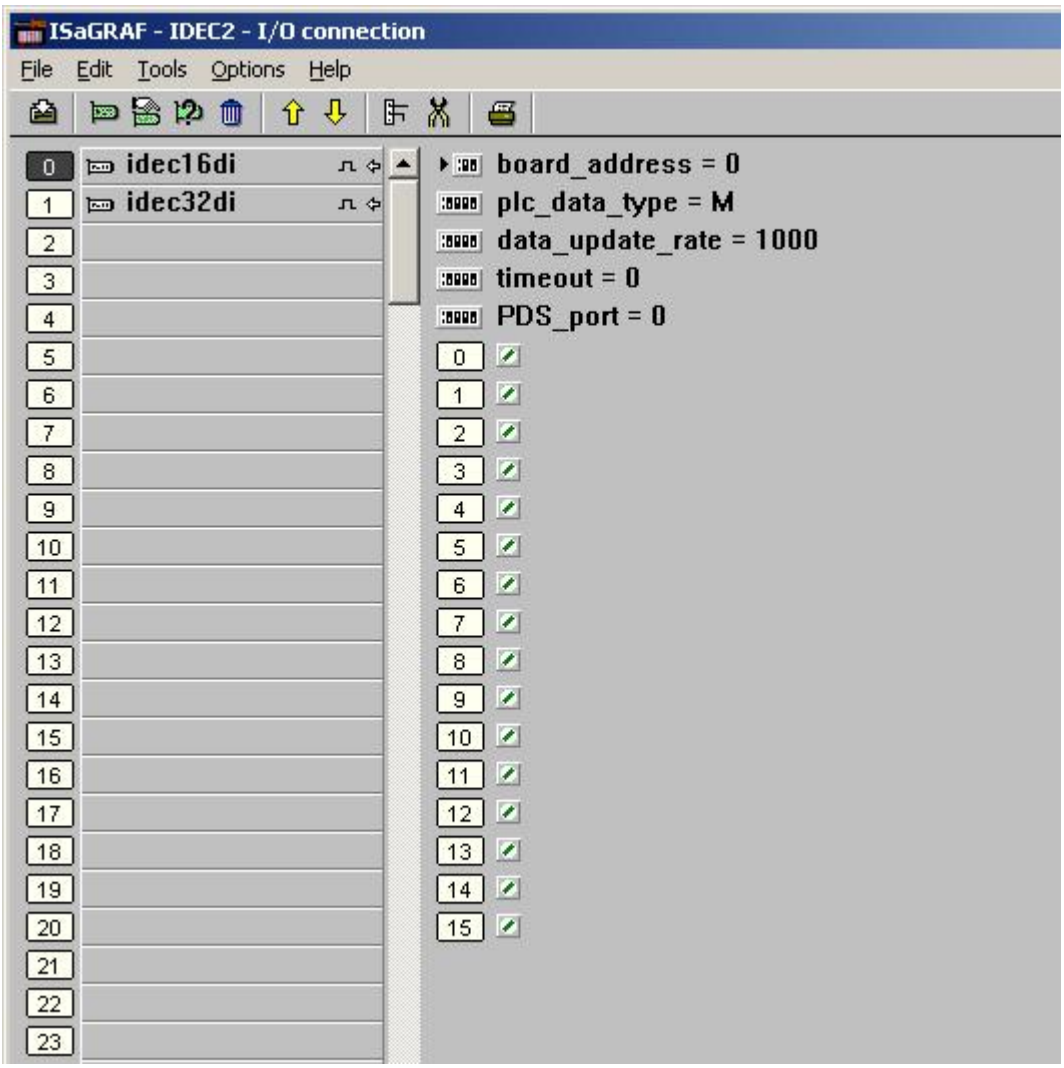
The Input boards supported by the Idec Driver are:

- 1 analog input
- analog input
- 8 analog input
- 16 analog input
- 16 digital input
- 32 digital input

The analog input boards all have the same basic layout as shown below.



The digital input boards all have the same basic layout as shown below.



The **board_address** field of the Idec ISaGRAF board (default value of 0) is the configurable register (16-bit) or point (binary) address in the Idec PLC. The allowable values for this address are outlined in the following table:

Board Type	Register Type	PLC Data Type	Standard Address Range	Expansion Address Range
16DI **32DI**	**Input**	**I**	**0-7, 10-17, 20-157**	**160-317***
	Output	**Q**	**0-7, 10-17, 20-157**	**160-317***
	Internal	**M**	**0-297, 300-317**	**320-637***
16DO **32DO**	**Output**	**Q**	**0-7, 10-17, 20-157**	**160-317***
	Internal	**M**	**0-297, 300-317**	**320-637***
16AI/AO **8AI/AO** **4AI/AO** **1AI/AO**	**Data Register**	**D** **(hidden parameter)**	**0-99***	**100-255* Expansion Area 1** **256-399* Expansion Area 2**

* Register ranges marked with an asterisk are not accessible with either the FA-1, or the FA-1J.

Note:	** A 16 channel digital board at start address 0, provides addressing for the following points: 0-7 and 10-17. Therefore the next consecutive board should be located at address 20 (not 16 or 18).

The **data_type** field is a configurable value that determines what type of registers/points to access in the PLC. As shown in the table above, valid values for digital boards are: I for Input points, Q for Output points, and M for internal points (default). The analog boards only allow access to Data Registers (value of D) and for this reason the data_type field is hidden for these boards.

The **data_update_rate** field of the **idecxxx** ISaGRAF board (default 2000) is the configurable number of *seconds* after which the RTU will request element array values from the Idec PLC. The RTU will also request data from the Idec PLC constantly if the cache data age is greater than the **data_update_rate**. I.e. if communications are lost with the PLC, they are retried until the communications are restored.

The **timeout** field of the ISaGRAF board driver provides a parameter for specifying the communications timeout on an individual I/O board (i.e. the timeout applies to communications associated with that board). Where this value is "0", the PLC device driver will use the default timeout (1200mS). Units for this field are in milliseconds.

The **PDS_port** field of the ISaGRAF board driver provides a parameter which defines which of multiple PDS RTU "PLC Device" ports will be used to communicate with the PLC or peripheral device. If only one "PLC Device" port is configured, this field is ignored.

4.4.1.1 idec16di

Idec PLC 16 Digital Input Board

Description

The **idec16di** I/O board provides sixteen digital input channels for a SCADAPack E Series RTU to communicate with an Idec PLC peripheral I/O device via a serial connection. The digital channels can be connected to Boolean variables within an ISaGRAF application. PLC data supported include coils, digital input status and holding registers. Connected ISaGRAF variables are updated continuously with the *Current State* of the digital point. This information is cache internally by the RTU and made available to the ISaGRAF application.

I/O Connection

Board Reference (hex)	000E
Library type	IO board
Data type	Digital (Boolean)
Channel type	Input
Number of channels	16

Board Configuration

<table>
<tr><td rowspan="8">board_address</td><td>Enter address</td><td>To…</td></tr>
<tr><td>0-7, 10-17, 20-157,</td><td>Read Inputs</td></tr>
<tr><td>160-317</td><td>Read Expansion Inputs</td></tr>
<tr><td>0-7, 10-17, 20-157</td><td>Read Outputs</td></tr>
<tr><td>160-317</td><td>Read Expansion Outputs</td></tr>
<tr><td>0-297, 300-317</td><td>Read Internal Relays</td></tr>
<tr><td>320-637</td><td>Read Expansion Internal Relays</td></tr>
<tr><td colspan="2">NOTE: A 16 channel board at start address 0 provides addressing for the following points: 0-7 and 10-17. Therefore the next consecutive board address should be located at address 20 (not 18).</td></tr>
<tr><td>data_update_rate</td><td colspan="2">Unit in mS</td></tr>
<tr><td>Timeout</td><td colspan="2">Unit in mS</td></tr>
<tr><td>plc_data_type</td><td colspan="2">I (Input), Q (Output), M (Internal)</td></tr>
<tr><td>Port</td><td colspan="2">0-3 = Port 0-3 on ES RTU, 4 = Diag Port</td></tr>
</table>

4.4.1.2 idec32di

Idec PLC 32 Digital Input Board

Description

The **idec16di** I/O board provides sixteen digital input channels for a SCADAPack E Series RTU to communicate with an Idec PLC peripheral I/O device via a serial connection. The digital channels

can be connected to Boolean variables within an ISaGRAF application. PLC data supported include coils, digital input status and holding registers. Connected ISaGRAF variables are updated continuously with the *Current State* of the digital point. This information is cache internally by the RTU and made available to the ISaGRAF application.

I/O Connection

Board Reference (hex)	000E
Library type	IO board
Data type	Digital (Boolean)
Channel type	Input
Number of channels	32

Board Configuration

board_address	Enter address	To…
	0-7, 10-17, 20-157,	**Read Inputs**
	160-317	**Read Expansion Inputs**
	0-7, 10-17, 20-157	**Read Outputs**
	160-317	**Read Expansion Outputs**
	0-297, 300-317	**Read Internal Relays**
	320-637	**Read Expansion Internal Relays**
	NOTE: **A 32 channel board at start address 0 provides addressing for the following points: 0-7, 10-17, 20-27 and 30-37. Therefore the next consecutive board address should be located at address 40 (not 38).**	
data_update_rate	Unit in mS	
Timeout	Unit in mS	
plc_data_type	I (Input), Q (Output), M (Internal)	
Port	0-3 = Port 0-3 on ES RTU, 4 = Diag Port	

4.4.1.3 idecxxai

1, 8, 8 or 16 Channel Idec PLC Analog Input Board

Description

The **idec*xx*ai** I/O board provides 1, 4, 8 or 16 analog input channels for a SCADAPack E Series RTU to communicate with an Idec PLC peripheral I/O device via a serial connection. The analog channels can be connected to Integer or Real variables within an ISaGRAF application. Connected ISaGRAF variables are updated continuously with the *Current Value* of the I/O point. This information is cache internally by the RTU and made available to the ISaGRAF application.

I/O Connection

Board Reference (hex)	0010
Library type	IO board

Data type	Analog (Integer or Real)
Channel type	Input
Number of channels	1, 4, 8 or 16

Board Configuration

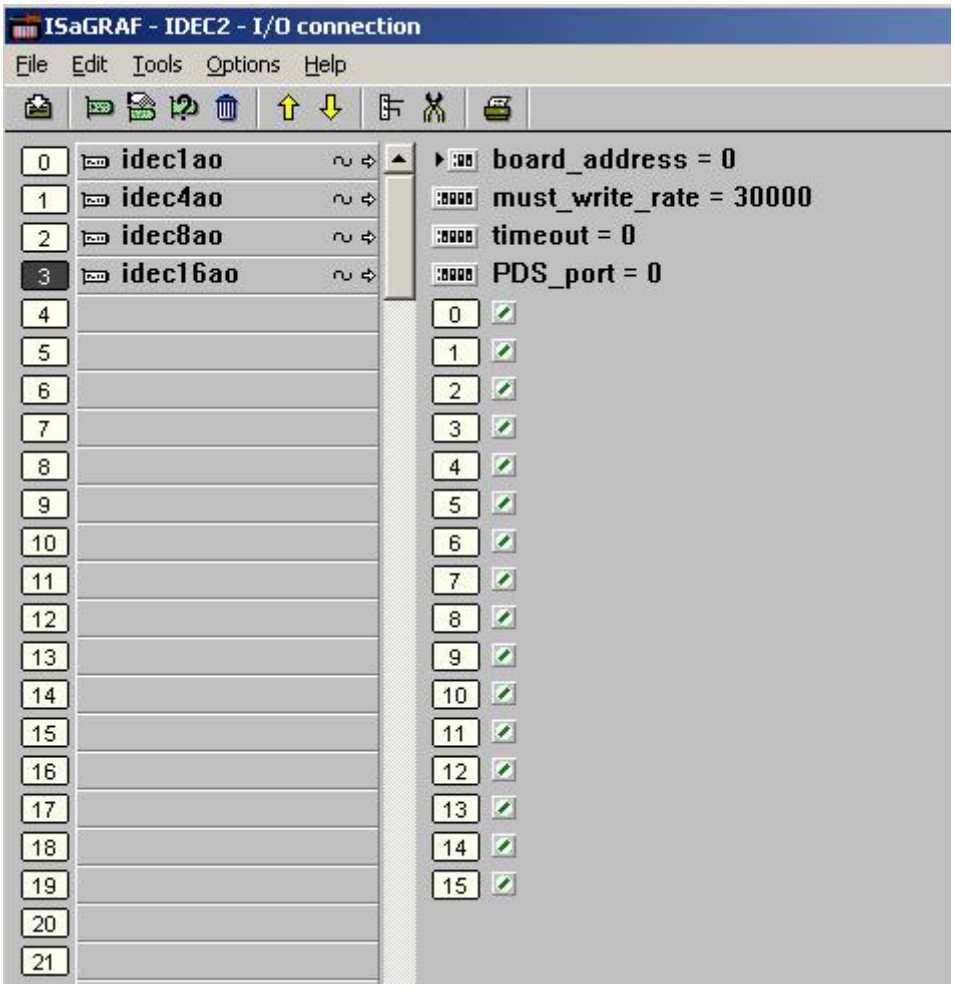
board_address	Enter address	To…
	0-99	**Read Idec Data Registers**
	160-317	**Read Idec Expansion Data Registers**
data_update_rate	Unit in mS	
Timeout	Unit in mS	
plc_data_type	D (Data Registers)	
Port	0-3 = Port 0-3 on ES RTU, 4 = Diag Port	

4.4.2 Output Boards

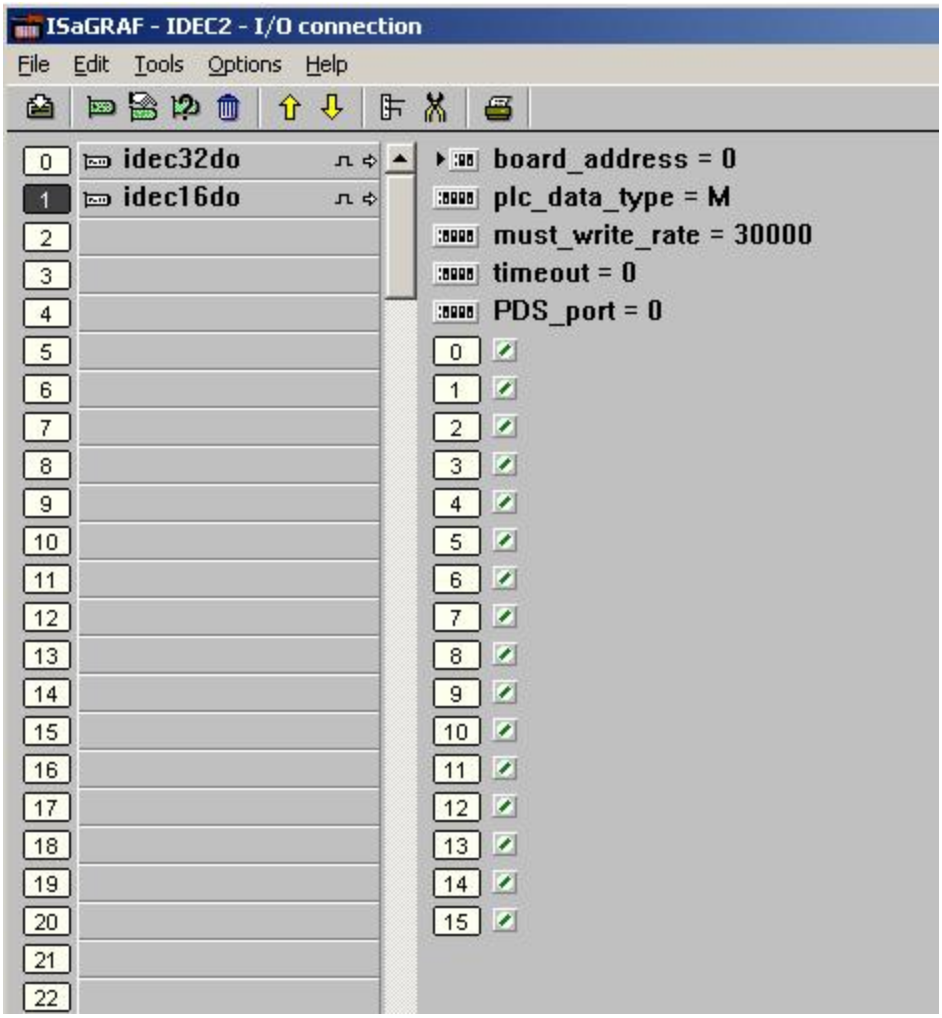
The Input boards supported by the Idec Driver are:

- 1 analog output
- analog output
- 8 analog output
- 16 analog output
- 16 digital output
- 32 digital output

The analog output boards all have the same basic layout as shown below.



The digital output boards all have the same basic layout as shown below.



Most of these parameters are the same as described for the Input Boards. The only difference is the **must_write_rate**. The unit for this parameter is in Milliseconds, and specifies the rate at which the data for the Output board is written to the PLC. Between "*must_write_rate*" periods, data is written to the PLC only when the ISaGRAF output variable values change. Individual I/O boards may have different must write rates allowing prioritization of data sent to a slave PLC.

4.4.2.1 idec16do

Idec PLC 16 Digital Output Board

Description

The **idec16do** I/O board provides sixteen digital output channels for a SCADAPack E Series RTU to communicate with an Idec PLC peripheral I/O device via a serial connection. The digital channels can be connected to Boolean variables within an ISaGRAF application. PLC data supported include digital outputs or holding registers and coils. The *Current State* of the connected I/O is continuously updated by the ISaGRAF variables. This information is cache internally by the RTU and made available to the I/O points.

I/O Connection

Board Reference (hex)	000F
Library type	IO board
Data type	Digital (Boolean)
Channel type	Output
Number of channels	16

Board Configuration

board_address	Enter address	To…
	0-7, 10-17, 20-157,	**Write Outputs**
	160-317	**Write Expansion Outputs**
	0-297, 300-317	**Write Internal Relays**
	320-637	**Read Expansion Internal Relays**
	NOTE: **A 16 channel board at start address 0 provides addressing for the following points: 0-7 and 10-17. Therefore the next consecutive board address should be located at address 20 (not 18).**	
data_update_rate	Unit in mS	
Timeout	Unit in mS	
plc_data_type	Q (Output), M (Internal)	
Port	0-3 = Port 0-3 on ES RTU, 4 = Diag Port	

4.4.2.2 idec32do

Idec PLC 32 Digital Output Board

Description

The **idec32do** I/O board provides thirty-two digital output channels for a SCADAPack E Series RTU to communicate with an Idec PLC peripheral I/O device via a serial connection. The digital channels can be connected to Boolean variables within an ISaGRAF application. PLC data supported include digital output or holding registers and coils. The *Current State* of the connected I/O is continuously updated by the ISaGRAF variables. This information is cache internally by the RTU and made available to the I/O points. .

I/O Connection

Board Reference (hex)	000F
Library type	IO board
Data type	Digital (Boolean)
Channel type	Output
Number of channels	32

Board Configuration

board_address	Enter address	To…
	0-7, 10-17, 20-157,	**Write Outputs**
	160-317	**Write Expansion Outputs**
	0-297, 300-317	**Write Internal Relays**
	320-637	**Read Expansion Internal Relays**
	NOTE: **A 16 channel board at start address 0 provides addressing for the following points: 0-7, 10-17, 20-27 and 30-37. Therefore the next consecutive board address should be located at address 40 (not 38).**	
data_update_rate	Unit in mS	
Timeout	Unit in mS	
plc_data_type	Q (Output), M (Internal)	
Port	0-3 = Port 0-3 on ES RTU, 4 = Diag Port	

4.4.2.3 idecxxao

1, 4, 8 or 16 Channel Idec PLC Analog Output Board

Description

The **idec*xx*ao** I/O board provides 1, 4, 8 or 16 analog output channels for a SCADAPack E Series RTU to communicate with an Idec PLC peripheral I/O device via a serial connection. The analog channels can be connected to Integer or Real variables within an ISaGRAF application. PLC data supported include analog output or holding registers. The *Current Value* of the connected I/O is continuously updated by the ISaGRAF variables. This information is cache internally by the RTU and made available to the ISaGRAF application.

I/O Connection

Board Reference (hex)	0011
Library type	IO board
Data type	Analog (Integer or Real)
Channel type	Output
Number of channels	1, 4, 8 or 16

Board Configuration

board_address	Enter address	To…
	0-99	**Write Idec Data Registers**
	100-399	**Write Idec Expansion Data Registers**
must_write_rate	Unit in mS	
Timeout	Unit in mS	
port	0-3 = Port 0-3 on ES RTU, 4 = Diag Port	
plc_data_type	D (Data register)	

4.5 Allen Bradley PLC I/O Boards

The Allen-Bradley PLC communicates with the SCADAPack E Series RTU using an ISaGRAF **df1_xxx** I/O board through an RTU '*PLC Device*' port. The DF1 registers are read and the return values cached in the RTU for access through an ISaGRAF input board. Outputs are written from the RTU's output cache to the DF1 PLC. The SCADAPack RTU's handling of the communications is the same as other PLC driver communications. The age and status of the data read from the DF1 PLC is present in RTU system points that can be accessed from within ISaGRAF or external to the RTU.

The DF1 Driver supports communications to the following Allen-Bradley PLC's:

- SLC 500 Series
- PLC 5 Series
- DF1 Generic PLC's

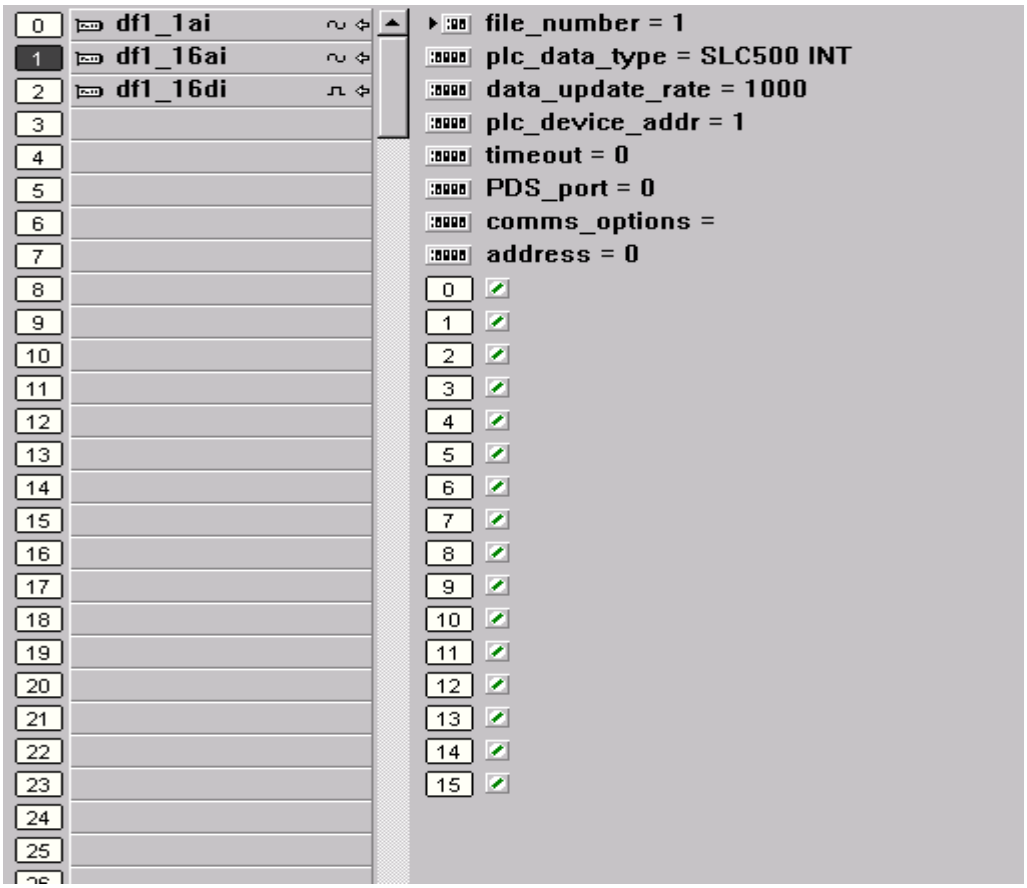
The **df1_xxx** ISaGRAF I/O boards use an RTU '*PLC Device*'port to communicate with the Allen-Bradley.

4.5.1 Input Boards

The Input boards supported by the DF1 Driver are:

- 1 analog input
- 16 analog input
- 16 digital input

These all have the same basic layout as shown below.



The **file_number** field of the DF1 ISaGRAF board (default 1) is the configurable file address of the required registers in the DF1 PLC.

The **plc_data_type** field of the DF1 ISaGRAF board (default SLC UINT for the AI boards, and SLC DISCRETE for the DI board) configures the board to communicate with the specified type of register in the specified PLC. Allowable values are outlined below:

Value	Description
SLC500 DISCRETE	Use on a digital board to communicate to a SLC500 PLC.
SLC500 INT	Use on an analog board to communicate to a SLC500 PLC. 16-bit signed value.
SLC500 REAL	Use on an analog board to communicate to a SLC500 PLC. 32-bit floating point value.
PLC5 DISCRETE	Use on a digital board to communicate to a PLC5 PLC.
PLC5 INT	Use on an analog board to communicate to a PLC5 PLC. 16-bit signed value.
PLC5 REAL	Use on an analog board to communicate to a PLC5 PLC. 32-bit floating point value.
GEN DISCRETE	Use on a digital board to communicate to a DF1 Generic PLC.
GEN INT	Use on an analog board to communicate to a DF1 Generic PLC. 16-bit signed value.

The **data_update_rate** field of the **df1_xxx** ISaGRAF board (default 1000) is the configurable number of *seconds* after which the RTU will request element array values from the DF1 PLC. The RTU will also request data from the Allen-Bradley PLC constantly if the cache data age is greater than the **data_update_rate**. I.e. if communications are lost with the PLC, they are retried until the communications are restored.

The **plc_device_addr** (default 1) field of the ISaGRAF board is the configurable address of the Allen-Bradley PLC.

The **timeout** field of the ISaGRAF board driver provides a parameter for specifying the communications timeout on an individual I/O board (i.e. the timeout applies to communications associated with that board). Where this value is "0", the PLC device driver will use the default timeout (1200mS). Units for this field are in milliseconds.

The **PDS_port** field of the ISaGRAF board driver provides a parameter which defines which of multiple PDS RTU "PLC Device" ports will be used to communicate with the PLC or peripheral device. If only one "PLC Device" port is configured, this field is ignored. ISaGRAF Slave PLC I/O boards that do not include this parameter can only be used when a single "PLC Device" port is configured on the SCADAPack E Series RTU.

The **comms_options** field is a string field that allows the user to set the local DF1 address, whether it's half or full duplex, and whether it uses a CRC or BCC. The format for this string is as follows:

XXX YYYY ZZZ , where:

- XXX is the DF1 Address that the PDS RTU will appear as (default is 0).
- YYYY is HALF or FULL for the duplex setting (default is FULL).
- ZZZ is CRC or BCC (default is CRC).

If any of the comms options fields are missing, then the default will be used for that parameter.

Note:	For Full Duplex operation set the DF1 address to be the address that you want the E Series RTU to appear as. However, for Half-Duplex operation set the DF1 address to be the 'Node Address' specified in the channel configuration of the PLC.

The **address** field of the ISaGRAF board driver specifies the offset address of the board into the specified file.

If floating point values are to be read out of the Allen-Bradley PLC (i.e. PLC5 REAL or SLC500 REAL) then ISaGRAF Analog Input (Real) variables should be attached to the Input Board channels as required.

4.5.1.1 df1_16di

DF1 PLC 16 Digital Input Board

Description

The **df1_16di** I/O board provides sixteen digital input channels for a SCADAPack E Series RTU to communicate with an Allen Bradley PLC peripheral I/O device via a serial connection. The digital channels can be connected to Boolean variables within an ISaGRAF application. PLC data supported include coils, digital input or holding registers. The ISaGRAF variable is continuously updated with the Current State of the attached I/O. This information is cache internally by the RTU and made available to the ISaGRAF application.

I/O Connection

Board Reference (hex)	000E
Library type	IO board
Data type	Digital (Boolean)
Channel type	Input
Number of channels	16

Board Configuration

board_address	DF1 File address
plc_data_type	SLC500 DISCRETE, PLC5 DISCRETE, GEN DISCRETE
data_update_rate	Unit in mS
plc_device_add	DF1 Slave address (1-254)
timeout	Unit in mS
Port	0-3 = Port 0-3 on ES RTU, 4 = Diag Port
comms_options	XXX YYYY ZZZ where: XXX is the DF1 Address that the PDS RTU will appear as (default is 0). YYYY is HALF or FULL for the duplex setting (default is FULL). ZZZ is CRC or BCC (default is CRC).
address	Offset in file

4.5.1.2 df1_xxai

1, 4, 8 or 16 Channel DF1 PLC Analog Input Board

Description

The **df1_*xx*ai** I/O board provides 1, 4, 8 or 16 analog input channels for a SCADAPack E Series RTU to communicate with an Allen Bradley PLC peripheral I/O device via a serial connection. The analog channels can be connected to Integer or Real variables within an ISaGRAF application. PLC data supported include analog inputs. The *Current Value* of the connected I/O is continuously updated by the ISaGRAF variables. This information is cache internally by the RTU and made available to the ISaGRAF application.

I/O Connection

Board Reference (hex)	0010
Library type	IO board
Data type	Analog (Integer or Real)
Channel type	Input
Number of channels	1, 4, 8 or 16

Board Configuration

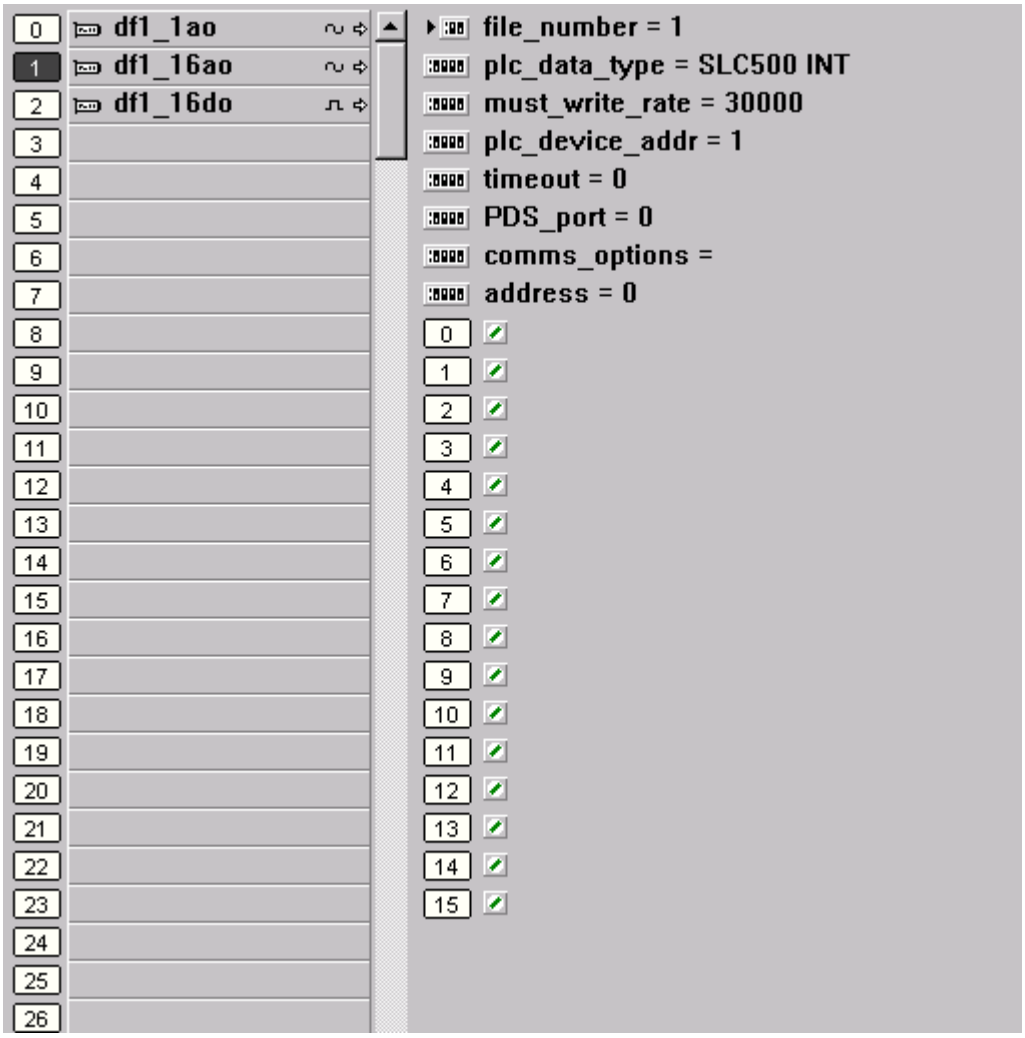
board_address	DF1 File address
plc_data_type	SLC500 INT, SLC500 REAL, PLC INT, PLC5 REAL, GEN INT
data_update_rate	Unit in mS
plc_device_add	DF1 Slave address (1-254)
timeout	Unit in mS
Port	0-3 = Port 0-3 on ES RTU, 4 = Diag Port
comms_options	XXX YYYY ZZZ where: XXX is the DF1 Address that the PDS RTU will appear as (default is 0). YYYY is HALF or FULL for the duplex setting (default is FULL). ZZZ is CRC or BCC (default is CRC).
address	Offset in file

4.5.2 Output Boards

The output boards supported by the DF1 Driver are:

- 1 analog output
- 16 analog output
- 16 digital output

These all have the same basic layout as shown below.



Most of these parameters are the same as described for the Input Boards. The only difference is the **must_write_rate**. The unit for this parameter is in Milliseconds, and specifies the rate at which the data for the Output board is written to the PLC. Between "*must_write_rate*" periods, data is written to the PLC only when the ISaGRAF output variable values change. Individual I/O boards may have different must write rates allowing prioritization of data sent to a slave PLC.

4.5.2.1 df1_16do

DF1 PLC 16 Digital Output Board

Description

The **df1_16do** I/O board provides sixteen digital output channels for a SCADAPack E Series RTU to communicate with an Allen Bradley PLC peripheral I/O device via a serial connection. The digital channels can be connected to Boolean variables within an ISaGRAF application. PLC data supported include digital outputs. The *Current State* of the connected I/O is continuously updated by the ISaGRAF variables. This information is cache internally by the RTU and made available to the I/O point.

I/O Connection

Board Reference (hex)	000F
Library type	IO board
Data type	Digital (Boolean)
Channel type	Output
Number of channels	16

Board Configuration

board_address	DF1 File address
plc_data_type	SLC500 INT, SLC500 REAL, PLC INT, PLC5 REAL, GEN INT
must_write_rate	Unit in mS
plc_device_add	DF1 Slave address (1-254)
timeout	Unit in mS
Port	0-3 = Port 0-3 on ES RTU, 4 = Diag Port
comms_options	XXX YYYY ZZZ where: XXX is the DF1 Address that the PDS RTU will appear as (default is 0). YYYY is HALF or FULL for the duplex setting (default is FULL). ZZZ is CRC or BCC (default is CRC).
address	Offset in file

4.5.2.2 df1_xxao

1, 4, 8 or 18 Channel DF1 PLC Analog Output Board

Description

The **df1_*xx*ao** I/O board provides 1, 4, 8 or 16 analog output channels to a SCADAPack E Series RTU to communicate with an Allen Bradley PLC peripheral I/O device via a serial connection. The analog channels can be connected to an Integer or Real variable within an ISaGRAF application. The connected I/O points are continuously controlled by the *Current Value* of the ISaGRAF variable. This information is cache internally by the RTU and made available to the I/O point.

I/O Connection

Board Reference (hex)	0011
Library type	IO board
Data type	Analog (Integer or Real)
Channel type	Output
Number of channels	1, 4, 8 or 16

Board Configuration

board_address	DF1 File address
plc_data_type	SLC500 INT, SLC500 REAL, PLC INT, PLC5 REAL, GEN INT
must_write_rate	Unit in mS
plc_device_add	DF1 Slave address (1-254)
timeout	Unit in mS
Port	0-3 = Port 0-3 on ES RTU, 4 = Diag Port
comms_options	XXX YYYY ZZZ where: XXX is the DF1 Address that the PDS RTU will appear as (default is 0). YYYY is HALF or FULL for the duplex setting (default is FULL). ZZZ is CRC or BCC (default is CRC).
address	Offset in file

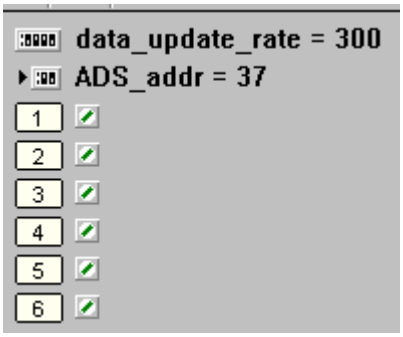
4.6 ADS Flow Monitor I/O Board

The ADS flow monitor communicates with the SCADAPack E Series RTU using an ISaGRAF **adsflow** I/O board through an RTU '*PLC Device*' port. The ADS monitor elements are read and the return values cached in the RTU for access through an ISaGRAF input board. The SCADAPack RTU's handling of the communications is the same as other PLC driver communications. The age and status of the data read from the ADS flow monitor is present in RTU system points that can be accessed from within ISaGRAF, or external to the RTU.

The ADS 3500 flow monitor must be fitted with the multiplexer communication option in order to support communication with the PDS RTU.

The **adsflow** ISaGRAF input board uses an RTU '*PLC Device*'port to communicate with the ADS Flow Monitor. The **data_update_rate** field of the adsflow ISaGRAF board (default 300) is the configurable number of *seconds* after which the RTU will request element array values from the ADS flow monitor. The RTU will also request data from the ADS flow monitor constantly if the cache data age is greater than the **data_update_rate**. I.e. if communications are lost with the monitor, they are retried until the communications are restored.

The **ADS_addr** field of the ISaGRAF board is the configurable address of the ADS flow monitor, usually the last two digits of the serial number on the top of the ADS flow monitor. For example, if the serial number on the top of the monitor read **4237**, the user would configure the value **37** in the **ADS_addr** of the board.



The values returned by the ads flow board are floating point values, representing the Local Data elements in the ADS flow monitor.

ISaGRAF Analog Input (Real) variables should be attached to the Input Board channels as required. The Input Board channels represent the following data values from the ADS monitor:

- 1 - Depth of flow as determined by the ultrasonic depth sensor
- 2 - Depth of flow as determined by the pressure sensor for surcharge measurements
- 3 - Flow velocity
- 4 - Flow Rate
- 5 - Current days flow total so far
- 6 - Previous days flow total

I/O Connection

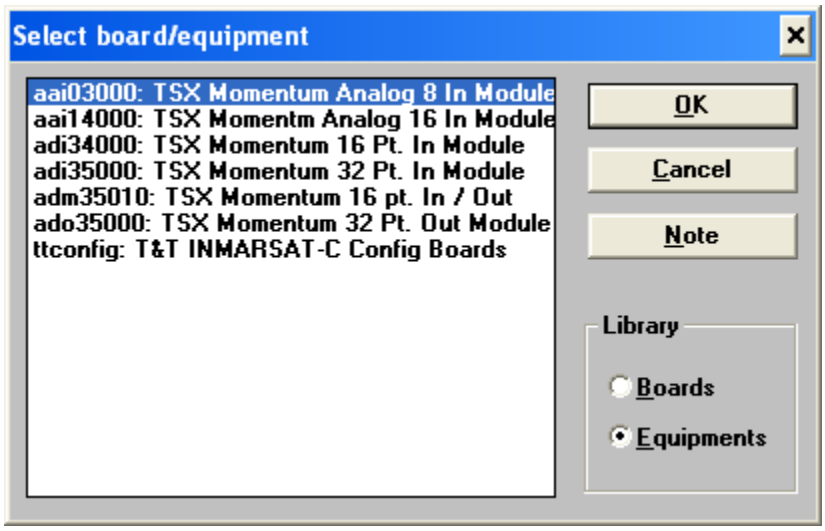
Board Reference (hex)	000B
Library type	IO board
Data type	Analog (Integer or Real)
Channel type	Input
Number of channels	LD[0] .. LD[5]

Board Configuration

Data_update_rate	Unit is Seconds
plc_device_add	Address of flow monitor

5 I/O Complex Equipment

As an additional extension of the data interface provided by the SCADAPack E Series RTU, access by ISaGRAF applications to data in external I/O complex peripheral devices is supported. Standard ISaGRAF I/O boards can continue to access the SCADAPack E Series I/O and DNP data exchange areas as usual, with an additional set of ISaGRAF boards provided for the RTU that allow data to be extracted from or written to these complex I/O modules. External peripheral data is cached internally by the SCADAPack RTU to maximize ISaGRAF application performance. The I/O complex equipments are presented for selection by checking the **Equipments** radio button in the Select Board/Equipment dialog as shown below.



5.1 TSX Momentum 8 Channel Differential Analog Input Module

For a Schneider Automation TSX Momentum 170 AAI 030 00 I/O module connected to a SCADAPack E Series RTU via the TSX Momentum 170 ENT 110 00 Ethernet Communication Adapter, the **aai03000** I/O can be used. This module provides 8 differential analog inputs channels for field data, 2 analog output channels for configuration of the 8 analog input channels and an addition 13 analog input channels to read the status of the I/O module into the SCADAPack RTU.

Input Sub-Module

This input sub-module provides 8 differential analog input channels to the TSX AAI 0300 module connected to the SCADAPack E Series RTU via TCP/IP using the TSX Momentum 170 ENT 110 00 Ethernet Adapter. The analog channels can be connected to a Real or Integer variables within an ISaGRAF application. Connected ISaGRAF variables are updated continuously with the *Current Value* of the I/O point. This information is cache internally by the SCADAPack RTU and made available to the ISaGRAF application.

Expected values on these channels range from:

- 0 to 32000, 0-100% scale: Unipolar Range is selected
- -32000 to 32000 0-100% scale: Bipolar Range is selected
- 32768: a broken wire

Board Configuration

data_update_rate	in mS
timeout	in mS
ip_address	IP address of TSX Ethernet Adapter in 111.222.333.444 format.

Params Sub-Module

The 2 channel analog output sub-module allows configuration of the eight differential analog input channels. The analog channels can be connected to Integer variables within an ISaGRAF application. The connected points are controlled by the *Current Hex Value* of the ISaGRAF variable. This information is cache internally by the SCADAPack E Series RTU and made available to the ISaGRAF application.

Params Output 1 configures the parameters of channels 4-1 using a four digit Hex number. That is the most significant digit in the Hex number configures channel 4 while the least significant digit configures channel 1.

Params Output 2 configures the parameters of channels 8-5 using 4 Hex digits. That is the most digit in the Hex number configures channel 8 while the least significant digit configures channel 5.

Channel Parameters are as follows:

Hex Value	Purpose
0	Reserved (Default condition)
2	± 5V & ± 20mA input range
3	± 10V input range
4	Channel Inactive

Hex Value	Purpose
A	1 -5V & 4-20mA input range (20% input offset)

For example, writing the value 16#AA32 (XXX where is 16 coming from) to Param Output 1, configures analog input channels 1-4 as follows:

Channel 1: ± 5V
Channel 2: ± 10V
Channel 3: 1-5V
Channel 4: 1-5V

Board Configuration

must_write_rate	in mS
timeout	in mS
ip_address	IP address of TSX Ethernet Adapter in 111.222.333.444 format. Must be same as above.

Status Sub-Module

This sub-module provides 13 analog input channels to read the module status and configuration information into ISaGRAF Integer variables. The first 4 channels always return constant values that depend on the type of module. However, all other channels return a varying value represented by 'xx' in the table below. Each input channel returns the following information:

Channel	Return Value	Description
1	13	Length of this status block
2	8	I/O module quantity of input words
3	2	I/O module quantity of output words
4	704	I/O module ID
5	xx	Comms Adapter Revision number
6	xx	ASCII header block length
7	xx	Last Ip to communicate (high word)
8	xx	Remaining Write ownership reservation time (mS)
9	N/A	Not Used
10	xx	I/O module health 0 => Not healthy 32768 => Healthy
11	xx	I/O module last error value
12	xx	I/O module error counter (0-65535)
13	Xx	Last IP to communicate (low word)

Board Configuration

data_update_rate	in mS
timeout	in mS
ip_address	Must be same as above.

5.2 TSX Momentum 16 Channel Single Ended Analog Input Module

For a Schneider Automation TSX Momentum 170 AAI 140 00 I/O module connected to a SCADAPack E Series RTU via the TSX Momentum 170 ENT 110 00 Ethernet Communication Adapter, the **aai14000** I/O can be used. This module provides 16 single ended analog inputs channels for field data, 4 analog output channels for configuration of the 16 analog input channels and an addition 13 analog input channels to read the status of the I/O module into the SCADAPack RTU.

Input Sub-Module

This sub-module provides 16 single ended analog input channels to the TSX AAI 140 00 module connected to the E Series RTU via TCP/IP using the TSX Momentum 170 ENT 110 00 Ethernet Adapter. The analog channels can be connected to a Real or Integer variables within an ISaGRAF application. Connected ISaGRAF variables are updated continuously with the *Current Value* of the I/O point. This information is cache internally by the E Series RTU and made available to the ISaGRAF application.

Expected values on these channels range from:

- 0 to 32000, 0-100% scale: Unipolar Range is selected
- -32000 to 32000 0-100% scale: Bipolar Range is selected
- 32768: a broken wire
- 768: Reverse polarity (unipolar)

Board Configuration

data_update_rate	in mS
timeout	in mS
ip_address	IP address of TSX Ethernet Adapter in 111.222.333.444 format.

Params Sub-Module

The 4 channel analog output sub-module allows configuration of the 16 single ended analog input channels. The analog channels can be connected to Integer variables within an ISaGRAF application. The connected points are controlled by the *Current Hex Value* of the ISaGRAF variable. This information is cache internally by the SCADAPack RTU and made available to the ISaGRAF application.

Params Output 1 configures the parameters of channels 4-1 using a 4 digit Hex number. That is the most significant digit in the Hex number configures channel 4 while the least significant Hex digit configures channel 1.

Params Output 2 configures the parameters of channels 8-5 using a 4 digit Hex number. That is the most significant hex digit configures channel 8 while the least significant hex digit configures channel 5.

Param Output 3 configures the parameters of channels 12-9 using a 4 digit Hex number. That is the most significant hex digit configures channel 12 while the least significant hex digit configures channel 9.

Param Output 4 configures the parameters of channels 16-13 using a 4 digit Hex number. That is the most significant hex digit configures channel 16 while the least significant hex digit configures channel 13.

Channel Parameters are as follows:

Hex Value	Purpose
0	Reserved (Default condition)
A	± 5V input range
B	± 10V input range
C	Channel Inactive
E	4-20mA input range (20% input offset)

For example, writing the value 16#EEBA to Param Output 1, configures analog input channels 1-4 as follows:

Channel 1: ± 5V
Channel 2: ± 10V
Channel 3: 4-20mA
Channel 4: 4-20MA

Board Configuration

must_write_rate	in mS
timeout	in mS
ip_address	IP address of XXX in 111.222.333.444 format. Must be same as above.

Status Sub-Module

This sub-module provides 13 analog input channels to read the module status and configuration information into ISaGRAF Integer variables. The first 4 channels always return constant values that depend on the type of module. However, all other channels return a varying value represented by 'xx' in the table below. Each input channel returns the following information:

Channel	Return Value	Description
1	13	Length of this status block
2	16	I/O module quantity of input words
3	4	I/O module quantity of output words
4	1217	I/O module ID
5	xx	Comms Adapter Revision number
6	xx	ASCII header block length
7	xx	Last Ip to communicate (high word)
8	xx	Remaining Write ownership reservation time (mS)
9	N/A	Not Used
10	xx	I/O module health 0 => Not healthy 32768 => Healthy
11	xx	I/O module last error value
12	xx	I/O module error counter (0-65535)

Channel	Return Value	Description
13	xx	Last IP to communicate (low word)

Board Configuration

data_update_rate	in mS
timeout	in mS
ip_address	IP address of XXX in 111.222.333.444 format.

5.3 TSX Momentum 16 Point Digital Input Module

For a Schneider Automation TSX Momentum 170 ADI 340 00 I/O module connected to a SCADAPack E Series RTU via the TSX Momentum 170 ENT 110 00 Ethernet Communication Adapter, the **adi34000** I/O can be used. This module provides 16 digital input channels for field data and 13 analog input channels to read the status of the I/O module into the SCADAPack E Series RTU.

Input Sub-Module

This sub-module provides 16 digital input channels to the TSX ADI 340 00 module connected to the SCADAPack E Series RTU via TCP/IP using the TSX Momentum 170 ENT 110 00 Ethernet Adapter. The digital input channels can be connected to Boolean variables within an ISaGRAF application. Connected ISaGRAF variables are updated continuously with the *Current State* of the I/O point. This information is cache internally by RTU and made available to the ISaGRAF application.

Board Configuration

data_update_rate	in mS
timeout	in mS
ip_address	IP address of TSX Ethernet Adapter in 111.222.333.444 format.

Status Sub-Module

This sub-module provides 13 analog input channels to read the module status and configuration information into ISaGRAF Integer variables. The first 4 channels always return constant values that depend on the type of module. However, all other channels return a varying value represented by 'xx' in the table below. Each input channel returns the following information:

Channel	Return Value	Description
1	13	Length of this status block
2	1	I/O module quantity of input words
3	0	I/O module quantity of output words
4	2	I/O module ID
5	xx	Comms Adapter Revision number
6	xx	ASCII header block length
7	xx	Last IP to communicate (low word)
8	xx	Remaining Write ownership reservation time (mS)
9	xx	Remaining outputs holdup time
10	xx	I/O module health 0 => Not healthy 32768 => Healthy
11	xx	I/O module last error value
12	xx	I/O module error counter (0-65535)
13	xx	Last IP to communicate (high word)

5.4 TSX Momentum 32 Point Digital Input Module

For a Schneider Automation TSX Momentum 170 ADI 350 00 I/O module connected to a SCADAPack E Series RTU via the TSX Momentum 170 ENT 110 00 Ethernet Communication Adapter, the **adi35000** I/O can be used. This module provides 32 digital input channels for field data and 13 analog input channels to read the status of the I/O module into the SCADAPack RTU.

Input Sub-Module

This sub-module provides 32 digital input channels to the TSX ADI 350 00 module connected to the E Series RTU via TCP/IP using the TSX Momentum 170 ENT 110 00 Ethernet Adapter. The digital input channels can be connected to Boolean variables within an ISaGRAF application. Connected ISaGRAF variables are updated continuously with the *Current State* of the I/O point. This information is cache internally by the E Series RTU and made available to the ISaGRAF application.

Board Configuration

data_update_rate	in mS
timeout	in mS
ip_address	IP address of TSX Ethernet Adapter in 111.222.333.444 format.

Status Sub-Module

This sub-module provides 13 analog input channels to read the module status and configuration information into ISaGRAF Integer variables. The first 4 channels always return constant values that depend on the type of module. However, all other channels return a varying value represented by 'xx' in the table below. Each input channel returns the following information:

Channel	Return Value	Description
1	13	Length of this status block
2	2	I/O module quantity of input words
3	0	I/O module quantity of output words
4	1	I/O module ID
5	xx	Comms Adapter Revision number
6	xx	ASCII header block length
7	xx	Last IP to communicate (low word)
8	xx	Remaining Write ownership reservation time (mS)
9	xx	Remaining outputs holdup time (mS)
10	xx	I/O module health 0 => Not healthy 32768 => Healthy
11	xx	I/O module last error value
12	xx	I/O module error counter (0-65535)
13	xx	Last IP to communicate (high word)

Board Configuration

data_update_rate	in mS
timeout	in mS
ip_address	Must be same as input sub-module.

5.5 TSX Momentum 16 Channel Input/ 16 Channel Output Module

For a Schneider Automation TSX Momentum 170 ADM 350 10 I/O module connected to a SCADAPack E Series RTU via the TSX Momentum 170 ENT 110 00 Ethernet Communication Adapter, the **adm35010** I/O can be used. This module provides 16 digital input and 16 digital output channels for field data, 1 analog output channel to configure the output holdup time as well as the standard 13 analog input channels to read the status of the I/O module into the SCADAPack RTU.

Input Sub-Module

This sub-module provides 16 digital input channels to the TSX ADM 350 10 module connected to the E Series RTU via TCP/IP using the TSX Momentum 170 ENT 110 00 Ethernet Adapter. The digital input channels can be connected to Boolean variables within an ISaGRAF application. Connected ISaGRAF variables are updated continuously with the *Current State* of the I/O point. This information is cache internally by the E Series RTU and made available to the ISaGRAF application.

Board Configuration

data_update_rate	in mS
Timeout	in mS
ip_address	IP address of TSX Ethernet Adapter in 111.222.333.444 format.

Digital Output Sub-Module

This sub-module provides 16 digital output channels to the TSX ADM 350 10 module connected to the SCADAPack E Series RTU via TCP/IP using the TSX Momentum 170 ENT 110 00 Ethernet Adapter. The digital output channels can be connected to relay coil outputs and are updated continuously with the *Current State* of the ISaGRAF variables. This information is cache internally by the SCADAPack RTU and made available to the ISaGRAF application.

Board Configuration

must_write_rate	in mS
timeout	in mS
ip_address	IP address of TSX Ethernet Adapter in 111.222.333.444 format. Must be same as above

DOHoldup Output Sub-Module

This sub-module provides 1 analog output channel to allow for the configuration of the 'Output Holdup Timeout Value'. This variable should be larger than 10x the value set in the digital output's 'must_write_rate' parameter.

Valid variable values are 31-5999, allowing an 'Output Holdup Timeout Value' of approximately 300-60000mS (~30mS-60s), given that each count represents 10mS.

Board Configuration

ip_address	IP address of Ethernet Adapter in 111.222.333.444 format. Must be same as above

Status Sub-Module

This sub-module provides 13 analog input channels to read the module status and configuration information into ISaGRAF Integer variables. The first 4 channels always return constant values that depend on the type of module. However, all other channels return a varying value represented by 'xx' in the table below. Each input channel returns the following information:

Channel	Return Value	Description
1	13	Length of this status block
2	1	I/O module quantity of input words
3	1	I/O module quantity of output words
4	8	I/O module ID
5	xx	Comms Adapter Revision number
6	xx	ASCII header block length
7	xx	Last IP to communicate (low word)
8	xx	Remaining Write ownership reservation time (mS)
9	Xx	Remaining outputs holdup time (mS)
10	xx	I/O module health 0 => Not healthy 32768 => Healthy
11	xx	I/O module last error value
12	xx	I/O module error counter (0-65535)
13	xx	Last IP to communicate (high word)

Board Configuration

data_update_rate	in mS
timeout	in mS
ip_address	IP address of XXX in 111.222.333.444 format. Must be same as above

5.6 TSX Momentum 32 Channel Digital Output Module

For a Schneider Automation TSX Momentum 170 ADO 350 00 I/O module connected to a SCADAPack E Series RTU via the TSX Momentum 170 ENT 110 00 Ethernet Communication Adapter, the **ado35000** I/O can be used. This module provides 16 digital input and 16 digital output channels for field data, 1 analog output channel to configure the output holdup time as well as the standard 13 analog input channels to read the status of the I/O module into the SCADAPack RTU.

Digital Output Sub-Module

This sub-module provides 32 digital output channels to the TSX ADO 350 00 module connected to the E Series RTU via TCP/IP using the TSX Momentum 170 ENT 110 00 Ethernet Adapter. The digital output channels can be connected to relay coil outputs and are updated continuously with the *Current State* of the ISaGRAF variables. This information is cache internally by the E Series RTU and made available to the ISaGRAF application.

Board Configuration

must_write_rate	in mS
timeout	in mS
ip_address	IP address of XXX in 111.222.333.444 format. Must be same as above

DOHoldup Output Sub-Module

This sub-module provides 1 analog output channel to allow for the configuration of the 'Output Holdup Timeout Value'. This variable should be larger than 10x the value set in the digital output's 'must_write_rate' parameter.

Valid variable values are 31-5999, allowing an 'Output Holdup Timeout Value' of approximately 300-60000mS (~30mS-60s), given that each count represents 10mS.

Board Configuration

ip_address	IP address of XXX in 111.222.333.444 format. Must be same as above

Status Sub-Module

This sub-module provides 13 analog input channels to read the module status and configuration information into ISaGRAF Integer variables. The first 4 channels always return constant values that depend on the type of module. However, all other channels return a varying value represented by 'xx' in the table below. Each input channel returns the following information:

Channel	Return Value	Description
1	13	Length of this status block
2	0	I/O module quantity of input words
3	2	I/O module quantity of output words
4	5	I/O module ID
5	xx	Comms Adapter Revision number
6	xx	ASCII header block length
7	xx	Last IP to communicate (low word)

8	xx	Remaining Write ownership reservation time (mS)
9	xx	Remaining outputs holdup time (mS)
10	xx	I/O module health 0 => Not healthy 32768 => Healthy
11	xx	I/O module last error value
12	xx	I/O module error counter (0-65535)
13	xx	Last IP to communicate (high word)

Board Configuration

data_update_rate	in mS
timeout	in mS
ip_address	IP address of XXX in 111.222.333.444 format. Must be same as above

SCADAPack E Series

ISaGRAF ADS Flow Interface Reference

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Document Revisions

Revision	Date	Modification	Author
1.00	14 Sept, 2005	Initial release of SCADAPack E Series ADS Flow Monitor Interface Reference	KN

1 Preface

1.1 Purpose

The purpose of this document is to describe the ADS 3500 Flow Monitor driver implementation for the Control Microsystems SCADAPack E Series RTU[1].

1.2 Assumed Knowledge

Familiarity with the ISaGRAF Workbench recommended.

1.3 Target Audience

- Systems Engineers
- Commissioning Engineers
- Maintenance Technicians

1.4 References

- SCADAPack E Series ISaGRAF Technical Reference Manual
- CJ International ISaGRAF Manuals
- Real Time Open Channel Flow Measurement document dated 13 December 1994
- Information from ADS Australia

[1]Also referred to simply as RTU

2 Overview

The ADS flow monitor communicates with the SCADAPack E Series RTU using an ISaGRAF **adsflow** I/O board through an RTU '*PLC Device*' port. The ADS monitor elements are read and the return values cached in the RTU for access through an ISaGRAF input board. The SCADAPack E Series RTU's handling of the communications is the same as other PLC driver communications. The age and status of the data read from the ADS flow monitor is present in RTU system points that can be accessed from within ISaGRAF or external to the RTU.

The ADS 3500 flow monitor must be fitted with the multiplexer communication option in order to support communication with the E Series RTU.

3 ISaGRAF I/O Board Interface

The **adsflow** ISaGRAF input board uses an RTU '*PLC Device*' port to communicate with the ADS Flow Monitor. The **data_update_rate** field of the adsflow ISaGRAF board (default 300) is the configurable number of *seconds* after which the RTU will request element array values from the ADS flow monitor. The RTU will also request data from the ADS flow monitor constantly if the cache data age is greater than the **data_update_rate**. I.e. if communications are lost with the monitor, they are retried until the communications are restored.

The **ADS_addr** field of the ISaGRAF board is the configurable address of the ADS flow monitor, usually the last two digits of the serial number on the top of the ADS flow monitor. For example, if the serial number on the top of the monitor read **4237**, the user would configure the value **37** in the **ADS_addr** of the board.

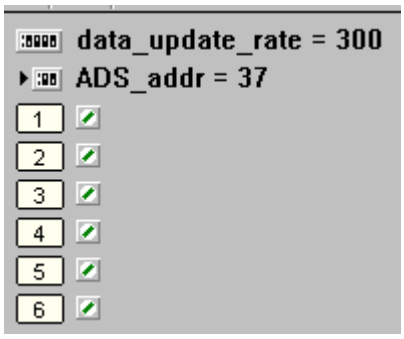

Figure 1: adsflow ISaGRAF board.

The values returned by the adsflow board are floating point values, representing the Local Data elements in the ADS flow monitor.

ISaGRAF Analog Input (Real) variables should be attached to the Input Board channels as required. The Input Board channels represent the following data values from the ADS monitor:

1 - Depth of flow as determined by the ultrasonic depth sensor

2 - Depth of flow as determined by the pressure sensor for surcharge measurements

3 - Flow velocity

4 - Flow Rate

5 - Current days flow total so far

6 - Previous days flow total

4 Communication Interface

The SCADAPack E Series RTU communicates with the ADS flow monitor using an RTU serial port configured as '*PLC Device*'. This port must configured to communicate at 2400 baud, 8 data bits, 1 stop bit, and no parity.

The ADS Flow Monitor has two external communication connectors that are internally multiplexed a direct RS232 connection and a dial-up modem connection. The SCADAPack E Series RTU will be connected to the direct RS232 connection of the ADS. The RTU will determine the state of the multiplexer, and thus its potential to communicate with the monitor at that point in time, by reading the state of Pin 1 (DCD) of the direct connect plug, which is connected to CTS of the RTU. If CTS is active, the RTU will assume that the ADS flow monitor is connected to its modem port, and as such, will not attempt to communicate with it[2]. The RTU must have an inactive state on its CTS input in order to communicate with the ADS flow monitor[3].

A cable configuration for mating the ADS flow monitor Direct Connect cable to the RTU, shown in

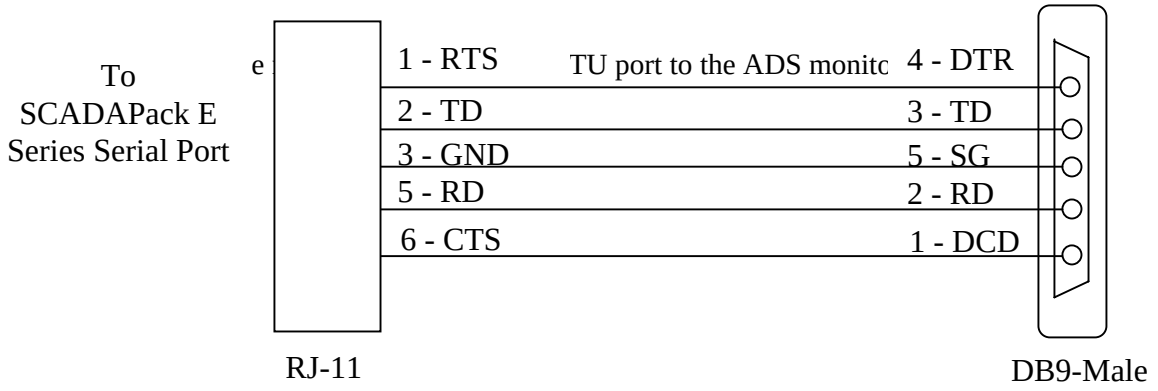

Figure 2: RJ-11 to DB9-M Converter Cable

The RTU will attempt to communicate with the ADS flow monitor by asserting Pin 4 (DTR), wait two seconds, and transmit a request for the first element through the TD line. The RTU will monitor the RD line for a valid response. If a valid response is received and decoded, the RTU will request the next element and wait for a response. This will continue until all the elements are read or an element read has failed. The RTU will drop DTR upon completion of the request regardless of the success of all the elements having been read. See State Diagram in Figure 3.

[2] ADS advises that the ADS 3500 flow monitor multiplexer option implements the opposite logic to the ADS 3600 flow monitor multiplexer defined in the ADS flow monitor documentation.

[3] For testing purposes, the ADS flow monitor can be polled by a PDS RTU via PSTN by using a PDS Modem Cable with the DCD line broken. Configure your local modem to ignore DTR (AT&D0), dial the remote ADS monitor from a PC using a terminal program (ATDT<number>), disconnect the PC from the modem, then connect the PDS modem cable to the modem and to the PDS RTU's 'PLC Device' port.

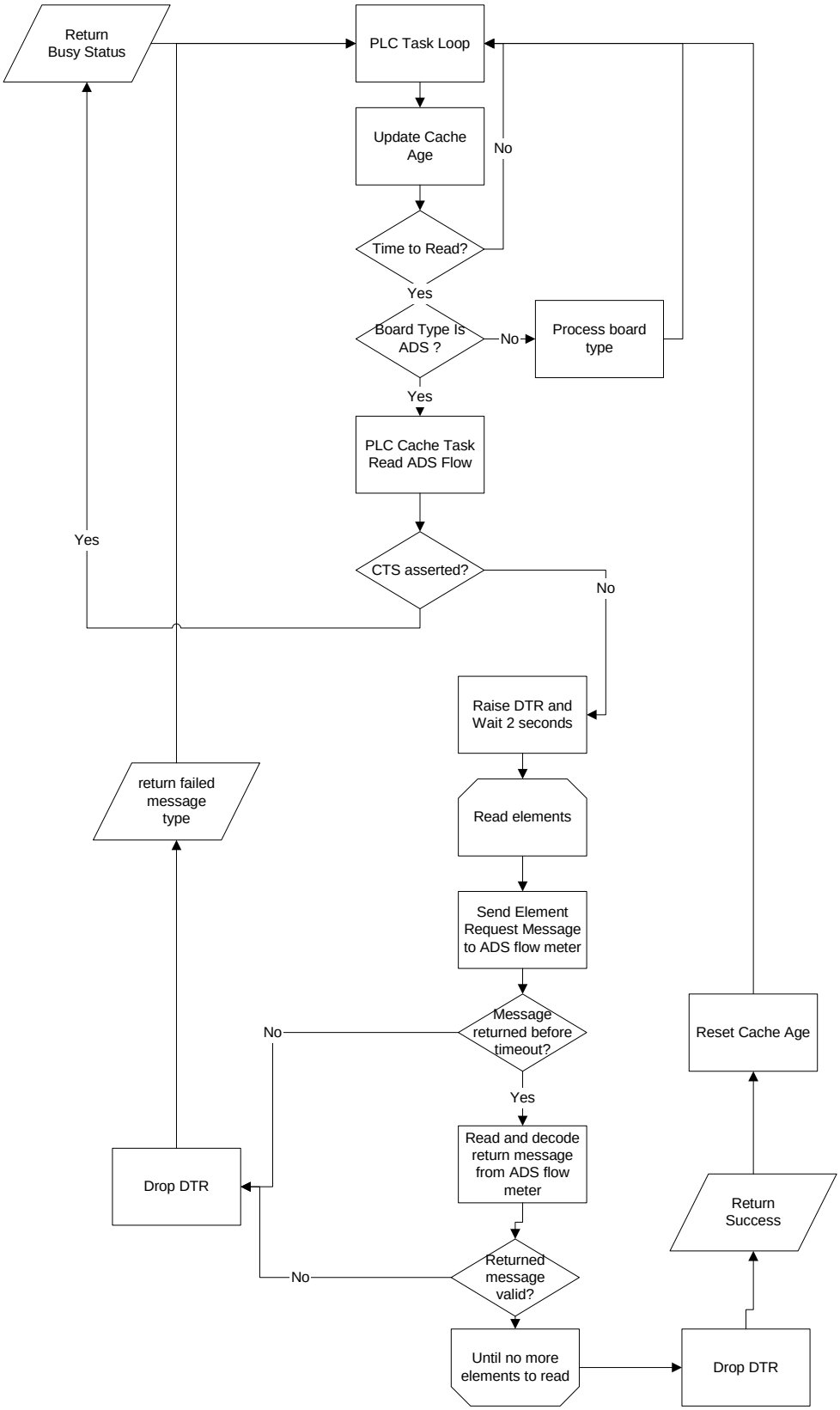

Figure 3: ADS Driver State Diagram

5 Data Communications Protocol

The ADS protocol supports addressing of the ADS monitor, and as such supports multiple ADS units on the same serial channel. If external multi-drop communication hardware is provided, it is possible for the SCADAPack E Series RTU to communicate with multiple ADS flow devices by adding additional **adsflow** ISaGRAF boards to the ISaGRAF application.

5.1 Request Message Format

The message format used to communicate requests to the ADS flow monitor can be broken up into three major parts- the Header, Body, and Tail.

HEADER						**BODY**	**TAIL**	
SOH	DEST	ORG	CTL	ID	LEN	Message Body (LEN bytes)	CRC Low	CRC Hi

Header - six bytes

SOH - 1 byte signifying the Start of Header. Always 01H;
DEST - 1 byte indicating the address of the intended message receiver;
ORG - 1 byte indicating the address of the message transmitter (always set to AF hex for the RTU)
CTL - 1 byte control word. Always set to 00H
ID - 1 byte Message ID. 11H is the only ID supported by the RTU
LEN - 1 byte Message Body length. The RTU only supports a length of 04H.

Body - LEN bytes

BODY - message body, containing the data request

Tail - 2 bytes

CRC(L) - Low byte of CRC; and
CRC(H) - High byte of CRC.

5.2 CRC16 Calculation Method

The CRC method used is a standard CRC-16 with the following polynomial:

$G(x) = x16 + x15 + x2 + x1$
Starting Value = 0000H
Feedback = A001H

The CRC is calculated using the body and header of the message.

5.3 Array Element Request

The Local Data Storage Array in the ADS flow monitor orders the data as follows:

LD(0) - Depth of flow as determined by the ultrasonic depth sensor;
LD(1) - Depth of flow as determined by the pressure sensor for surcharge measurements;
LD(2) - Flow velocity;
LD(3) - Flow Rate;
LD(4) - Current days flow total so far; and
LD(5) - Previous days flow total.

The RTU sends a Local Data Array Element Request message to the ADS flow monitor. The value of the Array Index can be from 0 to 5 (total six elements), and takes the following format:

Index	SOH	DEST	ORG	CTL	ID	LEN	BODY				CRC Low	CRC Hi
0	01		AF	00	11	04	'L'	'D'	'\0'	00		
1	01		AF	00	11	04	'L'	'D'	'\0'	01		
2	01		AF	00	11	04	'L'	'D'	'\0'	02		
3	01		AF	00	11	04	'L'	'D'	'\0'	03		
4	01		AF	00	11	04	'L'	'D'	'\0'	04		
5	01		AF	00	11	04	'L'	'D'	'\0'	05		

The value of DEST is inserted by the user in the PLC I/O board, which is the last two digits of the serial number on the top of the ADS monitor. The RTU has its address set to AF (hex). Note that all values are hexadecimal except for 'L', 'D', & '\0', which are ASCII characters. The CRC is calculated using the body and header of the message.

5.4 Array Element Response

The ADS flow monitor will respond to the Array Element Request in the following response format:

SOH	DEST	ORG	CTL	ID	LEN	BODY(float value)				CRC Low	CRC Hi
01	AF		00	11	04	(MSB)			(LSB)		

Note that the returned float value is in the IEEE 32-bit single precision format with the most significant byte transmitted first. The CRC is calculated using the body and header of the message. The ORG address is the address of the ADS flow device.

5.5 Typical Message Exchange

The following is an example message pair exchanged between E Series RTU and ADS Flow Meter (bytes shown in Hex in transmission order):

← E Series RTU: 01 37 AF 00 11 04 4C 44 00 00 CD C8
→ ADS Flow: 01 AF 37 00 11 04 3F 9D F3 B6 00 FD

6 System Points

RTU system points are provided to indicate the status of the ISaGRAF I/O boards that are used for Slave I/O communications with devices such as PLCs, and the ADS Flow Monitor.

Where multiple ISaGRAF Slave I/O boards are present in an ISaGRAF application, the next sequential system point pairs are used for the next Slave I/O board, regardless of whether the ISaGRAF boards are consecutive as shown in the table below.

Point Description	Point Number	Point Type
ISaGRAF Slave I/O board 1 communication status	53300	16-bit unsigned integer (read-only)
ISaGRAF Slave I/O board 1 data cache age	53301	16-bit unsigned integer (read-only)
ISaGRAF Slave I/O board 2 communication status	53302	16-bit unsigned integer (read-only)
ISaGRAF Slave I/O board 2 data cache age	53303	16-bit unsigned integer (read-only)
…		
ISaGRAF Slave I/O board 50 communication status	53398	16-bit unsigned integer (read-only)
ISaGRAF Slave I/O board 50 data cache age	53399	16-bit unsigned integer (read-only)

Each ISaGRAF Slave I/O board has two system points associated with it. The communications status and the data cache age.

The communication status indicates the status of the communication with the ADS flow monitor for all data points on the I/O board. For more information see section ***6.1 - Return Status Values***.

The age of the cached data is stored in the Slave I/O Board Data Cache Age system point for that I/O board. For more information see section ***6.2 - Data Cache Age***.

6.1 Return Status Values

The return status values for the **adsflow** board communications status are as follows:

Status	Comment	Value
Success	No error encountered	0
Unknown Error	An undefined error has occurred.	101
Illegal Address	The ADS flow monitor did not give the correct response address in its return message	103
Timeout	The ADS flow monitor did not respond	104
Corrupt Message	The message from the ADS flow monitor was not understood by the RTU.	106
Busy	The ADS Flow monitor has DCD indication asserted. The ADS monitor is probably communicating through the modem port.	107

6.2 Data Cache Age

The age of the data in the RTU cache for the ADS flow monitor array elements are presented by reading system point for the I/O board (usually Slave I/O board 1 system points). The cache age is initialized to zero when the ISaGRAF application starts and increases until a successful read occurs, after which time the value is reset to zero.

This system point may be used by the ISaGRAF application to determine the suitability of using the input data from the I/O board.

7 Diagnostics

The SCADAPack E Series RTU indicates configuration or communication diagnostics via Diagnostic Display mode from a Command line session.

Configuration diagnostics are indicated via ISaGRAF I/O board messages and are always displayed when in Diagnostic Display mode (use DIAG command at command prompt).

Communication diagnostics for the ADS Flow meter are enabled when the following commands are entered at the RTU command prompt:

```
PLCDIAG ENABLE COMMS_ERROR
DIAG
```

SCADAPack E Series

AGA Function Block Reference

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Document Revisions

Revision	Date	Modification	Author
1.00	19 September 2005	Initial release of SCADAPack E Series AGA Function Block Reference	KN

1 Introduction

The following function blocks are for use in a SCADAPack E Series RTU. The function blocks are based on the following documentation:

- AGA Report 3 – Part 4 (1992) - Orifice Metering. Background, Development, Implementation Procedure.
- AGA Report 8 (1992) – Compressibility factors of Natural Gas and other Related Hydrocarbons.
- AGA Report 7 – Measurement of Gas by Turbine Meters.
- AGA Report 9 – Measurement of Gas by Multipath Ultrasonic Meters.

Section 4.3.4 of AGA Report3 (page 48) contains example parameters to plug into the AGA 3 function blocks. These should be within 50 parts per million (as stated on that page).

2 Systems of Units

The AGA Function blocks defined in this document allow the user to select the systems of units to be used as inputs and outputs. The systems of units available to the user are: U.S., IP, Metric, and S.I.

The following table gives the corresponding units to the different systems of units:

Variables	U.S.	IP	Metric	S.I.
TORF, TPIPE, TB, TH, TF, TD, TGR, TA, THGC, TWC, TAC	F	F	C	K
PB, PGR, PD, PF	PSIA	PSIA	Bar	MPA(*)
HW	IN H_2O	IN H_2O	Millibar	PA
GLPDWC, GLHWDWC, GLHG, GLPDWL, GLHWDWL, GLH2OL	Ft/Sec^2	Ft/Sec^2	mm/Sec^2	M/Sec^2
OD, DP	IN	Ft	mm	M
HV	BTU/Ft^3	BTU/Ft^3	MJ/M^3	MJ/M^3
H, HH_2O, HPDW, HHWDW	Ft	Ft	M	M
QV	Ft^3/Hr	Ft^3/Hr	M^3/Hr	M^3/S
RHOS, RHOB, RHOTP	LBM/Ft^3	LBM/Ft^3	Kg/M^3	Kg/M^3

(*) NOTE: S.I uses PA for pressure instead of MPA but because PA is too small we use MPA in this code for improved numeric resolution.

Also note that gas Relative Density (GRGR) can also be referred to as Specific Gravity.

2.1 Other Useful Conversions

1 PSI = 0.06895 BAR

1 BAR = 14.50326 PSI

1PSI = 6.8948 KPa

1 BAR = 100KPa (0.1MPa)

oC = 5/9(oF – 32)

oF = 9/5 oC + 32

3 Function Blocks

3.1 Introduction

The following sections outline the use of ISaGRAF's AGA function blocks. They can be divided into 2 main groups:

1) Function blocks that are used to determine the compressibility of a gas (AGA Report 8), and
2) Function blocks that are used to calculate the flow rate of a gas (AGA Report 3, AGA Report 7, and AGA Report 9).

AGA 3 concerns itself with calculating the flow of gas in a pipe when the measurements are taken using an orifice meter. AGA 7 calculates the flow using turbine meters.

Note:	Each AGA computation (8, 3, and 7) can require the use of more than one function block. If all of the required function blocks required for a specific calculation are not used, then the results for the calculation will not be available.

3.2 AGA 8

There are 2 main methods for calculating a gas supercompressibility factor, as outlined in American Gas Association (AGA) Report 8. These are the **Detailed Method** and the **Gross Method**.

For both of the methods, the user will generally just require the running of the function block once during startup. The reason being, that unless the gas composition changes, there is no need to repeatedly re-calculate the compressibility of the gas. These calculations can place a considerable loading on the RTU processor and affect the ISaGRAF scan rate, so the less often they are run the better.

For the "Detailed Method" use both AGA8DTGC and AGA8DTL function blocks. For the "Gross Method" use just AGA8GRS function block.

3.2.1 Detailed Method

The Detailed Method requires the knowledge of the exact composition of the gas. The AGA 8 Detail calculation is broken into 2 ISaGRAF C-function blocks, which must be used together: AGA8DTGC and AGA8DTL.

3.2.1.1 AGA 8 Detail Gas Composition Function Block (AGA8DTGC).

Inputs to the first function block (aga8dtgc) are the percentage molar gas compositions. This function simply stores some parameters required by AGA8DTL, and therefore does not need triggering. It must appear before the following AGA 8 function block (AGA8DTL).

Inputs:

GC0(real) - methane mole fraction

GC1(real) - nitrogen mole fraction

GC2(real) - carbon dioxide mole fraction

GC3(real) - ethane mole fraction

GC4(real) - propane mole fraction

GC5(real) - water mole fraction

GC6(real) - hydrogen sulfide mole fraction

GC7(real) - hydrogen mole fraction

GC8(real) - carbon monoxide mole fraction

GC9(real) - oxygen mole fraction

GC10(real) - i-butane mole fraction

GC11(real) - n-butane mole fraction

GC12(real) - i-pentane mole fraction

GC13(real) - n-pentane mole fraction

GC14(real) - hexane mole fraction

GC15(real) - heptane mole fraction

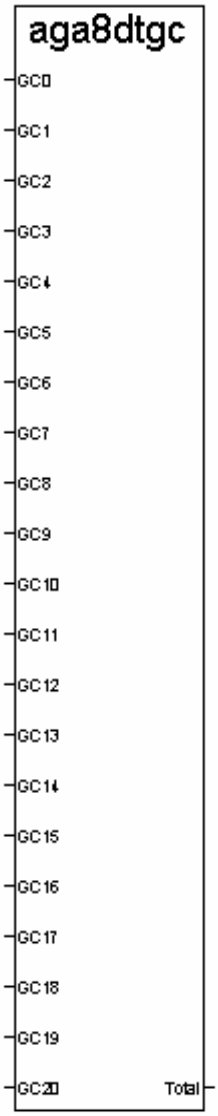
GC16(real) - octane mole fraction

GC17(real) - nonane mole fraction

GC18(real) - decane mole fraction

GC19(real) - helium mole fraction

GC20(real) - argon mole fraction



Returns: Total(real)

Prototype: AGA8DTGC(GC0..GC20)

Total := AGA8DTGC.Total

The output value (Total) is the sum of all the input molar percentages. This value must be between 0.98 and 1.02 for the AGA8DTL function block to work correctly (see Section ***5-Function Block Error Codes***).

The above function block requires no trigger, and must be used in conjunction with the following block to complete the AGA 8 Detailed calculations.

3.2.1.2 AGA 8 Detail Function Block (AGA8DTL).

The second AGA 8 function block (aga8dtl) must be inserted after the above gas composition function block.

Inputs:

REQ(boo) - Initiate AGA 8 Detailed Method calculation. Rising edge triggered.

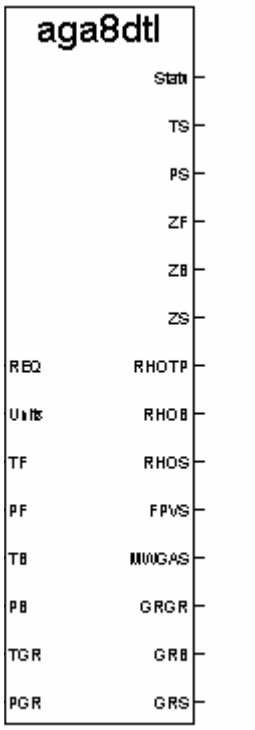
Units(ana) - Units used in inputs (See Section 2)

1 = U.S.

2 = IP

3 = Metric

4 = S.I.



TF(real) - flowing gas temperature

PF(real) - flowing gas pressure

TB(real) - base temperature

PB(real) - base pressure

TGR(real) - reference temperature for relative density

PGR(real) - reference pressure for relative density

Returns:

Status(ana) - Indicates return status (see Section 5).

TS(real) - standard temperature (288.706 deg K, i.e. 60.0 deg F)

PS(real) - standard pressure (in MPa equal to 14.73 psia)

ZF(real) - gas compressibility factor @ tf & pf

ZB(real) - gas compressibility factor @ tb & pb

ZS(real) - gas compressibility factor @ ts & ps

RHOTP(real) - density of fluid at flowing (tf & pf) conditions (kg/m^3)

RHOB(real) - density of fluid at base (tb & pb) conditions (kg/m^3)

RHOS(real) - density of fluid at standard (ts & ps) conditions (kg/m^3)

FPVS(real) - gas supercompressibility factor @ ts & ps

MWGAS(real) - molecular weight of gas

GRGR(real) - gas relative density at reference (tgr & pgr) conditions

GRB(real) - gas relative density at base (tb & pb) conditions

GRS(real) - gas relative density at standard (ts & ps) conditions

Prototype: - AGA8DTL(REQ,UNITS,TF,PF,TB,PB,TGR,PGR)

3.2.2 Gross Method

The Gross Method for calculating gas supercompressability uses a combination of the following inputs (when the exact composition of the gas is not known):

1) Volumetric Gross Heating Value of the gas mixture.

2) Relative Density of gas at Reference conditions (TGR and PGR).

3) Mole Fraction of Carbon Dioxide.

4) Mole fraction of Nitrogen.

Gross Method 1 uses the inputs 1, 2, and 3 above.

Gross Method 2 uses the inputs 2, 3, and 4 above.

Inputs:

REQ(boo) - Initiate AGA 8 Gross Method calculation. Rising edge triggered.

Units(ana) - Units used in inputs (See Section 2)

1 = U.S.

2 = IP

3 = Metric

4 = S.I.

METHOD(ana) - method to be used

1=enter heating value, mole CO2 fraction and gas relative density

2=enter mole CO2 fraction, mole N2 fraction and gas relative density

HV(real) - gross volumetric heating value for the gas mixture (input for method 1)

GRGR(real) - gas relative density at reference (tgr & pgr) conditions (input for method 1 & 2)

GC1(real) - nitrogen mole fraction (input for method 2)

GC2(real) - carbon dioxide mole fraction (input for method 1 & 2)

GC3(real) - hydrogen mole fraction (input for method 1 & 2)

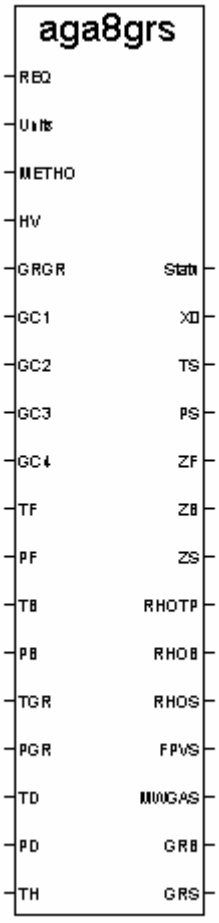
GC4(real) - carbon monoxide mole fraction (input for method 1 & 2)

TF(real) - flowing gas temperature

PF(real) - flowing gas pressure

TB(real) - base temperature

PB(real) - base pressure



TGR(real) - reference temperature for relative density

PGR(real) - reference pressure for relative density

TD(real) - reference temperature for calorimeter density

PD(real) - reference pressure for calorimeter density

TH(real) - reference temperature for combustion

Returns:

Status(ana) - indicates return status (see Section 5).

X0(real) - equivalent hydrocarbon mole fraction

TS(real) - standard temperature (519.67 deg R which is 60.0 deg F)

PS(real) - standard pressure (in MPa equal to 14.73 psia)

ZF(real) - gas compressibility factor @ tf & pf

ZB(real) - gas compressibility factor @ tb & pb

ZS(real) - gas compressibility factor @ ts & ps

RHOTP(real) - density of fluid at flowing (tf & pf) conditions

RHOB(real) - density of fluid at base (tb & pb) conditions

RHOS(real) - density of fluid at standard (ts & ps) conditions

FPVS(real) - gas supercompressibility factor @ ts & ps

MWGAS(real) - molecular weight of gas

GRB(real) - gas relative density at base (tb & pb) conditions

GRS(real) - gas relative density at standard (ts & ps) conditions

Prototype: - AGA8GRS(REQ,UNITS, METHOD, HV, GRGR, GC1, GC1, GC1, TF, PF, TB, PB, TGR, PGR, TD, PD, TH)

3.3 AGA 3

Once the gas compressibility has been calculated using one of the methods above, the AGA 3 function blocks can then be used to calculate the flow rate of the gas. AGA 3 calculations are required when an orifice plate meter is used to measure differential pressures.

Before calculating the flowing rate of the gas, it may be necessary to correct instrumentation calibration. This may be required if any of the following are true:

1) If a deadweight calibrator is used and the gravitational force at the location where calibrated is different to the running location,
2) If a manometer is used the density of the liquid and/or gas may need correction.

To perform instrument calibration correction use ISaGRAF's AGA3CFAC function block.

To calculate the flow rate the user will need to use both the AGA 3 function blocks. The first function block (AGA3STAT) sets some static variables for use in the AGA 3 calculations. The second function block (AGA3ORIF) triggers the actual orifice calculations to occur.

The AGA 3 documentation states that T_S and P_S should be entered, but these are constants (T_S = 60F P_S=14.73PSIA), so they are not required as inputs into the function block.

3.3.1 AGA 3 Instrument Calibration Correction

3.3.1.1 AGA 3 Calibration Factor (AGA3CFAC)

NOTE: The output variable from this function block is an input for the AGA3ORIF function block.

Inputs:

MMAN(ana)=mercury manometer used (1=yes, 2=no)

AL(real)=latitude of meter

H(real)=elevation of meter

TA(real)=ambient temperature

THGC(real)=hg temp. when mano. calibrated

RHOTP(real)=flowing density of fluid

HW(real)=differential

MH2O(ana)=diff. press. calibration using water mano. (1=yes, 2=no)

TWC(real)=water temp. when calibrated

TAC(real)=air temp. when calibrated

ALH2O(real)=latitude of h2o calibration

HH2O(real)=elevation of h2o calibration

MPDW(ana)=static pressure calibration deadweight used (1=yes, 2=no)

GLPD1(real)=gravitational acceleration for weights

ALPDW(real)=latitude of static dw calibration

ALPDW (real)=elevation of static dw calibration

MHWDW(ana)=diff pressure calibration deadweight used (1=yes, 2=no)

GLHW1(real)=gravitational accelaration for weights

ALHWDW(real)=latitude of static dw calibration

HHWDW(real)=elevation of static dw calibration

FUSER(real)=input user calibration factor

MGLMAN(ana)=input (1) or calculate

(2) local gravitational acceleration for mercury manometer.

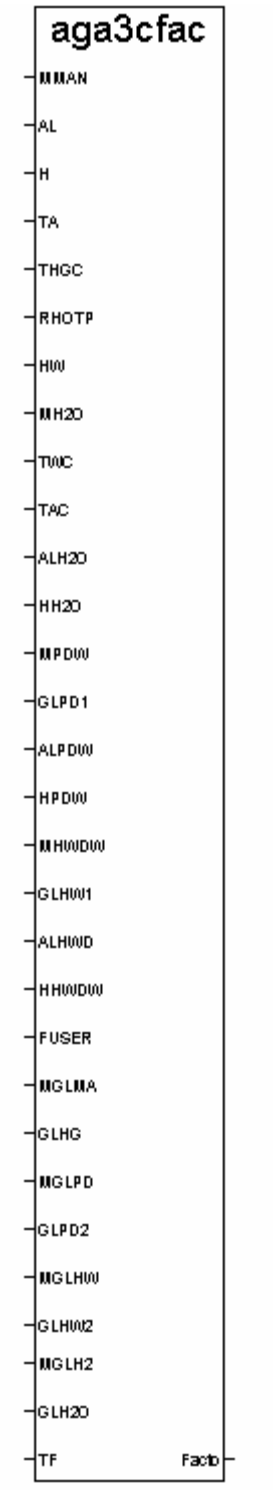
GLHG(real)=input local gravitational acceleration for mercury manometer

MGLPDW(ana)=input (1) or calculate

(2) gravitational acceleration for deadweight static pressure

GLPD2(real)=input local gravitational acceleration for deadweight static pressure

MGLHWDW(ana)=input (1) or calculate (2) gravitational acceleration for deadweight diff. pressure



GLHW2(real)=input local gravitational acceleration for deadweight diff. pressure

MGLH2O(ana)=input (1) or calculate (2) gravitational acceleration for h2o diff. pressure

GLH2OL(real)=input local gravitational acceleration for h2o diff. pressure

TF(real)=flowing temprature

Returns:

FACTOR(real)= Calibration factors multiplied together

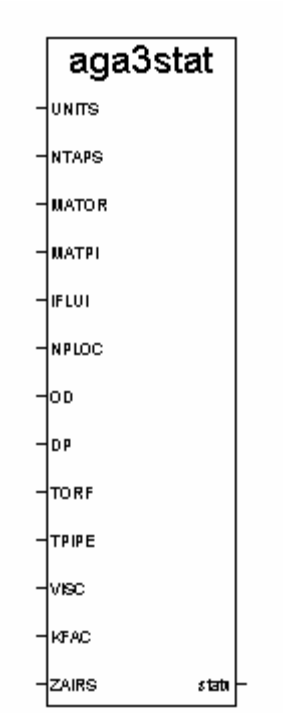
Prototype: - AGA3CFAC(MMAN, AL, H, TA, THGC, RHOTP, HW, MH2O,
TWC, TAC, ALH2O, HH2O, MPDW, GLPD1, ALPDW,
ALPDW, MHWDW, GLHW1, ALHWDW, HHWDW,
FUSER, MGLMAN, GLHG, MGLPDW, GLPD2,
MGLHWDW, GLHW2, MGLH2O, GLH2OL, TF)

3.3.2 AGA 3 Orifice Flow Calculations

3.3.2.1 AGA 3 Static Inputs Function Block (AGA3STAT).

This function simply stores some parameters required by AGA3ORIF, and therefore does not need triggering. It must appear before the following AGA 3 function block (AGA3ORIF).

Inputs:



Units(ana) - Units used in inputs (See Section 2)

1 = U.S.

2 = IP

3 = Metric

4 = S.I.

NTAP(ana) - type of taps (1=flange, 2=pipe)

MATORF(ana) - orifice material

1 = stainless steel,

2 = monel,

3 = carbon steel)

MATPIPE(ana) - pipe material

1 = stainless steel,

2 = monel,

3 = carbon steel)

IFLUID(ana) - 1 compressible fluid, 2 non-compressible fluid

NPLOC(ana) - location of taps (1 upstream, 2 downstream)

OD(real) - temperature uncorrected orifice diameter

PD(real) - temperature uncorrected pipe diameter

TORF(real) - orifice diameter measurement temp

TPIPE(real) - pipe diameter measurement temp.

VISC(real) - absolute viscosity of fluid flowing

(recommended default=0.010268 cp - pg 34 AGA Report 3 - part 4)

KFAC(real) - isentropic exponent (recommended default=1.3 - pg 34 AGA Report 3 - part 4)

ZAIRS(real) - compressibility factor of air at ts & ps, only used in pipe taps to calculate fb.

Returns:

Status(ana) – 0 if no inputs are zero (no error)

1 Error – at least one of the inputs are zero (none should be)

Prototype: - AGA3STAT(Units, NTAP, MATORF, MATPIPE, IFLUID, NPLOC, OD, PD, TORF, TPIPE, VISC, KFAC, ZAIRS)

3.3.2.2 AGA 3 Orifice Calculations Function Block (AGA3ORIF).

This function Block takes more input parameters that are required for the AGA 3 Orifice flow calculations. AGA3ORIF calculates (among other things) the volume flow rate and the mass flow rate of the gas.

If the calibration correction function block (AGA3CFAC) has not been used, then a default value of 1.0 can be used as the FACTR input, otherwise use the output of the AGA3CFAC function block for the FACTR input.

Inputs:

REQ(boo) - Initiate AGA 3 calculation

Units(ana) - Units used in inputs

1 = U.S.

2 = IP

3 = Metric

4 = S.I.

PF(real) - static pressure

TF(real) - flowing temperature

RHOTP(real) - density of fluid at flowing conditions (from AGA 8)

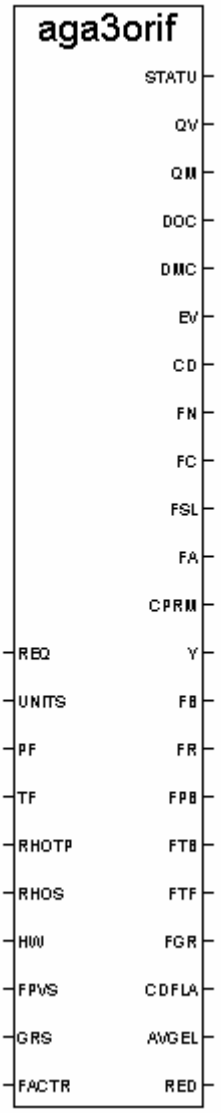
RHOS(real) - density of fluid at standard conditions (from AGA 8)

HW(real) - differential pressure

FPVS(real) - Supercompressibility factor at ts & ps (from AGA 8)

GRS(real) - relative density at standard conditions (ts & ps)

FACTR(real) - all calibration factors (appendix a 1992 AGA3, part 3) and user factor multiplied together. (both pipe & flange)



Returns:

Status(ana) - indicates return (see Section 5).

QV(real) - volume flow rate at standard (ts & ps) conditions

QM(real) - mass flow rate at standard (ts & ps) conditions

DOC(real) - temperature corrected orifice diameter

DMC(real) - temperature corrected pipe diameter

EV(real) - velocity of approach factor (flange)

CD(real) - orifice plate coefficient of discharge (flange)

FN(real) - numeric conversion factor (flange factor)

FC(real) - orifice calculation factor (flange factor)

FSL(real) - orifice slope factor (flange factor)

FA(real) - pipe taps orifice thermal expansion factor (pipe)

CPRM(real) - pipe taps orifice flow constant (pipe)

Y(real) - expansion factor (flange and pipe)

FB(real) - basic orifice factor (pipe)

FR(real) - reynolds number factor (pipe)

FPB(real) - base pressure factor (pipe and flange factor)

FTB(real) - base temperature factor (pipe and flange factor)

FTF(real) - flowing temperature factor (pipe and flange factor)

FGR(real) - relative density factor (pipe and flange factor)

CDFLAG(real) - orifice plate coefficient of discharge bounds flag

AVGVEL(real) - average fluid velocity in pipe

RED(real) - pipe reynolds number

Prototype: - AGA3ORIF(REQ, Units, PF, TF, RHOTP, RHOS, HW, FPVS, GRS, FACTR)

3.4 AGA 7_9

AGA 7 calculations are required when a turbine meter is used to measure gas flows. AGA 9 calculations are required when ultrasonic meters are used to measure gas flows.

Once the gas compressibility has been calculated using one of the AGA 8 methods above, the AGA 7_9 function block can be used to calculate the flow rate of the gas.

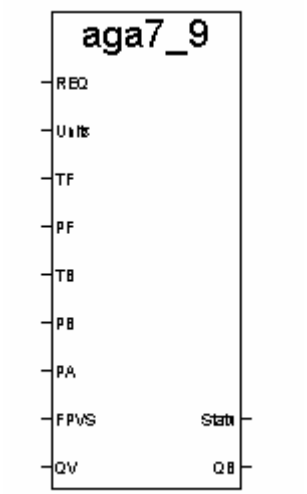
The AGA 7_9 function block primarily concerns itself with converting a flow rate at flowing conditions (calculated by the appropriate flow meter) back to base conditions (T_B and P_B) for billing purposes. The flow rate will be supplied by the flow meter (turbine or ultrasonic) and will be input into the AGA7_9 function block.

Turbine meters will generally output pulses that will need to be converted to a flow rate in the ISaGRAF application.

3.4.1 AGA 7_9 meter flow calculation

3.4.1.1 AGA 7/9 (AGA7_9)

Inputs:



REQ(boo) - Initiate AGA 7/9 calculation

UNITS(ana) - units used in inputs

1 - U.S.

2 - IP

3 - Metric

4 - S.I.

TF(real) - flowing gas temperature

PF(real) – static gauge pressure*

TB(real) - base temperature

PB(real) - base pressure

PA(real) - atmospheric (barometric) pressure*

FPVS(real) - gas supercompressibility factor @ ts & ps

QV(real) - rate of flow at flowing conditions

(*) Pflow = PF + PA, where Pflow is the absolute pressure at flowing conditions. Sometimes this is the pressure that is made available to the function block. Under these circumstances use this Pflow as PF and set PA to 0.

Returns:

STATUS(ANA) - 0 if no error

1 error. if units, or fpvs are 0.

QB(real) - rate of flow at base conditions @ tb & pb

Prototype: - AGA7TRBN(REQ, Units, TF, PF, TB, PB, PA, FPVS, QV)

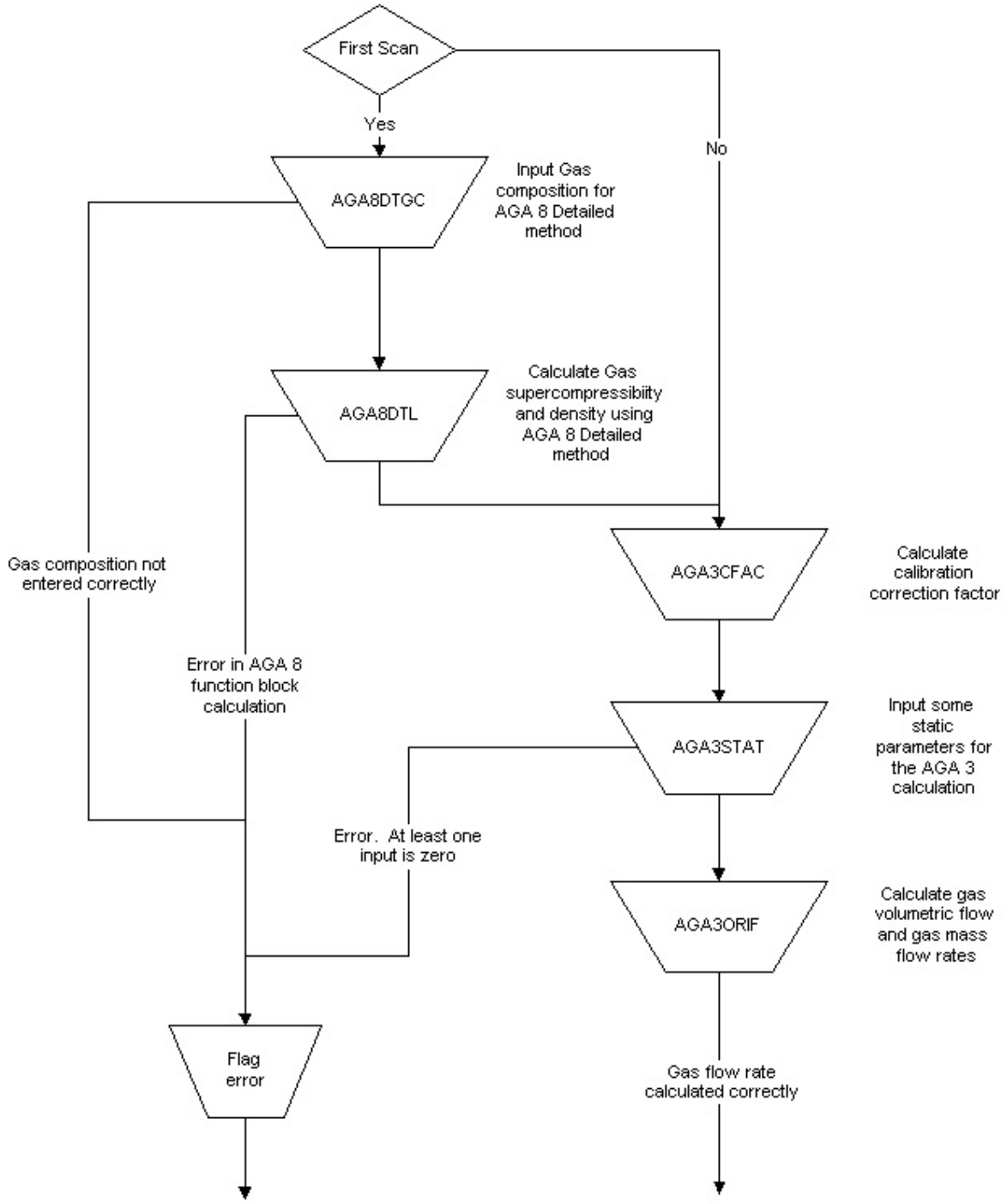
********Need an example here of how to convert pulses into a flow rate**********

4 Flow Chart Examples

4.1 Orifice Flow Calculations Using Detailed Method

For this example, assume that the gas composition is not changing, and the exact gas composition is known (hence use AGA 8 detailed method). We are using an orifice meter for differential pressure input, and also wish to calculate the calibration correction factor.

This example flowchart details which AGA Function Blocks would be used:



5 Function Block Error Codes

The following error codes may appear in the STATUS output parameter from the ISaGRAF AGA Function Blocks.

Code	Severity	Description
0		No warning or error
1	Error	pressure has a negative derivative default gas density used
2	Warning	density in braket exceeds maximum default proceedure used
3	Error	maximum iterations exceeded in braket default density used
4	Error	maximum iterations in ddetail exceeded last density used
5	Error	the root was not bounded in dgross
6	Error	no convergence in dgross
7	Error	virgs squre root negative
8	Error	combined values of grgr, x[2] and hv not consistent
9	Error	invalid term in virgs
For all of the above errors the z factor cannot be calculated and for the warnings the z factor is calculated		
11	Error	method was not 1 or 2
12	Error	flowing pressure (Pf) <= 0.0 or > 1740.0 psia
13	Error	flowing temperature (Tf) < 14.0 or > 149.0 deg F
14	Error	heating value (hv) < 477.0 or > 1211.0 btu/ft^3
15	Error	gas relative density (grgr) < 0.55 or > 0.870
16	Error	mole fraction for N_2 < 0.0 or > 0.50 or for CO_2 < 0.0 or > 0.30 or for H_2 < 0.0 or > 0.10 or for CO < 0.0 or > 0.03
17	Error	reference temperature < 32.0 or > 77.0 deg F
18	Error	reference pressure < 13.0 or > 16.0 psia
For all of the above errors the z factor is not calculated		
22	Warning	flowing pressure (Pf) <= 0.0 or > 1200.0 psia
23	Warning	flowing temperature (Tf) < 32.0 or > 130.0 deg F
24	Warning	heating value (HV) < 805.0 or > 1208.0 btu/ft^3
25	Warning	gas relative density (grgr) < 0.55 or > 0.800
26	Warning	mole fraction for N_2 < 0.0 or > 0.20 or for CO_2 < 0.0 or > 0.20 or for H_2 < 0.0 or > 0.0 or for CO < 0.0 or > 0.0
For all of the above warnings the z factor is calculated		
32	Error	flowing pressure (Pf) < 0.0 or > 40,000. psia
33	Error	flowing temperature (Tf) < -200 or > 760 deg f
36	Error	mole fraction for methane < 0.0 or > 1.0 for nitrogen < 0.0 or > 1.0 for carbon dioxide < 0.0 or > 1.0 for ethane < 0.0 or > 1.0 for propane < 0.0 or > 0.12 for water < 0.0 or > 0.10

		for H_2S < 0.0 or > 1.0 for hydrogen < 0.0 or > 1.0 for carbon monoxide < 0.0 or > 0.03 for oxygen < 0.0 or > 0.21 for butanes < 0.0 or > 0.06 for pentanes < 0.0 or > 0.04 for hexanes + < 0.0 or > 0.10 for helium < 0.0 or > 0.03 for argon < 0.0 or > 1.0
37	Error	reference temperature < 32.0 or > 77.0 deg F
38	Error	reference pressure < 13.0 or > 16.0 psia
39	Error	sum of mole fractions < 0.98 or > 1.020
For all of the above errors the z factor is not calculated		
42	Warning	flowing pressure (Pf) < 0.0 or > 1750. psia
43	Warning	flowing temperature (Tf) < 17 or > 143 deg F
46	Warning	mole fraction for methane < 0.45 or > 1.0 for nitrogen < 0.0 or > 0.5 for carbon dioxide < 0.0 or > 0.3 for ethane < 0.0 or > 0.1 for propane < 0.0 or > 0.04 for water < 0.0 or > 0.0005 for H_2S < 0.0 or > 0.0002 for hydrogen < 0.0 or > 0.1 for carbon monoxide < 0.0 or > 0.03 for oxygen < 0.0 or > 0.0 for butanes < 0.0 or > 0.01 for pentanes < 0.0 or > 0.003 for hexanes + < 0.0 or > 0.002 for helium < 0.0 or > 0.002 for argon < 0.0 or > 0.0
49	Warning	sum of mole fractions < 0.9999 or > 1.0001
For all of the above warnings the z factor is calculated		
51	Error	ntaps was not 1 or 2
52	Error	flowing pressure was <= 0.0 or > 40000. psia
53	Error	flowing temperature < -200. or > 760. deg F
54	Error	matorf or matpipe was not 1, 2 or 3
55	Error	orifice diameter was <= 0 or => 100.0 inches
56	Error	pipe diameter was <= 0 or => 100.0 inches
57	Error	flowing or standard density was <= 0.0 lbm/ft^3
58	Error	differential pressure was <= 0.0 inches H_2O
59	Error	gas viscosity was < 0.005 or > 0.5 centipoises
60	Error	isentropic exponent <= 1.0 or => 2.0
61	Error	ifluid was not 1 or 2
62	Error	standard temperature was not = 60.0 deg F
63	Error	standard pressure was not = 14.73 psia
64	Error	tap location was not 1 or 2 for ntaps=2 (pipe) or tap location was not 1 for ntaps=1 (flange)

65	Error	supercompressibility factor was <= 0.0
66	Error	relative density at standard conditions was < 0.07 or > 1.52
67	Error	calibration factor was <= 0.0
68	Error	compressibility factor at standard conditions <= 0.0
69	Error	beta ratio (do/dm) <= 0.0 or => 1.0
For all of the above errors a flow rate is not calculated		
75	Warning	orifice diameter was < 0.45 inches
76	Warning	pipe diameter was < 2.0 inches
79	Warning	beta ratio (do/dm) was < 0.1 or > 0.75

SCADAPack E Series

DF1 PLC ISaGRAF Interface

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Document Revisions

Revision	Date	Modification	Author
1.10	18 January 2006	Incorporated December 19 changes	KN
1.00	15 Sept, 2005	Initial release of SCADAPack E Series DF1 PLC Interface Manual	KN

1 Preface

1.1 Purpose

The purpose of this document is to describe the DF1 driver implementation for the SCADAPack E Series RTU.

1.2 Assumed Knowledge

Exposure to the ISaGRAF Workbench is recommended.

1.3 Target Audience

- Systems Engineers
- Commissioning Engineers
- Maintenance Technicians

1.4 References

- E Series Configurator User Manual
- CJ International ISaGRAF Manuals
- Allen-Bradley DF1 Protocol and Command Set

2 Overview

The Allen-Bradley PLC communicates with the SCADAPack E Series RTU[1] using an ISaGRAF **df1_xxx** I/O board through an RTU '*PLC Device*' port. The DF1 registers are read and the return values cached in the RTU for access through an ISaGRAF input board. Outputs are written from the RTU's output cache to the DF1 PLC. The SCADAPack E Series RTU's handling of the communications is the same as other PLC driver communications. The age and status of the data read from the DF1 PLC is present in RTU system points that can be accessed from within ISaGRAF, or external to the RTU.

The DF1 Driver supports communications to the following Allen-Bradley PLC's:

- SLC 500 Series
- PLC 5 Series
- DF1 Generic PLC's

[1] Also simply referred to as RTU throughout the rest of this document

3 ISaGRAF I/O Board Interface

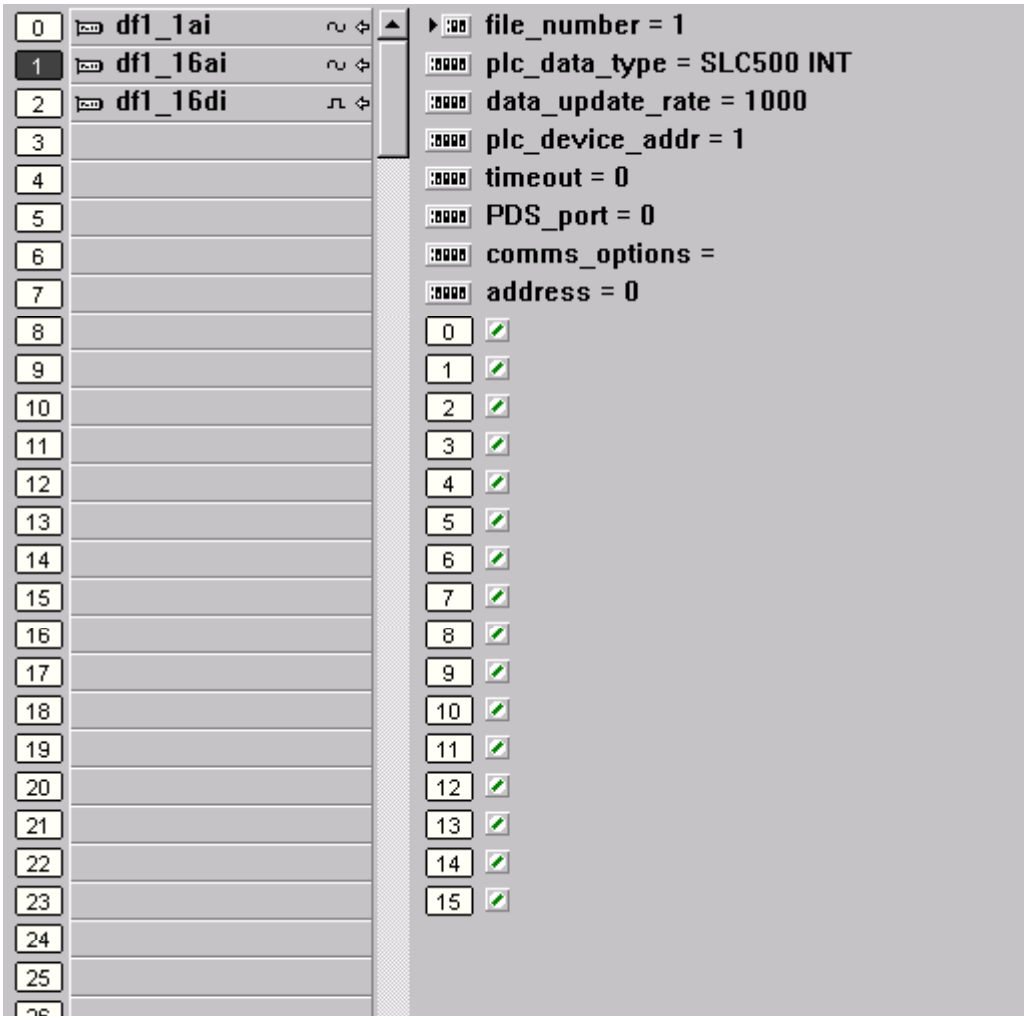
The **df1_xxx** ISaGRAF I/O boards use an RTU port configured as a '*PLC Device*' to communicate with the Allen-Bradley RTU.

3.1 Input Boards

The Input boards supported by the DF1 Driver are:

- 1 analog input
- 16 analog input
- 16 digital input

These all have the same basic layout as shown below.



The **file_number** field of the DF1 ISaGRAF board (default 1) is the configurable file address of the required registers in the DF1 PLC.

The **plc_data_type** field of the DF1 ISaGRAF board (default SLC UINT for the AI boards, and SLC DISCRETE for the DI board) configures the board to communicate with the specified type of register in the specified PLC. Allowable values are outlined below:

Value	Description
SLC500 DISCRETE	Use on a digital board to communicate to a SLC500 PLC.
SLC500 INT	Use on an analog board to communicate to a SLC500 PLC. 16-bit signed value.
SLC500 REAL	Use on an analog board to communicate to a SLC500 PLC. 32-bit floating point value.
PLC5 DISCRETE	Use on a digital board to communicate to a PLC5 PLC.
PLC5 INT	Use on an analog board to communicate to a PLC5 PLC. 16-bit signed value.
PLC5 REAL	Use on an analog board to communicate to a PLC5 PLC. 32-bit floating point value.
GEN DISCRETE	Use on a digital board to communicate to a DF1 Generic PLC.
GEN INT	Use on an analog board to communicate to a DF1 Generic PLC. 16-bit signed value.

The **data_update_rate** field of the **df1_xxx** ISaGRAF board (default 1000) is the configurable number of *seconds* after which the RTU will request element array values from the DF1 PLC. The RTU will also request data from the Allen-Bradley PLC constantly if the cache data age is greater than the **data_update_rate**. I.e. if communications are lost with the PLC, they are retried until the communications are restored.

The **plc_device_addr** (default 1) field of the ISaGRAF board is the configurable address of the Allen-Bradley PLC.

The **timeout** field of the ISaGRAF board driver provides a parameter for specifying the communications timeout on an individual I/O board (i.e. the timeout applies to communications associated with that board). Where this value is "0", the PLC device driver will use the default timeout (1200mS). Units for this field are in milliseconds.

The **PDS_port** field of the ISaGRAF board driver provides a parameter which defines which of multiple E Series RTU ports configured as a "PLC Device" will be used to communicate with the PLC or peripheral device. If only one port is configured as a "PLC Device" this field is ignored. ISaGRAF Slave PLC I/O boards that do not include this parameter can only be used when a single E Series port is configured as a "PLC Device".

The **comms_options** field is a string field that allows the user to set the local DF1 address, whether it's half or full duplex, and whether it uses a CRC or BCC. The format for this string is as follows:

XXX YYYY ZZZ (with spaces in between the parameters) , where:

- XXX is the DF1 Address that the E Series RTU will appear as (default is 0).
- YYYY is HALF or FULL for the duplex setting (default is FULL).
- ZZZ is CRC or BCC (default is CRC).

If any of the comms options fields are not populated, then the default will be used for that parameter.

Note: For Full Duplex operation set the DF1 address to be the address that you want the E Series RTU to appear as. However, for Half-Duplex operation set the DF1 address to be the 'Node Address' specified in the channel configuration of the PLC.

The **address** field of the ISaGRAF board driver specifies the offset address of the board into the specified file (i.e. the file_number above). Range: 0 – 255.

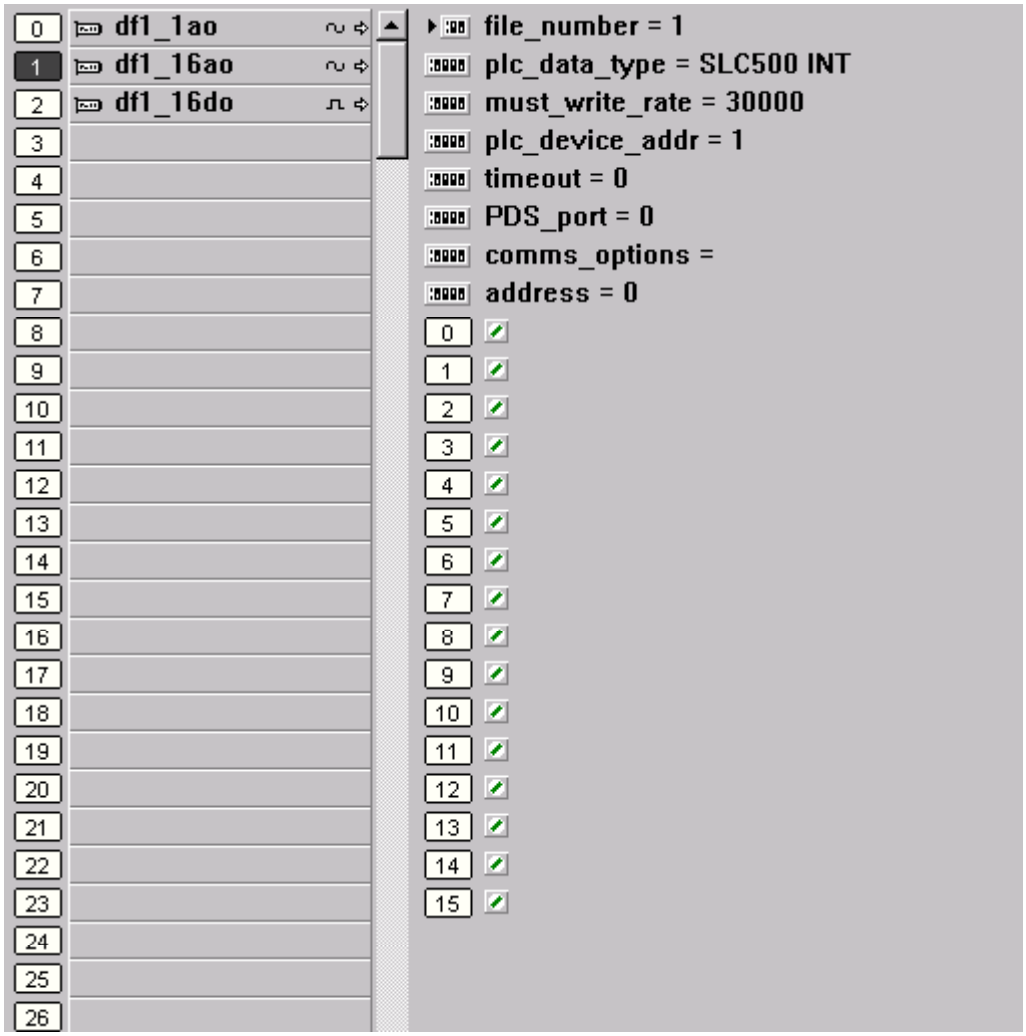
If floating point values are to be read out of the Allen-Bradley PLC (i.e. PLC5 REAL or SLC500 REAL) then ISaGRAF Analog Input (Real) variables should be attached to the Input Board channels as required.

3.2 Output Boards

The Input boards supported by the DF1 Driver are:

- 1 analog output
- 16 analog output
- 16 digital output

These all have the same basic layout as shown below.



Most of these parameters are the same as described for the Input Boards. The only difference is the **must_write_rate**. The unit for this parameter is the Milliseconds and specifies the rate at which the data for the output board is written to the PLC. Between "*must_write_rate*" periods, data is written to

the PLC only when the ISaGRAF output variable values change. Individual I/O boards may have different must write rates allowing prioritization of data sent to a slave PLC.

4 Communications Interface

The SCADAPack E Series RTU communicates with the Allen-Bradley PLC using an RTU serial port configured as a '*PLC Device*'. This port must be configured to with the same settings as the PLC port to which it will be communicating with.

A cable configuration for connecting a SLC500 PLC to the RTU port is shown in Figure 1.

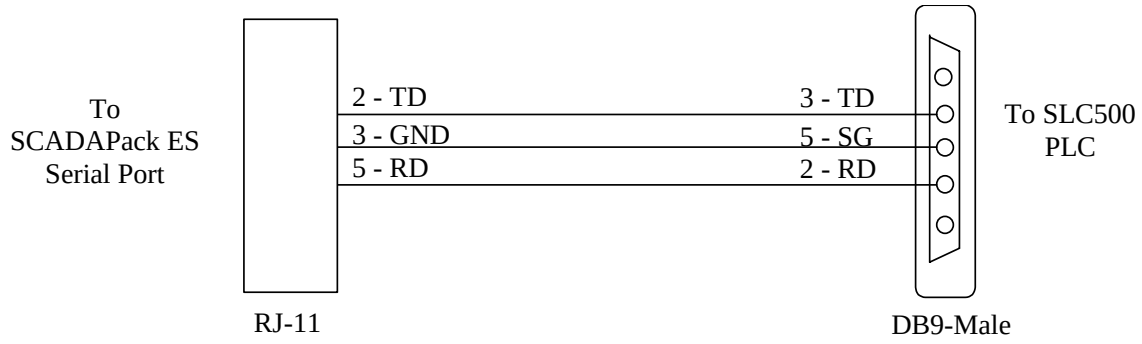


Figure 1: RJ-12 to DB9-M Converter Cable

5 Data Communication Protocol

Refer to *Allen-Bradley DF1 Protocol and Command Set* for a full description of the DF1 protocol as implemented by the driver.

Each of the different DF1 PLC types as selected by the user (SLC500, PLC5, and Generic) result in different DF1 commands being issued. The table below outlines the types of commands issued.

PLC TYPE	**DF1 COMMANDS**
SLC 500	Protected typed logical Read Protected typed logical Write
PLC5	Typed Read Typed Write Read-Modify-Write (bit)
Generic	Unprotected Read Unprotected Write Unprotected bit Write

6 System Points

RTU system points are provided to indicate the status of the ISaGRAF I/O boards that are used for Slave I/O communications with devices such as PLCs, and the DF1 PLC.

Where multiple ISaGRAF Slave I/O boards are present in an ISaGRAF application, consecutive, sequential system point pairs are used for the next Slave I/O board, regardless of what PLC port the boards are connected to. Each ISaGRAF kernel is allocated a separate set of system points for Slave I/O boards.

Each ISaGRAF Slave I/O board has two system points associated with it. The communications status, and the data cache age.

The communication status indicates the status of the communication with the DF1 PLC for all data points on the I/O board. For more information see Section ***6.1-Return Status Values***.

The age of the cached data is stored in the Slave I/O Board Data Cache Age system point for that I/O board. For more information see section ***6.2 - Data Cache Age***.

The RTU Slave I/O board status system points for ISaGRAF Kernel 1 are as follows.

System Point Description	Point Number	Point Type
ISaGRAF Kernel 1 Slave I/O board 1 communication status	53300	16-bit unsigned integer (read-only)
ISaGRAF Kernel 1 Slave I/O board 1 data cache time	53301	16-bit unsigned integer (read-only)
ISaGRAF Kernel 1 Slave I/O board 2 communication status	53302	16-bit unsigned integer (read-only)
ISaGRAF Kernel 1 Slave I/O board 2 data cache time	53303	16-bit unsigned integer (read-only)
…		
ISaGRAF Kernel 1 Slave I/O board 60 communication status	53418	16-bit unsigned integer (read-only)
ISaGRAF Kernel 1 Slave I/O board 60 data cache time	53419	16-bit unsigned integer (read-only)

The RTU Slave I/O board status system points for ISaGRAF Kernel 2 are as follows.

System Point Description	Point Number	Point Type
ISaGRAF Kernel 2 Slave I/O board 1 communication status	53422	16-bit unsigned integer (read-only)
ISaGRAF Kernel 2 Slave I/O board 1 data cache time	53423	16-bit unsigned integer (read-only)
ISaGRAF Kernel 2 Slave I/O board 2 communication status	53424	16-bit unsigned integer (read-only)
ISaGRAF Kernel 2 Slave I/O board 2 data cache time	53425	16-bit unsigned integer (read-only)
…		

System Point Description	Point Number	Point Type
ISaGRAF Kernel 2 Slave I/O board 14 communication status	53448	16-bit unsigned integer (read-only)
ISaGRAF Kernel 2 Slave I/O board 14 data cache time	53449	16-bit unsigned integer (read-only)

6.1 Return Status Values

The return status values for the **df1_xxx** board communications status are as follows:

Status	Comment	Value
Success	No error encountered	0
Unknown Error	An undefined error has occurred.	101
Illegal Address	The DF1 PLC did not give the correct response address in its return message	103
Timeout	The DF1 PLC did not respond	104
Corrupt Message	The message from the DF1 PLC was not understood by the RTU.	106
Busy	The DF1 PLC is busy.	107
Undefined address	The DF1 PLC does not have the requested address defined.	108

6.2 Data Cache Age

The age of the data in the RTU cache for the DF1 PLC array elements are presented by reading system point for the I/O board (usually Slave I/O board 1 system points). The cache age is initialized to zero when the ISaGRAF application starts and increases until a successful read occurs, after which time the value is reset to zero.

This system point may be used by the ISaGRAF application to determine the suitability of using the input data from the I/O board.

7 Diagnostics

The SCADAPack E Series RTU indicates configuration or communication diagnostics via Diagnostic Display mode from a Command line session.

Configuration diagnostics are indicated via ISaGRAF I/O board messages and are always displayed when in Diagnostic Display mode (use DIAG command at command prompt).

Communication diagnostics for the DF1 PLC are enabled when the following commands are entered at the SCADAPack E Series RTU command prompt:

```
PLCDIAG ENABLE COMMS_ERROR
DIAG
```

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Document Revisions

Revision	Date	Modification	Author
1.10	18 January 2006	Incorporate December 19th changes	KN
1.00	16 Sept, 2005	Initial release of SCADAPack E Series Idec PLC Interface Manual	KN

1 Preface

1.1 Purpose

The purpose of this document is to describe the Idec driver implementation for the Control Microsystems SCADAPack E Series RTU[1].

1.2 Assumed Knowledge

Familiarity with the ISaGRAF Workbench recommended.

1.3 Target Audience

- Systems Engineers
- Commissioning Engineers
- Maintenance Technicians

1.4 References

- E Series ISaGRAF Technical Reference Manual
- CJ International ISaGRAF Manuals
- Idec IZUMI FA-1/FA-1J/FA-2/FA-2J Users Manual

[1] Also referred to simply as RTU throughout the rest of this document

2 Overview

The Idec FA-2J PLC communicates with the SCADAPack E Series RTU using an ISaGRAF **idecxxx** I/O board through an RTU serial port configured as a *'PLC Device'*. The Idec registers are read and the return values cached in the RTU for access through an ISaGRAF input board. Outputs are written from the RTU's output cache to the Idec PLC. The SCADAPack E Series RTU's handling of the communications is the same as other PLC driver communications. The age and status of the data read from the Idec PLC is present in RTU system points that can be accessed from within ISaGRAF, or external to the RTU.

The Idec Driver supports communications to the following Idec PLC's:

- FA-1 and FA-1J series (Theses PLCs don't support expansion areas and data registers)
- FA-2 and FA2J series

3 ISaGRAF I/O Board Interface

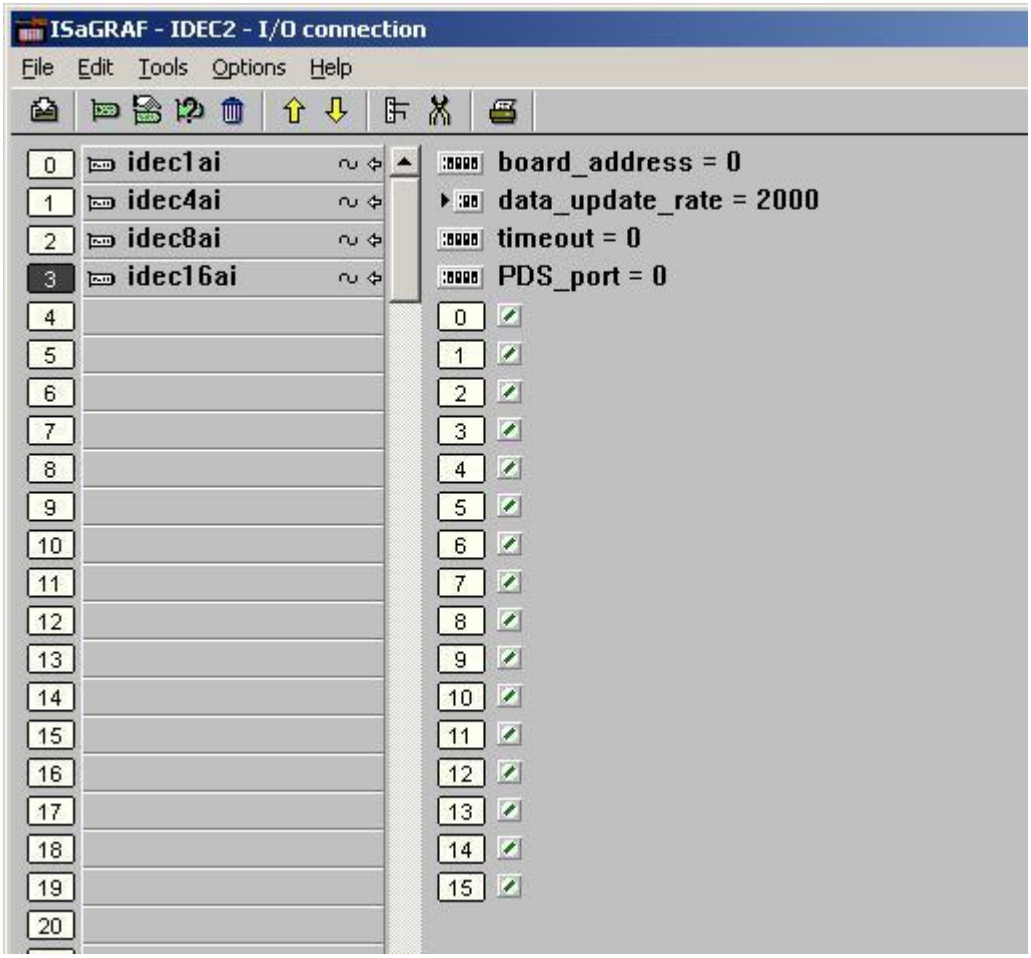
The **idecxxx** ISaGRAF I/O boards use a SCADAPack E Series RTU serial port configured as a '*PLC Device*' to communicate with the Idec PLC.

3.1 Input Boards

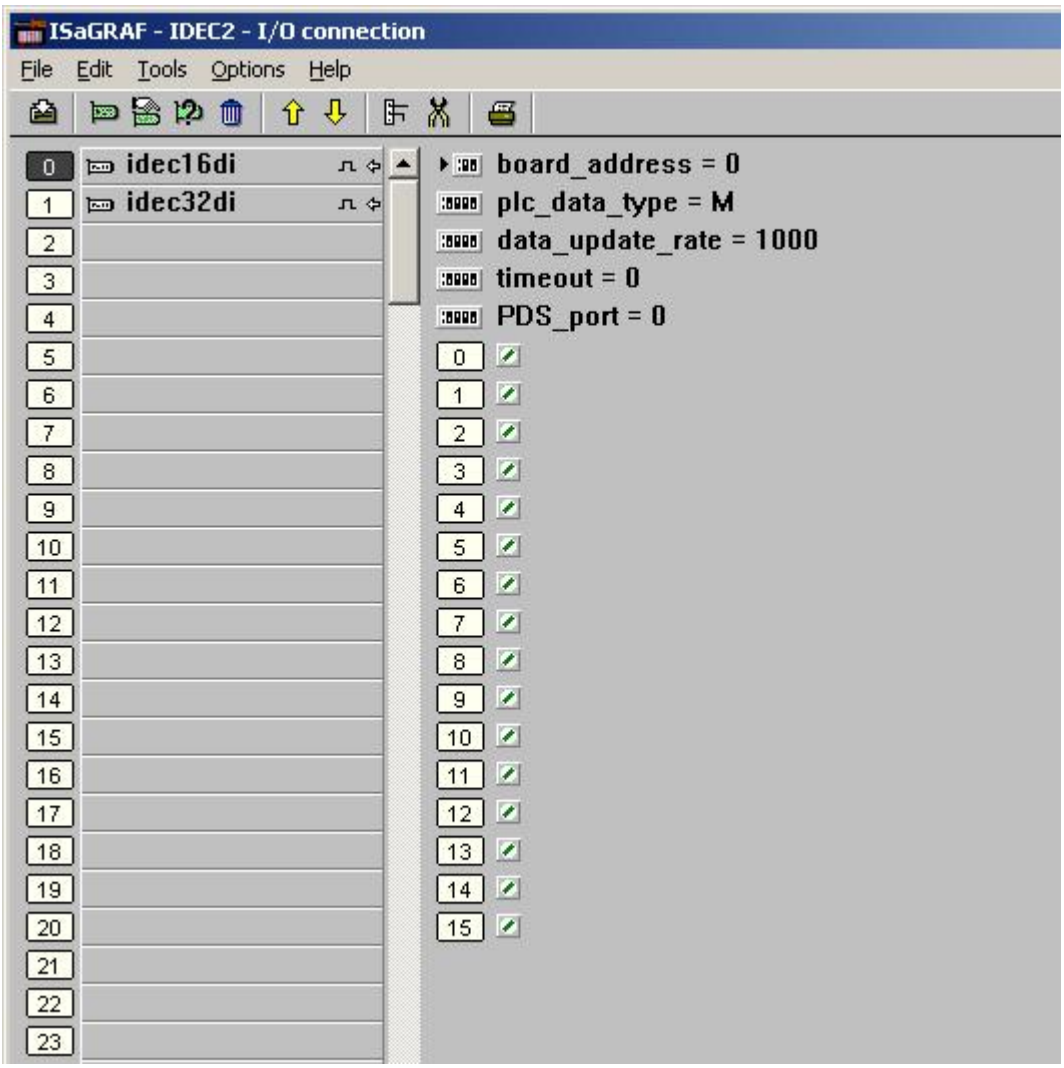
The Input boards supported by the Idec Driver are:

- 1 analog input
- analog input
- 8 analog input
- 16 analog input
- 16 digital input
- 32 digital input

The analog input boards all have the same basic layout as shown below.



The digital input boards all have the same basic layout as shown below.



The **board_address** field of the Idec ISaGRAF board (default value of 0) is the configurable register (16-bit) or point (binary) address in the Idec PLC. The allowable values for this address are outlined in the following table:

Board Type	Register Type	PLC Data Type	Standard Address Range	Expansion Address Range
16DI 32DI	Input	I	0-7, 10-17, 20-157	160-317*
	Output	Q	0-7, 10-17, 20-157	160-317*
	Internal	M	0-297, 300-317	320-637*
16DO 32DO	Output	Q	0-7, 10-17, 20-157	160-317*
	Internal	M	0-297, 300-317	320-637*
16AI/AO 8AI/AO 4AI/AO 1AI/AO	Data Register	D (hidden parameter)	0-99*	100-255* Expansion Area 1 256-399* Expansion Area 2

* Register ranges marked with an asterisk are not accessible with either the FA-1, or the FA-1J.

Note:	A 16 channel digital board at start address 0, provides addressing for the following points: 0-7 and 10-17. Therefore the next consecutive board should be located at address 20 (not 16 or 18). Similarly for the 32 digital point boards.

The **data_type** field is a configurable value that determines what type of registers/points to access in the PLC. As shown in the table above, valid values for digital boards are: I for Input points, Q for Output points, and M for internal points (default). The analog boards only allow access to Data Registers (value of D) and for this reason the data_type field is hidden for these boards.

The **data_update_rate** field of the **idecxxx** ISaGRAF board (default 2000) is the configurable number of *seconds* after which the RTU will request element array values from the Idec PLC. The SCADAPack E Series RTU will also request data from the Idec PLC constantly if the cache data age is greater than the **data_update_rate**. I.e. if communications are lost with the PLC, they are retried until the communications are restored.

The **timeout** field of the ISaGRAF board driver provides a parameter for specifying the communications timeout on an individual I/O board (i.e. the timeout applies to communications associated with that board). Where this value is "0", the PLC device driver will use the default timeout (1200mS). Units for this field are in milliseconds.

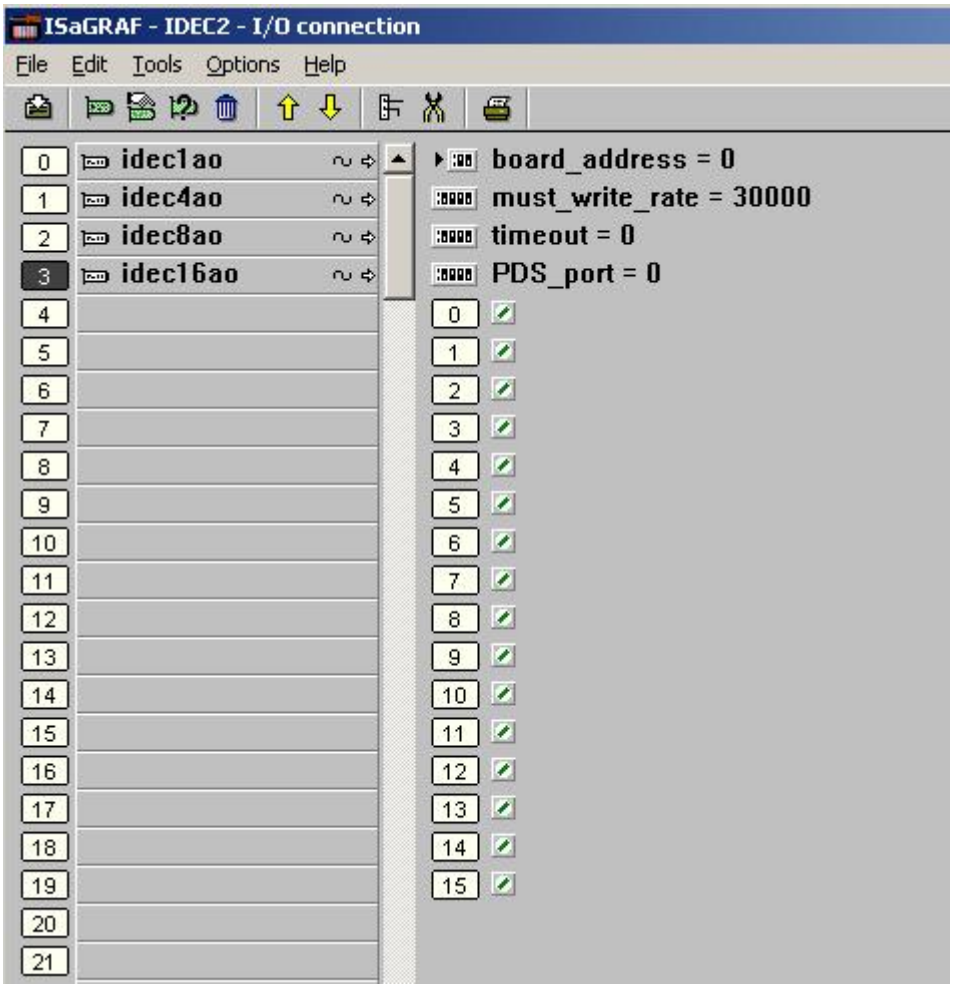
The **PDS_port** field of the ISaGRAF board driver provides a parameter which defines which of the multiple RTU "PLC Device" ports will be used to communicate with the PLC or peripheral device. If only one "PLC Device" port is configured, this field is ignored.

3.2 Output Boards

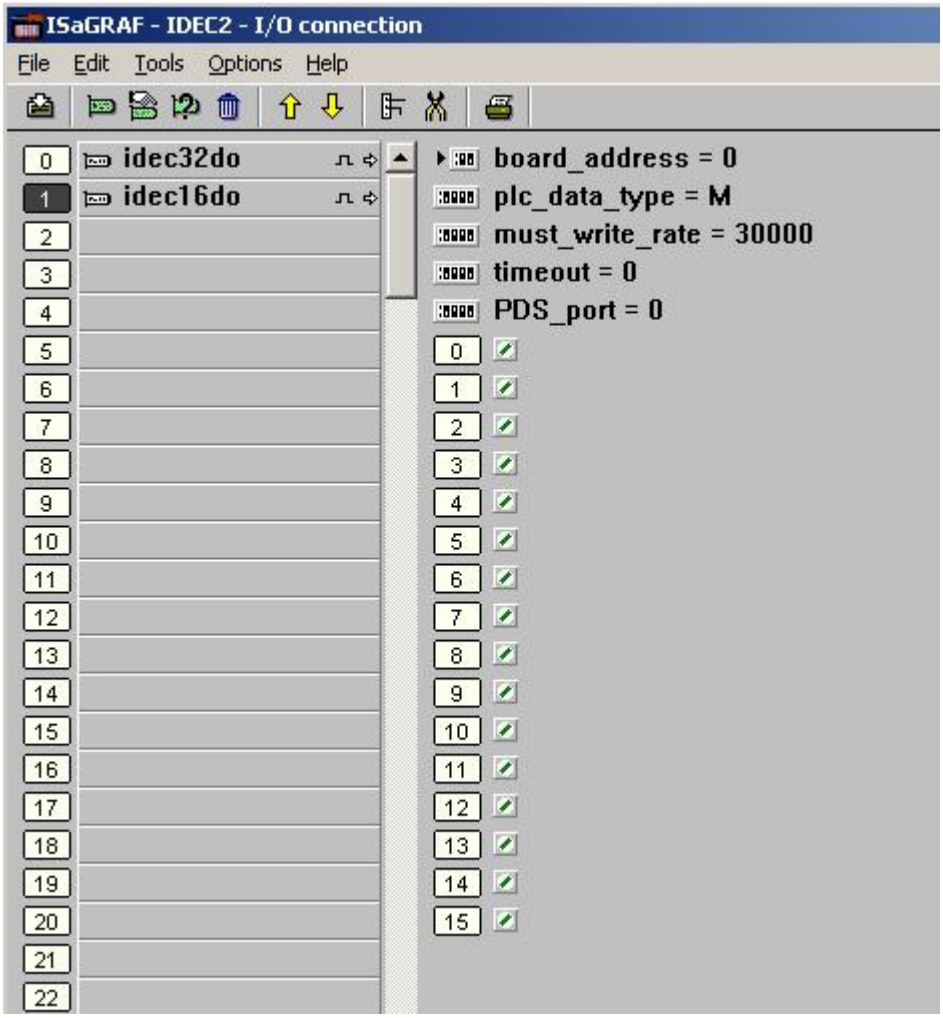
The Input boards supported by the Idec Driver are:

- 1 analog output
- analog output
- 8 analog output
- 16 analog output
- 16 digital output
- 32 digital output

The analog output boards all have the same basic layout as shown below.



The digital output boards all have the same basic layout as shown below.



Most of these parameters are the same as described for the Input Boards. The only difference is the **must_write_rate**. The unit for this parameter is the milliseconds, and specifies the rate at which the data for the Output board is written to the PLC. Between "*must_write_rate*" periods, data is written to the PLC only when the ISaGRAF output variable values change. Individual I/O boards may have different must write rates allowing prioritization of data sent to a slave PLC.

4 Communication Interface

The SCADAPack E Series RTU communicates with the Idec FA-1/FA-2 PLC using an RTU serial port configured as a '*PLC Device*'. This port must be configured with the same settings as the serial port on the Idec PLC onto which communications will be established. By default the Idec PLC's communicate at 9600,8,E,1. The RTUs serial port must connect to an "Idec RS232C Link Adaptor" to convert the RS232 from the SCADAPack E Series RTU to the current loop protocol used by the Idec PLC.

A cable configuration for connecting a fa-2j PLC to the RTU port is shown in Figure 1.

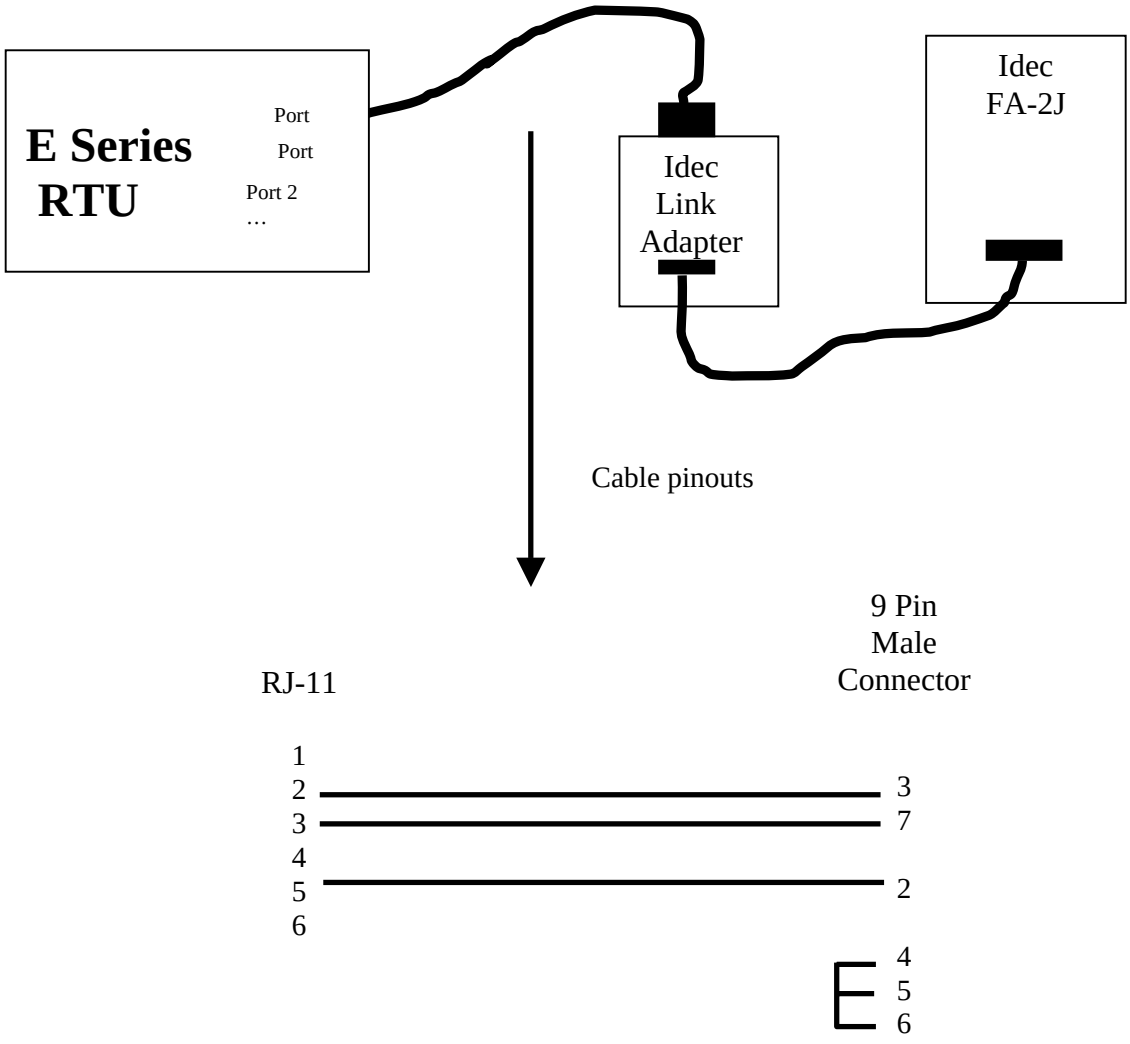


Figure 1: Standard connection diagram and E Series RTU cable pin out

5 Data Communications Protocol

Refer to *Idec IZUMI FA-1/FA-1J/FA-2/FA-2J Users Manual* for a full description of the Idec protocol as implemented by the driver.

Each of the different Idec PLC types support different Idec commands. The table below outlines the types of commands issued by the Idec driver in the SCADAPack E Series RTU.

PLC TYPE	Supported Idec Command Code	Supported Idec Type Codes
FA-1/FA-1J	0x42 - Monitor	0x31 – I/O 0x32 – IR
	0x4B – Direct Set/Reset	0x31 – I/O Reset 0x32 – IR Reset 0x39 – I/O Set 0x3A – IR Set
FA-2/FA-2J	0x42 - Monitor	0x31 – I/O 0x32 – IR 0x37 – Data Registers 0x38 – Data Registers (expansion) 0x3E – I/O (expansion) 0x3F – IR (expansion)
	0x4B – Direct Set/Reset	0x31 – I/O Reset 0x32 – IR Reset 0x34 – I/O Reset (expansion) 0x35 – IR Reset (expansion) 0x39 – I/O Set 0x3A – IR Set 0x3C – I/O Set (expansion) 0x3D – IR Set (expansion)
	0x4C – Data Register Write	0x37 – DR (0-99, 100-255) 0x38 – DR (256-399)

6 System Points

SCADAPack E Series RTU system points are provided to indicate the status of the ISaGRAF I/O boards that are used for Slave I/O communications with devices such as PLCs, and the Idec PLC.

Where multiple ISaGRAF Slave I/O boards are present in an ISaGRAF application, consecutive, sequential system point pairs are used for the next Slave I/O board, regardless of what PLC port the boards are connected to. Each ISaGRAF kernel is allocated a separate set of system points for Slave I/O boards. Each ISaGRAF Slave I/O board has two system points associated with it. The communications status and the data cache age.

The communication status indicates the status of the communication with the Idec PLC for all data points on the I/O board. For more information see Section ***0-Return Status*** Values.

The age of the cached data is stored in the Slave I/O Board Data Cache Age system point for that I/O board. For more information see Section ***6.2-Data Cache Age***.

The RTU Slave I/O board status system points for ISaGRAF Kernel 1 are as follows

System Point Description	Point Number	Point Type
ISaGRAF Kernel 1 Slave I/O board 1 communication status	53300	16-bit unsigned integer (read-only)
ISaGRAF Kernel 1 Slave I/O board 1 data cache time	53301	16-bit unsigned integer (read-only)
ISaGRAF Kernel 1 Slave I/O board 2 communication status	53302	16-bit unsigned integer (read-only)
ISaGRAF Kernel 1 Slave I/O board 2 data cache time	53303	16-bit unsigned integer (read-only)
…		
ISaGRAF Kernel 1 Slave I/O board 60 communication status	53418	16-bit unsigned integer (read-only)
ISaGRAF Kernel 1 Slave I/O board 60 data cache time	53419	16-bit unsigned integer (read-only)

The RTU Slave I/O board status system points for ISaGRAF Kernel 2 are as follows:

System Point Description	Point Number	Point Type
ISaGRAF Kernel 2 Slave I/O board 1 communication status	53422	16-bit unsigned integer (read-only)
ISaGRAF Kernel 2 Slave I/O board 1 data cache time	53423	16-bit unsigned integer (read-only)
ISaGRAF Kernel 2 Slave I/O board 2 communication status	53424	16-bit unsigned integer (read-only)
ISaGRAF Kernel 2 Slave I/O board 2 data cache time	53425	16-bit unsigned integer (read-only)
…		

ISaGRAF Kernel 2 Slave I/O board 14 communication status	53448	16-bit unsigned integer (read-only)
ISaGRAF Kernel 2 Slave I/O board 14 data cache time	53449	16-bit unsigned integer (read-only)

6.1 Return Status Values

The return status values for the **Idecxxx** board communications status are as follows:

Status	Comment	Value
Success	No error encountered	0
Unknown Error	An undefined error has occurred.	101
Illegal Address	The user has requested a invalid address	103
Timeout	The Idec PLC did not respond	104
Corrupt Message	The message from the Idec PLC was not understood by the SCADAPack E Series RTU.	106

6.2 Data Cache Age

The age of the data in the RTU cache for the Idec PLC array elements are presented by reading system point for the I/O board (usually Slave I/O board 1 system points). The cache age is initialized to zero when the ISaGRAF application starts and increases until a successful read occurs, after which time the value is reset to zero.

This system point may be used by the ISaGRAF application to determine the suitability of using the input data from the I/O board.

7 Diagnostics

The SCADAPack E Series RTU indicates configuration or communication diagnostics via Diagnostic Display mode from a Command line session.

Configuration diagnostics are indicated via ISaGRAF I/O board messages and are always displayed when in Diagnostic Display mode (use DIAG command at command prompt).

Communication diagnostics for the Idec PLC are enabled when the following commands are entered at the SCADAPack E Series RTU command prompt:

```
PLCDIAG ENABLE *
DIAG
```

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Document Revisions

Revision	Date	Modification	Author
1.10	18 January 2006	Incorporated December 19 changes	KN
1.00	19 September 2005	Initial release of SCADAPack E Series Modbus PLC Interface Reference Manual	KN

1 Preface

1.1 Purpose

The purpose of this document is to describe the SCADAPack E Series RTU[1] device driver for Modbus and Open Modbus/TCP protocols, its interface with ISaGRAF, and using it for communicating with PLC and peripheral devices. The RTUs provide a PLC interface for serial Modbus PLC devices and Open Modbus/TCP PLC interfaces.

1.2 Assumed Knowledge

Familiarity with the Modbus protocol and the ISaGRAF Workbench is recommended.

1.3 Target Audience

- Systems Engineers
- Commissioning Engineers
- Maintenance Technicians

1.4 References

- E Series ISaGRAF Technical Reference Manual
- CJ International ISaGRAF User Manual
- Protocol documentation for various Modbus PLC devices
- Open Modbus/TCP Specification Revision 1.0, March 1999
- Schneider Automation Inc. 870 USE 112 00 - TSX Momentum Ethernet Adapter
- Schneider Automation Inc. 870 USE 002 00 - TSX Momentum I/O Bases

[1] Also simply referred to as RTU throughout this document

2 Overview

2.1 Master/Slave and Client/Server Terminology

PLC and peripheral devices may communicate with the Control Microsystems SCADAPack E Series RTU using ISaGRAF **Slave** I/O boards. PLC or peripheral device elements are read and the return values cached in the RTU for access through an ISaGRAF input board. Similarly, ISaGRAF output board data can be transferred to the PLC or peripheral device. The SCADAPack E Series RTU's interface with ISaGRAF is detailed in the *SCADAPack E Series ISaGRAF Technical Reference Manual*. The status of the data read from the PLC or peripheral device is present in RTU system points that can be accessed from within ISaGRAF or external to the RTU.

When using ISaGRAF Modbus PLC I/O boards for communication with a Modbus peripheral device, or devices, the SCADAPack E Series RTU is a **Modbus Master**. The peripheral device(s) must be Modbus Slave(s).

When using ISaGRAF Modbus/TCP I/O boards for communication with Modbus/TCP peripheral devices, the SCADAPack E Series RTU is an **Open Modbus/TCP Client**. The peripheral device(s) must be Open Modbus/TCP **Server**(s) (e.g. Ethernet PLC). Open Modbus/TCP protocol is also known as MBAP protocol, but is referred to as Open Modbus/TCP protocol throughout this manual.

2.2 I/O Board Types

Where a SCADAPack E Series RTU has one or more of its serial ports configured as a '*PLC Device*' and ***mbus..*** or ***mod..*** I/O boards are used within the ISaGRAF application, the RTU communicates using serial "Modbus RTU" protocol. Note that the RTU does not support "Modbus ASCII" protocol. The RTU communication port data rate and parity format are used by its Modbus PLC device driver. RS232, RS422 and RS485 communications are all supported.

Note that ***mbus..*** ISaGRAF I/O boards generally supersede ***mod..*** I/O boards. Whilst the SCADAPack E Series RTU maintains compatibility with the older ***mod..*** I/O boards, it is recommended that ***mbus..*** I/O boards are used instead. An exception to this may be where a ***mod..*** I/O board uses a Modbus function code not available on ***mbus..*** I/O boards (see Section ***3.4 - Modbus registers***)

mod.. ISaGRAF I/O boards can not be used when multiple communication ports are configured for PLC peripheral device communications due to the requirement to specify which of these ports connects to the device. Use only ***mbus..*** and/or ***mtcp..*** I/O boards in this situation.

When the *Modbus/TCP(client)* IP service is enabled on the SCADAPack E Series RTU and ***mtcp..*** I/O boards are used in an ISaGRAF application, the RTU communicates using Open Modbus/TCP communication protocol. The protocol connects TCP socket(s) between the SCADAPack E Series RTU (Client) and the peripheral device(s) (Servers). TCP/IP over Ethernet and PPP communications from the RTU are supported.

The SCADAPack E Series RTU supports simultaneous communication using serial Modbus and Open Modbus/TCP protocols. i.e. ***mbus..*** I/O boards can communicate with Modbus peripherals on one or more RTU serial ports, and at the same time, ***mtcp..*** I/O boards can communicate with Modbus/TCP peripherals on an E Series RTU TCP/IP interface (e.g. Ethernet).

2.3 Modbus Addressing Terminology

The SCADAPack E Series RTU uses 5-digit Modbus address numbering, where the leading digit generally represents the register data type. In addition, the numbering within each register data type adheres to the classical Modicon PLC numbering convention, commencing at register 1. (Note that

the Modbus protocol description implies the register data type from the protocol function code, and uses 4-digit hexadecimal addressing commencing at register 0).

For example:

A register read by the SCADAPack E Series RTU specifying Modbus register 40010 is represented by Modbus protocol function code 3, protocol register address 0x0009.

See sections ***3.4 - Modbus registers*** and ***4.3 - Modbus/TCP Registers*** for details on register address ranges and Modbus function codes.

Some Modbus systems use 6-digit addressing, as opposed to the 5-digit Modbus register addressing described above. 6-digit addressing is designed to enable access to additional registers in each register range. A 6 digit address is made up of a single digit numeric prefix and a 5-digit Modbus register number.

For example:

Registers 300001 – 309999 are equivalent to 5-digit Modbus register addresses 30001 – 39999. However, input registers 310000 – 365536 are not addressable with the SCADAPack E Series RTU's 5-digit register address.

Note that in the 5-digit addressing regime used by the SCADAPack E Series RTU, *HOLDING REGISTERS* are extended beyond register 49999. RTU Modbus register addresses 50000 – 65535 are the equivalent to 6-digit holding register numbers 450000 – 465535. So the SCADAPack E Series RTU can address holding registers equivalent to the (6-digit) range 400001-409999 & 450000-465535.

2.4 PLC Data Types

PLC devices present data in a variety of ways through register interfaces. The SCADAPack E Series RTU supports the following commonly used data types when communicating with Modbus devices. These data types are supported for both serial Modbus and Open Modbus/TCP:

IEC DISCRETE	-	discrete input/output/coil data in IEC61131-3 international standard format
984 DISCRETE	-	discrete input/output/coil data in big endian Modicon 984 PLC format
IEC UINT	-	unsigned 16-bit integer data (values 0 ~ 65535)
IEC INT	-	signed 16-bit integer data (values –32768 ~ 32767)
IEC DINT	-	signed 32-bit integer data (value $-2^{31} \sim 2^{31}-1$) in IEC61131-3 international standard format
IEC REAL	-	32-bit floating point (real) data in IEC-754 international standard format
SWAP REAL	-	32-bit floating point data in swapped register real format

See Section ***5 - Data Conversion*** detailing the use of these PLC Data Types with the RTU.

3 Serial Modbus Master I/O Board Interfaces

The ***mbus..*** ISaGRAF boards use a SCADAPack E Series RTU serial port configured as a '*PLC Device*' to communicate with Modbus peripheral devices (herein described as PLCs).

3.1 Multiple I/O boards

Multiple I/O boards may be configured within the same ISaGRAF application. Each I/O board can access different PLC register data within the same PLC device. Where external physical connections permit, multiple I/O boards can also access PLC register data in multiple PLC devices. E.g. Multi-drop RS485 permits uniquely addressed Modbus PLCs to be connected to a SCADAPack E Series RTU serial port. In addition, multiple I/O boards may be configured to use different RTU serial ports configured as a "PLC Device".

Note:	Each of the ISaGRAF application's PLC I/O boards uses a separate Modbus request to read or write its data. Improved Modbus communication efficiency can be achieved by grouping Modbus registers together and using less I/O boards with a larger number of channels (e.g. Mbus64ai), rather than more I/O boards with a smaller number of channels.

A maximum of 100 Slave I/O Boards may be configured in total for all communication ports and across both ISaGRAF applications running on the separate kernels. Recall, also that each ISaGRAF application has a total limit of 255 I/O boards for all board types.

Communication status is available on the first 60 I/O boards for ISaGRAF kernel 1, and 14 I/O boards for ISaGRAF kernel 2. See section ***11 - System Points*** for more information.

ISaGRAF "Complex Equipment" types are comprised of configurations similar to I/O boards. Where a Complex Equipment type includes slave PLC I/O board configurations, each such I/O board configuration within the Complex Equipment type counts towards the limit of 100 slave I/O boards on that communications channel. A corresponding pair of system points relates to each PLC Slave I/O board on the lowest PDS RTU port number, as described in section ***11 - System Points***.

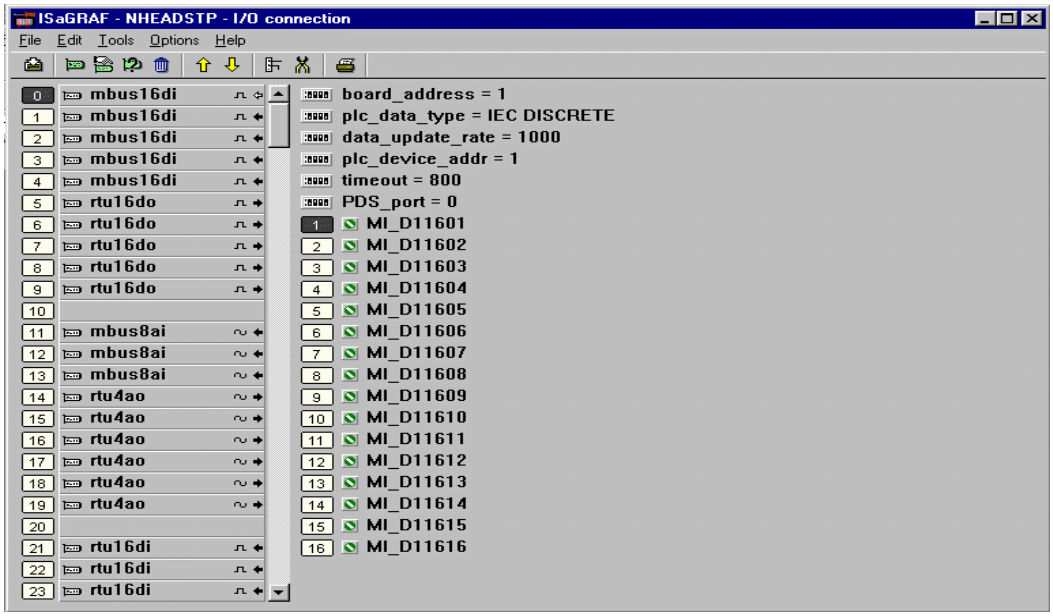


Figure 3-1: ISaGRAF Project Multiple I/O boards

3.2 Modbus Input Boards

Modbus PLC Input Board variables are updated at the start of the ISaGRAF application scan. The value presented to the ISaGRAF variables is the value returned by the PLC to the previous read request. This read may have occurred during previous ISaGRAF application scans. The “data update rate” parameter on the I/O board sets the "scan" rate of the PLC data. The PLC communication status is updated if there is an error returned from the PLC, or no response from the PLC after a data request by the RTU (see Section ***11.1 - Modbus Status Values***). The status is cleared by the SCADAPack E Series RTU upon successful communications. To catch transient errors, you can use ISaGRAF code to store non-zero values.

❖ Input Board Parameters

board_address: specifies the Modbus Slave PLC data registers to access when reading from PLC data into ISaGRAF variables. The PLC data type accessed is specific to the Slave PLC I/O board type and board address (see

Table 3-1 below).

plc_data_type: specifies the Modbus PLC data register type. Various PLC data types are supported for Boolean and Analog boards. See section ***5 - Data Conversion*** for more information.

data_update_rate: The unit for this parameter is the millisecond (ms), and specifies the rate at which the data for the input board is extracted from the PLC. Individual I/O boards may have different data update rates allowing prioritization of data extracted from a slave PLC. Note that the SCADAPack E Series RTU may not be able to read all requested PLC data within the time set by the data update rate depending on the quantity of data to be read, rate of write requests and PLC communication speed. In this case the update rates will be slower.

plc_device_addr: This parameter specifies the PLC device address. All Modbus PLC devices on the same communication channel (e.g. multi-dropped or bridged) must have unique device addressing in order to be identified. ISaGRAF may access data from multiple PLCs via the same communication interface. In this case a separate I/O board will be required for each PLC device. Values for this parameter are usually in the range 1-254.

timeout: The Modbus PLC device driver provides a parameter for specifying the communications timeout on an individual I/O board (i.e. the timeout applies to communications associated with that board). Where this value is “0”, the PLC device driver will use the default timeout (1200ms). Units for this field are the millisecond (ms).

PDS_port: this parameter defines which of multiple SCADAPack E Series RTU ports configured as a “PLC Device” will be used to communicate with the PLC or peripheral device. If only one “PLC Device” port is configured, this field is ignored. ISaGRAF Slave PLC I/O boards that do not include this parameter can only be used when a single “PLC Device” port is configured on the SCADAPack E Series RTU.

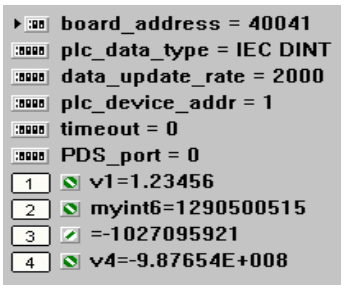


Figure 3-2: Modbus Input Board Connection Setup

The sample screen shot above illustrates the board parameters for a ***mbus4ai*** I/O connection. PLC #1 holding registers are read every 2 seconds into the variables on I/O channels 1 through 4. A pair of holding registers is read per I/O board channel as the PLC data type specifies 32-bit format variables (IEC DINT). So holding registers 40041 through 40048 are read. The holding register pair for channel 1 is in IEC REAL (32-bit floating-point) format as there is an analog input *real* variable connected to the channel. The holding register pair for channel 2 is in IEC DINT (32-bit signed integer) format as the ISaGRAF variable on the I/O channel is an analog input *integer* variable. The holding register pair for channel 3 is in IEC DINT (32-bit signed integer) format as there is no ISaGRAF variable on the I/O channel. The holding register pair for channel 4 is in IEC REAL (32-bit floating-point) format as there is an analog input *real* variable connected to the channel. The default PLC timeout of 1200ms is applied as the "timeout" value is 0.

❖ **"OPERATE" on Input Boards**

The ISaGRAF "OPERATE" function may be used on a Modbus PLC Input Board variable provided that the PLC Modbus register read by the input board can also be written, i.e. COILS or HOLDING REGISTERS. This permits PLC registers to be inputs into ISaGRAF, but have them "Preset" or initialized in the PLC by the ISaGRAF application.

For more information see *E Series ISaGRAF Technical Reference* manual.

3.3 Modbus Output Boards

ISaGRAF output board variables are updated at the end of the ISaGRAF application scan. ISaGRAF output variables are sent to the PLC when an ISaGRAF application changes the value of a variable attached to the Modbus PLC Output Board. They are sent to the PLC after this occurs, but the ISaGRAF scan continues executing while the PLC communications are in progress. In order words, communications to the PLC is occurs asynchronously to the program scan.

In addition, output board data is updated to the PLC under the following conditions:

- When the ISaGRAF application starts, all output board data is written
- If the PLC does not respond to a control, it is re-sent until it is responded
- All output board data is written at a background "must write rate".

❖ **Output Board Parameters**

board_address: specifies the Slave PLC data registers to access when writing from ISaGRAF variables to PLC data. The PLC data type accessed is specific to the Slave PLC I/O board and board address. See

Table 3-1 below.

plc_data_type: specifies the Modbus PLC data register type. Various PLC data types are supported for Boolean and Analog boards. See section ***5 - Data Conversion*** for more information.

plc_device_addr: This parameter specifies the PLC device address. All Modbus PLC devices on the same communication channel (e.g. multi-dropped or bridged) must have unique device addressing in order to be identified. ISaGRAF may access data from multiple PLCs via the same communication

interface. In this case a separate I/O board will be required for each PLC device. Values for this parameter are usually in the range 1-254.

must_write_rate: The unit for this parameter is the millisecond (ms), and specifies the rate at which the data for the output board is written to the PLC. Between "*must_write_rate*" periods, data is written to the PLC only when the ISaGRAF output variable values change. Individual I/O boards may have different must write rates allowing prioritization of data sent to a slave PLC. See section ***11.3 - PLC Output Board Default Background Update Rate***.

timeout: The Modbus PLC device driver provides a parameter for specifying the communications timeout on an individual I/O board (i.e. the timeout applies to communications associated with that board). Where this value is "0", the PLC device driver will use the default timeout (1200mS). Units for this field are in milliseconds.

PDS_port: this parameter defines which of multiple SCADAPack E Series RTU serial ports configured as a "PLC Device" will be used to communicate with the PLC or peripheral device. If only one "PLC Device" port is configured, this field is ignored. ISaGRAF Slave PLC I/O boards that do not include this parameter can only be used when a single "PLC Device" port is configured on the SCADAPack E Series RTU.

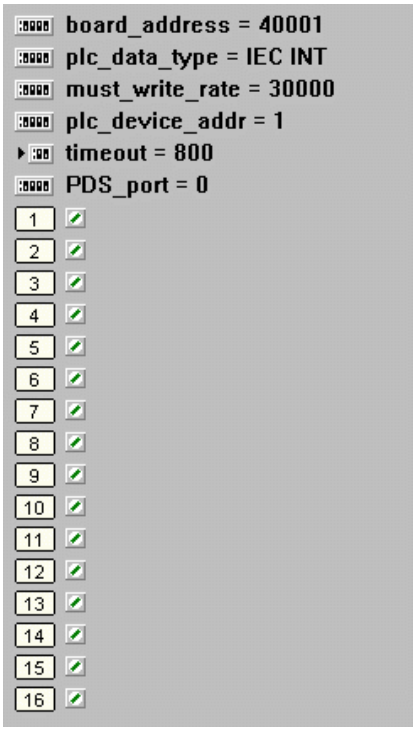


Figure 3-3: Modbus Output Board Connection Setup

In the above ***mbus16ao*** example, PLC #1 holding registers 40001 through 40016 are set from variables on I/O channels 1 through 16. Holding registers are written in IEC INT (16-bit signed integer format) when the ISaGRAF variable on the I/O channel changes, and at a rate of every 30 seconds even if they don't change. The PLC has 800ms to respond to a register write command for up to 16 registers.

3.4 Modbus registers

The following table describes the relationship between ISaGRAF Modbus I/O board types, the Modbus address ranges and functions used.

Table 3-1: ISaGRAF Modbus Slave PLC I/O Board Register Access

IsaGRAF Modbus Slave I/O Board Type	ISaGRAF Modbus Board Address	Type of PLC Register	Uses Modbus Function Code
MbusnnDI	1- 9999	Reads discrete COILS	1
OPERATE on MbusnnDI variable	1- 9999	Presets discrete COILS	5
MbusnnDI	10001-19999	Reads discrete INPUTS	2
MbusnnDI	40001-65535	Reads HOLDING Registers as bits	3
OPERATE on MbusnnDI variable	40001-65535	Presets HOLDING Register	16
MbusnnDO	1- 9999	Writes discrete COILS	5
MbusnnDO	40001-65535	Writes bits to HOLDING Registers	16
MbusnnAI	30001-39999	Reads INPUT Registers	4
MbusnnAI	40001-65535	Reads HOLDING Registers	3
OPERATE on MbusnnAI variable	40001-65535	Presets HOLDING Register	16
MODnnAO	40001-65535	Writes single HOLDING Register	6
MbusnnAO	40001-65535	Writes HOLDING Registers	16

Board Types

The following Modbus PLC I/O board types are available:

Board Name	ref+	ISaGRAF Data Type	PLC Data Types supported
mod4ao	000A	4 Analog Outputs*1	} IEC UINT to Holding Regs only
mod8ao	000A	8 Analog Outputs*1	} (single reg write using func code 6)
mbus16di	000E	16 Boolean Inputs	} IEC DISCRETE, 984 DISCRETE
mbus32di	000E	32 Boolean Inputs	} from Input Status, Coil Registers, } Holding Registers
mbus16do	000F	16 Boolean Outputs	} IEC DISCRETE, 984 DISCRETE
mbus32do	000F	32 Boolean Outputs	} to Coil Registers, Holding Registers

mbus1ai	0010	1 Analog Input*1	}
mbus4ai	0010	4 Analog Inputs*1	} IEC UINT, IEC INT, IEC DINT,
mbus8ai	0010	8 Analog Inputs*1	} IEC REAL, SWAP REAL from Input
mbus16ai	0010	16 Analog Inputs*1	} Registers, Holding Registers
mbus32ai	0010	32 Analog Inputs*1	}
mbus64ai	0010	64 Analog Inputs*1	}
mbus1ao	0011	1 Analog Output*1	}
mbus4ao	0011	4 Analog Outputs*1	} IEC UINT, IEC INT, IEC DINT,
mbus8ao	0011	8 Analog Outputs *1	} IEC REAL, SWAP REAL to
mbus16ao	0011	16 Analog Outputs *1	} Holding Registers
mbus32ao	0011	32 Analog Outputs *1	}
mbus64ao	0011	64 Analog Outputs *1	}

+ ref value is in Hexadecimal and is an internal ISaGRAF I/O board field.

*1 Analog input and output board conversion may be used.

Note that the ISaGRAF "Operate" function can also be used to preset input variables on the **mbus*xx*di** and **mbus*xx*ai** I/O boards. For more information see the *E Series ISaGRAF Technical Reference* manual.

❖ **Information for Advanced ISaGRAF users:**

Other I/O Boards, I/O configurations or Complex Equipment types based on the reference numbers shown in the above table are possible. The following guidelines must be observed when configuring new I/O interface types:

- There is an upper limit of 32 I/O channels per PLC digital board for the various Modbus board types.
- There is an upper limit of 64 I/O channels per PLC analog board for the various Modbus board types.
- A plc_data_type user parameter is defined for Slave PLC I/O boards. The value of this parameter field is a string field describes the data type of data being accessed (See section ***5-Data Conversion*** for more information.) – e.g. "IEC UINT".
- An additional plc_dev_type hidden parameter string field describes the plc type, communication channel type and special controls. The value of this field is driver specific. E.g. "ms" indicates advanced Modbus board (m), serial comms interface (s)

4 Modbus TCP Client I/O Board Interface

The ***mtcp*..** ISaGRAF boards are to be used by the SCADAPack E Series RTU to communicate via Ethernet or PPP serial interfaces with the Open Modbus/TCP protocol peripheral devices (herein described as PLCs).

Note:	Each the ISaGRAF application's PLC I/O boards use a separate Modbus/TCP request to read or write its data. Improved Modbus communication efficiency can be achieved by grouping Modbus registers together and using less I/O boards with a larger number of channels (e.g. mtcp64ai), rather than more I/O boards with a smaller number of channels.

A maximum of 100 Modbus/TCP Slave I/O Boards may be configured in total across both RTU ISaGRAF applications.

ISaGRAF "Complex Equipment" types are comprised of configurations similar to I/O boards. Where a Complex Equipment type includes slave PLC I/O board configurations, each such I/O board configuration within the Complex Equipment type counts towards the limit of 100 Slave I/O boards. A corresponding pair of system points relates to each PLC Slave I/O board as described in section ***8.7 - Open Modbus/TCP Server***.

Modbus/TCP boards utilize default IEC data types. Where applicable, the data type may be available for the user to choose.

4.1 Modbus/TCP Input Boards

Modbus/TCP PLC Input Board variables are updated at the start of an ISaGRAF application scan. The value presented to the ISaGRAF variables is the value returned by the PLC from the previous read request. This read may have occurred during previous ISaGRAF application scans. The "data update rate" parameter on the I/O board sets the "scan" rate of the PLC data. The PLC communication status is updated if there is an error returned from the PLC, or no response from the PLC after a data request by the PDS. (See Section ***11.1 - Modbus Status Values***). The status is cleared by the SCADAPack E Series RTU upon successful communications. To catch transient errors you can use ISaGRAF code to store non-zero values.

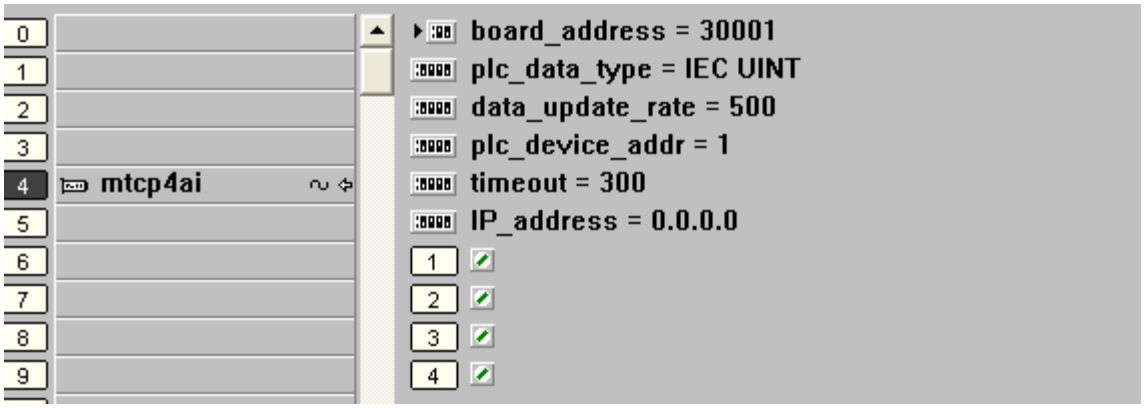


Figure 4-1: ISaGRAF Modbus/TCP board

❖ **Input Board Parameters**

board_address: specifies the Modbus/TCP PLC data registers to access when reading from PLC data into ISaGRAF variables. The PLC data type accessed is the same as Modbus Slave PLC I/O boards detailed in section ***3.4 - Modbus registers***.

plc_data_type: specifies the Modbus/TCP PLC data register type. Various data types are supported. See section ***5 - Data Conversion*** for more information.

data_update_rate: The unit for this parameter is the millisecond (ms), and specifies the rate at which the data for the Input board is extracted from the PLC. Individual I/O boards may have different data update rates allowing prioritization of data extracted from a slave PLC. Note that the SCADAPack E Series RTU may not be able to read all requested PLC data within the time set by the data update rate depending on the quantity of data to be read, rate of write requests and PLC communication speed. In this case the update rates will be slower.

plc_device_address: This parameter specifies the PLC device (unit) address. All Modbus PLC devices accessed at the same IP address (e.g. via a Modbus bridge) must have a unique unit address in order to be identified. ISaGRAF may access data from different units on the same IP address or at different IP addresses. In all these cases a separate I/O board will be required for each device.

timeout: The Modbus/TCP PLC device driver provides a parameter for specifying the communications timeout on an individual I/O board (i.e. the timeout applies to communications associated with that board). Where this value is "0", the PLC device driver will use the default timeout (1200ms). Units for this field are in ms.

IP_address: This parameter specifies the IP network address that the SCADAPack E Series RTU connects to for communication with the PLC for this I/O board. Enter the IP address of the Modbus/TCP PLC, or Modbus bridge if applicable.

❖ **"OPERATE" on Input Boards**

The ISaGRAF "OPERATE" function may be used on Modbus/TCP Input Boards where the register read by the input board is also writeable e.g. coils or holding registers. This permits registers to be inputs into ISaGRAF but have them "Preset" or initialized in the PLC by ISaGRAF.

For more information see the *E Series ISaGRAF Technical Reference* manual.

4.2 Modbus/TCP Output Boards

Modbus/TCP PLC Output Board data is written to the PLC when an ISaGRAF application changes the value of a variable attached to the Output board. In addition, output board data is written to the PLC under the following conditions:

- When the ISaGRAF application starts, all output board data is written
- If the PLC does not respond to a control, it is re-sent until it is responded
- All output board data is rewritten at a background update rate

❖ **Output Board Parameters**

board_address: specifies the Modbus/TCP PLC data registers to access when reading from PLC data into ISaGRAF variables. The PLC data type accessed is the same as Modbus Slave PLC I/O boards detailed in section ***3.4 - Modbus registers***. .

plc_data_type: specifies the Modbus/TCP PLC data register type. Various data types are supported. See section 5 for more information.

plc_device_address: This parameter specifies the PLC device (unit) address. All Modbus PLC devices accessed at the same IP address (e.g. via a Modbus bridge) must have a unique unit address

in order to be identified. ISaGRAF may access data from different units on the same IP address or at different IP addresses. In all these cases a separate I/O board will be required for each device.

must_write_rate: The unit for this parameter is milliseconds (ms) and specifies the rate at which the data for the output board is written to the PLC. Between "*must_write_rate*" periods, data is only written to the PLC when the ISaGRAF output variable values change. Individual I/O boards may have different must write rates allowing prioritization of data sent to slave PLC(s). See section ***11.3 - PLC Output Board Default Background Update Rate***

timeout: The Modbus/TCP PLC device driver provides a parameter for specifying the communications timeout on an individual I/O board (i.e. the timeout applies to communications associated with that board). Where this value is "0", the PLC device driver will use the default timeout (1200mS). The unit for this field is the millisecond (ms).

IP_address: This parameter specifies the IP network address that the SCADAPack E Series RTU connects to for communication with the PLC for this I/O board. Enter the IP address of the Modbus/TCP PLC, or Modbus gateway or bridge, as applicable.

4.3 Modbus/TCP Registers

The following table describes the relationship between ISaGRAF Modbus/TCP I/O board types, the Modbus address ranges and functions used.

Table 4-1: ISaGRAF Modbus/TCP Slave PLC I/O Board Register Access

ISaGRAF Modbus Slave I/O Board Type	ISaGRAF Modbus Board Address	Type of PLC Register	Uses "Open Modbus/TCP" Function Code
MtcpnnDI	1- 9999	Reads discrete COILS	1
OPERATE on MbusnnDI variable	1- 9999	Presets discrete COILS	5
MtcpnnDI	10001-19999	Reads discrete INPUTS	2
MtcpnnDI	40001-65535	Reads HOLDING Registers as bits	3
OPERATE on MtcpnnDI variable	40001-65535	Presets HOLDING Register	16
MtcpnnDO	1- 9999	Writes discrete COILS	5
MtcpnnDO	40001- 65535	Writes bits to HOLDING Registers	16
MtcpnnAI	30001-39999	Reads INPUT Registers	4
MtcpnnAI	40001-65535	Reads HOLDING Registers	3
OPERATE on MtcpnnAI variable	40001-65535	Presets HOLDING Register	16
MtcpnnAO	40001-65535	Writes HOLDING Registers	16

4.4 Modbus/TCP Board Types

The following Modbus/TCP I/O board types are available:

Board Name	ref+	ISaGRAF Data Type	PLC Data Types supported
mtcp16di	000E	16 Boolean Inputs	} IEC DISCRETE, 984 DISCRETE
mtcp32di	000E	32 Boolean Inputs	} from Input Status, Coil Registers,

			} Holding Registers
mtcp16do	000F	16 Boolean Outputs	} IEC DISCRETE, 984 DISCRETE
mtcp32do	000F	32 Boolean Outputs	} to Coil Registers, Holding Registers
mtcp1ai	0010	1 Analog Input*1	}
mtcp4ai	0010	4 Analog Inputs*1	} IEC UINT, IEC INT, IEC DINT,
mtcp8ai	0010	8 Analog Inputs*1	} IEC REAL, SWAP REAL from
mtcp16ai	0010	16 Analog Inputs*1	} Input Registers, Holding Registers
mtcp32ai	0010	32 Analog Inputs*1	}
mtcp64ai	0010	64 Analog Inputs*1	}
mtcp1ao	0011	1 Analog Output*1	}
mtcp4ao	0011	4 Analog Outputs*1	} IEC UINT, IEC INT, IEC DINT,
mtcp8ao	0011	8 Analog Outputs *1	} IEC REAL, SWAP REAL to
mtcp16ao	0011	16 Analog Outputs *1	} Holding Registers
mtcp32ao	0011	32 Analog Outputs *1	}
mtcp64ao	0011	64 Analog Outputs *1	}

+ ref value is in Hexadecimal and is an internal ISaGRAF I/O board field.

*1 Analog input and output board conversion may be used. ISaGRAF "Operate" functions may also be used.

For more information see the *E Series ISaGRAF Technical Reference*

❖ **Information for Advanced ISaGRAF users:**

Other I/O Boards, I/O configurations or Complex Equipment types based on the reference numbers shown in the above table are possible. The following guidelines must be followed when configuring new I/O interface types:

- There is an upper limit of 32 I/O channels per digital board for the various Modbus/TCP board types.
- There is an upper limit of 64 I/O channels per analog board for the various Modbus/TCP board types.
- A plc_data_type user parameter is defined for Slave PLC I/O boards. The value of this parameter field is a string field describes the data type of data being accessed (See section ***5 - Data Conversion*** for more information.) – e.g. "IEC UINT".
- An additional plc_dev_type hidden parameter string field describes the plc type, communication channel type and special controls. The value of this field is driver specific. E.g. "mtr" indicates advanced Modbus board (m), TCP socket interface (t), optional reset outputs on ISaGRAF application halted (r).

4.5 Open Modbus/TCP Conformance Classes

The Open Modbus/TCP standard defines conformance classes for Master & Slave (Client & Server) devices.

When using the ISaGRAF PLC I/O boards in the following way, the SCADAPack E Series RTU conforms to the requirements for Open Modbus/TCP **Conformance CLASS 0** devices:

- **mtcp*xx*di** – board address: 40001-65535
  plc data type: IEC DISCRETE
  uses Modbus function code 3 – read multiple registers
- **mtcp*xx*do** – board address: 40001-65535
  plc data type: IEC DISCRETE
  uses Modbus function code 16 – write multiple registers
- **mtcp*xx*ai** – board address: 40001-65535
  plc data type: IEC INT, IEC UINT, IEC DINT, IEC REAL
  uses Modbus function code 3 – read multiple registers
- **mtcp*xx*ao** – board address: 40001-65535
  plc data type: IEC INT, IEC UINT, IEC DINT, IEC REAL
  uses Modbus function code 16 – write multiple registers

Use of the ISaGRAF PLC I/O boards in the following ways requires the PLC slave device (Open Modbus/TCP server) to be at least an Open Modbus/TCP **Conformance CLASS 1** device:

- **mtcp*xx*di** – board address: 1-9999
  plc data type: IEC DISCRETE
  uses Modbus function code 1 – read coils
- **mtcp*xx*di** – board address: 10001-19999
  plc data type: IEC DISCRETE
  uses Modbus function code 2 – read input discrete (status)
- **mtcp*xx*ai** – board address: 30001-39999
  plc data type: IEC INT, IEC UINT, IEC DINT, IEC REAL
  uses Modbus function code 4 – read input registers
- **mtcp*xx*do** – board address: 1-9999
  plc data type: IEC INT, IEC UINT, IEC DINT, IEC REAL
  uses Modbus function code 5 – write coil

5 Data Conversion

A single ISaGRAF PLC I/O board will support one Modbus PLC data type for all channels on that I/O board. Where real ISaGRAF analog variables are attached to an integer ISaGRAF PLC I/O board, or where integer ISaGRAF analog variables are attached to a real ISaGRAF PLC I/O board, conversion rules apply as detailed in section ***5.2 - Modbus Data Conversion*** and in the *E Series ISaGRAF Technical Reference* manual.

The exception to this is where the PLC data type is "IEC DINT". Integer and real ISaGRAF analog variables use "IEC DINT" and "IEC REAL" PLC data types respectively on the same I/O board. Data conversion depends upon PLC Data types as described below.

5.1 Modbus PLC Data Types

The following data types are supported by the SCADAPack E Series Modbus serial and Open Modbus/TCP PLC interfaces.

- IEC DISCRETE

Binary (discrete) data packed into an 8-bit value where the least significant bit of the value represents the low discrete bit number. For a protocol message that contains 16 discrete coils at addresses 11-26 for example, coil 11 is represented by the least significant bit of the first byte in the protocol, and coil 26 is represented by the most significant bit of the second byte in the protocol. This data type can be used to access PLC inputs, coils or holding register bits.

- 984 DISCRETE

Binary (discrete) data usually packed into a 16-bit value where the least significant bits of the 16-bit value represent the high discrete bit numbers. For a protocol message that contains 16 discrete coils at addresses 30-45 for instance, coil 30 is represented by the most significant bit of the 16-bit value, and coil 45 is represented by the least significant bit of the 16-bit value. This data type can be used to access PLC inputs, coils or holding register bits.

- IEC UINT

Unsigned 16-bit integer value. Valid values are 0 ~ 65535. This is the default data type used by the SCADAPack E Series RTU for Modbus PLC register data. This data type can be used to access PLC input registers or holding registers.

- IEC INT

Signed 16-bit integer value. Valid values are –32768 ~ 32767. This data type can be used to access PLC input registers or holding registers.

- IEC DINT

Signed 32-bit double integer value, organized as two words in the protocol in Little Endian format (least significant word first). Valid values are $-2^{31} \sim 2^{31}-1$. I/O boards utilizing this data type will automatically select between IEC DINT data format for ISaGRAF integer analog variables, and IEC REAL data format for ISaGRAF real analog variables on the I/O board. This data type generally accesses a consecutive pair of 16-bit holding registers.

- IEC REAL

IEC-754 format 32-bit floating point real value, organized as two words in the protocol in Little Endian register format (least significant word in first register). This data type generally accesses a consecutive pair of 16-bit holding registers.

- SWAP REAL

IEC-754 format 32-bit floating point real value, organized as two words in the protocol in swapped (Big Endian) register format (most significant word in first register). This data type generally accesses a consecutive pair of 16-bit holding registers.

5.2 Modbus Data Conversion

mbusxxdi, mbusxxdo, mtcpxxdi, mtcpxxdo I/O boards require no data conversion other than the order of discrete bit numbers. "984 DISCRETE" data type reverses the bit order within 16-bit groups.

mbusxxai, mbusxxao, mtcpxxai, mtcpxxao I/O boards require no data conversion other than register pair ordering for 32-bit values. "SWAP REAL" data type reverses the holding register order for 32-bit floating point register pair.

Table 5-1 below provides examples of Modbus data conversion for SCADAPack E Series RTU analog input and analog output Modbus PLC I/O boards. Conversion examples show integer / real conversion results, including numeric range truncation (for ***mbusxxao*** & ***mtcpxxao***)

NOTE 1: ISaGRAF "OPERATE" function for ***mbusxxai*** and ***mtcpxxai*** boards uses the same numeric conversion and range truncation when initializing input board variable values as does the corresponding ***mbusxxao*** or ***mtcpxxao*** board when setting output board registers.

NOTE 2: The Open Modbus/TCP Server data conversion for the SCADAPack E Series configuration point values is detailed in section ***10.4.5 - Supported Data Types***.

Table 5-1: ISaGRAF / Modbus Data Conversion

SCADAPack E Series I/O Board Type	Data Type / Range	ISaGRAF Variable Type	Conversion Examples
Mbusxxai Mtcpxxai	IEC UINT 0 ~ 65535	Integer	Reg value = 40000, Variable = 40000
		Real	Reg value = 45678, Variable = 45678.0
Mbusxxai Mtcpxxai	IEC INT -32768 ~ 32767	Integer	Reg value = 20000, Variable = 20000
		Real	Reg value = -15000, Variable = -15000.0
Mbusxxai Mtcpxxai	IEC REAL SWAP REAL	Integer	Reg pair value = 12345.678 Variable = 12345
		Real	Reg pair value = -159.876 Variable = -159.876
Mbusxxai Mtcpxxai	IEC DINT $-2^{31} \sim 2^{31}-1$	Integer (IEC DINT)	Reg pair value = 12345678 Variable = 12345678
		Real (IEC REAL)	Reg pair value = 9988.77 Variable = 9988.77
Mbusxxao Modxxao Mtcpxxao	IEC UINT 0 ~ 65535	Integer	Variable value = -987, Reg = 0 Variable value = 50000, Reg = 50000 Variable value = 70000, Reg = 65535
		Real	Variable value = -99.33, Reg = 0 Variable value = 45678.3, Reg = 45678 Variable value = 123456.7, Reg = 65535
Mbusxxao mtcpxxao	IEC INT -32768 ~ 32767	integer	Variable value = -39000, Reg = -32768 Variable value = 10000, Reg = 10000 Variable value = 45000, Reg = 32767
		real	Variable value =-45678.0, Reg = -32768 Variable value = -99.33, Reg = -99 Variable value = 34568.7, Reg = 32767
Mbusxxao mtcpxxao	IEC REAL SWAP REAL	integer	Variable = -99000, Reg pair = -99000.0 Variable = 100000, Reg pair = 100000.0
		real	Variable = -77.06, Reg pair = --77.06 Variable =123456.7, Reg pair = 123456.7

mbusxxao mtcpxxao	IEC DINT $-2^{31} \sim 2^{31}-1$	integer (IEC DINT)	Variable=12345678, Reg pair =12345678
		real (IEC REAL)	Variable = 9988.77, Reg pair = 9988.77

6 Modbus TCP/Client Complex Equipment Types

ISaGRAF complex equipment types can be used with the SCADAPack E Series RTU to provide a simple device template to an ISaGRAF application. Complex equipment types are usually specific to particular equipment models. For further information on complex equipment types for devices not appearing in the following list, please contact Control Microsystems.

Note that ISaGRAF "Complex Equipment" types are comprised of configurations similar to I/O boards. When a Complex Equipment type includes slave PLC I/O board configurations, each such I/O board configuration within the Complex Equipment type counts towards the limit of 50 Slave I/O boards and has a corresponding pair of system points as described in section ***8.7 - Open Modbus/TCP Server***. Up to 40 Complex Equipment types, each with 2 or 3 I/O boards (summing up to about 100 I/O boards) can inter-operate with a single SCADAPack E Series RTU at the same time.

6.1 Complex Equipment Types Summary

The following ISaGRAF Complex Equipment types are provided for use with the SCADAPack E Series RTU.

Table 6-1: ISaGRAF Complex Equipment Types

Complex Equipment Type	Equipment Model	Description
adi34000	170 ADI 340 00	Schneider TSX Momentum 16 Pt. Digital Input module with 170 ENT 110 00 Ethernet communication adapter
adi35000	170 ADI 350 00	Schneider TSX Momentum 32 Pt. Digital Input module with 170 ENT 110 00 Ethernet communication adapter
adm35010	170 ADM 350 10	Schneider TSX Momentum mixed 16 Pt. Digital Input / 16. Pt. Digital Output module with 170 ENT 110 00 Ethernet communication adapter
aai03000	170 AAI 030 00	Schneider TSX Momentum Analog 8 Channel Differential Input module with 170 ENT 110 00 Ethernet communication adapter
aai14000	170 AAI 140 00	Schneider TSX Momentum Analog 16 Channel Single-Ended Input module with 170 ENT 110 00 Ethernet communication adapter
ado35000	170 ADO 350 00	Schneider TSX Momentum 32 Pt. Digital Output module with 170 ENT 110 00 Ethernet communication adapter

For more information see Schneider Automation documents: 870 USE 002 00 and 870 USE 112 00.

6.2 “adi34000” TSX Momentum 170 ADI 340 00

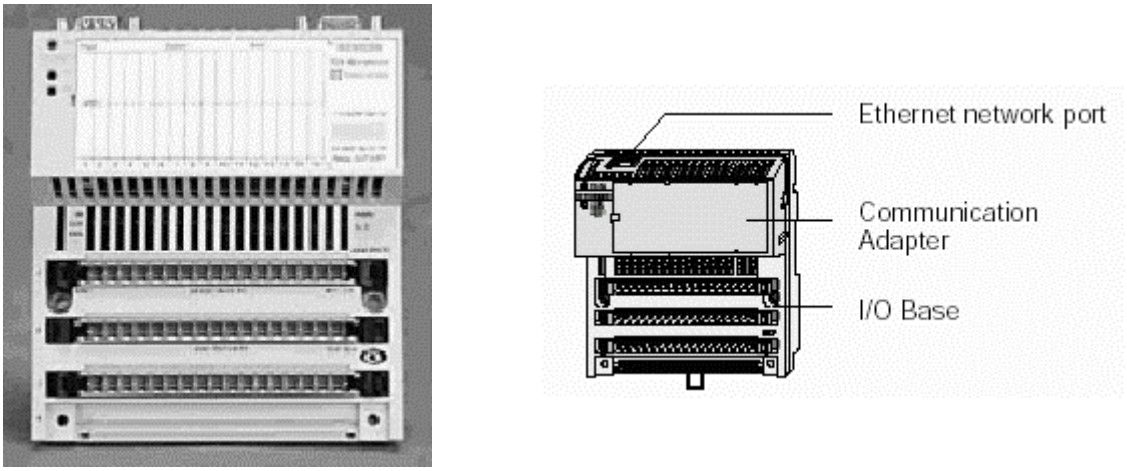


Figure 6-1: Schneider TSX Momentum I/O Units

This complex equipment type permits a TSX Momentum 16 Point Input module to be used as distributed Ethernet I/O on a SCADAPack E Series RTU.

Using this module requires a BOOTP entry be added to the SCADAPack E Series RTU BOOTP server configuration table. This may be added via the RTU command prompt, or via the E Series Configurator tool. For more information see Section ***13-How Do I Change a Modbus/TCP Device….*** or the *E Series Operation Reference Manual*.

Note that an IP address must be entered for each I/O board’s “IP_address” parameter. The value must be the same for all boards within the same complex equipment type. ***Figure 6-2*** details the ISaGRAF Complex Equipment technical note.

6.3 “adi35000” TSX Momentum 170 ADI 350 00

This complex equipment type permits a TSX Momentum 32 Point Input module to be used as distributed Ethernet I/O on a SCADAPack E Series RTU.

Using this module requires a BOOTP entry be added to the SCADAPack E Series RTU BOOTP server configuration table. This may be added via the RTU command prompt, or via the E Series Configurator package. For more information see Section ***13-How Do I Change a Modbus/TCP Device….*** or the *E Series Operation Reference Manual.*

Note that an IP address must be entered for each I/O board’s “IP_address” parameter. The value must be the same for all boards within the same complex equipment type. ***Figure 6-3*** details the ISaGRAF Complex Equipment technical note.

Figure 6-2: ISaGRAF “adi34000” complex equipment Technical Note

name: - TSX Momentum 170 ADI 340 00 16 Pt. In Module
supplier: - Schneider Automation Inc.
reference: - ADI34000
description: - TSX Momentum I/O module equipment boards for the SCADAPack E Series RTU using the TSX Momentum 170 ENT 110 00 Ethernet Communication Adapter
For more information see Schneider Automation documents 870 USE 002 00 and 870 USE 112 00

configuration:

16 digital inputs

- data_update_rate in milliseconds (ms)
- timeout in ms
- IP_address IP address string

13 analog inputs (Module Status Block)

- data_update_rate in ms
- timeout in ms
- IP_address IP address string (must be same as above)

where the analog inputs are defined as follows:

Length of status block (13)
I/O module quantity of input words (1)
I/O module quantity of output words (0)
I/O module ID number (2)
Comms Adapter revision number
ASCII header block length
Last IP to communicate (high word)
Not Used
Not used
I/O module health (32768 = healthy, 0 = not healthy)
I/O module last error value
I/O module error counter (0..65535)
Last IP to communicate (low word)

Figure 6-3: ISaGRAF "adi35000" complex equipment Technical Note

name: - TSX Momentum 170 ADI 350 00 32 Pt. In Module
supplier: - Schneider Automation Inc.
reference: - ADI35000
description: - TSX Momentum I/O module equipment boards for the SCADAPack E Series RTU using TSX Momentum 170 ENT 110 00 Ethernet Communication Adapter
For more information see Schneider Automation documents
870 USE 002 00 and 870 USE 112 00

configuration:

32 digital inputs

- data_update_rate in milliseconds (ms)
- timeout in ms
- IP_address IP address string

13 analog inputs (Module Status Block)

- data_update_rate in ms
- timeout in ms
- IP_address - IP address string (must be same as above)

where the analog inputs variables are are defined as follows:

Length of status block (13)
I/O module quantity of input words (2)
I/O module quantity of output words (0)
I/O module ID number (1)
Comms Adapter revision number
ASCII header block length
Last IP to communicate (high word)
Not Used
Not Used
I/O module health (32768 = healthy, 0 = not healthy)
I/O module last error value
I/O module error counter (0..65535)
Last IP to communicate (low word)

6.4 "adm35010" TSX Momentum 170 ADM 350 10

This complex equipment type permits a TSX Momentum mixed 16 Point Input / 16 Point Output module to be used as distributed Ethernet I/O on a SCADAPack E Series RTU.

Using this module requires a BOOTP entry be added to the SCADAPack E Series RTU BOOTP server configuration table. This may be added via the RTU command prompt, or via the E Series Configurator tool. For more information see Section ***13-How Do I Change a Modbus/TCP Device….*** or the *E Series Operation Reference Manual*.

Special timing parameter considerations need to be made for this Complex I/O equipment type when using the digital output channels. The module will drop its outputs after a period of communication loss with the RTU. The period is specified by the value of this variable. The value of the variable must be much longer than the "must_write_rate" parameter field for the digital outputs (e.g. 3 times longer). Note that the 1 count of the variable value is equivalent to 10ms. The "must_write_rate" field is entered in ms. The PLC cache interface treats communications with remote PLC devices synchronously that is a control may have to wait for an outstanding poll response from the PLC prior to being able to deliver a queued control request. Particularly where multiple complex equipment types are used on the same E Series RTU, consideration must be given to potential delays, which may cause outputs to be temporarily cleared by the unit due to a perceived loss of communications.

The digital output board on this complex equipment type uses hidden string "mtr" for the plc_dev_type. "m" is for advanced Modbus, "t" for TCP socket interface, and "r" causes the RTU to clear the outputs to the module when the ISaGRAF application is stopped.

Note that an IP address must be entered for each I/O board's "IP_address" parameter. The value must be the same for all I/O boards within the same complex equipment type.

Figure 7-4 details the ISaGRAF Complex Equipment technical note.

Figure 6-4: ISaGRAF "adm35010" complex equipment Technical Note

name: - TSX Momentum 170 ADM 350 10 16 Pt. In / 16 Pt. Out Module
supplier: - Schneider Automation Inc.
reference: - ADM35010
description: - TSX Momentum I/O module equipment boards for the E Series RTU using TSX Momentum 170 ENT 110 00 Ethernet Communication Adapter
For more information see Schneider Automation documents 870 USE 002 00 and 870 USE 112 00

configuration:

16 digital inputs

- data_update_rate in ms
- timeout in ms
- IP_address IP address string

16 digital outputs

- must_write_rate in ms
- timeout in ms
- IP_address IP address string (must be same as above)

1 analog output (Outputs Holdup Timeout Value)

- IP_address IP address string (must be same as above)

Valid variable values:
31-5999, each count being 10ms, so timeout range is ~300 ms to ~60 seconds

Note that the value of the analog variable on this I/O board channel should be larger than ten times the value set in the digital output's "must_write_rate" parameter

13 analog inputs (Module Status Block)

- data_update_rate in ms
- timeout in ms
- IP_address IP address string (must be same as above)

Where the analog input variables are defined as follows:

Length of status block (13)
I/O module quantity of input words (1)
I/O module quantity of output words (1)
I/O module ID number (8)
Comms Adapter revision number
ASCII header block length
Last IP to communicate (high word)
Remaining write ownership reservation time (mS)
Remaining outputs holdup time (mS)
I/O module health (32768 = healthy, 0 = not healthy)
I/O module last error value
I/O module error counter (0..65535)
Last IP to communicate (low word)

6.5 “aai03000” TSX Momentum 170 AAI 030 00

This complex equipment type permits a TSX Momentum Analog 8 Channel Differential Input module to be used as distributed Ethernet I/O on a SCADAPack E Series RTU.

Using this module requires a BOOTP entry be added to the SCADAPack E Series RTU BOOTP server configuration table. This may be added via the RTU command prompt, or via the E Series Configurator software. For more information see Section ***13-How Do I Change a Modbus/TCP Device….***or the *E Series Operation Reference Manual*.

Note than an IP address must be entered for each I/O board’s “IP_address” parameter. The value must be the same for all boards within the same complex equipment type.

Special configuration parameters need to be set up for correct operation of this module. It is recommended that ISaGRAF variables be attached to the “Param” I/O board channels with initial values to configure the input range for the analog input channels on this device. It is suggested for clarity that the attached ISaGRAF output variables be set with a display format “+1A2B” to indicate hexadecimal when viewed. Each Hex digit then represents the configuration mode for 1 Analog Input channel. Note that the configuration digit is specific to this type of module. For clarity it is recommended that a comment field be applied to the ISaGRAF output variable explicitly describing the AI channel parameters.

Figure 6-5 details the ISaGRAF Complex Equipment technical note.

6.6 “aai14000” TSX Momentum 170 AAI 140 00

This complex equipment type permits a TSX Momentum Analog 16 Channel Single-Ended Input module to be used as distributed Ethernet I/O on the SCADAPack E Series RTU.

Using this module requires a BOOTP entry be added to the RTU BOOTP server configuration table. This may be added via the RTU command prompt, or via the E Series Configurator Tool. For more information see Section ***13-How Do I Change a Modbus/TCP Device….*** or the *E Series Operation Reference Manual*.

Note than an IP address must be entered for each I/O board’s “IP_address” parameter. The value must be the same for all boards within the same complex equipment type.

Special configuration parameters need to be set up for correct operation of this module. It is recommended that ISaGRAF variables be attached to the “Param” I/O board channels with initial values to configure the input range for the analog input channels on this device. It is suggested for clarity that the attached ISaGRAF output variables be set with a display format “+1A2B” to indicate hexadecimal when viewed. Each Hex digit then represents the configuration mode for 1 Analog Input channel. Note that the configuration digit is specific to this type of module. For clarity it is recommended that a comment field be applied to the ISaGRAF output variable explicitly describing the AI channel parameters.

Figure 6-6 details the ISaGRAF Complex Equipment technical note.

Figure 6-5: ISaGRAF "aai03000" complex equipment Technical Note

name: - TSX Momentum 170 AAI 030 00 Analog 8 Channel Differential Input Module
supplier: - Schneider Automation Inc.
reference: - AAI03000
description: - TSX Momentum I/O module equipment boards for the SCADAPack E Series RTU using TSX Momentum 170 ENT 110 00 Ethernet Communication Adapter
For more information see Schneider Automation documents
870 USE 002 00 and 870 USE 112 00

configuration:

8 analog inputs

- data_update_rate in ms
- timeout in ms
- IP_address IP address string

Values on these channels are:

- Unipolar range selected: 0 to 32000 0~100% scale
- Bipolar range selected: -32000 to 32000 –100~+100% scale
- Broken wire -32768

2 analog outputs (Parameters for input channels)

- must_write_rate in ms
- timeout in ms
- IP_address IP address string (must be same as above)

Variables on this board are:

- Param output 1: 4 Hex digits representing channels 4-1 parameters
- Param output 2: 4 Hex digits representing channels 8-5 parameters

Parameter codes:

0 Hex = Reserved (Default condition control)
2 Hex = +/- 5V & +/- 20mA input range
3 Hex = +/- 10V input range
4 Hex = Channel inactive
A Hex = 1..5V & 4..20mA input range

E.g. Param output 1 = 16#AA32 selects channel 1 as +/-5V, 2 as +/-10V, 3&4 as 1..5V

13 analog inputs (Module Status Block)

- data_update_rate in ms
- timeout in ms
- IP_address IP address string (must be same as above)

where the Variables on this board are defined as follows:

Length of status block (13)	
I/O module quantity of input words (8)	Not Used
I/O module quantity of output words (2)	I/O module health (32768 = healthy, 0 = not healthy)
I/O module ID number (704)	I/O module last error value
Comms Adapter revision number	I/O module error counter (0..65535)
ASCII header block length	Last IP to communicate (low word)
Last IP to communicate (high word)	
Remaining write ownership reservation time (ms)	

Figure 6-6: ISaGRAF "aai14000" complex equipment Technical Note

name: - TSX Momentum 170 AAI 140 00 Analog 16 Channel Single Ended Input Module
supplier: - Schneider Automation Inc.
reference: - AAI14000
description: - TSX Momentum I/O module equipment boards for the SCADAPack E Series RTU using TSX Momentum 170 ENT 110 00 Ethernet Communication Adapter
For more information see Schneider Automation documents
870 USE 002 00 and 870 USE 112 00

configuration:

16 analog inputs

- data_update_rate in ms
- timeout in ms
- IP_address IP address string

Values on these channels are:

- Unipolar range selected: 0 to 32000 0-100% scale
- Bipolar range selected: -32000 to 32000 –100~+100% scale
- Broken wire (4-20mA only) -32768
- Reverse polarity (unipolar) -768

4 analog outputs (Parameters for input channels)

- must_write_rate in ms
- timeout in ms
- IP_address IP address string (must be same as above)

Variables on this board are:

- Param output 1: 4 Hex digits representing channels 4-1 parameters
- Param output 2: 4 Hex digits representing channels 8-5 parameters
- Param output 3: 4 Hex digits representing channels 12-9 parameters
- Param output 4: 4 Hex digits representing channels 16-13 parameters

Parameter codes 0 Hex = Reserved (Default condition control)
A Hex = +/- 5V input range
B Hex = +/- 10V input range
C Hex = Channel inactive
E Hex = 4..20mA input range

E.g. Param output 1 = 16#EEBA selects channel 1 as +/-5V, 2 as +/-10V, 3&4 as 4..20mA

13 analog inputs (Module Status Block)

- data_update_rate in ms
- timeout in ms
- IP_address IP address string (must be same as above)

Variables on this board are:

Length of status block (13)	Last IP to communicate (high word)
I/O module quantity of input words (16)	Remaining write ownership reservation time (mS)
I/O module quantity of output words (4)	Not Used
I/O module ID number (1217)	I/O module health (32768 = healthy, 0 = not healthy)
Comms Adapter revision number	I/O module last error value
ASCII header block length	I/O module error counter (0..65535)

6.7 "ado35000" TSX Momentum 170 ADO 350 00 (continue)

This complex equipment type permits a TSX Momentum 32 Point Output module to be used as distributed Ethernet I/O on a SCADAPack E Series RTU. Using this module requires a BOOTP entry be added to the RTU's BOOTP server configuration table. This may be added via the RTU command prompt, or via the E Series Configurator tool. For more information see Section ***13-How Do I Change a Modbus/TCP Device….***or the *E Series Operation Reference Manual*. ***Figure 6-7*** details the ISaGRAF Complex Equipment technical note.

Note that an IP address must be entered for each I/O board's "IP_address" parameter. The value must be the same for all boards within the same complex equipment type.

Figure 6-7: ISaGRAF "ado35000" complex equipment Technical Note

name: - TSX Momentum 170 ADO 350 00 32 Pt. Out Module
supplier: - Schneider Automation Inc.
reference: - ADO35000
description: - TSX Momentum I/O module equipment boards for the E Series RTU using TSX Momentum 170 ENT 110 00 Ethernet Communication Adapter
For more information see Schneider Automation document 870 USE 112 00

configuration:

32 digital outputs - must_write_rate in Ms
- Timeout in ms
- IP_address IP address string (must be same as above)

1 analog output (Outputs Holdup Timeout Value)
IP_address IP address string (must be same as above)

Valid variable values: 31-5999, each count being 10mS, so timeout range is ~300 ms to ~60s.

Note that the value of the analog variable on this I/O board channel should be larger than ten times the value set in the digital output's "must_write_rate" parameter

13 analog inputs (Module Status Block)
- data_update_rate in ms
- timeout in ms
- IP_address IP address string (must be same as above)

Variables on this board are:

Length of status block (13)
I/O module quantity of input words (0)
I/O module quantity of output words (2)
I/O module ID number (5)
Comms Adapter revision number
ASCII header block length
Last IP to communicate (low word)
Remaining write ownership reservation time (mS)
I/O module last error value
I/O module error counter (0..65535)
Last IP to communicate (high word)
I/O module health (32768 = healthy, 0 = not healthy)
Remaining outputs holdup time (mS)

7 Communications Interface

7.1 Serial Modbus Communications

When using serial Modbus master communications, the SCADAPack E Series RTU communicates with the PLC or peripheral devices using RTU serial port(s) configured as '*PLC Device*'. Each port must be configured to communicate at the same rate and in the same format as the peripheral device(s). For example 9600 bps, 8 data bits, 1 stop bit, and no parity.

A sample cable configuration for connecting a PLC to a SCADAPack E Series RTU RS232 port is shown in ***Figure 7-1***.

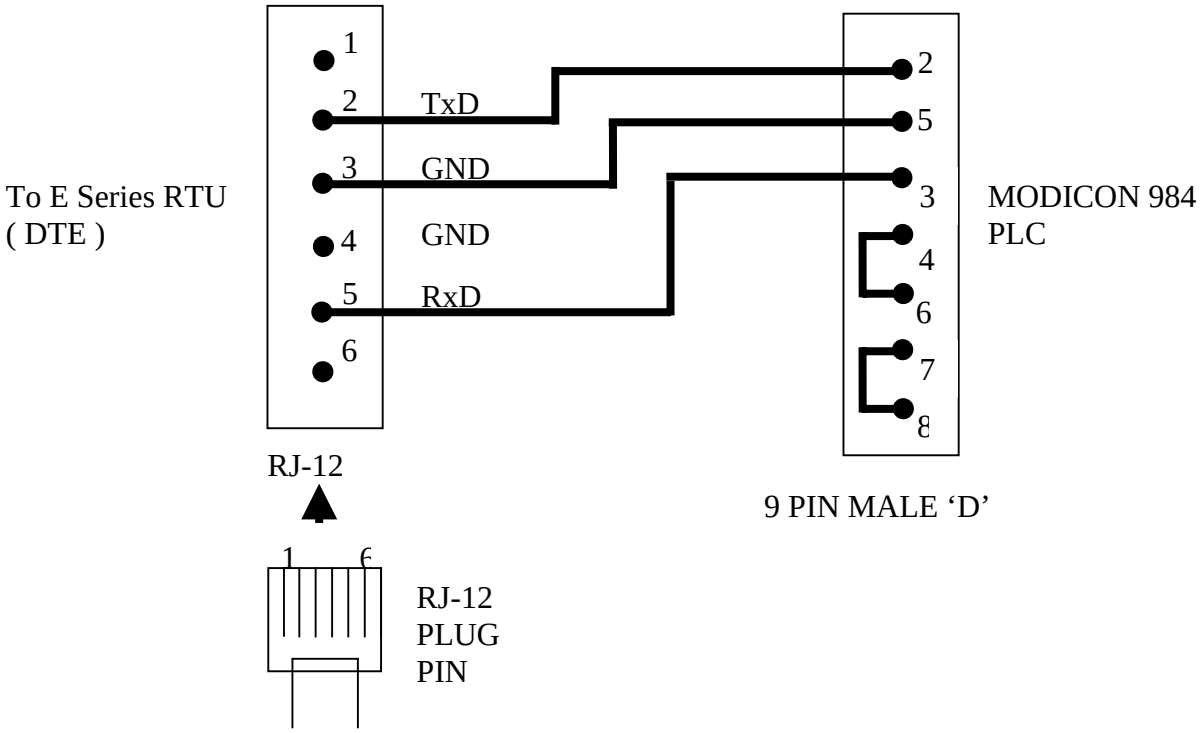


Figure 7-1: E Series RTU to PLC Cable

The SCADAPack E Series RTU does not assert any hardware handshaking lines when communicating using RS232, RS422 or 4-wire RS485 with its Modbus PLC device driver. If the Modbus PLC requires hardware handshaking (e.g. CTS asserted), it must be provided in the cabling to the PLC (as shown above). When 2-wire RS485 communications is used, the SCADAPack E Series RTU provides RS485 transmitter/receiver control internally. For more information see *the E Series User Manual.*

7.2 Modbus/TCP Client Communications

Modbus/TCP Client communications is support by the SCADAPack E Series RTU.

When using Modbus/TCP communications, the RTU communicates with the PLC or peripheral devices using a TCP/IP interface. This may be the RTU's Ethernet interface configured as "RemIO + TCP/IP", or a serial port configured as '*PPP-TCP/IP*'.

In addition, the RTU's "IP Services" configuration must have "Modbus/TCP Client" service enabled for operation of Modbus/TCP protocol. This configuration can be made on the E Series Configurator "TCP/IP" page. For more information see the *E Series TCP/IP Technical Reference* manual.

Enabling Modbus/TCP Client service requires the RTU to be restarted in order to start the RTU's PLC Cache task.

The SCADAPack E Series RTU may connect to any Open Modbus/TCP protocol device including PLCs, I/O modules and Modbus Bridges.

Each Modbus/TCP I/O board specifies an "*IP_address*" parameter that must be configured with the address of the Modbus/TCP device that the RTU is communicating with (for that I/O board). It is assumed that the E Series RTU and the Modbus/TCP device(s) have fixed IP address which are unique on the IP network to which they are connected.

The RTU's Modbus/TCP client attaches to TCP port number "502" in each target Modbus/TCP server device. (Can be changed by advanced ISaGRAF users if required).

Some Modbus/TCP devices expect to obtain their IP addresses from another device on their network rather than being configured with their address, locally. For this purpose, the SCADAPack E Series RTU supports BOOTP Server capability. BOOTP Server must also be enabled in the RTU's "IP Services" configuration to support this capability. See section ***7.4- BOOTP Server Configuration*** for more information.

For further information on connecting to the SCADAPack E Series RTUs to TCP/IP networks, refer to the *E Series TCP/IP Reference* manual.

7.3 Modbus/TCP Server Communications

Modbus/TCP Server communications is also supported by the SCADAPack E Series RTU.

When using Modbus/TCP Server communications, the RTU communicates with Modbus/TCP clients using one of its TCP/IP interfaces. This may be the RTU's Ethernet interface configured as "RemIO + TCP/IP", or a serial port configured as '*PPP-TCP/IP*'.

In addition, the RTU's "IP Services" configuration must have "Modbus/TCP Server" service enabled for operation of Modbus/TCP protocol. This configuration can be made on the E Series Configurator's "TCP/IP" page. For more information see the *E Series TCP/IP Technical Reference* manual.

Enabling Modbus/TCP Server service requires the RTU to be restarted in order to start the RTU's Modbus/TCP Server listening task. The RTU's Modbus/TCP Server 'listens' on TCP port number

"502" for any Modbus/TCP client devices attempting to connect. Note that the Open Modbus/TCP server supports a maximum of 5 concurrent client connections. An open socket will be closed if there is no activity detected for 120 seconds (see section ***8.8 - TCP / Operating System Issues*** for more information regarding the inactivity disconnect timeout).

For further information on connecting SCADAPack E Series RTUs to TCP/IP networks, refer to the *E Series TCP/IP Reference* manual.

7.4 BOOTP Server Configuration

BOOTP is a TCP/IP application protocol that utilizes UDP socket communications. The E Series RTU may be configured to start a BOOTP server by selecting it using from the E Series Configurator's "TCP/IP Services" configuration. The BOOTP server (E Series RTU) listens for requests from a BOOTP client (typically an IP device on a LAN).

Typically, the BOOTP client uses its Ethernet MAC address to identify itself, and via *broadcast* IP messages, requests a BOOTP server to configure its parameters.

The E Series RTU is capable of configuring a BOOTP client's "your-ip" address. However, the E Series RTU will not configure any of the other BOOTP standard or extended fields. (see RFC 951 and later).

The E Series Configurator tool provides a configuration interface for the E Series RTU's BOOTP server. The user enters an Ethernet-MAC / IP address pair for each node requiring BOOTP configuration of its IP address. Note that the E Series RTU will not answer a BOOTP request from a client node unless there is a corresponding entry in the Ethernet-MAC / IP address table.

Note:	Devices refer to their Ethernet-MAC address in different ways, such as "IEEE Global Address". In all cases, the Ethernet-MAC address will contain a 12 digit hexadecimal number.

Ethernet-MAC address entry in the E Series RTU, for BOOTP, may be in any of the following formats (12 hexadecimal digits, case insensitive):

00:1A:2B:3C:4D:5E

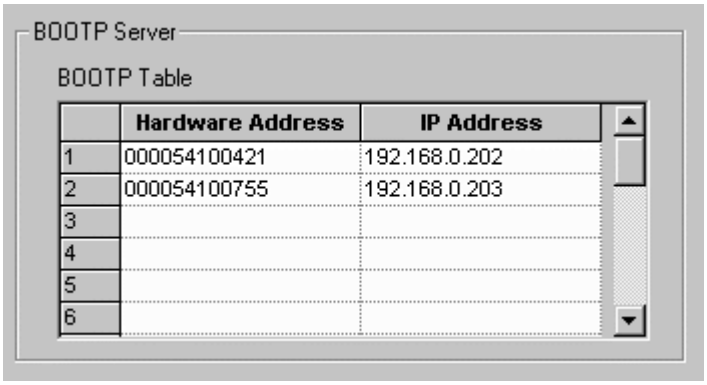
00-1A-2B-3C-4D-5E

001A2B3C4D5E

IP address entry must be in the following format (leading zeroes not required): 192.168.1.97

7.4.1 Configuring BOOTP with the E Series Configurator

The following figure shows the E Series Configuration of the BOOTP table. This is found in the "Adv. TCP/IP" tab of the E Series Configurator.



Enter the BOOTP client details in the table, in the same format as described above. The "Hardware Address" field is the Ethernet-MAC address in one of the three formats described. The configured "IP Address" is configured in the device with the specified hardware address.

Changes to the BOOTP Table in the E Series Configurator should be followed by "WRITE". BOOTP Table changes become active in the E Series RTU immediately (i.e. no need to restart the RTU).

7.4.2 Configuring BOOTP from the Command Line

In addition to configuring the BOOTP table via the E Series Configurator, the E Series RTU command line provides a management command to manipulate the BOOTP server configuration table.

```
Command: bootp /?
BOOTP protocol loads IP address to remote Ethernet devices
BOOTP command manipulates configuration table
(Note changes ARE permanent)
Usage:
BOOTP PRINT
BOOTP ADD remote-MAC remote-IP
BOOTP DELETE [remote-MAC]
             [remote-IP]
```

For example, the following command prints the BOOTP configuration table:

```
Command: bootp print

BOOTP entries:
Ethernet MAC Addr       IP Addr Loaded  Load Count
00-01-02-03-04-05       192.168.0.242   1
01-02-03-04-05-06       158.234.186.168 2
```

This indicates the configured BOOTP server entries (what IP Address will be loaded to which Ethernet MAC address), and indicates how many times the BOOTP server has sent BOOTP response commands to the appropriate BOOTP client.

The following command ADDS or REPLACES an entry in the BOOTP configuration table:

```
Command: bootp add 01-02-03-04-AA-BB 158.234.186.168
```

An existing entry with a matching Ethernet MAC address OR matching IP address will be replaced by the new entry. This is typically used if an existing Modbus/TCP device is replaced by another device with a different Ethernet MAC Addr, for example.

The following command REMOVES an entry in the BOOTP configuration table:

```
Command: bootp del 01-02-03-04-AA-BB
```

Either the Ethernet-MAC address or IP address may be used to specify which BOOTP entry to remove, but the string used in the "del" command must exactly match the string in the BOOTP entry in order for the entry to be removed successfully.

Changes made to the BOOTP configuration table via the E Series Configurator or command line are retained in NON-VOLATILE MEMORY and DO NOT require the E Series RTU to be reset in order to take effect. However, remember to make a record of the RTU's configurations after they are modified.

When BOOTP diagnostics are enabled (via TCPDIAG command), the E Series RTU diagnostic stream indicates when a remote device is configured via BOOTP by the PDS RTU. E.g.

```
BOOTP>>loaded IP: 158.234.186.168  to MAC: 01-02-03-04-AA-BB
```

8 Data Communications Protocol

The following sections detail the framing of the basic Modbus RTU data communication protocols.

Modbus application layer protocol is used by both serial Modbus, and Open Modbus/TCP. Details of the application layer protocol may be found in Modbus or Open Modbus/TCP documentation.

8.1 Modbus Serial Communication Format

The basic frame structure for Modbus RTU serial protocol is as follows:

❖ Request

Slave ID	Function Code	Function dependent request data ….	CRC16 (msb)	CRC16 (lsb)

Maximum request frame size 256 bytes

❖ Response

Slave ID	Function Code	Function dependent response data ….	CRC16 (msb)	CRC16 (lsb)

The *Slave ID* of the request is returned in the Response. The *Function Code* of the request is returned in the response if there were no errors. An error response has the most significant bit of the request function code set on (see Error Response). Maximum response frame size 256 bytes

❖ Error Response

Slave ID	Function Code	Exception Code	CRC16 (msb)	CRC16 (lsb)

The *Slave ID* of the request is returned in the Response. The *Function Code* in an error response has the most significant bit of the request function code set on. I.e. Error Function Code = Request Function Code + 0x80. Maximum response frame size 256 bytes.

Useful *Exception Codes* are:

0x01 = Illegal Function	(slave doesn't support function in request)
0x02 = Illegal Data Address	(slave doesn't have register specified in request)
0x03 = Illegal Data Value	(value in request out of range for register in slave)
0x04 = Illegal Response Length	(request would cause response to exceed 256 bytes)

8.2 CRC16 Calculation Method

CRC error checking is only performed for Modbus serial communications. Two CRC error check codes are appended to the end of both Modbus request and reply messages.

The CRC method used is a standard CRC-16 with the following polynomial:

$G(x) = x^{16} + x^{15} + x^2 + x^1$

Starting Value = FFFFH

Feedback = A001H

The CRC is calculated using the body and header of the message (i.e. whole message excluding CRC bytes).

8.3 Open Modbus/TCP Communication Format

The basic frame structure for Open Modbus/TCP protocol is as follows. This is the stream data transported via the TCP socket connection and does not include TCP/IP protocol bytes.

❖ Request

Transaction ID (msb) 0*	Transaction ID (lsb) 0*	Protocol ID (msb) 0	Protocol ID (lsb) 0	Length (msb) 0	Length (lsb)
Unit ID	Function Code	Function dependent request data ….			

**Transaction ID* is echoed by the Modbus/TCP server and may be used by a client. The E Series RTU sets these bytes to 0 in requests.

Protocol ID identifies the message protocol following in the data stream. When both these bytes are 0, it indicates Modbus/TCP protocol.

Length (lsb) indicates the number of bytes following in the rest of the frame. Minimum value is 3, maximum value is 255.

Unit ID uniquely identifies the Modbus device, and is equivalent to Slave ID of serial Modbus.

CRC error checking is not used for Open Modbus/TCP communications. Instead it relies on TCP/IP stack layers to provide error free transmission of data.

Function Code and following data is equivalent to serial Modbus RTU protocol.

❖ Response

Transaction ID (msb)	Transaction ID (lsb)	Protocol ID (msb) 0	Protocol ID (lsb) 0	Length (msb) 0	Length (lsb)
Unit ID	Function Code	Function dependent response data ….			

Transaction ID is echoed by the Modbus/TCP server in the response.

Length (lsb) indicates the number of bytes following in the rest of the frame. Minimum value is 3, maximum value is 255.

Unit ID is equivalent to Slave ID of serial Modbus.

❖ Error Response

Transaction ID (msb)	Transaction ID (lsb)	Protocol ID (msb) 0	Protocol ID (lsb) 0	Length (msb) 0	Length (lsb) 3
Unit ID	Function Code	Exception Code			

Transaction ID is echoed by the Modbus/TCP server in the response

The *Unit ID* of the request is returned in the Response.

The *Function Code* in an error response has the most significant bit of the request function code set on, i.e. Error Function Code = Request Function Code + 0x80

Useful *Exception Codes* are listed in the following table.

Exception Code	Code Description	Comment
0x01	Illegal Function	slave doesn't support function in request
0x02	Illegal Data Address	slave doesn't have register specified in request
0x03	Illegal Data Value	value in request out of range for register in slave
0x04	Illegal Response Length	request would cause response to exceed 256 bytes
0x0A	Gateway Target Device Failed to Respond	returned by Gateway when no response from remote device

8.4 Open Modbus/TCP Socket Communication

Open Modbus/TCP communications are always initiated by the client (e.g. E Series RTU, SCADA master station, etc.). The client opens a TCP socket on a Modbus/TCP Server (e.g. PLC, I/O block, Gateway, Bridge). The socket is connected with the configured IP address of the server, using assigned TCP port number "502". Open Modbus/TCP protocol packets are exchanged between the client and the server across the open TCP socket.

8.5 Open Modbus/TCP Client Procedures

An error causes the socket to be disconnected by the client. Before the client sends a new request, it attempts to open a new socket at the assigned port number on the server.

8.6 Open Modbus/TCP Server Procedures

The Open Modbus/TCP Server may disconnect a connected client (closing the socket) under the following conditions

- error detected - invalid header (i.e. does not conform to Open Modbus/TCP Specification)
- error detected - invalid message (e.g. length differs to that specified in header, etc.)
- requested unit identifier differs to RTU configuration value
- inactivity timeout (see Section ***8.8 - TCP / Operating System Issues*** for more information regarding inactivity timeout).
- RTU orderly shutdown (e.g. remote cold reset received). Disconnects all connected clients.

8.7 Open Modbus/TCP Server

This section documents issues specific to the Modbus/TCP Server, where as issues common to the Modbus/TCP Server and the Modbus Slave such as conformance classes, mapping of Modbus addresses to the RTU point address space, and the circumstances under which specific response exception codes are generated, are detailed in Section ***10 - Modbus/TCP Server and Modbus Slave Implementation Issues***.

The SCADAPack E Series RTU Modbus/TCP server shall only be operational if the RTU's "IP Services" configuration has the "Modbus/TCP Server" service enabled. This configuration can be made from the E Series Configurator's "TCP/IP" page. For more information see the *E Series User* manual.

8.8 TCP / Operating System Issues

The E Series Modbus/TCP server listens on port 502 for any incoming connections. On detecting an incoming connection a new task is created to handle the client connection. A new socket will be opened with an inactivity timeout of 120 seconds (2 minutes). The inactivity timer is re-triggered for each Modbus request received. Conventionally, following a successful transaction, it will be the client that closes the connection, though if the inactivity timer expires with the socket still open, the SERVER shall close the connection. On disconnection, the task created to handle this transaction will be destroyed. Note that if the Modbus/TCP Server receives only part of a message, a shorter inactivity timeout of 30 seconds will be applied. The E Series Modbus/TCP server supports a maximum of 5 concurrent clients.

9 Modbus Slave

This section documents the issues specific to the native Modbus Slave driver. Issues common to the Modbus/TCP Server and the Modbus Slave such as conformance classes, mapping of Modbus addresses to the RTU point address space, and the circumstances under which specific response exception codes are generated, are detailed in Section ***10 - Modbus/TCP Server and Modbus Slave Implementation Issues***.

The E Series RTU supports a native Modbus Slave driver (i.e. does not require ISaGRAF) as well as the default Modbus Slave implementation included in ISaGRAF. Note that the Modbus Slave detailed hereafter in this document refers to the native Modbus Slave driver, which maps directly into the RTU point database. Consult the E Series ISaGRAF Technical Reference for details concerning the ISaGRAF Modbus Slave implementation.

The native E Series Modbus Slave shall only be operational if any of the serial port functions are set to ***Modbus Slave***. This configuration can be made from the E Series Configurator's "Ports" page. Note that the RTU must be restarted to activate any subsequent port changes. Note also that the Modbus Slave can be independently applied to multiple serial ports, though the single **Slave Address** is applied to all instances of the Modbus Slave driver (see Section ***11.5 - Modbus Slave Address*** for details regarding Modbus Slave configuration system points).

10 Modbus/TCP Server and Modbus Slave Implementation Issues

This section details the implementation issues that are common to both the Modbus/TCP Server and the native Modbus Slave.

10.1 Conformance Classes

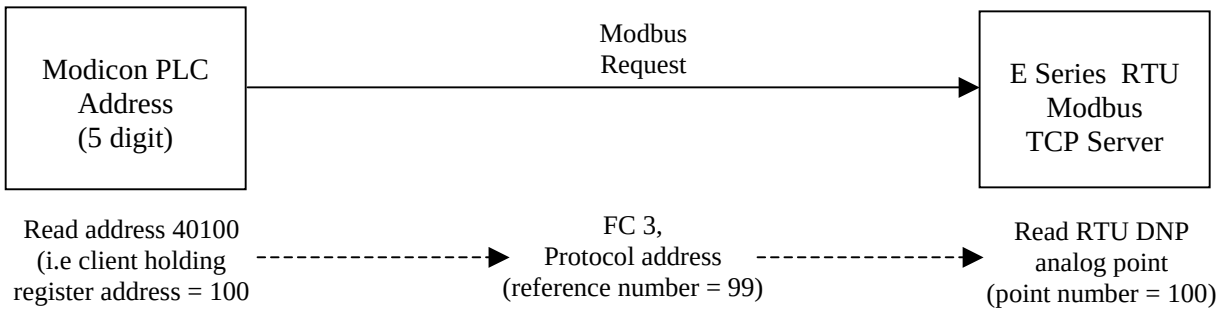
The following classes (and function codes) are supported by the Modbus/TCP Server and the native Modbus Slave.

- Class 0 (function codes 3 and 16)
- Class 1 (function codes 1, 2, 4, 5, 6, and 7)
- Class 2 (function code 15 only).

10.2 Modbus Address Mapping to RTU Point Address Space

This section identifies how the binary and analog Modbus addresses are mapped to the RTU point address space. The "Modbus address" referenced in this section is the Modicon PLC client style register address (protocol address + 1). This Modbus address is mapped directly (i.e. 1-1) to the RTU point number. **For analog multiple read/writes, this mapping is relevant for the start address only**. The mapping of subsequent registers to RTU points is dependent on the RTU configuration point DNP static object types (e.g 16-bit, 32-bit and floating point object types). Note that as a result of these mapping rules, it is possible to reference a different 32-bit analog point in the RTU with the same Modbus register, based on different reference numbers and word counts of separate Modbus requests. Section ***10.2.3 - Modbus Register / 32-bit Analog Point Mapping Configuration*** discusses the required configurations to ensure consistent and deterministic mapping of Modbus registers to 32-bit analog points. See Sections ***10.2.2.1-Read Multiple Registers (Function Codes 3 & 4)*** and ***10.2.2.4-Function Codes 6 & 16: Write Single and Multiple Registers*** for more information on function codes that reference analog points.

This standard mapping is illustrated in the following example using 5 digit addressing



For clients using 5 digit addressing, the addressable range of both the client register address and the RTU point numbers are from 1 to 9999, and this corresponds to a protocol address (reference number) addressable range from 0 – 9998.

For clients using 6 digit addressing, the addressable range of both the client register address and the RTU point numbers are from 1 to 65535, and this corresponds to a protocol address (reference number) addressable range from 0 – 65534.

Note that in the E Series RTU, the minimum derived point (i.e. non-physical) is always greater than the maximum physical point number. Refer to the *E Series RTU Configuration Technical Reference Manual* for the RTU point numbering methodology.

The following sections describe how each function code is affected by point mapping. See Section ***10.4- Exception Codes*** for information on how multiple read / write requests are handled when some of the requested addresses are invalid.

10.2.1 Binary Addresses

Consider the following

- modbus address = *x*
- *binary output point* may be physical binary output or derived binary
- *binary input point* may be physical binary input or derived binary
- NONE of the requested points exist if for **every** modbus address *x* referenced in the request, no RTU configuration point *x* exists.

10.2.1.1 Function Code 1: Read Discrete Coils

FC 1 will invoke point reads for every modbus address *x* referenced in the request, described as follows …

- if NONE of the requested points exist then return ILLEGAL FUNCTION (01)
- if *x* exists as a *binary output point* then the current value of binary output *x* will be read
- if at least one of the requested points exist and *x* does NOT exist as a *binary output point* then a zero value for modbus address *x* will be returned in the response.

10.2.1.2 Function Code 2: Read Discrete Inputs

FC 2 will invoke point reads for every modbus address *x* referenced in the request, described as follows …

- if NONE of the requested points exist then return ILLEGAL FUNCTION (01)
- if *x* exists as a *binary input point* then the current value of binary input *x* will be read
- if at least one of the requested points exist and *x* does NOT exist as a *binary input point* then a zero value for modbus address *x* will be returned in the response.

10.2.1.3 Function Code 5: Preset Discrete Coil

FC 5 will invoke point writes, described as follows …

- if *x* exists as a *binary output point* then binary output *x* will be controlled
- if *x* does NOT exist as a *binary output point* then return ILLEGAL FUNCTION (01)

10.2.1.4 Function Code 15 : Write Multiple Coils

FC 15 will invoke point writes for every modbus address *x* referenced in the request, described as follows …

- if *x* exists as a *binary output point* then binary output *x* will be controlled
- if *x* does NOT exist as a *binary output point* then stop processing request and return ILLEGAL FUNCTION (01)

10.2.2 Analog Addresses

This section details the specific mapping for function codes that reference analog addresses. As noted earlier, it is possible to result in inconsistent mapping where modbus registers map to 32-bit analog points. Section ***10.2.3 - Modbus Register / 32-bit Analog Point Mapping Configuration*** demonstrates the configurations required to ensure consistent mapping of Modbus registers to 32-bit analog points.

Consider the following

- modbus address = *x*
- corresponding analog configuration point = *x' (*depends on DNP static object type of point. If all points referenced are "16 bit analogs" then *x' = x)*
- *analog output point* may be physical analog output or derived analog
- analog input point may be physical analog input or derived analog
- NONE of the requested points exist if for **every** modbus address *x* referenced in the request, no RTU configuration point *x'* exists.

10.2.2.1 Read Multiple Registers (Function Codes 3 & 4)

The register address ←→ point mapping decribed in this section relates primarily to the start register address specified in the modbus request. The word count included in the request, in conjunction with the DNP static object type of the mapped points, will affect the number of RTU confguration points included in the response. The following example illustrates this mapping for function code 3.

Consider the modbus request as follows (starting from the function code)

… 03 03 e8 00 03

which translates to …"read 3 holding registers at reference number 1000" (41001 in Modicon 984).

The reference number 1000 would therefore map to RTU point number 1001.

Consider the following RTU points configurations

Analog 1001 : DNP static object type ➔ 16 bit analog
Analog 1002 : DNP static object type ➔ 32 bit analog
Analog 1003 : DNP static object type ➔ 16 bit analog …

This would map RTU analog points to modbus client holding register addresses as follows

RTU Analog 1001 maps to client holding register address 1001
RTU Analog 1002 maps to client holding register address 1002 and 1003.

Note that RTU Analog point 1003 would not be included in the response.

10.2.2.2 Function Code 3: Read Holding Registers

FC 3 will invoke point reads for every modbus address *x* referenced in the request, described as follows …

- if NONE of the requested points exist then return ILLEGAL FUNCTION (01)

- if *x'* exists as an *analog output point* then the current value of analog output *x'* will be read
- if at least one of the requested points exist and *x'* does NOT exist as an *analog output point* then a zero value for modbus address *x* will be returned in the response.

10.2.2.3 Function Code 4: Read Input Registers

FC 4 will invoke point reads for every modbus address *x* referenced in the request, described as follows …

- if NONE of the requested points exist then return ILLEGAL FUNCTION (01)
- if *x'* exists as an *analog input point* then the current value of analog input *x'* will be read
- if at least one of the requested points exist and *x'* does NOT exist as an *analog input point* then a zero value for modbus address *x* will be returned in the response.

10.2.2.4 Function Codes 6 & 16: Write Single and Multiple Registers

FC 6 and FC 16 will invoke point writes for every modbus address *x* referenced in the request, described as follows …

- if *x'* exists as an *analog output point* then analog output *x'* will be controlled
- if *x'* does NOT exist as an *analog output point* then stop processing request and return ILLEGAL FUNCTION (01)

The register address ←→ point mapping described above for function code 16, relates primarily to the start register address specified in the modbus request. The word count included in the request, in conjunction with the DNP static object type of the mapped points, will affect the number of RTU points controlled by the request. The following example illustrates this mapping.

Consider the modbus request as follows (starting from the function code)

… 10 03 e8 00 03 06 00 08 00 04 00 00

which translates to …"write 3 holding registers at reference number 1000" (41001 in Modicon 984).

The reference number 1000 would therefore map to RTU point number 1001. Consider the following RTU points configurations

Analog 1001 : DNP static object type ➔ 16 bit analog
Analog 1002 : DNP static object type ➔ 32 bit analog
Analog 1003 : DNP static object type ➔ 16 bit analog …

This would result in the following controls

RTU Analog point 1001 is assigned the integer value 8
RTU Analog point 1002 is assigned the integer value 4.

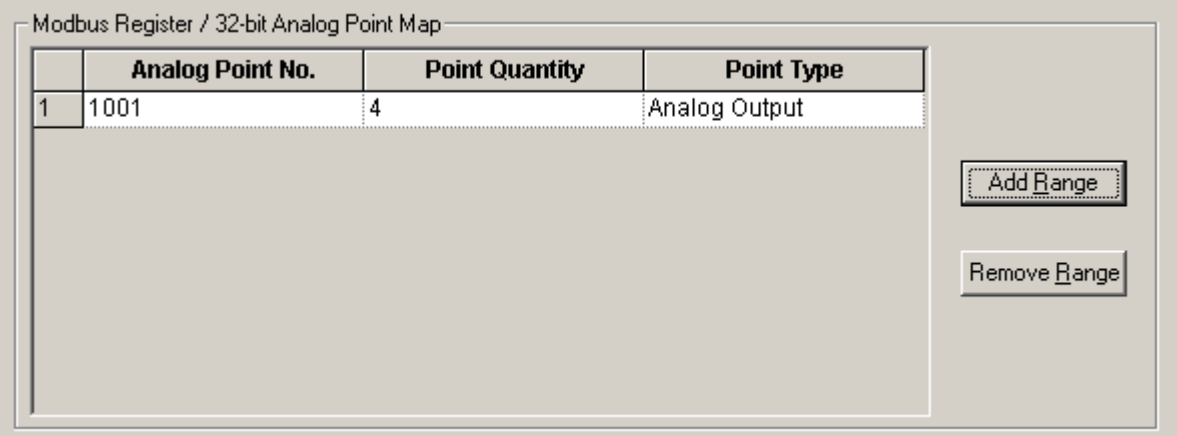
Note that Analog point 1003 is not controlled.

10.2.3 Modbus Register / 32-bit Analog Point Mapping Configuration

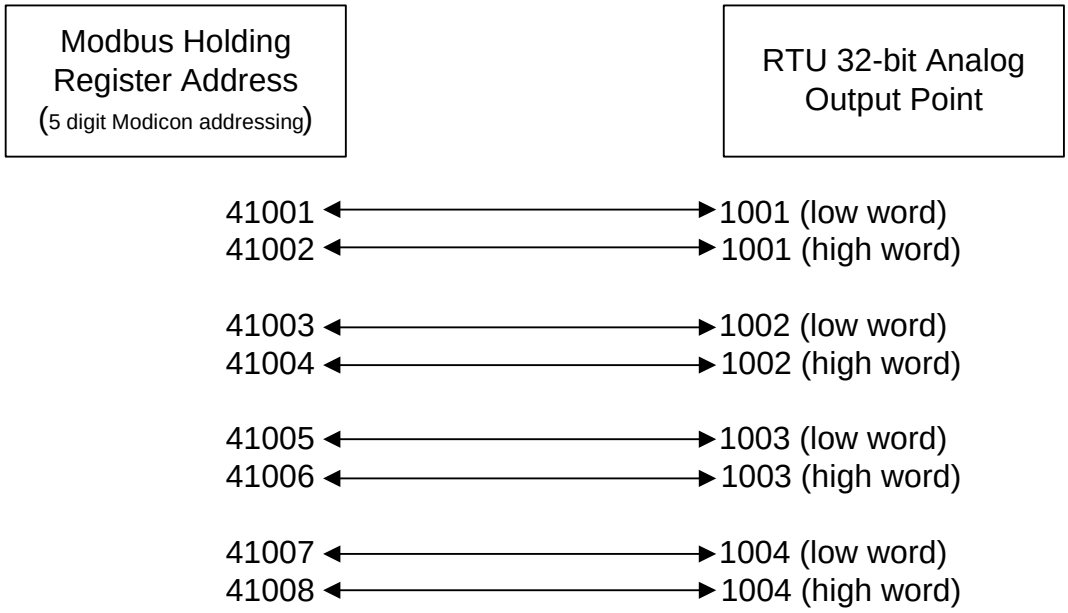
As noted earlier, it is possible to reference a different 32-bit analog point in the RTU with the same modbus register, based on different reference numbers and word counts of separate modbus requests. In order to ensure a consistent and deterministic mapping, it is possible to specify an RTU configuration that identifies 32-bit analog configuration points from the perspective of the Modbus/TCP Server and the native Modbus Slave. This additional configuration is available in

firmware releases 7.3-5 and later, and can be specified using the E Series Configurator tool. Note that it can only be included in a RTU configuration file.

The following image displays the E Series Configurator interface, which specifies analog points 1001-1004 as 32-bit **output** points. This interface is accessible via the **Modbus** page within the E Series Configurator (access the RTU Types dialog box if the **Modbus** tab is not visible).



This configuration would result in the consistent register / point mapping as shown in the following diagram, irrespective of the reference number and the word count specified in the request.



e.g. a modbus request to control single holding register 41005 would result in controlling RTU analog point 1003, where as without the additional mapping configuration shown on the previous page, this control would have otherwise mapped to analog point 1005.

Note that an attempt to control single holding register 41006 would result in an exception response, as this register would always map to the high word of analog 1003. Similarly multiple register

requests whose start reference number is the high word of a designated 32-bit analog will always be considered invalid and therefore return an exception response.

This configuration can also be directly manipulated in a configuration file using the **MR** table format. Consult the E Series Configuration File Format document for more information regarding the **MR** table format.

10.3 Function Code 7

This function code allows for the client to request the server to return an exception status that is stored in a pre-determined range of 8 coils. RTU binary system (scratchpad) points 50000 to 50007 are allocated for this purpose.

- RTU binary point 50000 will map to the least significant bit of the response byte.
- RTU binary point 50007 will map to the most significant bit of the response byte.

10.4 Exception Codes

This section lists some specific circumstances under which response exception codes may be generated. Refer to the Open Modbus/TCP Specification for the full list of exception codes and their descriptions.

10.4.1 Read Multiple Coils / Register Issues

Requests to read multiple coils/registers will generate a successful response, if at least one of the requested addresses is valid, and the invalid data addresses shall be returned with a zero value. If all requested addresses are invalid, the response exception code shall be set to ILLEGAL FUNCTION (01).

10.4.2 Write Multiple Coils / Register Issues

Requests to write to multiple coils/registers may generate a successful response only if all of the requested addresses are valid and all controls succeed. If at least one of the requested addresses is invalid or a control does not succeed then the remaining controls in the request are ignored and an exception response is returned with exception code ILLEGAL FUNCTION (01).

10.4.3 Writes to RTU Points under ISaGRAF Control

Any requests to write to coils / registers that may be under the exclusive control of the RTU sequencer (ISaGRAF), will generate the response exception code ILLEGAL FUNCTION (01) even if previous controls in the same multiple write request have been successful. Read requests to points under ISaGRAF control will be successful.

10.4.4 Invalid Addresses

Any requests that reference RTU point numbers outside of the range 0-65535 will generate the response exception code ILLEGAL DATA ADDRESS (02). See Section ***10.2-Modbus Address Mapping to RTU Point Address Space*** for details on how Modbus addresses map to RTU point numbers.

10.4.5 Supported Data Types

The SCADAPack E Series RTU Modbus/TCP Server and the native Modbus Slave shall support the IEC61131 data types as described in the Open Modbus/TCP specification.

The following table lists the IEC61131 data type interpreted for function codes 3, 4 and 16. The interpreted data type is dependant on the DNP static object type of the RTU configuration point (configurable on a per point basis). Refer to the *E Series RTU Configuration Technical Reference Manual* for more information.

Table 10-1: Mapped Point Data Types

Mapped Point DNP Static Object Type	**IEC61131 Data Type (included in response)**
Object 1 Var 1 (binary input no status) Object 1 Var 2 (binary input with status) Object 10 Var 2 (binary output status)	DISCRETE Binary (discrete) data packed into 8-bit values where least significant bit represents low discrete bit numbers.
Object 30 Var 1 (32-bit analog with status) Object 30 Var 3 (32-bit analog no status) Object 40 Var 1 (32-bit analog output sts)	DINT (signed 32-bit integer value) Bits 15 - 0 of 1st register = bits 15 - 0 of DINT Bits 15 – 0 of 2nd register = bits 31 - 16 of DINT
Object 30 Var 2 (16-bit analog with status) Object 30 Var 4 (16-bit analog no status) Object 40 Var 2 (16-bit analog output sts)	INT (signed 16-bit integer value) Bits 15 – 0 of register = bits 15 - 0 of INT
Object 30 Var 5 (short float point with sts) Object 40 Var 3 (short float point output sts)	REAL (32-bit Intel single precision real) Bits 15 – 0 of first register = bits 15 – 0 of REAL (bits 15 - 0 of significance) Bits 15 – 0 of second register = bits 31 - 16 of REAL (exponent + bits 23-16 of significance)
Object 20 Var 1 (32-bit counter with status) Object 20 Var 5 (32-bit counter no status)	UDINT (unsigned 32-bit integer value) Bits 15 – 0 of first register = bits 15 - 0 of UDINT Bits 15 – 0 of second register = bits 31-16 of UDINT
Object 20 Var 2 (16-bit counter with status) Object 20 Var 6 (16-bit counter no status)	UINT (unsigned 16-bit integer value) Bits 15 - 0 of register = bits 15 - 0 of INT

11 System Points

RTU system points are provided to indicate the status of some ISaGRAF I/O boards that are used for Slave I/O communications with peripheral devices such as PLCs.

Where multiple ISaGRAF Slave I/O boards are present in an ISaGRAF application, consecutive, sequential system point pairs are used for the next Slave I/O board, regardless of what PLC port the boards are connected to. Each ISaGRAF kernel is allocated a separate set of system points for Slave I/O boards.

The status for the ISaGRAF Slave I/O boards reported (according to the above rules) has two system points associated with it. The *communications status*, and the *data cache time*.

ISaGRAF Complex Equipment types internally contain ISaGRAF I/O board information. Each I/O board within a complex equipment type is the equivalent to a separate I/O board, and so may also have a pair of system points associated with each I/O board within the complex equipment type.

The *communication status* indicates the status of the communication with the PLC for the data on the I/O board. For more information see Section ***11.1-Modbus Status Values***.

The age of the cached data for a slave Input Boards is stored in the *cache time* system point for that board. For more information see Section ***11.2-Data Cache Time***.

A separate RTU system point is provided to set the *background update rate* of PLC Output Boards. For more information see Section ***11.3 - PLC Output Board Default Background Update Rate***.

The RTU Slave I/O board status system points for ISaGRAF Kernel 1 are as follows:

System Point Description	Point Number	Point Type
ISaGRAF Kernel 1 Slave I/O board 1 communication status	53300	16-bit unsigned integer (read-only)
ISaGRAF Kernel 1 Slave I/O board 1 data cache time	53301	16-bit unsigned integer (read-only)
ISaGRAF Kernel 1 Slave I/O board 2 communication status	53302	16-bit unsigned integer (read-only)
ISaGRAF Kernel 1 Slave I/O board 2 data cache time	53303	16-bit unsigned integer (read-only)
…		
ISaGRAF Kernel 1 Slave I/O board 60 communication status	53418	16-bit unsigned integer (read-only)
ISaGRAF Kernel 1 Slave I/O board 60 data cache time	53419	16-bit unsigned integer (read-only)

The RTU Slave I/O board status system points for ISaGRAF Kernel 2 are as follows:

System Point Description	Point Number	Point Type
ISaGRAF Kernel 2 Slave I/O board 1 communication status	53422	16-bit unsigned integer (read-only)
ISaGRAF Kernel 2 Slave I/O board 1 data cache time	53423	16-bit unsigned integer (read-only)

ISaGRAF Kernel 2 Slave I/O board 2 communication status	53424	16-bit unsigned integer (read-only)
ISaGRAF Kernel 2 Slave I/O board 2 data cache time	53425	16-bit unsigned integer (read-only)
…		
ISaGRAF Kernel 2 Slave I/O board 14 communication status	53448	16-bit unsigned integer (read-only)
ISaGRAF Kernel 2 Slave I/O board 14 data cache time	53449	16-bit unsigned integer (read-only)

11.1 Modbus Status Values

The ***mod.. mbus..*** and ***mtcp..*** I/O board communication status system point values are updated by the E Series RTU Modbus PLC driver as follows:

Modbus Exception Code	**Status**	**Comment**	**RTU Status**
-	Success	No error encountered	0
0x01	Illegal Function	Slave device does not support requested Modbus function code	103
0x02	Illegal Data Address	Reading or Writing an invalid register address was attempted. This may be returned by RTU's device driver, or by Modbus device	103
0x03	Data Value out of Range	Reported by the Modbus device if register value was outside supported value range and could not be written	108
0x04	Illegal Response Length	A request was rejected by the Modbus device as it would have resulted in a response exceed the maximum allowed size (256 bytes)	103
0x0B	Gateway Target Failed	Gateway reported Modbus device did not respond	104
-	Timeout	The Modbus device did not respond	104
-	Socket connect Failed	Could not connect the TCP socket to a server at the configured IP address	104
-	Invalid Message	The message from the Modbus device was not understood by the RTU	106
other	Unknown Error	An undefined error has occurred	101

11.2 Data Cache Time

The age of the data in the RTU cache for Modbus PLC and Modbus/TCP Input board data is presented in data 'Cache Time' system points. The cache time is initialized to zero when the ISaGRAF application starts and increases until a successful read occurs, after which time the value is reset to zero.

The system point corresponding to a slave PLC input board may be used by the ISaGRAF application to determine the suitability of using the input data from the input board. (I.e. if the value is too high, then the data is stale and the ISaGRAF application may choose not to use it).

Each Input board has its own data cache time system point. The data cache time system points for Output boards always indicate zero.

11.3 PLC Output Board Default Background Update Rate

The following SCADAPack E Series RTU system point controls the default *background update rate* of all Slave PLC Output Boards on the RTU. Where an I/O board's "*must write rate*" parameter is zero, or if the older style PLC ISaGRAF I/O boards (that don't have a *must write rate*) are in use, the E Series RTU writes all ISaGRAF PLC output board variables to the appropriate PLC at this rate. This occurs regardless of whether changes are occurring on the ISaGRAF output variable, or not. The purpose of the "must write" is to ensure RTU output variable values are updated in the PLC.

For example, if the PLC is initialized or replaced, then the output values are re-written by the RTU. Similarly, a Modbus/TCP device may clear its outputs upon loss of communications unless a periodic write is made to its outputs.

The default value of the *background update rate* is 60 seconds. It may be adjusted by the user or specified in an RTU configuration, and is a non-volatile RTU system point that is retained by the RTU.

Changes in the *background update rate* take effect when an ISaGRAF application is loaded and started, or re-started.

System Point Description	Point Number	Point Type
ISaGRAF PLC Output Board Background Update Rate (Secs)	53420	32-bit unsigned integer

Note that the background updates are disabled by setting the system point value to 0 (zero). This may be used to optimize the Slave PLC communications bandwidth where background writes are not appropriate or necessary.

11.4 Modbus/TCP Server Unit Identifier

The following E Series RTU system point determines the configuration value of the Modbus/TCP Server *Unit Identifier*. Responses are sent to Open Modbus/TCP requests that include a unit identifier that matches this configuration value. If the unit identifier included in the request differs from the configuration value, the request is therefore determined to invalid for this RTU, and the socket is closed.

The default value of the *Unit Identifier* is 1. It may be adjusted by the user or specified in an RTU configuration, and is a non-volatile RTU system point that is retained by the RTU. Changes in the *Unit Identifier* take effect when the RTU is restarted.

System Point Description	Point Number	Point Type
Open Modbus/TCP Server Unit Identifier	54038	32-bit unsigned integer

11.5 Modbus Slave Address

The following E Series RTU system point determines the configuration value of the Modbus Slave *Slave Address*. This applies only to the native Modbus Slave driver. The slave address of the ISaGRAF based Modbus Slave is detailed in the E Series ISaGRAF Technical Reference.

System Point Description	Point Number	Point Type
Modbus Slave Address	52014	16-bit unsigned integer

The rules that determine how the Modbus Slave driver responds to requests according to the specified slave address are detailed as follows:

- Responses are sent to serial Modbus requests that include a slave address that matches the *Modbus Slave Address* configured value in the RTU.
- If the slave address included in the request is zero, i.e. broadcast address, the Modbus Slave will respond irrespective of the configuration value of the *Modbus Slave Address.*
- If the specified slave address is non-zero AND differs from the configuration value, no response is sent for the request.

The default value of the *Slave Address* is 1. It may be adjusted by the user or specified in an RTU configuration, and is a non-volatile RTU system point that is retained by the RTU. Changes in the *Slave Address* take effect when the RTU is restarted. Valid *Slave Address* configuration values are in the range of 1 – 247.

12 Diagnostics

The SCADAPack E Series RTU indicates configuration or communication diagnostics via Diagnostic Display mode from a Command line session.

Configuration diagnostics are indicated via ISaGRAF I/O board messages if there are problems opening ISaGRAF PLC I/O boards. These are always displayed when in Diagnostic Display mode (use DIAG command at command prompt).

Communication diagnostics for the Modbus serial and Modbus/TCP drivers are controlled by the PLCDIAG command at the PDS RTU command prompt. The syntax is as follows:

```
PLCDIAG DISABLE filter-name [filter-name…]
PLCDIAG ENABLE  filter-name [filter-name…]
```

Where filter name is one, or more of the following combinations:

*	all Modbus diagnostic messages
TX	transmit packet bytes display for Modbus Master / Client Indicating transmitted data by <--Modbus Master- Or <--Modbus/TCP Client -
RX	receive packet bytes display Indicating received data by –Modbus Master--> Or -Modbus/TCP Client-->
COMMS_ERROR	communication error diagnostics Including timeout and TCP socket connection information
PLC_ERROR	error diagnostics on error messages returned by the PLC
ISAGRAF	rx/tx packet diagnostics for RTU “ISaGRAF” serial port – not applicable to PLC Cache operation (see the *E Series ISaGRAF Technical Reference*)
Modbus(ISaGRAF)	rx/tx packet diagnostics for RTU “Modbus” serial port – not applicable to PLC Cache operation (see the E Series *ISaGRAF Technical Reference*)
MODTCP_SRV	rx/tx packet diagnostics for RTU Open Modbus/TCP Server
MOD_SLAVE	rx/tx packet diagnostics for RTU native Modbus Slave

Multiple filters may be specified at the same time with the PLCDIAG command. Use the command line DIAG command to enter the E Series RTU Diagnostic Display mode after the filters are set.

E.g.

```
PLCDIAG DISABLE TX RX
PLCDIAG ENABLE COMMS_ERROR PLC_ERROR
DIAG
```

13 How Do I Change a Modbus/TCP Device….

Modbus/TCP devices using BOOTP may require E Series RTU re-configuration. This may be necessary, for example, if the Modbus/TCP device is replaced. See the sections below.

If the device does not use BOOTP to configure its own IP address, it must be reconfigured with the correct IP address by following the procedure detailed in the device's user manual.

Warning

DUPLICATE ADDRESS HAZARD. Having two or more devices with the same IP address can cause unpredictable operation of your network. Before removing any adapter from service, or adding any adapter, ensure there is no possibility of a duplicate address appearing on your network. Failure to observe this precaution can result in injury or equipment damage.

REMEMBER: After changing the configuration of an RTU, make a permanent record of the RTU's new configuration.

13.1 Change a Modbus/TCP Device Using the E Series Configurator

Establish communication with the RTU using the E Series Configurator either locally, or remotely.
Ensure the E Series Configurator "RTU Types" includes "TCP/IP".
Select the "Adv. TCP/IP" page, and read the current configuration of the PDS RTU.

To replace an existing device:

Identify the relevant BOOTP entry in the E Series Configurator's BOOTP Configuration Table.
Change the entry's Ethernet-MAC address to that of the new device.
Write the configuration to the RTU. The BOOTP entry is now active.
Connect the new device to the network & power it up.

To add a new device:

Choose the first free BOOTP entry in the E Series Configurator's BOOTP Configuration Table.
Add the new device's Ethernet-MAC address to the table.
Add the desired IP address for the entry.
Write the configuration to the RTU. The BOOTP entry is now active.
Connect the new device to the network & power it up.

13.2 Change a Modbus/TCP Device Using COMMAND LINE

The E Series RTU's command line is available:

Using Telnet, when enabled on the PDS RTU
Using a terminal program plugged into an RTU (e.g. the DIAG port)
Using a terminal program plugged into an RTU's ISaGRAF port, and by pressing <Enter><Enter><Enter>

The SCADAPack E Series RTU command line can be use to replace an existing Modbus/TCP device BOOTP entry, or add a new Modbus/TCP device BOOTP entry. This is only applicable for devices that use BOOTP as a means of configuring their IP addresses.

If you are replacing an existing device you will need to know the IP address being used by the old device. You will also need to know the new device's Ethernet-MAC address (12-digit hexadecimal number).

If you are adding a new BOOTP entry, you will need to know the desired IP address for the new device as well as its Ethernet-MAC address.

You can check all configured BOOTP entries by using the command:

```
bootp print
```

From the E Series RTU command line, enter the following command to add or change a BOOTP entry:

`bootp` *`add Ethernet-MAC-addr IP-address`*

For example: `bootp add 01020304AABB 158.234.186.168`

You can re-check the changed BOOTP entries by using: `bootp print`

You can check BOOTP operation with a new device by performing the following procedures:

- Enable BOOTP diagnostics & enter diagnostic mode with the commands:

```
tcpdiag enable BOOTP  <enter>
diag
```

Connect the new device to the network & power it up. When the new device sends a BOOTP request for an IP address, the E Series RTU should display something similar to:

```
BOOTP>>loaded IP: 158.234.186.168  to MAC: 01020304AABB
```

Communication may also be verified by issuing a PING command. For example:

```
ping 158.234.186.168
```