OPERATOR'S MANUAL

CR1000 Measurement and Control System

Revision: 7/08

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Section 1. Introduction

Whether in extreme cold in Antarctica, scorching heat in Death Valley, salt spray from the Pacific, micro-gravity in space, or the harsh environment of your office, Campbell Scientific dataloggers support research and operations all over the world. Our customers work a broad spectrum of applications, from those more complex than any of us imagined, to those simpler than any of us thought practical. The limits of the CR1000 are defined by our customers. Our intent with the CR1000 manual is to guide you to the tools you need to explore the limits of your application.

You can take advantage of the CR1000's powerful analog and digital measurement features by spending a few minutes working through the Quickstart Tutorial of Section 2 and the Overview of Section 3. For more demanding applications, the remainder of the manual and other Campbell Scientific publications are available. If you are programming with CRBASIC, you will need the extensive Help available with the CRBASIC Editor software. Formal CR1000 training is also available from Campbell Scientific.

This manual is organized to take you progressively deeper into the complexity of CR1000 function. You may not find it necessary to progress beyond the Quick Start Tutorial or Overview sections. Section 2 Quick Start Tutorial gives a cursory view of CR1000 data acquisition and walks you through a first attempt at data acquisition. Section 3 Overview reviews salient topics, which are covered in-depth in subsequent sections and Appendices.

More in-depth study requires other Campbell Scientific publications, most of which are available on-line at www.campbellsci.com. Generally, if a particular feature of the CR1000 requires a peripheral hardware device, more information will be available in the manual written for that device. Manuals for Campbell Scientific products are available at www.campbellsci.com.

If you are unable to find the information you need, please contact us at 435-753-2342 and speak with an applications engineer. Or you can email us at support@campbellsci.com.

Section 2. Quickstart Tutorial

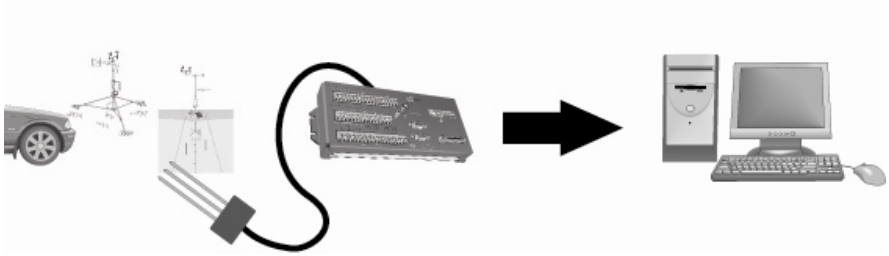
Quickstart tutorial gives a cursory look at CR1000 data acquisition.

2.1 Primer – CR1000 Data Acquisition

Data acquisition with the CR1000 is the result of a step wise procedure involving the use of electronic sensor technology, the CR1000, a telecommunications link, and PC datalogger support software.

2.1.1 Components of a Data Acquisition System

CR1000s are only one part of a data acquisition system. To get good data, suitable sensors and a reliable data retrieval method are required. A failure in any part of the system can lead to "bad" data or no data.



2.1.1.1 Sensors

Suitable sensors accurately and precisely transduce environmental change into measurable electrical properties by outputting a voltage, changing resistance, outputting pulses, or changing states.

Read more! Accuracy, precision and resolution are discussed in Section C.2.1.

2.1.1.2 Datalogger

CR1000s can measure almost any sensor with an electrical response.

CR1000s measure electrical signals and convert the measurement to engineering units, perform calculations and reduce data to statistical values. Every measurement does not need to be stored. The CR1000 will store data in memory awaiting transfer to the PC via external storage devices or telecommunications.

2.1.1.3 Data Retrieval

The main objective of a data acquisition system is to provide data files on a PC.

Data are copied, not moved, from the CR1000 to the PC. Multiple users may have access to the same CR1000 without compromising data or coordinating data collection activities.

RS-232 and CS I/O ports are integrated with the CR1000 wiring panel to facilitate data collection.

On-site serial communications are preferred if the datalogger is near the PC, and the PC can dedicate a serial (COM) port for the datalogger. On-site methods such as direct serial connection or infrared link are also used when the user visits a remote site with a laptop or PDA.

In contrast, telecommunications provide remote access and the ability to discover problems early with minimum data loss. A variety of devices, and combinations of devices, such as telephone modems, radios, satellite transceivers, and TCP/IP network modems are available for the most demanding applications.

2.1.2 CR1000 Mounting

The CR1000 module integrates electronics with a sealed stainless steel clamshell, making it economical, small, and very rugged.

2.1.3 Wiring Panel

The CR1000 module connects to the wiring panel, which provides terminals for connecting sensors, power and communications devices. The wiring panel also incorporates surge protection against phenomena such as lightning. See FIGURE 2.1-1.

2.1.4 Battery Backup

A lithium battery backs up the CR1000 clock, program, and memory if it loses power.

2.1.5 Power Supply

The CR1000 can be powered by a nominal 12 volt DC source through the green “POWER IN” connector. Acceptable power range is 9.6 to 16 VDC.

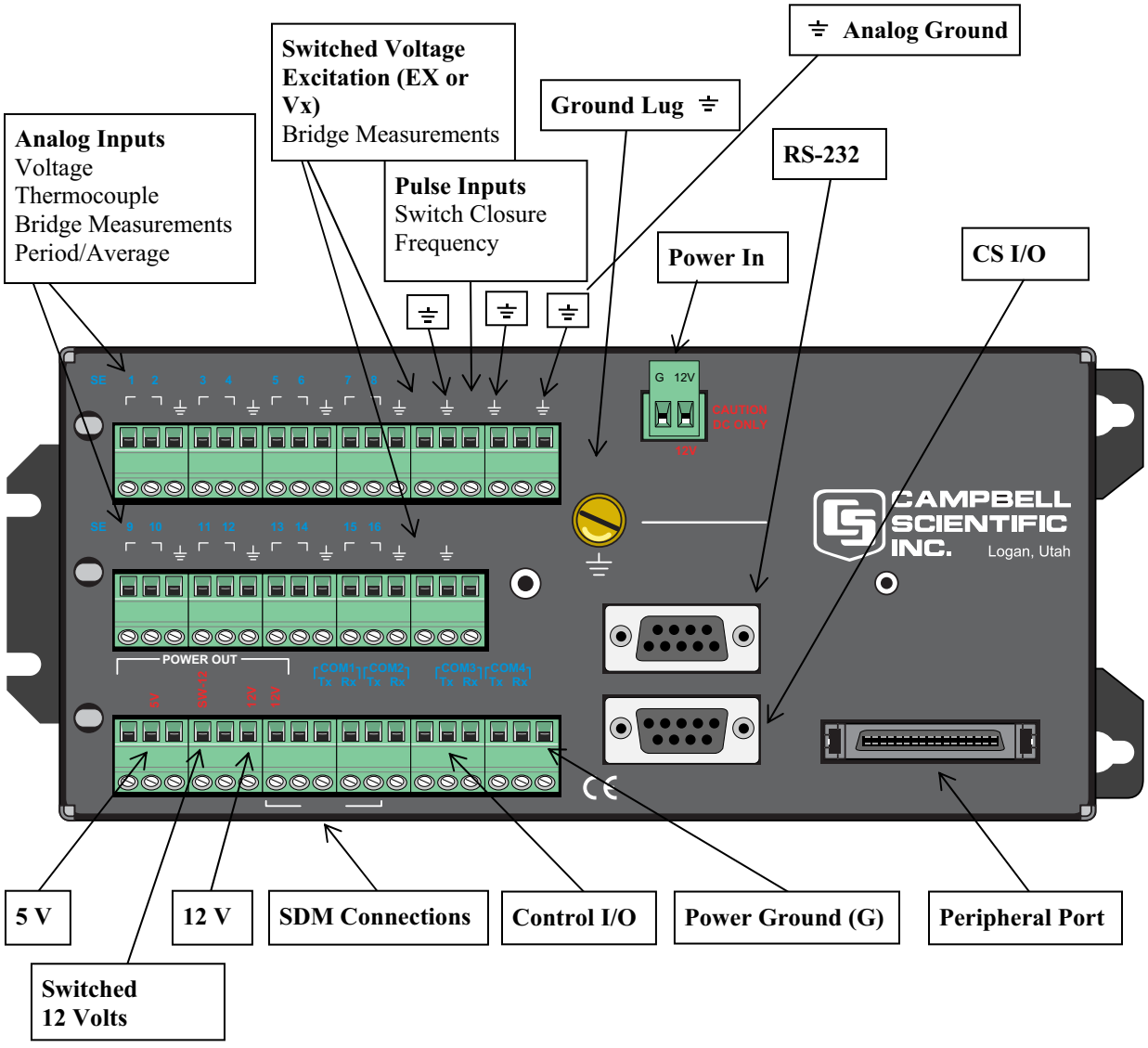


FIGURE 2.1-1. CR1000 Wiring Panel

2.1.6 Analog Sensors

Analog sensors output continuous voltages that vary with the phenomena measured.

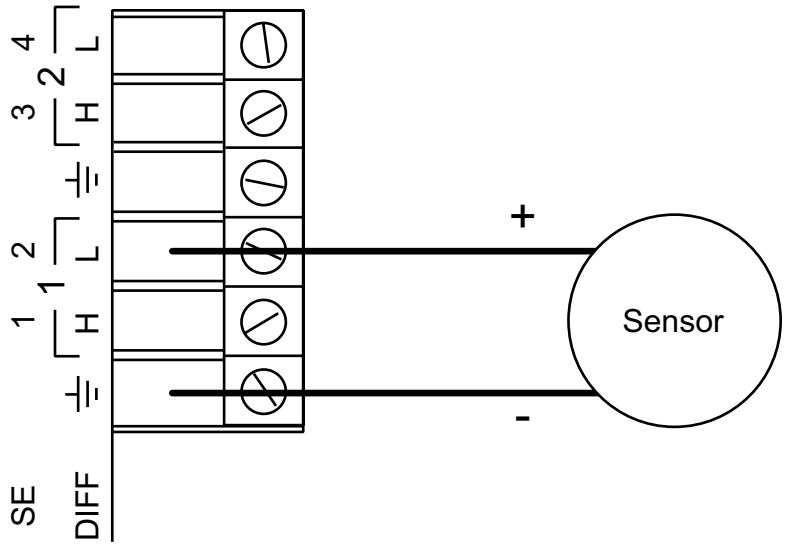
Analog sensors connect to analog terminals. Analog terminals are configured as single-ended (measured with respect to ground) or differential (high input measured with respect to the low input of a channel pair (FIGURE 2.1-3)).

Analog channels are configured individually as 8 differential or 16 single ended Channels (FIGURE 2.1-2).

Differential Channel	Single-Ended Channel
1H	1
1L	2
2H	3
2L	4
3H	5
3L	6
4H	7
4L	8
5H	9
5L	10
6H	11
6L	12
7H	13
7L	14
8H	15
8L	16

FIGURE 2.1-2. Single-ended and Differential Input Channels

Sensor Wired to Single-Ended Channel #2



Sensor Wired to Differential Channel #1

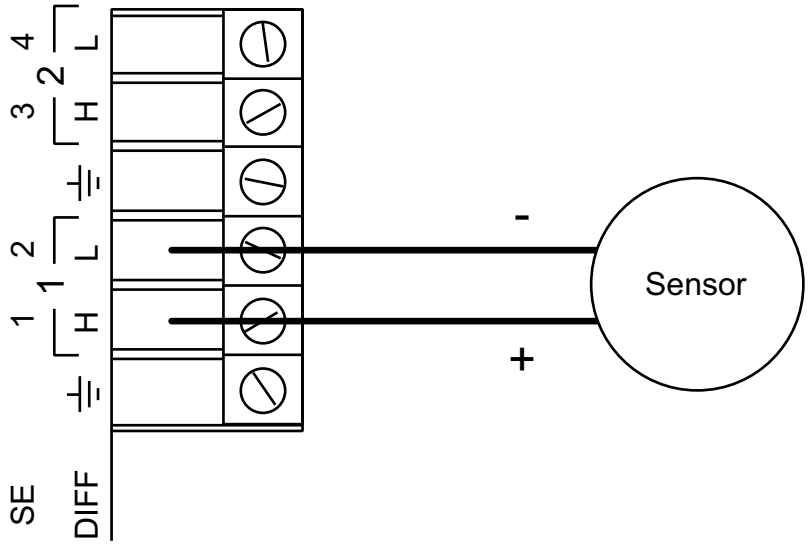


FIGURE 2.1-3. Single-ended and Differential Analog Sensor Wiring

2.1.7 Bridge Sensors

Bridge sensors change resistance with respect to environmental change. Resistance is determined by measuring the difference between the excitation voltage supplied to the bridge by the CR1000 and the voltage detected by the CR1000 returning from the bridge. The CR1000 supplies a precise excitation voltage via excitation terminals. Return voltage is measured on analog terminals (FIGURE 2.1-4).

Potentiometer from Wind Vane Wired to Excitation Channel #1

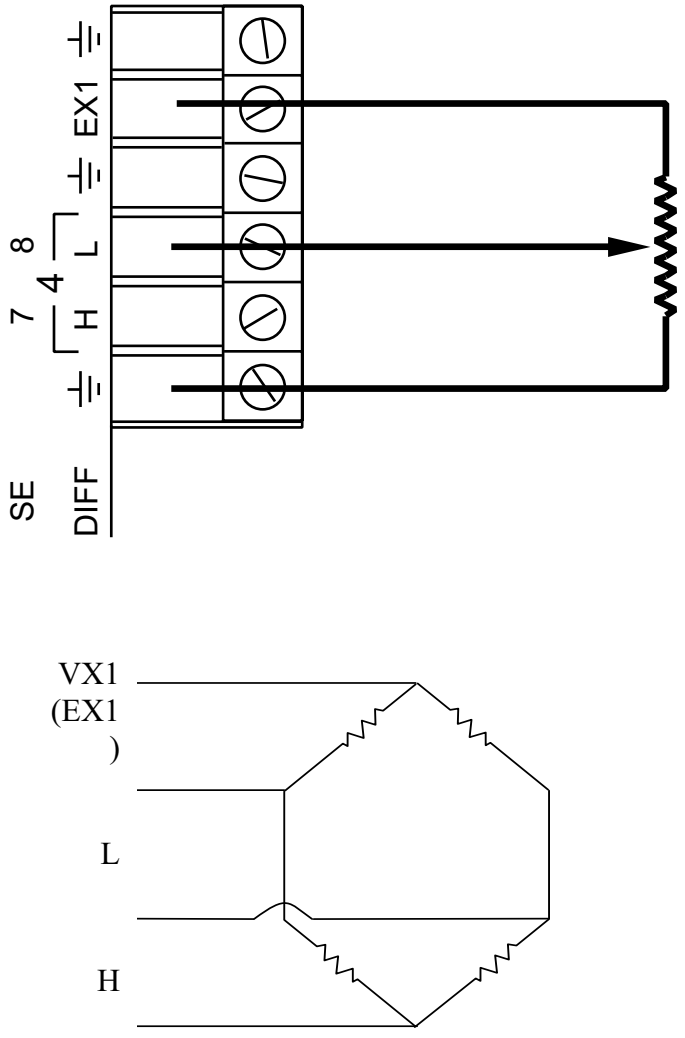


FIGURE 2.1-4. Half and Full Bridge Wiring

2.1.8 Pulse Sensors

The CR1000 can measure switch closures, low-lever AC signals (waveform breaks zero volts), or voltage pulses (±20 VDC) on pulse channels (FIGURE 2.1-5 and FIGURE 2.1-6).

Period averaging sensors are connected to single-ended analog channels.

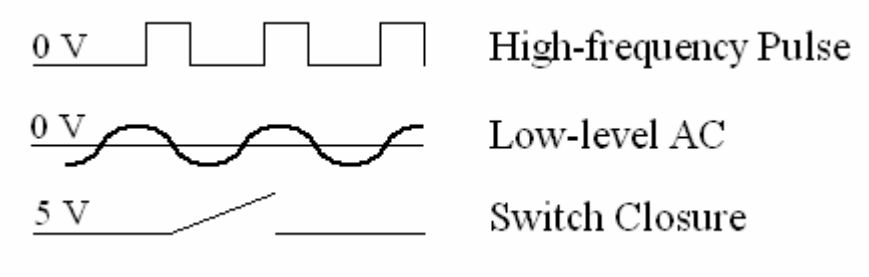


FIGURE 2.1-5. Pulse Input Types

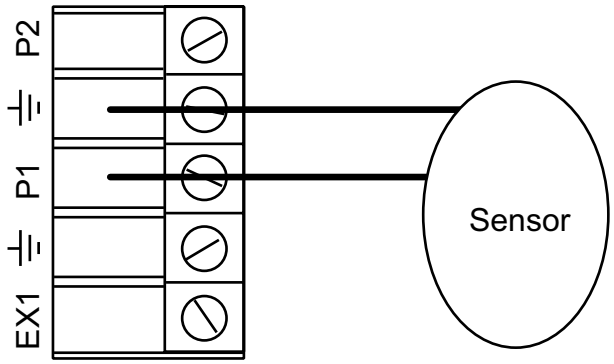
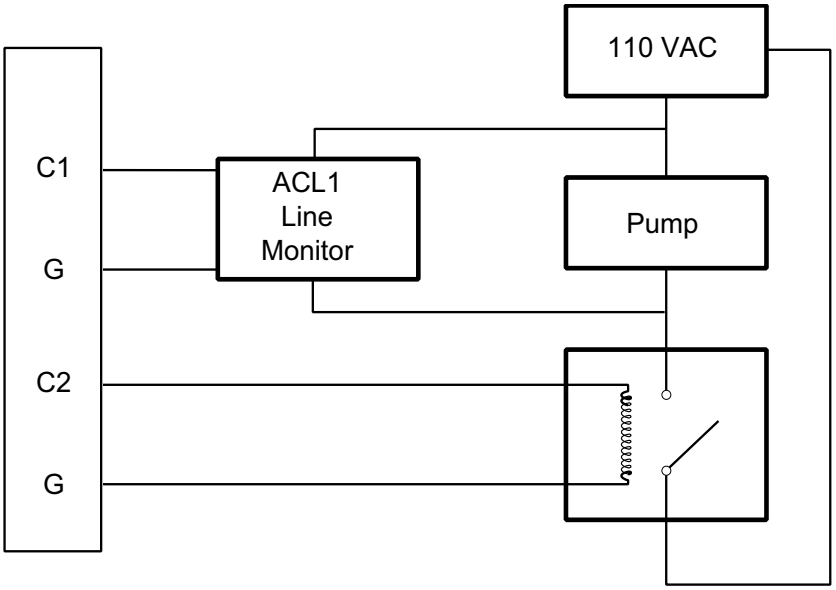


FIGURE 2.1-6. Anemometer Wired to Pulse Channel #1

2.1.9 Digital I/O Ports

The CR1000 has 8 Digital I/O ports selectable, under program control, as binary inputs or control outputs. These ports have multiple function capability including: edge timing, device driven interrupts, switch closure pulse counting, high frequency pulse counting, asynchronous communications, SDI-12 communications, SDM communications, and as shown in FIGURE 2.1-7, turning on/off devices and monitoring whether the device is operating or not.

Digital I/O Ports Used to Control/Monitor Pump



C1 -Used as input to monitor pump status.

C2 -Used as output to switch power to a pump via a solid state relay.

FIGURE 2.1-7. Control and Monitoring of a Device using Digital I/O Ports

2.1.10 RS-232 Sensors

RS-232 sensors can be connected to either the 9-pin RS-232 port or digital I/O port pairs.. FIGURE 2.1-8 illustrates use of RS-232 or digital I/O ports.

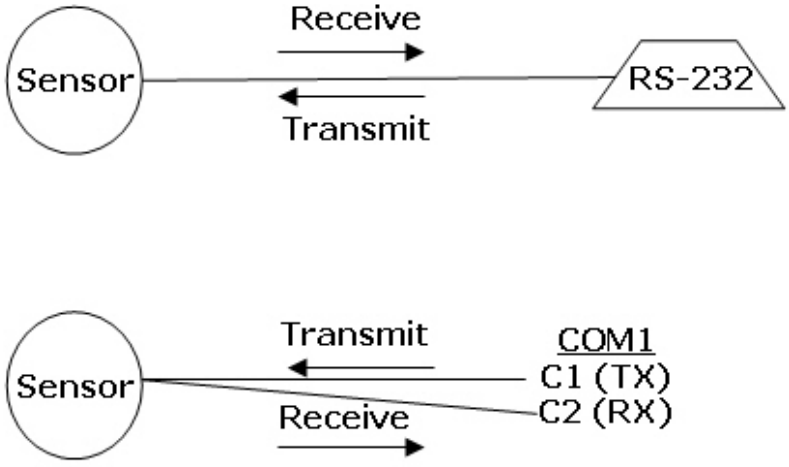


FIGURE 2.1-8. Use of RS-232 and Digital I/O when Reading RS-232 Devices

2.2 Hands-on Exercise – Measuring a Thermocouple

This tutorial is a stepwise procedure for configuring a CR1000 to make a simple thermocouple measurement and send the resulting data to a PC. Discussions include programming, real-time data monitoring, collecting data, and viewing data. Principles discussed are applicable to all CR1000 applications.

2.2.1 Connections to the CR1000

Connect power and RS-232 cables to the CR1000 as illustrated in FIGURE 2.2-1.

Compatible power supplies are discussed in Section 6 Power Supply. When connecting power to the CR1000, first remove the green power connector from the wiring panel. Insert the positive 12 V lead into the terminal labeled "12V", and the ground lead into the terminal labeled "G". Confirm the polarity of the wires before re-inserting the connector.

Connect the serial cable supplied with the CR1000 between the port labeled "RS-232" on the CR1000 and the serial (COM) port on the computer. For computers with USB ports, a USB-to-serial adaptor is required.

FIGURE 2.2-1. Power and RS-232 Connections

2.2.2 PC200W Software

Obtain and install PC200W. PC200W is available on the Campbell Scientific Resource CD or at www.campbellsci.com.

When PC200W is first opened, the EZSetup Wizard is launched. Click the **Next** button and follow the prompts to select the **CR1000**, the **COM** port on the computer that will be used for communications, **115200** baud, and **PakBus Address 1**. When prompted with the option to **Test Communications**, click the **Finish** button.

If a datalogger was not added with the Wizard, click the + (add) button to invoke the Wizard.

After exiting the EZSetup wizard, the **Clock / Program** tab is presented, as shown in FIGURE 2.2-2. Current Datalogger Profile, Clock, and Datalogger Program features are integrated into this tab. Tabs to the right are used to select **Monitor Data** and **Collect Data** options. Buttons to the right of the tabs are used to run **Split**, **View**, and **Short Cut** applications.

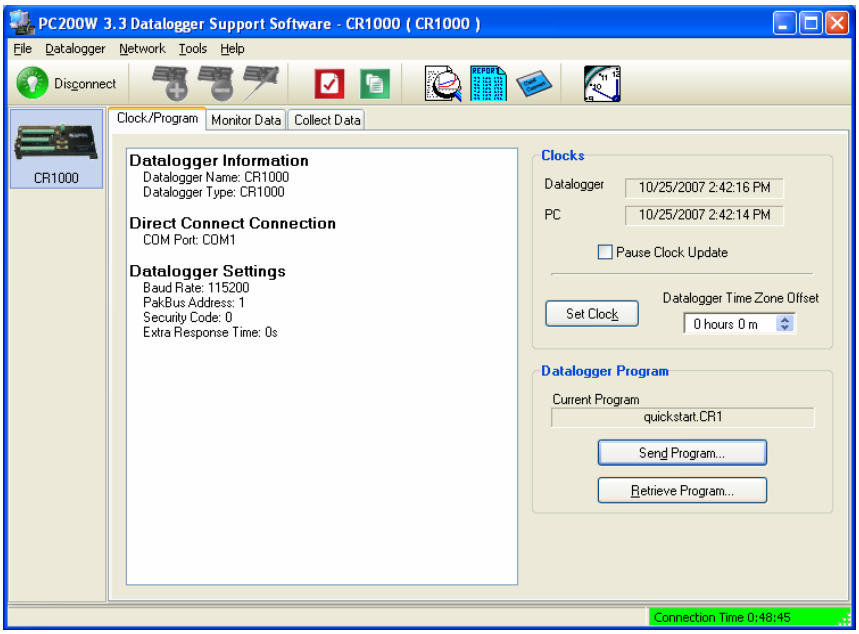


FIGURE 2.2-2. PC200W Setup/Connect Tab

2.2.2.1 Programming with Short Cut

To assist with this exercise, a type T thermocouple is shipped with the CR1000 (packaged with the screwdriver). The thermocouple is a pair of 5-inch wires with blue / red insulation, soldered together at one end.

Historical Note:

In the space race era, a field thermocouple measurement was a complicated and cumbersome process incorporating thermocouple wire with three junctions, a micro-volt meter, a vacuum flask filled with an ice slurry, and a thick reference book. One thermocouple junction connected to the µV meter, another sat in the vacuum flask, and the third was inserted into the location of the temperature of interest. When things settled out, the micro-volt meter was read, and the value looked up in the appropriate table in the reference book to determine the temperature. Then along came Eric and Evan Campbell. Campbell Scientific designed the first CR7 datalogger to make thermocouple measurements without the need of vacuum flasks, third junctions, or reference books. Now, there's an idea!

Nowadays, a thermocouple consist of two wires of dissimilar metals, such as copper and constantan, joined at one end. The joined end is the measurement junction; the junction that is created when the thermocouple is wired to the CR1000 is the reference junction.

When the two junctions are at different temperatures, a voltage proportional to the temperature difference is induced into the wires. The thermocouple measurement requires the reference junction temperature to calculate the measurement junction temperature using proprietary algorithms in the CR1000 operating system.

Objective: Program the CR1000 to accomplish the following tasks.

Every one second, measure air temperature in degrees C with a type T thermocouple and store one-minute average battery voltage, panel temperature, and thermocouple temperature.

Procedure:

Click on the **Short Cut** button in the upper right of the PC200W window to open Short Cut as shown in FIGURE 2.2-3.

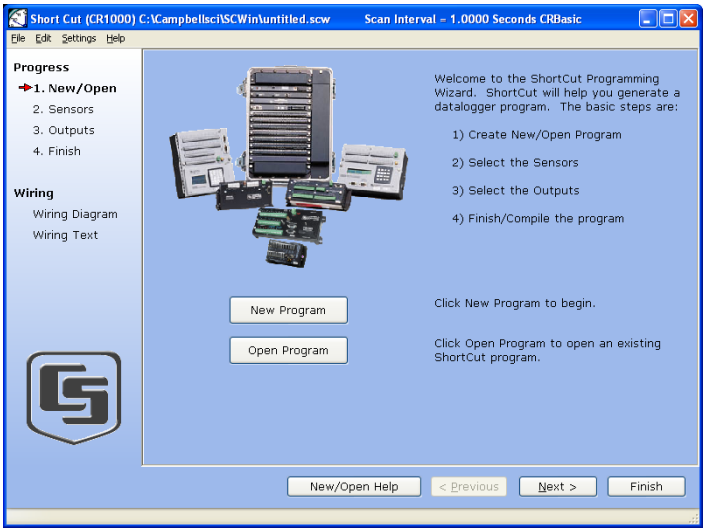


FIGURE 2.2-3. Short Cut "1. New/Open" Page

Use the Help in conjunction with the steps outlined below:

Step 1: Open a new or existing file.

NOTE The first time Short Cut is run, a prompt asks for a choice of "AC Noise Rejection." If the CR1000 will be used in the United States, choose "60 Hz"; many other countries use "50 Hz" power mains systems. A second prompt asks for a choice of "Sensor Support." Choose "Campbell Scientific, Inc."

On the "**1. New/Open"** page, click [**New Program]**. Use the drop-down list box that appears to select **CR1000**. Click [**OK**]. Enter a 1 second Scan Interval and click [**OK]**. Click on [Next>] to progress to "**2. Sensors"** page.

Step 2: Select sensors to be measured.

Note: Settings | Sensor Support allows selection of alternate sensor sets.

Sensors page is divided into two sections: Available Sensors and Selected table, as shown in FIGURE 2.2-4. Sensors desired are chosen from the available sensors tree.

On the Available Sensors tree, open the **Sensors** folder to show several sub-folders. Each sub-folder includes a class of sensors. Open the Temperature sub-folder to display available temperature sensors.

Double click on the **Wiring Panel Temperature** sensor to add it to the selected sensors table. Click **OK** on the next screen to accept the PTemp_C label.

Double click on the **Type T Thermocouple.** Change the number of sensors to add to "1" and click **OK**. On the next screen, make sure Ptemp_C is selected for the Reference Temperature Measurement, and click **OK** to accept the Temp_C label.

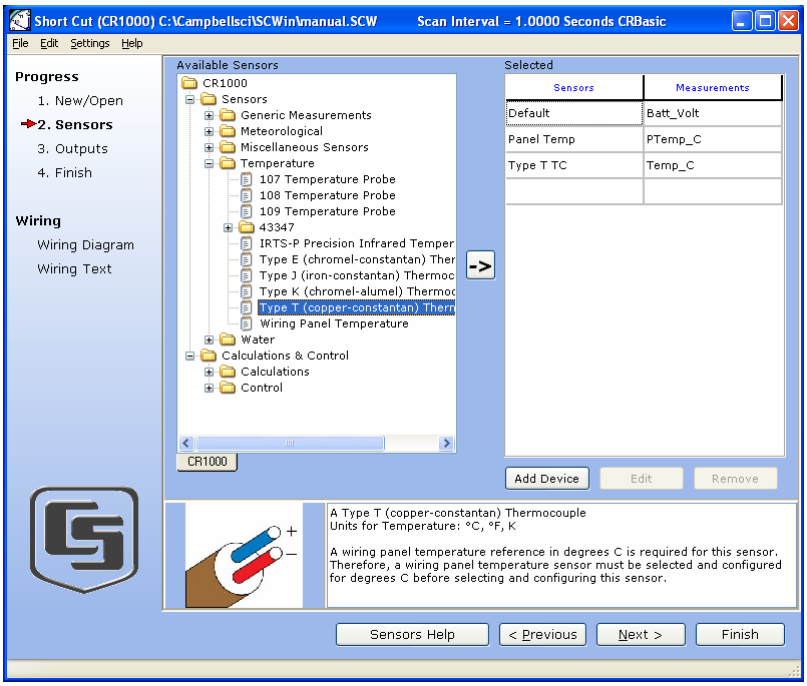


FIGURE 2.2-4. Short Cut Sensors Page

Click on **Wiring Diagram** to view the sensor wiring diagram, as shown in FIGURE 2.2-5. Wire the Type T Thermocouple (provided) to the CR1000 as shown on the diagram. Click on **3. Outputs** to continue with Step 3.

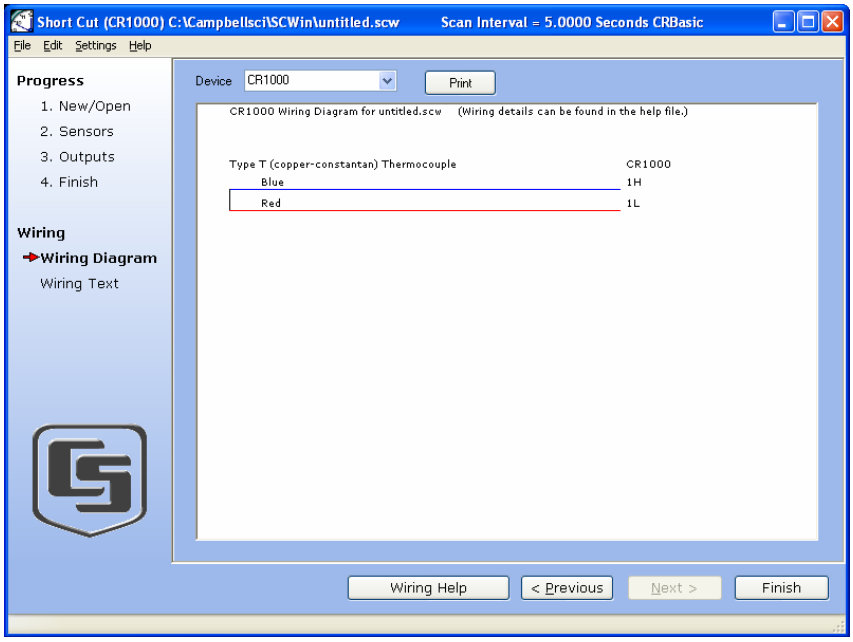


FIGURE 2.2-5. Short Cut Wiring Diagram

Step 3: Data Storage Output Processing.

The Outputs page has a list of Selected Sensors to the left, and data storage Tables to the right as shown in FIGURE 2.2-6. Two Tables, Table1 and Table2, are available by default. Both Tables have a **Store Every** field and a list box to select time units. These are used to set the interval at which data will be stored.

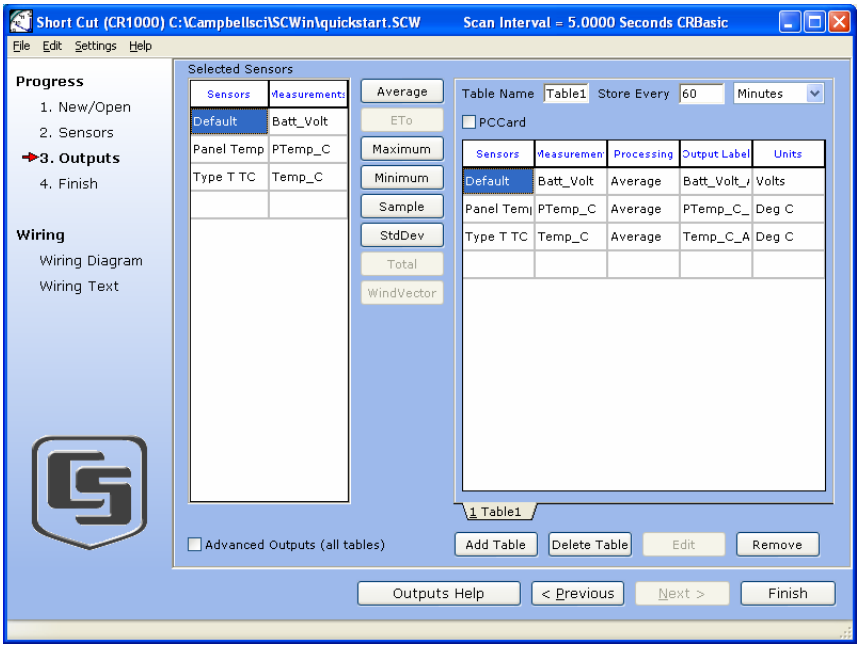


FIGURE 2.2-6. Short Cut Outputs Page

This exercise calls for one-minute data storage processing, so only one data table is needed. To remove Table2, click on **Table2** tab to activate it, and click the **Delete Table** button.

The **Table Name** field is the name that will be used for the Table in which data are stored. Change the default name of Table1 to OneMin, and change the interval to 1 minute.

To add a measurement to data storage Table OneMin, highlight a measurement under Selected Sensors (Batt_Volt) and click the appropriate processing button (Average). Select the Batt_Volt, PTemp_C, and Temp_C measurements and apply Average processing to each to add them to the OneMin Table measurements.

Click **Finish** and name the file "Quickstart" to continue with Step 4 and complete the program.

Step 4: Program Finish.

As shown in FIGURE 2.2-7, any errors the compiler may have detected are displayed, along with the names of the files that were created. The file Quickstart.CR1 is the program file that is to be sent to the CR1000. Quickstart.def is a summary of the sensor wiring and measurement labels.

Click the **Summary** tab and / or **Print** buttons to view and print the summaries. Click the X button to exit the Short Cut window.

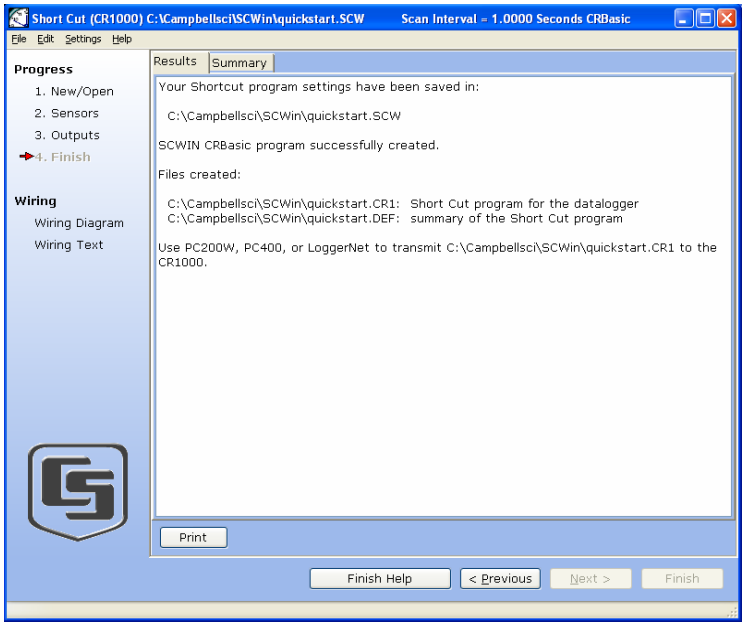


FIGURE 2.2-7. Short Cut Finish Page

2.2.2.2 Connecting to the Datalogger

From the PC200W **Clock / Program** tab, click on the **Connect** button to establish communications with the CR1000 (FIGURE 2.2-8). When communications have been established, the text on the button will change to **Disconnect**.

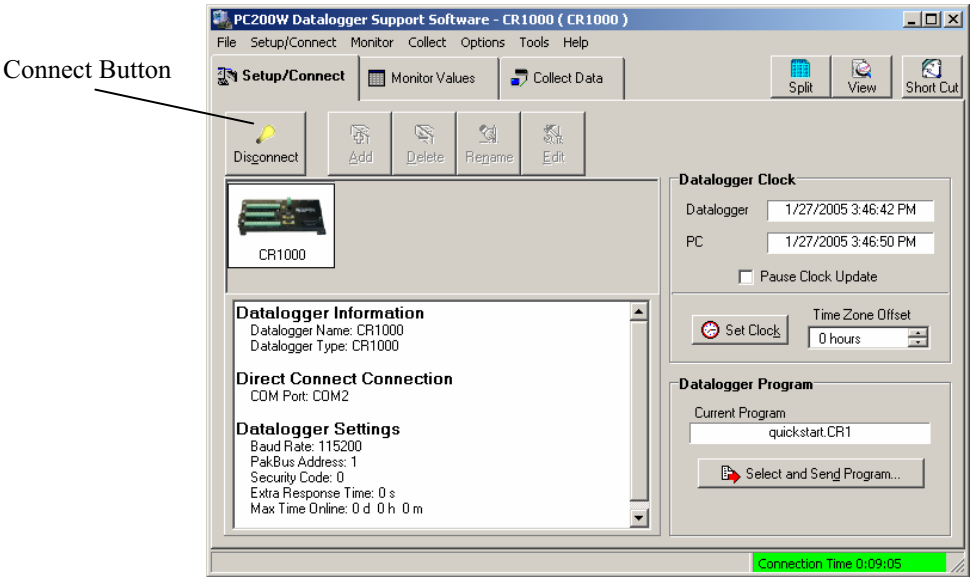


FIGURE 2.2-8. Using PC200W Connect Button to Establish Communication Link

2.2.2.3 Synchronizing the Clocks

Click the **Set Clock** button to synchronize the datalogger's clock with the computer's clock.

2.2.2.4 Sending the Program

Click the **Send Program** button. Navigate to the C:\CampbellSci\SCWin folder and select the file QED.CR1 and click the **Open** button. A progress bar is displayed, followed by a message that the program was successfully sent.

2.2.2.5 Monitoring Data Tables

The **Monitor Data** window (FIGURE 2.2-9) is used to display the current sensor measurement values from the Public Table, and the most recent data from the OneMin table. After sending a program to the CR1000, a good practice is to monitor the measurements to ensure they are reasonable.

Click on the **Monitor Data** tab. The Public table is automatically selected and displayed. To view the OneMin table, click the **Add** button, select a cell in which to place the first value, select the **OneMin** table, and click the **Paste** button.

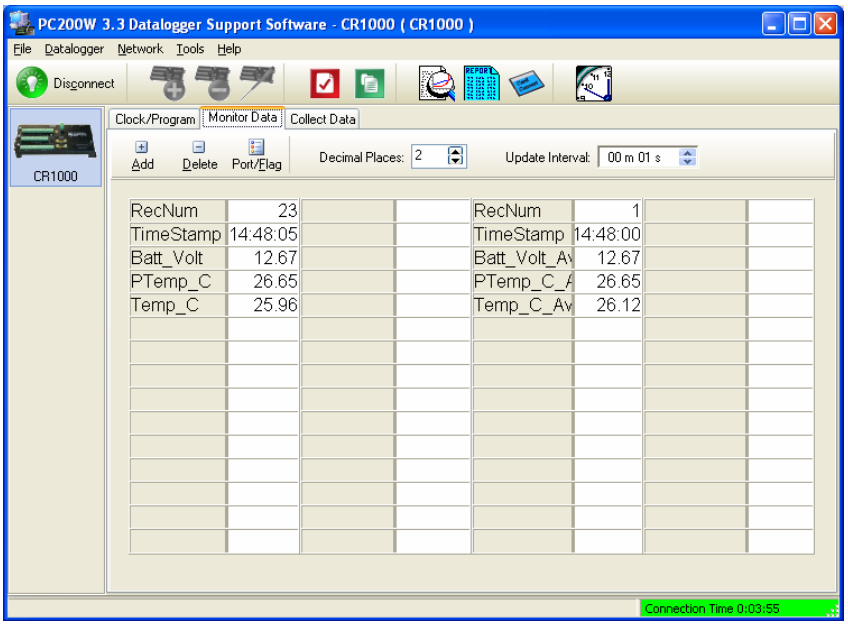


FIGURE 2.2-9. PC200W Monitor Values Tab

2.2.2.6 Collecting Data

Click on the **Collect Data** tab (FIGURE 2.2-10). From the Collect Data window, choose what data to collect, and where to store the collected data.

Click on the **OneMin** table, with the option **New data from datalogger** selected. Click the **Collect** button and a dialog box appears, prompting for a file name. Click the **Save** button to use the default file name CR1000_OneMin.dat. A progress bar, followed by the message **Collection Complete** is displayed.

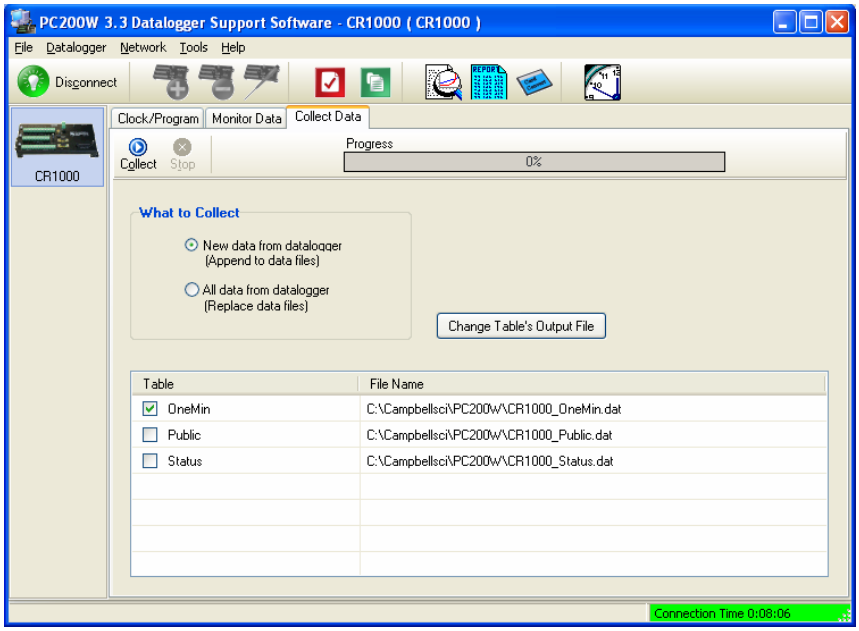


FIGURE 2.2-10. PC200W Collect Data Tab

2.2.2.7 Viewing Data

To view the collected data, click on the **View** button (located in the upper right-central portion of the main screen). Options are accessed by using the menus or by selecting the toolbar icons. Move and hold the mouse over a toolbar icon for a few seconds for a brief description of that icon's function.

To open a data file, click the **Open file** icon (FIGURE 2.2-11), and double click on the file CR1000_OneMin.dat in the PC200W folder. Click the **Expand Tabs** icon to display the data in columns with column headings. To graph thermocouple temperature, click on the data column with the heading Temp_C, then click the **Show Graph, 1 Y axis** icon on the toolbar.

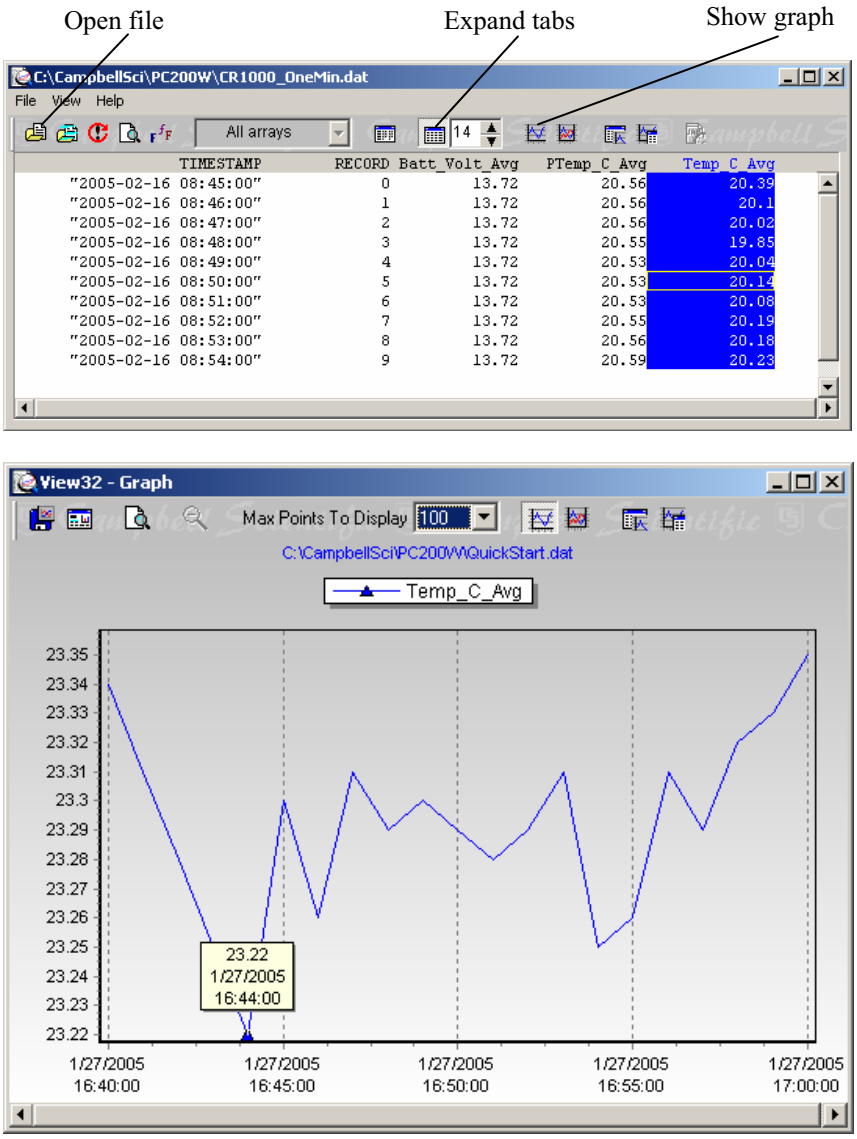


FIGURE 2.2-11. PC200W View Data Utility

Close the graph and view screens, and close PC200W.

Section 3. Overview

3.1 CR1000 Overview

The CR1000 Datalogger is a precision instrument designed for demanding low-power measurement applications. CPU, analog and digital inputs, analog and digital outputs, and memory are controlled by the operating system in conjunction with the user program. The user program is written with CRBASIC, a programming language that includes data processing and analysis routines as well as a standard BASIC instruction set. Campbell Scientific's datalogger support software facilitate program generation, editing, data retrieval, and real-time data monitoring (see Section 13 Support Software).

FIGURE 3.1-1 illustrates principal features of common CR1000-based data acquisition systems.

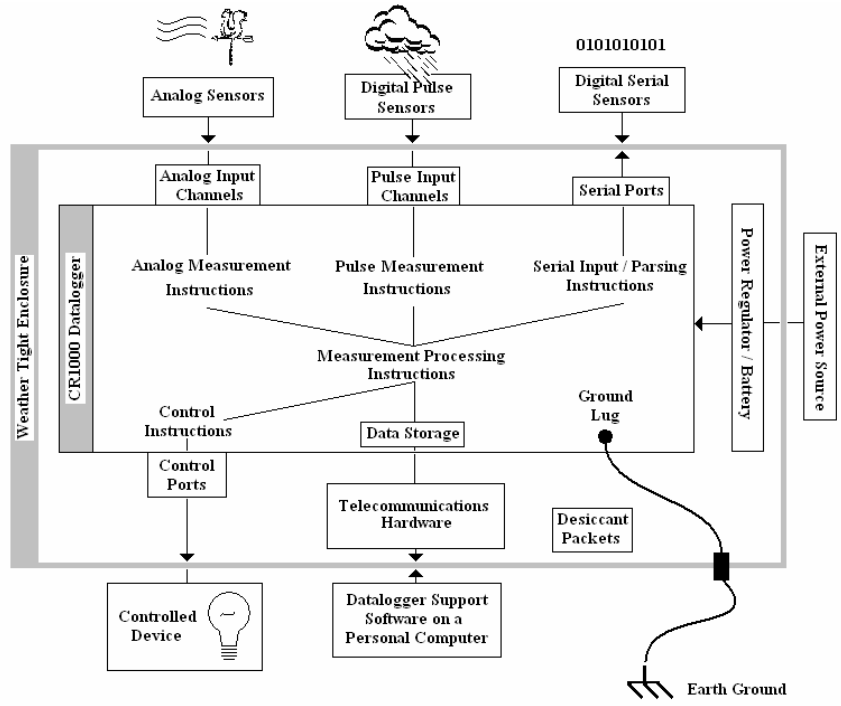


FIGURE 3.1-1. Principal Features of CR1000 Data Acquisition Systems

As a simple concept, the CR1000 is a multimeter with memory and timekeeping. It is one part of a data acquisition system. To acquire quality data, suitable sensors and reliable telecommunications devices are also required.

Sensors transduce phenomena into measurable electrical forms, outputting voltage, current, resistance, pulses, or state changes. The CR1000, sometimes with the assistance of various peripheral devices, can measure nearly all electronic sensors.

The CR1000 measures analog voltage and pulse signals, representing the magnitudes numerically. Numeric values are scaled to the unit of measure such as millivolts and pulses, or in user specified engineering units such as wind direction and wind speed. Measurements can be processed through calculations or statistical operations and stored in memory awaiting transfer to a PC via external storage or telecommunications.

The CR1000 has the option of evaluating programmed instructions sequentially, or in pipeline mode, wherein the CR1000 decides the order of instruction execution.

3.1.1 Sensor Support

Read more! See Section 4 Sensor Support.

The following sensor types are supported by the CR1000 datalogger:

Analog voltage
Analog current (with a shunt resistor)
Thermocouples
Resistive bridges
Pulse output
Period output
Frequency output
Serial smart sensors
SDI-12 sensors

A library of sensor manuals and application notes are available at www.campbellsci.com to assist in measuring many sensor types. Consult with a Campbell Scientific applications engineer for assistance in measuring unfamiliar sensors.

3.1.2 Input / Output Interface: The Wiring Panel

The wiring panel of the CR1000 is the interface to all CR1000 functions. Most CR1000 functions are best introduced by reviewing features of the CR1000 wiring panel. FIGURE 2.1-1 illustrates the wiring panel and some CR1000 functions accessed through it.

Read more! Expansion accessories increase the input / output capabilities of the wiring panel. Read Section 5 Measurement and Control Peripherals for more information.

3.1.2.1 Measurement Inputs

Measurements require a physical connection with a sensor at an input channel and CRBASIC programming to instruct the CR1000 how to make, process, and store the measurement. The CR1000 wiring panel has the following input channels:

Analog Voltage: 16 channels (Diff 1 - 8 / SE 1 - 16) configurable as 8 differential or 16 single-ended inputs.

- Input voltage range: -5000 mV to +5000 mV.
- Measurement resolution: 0.67 µV to 1333 µV

Period Average: 16 channels (SE 1 -16)

- Input voltage range: -2500 mV to +2500 mV.
- Maximum frequency: 200 kHz

Technical Note -- Pulse Count vs. Period Average

Pulse count and period average measurements both can be used to measure sensors that output frequency. Yet pulse count and period average measurement methods are quite different, resulting in different characteristics for each type. Pulse count measurements use dedicated counter hardware that is always monitoring the input signal, even when the datalogger goes to sleep mode between scans. Period average measurements utilize multiplexed voltage measurement hardware and so only monitor the input signal during the execution of a period average instruction. Consequently, pulse count measurement intervals can generally be made much longer than period average measurement intervals, which is advantageous if trying to minimize the effects of low-frequency noise. Pulse count measurements are not appropriate for sensors that are powered down between scans, whereas period average measurements work well as they can be placed in the scan so as to execute only when the sensor is powered up and outputting valid frequency information.

Period average measurements utilize a high-frequency digital clock to measure time differences between signal transitions, whereas pulse count measurements simply accumulate the number of counts. As a result, period average measurements offer much better frequency resolution per measurement interval, as compared to pulse count measurements. The frequency resolution of pulse count measurements can be improved by extending the measurement interval by increasing the scan interval and by averaging.

Pulse: 2 channels (P1 - P2) configurable for counts or frequency of the following signal types:

- High level 5V square waves
- Switch closures
- Low-level A/C sine waves

Digital I/O: 8 channels (C1 - C8) configurable for serial input, SDM, SDI-12, state, frequency, pulses.

- C1 - C8: state, frequency and pulse measurements.
- C1 - C3: Synchronous Devices for Measurement (SDM) input / output.
- C1, C3, C5, C7: SDI-12 input / output.
- C1 - C2, C3 - C4, C5 - C6, C7 - C8: serial communication input / output.

9-Pin RS-232: 1 port (Computer RS-232) configurable for serial input.

3.1.2.2 Voltage Outputs

The CR1000 supplies precision voltage excitation for resistive measurements through the following output channels:

Switched Analog Voltage Output (Excitation): 3 channels (Vx/VX1 (VX1 (EX1)) – Vx/VX3 (EX3)) for precise voltage excitation ranging from -2500 mV to +2500 mV. Each channel will source up to 25 mA.

The CR1000 can be used as a PLC (programmable logic controller). Utilizing peripheral relays and analog output devices, the CR1000 can manage binary and variable control devices through the following output channels:

Read more! See Section 5.4 Control Output.

Continuous Analog Voltage Output: available by adding a peripheral analog output device available from Campbell Scientific..

Digital I/O: 8 channels (C1 - C8) configurable for pulse output duration.

Switched 12 Volts (SW-12): controls (switches on / off) primary battery voltage under program control for use with external devices, such as humidity sensors, requiring controlled 12 V. SW-12 can source up to 600 mA.

3.1.2.3 Grounding Terminals

Read more! See Section 7 Grounding.

Proper grounding will lend stability and protection to a data acquisition system. It is the easiest and least expensive insurance against data loss -- and the most neglected. The following terminals are provided for connection of sensor and datalogger grounding:

Signal Grounds: 12 terminals (⏚) used as reference for single-ended analog inputs, pulse inputs, excitation returns, and as a ground for sensor shield wires. Signal returns for pulse inputs should use ⏚ terminals located next to pulse inputs.

Power Grounds: 6 terminals (G) used as returns for 5V, SW12, 12V, and C1-C8 outputs. Use of G grounds for these outputs minimizes potentially large current flow through the analog voltage measurement section of the wiring panel, which can cause single-ended voltage measurement errors.

Ground Lug: 1 terminal (⏚), the large ground lug is used to connect a heavy gage wire to earth ground. A good earth connection is necessary to secure the ground potential of the datalogger and shunt transients away from electronics. Minimum 14 AWG wire is recommended.

3.1.2.4 Power Terminals

Read more! See Section 6 Power Supply.

Power In

Power Supply: One green plug (POWER IN): for connecting power from an external power source to the CR1000. These are the only terminals used to input battery power; other 12V terminals and the SW-12 terminal are output only terminals for supplying power to other devices. Review power requirements and power supply options in Section 6 CR1000 Power Supply before connecting power.

Power Out

Peripheral 12 V Power Source: 2 terminals (12V) and associated grounds (G) supply power to sensors and peripheral devices requiring nominal 12 VDC. This supply may drop as low as 9.6 VDC before datalogger operation stops. Precautions should be taken to minimize the occurrence of data from underpowered sensors.

Peripheral 5 Volt Power Source: 1 terminal (5V) and associated ground (G) supply power to sensors and peripheral devices requiring regulated 5 VDC.

3.1.2.5 Communications Ports

Read more! See Section 13 Telecommunication and Data Retrieval and Section 14 PakBus Overview.

The CR1000 is equipped with several communications ports. Communication ports allow the CR1000 to communicate with other computing devices, such as a PC, or with other Campbell Scientific dataloggers.

NOTE RS-232 communications normally operate well up to a transmission cable capacitance of 2500 picofarads, or approximately 50 feet of commonly available serial cable.

9-pin RS-232: 1 DCE port for communicating with a PC through the supplied serial cable, serial sensors, or through 3rd party serial telecommunications devices. Acts as a DTE device with a null-modem cable.

Read more! See Appendix B Serial Pin-out

9-pin CS I/O port: 1 port for communicating through Campbell Scientific telecommunications peripherals.

2-pin RS-232: 4 ports configurable from Control I/O ports for communication with serial sensors or other Campbell Scientific dataloggers.

Peripheral: 1 port for use with some Campbell Scientific CF memory card modules and IP network link hardware. See Section 10.2 for CF card precautions.

NOTE The 9-pin RS-232 port is not isolated. "Isolation" means electrically isolated, often by means of optical (light operated) isolation components, from the communications node at the other end of the connection. Optical isolation prevents some electrical problems such as ground looping, which can cause significant errors in single-ended measurements. If optical isolation is required, Campbell Scientific offers the SC32B Optically Isolated RS-232 Interface as a CR1000 accessory, which connects to the CS I/O port.

3.1.3 Power Requirements

Read more! See Section 6 Power Supply.

The CR1000 operates from a DC power supply with voltage ranging from 9.6 to 16 V, and is internally protected against accidental polarity reversal. The CR1000 has modest input power requirements. In low power applications, it can operate for several months on non-rechargeable batteries. Power systems for longer-term remote applications typically consist of a charging source, a charge controller, and a rechargeable battery. When AC line power is available, an AC/AC or AC/DC wall adapter, a charge controller, and a rechargeable battery can be used to construct a UPS (uninterruptible power supply). Contact a Campbell Scientific applications engineer for assistance in acquiring the items necessary to construct a UPS.

Applications requiring higher current requirements, such as satellite or cellular phone communications, should be evaluated by means of a power budget with a knowledge of the factors required by a robust power system. Contact a Campbell Scientific applications engineer if assistance is required in evaluating power supply requirements.

Common power devices are listed below:

Batteries
- Alkaline D-cell - 1.5 V/cell
- Rechargeable Lead-Acid battery

Charge Sources
- Solar Panels
- Wind Generators
- AC/AC or AC/DC wall adapters

3.1.4 Programming: Firmware and User Programs

The CR1000 is a highly programmable instrument, adaptable to the most demanding measurement and telecommunications requirements.

3.1.4.1 Firmware: OS and Settings

Read more! See Section 8 CR1000 Configuration.

Firmware consists of the operating system (OS) and durable configuration settings. OS and settings remain intact when power is cycled.

Good News! The CR1000 is shipped factory ready with all settings and firmware necessary to communicate with a PC via RS-232 and to accept and execute user application programs. OS upgrades are occasionally made available at www.campbellsci.com.

For more complex applications, some settings may need adjustment. Adjustments are accomplished with CSI's DevConfig Software (Section 8.1 DevConfig), CR1000KD Keyboard Display (Section 17 CR1000KD: Using the

Keyboard Display), or through datalogger support software (see Section 13 Support Software)..

OS files are sent to the CR1000 with DevConfig, through the program Send button in datalogger support software, or with a CF card. When the OS is sent via DevConfig, most settings are cleared, whereas, when sent via datalogger support software, most settings are retained.

3.1.4.2 User Programming

Read more! See Section 9 CR1000 Programming and Section 10 CRBASIC Programming Instructions and CRBASIC help for more programming assistance.

A CRBASIC program directs the CR1000 how and when sensors are to be measured, calculations made, and data stored. A program is created on a PC and sent to the CR1000. The CR1000 can store a number of programs in memory, but only one program is active at a given time. Three Campbell Scientific software applications, Short Cut, CRBASIC Editor, and Transformer Utility create CR1000 programs.

1. Short Cut creates a datalogger program and wiring diagram in four easy steps. It supports most sensors sold by Campbell Scientific and is recommended for creating simple programs to measure sensors and store data.
2. Programs generated by Short Cut are easily imported into CRBASIC Editor for additional editing. For complex applications, experienced programmers often create essential measurement and data storage code with Short Cut, then edit the code with CRBASIC Editor. Note that once a Short Cut generated program has been edited with CRBASIC Editor, it can no longer be modified with Short Cut.
3. Transformer utility converts CR10X code to CR1000 code, which can then be imported into CRBASIC Editor. Because of differences in syntax, not all CR10X code is fully convertible. Transformer is included with PC400 and LoggerNet software and is typically accessed from Windows Explorer in C:\Campbellsci\Loggernet or C:\Campbellsci\PC400 folders, or from Windows Desktop: Start | All Programs | LoggerNet | Utilities | Transformer.

3.1.5 Memory and Data Storage

Read more! See Section 12 Memory and Data Storage.

The CR1000 has 2 MBytes Flash EEPROM used to store the operating system. Another 512 K of Flash stores configuration settings. Beginning with CR1000 serial number 11832, 4 MBytes of SRAM are available for program storage (32K), operating system use, and data storage. The size of available memory is posted in the status table (Appendix A). Additional data storage is optionally available by using a Compact Flash card in the CFM100 Compact Flash Module or NL115 Ethernet Interface and Compact Flash Module.

Program storage memory is usually partitioned as a single drive, CPU:. CC640 camera applications require storage of image files on a USR: virtual drive, which is partitioned from the CR1000 data storage memory.

3.1.6 Communications

Read more! See Section 13 Telecommunications and Data Retrieval.

The CR1000 communicates with external devices to receive programs, send data, or act in concert with a network. The primary communication protocol is PakBus. Modbus and DNP3 communication protocols are also supported.

3.1.6.1 PakBus

Read more! See Section 14 PakBus Overview.

The CR1000 communicates with Campbell Scientific support software, telecommunication peripherals, and other dataloggers via PakBus, a proprietary network communications protocol. PakBus is a protocol similar in concept to IP (Internet protocol). By using signatured data packets, PakBus increases the number of communications and networking options available to the CR1000. Communication can occur via RS-232, CS I/O, or digital I/O ports.

Advantages of PakBus:

- Simultaneous communication between the CR1000 and other devices.
- Peer-to-peer communication — no PC required.
- Other PakBus dataloggers can be used as "sensors" to consolidate all data into one CR1000.
- Routing – the CR1000 can act as a router, passing on messages intended for another logger. PakBus supports automatic route detection and selection.
- Short distance networks with no extra hardware – A CR1000 can talk to another CR1000 over distances up to 30 feet by connecting transmit, receive and ground wires between the dataloggers. PC communications with a PakBus datalogger via the CS I/O port, over phone modem or radio, can be routed to other PakBus dataloggers.
- Datalogger to datalogger communications – special CRBASIC instructions simplify transferring data between dataloggers for distributed decision making or control.
- In a PakBus network, each datalogger is set to a unique address before installed in the network. Default PakBus address is 1. To communicate with the CR1000, the datalogger support software (see Section 13) must know the CR1000's PakBus address. The PakBus address is changed using the CR1000KD Keyboard Display, DevConfig software, CR1000 status table, or PakBus Graph software.

3.1.6.2 Modbus

Read more! See Section 15.2 Modbus.

The CR1000 supports Modbus Master and Modbus Slave communication for inclusion in Modbus SCADA networks.

3.1.6.3 DNP3 Communication

Read more! See Section 15.1 DNP3.

The CR1000 supports DNP3 Slave communication for inclusion in DNP3 SCADA networks.

3.1.6.4 Keyboard Display

Read more! See Section 17 CR1000KD: Using the Keyboard Display.

The CR1000KD Keyboard Display is a powerful tool for field use. It allows complete access to most datalogger tables and function, allowing the user to monitor, make modifications, and troubleshoot a datalogger installation conveniently and in most weather conditions.

3.1.6.4.1 Custom Menus

Read more! To implement custom menus, see CRBASIC Help for the DisplayMenu() instruction.

CRBASIC programming in the CR1000 facilitates creation of custom menus for the CR1000KD Keyboard Display.

FIGURE 3.1-2 shows windows from a simple CR1000KD custom menu named "DataView". "DataView" appears as the main menu on the CR1000KD. DataView has menu item, "Counter", and submenus "PanelTemps", "TCTemps", and "System Menu". "Counter" allows selection of 1 of 4 values. Each submenu displays two values from CR1000 memory. PanelTemps shows the CR1000 wiring panel temperature at each scan, and the one minute sample of panel temperature. TCTemps displays two thermocouple temperatures.

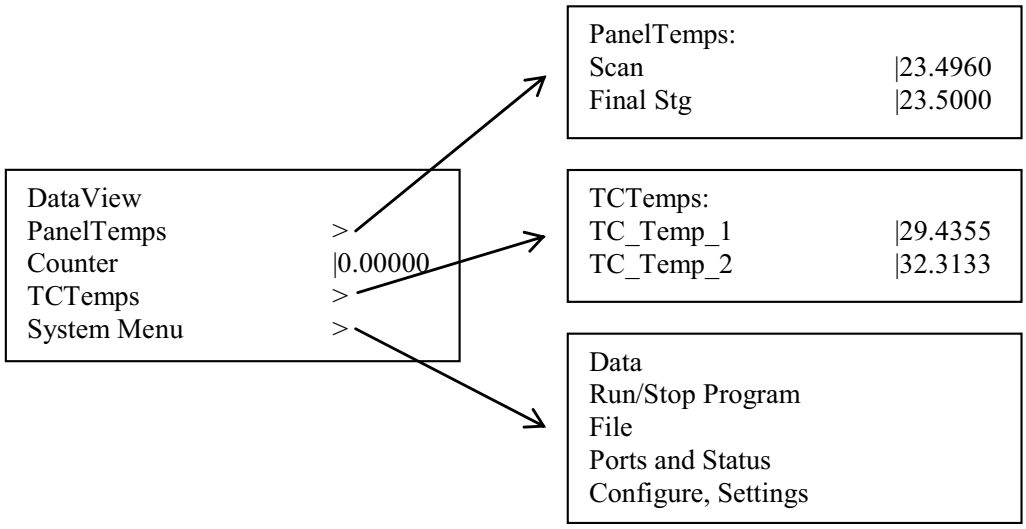


FIGURE 3.1-2. CR1000KD Custom Menu Example

3.1.7 Security

CR1000 applications may include collection of sensitive data, operation of critical systems, or networks accessible by many individuals. CR1000 security provides means by which partial or complete lock-out can be accomplished in the CRBASIC program code.

Up to three levels of security can be set in the datalogger. Level 1 must be set before Level 2. Level 2 must be set before Level 3. If a level is set to 0, any level greater than it will also be set to 0 (e.g., if Level 2 is 0, Level 3 is 0). Valid security codes are 1 through 65535 (0 is no security). Each level must have a unique code. If security is set to a negative code in the CR1000, a positive code must be entered to unlock the CR1000. That positive code = 65536 + (negative security code). For example, a security code of -1111 must be entered as 64425 to unlock the CR1000.

Security can be enabled using DevConfig, the CR1000KD, Status Table, or the SetSecurity() instruction.

Functions affected by each level of security are:

Level 1: collecting data, setting the clock, and setting variables in the Public table are unrestricted. Enter level 1 password to change or retrieve the datalogger program or set variables in the Status table.

Level 2: collecting data are unrestricted. Enter level 2 password to set the clock or change variables in the public table. Enter level 1 password to change the datalogger program or non-read-only postings in the status table.

Level 3: Enter level 3 password to collect data. Enter level 2 password to collect data, set public variable and set the clock. Enter level 1 password to open all datalogger functions to unrestricted use.

Security can be bypassed at the datalogger using a CR1000KD. Pressing and holding the "Del" key while powering up a CR1000 will cause it to abort loading a program and provide a two minute window to either review or disable security codes in the settings editor (not status table) with the CR1000KD. CR1000KD security bypass does not allow telecommunications access without first correcting the security code.

3.1.8 Care and Maintenance

Read more! See Section 18 Care and Maintenance.

With reasonable care, the CR1000 should give many years of reliable service.

3.1.8.1 Protection from Water

The CR1000 and most of its peripherals must be protected from moisture. Moisture in the electronics will seriously damage, and probably render un-repairable, the CR1000. Water can come from flooding or sprinkler irrigation, but most often comes as condensation. Protecting from water is as easy as placing the CR1000 in a weather tight enclosure with desiccant. The CR1000 is shipped with desiccant to reduce humidity. Desiccant should be changed periodically. Do not completely seal the enclosure if lead acid batteries are

present; hydrogen gas generated by the batteries may build up to an explosive concentration.

3.1.8.2 Protection from Voltage Transients

Read more! See Section 7 Grounding.

The CR1000 must be grounded to minimize the risk of damage by voltage transients associated with power surges and lightning induced transients. Earth grounding is required to form a complete circuit for voltage clamping devices internal to the CR1000.

3.1.8.3 Calibration

Read more! See Section 0 Self-Calibration.

The CR1000 uses an internal voltage reference to routinely calibrate itself. To maintain electrical specifications, Campbell Scientific recommends factory recalibration every two years. For calibration services, contact Campbell Scientific to obtain a Return Materials Authorization (RMA) prior to shipping.

3.1.8.4 Internal Battery

CAUTION Misuse of the lithium battery or installing it improperly can cause severe injury. Fire, explosion, and severe burn hazard! Do not recharge, disassemble, heat above 100°C (212°F), solder directly to the cell, incinerate, nor expose contents to water. Dispose of spent lithium batteries properly.

The CR1000 contains a lithium battery that operates the clock and SRAM when the CR1000 is not externally powered. In a CR1000 stored at room temperature, the lithium battery should last approximately 10 years (less at temperature extremes). In installations where the CR1000 is powered most of the time, the lithium cell should last much longer. Lithium battery voltage can be monitored from the CR1000 Status Table. Operating range of the battery is 2.7 to 3.6 VDC. Replace the battery when the voltage is below 2.7 VDC.

3.2 PC Support Software

Read more! See Section 16 Support Software.

Several datalogger support software products for Windows are available. Software for datalogger setup and simple applications, PC200W and Short Cut, are available at no cost at www.campbellsci.com. For more complex programming, telecommunications, networking, and reporting features, full-featured products are available from Campbell Scientific.

1. PC200W Starter Software is available at no charge at www.campbellsci.com. It supports a transparent RS-232 connection between PC and CR1000, and includes Short Cut for creating CR1000 programs. Tools for setting the datalogger clock, sending programs, monitoring sensors, and on-site viewing and collection of data are also included.

2. PC400 supports a variety of telecommunication options, manual data collection, and data monitoring displays. Short Cut, CRBASIC Editor, and Transformer Utility are included for creating CR1000 programs. PC400 does not support complex communication options, such as phone-to-RF, PakBus® routing, or scheduled data collection.

3. LoggerNet supports combined telecommunication options, customized data monitoring displays, and scheduled data collection. It includes Short Cut, CRBASIC Editor, and Transformer Utility programs for creating CR1000 programs. It also includes tools for configuring, trouble-shooting, and managing datalogger networks. LoggerNet Admin and LoggerNet Remote are also available for more demanding applications.

3.3 Specifications

Electrical specifications are valid over a -25° to +50°C range unless otherwise specified; non-condensing environment required. To maintain electrical specifications, Campbell Scientific recommends recalibrating dataloggers every two years. We recommend that the system configuration and critical specifications are confirmed with Campbell Scientific before purchase.

PROGRAM EXECUTION RATE

10 ms to 30 min. @ 10 ms increments

ANALOG INPUTS

8 differential (DF) or 16 single-ended (SE) individually configured. Channel expansion provided by AM16/32 and AM25T multiplexers.

RANGES and RESOLUTION: Basic resolution (Basic Res) is the A/D resolution of a single conversion. **Resolution of DF measurements with input reversal is half the Basic Res.**

	Input Referred Noise Voltage	
Input Range (mV)[1]	*DF Res (µV)*[2]	*Basic Res (µV)*
±5000	667	1333
±2500	333	667
±250	33.3	66.7
±25	3.33	6.7
±7.5	1.0	2.0
±2.5	0.33	0.67

[1]Range overhead of ~9% exists on all ranges to guarantee that full-scale values will not cause over-range.

[2]Resolution of DF measurements with input reversal.

ACCURACY[3]:
±(0.06% of reading + offset), 0° to 40°C
±(0.12% of reading + offset), -25° to 50°C
±(0.18% of reading + offset), -55° to 85°C

[3]The sensor and measurement noise are not included and the offsets are the following:

Offset for DF w/input reversal = 1.5·Basic Res + 1.0 µV
Offset for DF w/o input reversal = 3·Basic Res + 2.0 µV
Offset for SE = 3·Basic Res + 3.0 µV

INPUT NOISE VOLTAGE: For DF measurements with input reversal on ±2.5 mV input range; digital resolution dominates for higher ranges.

250 µs Integration:	0.34 µV RMS
50/60 Hz Integration:	0.19 µV RMS

MINIMUM TIME BETWEEN VOLTAGE MEASUREMENTS: Includes the measurement time and conversion to engineering units. For voltage measurements, the CR1000 integrates the input signal for 0.25 ms or a full 16.66 ms or 20 ms line cycle for 50/60 Hz noise rejection. DF measurements with input reversal incorporate two integrations with reversed input polarities to reduce thermal offset and common mode errors and therefore take twice as long.

250 µs Analog Integration:	~1 ms SE
1/60 Hz Analog Integration:	~20 ms SE
1/50 Hz Analog Integration:	~25 ms SE

COMMON MODE RANGE: ±5 V

DC COMMON MODE REJECTION: >100 dB

NORMAL MODE REJECTION: 70 dB @ 60 Hz when using 60 Hz rejection

SUSTAINED INPUT VOLTAGE W/O DAMAGE: ±16 Vdc max.

INPUT CURRENT: ±1 nA typical, ±6 nA max. @ 50°C; ±90 nA @ 85°C

INPUT RESISTANCE: 20 Gohms typical

ACCURACY OF BUILT-IN REFERENCE JUNCTION THERMISTOR (for thermocouple measurements):
±0.3°C, -25° to 50°C
±0.8°C, -55° to 85°C (-XT only)

ANALOG OUTPUTS

3 switched voltage, active only during measurement, one at a time.

RANGE AND RESOLUTION: Voltage outputs programmable between ±2.5 V with 0.67 mV resolution.

ACCURACY: ±(0.06% of setting + 0.8 mV), 0° to 40°C
±(0.12% of setting + 0.8 mV), -25° to 50°C
±(0.18% of setting + 0.8 mV), -55° to 85°C (-XT only)

CURRENT SOURCING/SINKING: ±25 mA

RESISTANCE MEASUREMENTS

MEASUREMENT TYPES: The CR1000 provides ratiometric measurements of 4- and 6-wire full bridges, and 2-, 3-, and 4-wire half bridges. Precise, dual polarity excitation using any of the 3 switched voltage excitations eliminates dc errors.

RATIO ACCURACY[3]: Assuming excitation voltage of at least 1000 mV, not including bridge resistor error.

±(0.04% of voltage reading + offset)/V_X

[3]The sensor and measurement noise are not included and the offsets are the following:

Offset for DF w/input reversal = 1.5·Basic Res + 1.0 µV
Offset for DF w/o input reversal = 3·Basic Res + 2.0 µV
Offset for SE = 3·Basic Res + 3.0 µV

Offset values are reduced by a factor of 2 when excitation reversal is used.

PERIOD AVERAGING MEASUREMENTS

The average period for a single cycle is determined by measuring the average duration of a specified number of cycles. The period resolution is 192 ns divided by the specified number of cycles to be measured; the period accuracy is ±(0.01% of reading + resolution). Any of the 16 SE analog inputs can be used for period averaging. Signal limiting are typically required for the SE analog channel.

INPUT FREQUENCY RANGE:

Input Range	*Signal (peak to peak)*[4] *Min*	*Max*	*Min. Pulse W.*	*Max*[5] *Freq.*
±2500 mV	500 mV	10 V	2.5 µs	200 kHz
±250 mV	10 mV	2 V	10 µs	50 kHz
±25 mV	5 mV	2 V	62 µs	8 kHz
±2.5 mV	2 mV	2 V	100 µs	5 kHz

[4]The signal is centered at the datalogger ground.

[5]The maximum frequency = 1/(Twice Minimum Pulse Width) for 50% of duty cycle signals.

PULSE COUNTERS

Two 24-bit inputs selectable for switch closure, high-frequency pulse, or low-level AC.

MAXIMUM COUNTS PER SCAN: 16.7×10^6

SWITCH CLOSURE MODE:
Minimum Switch Closed Time: 5 ms
Minimum Switch Open Time: 6 ms
Max. Bounce Time: 1 ms open w/o being counted

HIGH-FREQUENCY PULSE MODE:
Maximum Input Frequency: 250 kHz
Maximum Input Voltage: ±20 V
Voltage Thresholds: Count upon transition from below 0.9 V to above 2.2 V after input filter with 1.2 µs time constant.

LOW-LEVEL AC MODE: Internal AC coupling removes AC offsets up to ±0.5 V.

Input Hysteresis: 16 mV @ 1 Hz
Maximum ac Input Voltage: ±20 V
Minimum ac Input Voltage:

Sine wave (mV RMS)	*Range (Hz)*
20	1.0 to 20
200	0.5 to 200
2000	0.3 to 10,000
5000	0.3 to 20,000

DIGITAL I/O PORTS

8 ports software selectable, as binary inputs or control outputs. C1-C8 also provide edge timing, subroutine interrupts/wake up, switch closure pulse counting, high frequency pulse counting, asynchronous communications (UART), SDI-12 communications, and SDM communications.

HIGH-FREQUENCY PULSE MAX: 400 kHz

SWITCH CLOSURE FREQUENCY MAX: 150 Hz

OUTPUT VOLTAGES (no load): high 5.0 V ±0.1 V; low <0.1

OUTPUT RESISTANCE: 330 ohms

INPUT STATE: high 3.8 to 5.3 V; low -0.3 to 1.2 V

INPUT HYSTERISIS: 1.4 V

INPUT RESISTANCE: 100 kohms

SWITCHED 12 V

One independent 12 V unregulated sources switched on and off under program control. Thermal fuse hold current = 900 mA @ 20°C, 650 mA @ 50°C, 360 mA @ 85°C.

SDI-12 INTERFACE SUPPORT

Control ports 1, 3, 5, and 7 may be configured for SDI-12 asynchronous communications. Up to ten SDI-12 sensors are supported per port. It meets SDI-12 Standard version 1.3 for datalogger mode.

CE COMPLIANCE

STANDARD(S) TO WHICH CONFORMITY IS DECLARED: IEC61326:2002

CPU AND INTERFACE

PROCESSOR: Renesas H8S 2322 (16-bit CPU with 32-bit internal core)

MEMORY: 2 Mbytes of Flash for operating system; 4 Mbytes of battery-backed SRAM for CPU usage, program storage and data storage.

SERIAL INTERFACES: CS I/O port is used to interface with Campbell Scientific peripherals; RS-232 port is for computer or non-CSI modem connection.

PARALLEL INTERFACE: 40-pin interface for attaching data storage or communication peripherals such as the CFM100 module

BAUD RATES: Selectable from 300 bps to 115.2 kbps. ASCII protocol is one start bit, one stop bit, eight data bits, and no parity.

CLOCK ACCURACY: ±3 min. per year

SYSTEM POWER REQUIREMENTS

VOLTAGE: 9.6 to 16 Vdc (reverse polarity protected)

TYPICAL CURRENT DRAIN:
Sleep Mode: ~0.6 mA
1 Hz Scan (8 diff. meas., 60 Hz rej., 2 pulse meas.)
w/RS-232 communication: 19 mA
w/o RS-232 communication: 4.2 mA
1 Hz Scan (8 diff. meas., 250 µs integ., 2 pulse meas.)
w/RS-232 communication: 16.7 mA
w/o RS-232 communication: 1 mA
100 Hz Scan (4 diff. meas., 250 µs integ.)
w/RS-232 communication: 27.6 mA
w/o RS-232 communication: 16.2 mA

CR1000KD CURRENT DRAIN:
Inactive: negligible
Active w/o backlight: 7 mA
Active w/backlight: 100 mA

EXTERNAL BATTERIES: 12 Vdc nominal

PHYSICAL SPECIFICATIONS

MEASUREMENT & CONTROL MODULE SIZE: 8.5" x 3.9" x 0.85" (21.6 x 9.9 x 2.2 cm)

CR1000WP WIRING PANEL SIZE: 9.4" x 4" x 2.4" (23.9 x 10.2 x 6.1 cm); additional clearance required for serial cable and sensor leads.

WEIGHT: 2.1 lbs (1 kg)

WARRANTY

Three years against defects in materials and workmanship.

Section 4. Sensor Support

Several features give the CR1000 the flexibility to measure many sensor types. Contact a Campbell Scientific applications engineer if assistance is required to assess sensor compatibility.

4.1 Powering Sensors

Read more! See Section 6 Power Supply.

The CR1000 is a convenient source of power for sensors and peripherals requiring a 5 or 12 VDC source. It has two continuous 12 Volt terminals (12V), one program-controlled switched 12 Volt terminal (SW-12), and one continuous 5 Volt terminal (5V). SW-12, 12V, and 5V terminals limit current internally for protection against accidental short circuits. Voltage on the 12V and SW-12 terminals will change with the DC supply used to power the CR1000. The 5V terminal is internally regulated to within ±4%, which is typically not adequate accuracy for bridge sensor excitation. TABLE 4.1-1 shows the current limits of 12V and 5V. Greatly reduced output voltages associated with 12V, SW-12, and 5V due to current limiting may occur if the current limits given in TABLE 4.1-1 are exceeded.

4.1.1 Switched Precision (-2500 to +2500 mV)

Three switched analog output (excitation) terminals (Vx/VX1 (VX1 (EX1)), Vx/VX2 (EX2), Vx/VX3 (EX3)) operate under program control. Check the accuracy specification of these channels in Section 3.3 to understand their limitations. Specifications are only applicable for loads not exceeding ±25 mA. CRBASIC instructions that control excitation channels include:

BrFull ()
BrFull6W ()
BrHalf ()
BrHalf3W ()
BrHalf4W ()
ExciteV ()

NOTE Excitation channels can be configured through the RevEx parameter of bridge instructions to provide a squarewave AC excitation for use with polarizing bridge sensors.

4.1.2 Continuous Regulated (5 Volt)

The 5V terminal is regulated and remains near 5 Volts (±4%) so long as the CR1000 supply voltage remains above 9.6 Volts. Measurement of 5V voltage output by the datalogger (by means of jumpering to an analog input) enables an accurate bridge measurement if 5V must be used for excitation.

4.1.3 Continuous Unregulated (Nominal 12 Volt)

Voltage on the 12V terminals will change with CR1000 supply voltage.

4.1.4 Switched Unregulated (Nominal 12 Volt)

Voltage on the SW-12 terminal will change with CR1000 supply voltage. Two CRBASIC instructions, SW12 () and PortSet (), control the SW-12 terminal. Each is handled differently by the CR1000.

SW12 () is a processing task instruction. Use it when controlling power to SDI-12 and serial sensors, which use SDI12Recorder () or SerialIn () instructions respectively. CRBASIC programming using IF THEN constructs to control SW-12, such as cell phone control, should also use the SW12 () instruction.

PortSet () is a measurement task instruction. Use it when powering analog input sensors that need to be turned on just prior to measurement.

TABLE 4.1-1. Current Sourcing Limits

Terminals Vx/VX1 (VX1 (EX1)), Vx/VX2 (EX2), Vx/VX3 (EX3)	**Current Source Limit ±25 mA Maximum**
SW12	< 900 mA @ 20°C
	< 730 mA @ 40°C
	< 650 mA @ 50°C
	< 570 mA @ 60°C
	< 360 mA @ 85°C
12V + SW12	< 3.00 A @ 20°C
	< 2.49 A @ 40°C
	< 2.31 A @ 50°C
	< 2.04 A @ 60°C
	< 1.56 A @ 85°C
5V + CSI/O	< 200 mA

4.2 Voltage Measurement

The CR1000 measures single-ended (SE) and / or differential (Diff) voltage inputs. Single-ended measurements use CRBASIC instruction VoltSE (), which returns the voltage difference between a single input (x.x mV) and ground (0 mV). Differential measurements use CRBASIC instruction VoltDiff (), which returns the voltage difference (x.x - y.y) between a high input (x.x mV) and a low input (y.y mV).

Associated with differential measurements is common-mode voltage, defined as the average DC voltage common to both the high and low inputs [(VHi + VLo) / 2] associated with a differential measurement. The CR1000 incorporates a differential instrumentation amplifier on its measurement front-end. This amplifier processes the difference between the voltage inputs, while rejecting common-mode signals, as long as the common-mode signals are within the ±5000 mV common-mode input range of the amplifier. The amplifier cannot properly reject common-mode signals that fall outside of the

±5000 mV common-mode input range. See Section 16.2 for more information on common-mode range.

NOTE Two sets of numbers are assigned to analog channels. For differential measurements, analog channels are numbered 1 - 8. Each differential channel as two inputs: high (H) and low (L). For single-ended measurement, analog channels are numbered 1-16.

NOTE Sustained voltages in excess of ±16 V input to the analog channels will damage CR1000 circuitry.

4.2.1 Electronic "Noise": VoltDiff() or VoltSE()?

Read More! Consult the following Campbell Scientific White Papers for an in-depth treatment of the advantages of differential and single-ended measurements. Find these papers at www.campbellsci.com.

"Preventing and Attacking Measurement Noise Problems"

"Benefits of Input Reversal and Excitation Reversal for Voltage Measurements"

"Voltage Measurement Accuracy, Self-Calibration, and Ratiometric Measurements

Deciding whether a differential or single-ended measurement is appropriate for a particular sensor requires sorting through trade-offs of accuracy and precision, available measurement hardware, and fiscal constraints.

In broad terms, analog voltage is best measured differentially because these measurements include noise reduction features, listed below, not included in single-ended measurements.

- Passive Noise Rejection
  - No voltage reference offset
  - Common-mode noise rejection
    - Rejects capacitively coupled noise

- Active Noise Rejection
  - Input reversal
    - Review Section 4.2.4.1 Input and Excitation Reversal for details
    - Doubles input reversal signal integration time

Reasons for using single-ended measurements, however, include:

- Sensor is not designed for differential measurement.
- Sensor number exceeds available differential channels.

Sensors with a high signal-to-noise ratio, such as a relative humidity sensor with a full scale output of 0 to 1000 mV, can normally be measured single-endedly without a significant reduction in accuracy or precision.

Sensors with low signal-to-noise ratio, such as thermocouples, should normally be measured differentially. However, if the measurement to be made does not require high accuracy or precision, such as thermocouples measuring brush fire temperatures, a single-ended measurement may be appropriate. If sensors require differential measurement, but adequate input channels are not available, an analog multiplexer should be acquired to expand differential input capacity.

4.2.2 Measurement Sequence

The CR1000 measures analog voltage by integrating the input signal for a fixed duration, then holding the integrated value during the successive approximation analog-to-digital (A/D) conversion. The CR1000 can make and store measurements from up to 8 differential or 13 single-ended channels at the minimum scan rate of 10 ms (100 Hz) using the fastest available voltage measurements. The maximum conversion rate is 2700 per second for measurements made on a single channel.

The timing of CR1000 measurements is precisely controlled. The measurement schedule is determined at compile time and loaded into memory. This schedule sets interrupts that drive the measurement task.

Using two different voltage measurement instructions with the same voltage range takes the same measurement time as using one instruction with two repetitions.

Historical Lesson: This is not the case with legacy CR10(X), 21X, CR23X, and CR7(X) dataloggers. Using multiple measurement “reps” in these dataloggers reduced overall measurement time.

Several parameters in CRBASIC voltage measurement instructions VoltDiff () and VoltSE () vary the sequence and timing of measurements. TABLE 4.2-1 lists these parameters.

TABLE 4.2-1. CRBASIC Parameters Varying Measurement Sequence and Timing

CRBASIC Parameter	Description
MeasOfs	Correct ground offset on single-ended measurements.
RevDiff	Reverse high and low differential inputs.
SettlingTime	Sensor input settling time.
Integ	Duration of input signal integration.
RevEx	Reverse polarity of excitation voltage.

4.2.3 Voltage Range

In general, a voltage measurement should use the smallest fixed input range that will accommodate the full scale output of the sensor being measured. This results in the best measurement accuracy and resolution. The CR1000 has six fixed input ranges for voltage measurements, along with an autorange option that enables the CR1000 to automatically determine the appropriate input voltage range for a given measurement. TABLE 4.2-2 describes the CR1000 input voltage range options along with the associated alphanumeric range codes.

TABLE 4.2-2. Analog Voltage Input Ranges with Options for Open Input Detect (OID) and Pull into Common Mode (PCM).

Range Code	Description
mV5000[1]	measures voltages between ±5000 mV
mV2500[2]	measures voltages between ±2500 mV
mV250[2]	measures voltages between ±250 mV
mV25[2]	measures voltages between ±25 mV
mV7_5[2]	measures voltages between ±7.5 mV
mV2_5[2]	measures voltages between ±2.5 mV
AutoRange[3]	datalogger determines the most suitable range

[1] Append with "C" to enable OID/PCM and set excitation to full-scale DAC (~2700 mV)

[2] Append with "C" to enable OID/PCM

[3] Append with "C" to enable OID/PCM on ranges ≤ ±250 mV, PCM on ranges > ±250 mV

Fixed Voltage Ranges

As listed in TABLE 4.2-2, the CR1000 has six fixed input ranges for voltage measurement. An approximately 9% range overhead exists on all input voltage ranges. For example, over-range on the ±2500 mV input range occurs at approximately +2725 mV and –2725 mV. The CR1000 indicates a measurement over-range by returning a NAN (Not-A-Number) for the measurement.

AutoRange

For signals that do not fluctuate too rapidly, AutoRange allows the CR1000 to automatically choose the voltage range to use. AutoRange makes two measurements. The first measurement determines the range to use, and is made with the 250 µs integration on the ±5000 mV range. The second measurement is made using the appropriate range with the integration specified in the instruction. Both measurements use the settling time programmed in the instruction. AutoRange optimizes resolution but takes longer than a measurement on a fixed range, because of the two measurements required.

An AutoRange measurement will return NAN (Not-A-Number) if the voltage exceeds the range picked by the first measurement. To avoid problems with a signal on the edge of a range, AutoRange selects the next larger range when the signal exceeds 90% of a range.

AutoRange is recommended for a signal that occasionally exceeds a particular range, for example, a Type J thermocouple measuring a temperature usually less than 476 °C (±25 mV range) but occasionally as high as 500 °C (±250 mV range). AutoRange should not be used for rapidly fluctuating signals, particularly signals traversing several voltage ranges rapidly. The possibility exists that the signal can change ranges between the range check and the actual measurement.

Open Input Detect / Pull into Common Mode

The CR1000 can check for an open measurement circuit or input, as can occur with a broken sensor wire. Simultaneously, the CR1000 will pull the signal

into common mode range. Range codes ending with "C" enable these features. Refer to TABLE 4.2-2 for limitations.

Open input detect works by connecting the voltage input to a 300 mV internal source for 50 µs. A differential voltage input has the high side connected to 300 mV and the low side connected to ground. After disconnecting, the input is allowed to settle, and the voltage measurement is made. If the sensor is open (inputs not connected but "floating") the input capacitor will remain floating near the voltage it was previously connected to; a measurement on the ±2.5 mV, ±7.5 mV, ±25 mV, or the ±250 mV voltage range will over range and return NAN (Not-A-Number). If the sensor is good, the signal from the sensor will drive the inputs to the correct value.

Briefly connecting the inputs to the internal CR1000 voltages also serves to pull a floating differential voltage into the CR1000 common mode (Section 7.2 Common Mode Range). This voltage range option should be used for making differential voltage measurements of thermocouples (TCDiff) and for other sensors with floating differential output (e.g., solar radiation sensors).

Open input detect on the ± 2500 mV input range (mV2500C) is available with some differences . The ± 2500 mV input range, the high side of the input is internally connected to a voltage that is greater than 2500 mV, but not large enough to over-range. To detect an open bridge, program If ... Then logic in the CRBASIC program to determine if the resulting measurement exceeds 2500 mV. For example, the BrHalf () instruction returns the value X defined as V1 / Vx, where V1 is the measured single-ended voltage and Vx is the user defined excitation voltage. A result of X > 1 indicates an open input for the V1 measurement.

Open Input Detect Cautionary Notes

1) if the input is not a truly open circuit, such as might occur on a wet cut cable end, the open circuit may not be detected because the input capacitor discharges through external leakage to ground to a normal voltage within the settling time of the measurement. This problem will be worse when a long settling time is selected, as more time is given for the input capacitors to discharge to a "normal" level.

2) if the open circuit is at the end of a very long cable, the test pulse (300 mV) may not charge the cable (with its high capacitance) up to a voltage that generates NaN or a distinct error voltage. The cable may even act as an aerial and inject noise which also might not read as an error voltage.

3) the sensor may "object" to the test pulse being connected to its output, even for 100 microseconds. There is little or no risk of damage, but the sensor output may be kicked into temporary oscillation. Longer settling times may avoid this.

4.2.4 Offset Voltage Compensation

Analog measurement circuitry in the CR1000 may introduce a small offset voltage to a measurement. Depending on the magnitude of the signal, this offset voltage may introduce significant error. For example, an offset of 3 µV on a 2500 mV signal introduces an error of only 0.00012%; however, the same offset on a 0.25 mV signal introduces an error of 1.2%.

The primary source of offset voltage is the Seebeck effect, which arises at the junctions of differing metals in electronic circuits. A secondary source of offset voltage are return currents incident to powering external devices through the CR1000. Return currents create voltage drop at the ground terminals that may be used as signal references.

CR1000 measurement instructions incorporate techniques to cancel these unwanted offsets. TABLE 4.2-3 lists measurement instructions and offset voltage compensation options available to each.

TABLE 4.2-3. Analog Measurement Offset Voltage Compensation

CRBASIC Voltage Measurement Instruction	Input Reversal (RevDiff = True)	Excitation Reversal (RevEx = True)	Measure Ground Reference Offset (MeasOff = True)	Background Calibration (RevDiff = False) (RevEx = False) (MeasOff = False)
VoltDiff ()	*			*
VoltSe ()			*	*
TCDiff ()	*			*
TCSe ()			*	*
BrHalf ()		*		*
BrHalf3W ()		*		*
Therm107 ()		*		*
Therm108 ()		*		*
Therm109 ()		*		*
BrHalf4W ()	*	*		*
BrFull ()	*	*		*
BrFull6W ()	*	*		*
AM25T ()	*	*		*

4.2.4.1 Input and Excitation Reversal (RevDiff, RevEx = True)

Reversing inputs (differential measurements) or reversing polarity of excitation voltage (bridge measurements) cancels stray voltage offsets. For example, if there is a +3 μVolt offset in the measurement circuitry, a 5 mV signal will be measured as 5.003 mV. When the input or excitation is reversed, the measurement will be -4.997 mV. Subtracting the second measurement from the first and dividing by 2 cancels the offset:

5.003 mV - (-4.997 mV) = 10.000 mV
10.000 mV / 2 = 5.000 mV.

When the CR1000 reverses differential inputs or excitation polarity, it delays the same settling time after the reversal as it does before the first measurement. Thus there are two delays per channel when either RevDiff or RevEx is used. If both RevDiff and RevEx are True, four measurements are performed; positive and negative excitations with the inputs one way and positive and negative excitations with the inputs reversed. To illustrate,

the CR1000 switches to the channel
sets the excitation, settles, **measures**,
reverses the excitation, settles, **measures**,
reverses the excitation, reverses the inputs, settles, **measures**,
reverses the excitation, settles, **measures.**

There are four delays per channel measured. The CR1000 processes the four sub-measurements into a single reported value. In cases of excitation reversal, excitation "on time" for each polarity is exactly the same to ensure that ionic sensors do not polarize with repetitive measurements.

Read more! A white paper entitled "The Benefits of Input Reversal and Excitation Reversal for Voltage Measurements" is available at www.campbellsci.com.

4.2.4.2 Ground Reference Offset Voltage (MeasOff = True)

When MeasOff is enabled (= True), the CR1000 measures the offset voltage of the ground reference prior to each VoltSe () or TCSe () measurement. This offset voltage is subtracted from the subsequent measurement.

4.2.4.3 Background Calibration (RevDiff, RevEx, MeasOff = False)

If RevDiff, RevEx, or MeasOff is disabled (= False) in a measurement instruction, offset voltage compensation is still performed, albeit less effectively, by using measurements from automatic background calibration. Disabling RevDiff, RevEx, or MeasOff speeds up measurement time; however, the increase in speed comes at the cost of accuracy 1) because RevDiff, RevEx, and MeasOff are more effective techniques, and 2) because background calibrations are performed only periodically, so more time skew occurs between the background calibration offsets and the measurements to which they are applied.

NOTE Disable RevDiff, RevEx and MeasOff when CR1000 module temperature and return currents are slow to change or when measurement duration must be minimal to maximize measurement frequency.

4.2.5 Measurements Requiring AC Excitation

Some resistive sensors require AC excitation. These include electrolytic tilt sensors, soil moisture blocks, water conductivity sensors and wetness sensing grids. The use of DC excitation with these sensors can result in polarization, which will cause erroneous measurement, shift calibration, or lead to rapid sensor decay.

Other sensors, e.g., LVDTs (Linear Variable Differential Transformer), require an AC excitation because they rely on inductive coupling to provide a signal. DC excitation will provide no output.

CR1000 bridge measurements can reverse excitation polarity to provide AC excitation and avoid ion polarization.

NOTE Sensors requiring AC excitation require techniques to minimize or eliminate ground loops. See Section 7.5 Ground Looping in Ionic Measurements.

4.2.6 Integration

Read more! See a white paper entitled "Preventing and Attacking Measurement Noise Problems" available at www.campbellsci.com.

The CR1000 incorporates circuitry to perform an analog integration on voltages to be measured prior to the A/D conversion. The magnitude of the frequency response of an analog integrator is a SIN(x) / x shape, which has notches (transmission zeros) occurring at 1 / (integer multiples) of the integration duration. Consequently, noise at 1 / (integer multiples) of the integration duration is effectively rejected by an analog integrator. TABLE 4.2-4 lists three integration durations available in the CR1000 and associated CRBASIC codes. If reversing the differential inputs or reversing the excitation is specified, there will be two separate integrations per measurement; if both reversals are specified, there will be four separate integrations.

TABLE 4.2-4. CRBASIC Measurement Settling Time and Integration Codes

Integration Time (ms)	CRBASIC Code	Comments
250 µs	250	Fast integration
16.667 ms	_60Hz	filters 60 Hz noise.
20 ms	_50Hz	filters 50 Hz noise.

4.2.6.1 AC Power Line Noise Rejection

Grid or mains power (50 or 60 Hz, 230 or 120 VAC) can induce electrical noise at integer multiples of 50 or 60 Hz. Small analog voltage signals, such as thermocouples and pyranometers, are particularly susceptible. CR1000 voltage measurements can be programmed to reject (filter) 50 or 60 Hz related noise.

4.2.6.1.1 AC Noise Rejection on Small Analog Signals

The CR1000 rejects AC power line noise on all voltage ranges except mV5000 and mV2500 by integrating the measurement over exactly one AC cycle before A/D conversion as illustrated in TABLE 4.2-5 and the full cycle technique of FIGURE 4.2-1.

TABLE 4.2-5. AC Noise Rejection Integration on Voltage Ranges Except mV5000 and mV2500

AC Power Line Frequency	Measurement Integration Duration	CRBASIC Integration Code
60 Hz	16.667 ms	_60Hz
50 Hz	20 ms	_50Hz

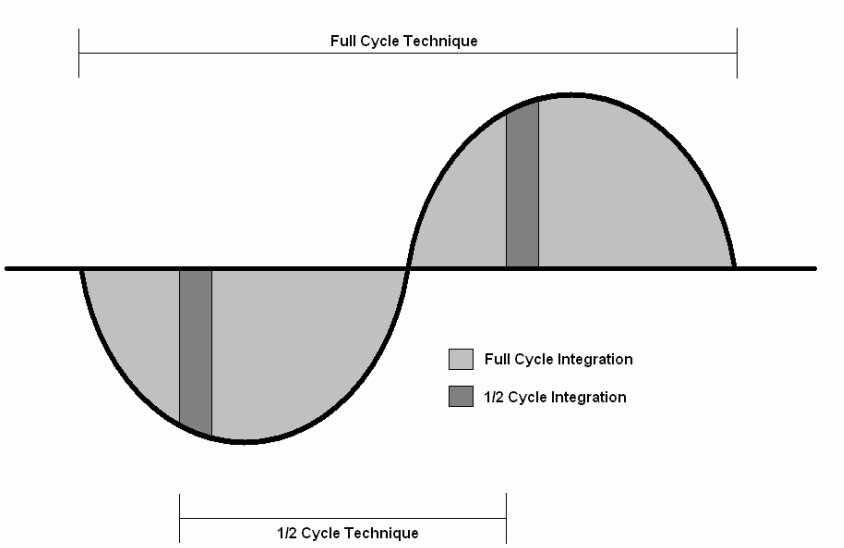


FIGURE 4.2-1. Full and ½ Cycle Integration Methods for AC Power Line Noise Rejection

4.2.6.1.2 AC Noise Rejection on Large Analog Signals

When rejecting AC noise on the 2500 mV and 5000 mV ranges, the CR1000 makes two fast measurements separated in time by ½ line cycle, as illustrated in FIGURE 4.2-1. For 60 Hz rejection , ½ line cycle = 8333 µs, meaning that the 2nd measurement must start 8333 µs after the integration for the first measurement was started. The A/D conversion time is approximately 170 µs, leaving a maximum input settling time of approximately 8333 µs - 170 µs = 8160 µs before the 2nd measurement is delayed too long to result in a rejection notch at 60 Hz. For 50 Hz rejection on the mV5000 and mV2500 input ranges, the maximum input settling time of approximately 10,000 - 170 µs = 9830 µs before the 2nd measurement is delayed too long to result in a rejection notch at 50 Hz. The CR1000 does not prevent or warn against setting the settling time beyond the ½ cycle limit. TABLE 4.2-6 lists details of the ½ line cycle AC power line noise rejection technique.

TABLE 4.2-6. AC Noise Rejection Integration on Voltage Ranges mV5000 and mV2500

AC Power Line Frequency	Measurement Integration Time	CRBASIC Integration Code	Default Settling Time	Maximum Recommended Settling Time*
60 Hz	250 µs x 2	_60Hz	3000 µs	8330 µs
50 Hz	250 µs x 2	_50Hz	3000 µs	10000 µs

*Excitation time equals settling time in measurements requiring excitation. The CR1000 cannot excite channels Vx/VX1 (VX1 (EX1)), Vx/VX2 (EX2), and Vx/VX3 (EX3) during A/D conversion. The ½ cycle technique with excitation limits the length of recommended excitation / settling time for the first measurement to ½ cycle. The CR1000 does not prevent or warn against setting a settling time beyond the ½ cycle limit. For example, a settling time of up to 50000 microseconds can be programmed, but the CR1000 will execute the measurement as follows:

1. CR1000 turns excitation on, waits 50000 microseconds, then makes the first measurement.
2. During A/D, CR1000 turns off excitation for ≈ 170 microseconds.
3. Excitation is switched on again for ½ cycle, then the second measurement is made.

Restated, a sensor does not see a continuous excitation of the length entered as the settling time before the second measurement if the settling time entered is greater than ½ cycle. Depending on the sensor used, a truncated second excitation may cause measurement errors.

4.2.7 Signal Settling Time

When the CR1000 switches to an analog input channel or activates excitation for a bridge measurement, a settling time is required for the measured voltage to settle to its true value before being measured. The rate at which the signal settles is determined by the input settling time constant which is a function of both the source resistance and input capacitance.

Rise and decay waveforms are exponential. Figure 4.2-3 shows rising and decaying waveforms settling to the true signal level, V_{so}.

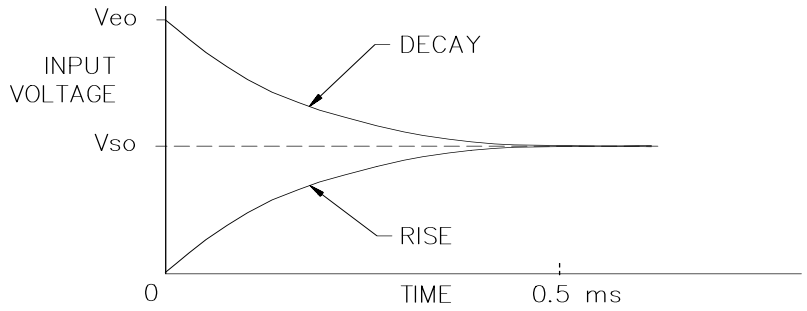


FIGURE 4.2-3. Input Voltage Rise and Transient Decay

The CR1000 delays after switching to a channel to allow the input to settle before initiating the measurement. The SettlingTime parameter of the associated measurement instruction is provided to allow the user to tailor measurement instructions settling times with 100 microsecond resolution. Default settling times are listed in TABLE 4.2-7, and are meant to provide sufficient signal settling in most cases. Additional settling time may be required when measuring high resistance (impedance) sensors and / or sensors

connected to the datalogger by long leads. Measurement time of a given instruction increases with increasing settling time. For example, a 1 ms increase in SettlingTime for a bridge instruction with input reversal and excitation reversal results in a 4 ms increase in time for the datalogger to perform the instruction.

TABLE 4.2-7. CRBASIC Measurement Settling Times

Settling Time Entry	Input Voltage Range	Integration Code	Settling Time*
0	All	250 ms	450 ms (default)
0	All	_50Hz	3 ms (default)
0	All	_60Hz	3 ms (default)
>100	All	All	µs entered

*Minimum settling time required to allow the input to settle to CR1000 resolution specifications.

A finite settling time is required for CR1000 voltage measurements for the following reasons:

1. A small switching transient occurs when the CR1000 switches to the single-ended or differential channel to be measured.

2. When switched voltage excitation is used in a bridge measurement, a relatively large transient on the signal conductor may be induced by capacitive coupling from the nearby excitation conductor in the cable.

3. Long 50 or 60 Hz integrations require a relatively long reset time of the internal integration capacitor before the next measurement due to dielectric absorption.

4.2.7.1 Minimizing Settling Errors

When long lead lengths are required the following general practices can be used to minimize or measure settling errors:

1. DO NOT USE WIRE WITH PVC INSULATED CONDUCTORS. PVC has a high dielectric which extends input settling time.

2. Where possible, run excitation leads and signal leads in separate shields to minimize transients.

3. When measurement speed is not a prime consideration, additional time can be used to ensure ample settling time. The settling time required can be measured with the CR1000.

4.2.7.2 Measuring the Necessary Settling Time

Settling time for a particular sensor and cable can be measured with the CR1000. Programming a series of measurements with increasing settling times will yield data that indicates at what settling time a further increase results in negligible change in the measured voltage. The programmed settling time at this point indicates the true settling time for the sensor and cable combination.

EXAMPLE 4.2-1 presents CRBASIC code to help determine settling time for a pressure transducer with 200 feet of cable. The code consists of a series of full-bridge measurements (BrFull ()) with increasing settling times. The pressure transducer is placed in steady-state conditions so changes in measured voltage are attributable to settling time rather than changes in the measured pressure. Reviewing Section 9 CR1000 Programming may help in understanding the CRBASIC code in the example.

EXAMPLE 4.2-1. CRBASIC Code: Measuring Settling Time

```
'CR1000 Series Datalogger
'Program to measure the settling time of a sensor
'measured with a differential voltage measurement

Public PT(20)      'Variable to hold the measurements

DataTable (Settle,True,100)
    Sample (20,PT(),IEEE4)
EndTable

BeginProg
    Scan (1,Sec,3,0)
        BrFull (PT(1),1,mV7_5,1,Vx1,1,2500,True,True,100,250,1.0,0)
        BrFull (PT(2),1,mV7_5,1,Vx1,1,2500,True,True,200,250,1.0,0)
        BrFull (PT(3),1,mV7_5,1,Vx1,1,2500,True,True,300,250,1.0,0)
        BrFull (PT(4),1,mV7_5,1,Vx1,1,2500,True,True,400,250,1.0,0)
        BrFull (PT(5),1,mV7_5,1,Vx1,1,2500,True,True,500,250,1.0,0)
        BrFull (PT(6),1,mV7_5,1,Vx1,1,2500,True,True,600,250,1.0,0)
        BrFull (PT(7),1,mV7_5,1,Vx1,1,2500,True,True,700,250,1.0,0)
        BrFull (PT(8),1,mV7_5,1,Vx1,1,2500,True,True,800,250,1.0,0)
        BrFull (PT(9),1,mV7_5,1,Vx1,1,2500,True,True,900,250,1.0,0)
        BrFull (PT(10),1,mV7_5,1,Vx1,1,2500,True,True,1000,250,1.0,0)
        BrFull (PT(11),1,mV7_5,1,Vx1,1,2500,True,True,1100,250,1.0,0)
        BrFull (PT(12),1,mV7_5,1,Vx1,1,2500,True,True,1200,250,1.0,0)
        BrFull (PT(13),1,mV7_5,1,Vx1,1,2500,True,True,1300,250,1.0,0)
        BrFull (PT(14),1,mV7_5,1,Vx1,1,2500,True,True,1400,250,1.0,0)
        BrFull (PT(15),1,mV7_5,1,Vx1,1,2500,True,True,1500,250,1.0,0)
        BrFull (PT(16),1,mV7_5,1,Vx1,1,2500,True,True,1600,250,1.0,0)
        BrFull (PT(17),1,mV7_5,1,Vx1,1,2500,True,True,1700,250,1.0,0)
        BrFull (PT(18),1,mV7_5,1,Vx1,1,2500,True,True,1800,250,1.0,0)
        BrFull (PT(19),1,mV7_5,1,Vx1,1,2500,True,True,1900,250,1.0,0)
        BrFull (PT(20),1,mV7_5,1,Vx1,1,2500,True,True,2000,250,1.0,0)
        CallTable Settle
    NextScan
EndProg
```

The first six measurements are shown in TABLE 4.2-8. Each trace in FIGURE 4.2-2. Settling Time for Pressure Transducercontains all 20 PT() values for a given record number, along with an averaged value showing the measurements as percent of final reading. The reading has settled to 99.5% of the final value by the fourteenth measurement, PT(14). This is a suitable accuracy for the application, so a settling time of 1400 μs is determined to be adequate.

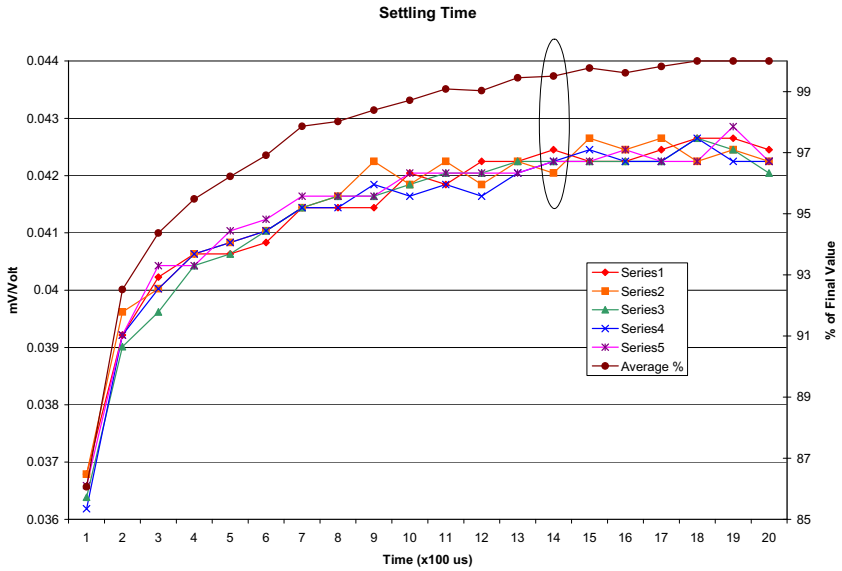


FIGURE 4.2-2. Settling Time for Pressure Transducer

TABLE 4.2-8. First Six Values of Settling Time Data

TIMESTAMP	RECORD	PT(1)	PT(2)	PT(3)	PT(4)	PT(5)	PT(6)
		Smp	Smp	Smp	Smp	Smp	Smp
1/3/2000 23:34	0	0.03638599	0.03901386	0.04022673	0.04042887	0.04103531	0.04123745
1/3/2000 23:34	1	0.03658813	0.03921601	0.04002459	0.04042887	0.04103531	0.0414396
1/3/2000 23:34	2	0.03638599	0.03941815	0.04002459	0.04063102	0.04042887	0.04123745
1/3/2000 23:34	3	0.03658813	0.03941815	0.03982244	0.04042887	0.04103531	0.04103531
1/3/2000 23:34	4	0.03679027	0.03921601	0.04022673	0.04063102	0.04063102	0.04083316

4.2.8 Self-Calibration

The CR1000 self-calibrates to compensate for changes induced by fluctuating operating temperatures and aging. Without self-calibration, measurement accuracy over the operational temperature range is worse by about a factor of 10. That is, over the extended temperature range of -40°C to 85°C, the accuracy specification of ±0.12% of reading can degrade to ±1% of reading with self-calibration disabled. If the temperature of the CR1000 remains the same, there will be little calibration drift with self-calibration disabled.

Unless a Calibrate () instruction is present in the running CRBASIC program, the CR1000 automatically performs self-calibration during spare time in a slow sequence (background), with a segment of the calibration occurring every 4 seconds (s). If there is insufficient time to do the background calibration because of a consuming user program, the CR1000 will display the following warning at compile time: “Warning when Fast Scan x is running background calibration will be disabled”.

The composite transfer function of the instrumentation amplifier, integrator, and analog-to-digital converter of the CR1000 is described by the following equation:

$$COUNTS = G * Vin + B$$

where COUNTS is the result from an analog-to-digital conversion, G is the voltage gain for a given input range, and B is the internally measured offset voltage.

Automatic self-calibration only calibrates the G and B values necessary to run a given CRBasic program, resulting in a program dependent number of self-calibration segments ranging from at least 6 to a maximum of 91. A typical number of segments required in self-calibration is 20 for analog ranges and 1 segment for the panel temperature measurement, totaling 21 segments. So, (21 segments) * (4 s / segment) = 84 s per complete self-calibration. The worst-case will be (91 segments) * (4 s / segment) = 364 s per complete self-calibration.

During instrument power-up, the CR1000 computes calibration coefficients by averaging 10 complete sets of self-calibration measurements. After power up, newly determined G and B values are low-pass filtered as followed: **Next_Value** = (1/5) * **New** + (4/5) * **Old**. For a step change of the **New** value, the low-pass filter **Next_Value** = (1/5) * **New** + (4/5) * **Old** results in 20% settling for 1 **New** value, 49% settling for 3 **New** values, 67% settling for 5 **New** values, 89% settling for 10 **New** values, and 96% settling for 14 **New** values. If this rate of update for measurement channels is too slow, a user can utilize the Calibrate () instruction. The Calibrate () instruction computes the necessary G and B values every scan without any low-pass filtering.

For a VoltSe () instruction, B is determined as part of self-calibration only if the parameter **MeasOff** = 0. An exception is B for VoltSe () on the ±2500 mV input range with 250 µs integration, which is always determined in self-calibration for use internally. For a VoltDiff () instruction, B is determined as part of self-calibration only if the parameter **RevDiff** = 0.

VoltSe () and VoltDiff () instructions on a given input range with the same integration durations, utilize the same G, but different B values. The 6 input voltage ranges (±5000 mV, ±2500 mV, ±250 mV, ±25 mV, ±7.5 mV, and ±2.5 mV) along with the 3 different integration durations (250 µs, _50Hz, & _60Hz) result in a maximum of 18 different gains (G), and 18 offsets for VoltSe () measurements (B), and 18 offsets for VoltDiff () measurements (B) to be determined during CR1000 self-calibration (maximum of 54 values).

The various G and B values can be viewed in the Status Table as CalGain(1) through CalGain(18), CalSeOffset(1) through CalSeOffset(18), and CalDiffOffset(1) through CalDiffOffset(18), with an order of 250 µs integration, _60Hz integration, and _50Hz integration on the following input voltage ranges: ±5000 mV, ±2500 mV, ±250 mV, ±25 mV, ±7.5 mV, and ±2.5 mV.

An example of the Calibrate instruction for all input ranges is given as Calibrate (cal(1),true), where Dest is an array of 54 values, and Range ≠ 0 in order to calibrate all input ranges. TABLE 4.2-9 describes the 54 values generated from the Calibrate (cal(1),true) instruction.

TABLE 4.2-9. Values Generated by the Calibrate () Instruction		
Array Element	**Description**	**Typical Value**
1	SE offset for ±5000 mV input range with 250 ms integration.	±5 LSB
2	Differential offset for ±5000 mV input range with 250 ms integration.	±5 LSB
3	Gain for ±5000 mV input range with 250 ms integration.	-1.34 mV/LSB
4	SE offset for ±2500 mV input range with 250 ms integration.	±5 LSB
5	Differential offset for ±2500 mV input range with 250 ms integration.	±5 LSB
6	Gain for ±2500 mV input range with 250 ms integration.	-0.67 mV/LSB
7	SE offset for ±250 mV input range with 250 ms integration.	±5 LSB
8	Differential offset for ±250 mV input range with 250 ms integration.	±5 LSB
9	Gain for ±250 mV input range with 250 ms integration.	-0.067 mV/LSB
10	SE offset for ±25 mV input range with 250 ms integration.	±5 LSB
11	Differential offset for ±25 mV input range with 250 ms integration.	±5 LSB
12	Gain for ±25 mV input range with 250 ms integration.	-0.0067 mV/LSB
13	SE offset for ±7.5 mV input range with 250 ms integration.	±10 LSB
14	Differential offset for ±7.5 mV input range with 250 ms integration.	±10 LSB
15	Gain for ±7.5 mV input range with 250 ms integration.	-0.002 mV/LSB
16	SE offset for ±2.5 mV input range with 250 ms integration.	±20 LSB
17	Differential offset for ±2.5 mV input range with 250 ms integration.	±20 LSB
18	Gain for ±2.5 mV input range with 250 ms integration.	-0.00067 mV/LSB
19	SE offset for ±5000 mV input range with 60 Hz integration.	±5 LSB
20	Differential offset for ±5000 mV input range with 60 Hz integration.	±5 LSB
21	Gain for ±5000 mV input range with 60 Hz integration.	-0.67 mV/LSB
22	SE offset for ±2500 mV input range with 60 Hz integration.	±5 LSB
23	Differential offset for ±2500 mV input range with 60 Hz integration.	±5 LSB
24	Gain for ±2500 mV input range with 60 Hz integration.	-0.34 mV/LSB
25	SE offset for ±250 mV input range with 60 Hz integration.	±5 LSB
26	Differential offset for ±250 mV input range with 60 Hz integration.	±5 LSB
27	Gain for ±250 mV input range with 60 Hz integration.	-0.067 mV/LSB
28	SE offset for ±25 mV input range with 60 Hz integration.	±5 LSB
29	Differential offset for ±25 mV input range with 60 Hz integration.	±5 LSB
30	Gain for ±25 mV input range with 60 Hz integration.	-0.0067 mV/LSB

31	SE offset for ±7.5 mV input range with 60 Hz integration.	±10 LSB
32	Differential offset for ±7.5 mV input range with 60 Hz integration.	±10 LSB
33	Gain for ±7.5 mV input range with 60 Hz integration.	-0.002 mV/LSB
34	SE offset for ±2.5 mV input range with 60 Hz integration.	±20 LSB
35	Differential offset for ±2.5 mV input range with 60 Hz integration.	±20 LSB
36	Gain for ±2.5 mV input range with 60 Hz integration.	-0.00067 mV/LSB
37	SE offset for ±5000 mV input range with 50 Hz integration.	±5 LSB
38	Differential offset for ±5000 mV input range with 50 Hz integration.	±5 LSB
39	Gain for ±5000 mV input range with 50 Hz integration.	-0.67 mV/LSB
40	SE offset for ±2500 mV input range with 50 Hz integration.	±5 LSB
41	Differential offset for ±2500 mV input range with 50 Hz integration.	±5 LSB
42	Gain for ±2500 mV input range with 50 Hz integration.	-0.34 mV/LSB
43	SE offset for ±250 mV input range with 50 Hz integration.	±5 LSB
44	Differential offset for ±250 mV input range with 50 Hz integration.	±5 LSB
45	Gain for ±250 mV input range with 50 Hz integration.	-0.067 mV/LSB
46	SE offset for ±25 mV input range with 50 Hz integration.	±5 LSB
47	Differential offset for ±25 mV input range with 50 Hz integration.	±5 LSB
48	Gain for ±25 mV input range with 50 Hz integration.	-0.0067 mV/LSB
49	SE offset for ±7.5 mV input range with 50 Hz integration.	±10 LSB
50	Differential offset for ±7.5 mV input range with 50 Hz integration.	±10 LSB
51	Gain for ±7.5 mV input range with 50 Hz integration.	-0.002 mV/LSB
52	SE offset for ±2.5 mV input range with 50 Hz integration.	±20 LSB
53	Differential offset for ±2.5 mV input range with 50 Hz integration.	±20 LSB
54	Gain for ±2.5 mV input range with 50 Hz integration.	-0.00067 mV/LSB

4.3 Bridge Resistance Measurements

Many sensors detect phenomena by way of change in a resistive circuit. Thermistors, strain gages, and position potentiometers are examples. Resistance measurements are special case voltage measurements. By supplying a precise, known voltage to a resistive circuit, then measuring the returning voltage, resistance can be calculated.

Five bridge measurement instructions are included in the CR1000. FIGURE 4.3-1 shows the circuits that are typically measured with these instructions. In the diagrams, resistors labeled R_s are normally the sensors and those labeled R_f are normally precision fixed (static) resistors. Circuits other than those diagrammed can be measured, provided the excitation and type of

measurements are appropriate. Program Code EXAMPLE 4.3-1 shows CR1000 code for measuring and processing four wire full bridge circuits.

All bridge measurements have the option (**RevEx**) to make one set of measurements with the excitation as programmed and another set of measurements with the excitation polarity reversed. The offset error in the two measurements due to thermal EMFs can then be accounted for in the processing of the measurement instruction. The excitation channel maintains the excitation voltage or current until the hold for the analog to digital conversion is completed. When more than one measurement per sensor is necessary (four wire half bridge, three wire half bridge, six wire full bridge), excitation is applied separately for each measurement. For example, in the four-wire half-bridge, when the excitation is reversed, the differential measurement of the voltage drop across the sensor is made with the excitation at both polarities and then excitation is again applied and reversed for the measurement of the voltage drop across the fixed resistor.

Calculating the resistance of a sensor that is one of the legs of a resistive bridge requires additional processing following the bridge measurement instruction. FIGURE 4.3-1 lists the schematics of typical bridge configurations and the calculations necessary to compute the resistance of any single resistor, provided the values of the other resistors in the bridge circuit are known.

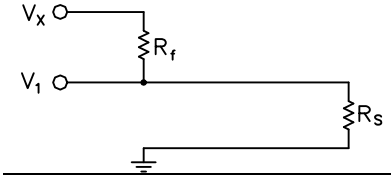
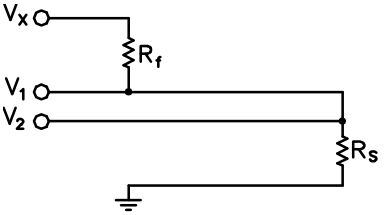
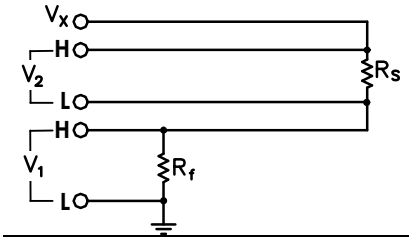
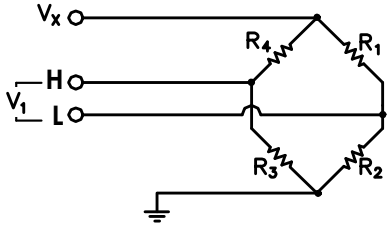
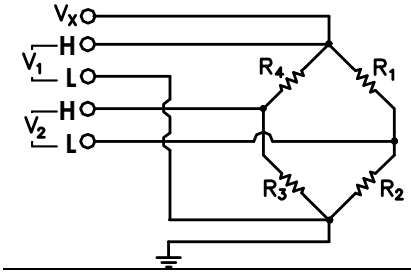
Sensor Schematic	Base Equation	Formulae
BrHalf 	X = result w/mult = 1, offset = 0 $X = \frac{V_1}{V_x} = \frac{R_s}{R_s + R_f}$	$R_s = R_f \frac{X}{1-X}$ $R_f = \frac{R_s(1-X)}{X}$
BrHalf3W  $X = \frac{2V_2 - V_1}{V_X - V_1} = \frac{R_S}{R_f}$	X = result w/mult = 1, offset = 0 $X = \frac{2V_2 - V_1}{V_X - V_1} = \frac{R_s}{R_f}$	$R_s = R_f X$ $R_f = R_s / X$
BrHalf4W 	X = result w/mult = 1, offset = 0 $X = \frac{V_2}{V_1} = \frac{R_s}{R_f}$	$R_s = R_f X$ $R_f = R_s / X$
BrFull 	X = result w/mult = 1, offset = 0 $X = 1000\frac{V_1}{V_X} = 1000\left(\frac{R_3}{R_3+R_4} - \frac{R_2}{R_1+R_2}\right)$	The following equations apply to BrFull and BrFull6W $R_1 = \frac{R_2(1-X_1)}{X_1}$ $R_2 = \frac{R_1 X_1}{1-X_1}$ where $X_1 = \frac{-X}{1000} + \frac{R_3}{R_3+R_4}$
BrFull6W 	X = result w/mult = 1, offset = 0 $X = 1000\frac{V_2}{V_1} = 1000\left(\frac{R_3}{R_3+R_4} - \frac{R_2}{R_1+R_2}\right)$	$R_3 = \frac{R_4 X_2}{1-X_2}$ $R_4 = \frac{R_3(1-X_2)}{X_2}$ where $X_2 = \frac{X}{1000} + \frac{R_2}{R_1+R_2}$

FIGURE 4.3-1. Circuits Used with Bridge Measurement Instructions

EXAMPLE 4.3-1. CRBASIC Code: 4 Wire Full Bridge Measurement and Processing

```
'Declare Variables
Public X
Public X1
Public R1
Public R2
Public R3
Public R4

'Main Program
BeginProg
    R2 = 1000    'Resistance of R2
    R3 = 1000    'Resistance of R3
    R4 = 1000    'Resistance of R4

    Scan(500,mSec,1,0)

        'Full Bridge measurement:
        BrFull (X,1,mV2500,1,1,1,2500,True,True,0,_60Hz,1.0,0.0)
        X1 = ((-1 * X) / 1000) + (R3 / (R3 + R4))
        R1 = (R2 * (1 - X1)) / X1

    NextScan

EndProg
```

4.3.1 Strain Calculations

Read more! FieldCalStrain in Section 11.1.6 FieldCalStrain () Demonstration Program.

A principal use of the four wire full bridge is the measurement of strain gages in structural stress analysis. StrainCalc () calculates microstrain, με, from an appropriate formula for the particular strain bridge configuration used. All strain gages supported by StrainCalc () use the full bridge electronic configuration. In strain gage parlance, “quarter bridge”, “half bridge” and “full bridge” refer to the number of active elements in the full bridge, i.e., 1, 2, or 4 active elements respectively.

StrainCalc () requires a bridge configuration code. TABLE 4.3-1 shows the equation invoked by each configuration code. Each code can be preceded by a negative sign (-). Use a positive code when the bridge is configured so the output decreases with increasing strain. Use a negative code when the bridge is configured so the output increases with increasing strain. In the equations below, a negative code sets the polarity of V_r to negative (-).

TABLE 4.3-1. Strain Equations	
Code	**Configuration**
1	Quarter bridge strain gage $\mu\varepsilon = \frac{-4 \cdot 10^6 V_r}{GF(1+2V_r)}$
2	Half bridge strain gage, one gage parallel to strain, the other at 90° to strain: $\mu\varepsilon = \frac{-4 \cdot 10^6 V_r}{GF[(1+\nu)-2V_r(\nu-1)]}$
3	Half bridge strain gage, one gage parallel to $+\varepsilon$, the other parallel to $-\varepsilon$: $\mu\varepsilon = \frac{-2 \cdot 10^6 V_r}{GF}$
4	Full bridge strain gage, 2 gages parallel to $+\varepsilon$, the other 2 parallel to $-\varepsilon$: $\mu\varepsilon = \frac{-10^6 V_r}{GF}$
5	Full bridge strain gage, half the bridge has 2 gages parallel to $+\varepsilon$ and $-\varepsilon$: the other half $+\nu\varepsilon$ and $-\nu\varepsilon$: $\mu\varepsilon = \frac{-2 \cdot 10^6 V_r}{GF(\nu+1)}$
6	Full bridge strain gage, one half $+\varepsilon$ and $-\nu\varepsilon$, the other half $-\nu\varepsilon$ and $+\varepsilon$.: $\mu\varepsilon = \frac{-2 \cdot 10^6 V_r}{GF[(\nu+1)-V_r(\nu-1)]}$

where:

ν = Poisson Ratio (0 if not applicable)
GF = Gage Factor
$V_r = 0.001(Source - Zero)$ if BRConfig code is positive (+)
$V_r = -0.001(Source - Zero)$ if BRConfig code is negative (-)

where:

"source" = the result of the full Wheatstone bridge measurement ($X = 1000 * V_1 / V_x$) when multiplier = 1 and offset = 0.

"zero" = gage offset to establish an arbitrary zero (see FieldCalStrain).

StrainCalc Example – See FieldCalStrain () Example for Quarter bridge.

4.4 Thermocouple Measurements

NOTE Thermocouples are easy to use with the CR1000. They are also inexpensive. However, they pose several challenges to the acquisition of accurate temperature data, particularly when using external reference junctions. Campbell Scientific **strongly encourages** any user of thermocouples to carefully evaluate Section 4.4.1 Error Analysis of Thermocouple Measurements. An introduction to thermocouple measurements is located in Section 2.2.

The micro-volt resolution and low-noise voltage measurement capability of the CR1000 is well suited for measuring thermocouples. A thermocouple consists of two dissimilar metal wires joined together at one end to form a junction. Practical thermocouples are constructed from two parallel insulated wires of dissimilar metals soldered or welded together at the junction. A temperature difference between the junction and the unconnected wires opposite the junction induces a temperature dependent voltage between the wires, referred to as the Seebeck effect. Measurement of the voltage between the unconnected wires opposite the junction provides a direct measure of the temperature difference between the junction and the measurement end. Metallic connections (e.g., solder) between the two dissimilar metal wires and the measurement device form parasitic thermocouple junctions, the effects of which cancel if the two wires are at the same temperature. Consequently, the two wires at the measurement end of the thermocouple, referred to as the reference junction, are placed in close proximity and thermally connected so that they are at the same temperature. Knowledge of the reference junction temperature provides the determination of a reference junction compensation voltage, corresponding to the temperature difference between the reference junction and 0°C. This compensation voltage, combined with the measured thermocouple voltage, can be used to compute the absolute temperature of the thermocouple junction. To facilitate thermocouple measurements, a thermistor is integrated into the CR1000 wiring panel for measurement of the reference junction temperature by means of the PanelTemp () instruction.

TCDiff () and TCSe () thermocouple instructions determine thermocouple temperatures using the following sequence. First, the temperature (°C) of the reference junction is determined. A reference junction compensation voltage is next computed based on the temperature difference between the reference junction and 0 °C. If the reference junction is the CR1000 analog input terminals, the temperature is conveniently measured with the PanelTemp () instruction. The actual thermocouple voltage is measured and combined with the reference junction compensation voltage. It is then used to determine the thermocouple junction temperature based on a polynomial approximation of NIST thermocouple calibrations.

4.4.1 Error Analysis

The error in the measurement of a thermocouple temperature is the sum of the errors in the reference junction temperature measurement plus the temperature-to-voltage polynomial fit error, the non-ideality of the thermocouple (deviation from standards published in NIST Monograph 175), the thermocouple voltage measurement accuracy, and the voltage-to-temperature polynomial fit error (difference between NIST standard and CR1000 polynomial approximations).

The discussion of errors that follows is limited to these errors in calibration and measurement and does not include errors in installation or matching the sensor and thermocouple type to the environment being measured.

4.4.1.1 Panel Temperature

The panel temperature thermistor (Betatherm 10K3A1A) is just under the panel in the center of the two rows of analog input terminals. It has an interchangeability specification of 0.1°C for temperatures between 0 and 70°C. Below freezing and at higher temperatures, this specification is degraded. Combined with possible errors in the completion resistor measurement and the Steinhart and Hart equation used to calculate the temperature from resistance, the accuracy of panel temperature is estimated at ± 0.1°C over -0 to 40°C, ± 0.3°C from -25 to 50°C, and ± 0.8°C from -55 to 85°C.

The error in the reference temperature measurement is a combination of the error in the thermistor temperature and the difference in temperature between the panel thermistor and the terminals the thermocouple is connected to. The terminal strip cover should always be used when making thermocouple measurements. It insulates the terminals from drafts and rapid fluctuations in temperature as well as conducting heat to reduce temperature gradients. In a typical installation where the CR1000 is in a weather proof enclosure not subject to violent swings in temperature or uneven solar radiation loading, the temperature difference between the terminals and the thermistor is likely to be less than 0.2°C.

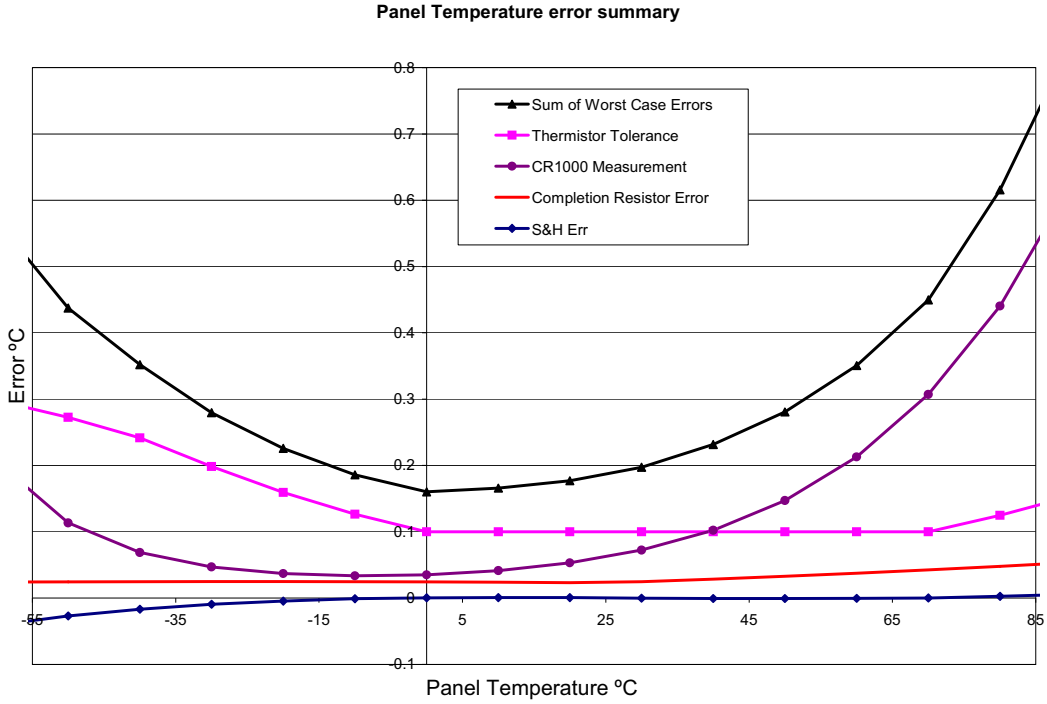


FIGURE 4.4-1. Panel Temperature Errors

With an external driving gradient, the temperature gradients on the input panel can be much worse. For example, the CR1000 was placed in a controlled temperature chamber. Thermocouples in channels at the ends and middle of each analog terminal strip measured the temperature of an insulated aluminum bar outside the chamber. The temperature of this bar was also measured by another datalogger. Differences between the temperature measured by one of the thermocouples and the actual temperature of the bar are due to the temperature difference between the terminals the thermocouple is connected to and the thermistor reference (the figures have been corrected for thermistor errors). FIGURE 4.4-2 shows the errors when the chamber was changed from -55 to 85°C in approximately 15 minutes. FIGURE 4.4-3 shows the results when going from 85 to 25°C. During these rapid changes in temperature, the temperature of panel thermistor will tend to lag behind the terminals because it is mounted deeper in the CR1000.

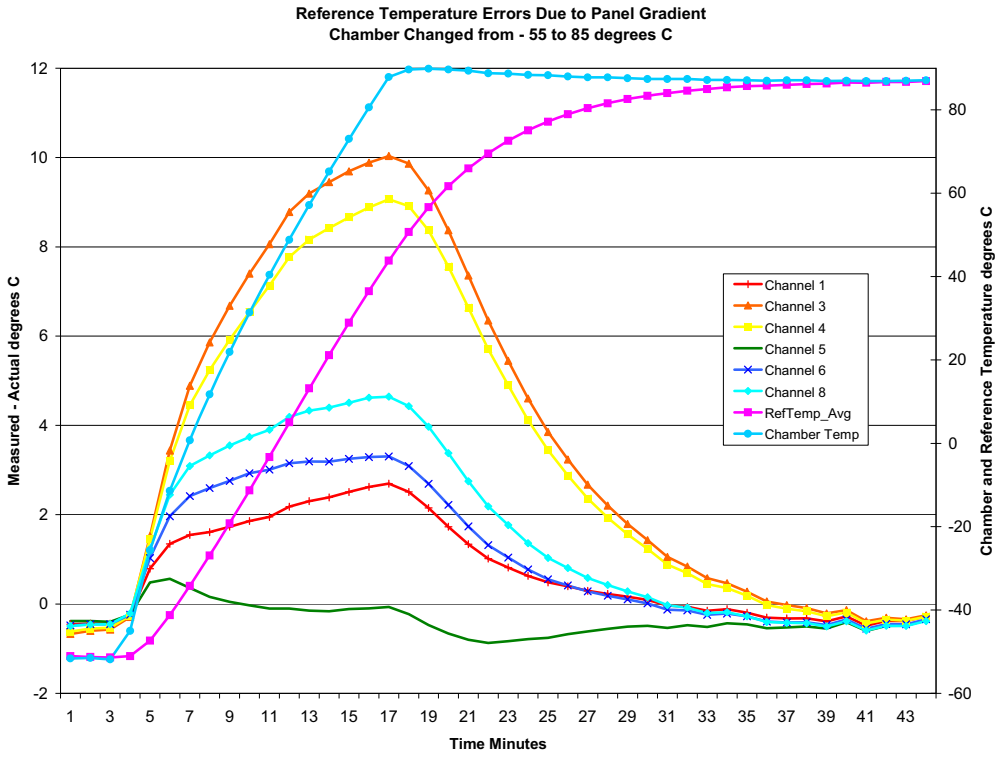


FIGURE 4.4-2. Panel Temperature Gradients during -55 to 80°C Change

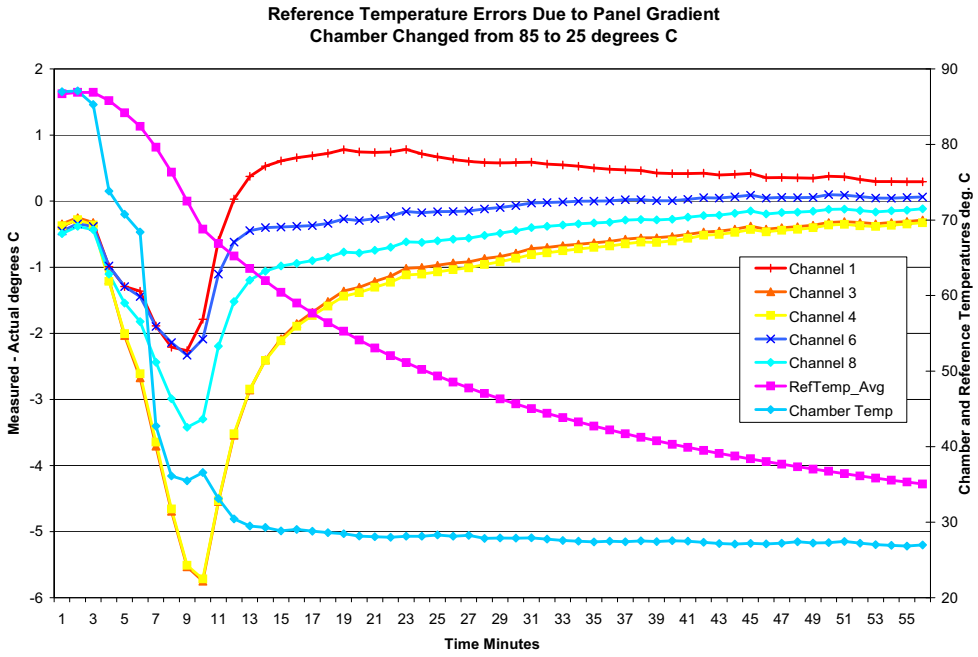


FIGURE 4.4-3. Panel Temperature Gradients during 80 to 25°C Change

4.4.1.2 Thermocouple Limits of Error

The standard reference that lists thermocouple output voltage as a function of temperature (reference junction at 0°C) is the NIST (National Institute of Standards and Technology) Monograph 175 (1993). ANSI (American National Standards Institute) has established limits of error on thermocouple wire which is accepted as an industry standard (ANSI MC 96.1, 1975). TABLE 4.4-1 gives the ANSI limits of error for standard and special grade thermocouple wire of the types accommodated by the CR1000.

TABLE 4.4-1. Limits of Error for Thermocouple Wire (Reference Junction at 0°C)

Thermocouple Type	Temperature Range°C	Limits of Error (Whichever is greater) Standard	Special
T	-200 to 0	± 1.0°C or 1.5%	
	0 to 350	± 1.0°C or 0.75%	± 0.5°C or 0.4%
J	0 to 750	± 2.2°C or 0.75%	± 1.1°C or 0.4%
E	-200 to 0	± 1.7°C or 1.0%	
	0 to 900	± 1.7°C or 0.5%	± 1.0°C or 0.4%
K	-200 to 0	± 2.2°C or 2.0%	
	0 to 1250	± 2.2°C or 0.75%	± 1.1°C or 0.4%
R or S	0 to 1450	± 1.5°C or 0.25%	± 0.6°C or 0.1%
B	800 to 1700	± 0.5%	Not Estab.

When both junctions of a thermocouple are at the same temperature there is no voltage produced (law of intermediate metals). A consequence of this is that a thermocouple cannot have an offset error; any deviation from a standard (assuming the wires are each homogeneous and no secondary junctions exist) is due to a deviation in slope. In light of this, the fixed temperature limits of error (e.g., ±1.0°C for type T as opposed to the slope error of 0.75% of the temperature) in the table above are probably greater than one would experience when considering temperatures in the environmental range (i.e., the reference junction, at 0°C, is relatively close to the temperature being measured, so the absolute error — the product of the temperature difference and the slope error — should be closer to the percentage error than the fixed error). Likewise, because thermocouple calibration error is a slope error, accuracy can be increased when the reference junction temperature is close to the measurement temperature. For the same reason differential temperature measurements, over a small temperature gradient, can be extremely accurate.

To quantitatively evaluate thermocouple error when the reference junction is not fixed at 0°C limits of error for the Seebeck coefficient (slope of thermocouple voltage vs. temperature curve) are needed for the various thermocouples. Lacking this information, a reasonable approach is to apply the percentage errors, with perhaps 0.25% added on, to the difference in temperature being measured by the thermocouple.

4.4.1.3 Accuracy of Thermocouple Voltage Measurement

The -25 to 50°C accuracy of a CR1000 differential voltage measurement, without input reversal, is specified as ± (0.12% of the measured voltage plus an offset error of 3 times the basic resolution of the range being used to make the measurement plus 2 µV). The offset error reduces to 1.5 times the basic resolution plus 1 µV if the differential measurement is made utilizing the option to reverse the differential input (RevDiff = True).

For optimum resolution, the ±2.5 mV range is used for all but high temperature measurements (TABLE 4.4-2). Using the 0.67 µV basic resolution of the ±2.5 mV range in the offset equations above, the offset portion of the accuracy specification is 4 µV without input reversal or 2 µV with input reversal. This offset portion of the accuracy specification dominates the voltage measurement error for temperatures in the environmental range. At the full scale the other part of the accuracy term is 0.12% of 2.5 mV = 2 µV. For example, assume that a type T thermocouple is used to measure a temperature of 45°C and that the reference temperature is 25°C. The voltage output by the thermocouple is 830.7 µV. At 45 degrees a type T thermocouple outputs 42.4 µV per °C. The percent of reading error in the voltage measurement is 0.0012 * 830.7 µV = 1 µV or 0.023°C (1 / 42.4). The basic resolution on the ±2.5 mV range is 0.67 µV or 0.016°C. The 2 µV offset is an error of 0.047°C. Thus, the possible error due to the voltage measurement is 0.07°C when reversing differential inputs, or 0.118°C when not reversing differential inputs.

Error in the temperature due to inaccuracy in the measurement of the thermocouple voltage is worst at temperature extremes, particularly when the temperature and thermocouple type require using the 250 mV range. For example, assume type K (chromel-alumel) thermocouples are used to measure temperatures around 1300°C. The TC output is on the order of 52 mV, requiring the ±250 mV input range. At 1300°C, a K thermocouple outputs 34.9 µV per °C. The percent of reading error in the voltage measurement is 0.0012

* 52 mV = 62 µV or 1.78°C (62 / 34.9). The basic resolution on the 250 mV range is 66.7 µV or 1.91°C. Thus, the possible error due to the voltage measurement is 4.38°C when reversing differential inputs, or 7.28°C when not reversing differential inputs.

TABLE 4.4-2. Voltage Range for Maximum Thermocouple Resolution (with reference temperature at 20°C)

TC Type and temp. range °C	Temp. range for ±2.5 mV range	Temp. range for ±7.5 mV range	Temp. range for ±25 mV range	Temp. range for ±250 mV range
T -270 to 400	-45 to 75	-270 to 180	-270 to 400	not used
E -270 to 1000	-20 to 60	-120 to 130	-270 to 365	>365
K -270 to 1372	-40 to 80	-270 to 200	-270 to 620	>620
J -210 to 1200	-25 to 65	-145 to 155	-210 to 475	>475
B 0 to 1820	0 to 710	0 to 1265	0 to 1820	not used
R -50 to 1768	-50 to 320	-50 to 770	-50 to 1768	not used
S -50 to 1768	-50 to 330	-50 to 820	-50 to 1768	not used
N -270 to 1300	-80 to 105	-270 to 260	-270 to 725	>725

When the thermocouple measurement junction is in electrical contact with the object being measured (or has the possibility of making contact) a differential measurement should be made to avoid ground looping.

4.4.1.4 Noise on Voltage Measurement

The typical input noise on the ±2.5 mV range for a differential measurement with 16.67 ms integration and input reversal is 0.19 µV RMS. On a type T thermocouple (approximately 40 µV/°C), this is 0.005°C. Note that this is an RMS value; some individual readings will vary by greater than this.

4.4.1.5 Thermocouple Polynomial: Voltage to Temperature

NIST Monograph 175 gives high order polynomials for computing the output voltage of a given thermocouple type over a broad range of temperatures. In order to speed processing and accommodate the CR1000's math and storage capabilities, four separate 6th order polynomials are used to convert from volts to temperature over the range covered by each thermocouple type. TABLE 4.4-3 gives error limits for the thermocouple polynomials.

TABLE 4.4-3. Limits of Error on CR1000 Thermocouple Polynomials (Relative to NIST Standards)

TC Type	Range °C			Limits of Error °C
T	**-270**	**to**	**400**	
	-270	to	-200	+ 18 @ -270
	-200	to	-100	± 0.08
	-100	to	100	± 0.001
	100	to	400	± 0.015
J	**-150**	**to**	**760**	± 0.008
	-100	to	300	± 0.002
E	**-240**	**to**	**1000**	
	-240	to	-130	± 0.4
	-130	to	200	± 0.005
	200	to	1000	± 0.02
K	**-50**	**to**	**1372**	
	-50	to	950	± 0.01
	950	to	1372	± 0.04

4.4.1.6 Reference Junction Compensation: Temperature to Voltage

Thermocouple instructions TCDiff () and TCSe () include the parameter TRef to incorporate the reference junction temperature into the measurement. A reference junction compensation voltage is computed from TRef as part of the thermocouple instruction, based on the temperature difference between the reference junction and 0°C. The polynomials used to determine the reference junction compensation voltage do not cover the entire thermocouple range, as illustrated in TABLE 4.4-3 and TABLE 4.4-4. Substantial errors in the reference junction compensation voltage will result if the reference junction temperature is outside of the polynomial fit ranges given in TABLE 4.4-4.

The reference junction temperature measurement can come from a PanelTemp () instruction, or from any other temperature measurement of the reference junction. The standard and extended (-XT) operating ranges for the CR1000 are -25 to +50 °C and –55 to 85 °C, respectively. These ranges also apply to the reference junction temperature measurement using PanelTemp ().

Two sources of error arise when the reference temperature is out of the polynomial fit range. The most significant error is in the calculated compensation voltage; however a small error is also created by non-linearities in the Seebeck coefficient.

TABLE 4.4-4. Reference Temperature Compensation Range and Polynomial Error Relative to NIST Standards

TC Type	Range °C	Limits of Error °C
T	-100 to 100	± 0.001
J	-150 to 296	± 0.005
E	-150 to 206	± 0.005
K	-50 to 100	± 0.01

4.4.1.7 Error Summary

The magnitude of the errors described in Section 4.4.1 illustrate that the greatest sources of error in a thermocouple temperature measurement are likely due to the limits of error on the thermocouple wire and in the reference temperature. Errors in the thermocouple and reference temperature linearizations are extremely small, and error in the voltage measurement is negligible.

TABLE 4.4-5 illustrates the relative magnitude of these errors in the environmental range. It shows a worst case situation where all errors are maximum and additive. A temperature of 45°C is measured with a type T (copper-constantan) thermocouple, using the ±2.5 mV range. The reference thermistor measures 25.1 °C, The terminal the thermocouple is connected to is 0.05°C cooler than the reference thermistor (0.15°C error).

TABLE 4.4-5. Example of Errors in Thermocouple Temperature

Source	Error: °C : % of Total Error			
	Single Differential 250 µs Integration		Reversing Differential 50/60 Hz Rejection Integration	
	ANSI TC Error (1°C)	TC Error 1% Slope	ANSI TC Error (1°C)	TC Error 1% Slope
Reference Temp.	0.15°:11.5%	0.15°:29.9%	0.15°:12.2%	0.15°:34.7%
TC Output	1.0°:76.8%	0.2°:39.8%	1.0°:81.1%	0.2°:46.3%
Voltage Measurement	0.12°:9.2%	0.12°:23.9%	0.07°:5.7%	0.07°:16.2%
Noise	0.03°:2.3%	0.03°:6.2%	0.01°:0.8%	0.01°:2.3%
Reference Linearization	0.001°:0.1%	0.001°:0.2%	0.001°:0.1%	0.001°:0.25%
Output Linearization	0.001°:0.1%	0.001°:0.2%	0.001°:0.1%	0.001°:0.25%
Total Error	1.302°:100%	0.502°:100%	1.232°:100%	0.432°:100%

4.4.1.8 Use of External Reference Junction

An external junction in an insulated box is often used to facilitate thermocouple connections. It can reduce the expense of thermocouple wire when measurements are made long distances from the CR1000. Making the external junction the reference junction, which is preferable in most applications, is accomplished by running copper wire from the junction to the CR1000. Alternatively, the junction box can be used to couple extension grade thermocouple wire to the thermocouples, with the PanelTemp () instruction used to determine the reference junction temperature.

Extension grade thermocouple wire has a smaller temperature range than standard thermocouple wire, but meets the same limits of error within that range. One situation in which thermocouple extension wire is advantageous is when the junction box temperature is outside the range of reference junction compensation provided by the CR1000. This is only a factor when using type K thermocouples, since the upper limit of the reference compensation

polynomial fit range is 100°C and the upper limit of the extension grade wire is 200°C. With the other types of thermocouples the reference compensation polynomial fit range equals or is greater than the extension wire range. In any case, errors can arise if temperature gradients exist within the junction box.

FIGURE 4.4-4 illustrates a typical junction box wherein the reference junction is the CR1000. Terminal strips will be a different metal than the thermocouple wire. Thus, if a temperature gradient exists between A and A' or B and B', the junction box will act as another thermocouple in series, creating an error in the voltage measured by the CR1000. This thermoelectric offset voltage is also a factor when the junction box is used as the reference junction. This offset can be minimized by making the thermal conduction between the two points large and the distance small. The best solution in the case where extension grade wire is being connected to thermocouple wire is to use connectors which clamp the two wires in contact with each other.

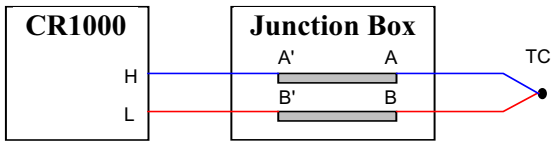


FIGURE 4.4-4. Diagram of Junction Box

When an external junction box is also the reference junction, the points A, A', B, and B' in FIGURE 4.4-4 all need to be very close in temperature (isothermal) to measure a valid reference temperature, and to avoid thermoelectric offset voltages. The box should contain elements of high thermal conductivity, which will act to rapidly equilibrate any thermal gradients to which the box is subjected. It is not necessary to design a constant temperature box; it is desirable that the box respond slowly to external temperature fluctuations. Radiation shielding must be provided when a junction box is installed in the field. Care must also be taken that a thermal gradient is not induced by conduction through the incoming wires. The CR1000 can be used to measure the temperature gradients within the junction box.

4.5 Pulse Count Measurement

FIGURE 4.5-1 shows a typical pulse sensor to CR1000 schematic. The CR1000 features two dedicated pulse input channels, P1 and P2. It also features eight digital I/O channels, C1 through C8, for measuring various pulse output sensors. Activated by the PulseCount () instruction, dedicated 24-bit counters on P1, P2 and C1 through C8 are used to accumulate all counts over the user specified scan interval. PulseCount () instruction parameters specify the pulse input type, channel used, and pulse output option.

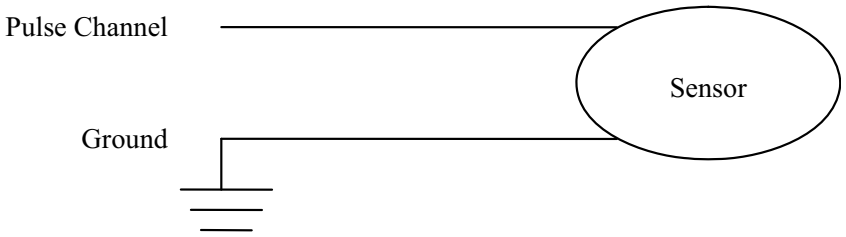


FIGURE 4.5-1. Schematic of a Pulse Sensor on a CR1000

NOTE The PulseCount () instruction cannot be used in a Slow Sequence scan.

Execution of PulseCount () within a scan involves determining the accumulated counts in each dedicated 24-bit counter since execution of the last PulseCount (). PulseCount () parameter (POption**)** determines if the output will be in counts (POption = 0) or frequency (POption = 1). Counts are the preferred output option for measuring number of tips from a tipping bucket rain gage, or the number of times a door opens. Many pulse sensors, such as anemometers and flow meters, are calibrated in terms of frequency (Hz or counts / second), and are best measured with the frequency option.

Resolution of the pulse counters is one count. Resolution of frequency is (1 / measurement interval). For example, the frequency resolution of PulseCount () returning a result every 1 second is 1 Hz. Accuracy is limited by a small scan interval error of ±(3 ppm of scan interval + 10 μs) plus the measurement resolution error of ± 1 Hz. The sum is essentially ± 1 Hz. Extending a 1 second measurement interval to 10 seconds, either by increasing the scan interval or by averaging, improves the resulting frequency resolution from 1 Hz to 0.1 Hz. Averaging can be accomplished by the Average (), AvgRun (), and AvgSpa () instructions. Alternatively, entering a number greater than 1 in (POption) parameter is to enter an averaging interval in milliseconds for a direct running average computation.

4.5.1 Pulse Input Channels P1 and P2

Read more! Review pulse counter specifications in Section 3.3. Review pulse counter programming in CRBASIC Help for the PulseCount () instruction.

FIGURE 4.5-2 illustrates pulse input types measured by the CR1000. Dedicated pulse input channels P1 and P2 can be configured to read high-frequency pulses, low-level AC signals, or switch closure.

NOTE Input channel expansion devices for all input types are available from Campbell Scientific.

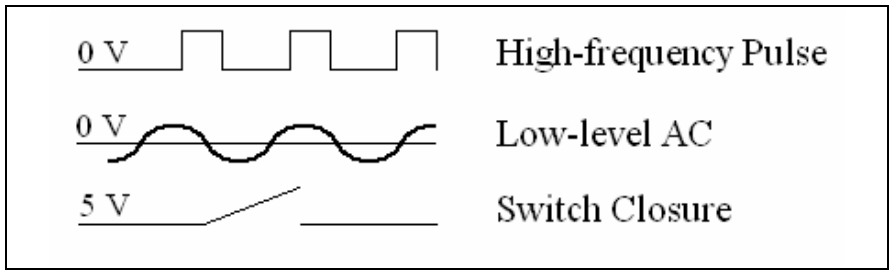


FIGURE 4.5-2. Pulse Input Types

CAUTION Maximum input voltage on pulse channels P1 and P2 is ±20 V. If pulse inputs of higher than ±20 V need to be measured, third party external signal conditioners should be employed. Contact a Campbell Scientific applications engineer if assistance is needed. Under no circumstances should voltages greater than ±50 V be measured.

4.5.1.1 High-frequency Pulse

Internal hardware routes high-frequency pulse to an inverting CMOS input buffer with input hysteresis. The CMOS input buffer is guaranteed to be an output zero level with its input ≥ 2.2 V, and guaranteed to be an output one with its input ≤ 0.9 V. An RC input filter with approximately a 1 µs time constant precedes the inverting CMOS input buffer, resulting in an amplitude reduction of high frequency signals between the P1 and P2 terminal blocks and the inverting CMOS input buffer as illustrated in FIGURE 4.5-3. For a 0 to 5 Volt square wave applied to P1 and P2, the maximum frequency that can be counted in high-frequency mode is approximately 250 kHz.

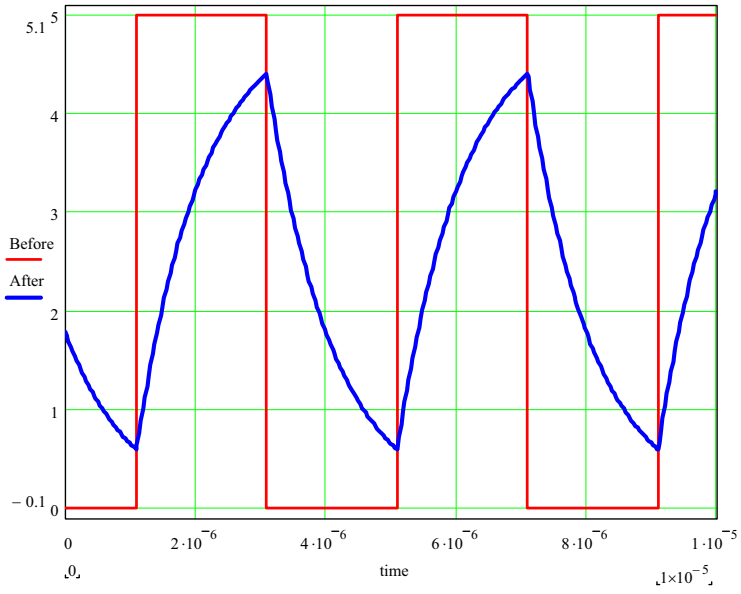


FIGURE 4.5-3. Amplitude reduction of pulse-count waveform before and after 1 µs time constant filter.

When a pulse channel is configured for high-frequency pulse, an internal 100 kΩ pull-up resistor to +5 Volt on the P1 or P2 input is employed. This pull-up resistor accommodates open-collector (open-drain) output devices for high-frequency input.

4.5.1.2 Low-Level AC

Rotating magnetic pickup sensors commonly generate AC output voltages ranging from millivolts at low rotational speeds to several volts at high rotational speeds. Channels P1 and P2 contain internal signal conditioning hardware for measuring low-level AC output sensors. When configured for low-level AC, P1 and P2 measure signals ranging from 20 mV RMS (±28 mV peak) to 14 V RMS (±20 V peak). Internal AC coupling is incorporated in the low-level AC hardware to eliminate DC offset voltages of up to ±0.5 V.

4.5.1.3 Switch Closure

Switch-closure mode of channels P1 and P2 measures switch closure events, such as occur with a common tipping bucket rain gage. An internal 100 kΩ pull-up resistor pulls the P1 or P2 input to +5 Volt with the switch open, whereas a switch closure to ground pulls the P1 or P2 input voltage to 0 V. An internal 3.3 ms time constant RC debounce filter is used to eliminate multiple counts from a single switch closure event.

4.5.2 Digital I/O Ports for Pulse Counting

Read more! Review digital I/O port specifications in Section 3.3. Review pulse counter programming in CRBASIC Help for the PulseCount () instruction.

Digital I/O Ports C1 – C8, when fitted with external pull-up resistors, can measure high-frequency or switch closure signals. Low-level AC signals cannot be measured directly.

NOTE A CSI peripheral (LLAC4) converts low-level AC signals to high-frequency signals.

Ports C1 – C8 have a small 25 ns input RC filter time constant between the terminal block and the CMOS input buffer, which allows for higher frequency operation (400 kHz maximum) compared with channels P1 and P2 (250 kHz maximum).

When configured for input, ports C1 – C8 each go into a digital CMOS input buffer that recognizes inputs ≥ 3.8 V as high and inputs ≤ 1.2 V as a low. Voltage levels < -8.0 V and > 16 V should not be connected.

An external pull-up resistor is required to counteract an internal 100 kΩ pull-down resistor to ground. Figure 4.5-4 illustrates the external pull-up resistors requirement when using ports C1 – C8 for switch closure. The external pull-up must pull the input to > 3.8 V with the switch open for reliable switch closure measurements.

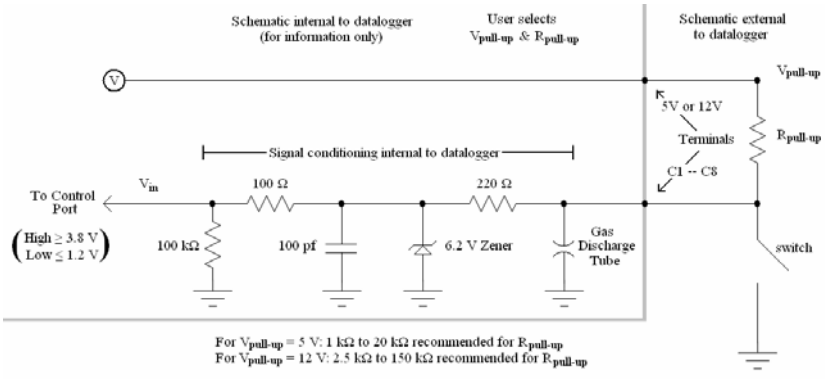


Figure 4.5-4 Schematic illustrating use of pull-up resistors when measuring pulse inputs on ports C1 – C8.

A pull-up resistor of 1 – 20 kΩ is recommended when connecting to a +5 V supply, and a pull-up resistor of 2.5 – 150 kΩ is recommended when connecting to a +12 V supply to provide adequate logic levels. Software switch debouncing of switch closure is incorporated in the switch-closure mode for digital I/O parts ports C1 – C8.

CAUTION Minimum and maximum input voltages on digital I/O channels C1 – C8 is –8.0 V and +16 V, respectively. If pulse inputs < -8.0 V or > +16 V are to be measured by C1 – C8, then external signal conditioning should be employed. Contact a Campbell Scientific applications engineer if assistance is needed. Under no circumstances should voltages greater than ±50 V be measured.

4.6 Period Averaging Measurements

The CR1000 can measure the period of a signal on any single-ended analog input channel (SE 1 -16). The specified number of cycles are timed with a resolution of 92 ns, making the resolution of the period measurement 92 ns divided by the number of cycles chosen.

Low-level signals are amplified prior to a voltage comparator. The internal voltage comparator is referenced to the user-entered threshold. The threshold parameter allows a user to reference the internal voltage comparator to voltages other than 0 V. For example, a threshold of 2500 mV allows a 0 to 5 V digital signal to be sensed by the internal comparator without the need of any additional input conditioning circuitry. The threshold allows direct connection of standard digital signals, but is not recommended for small amplitude sensor signals. For sensor amplitudes less than 20 mV peak-to-peak, a DC blocking capacitor is recommended to center the signal at CR1000 ground (threshold = 0) because of offset voltage drift along with limited accuracy (± 10 mV) and resolution (1.2 mV) of a threshold other than 0. FIGURE 4.6-1 shows an example circuit.

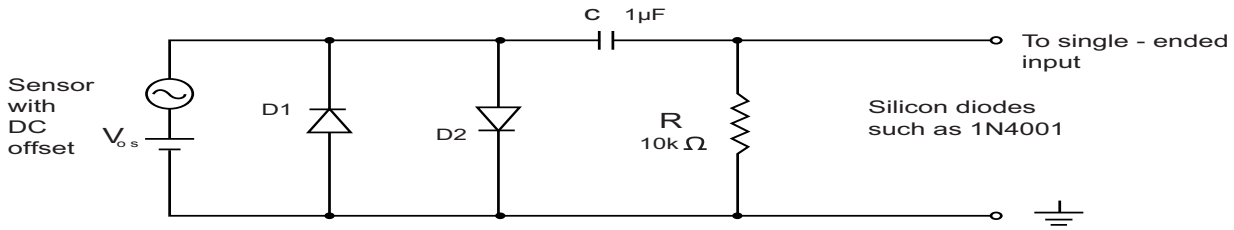


FIGURE 4.6-1. Input conditioning circuit for low-level and high level period averaging.

The minimum pulse width requirements increase (maximum frequency decreases) with increasing gain. Signals larger than the specified maximum for a range will saturate the gain stages and prevent operation up to the maximum specified frequency. As shown in FIGURE 4.6-1, back-to-back diodes are recommended to limit large amplitude signals to within the input signal ranges.

CAUTION Noisy signals with slow transitions through the voltage threshold have the potential for extra counts around the comparator switch point. A voltage comparator with 20 mV of hysteresis follows the voltage gain stages. The effective input referred hysteresis equals 20 mV divided by the selected voltage gain. The effective input referred hysteresis on the ± 25 mV range is 2 mV; consequently, 2 mV of noise on the input signal could cause extraneous counts. For best results, select the largest input range (smallest gain) that meets the minimum input signal requirements.

4.7 SDI-12 Recording

Read more! Section 11.3 SDI-12 Sensor Support and Section 10.11 Serial Input/Output.

SDI-12 is a communications protocol developed to transmit digital data from smart sensors to data acquisition units. It is a simple protocol, requiring only a single communication wire. Typically, the data acquisition unit also supplies power (12V and ground) to the SDI-12 sensor. The CR1000 is equipped with four SDI-12 input channels (C1, C3, C5, C7) and an SDI12Recorder () CRBASIC instruction.

4.8 RS-232 and TTL Recording

Read more! See Section Error! Reference source not found. **Serial Input.**

Many smart sensors output digital data through RS-232 or TTL protocols. The CR1000 is equipped to read the output of most RS-232 sensors on the 9-pin RS-232 port and the CS I/O port with a SC105 interface. For TTL logic, four communications ports can be configured from digital I/O ports, i.e., C1 & C2, C3 & C4, C5 & C6, C7 & C8. If additional RS-232 input is required, an RS-232 to TTL logical converter (available from Campbell Scientific) can be used with the digital I/O ports. RS-232 and TTL data must usually be read then parsed (split up).

4.9 Field Calibration of Linear Sensor

Read more! Section 11.1 FieldCal has complete FieldCal information.

Calibration increases accuracy of a measurement device by adjusting its output, or the measurement of its output, to match independently verified quantities. Adjusting a sensor output directly is preferred, but not always possible or practical. By adding FieldCal () or FieldCalStrain () instructions to the CR1000 program, a user can easily adjust the measured output of a linear sensors by modifying multipliers and offsets.

4.10 Cabling Effects on Measurements

Sensor cabling can have significant effects on sensor response and accuracy. This is usually only a concern with sensors acquired from manufacturers other than Campbell Scientific. Campbell Scientific sensors are engineered for optimal performance with factory installed cables.

4.10.1 Analog Sensors

Cable length in analog sensors is most likely to affect the signal settling time. For more information, see Section 4.2.7.

4.10.2 Digital Sensors

Because of the long interval between switch closures in tipping bucket rain gages, appreciable capacitance can build up between wires in long cables. A built up charge can cause arcing when the switch closes, shortening switch life. As shown in Figure 4.10-1, a current limiting100 ohm resistor, connected in series at the switch, prevents arcing. This resistor is installed on all rain gages currently sold by Campbell Scientific.

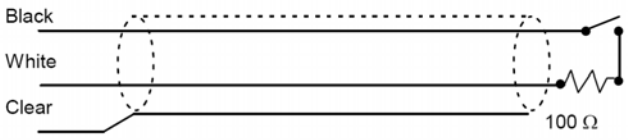


FIGURE 4.10-1. Current Limiting Resistor in a Tipping Bucket Rain Gage Circuit

4.10.3 Serial Sensors

4.10.3.1 RS-232 Sensors

RS-232 sensors cable lengths should be limited to 50 feet.

4.10.3.2 SDI-12 Sensors

The SDI-12 standard allows cable lengths of up to 200 feet. Campbell Scientific does not recommend SDI-12 sensor lead lengths greater than 200 feet; however, longer lead lengths can sometimes be accommodated by increasing the wire gage and/or powering the sensor with a second 12 vdc power supply placed near the sensor.

Section 5. Measurement and Control Peripherals

Peripheral devices are available for expanding the CR1000's on-board input / output capabilities. Classes of peripherals are discussed below according to use. Some peripherals are designed as SDM (Synchronous Devices for Measurement) devices. SDM devices are intelligent peripherals that receive instruction from and send data to the CR1000 over a proprietary 3-wire serial communications link utilizing channels C1, C2, and C3.

Read more! For complete information on available measurement and control peripherals, go to www.campbellsci.com, or contact a Campbell Scientific applications engineer.

5.1 Analog Input Expansion

Mechanical relay and solid state relay multiplexers are available to expand the number of analog sensor inputs. Multiplexers are designed for single-ended, differential, bridge resistance, or thermocouple inputs.

5.2 Pulse Input Expansion Modules

Pulse input expansion modules are available for switch closure, state, pulse count and frequency measurements, and interval timing.

5.3 Serial Input Expansion Modules

Capturing input from intelligent serial output devices can be challenging. Several Campbell Scientific serial I/O modules are designed to facilitate reading and parsing serial data. Campbell Scientific recommends consulting with an applications engineer when deciding which serial input module is suited to a particular application.

5.4 Control Output

Controlling power to an external device is a common function of the CR1000. Devices are available for binary (on / off) or analog (variable) control.

Many devices can conveniently be controlled with the SW-12 (Switched 12 Volt) terminal on the CR1000. Applications requiring more control channels or greater power sourcing capacity can usually be satisfied by using one of Campbell Scientific's multiple-channel control modules or by using control ports (C1 - C8) in conjunction with single-channel switching relays.

5.4.1 Binary Control

5.4.1.1 Digital I/O Ports

Each of eight digital I/O ports (C1 - C8) can be configured as an output port and set low (0 V) or high (5 V) using the PortSet () or WriteIO () instructions. A digital output port is normally used to operate an external relay driver circuit because the port itself has very limited drive capability (2.0 mA minimum at 3.5 V).

5.4.1.2 Switched 12 V Control

The SW-12 port can be set low (0 V) or high (12 V) using the PortSet () or SW12 () instructions. The port is often used to control low power devices such as sensors that require 12 V during measurement. Current sourcing must be limited to 900 mA or less at 20°C.

A 12V switching circuit, driven by a digital I/O port, is also available from Campbell Scientific.

NOTE The SW-12 supply is unregulated and can supply up to 900 mA at 20°C and up to 630 mA at 50°C. A resettable polymeric fuse protects against over-current. Reset is accomplished by removing the load or turning off the SW-12 for several seconds.

5.4.1.3 Relays and Relay Drivers

Several relay drivers are manufactured by Campbell Scientific. Contact a Campbell Scientific applications engineer for more information, or get more information at www.campbellsci.com.

Compatible, inexpensive and reliable single-channel relay drivers for a wide range of loads are available from various electronic vendors such as Crydom, Newark, Mouser, etc.

5.4.1.4 Component Built Relays

FIGURE 5.4-1 shows a typical relay driver circuit in conjunction with a coil driven relay which may be used to switch external power to some device. In this example, when the control port is set high, 12 V from the datalogger passes through the relay coil, closing the relay which completes the power circuit to a fan, turning the fan on.

In other applications it may be desirable to simply switch power to a device without going through a relay. FIGURE 5.4-2 illustrates a circuit for switching external power to a device without going through a relay. If the peripheral to be powered draws in excess of 75 mA at room temperature (limit of the 2N2907A medium power transistor), the use of a relay (FIGURE 5.4-1) would be required.

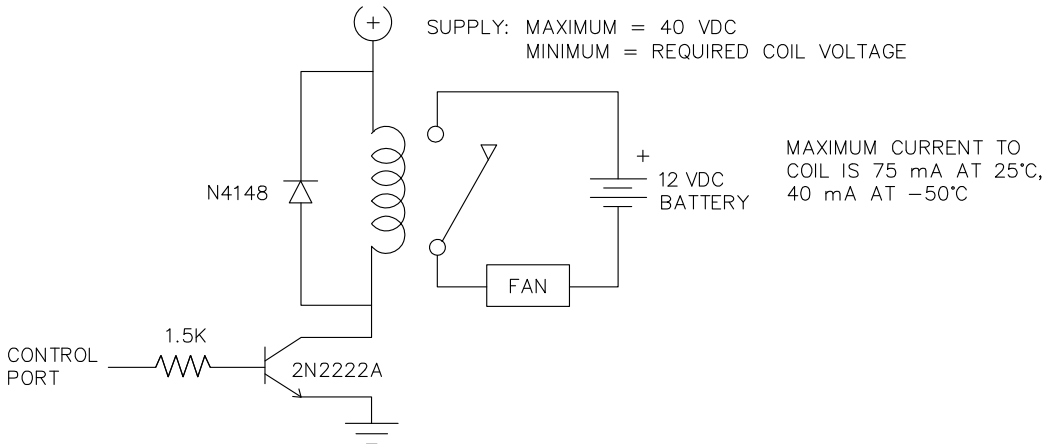


FIGURE 5.4-1. Relay Driver Circuit with Relay

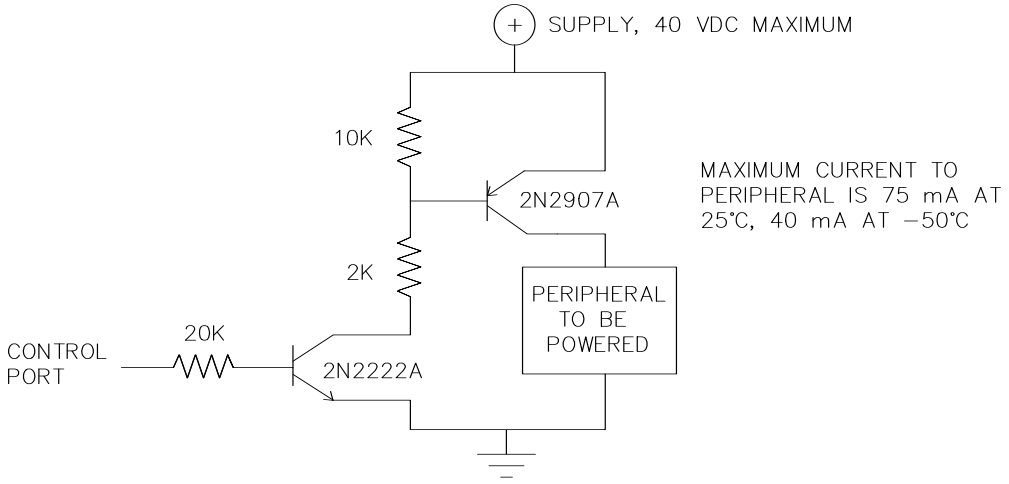


FIGURE 5.4-2. Power Switching without Relay

5.5 Analog Control / Output Devices

The CR1000 can scale measured or processed values and transfer these values in digital form to a CSI analog output device. The analog output device then performs a digital-to-analog conversion and outputs an analog voltage or current signal. The output signal is maintained until updated by the datalogger.

5.6 Other Peripherals

5.6.1 TIMs

Terminal Input Modules are devices that provide simple measurement support circuits in a convenient package. TIMs include voltage dividers for cutting the output voltage of sensors to voltage levels compatible with the CR1000, modules for completion of resistive bridges, and shunt modules for measurement of analog current sensors.

5.6.2 Vibrating Wire

Vibrating wire modules interface vibrating wire transducers to the CR1000.

5.6.3 Low-level AC

Low-level AC input modules increase the number of low-level AC signals a CR1000 can monitor by converting low-level AC to high-frequency pulse.

Section 6. CR1000 Power Supply

Reliable power is the foundation of a reliable data acquisition system. When designing a power supply, consideration should be made regarding worst-case power requirements and environmental extremes.

Excessive switching noise or AC ripple present on a DC power supply can increase measurement noise. Noise sources include power transformers, regulators, and grid or mains power inclusively. Using high quality power regulators reduces noise due to power regulation. Utilizing 50 or 60 Hz integration times for voltage measurements (see Section 4) improves rejection of power supply induced noise. The CRBasic standard deviation instruction, SDEV () can be used to evaluate measurement noise.

Contact Campbell Scientific if assistance in selecting a power supply is needed, particularly with applications in extreme environments.

6.1 Power Requirement

The CR1000 operates from a DC power supply with voltage ranging from 9.6 to 16 V. It is internally protected against accidental polarity reversal. A transient voltage suppressor (TVS) diode on the 12 V power input terminal provides transient protection by clamping voltages in the range of 19 to 21 V. Sustained input voltages in excess of 19 V can damage the TVS diode.

CAUTION The 12V and SW12 terminals on the wiring panel are not regulated by the CR1000; they obtain power directly from the POWER IN terminal. When using the CR1000 wiring panel to source power to other 12 V devices, be sure the power supply regulates the voltage within the range acceptable to the connected device.

6.2 Calculating Power Consumption

Read more! Section 3.3 Specifications -- System Power Requirements

System operating time for batteries can be determined by dividing the battery capacity (ampere-hours) by the average system current drain (amperes). The CR1000 typically draws 0.5 mA in the sleep state (with display off), 0.6 mA with a 1 Hz sample rate, and >10 mA with a 100 Hz sample rate.

6.3 Campbell Scientific Power Supplies

Campbell Scientific carries several power supplies including alkaline and solar options. Complete power supply information is available in manual or brochure form at www.campbellsci.com.

6.4 Battery Connection

When connecting external power to the CR1000, remove the green POWER IN connector from the CR1000 front panel. Insert the positive 12 V lead into the terminal marked "12V". Insert the ground lead in the terminal marked "G" (ground). The CR1000 is internally protected against, but will not function with, reversed external power polarity.

6.5 Vehicle Power Connections

If a CR1000 is powered by a motor vehicle supply, a second supply may be needed. When starting the motor of the vehicle, the battery voltage may drop below 9.6 V. This causes the CR1000 to stop measurements until the voltage again equals or exceeds 9.6 V. A second supply can be provided to prevent measurement lapses during vehicle starting. FIGURE 6.5-1 illustrate how a second power supply should be connected to the CR1000. The diode OR connection causes the supply with the largest voltage to power the CR1000 and prevents the second backup supply from attempting to power the vehicle.

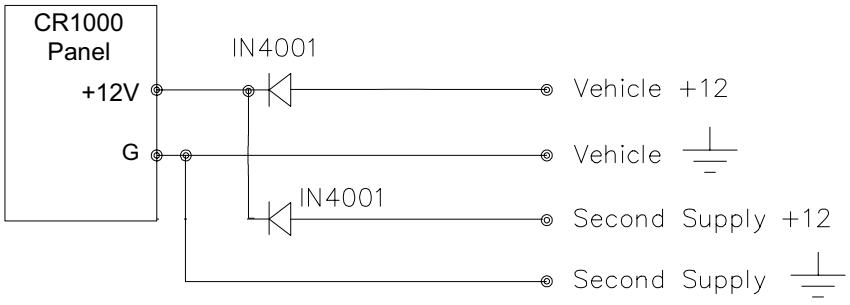


FIGURE 6.5-1. Connecting CR1000 to Vehicle Power Supply

Section 7. Grounding

Grounding the CR1000 and its peripheral devices and sensors is critical in all applications. Proper grounding will ensure the maximum ESD (electrostatic discharge) protection and higher measurement accuracy.

7.1 ESD Protection

ESD (electrostatic discharge) can originate from several sources, the most common, and most destructive, being primary and secondary lightning strikes. Primary lightning strikes hit the datalogger or sensors directly. Secondary strikes induce a voltage in power lines or sensor wires.

The primary devices for protection against ESD are gas-discharge tubes (GDT). All critical inputs and outputs on the CR1000 are protected with GDTs or transient voltage suppression diodes. GDTs fire at 150 V to allow current to be diverted to the earth ground lug. To be effective, the earth ground lug must be properly connected to earth (chassis) ground. As shown in FIGURE 7.1-1, the power ground and signal ground are independent lines until joined inside the CR1000.

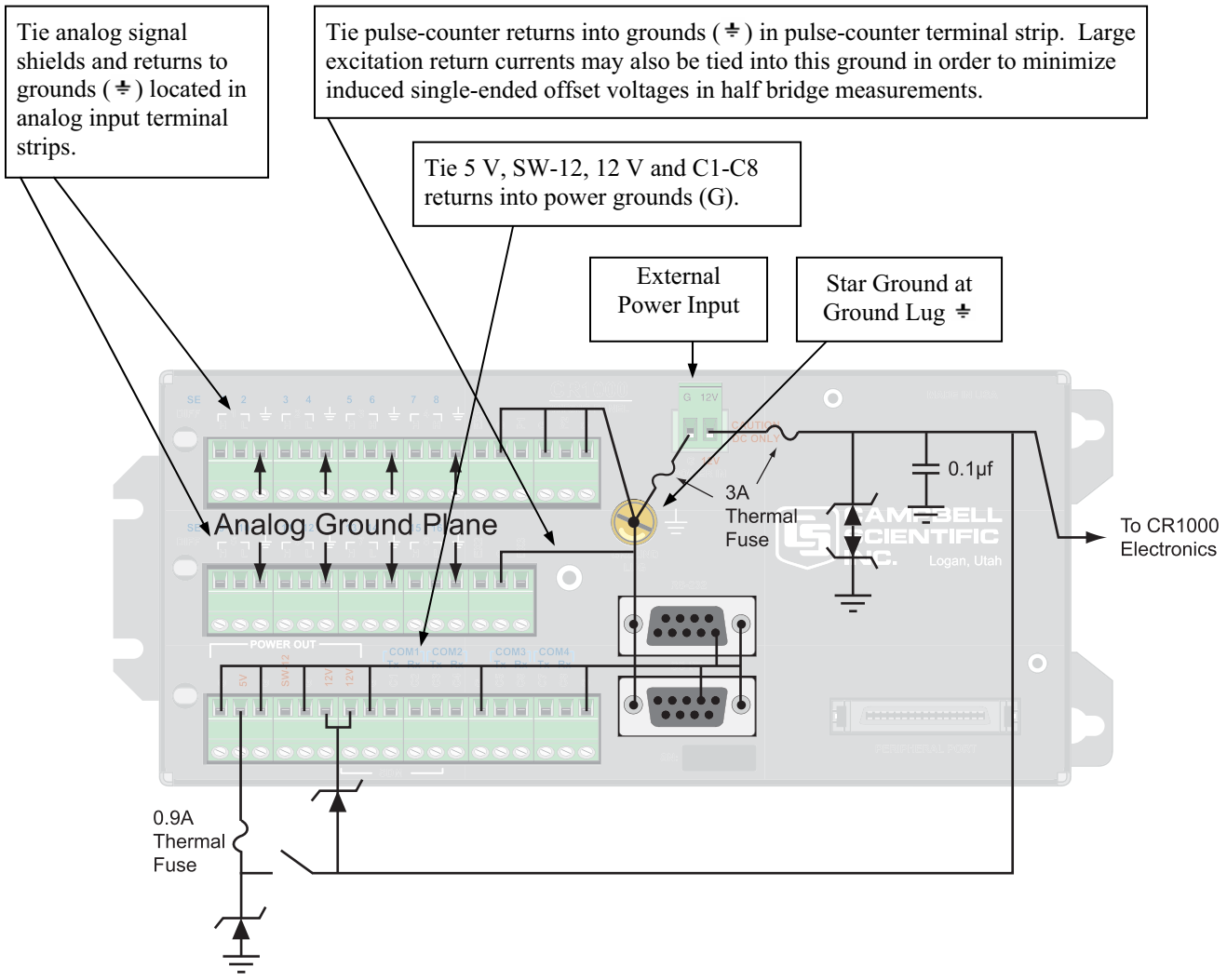


FIGURE 7.1-1. Schematic of CR1000 Grounds

The 9-pin serial I/O ports on the CR1000 are another path for transients. Communications paths such a telephone or short-haul modem lines should have spark gap protection. Spark gap protection is often an option with these products, so it should always be requested when ordering. Spark gaps for these devices must be connected to either the CR1000 earth ground lug, the enclosure ground, or to the earth (chassis) ground.

A good earth (chassis) ground will minimize damage to the datalogger and sensors by providing a low resistance path around the system to a point of low potential. Campbell Scientific recommends that all dataloggers be earth (chassis) grounded. All components of the system (dataloggers, sensors, external power supplies, mounts, housings, etc.) should be referenced to one common earth (chassis) ground.

In the field, at a minimum, a proper earth ground will consist of a 6 to 8 foot copper sheathed grounding rod driven into the earth and connected to the CR1000 Ground Lug with a 12 AWG wire. In low conductive substrates, such as sand, very dry soil, ice, or rock, a single ground rod will probably not

provide an adequate earth ground. For these situations, consult the literature on lightning protection or contact a qualified lightning protection consultant.

In vehicle applications, the earth ground lug should be firmly attached to the vehicle chassis with 12 AWG wire or larger.

In laboratory applications, locating a stable earth ground is challenging, but still necessary. In older buildings, new AC receptacles on older AC wiring may indicate that a safety ground exists when in fact the socket is not grounded. If a safety ground does exist, it is good practice to verify that it carries no current. If the integrity of the AC power ground is in doubt, also ground the system through the buildings, plumbing or another connection to earth ground.

7.1.1 Lightning Protection

The most common and destructive ESDs are primary and secondary lightning strikes. Primary lightning strikes hit instrumentation directly. Secondary strikes induce voltage in power lines or wires connected to instrumentation. While elaborate, expensive and nearly infallible lightning protection systems are available, Campbell Scientific has for many years employed a simple and inexpensive design that protects most systems in most circumstances. It is, however, not infallible.

NOTE Lightning strikes may damage or destroy the CR1000 and associated sensors and power supplies.

In addition to protections discussed in Section 7.1, use of a simple lightning rod and low-resistance path to earth ground is adequate protection in many installations. A lightning rod serves two purposes. Primarily, it serves as a preferred strike point. Secondarily, it dissipates charge, reducing the chance of a lightning strike. FIGURE 7.1-2 shows a simple lightning protection scheme utilizing a lightning rod, metal mast, heavy gage ground wire, and ground rod to direct damaging current away from the CR1000.

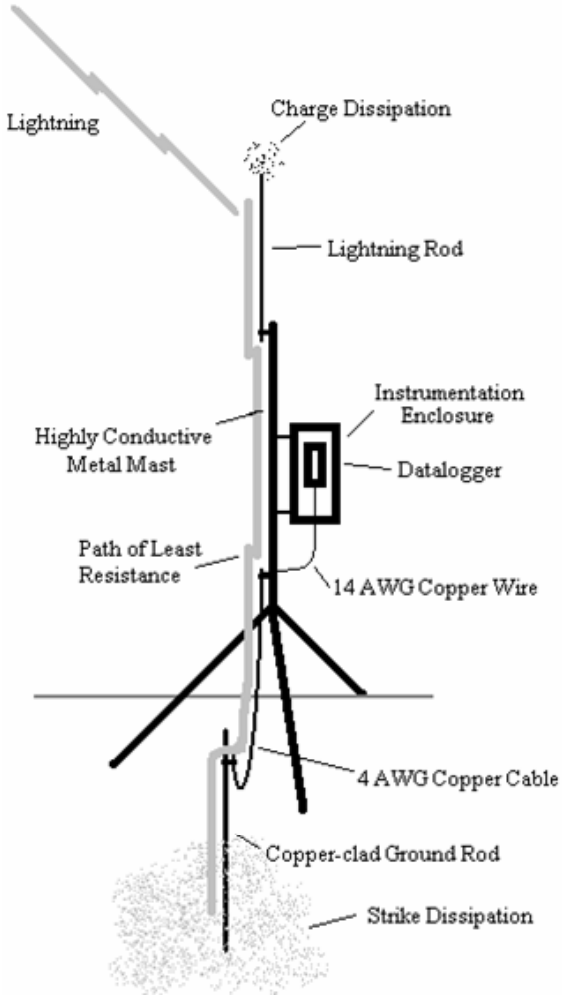


FIGURE 7.1-2. CR1000 Lightning Protection Scheme

7.2 Common Mode Range

To make a differential measurement, voltage inputs must be within the CR1000 common mode range of ±5 V. The common mode range is the voltage range, relative to CR1000 ground, within which both inputs of a differential measurement must lie, in order for the differential measurement to be made. For example, if the high side of a differential input is at 4 V and the low side is at 3 V relative to CR1000 ground, there is no problem. A measurement made on the ±5000 mV range will return 1000 mV. However, if the high input is at 5.8 V and the low input is at 4.8 V, the measurement can not be made because the high input is outside of the ±5 V common mode range. The CR1000 indicates the overrange by returning NAN (not-a-number). Sensors that have a floating output, or are not referenced to ground through a separate connection, may need the CR1000 to use a voltage range "C" option to pull the sensor into common mode range or to have the one side of the differential input (usually the low input) connected to ground to ensure the signal remains within the common mode range.

Common mode range can be exceeded when the CR1000 is measuring the output from a sensor which has its own grounded power supply and the low side of the signal is referenced to the sensor's power supply ground. If the CR1000 ground and the sensor ground are at sufficiently different potentials, the signal will exceed the common mode range. To solve this problem, the sensor power ground and the CR1000 ground should be connected, creating one ground for the system.

Problems with exceeding common mode range can be encountered when the CR1000 is used to read the output of external signal conditioning circuitry if a good ground connection does not exist between the external circuitry and the CR1000. When operating where AC power is available, it is not always safe to assume that a good ground connection exists through the AC wiring. If a CR1000 is used to measure the output from a laboratory instrument (both plugged into AC power and referencing ground to outlet ground), the best practice is to run a ground wire between the CR1000 and the external circuitry.

7.3 Single-Ended Measurement Reference

Low-level single-ended voltage measurements are sensitive to ground potential fluctuations. The grounding scheme in the CR1000 has been designed to eliminate ground potential fluctuations due to changing return currents from 12V, SW-12, 5V, and the control ports. This is accomplished by utilizing separate signal grounds (⏚) and power grounds (G). To take advantage of this design, observe the following grounding rule:

NOTE Always connect a device's ground next to the active terminal associated with that ground. Several ground wires can be connected to the same ground terminal.

Examples:

1. Connect 5 Volt, 12 Volt, and control grounds to G terminals.
2. Connect excitation grounds to the closest ⏚ terminal on the excitation terminal block.
3. Connect the low side of single-ended sensors to the nearest ⏚ terminal on the analog input terminal blocks.
4. Connect shield wires to the nearest ⏚ terminal on the analog input terminal blocks.

If offset problems occur because of shield or ground leads with large current flow, tying the problem leads into the ⏚ terminals next to the excitation and pulse-counter channels should help. Problem leads can also be tied directly to the ground lug to minimize induced single-ended offset voltages.

7.4 Ground Potential Differences

Because a single-ended measurement is referenced to CR1000 ground, any difference in ground potential between the sensor and the CR1000 will result in a measurement error. Differential measurements MUST be used when the

input ground is known to be at a different ground potential from CR1000 ground.

Ground potential differences are a common problem in application measuring full bridge sensors (strain gages, pressure transducers, etc), and thermocouples when used to measure soil temperature.

7.4.1 Soil Temperature Thermocouple

If the measuring junction of a copper-constantan thermocouple being used to measure soil temperature is not insulated, and the potential of earth ground is 1 mV greater at the sensor than at the point where the CR1000 is grounded, the measured voltage will be 1 mV greater than the thermocouple output, or approximately 25°C high.

7.4.2 External Signal Conditioner

External signal conditioners, e.g. an infrared gas analyzer (IRGA), are frequently used to make measurements and send analog information to the CR1000. These instruments are often powered by the same AC line source as the CR1000. Despite being tied to the same ground, differences in current drain and lead resistance result in different ground potential at the two instruments. For this reason, a differential measurement should be made on the analog output from the external signal conditioner.

7.5 Ground Looping in Ionic Measurements

When measuring soil moisture blocks or water conductivity, the potential exists for a ground loop which can adversely affect the measurement. This ground loop arises because the soil and water provide an alternate path for the excitation to return to CR1000 ground, and can be represented by the model diagrammed in FIGURE 7.5-1.

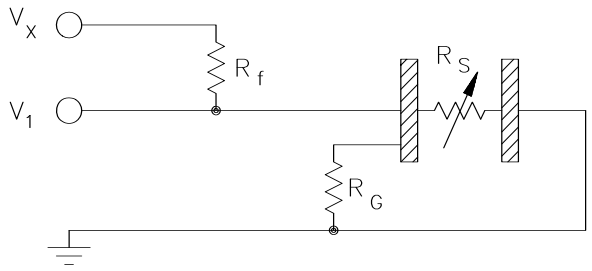


FIGURE 7.5-1. Model of Resistive Sensor with Ground Loop

In Equation 14.5-1, V_x is the excitation voltage, R_f is a fixed resistor, R_s is the sensor resistance, and R_G is the resistance between the excited electrode and CR1000 earth ground. With R_G in the network, the measured signal is:

$$V_1 = V_x \frac{R_s}{(R_s + R_f) + R_s R_f / R_G} \qquad [14.5\text{-}1]$$

R_sR_f/R_G is the source of error due to the ground loop. When R_G is large, the equation reduces to the ideal. The geometry of the electrodes has a great effect on the magnitude of this error. The Delmhorst gypsum block used in the 227 probe has two concentric cylindrical electrodes. The center electrode is used for excitation; because it is encircled by the ground electrode, the path for a ground loop through the soil is greatly reduced. Moisture blocks which consist of two parallel plate electrodes are particularly susceptible to ground loop problems. Similar considerations apply to the geometry of the electrodes in water conductivity sensors.

The ground electrode of the conductivity or soil moisture probe and the CR1000 earth ground form a galvanic cell, with the water/soil solution acting as the electrolyte. If current was allowed to flow, the resulting oxidation or reduction would soon damage the electrode, just as if DC excitation was used to make the measurement. Campbell Scientific probes are built with series capacitors in the leads to block this DC current. In addition to preventing sensor deterioration, the capacitors block any DC component from affecting the measurement.

Section 8. CR1000 Configuration

The CR1000 may require changes to factory default settings depending on the application. Most settings concern telecommunications between the CR1000 and a network or PC.

Good News! The CR1000 is shipped factory ready with all settings and firmware necessary to communicate with a PC via RS-232 and to accept and execute user application programs.

8.1 DevConfig

DevConfig (Device Configuration Utility) is the preferred tool for configuring the CR1000. It is made available as part of LoggerNet, PC400, and at www.campbellsci.com. Most settings can also be entered through the CR1000KD (Section 17.6 Settings).

Features of DevConfig include:

- Communicates with devices via direct RS-232 only.
- Sends operating systems to supported device types.
- Sets datalogger clocks and sends program files to dataloggers.
- Identifies operating system types and versions.
- Provides a reporting facility wherein a summary of the current configuration of a device can be shown, printed or saved to a file. The file can be used to restore settings, or set settings in like devices.
- Provides a terminal emulator useful in configuring devices not directly supported by DevConfig's graphical user interface.
- Shows Help as prompts and explanations. Help for the appropriate settings for a particular device can also be found in the user's manual for that device.
- Updates from Campbell Scientific's web site.

As shown in FIGURE 8.1-1, the DevConfig window is divided into two main sections: the device selection panel on the left side and tabs on the right side. After choosing a device on the left, choose from the list of the serial ports (COM1, COM2, etc.) installed on the PC. A selection of baud rates is offered only if the device supports more than one baud rate. The page for each device presents instructions to set up the device to communicate with DevConfig. Different device types offer one or more tabs on the right.

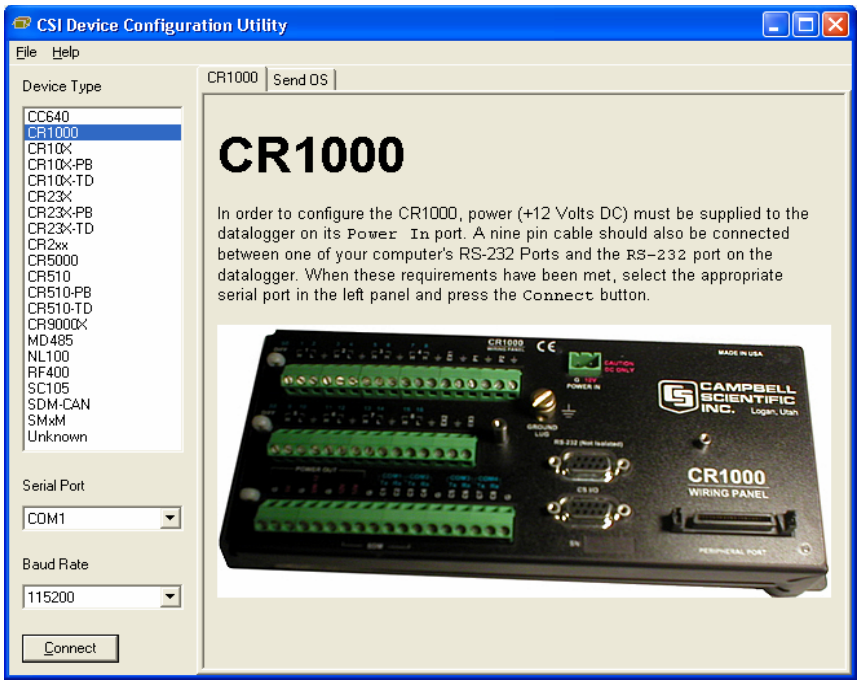


FIGURE 8.1-1. DevConfig CR1000 Facility

When the Connect button is pressed, the device type, serial port, and baud rate selector controls become disabled and, if DevConfig is able to connect to the CR1000, the button will change from "Connect" to "Disconnect".

8.2 Sending the Operating System

8.2.1 Sending OS with DevConfig

The CR1000 is shipped with the operating system pre-loaded. However, OS updates are made available at www.campbellsci.com and can be sent to the CR1000. FIGURE 8.2-1 and FIGURE 8.2-2 show DevConfig windows displayed during the OS download process.

CAUTION Sending an operating system with DevConfig will erase all existing data and reset all settings to factory defaults.

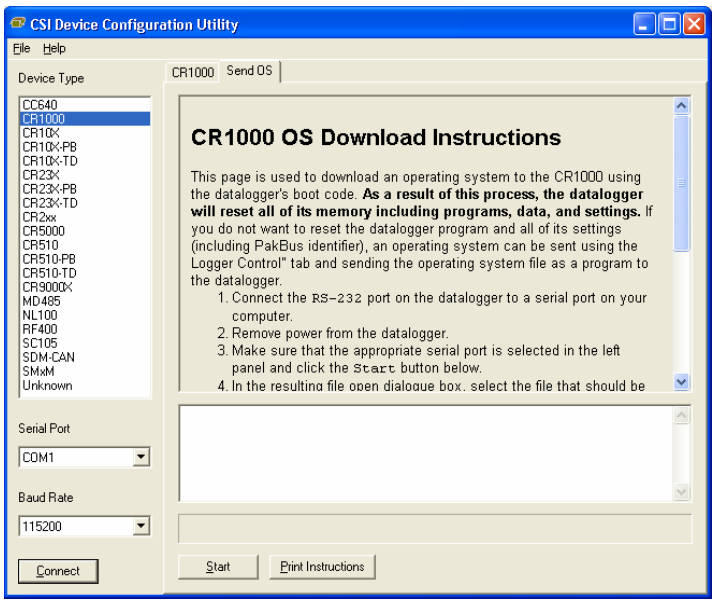


FIGURE 8.2-1. DevConfig OS download window for CR1000.

The text at right gives the instructions for sending the OS. Follow these instructions.

When the **Start** button is clicked, DevConfig offers a file open dialog box that prompts for the operating system file (*.obj file). When the CR1000 is then powered-up, DevConfig starts to send the operating system.

When the operating system has been sent, a message dialog will appear similar to the one shown in FIGURE 8.2-2.

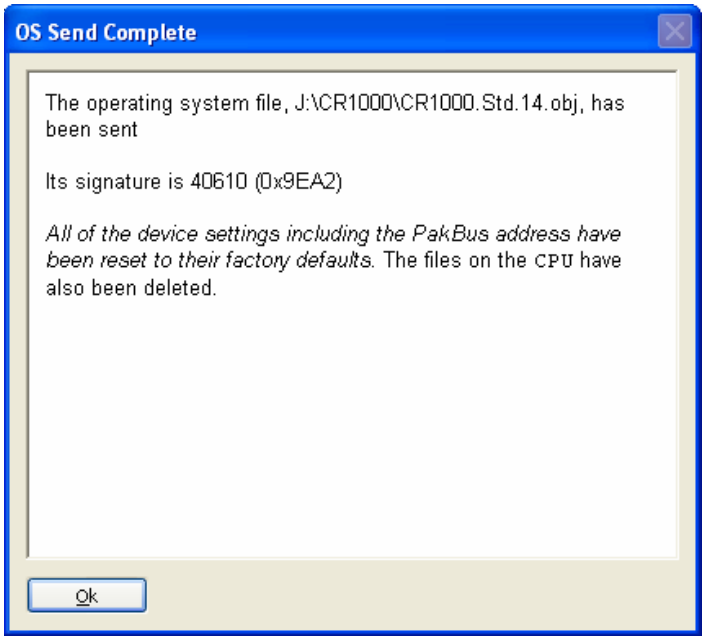


FIGURE 8.2-2. Dialog Box Confirming a Successful OS Download

The information in the dialog helps to corroborate the signature of the operating system sent.

8.2.2 Sending OS to Remote CR1000

Operating systems can be sent remotely using the Program Send feature in LoggerNet, PC400, and PC200W. Sending an OS via Program Send retains settings unless changes in the new OS prevent it.

CAUTION To ensure a remote OS download does not alter telecommunications settings, observe the precautions indicated in Sections 8.2.1 and 8.2.2.

EXAMPLE 8.2-1 lists text in a common default .cr1 file.

EXAMPLE 8.2-1. CRBASIC Code: A simple Default.CR1 file to control SW-12 switched power terminal.

```
BeginProg
  Scan (1,Sec,0,0)
    If TimeIntoInterval (15,60,Sec) Then SW12 (1)
    If TimeIntoInterval (45,60,Sec) Then SW12 (0)
  NextScan
EndProg
```

CAUTION Depending on the method and quality of telecommunications, sending an OS via Program Send may take an inordinate amount of time.

8.2.3 Sending OS Using CF Card

Refer to Section 12.6 File Control.

8.3 Settings

8.3.1 Settings via DevConfig

The CR1000 has a number of properties, referred to as "settings", some of which are specific to the PakBus communications protocol.

Read more! PakBus is discussed in Section 14 PakBus Overview and the PakBus Networking Guide available at www.campbellsci.com.

DevConfig | Settings Editor tab provides access to most of the PakBus settings, however, the Deployment tab makes configuring most of these settings easier.

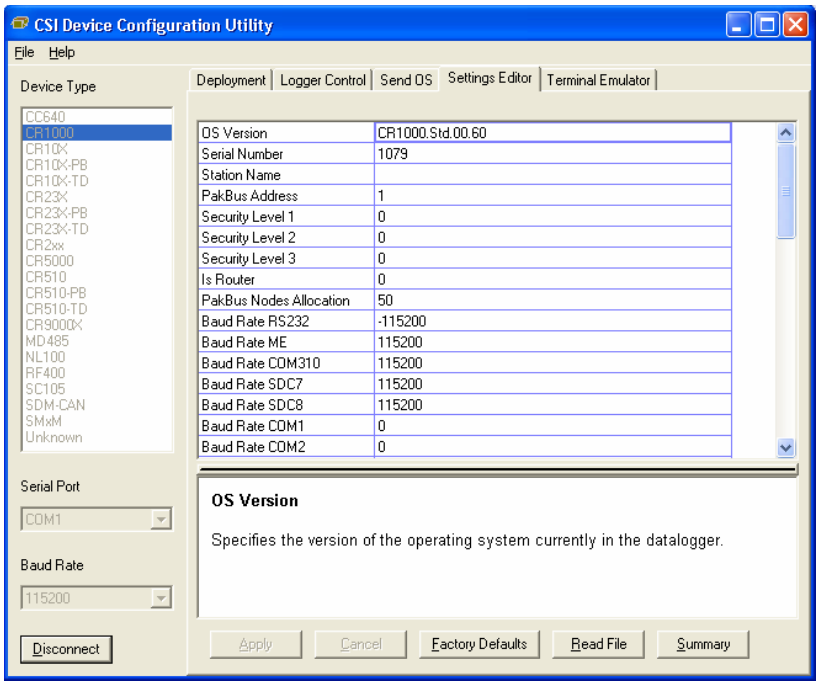


FIGURE 8.3-1. DevConfig Settings Editor

As shown in FIGURE 8.3-1, the top of the Settings Editor is a grid that allows the user to view and edit the settings for the device. The grid is divided into two columns with the setting name appearing in the left hand column and the setting value appearing in the right hand column. Change the currently selected cell with the mouse or by using up-arrow and down-arrow keys as well as the Page-Up and Page-Down keys. When clicking in the setting names column, the value cell associated with that name will automatically be made active. Edit a setting by selecting the value, pressing the F2 key or by double clicking on a value cell with the mouse. The grid will not allow read-only settings to be edited.

The bottom of the Settings Editor displays help for the setting that has focus on the top of the screen.

Once a setting is changed, click **Apply** or **Cancel**. These buttons will only become enabled after a setting has been changed. If the device accepts the settings, a configuration summary dialogue is shown (FIGURE 8.3-2) that gives the user a chance to save and print the settings for the device.

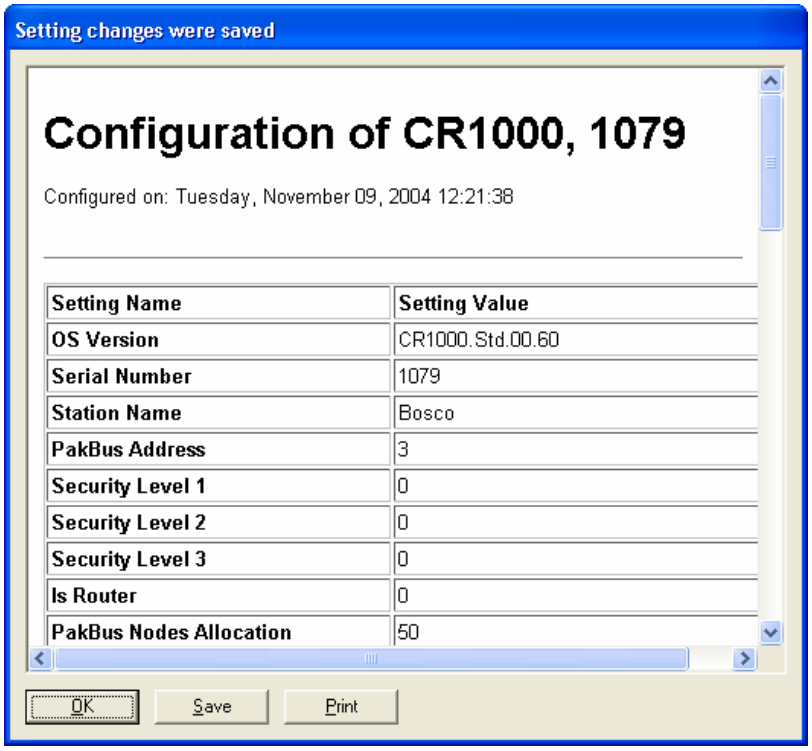


FIGURE 8.3-2. Summary of CR1000 Configuration

Clicking the **Factory Defaults** button on the Settings Editor will send a command to the device to revert to its factory default settings. The reverted values will not take effect until the final changes have been applied. This button will remain disabled if the device does not support the DevConfig protocol messages.

Clicking **Save** on the summary screen will save the configuration to an XML file. This file can be used to load a saved configuration back into a device by clicking **Read File** and **Apply**.

8.3.1.1 Deployment Tab

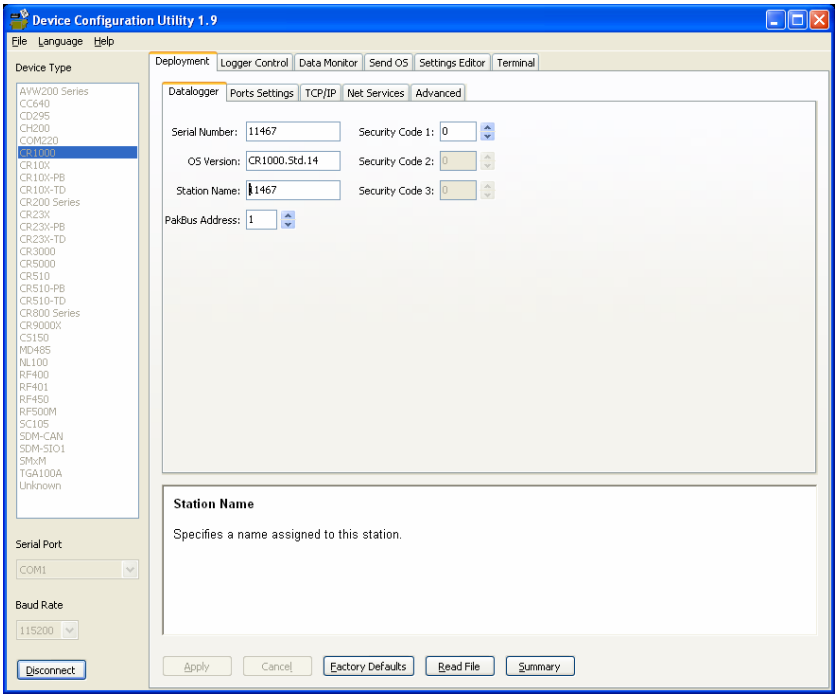


FIGURE 8.3-3. DevConfig Deployment Tab

As shown in FIGURE 8.3-3, the **Deployment** tab allows the user to configure the datalogger prior to deploying it. **Deployment** tab settings can also be accessed through the **Setting Editor** tab and the Status table.

8.3.1.1.1 Datalogger Sub-Tab

Serial Number displays the CR1000 serial number. This setting is set at the factory and cannot be edited.

OS Version displays the operating system version that is in the CR1000. The default station name is the CR1000 serial number.

Station Name displays the name that is set for this station.

PakBus Address allows users to set the PakBus address of the datalogger. The allowable range is between 1 and 4094. Each PakBus device should have a unique PakBus address. Addresses >3999 force other PakBus devices to respond regardless of their respective PakBus settings. See the PakBus Networking Guide for more information.

Security – See Section 3.1.7

8.3.1.1.2 Ports Settings Sub-Tab

As shown in FIGURE 8.3-4, the port settings tab has the following settings.

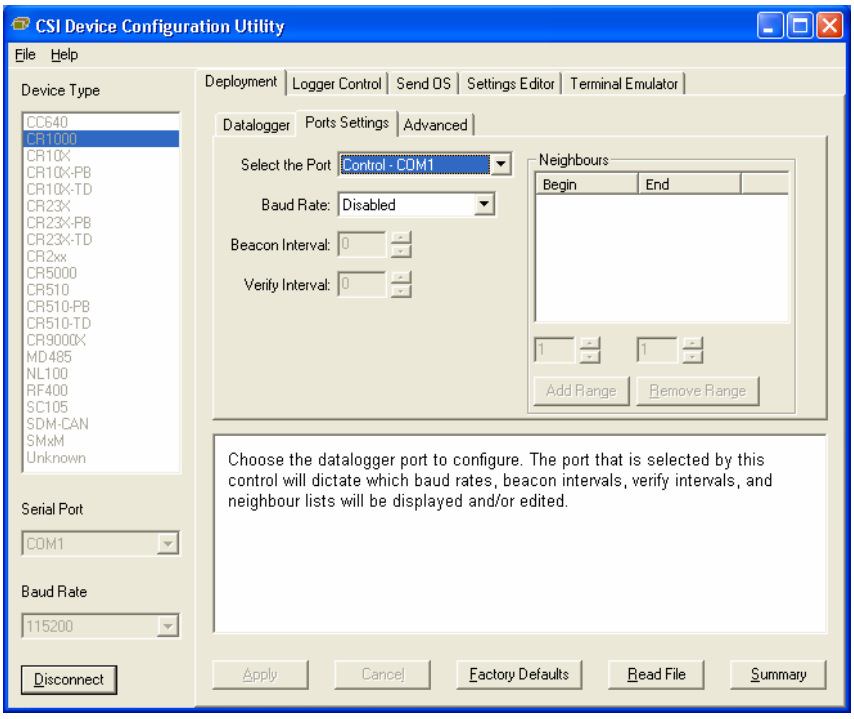


FIGURE 8.3-4. DevConfig Deployment | Ports Settings Tab

Read more! PakBus Networking Guide available at www.campbellsci.com.

Selected Port specifies the datalogger serial port to which the beacon interval and hello setting values will be applied.

Beacon Interval sets the interval (in seconds) on which the datalogger will broadcast beacon messages on the port specified by Selected Port.

Verify Interval specifies the interval (in seconds) at which the datalogger will expect to have received packets from neighbors on the port specified by Selected Port. A value of zero (default) indicates that the datalogger has no neighbor list for this port.

Neighbors List, or perhaps more appropriately thought of as the "allowed neighbors list", displays the list of addresses that this datalogger expects to find as neighbors on the port specified by Selected Port. As items are selected in this list, the values of the **Begin** and **End** range controls will change to reflect the selected range. Multiple lists of neighbors can be added on the same port.

Begin and End Range are used to enter a range of addresses that can either be added to or removed from the neighbors list for the port specified by Selected Port. As users manipulate these controls, the Add range and Remove Range buttons will be enabled or disabled depending on the relative values in the controls and whether the range is present in or overlaps with the list of address

ranges already set up. These controls will be disabled if the **Verify Interval** value is set to zero.

Add Range will cause the range specified in the **Begin** and **End** range to be added to the list of neighbors to the datalogger on the port specified by Selected Port. This control will be disabled if the value of the **Verify Interval** is zero or if the end range value is less than the begin range value.

Remove Range will remove the range specified by the values of the **Begin** and **End** controls from the list of neighbors to the datalogger on the port specified by Selected Port. This control will be disabled if the range specified is not present in the list or if the value of **Verify Interval** is set to zero.

Help is displayed at the bottom of the Deployment tab. When finished, **Apply** the settings to the datalogger. The Summary window will appear. **Save** or **Print** the settings to archive or to use as a template for another datalogger.

Cancel causes the datalogger to ignore the changes. **Read File** provides the opportunity to load settings saved previously from this or another similar datalogger. Changes loaded from a file will not be written to the datalogger until **Apply** is clicked.

8.3.1.1.3 Advanced Sub-Tab

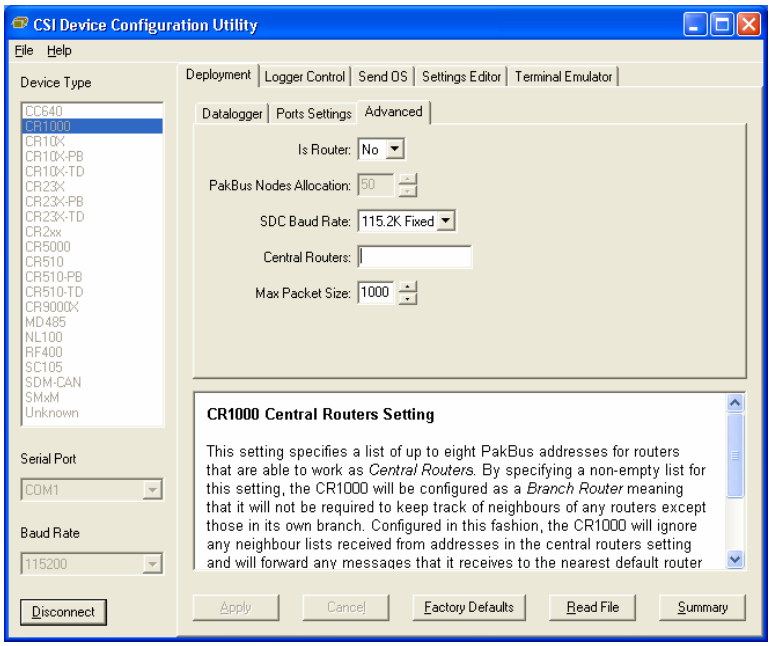


FIGURE 8.3-5. DevConfig Deployment | Advanced Tab

Is Router allows the datalogger to act as a PakBus router.

PakBus Nodes Allocation indicates the maximum number of PakBus devices the CR1000 will communicate with if it is set up as a router. This setting is used to allocate memory in the CR1000 to be used for its routing table.

Max Packet Size is the size of PakBus packets transmitted by the CR1000.

8.3.1.2 Logger Control Tab

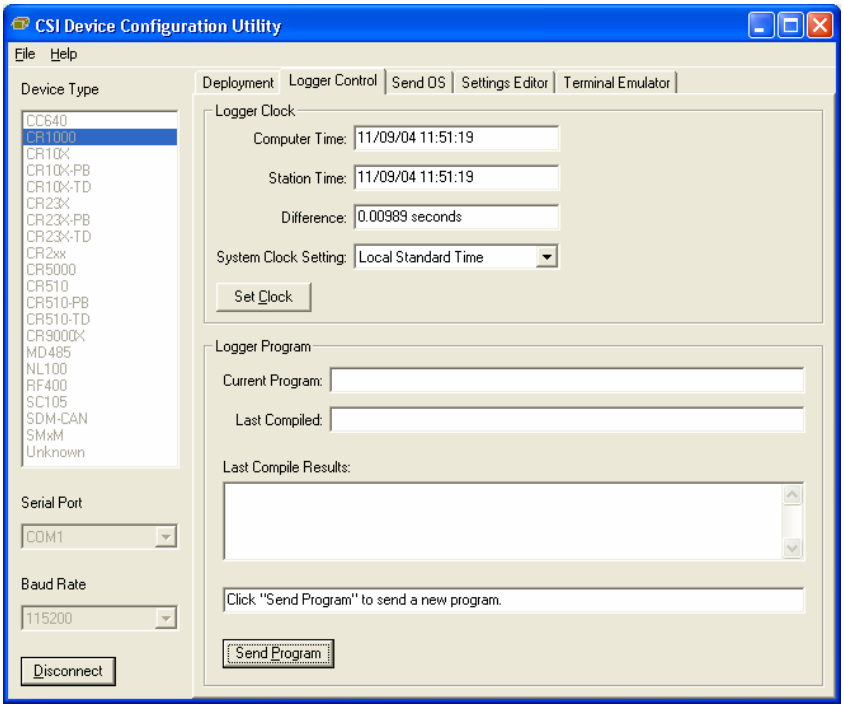


FIGURE 8.3-6. DevConfig Logger Control Tab

The clock in the PC and the datalogger will be checked every second and the difference displayed. The **System Clock Setting** allows entering what offset, if any, to use with respect to standard time (Local Daylight Time or UTC, Greenwich mean time). The value selected for this control will be remembered between sessions. Clicking the **Set Clock** button will synchronize the station clock to the current computer system time.

Current Program displays the current program known to be running in the datalogger. This value will be empty if there is no current program.

The **Last Compiled** field displays the time when the currently running program was last compiled by the datalogger. As with the Current Program field, this value will be read from the datalogger if it is available.

Last Compile Results shows the compile results string as reported by the datalogger.

The **Send Program** button presents an open file dialog from which to select a program file to be sent to the datalogger. The field above the button will be updated as the send operation progresses. When the program has been sent the Current Program, Last Compiled, and Last Compile Results fields will be filled in.

8.3.2 Settings under Program Control

Status table settings can be changed by the active program using the SetStatus () instruction, unless they are set to "read only." Care should be taken when letting the program set settings, so the user is not inadvertently locked out of CR1000 communications.

8.3.3 Settings via Terminal Emulator

CR1000 Terminal Mode is designed to aid Campbell Scientific engineers in operating system development. It has some features useful to users. However, it is frequently modified and cannot be relied upon to have the same features or formats from version to version of the OS.

DevConfig Terminal tab offers a terminal emulator that can be used to access the CR1000 Terminal Mode. After clicking on the DevConfig Terminal Emulator tab, press "Enter" several times until the CR1000 terminal mode prompt "CR1000>" is returned. Terminal mode commands consist of a single character and "Enter". Sending an "H" and "Enter" will return a list of the terminal commands. HyperTerminal, a communications tool available with many installations of Windows PC operating systems, can also be used to access Terminal Mode.

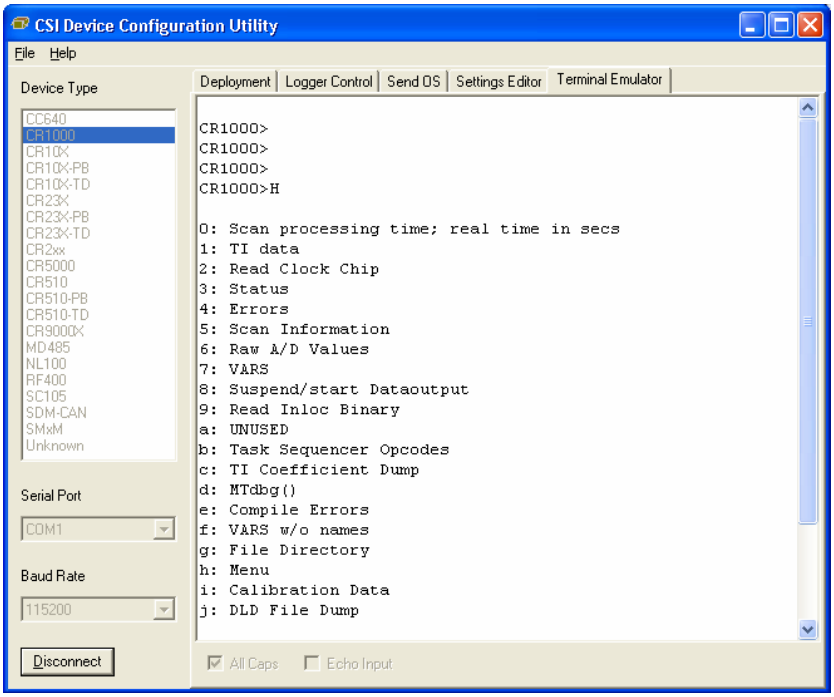


FIGURE 8.3-7. DevConfig Terminal Emulator Tab

ESC or a 40-second timeout will terminate on-going commands.

8.3.4 Durable Settings

Many CR1000 settings can be changed remotely over a telecommunications link either directly or as part of the CRBASIC program. This convenience comes with the risk of inadvertently changing settings and disabling communications. Such an instance will likely require an on-site visit to correct the problem. For example, digital cell modems are often controlled by the switched 12 Volt (SW-12) channel. SW-12 is normally off, so, if the program controlling SW-12 is disabled, such as by replacing it with a program that neglects SW-12 control, the cell modem is switched off and the remote CR1000 drops out of telecommunications.

Campbell Scientific recommends implementing one or both of the provisions described in Sectons 8.3.4.1 and 8.3.4.2 to help preserve remote communication, or other vital settings.

8.3.4.1 "Include" File

The Include file is a CRBASIC program file that resides in memory and compiles as an add-on to the user entered program. The Include file typically begins with the SlowSequence instruction and contains code to set essential telecommunications or other settings. This feature is enabled by sending the Include file to the CR1000 using the File Contol feature, then entering the path and name of the file in the Include file setting in the CR1000 using DevConfig or PakBusGraph. There is no restriction on the length of the Include file. EXAMPLE 8.3-1 shows a program that expects an Include file to control power to a modem. EXAMPLE 8.3-2 lists the Include file code.

EXAMPLE 8.3-1. CRBASIC Code: A simple main program wherein the programmer expects an Include file to be activated.

```
'Include Example.CR1 – Main Program

'Assumes that an Include file is loaded onto the CR1000 CPU: Drive
'The Include file will control power to the cellular phone modem.

Public PTemp, batt_volt

DataTable (Test,1,-1)
    DataInterval (0,15,Sec,10)
    Minimum (1,batt_volt,FP2,0,False)
    Sample (1,PTemp,FP2)
EndTable

BeginProg
    Scan (1,Sec,0,0)
        PanelTemp (PTemp,250)
        Battery (Batt_volt)
        CallTable Test
    NextScan

EndProg
```

EXAMPLE 8.3-2. CRBASIC Code: A simple Include file to control SW-12 switched power terminal.

```
'Include File.CR1 – "Add-on" Program

'Control Cellular modem power for the main program.
'Cell phone + to be wired to SW-12 terminal, - to G.

SlowSequence
Scan (1,Sec,0,0)
    If TimeIntoInterval (9,24,Hr) Then SW12 (1)      'Modem on at 9:00 AM
    If TimeIntoInterval (17,24,Hr) Then SW12 (0)     'Modem off at 5:00 PM
NextScan
```

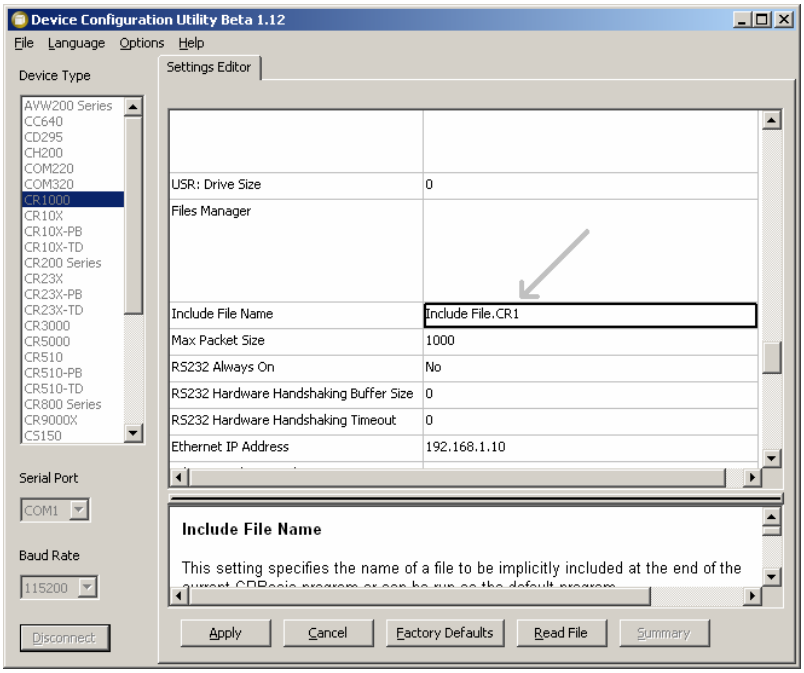


FIGURE 8.3-8. CR1000 "Include File" settings via DevConfig.

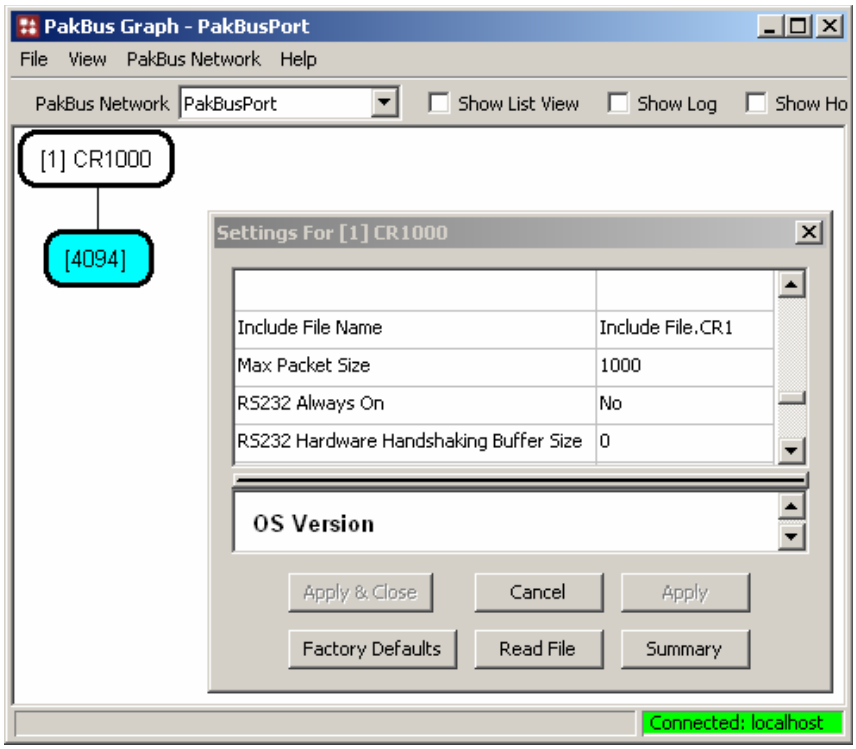


FIGURE 8.3-9. "Include File" settings via LoggerNet | PakBusGraph – provides a settings portal via telecommunications.

8.3.4.2 Default.CR1 File

Default.CR1 can be stored on the CR1000 CPU: drive. At power up, the CR1000 looks for and, when it exists, loads default.CR1 if no other program takes priority (see Section 8.5.3 Priorities). Default.CR1 cannot be more than a few lines of code.

EXAMPLE 8.3-3. CRBASIC Code: A simple Default.CR1 file to control SW-12 switched power terminal.

```
BeginProg
    Scan (1,Sec,0,0)
        If TimeIntoInterval (15,60,Sec) Then SW12 (1)
        If TimeIntoInterval (45,60,Sec) Then SW12 (0)
    NextScan
EndProg
```

8.3.4.3 Priorities

1) When the CR1000 powers up, the program file (.CR1) marked as "Run On Power-up" or "Run Always" or "Run Now" (order of priority) becomes the current program.

2) If there is a file specified in the Include File Name setting, it will be compiled at the end of the program selected in 1).

3) If there is no file selected in 1), or if the selected file cannot be compiled, the CR1000 will run the program listed in the Include File Name setting.

4) If the program listed in the Include File Name setting cannot be run or if no program is specified, the CR1000 will attempt to run the program named default.cr1 on its CPU: drive.

5) If there is no default.cr1 file or it cannot be compiled, the CR1000 will not currently run any program.

Section 9. CR1000 Programming

9.1 Inserting Comments into Program

Comments are non-functioning text placed within the body of a program to document or clarify program algorithms.

As shown in EXAMPLE 9.1-1, comments are inserted into a program by preceding the comment with a single quote ('). Comments can be entered either as independent lines or following CR1000 code. When the CR1000 compiler sees a single quote ('), it ignores the rest of the line.

EXAMPLE 9.1-1. CRBASIC Code: Inserting Comments

```
'Declaration of variables starts here.
Public Start(6)                          'Declare the start time array
```

9.2 Uploading CR1000 Programs

The CR1000 requires a program be sent to its memory to direct measurement, processing, and data storage operations. Programs are sent with PC200W, PC400, or LoggerNet support software. Programs can also be sent from a CF card.

Read more! See 12.6 File Control and the CF card storage module manual.

9.3 Writing CR1000 Programs

Programs are created with either Short Cut, CRBASIC Editor, or Transformer. Short Cut is available at no charge at www.campbellsci.com. CRBASIC Editor and Transformer are programs in PC400 and LoggerNet Datalogger Support Software Suites. Programs can be up to 490 kbytes in size although typical programs are much smaller.

NOTE "Transformer", a utility included with PC400 and LoggerNet Software, converts most CR10X datalogger code to CR1000 datalogger code.

9.3.1 Short Cut Editor and Program Generator

Short Cut is easy-to-use menu-driven software that presents the user with lists of predefined measurement, processing, and control algorithms from which to choose. The user makes choices and Short Cut writes the CRBASIC code required to perform the tasks. Short Cut creates a wiring diagram to simplify connection of sensors and external devices. Section 2, Quickstart Tutorial, works through a measurement example using Short Cut.

For many complex applications, Short Cut is still a good place to start. When as much information as possible is entered, Short Cut will create a program

template from which to work, already formatted with most of the proper structure, measurement routines, and variables. The program can then be edited further using CRBASIC Program Editor.

9.3.2 CRBASIC Editor

CR1000 application programs are written in a variation of BASIC (Beginner's All-purpose Symbolic Instruction Code) computer language, CRBASIC (Campbell Recorder BASIC). CRBASIC Editor is a text editor that facilitates creation and modification of the ASCII text file that constitutes the CR1000 application program. CRBASIC Editor is available as part of PC400, RTDAQ, or LoggerNet datalogger support software packages.

Fundamental elements of CRBASIC include:

- Variables – named packets of CR1000 memory into which are stored values that normally vary during program execution. Values are typically the result of measurements and processing. Variables are given an alphanumeric name and can be dimensioned into arrays of related data.
- Constants – discrete packets of CR1000 memory into which are stored specific values that do not vary during program executions. Constants are given alphanumeric names and assigned values at the beginning declarations of a CRBASIC program.

NOTE Keywords and predefined constants are reserved for internal CR1000 use. If a user programmed variable happens to be a keyword or predefined constant, a runtime or compile error will occur. To correct the error, simply change the variable name by adding or deleting one or more letters, numbers, or the underscore (_) from the variable name, then recompile and resend the program. CRBASIC Help provides a list of keywords and pre-defined constants.

- Common instructions – Instructions and operators used in most BASIC languages, including program control statements, and logic and mathematical operators.
- Special instructions – Instructions unique to CRBASIC, including measurement instructions that access measurement channels, and processing instructions that compress many common calculations used in CR1000 dataloggers.

These four elements must be properly placed within the program structure.

9.3.3 Transformer

This section is not yet available.

9.4 Numerical Formats

Four numerical formats are supported by CRBASIC. Most common is the use of base 10 numbers. Scientific notation, binary, and hexadecimal formats may also be used, as shown in TABLE 9.4-1. Only standard base 10 notation is supported by Campbell Scientific hardware and software displays.

TABLE 9.4-1. Formats for Entering Numbers in CRBASIC

Format	Example	Base 10 Equivalent Value
Standard	6.832	6.832
Scientific notation	5.67E-8	$5.67X10^{-8}$
Binary	&B1101	11
Hexadecimal	&HFF	255

Binary format is useful when loading the status (1 = high, 0 = low) of multiple flags or ports into a single variable, e.g., storing the binary number &B11100000 preserves the status of flags 8 through 1. In this case, flags 1 - 5 are low, 6 - 8 are high. Program Code EXAMPLE 9.4-1 shows an algorithm that loads binary status of flags into a LONG integer variable.

EXAMPLE 9.4-1. CRBASIC Code: Program to load binary information into a single variable.

```
Public FlagInt As Long

Public Flag(8) As Boolean
Public I

DataTable (FlagOut,True,-1)
    Sample (1,FlagInt,UINT2)
EndTable

BeginProg
    Scan (1,Sec,3,0)
        FlagInt = 0
        For I = 1 To 8
            If Flag(I) = true then
                FlagInt = FlagInt + 2 ^ (I - 1)
            EndIf
        Next I
        CallTable FlagOut
    NextScan
EndProg
```

9.5 Structure

TABLE 9.5-1 delineates CRBASIC program structure:

TABLE 9.5-1. CRBASIC Program Structure

Declarations	*Define datalogger memory usage. Declare constants, variables, aliases, units, and data tables.*
Declare constants	*List fixed constants*
Declare Public variables	*List / dimension variables viewable during program execution*
Dimension variables	*List / dimension variables not viewable during program execution.*
Define Aliases	*Assign aliases to variables.*
Define Units	*Assign engineering units to variable (optional). Units are strictly for documentation. The CR1000 makes no use of Units nor checks Unit accuracy.*
Define data tables.	*Define stored data tables*
Process/store trigger	*Set triggers when data should be stored. Triggers may be a fixed interval, a condition, or both.*
Table size	*Set the size of a data table*
Other on-line storage devices	*Send data to a CF card if available*
Processing of Data	*List data to be stored in the data table, e.g. samples, averages, maxima, minima, etc.*
	Processes or calculations repeated during program execution can be packaged in a subroutine and called when needed rather than repeating the code each time.
Begin Program	*Begin Program defines the beginning of statements defining datalogger actions.*
Set scan interval	*The scan sets the interval for a series of measurements*
Measurements	*Enter measurements to make*
Processing	*Enter any additional processing*
Call Data Table(s)	*Declared data tables must be called to process and store data*
Initiate controls	*Check measurements and initiate controls if necessary*
NextScan	*Loop back to Set Scan and wait for the next scan*
End Program	*End Program defines the ending of statements defining datalogger actions.*

EXAMPLE 9.5-1 demonstrates the proper structure of a CRBASIC program.

EXAMPLE 9.5-1. CRBASIC Code: Proper Program Structure

```
'Declarations

'Define constants
Const RevDiff=1
Const Del=0 'default
Const Integ=250
Const Mult=1
Const Offset=0

'Define public variables
Public RefTemp
Public TC(6)

'Define units
Units RefTemp=degC
Units TC=DegC

'Define data tables
DataTable (Temp,1,2000)
    DataInterval (0,10,min,10)
    Average (1,RefTemp,FP2,0)
    Average (6,TC(),FP2,0)
EndTable

'Begin Program
BeginProg

'Set scan interval
    Scan (1,Sec,3,0)

'Measurements
    PanelTemp (RefTemp, 250)
    TCDiff (TC(),6,mV2_5C ,1,TypeT,RefTemp,RevDiff,Del,Integ,Mult,Offset)

'Processing (None)

'Call data table
    CallTable Temp

'Initiate controls (None)

'Loop to next scan
    NextScan

'End Program
End Prog
```

Declare constants

Declare public variables, dimension array, and declare units.

Define Data Table

Declarations

Measure

Scan loop

Call Data Table

9.6 Declarations

Constants (and pre-defined constants), Public variables, Dim variables, Aliases, Units, Data Tables, Subroutines are declared at the beginning of a CRBASIC program.

9.6.1 Variables

A variable is a packet of memory, given an alphanumeric name, through which pass measurements and processing results during program execution. Variables are declared either as Public or Dim at the discretion of the programmer. Public variables can be viewed through the CR1000KD or software numeric monitors. Dim variables cannot.

9.6.1.1 Arrays

When a variable is declared, several variables of the same root name can also be declared. This is done by placing a suffix of "(x)" on the alphanumeric name, which creates an array of x number of variables that differ only by the incrementing number in the suffix. For example, rather than declaring four similar variables as follows,

```
Public TempC1
Public TempC2
Public TempC3
Public TempC4
```

simply declare a variable array as shown below:

```
Public TempC(4),
```

This creates in memory the four variables TempC(1), TempC(2), TempC(3), and TempC(4).

A variable array is useful in program operations that affect many variables in the same way. EXAMPLE 9.6-1 shows program code using a variable array to reduce the amount of code required to convert four temperatures from Celsius degrees to Fahrenheit degrees.

EXAMPLE 9.6-1. CRBASIC Code: Using a variable array in calculations.

```
Public TempC(4)
Public TempF(4)
Dim T

BeginProg
    Scan (1,Sec,0,0)
        Therm107 (TempC(),4,1,Vx1,0,250,1.0,0)
        For T = 1 To 4
            TempF(T) = TempC(T) * 1.8 + 32
        Next
    NextScan
EndProg
```

9.6.1.2 Dimensions

Occasionally, a multi-dimensioned array is required by an application. Dimensioned arrays can be thought of just as distance, area, and volume measurements are thought of. A single dimensioned array, declared as VariableName(x), with (x) being the index, can be thought of as *x* number of variables is a series. A two-dimensional array, declared as

Public (or Dim) VariableName(x,y),

with (x,y) being the indicies, can be thought of as (*x*) * (*y*) number of variables in a square x-by-y matrix. Three-dimensional arrays (VariableName (x,y,z), (x,y,z) being the indicies) have (x) * (y) * (z) number of variables in a cubic x-by-y-by-z matrix. Dimensions greater than three are not permitted by CRBASIC. Strings can be declared at a maximum of two dimensions. The third dimension is used internally for accessing characters within a string.

When using variables in place of integers as the dimension indicies, e.g. EXAMPLE 9.6-2, declaring the indicies as Long variables is recommended as doing so allows for much more efficient use of CR1000 resources.

EXAMPLE 9.6-2. Using Variable Array Dimension Indicies

```
Dim aaa As Long
Dim bbb As Long
Dim ccc As Long
Public VariableName(4,4,4) as Float

BeginProg
    Scan()
        aaa = 3
        bbb = 2
        ccc = 4
        VariableName(aaa,bbb,ccc) = 2.718
    NextScan
EndProg
```

9.6.1.3 Data Types

Variables and stored data can be configured with various data types to optimize program execution and memory usage.

The declaration of variables (via the **DIM** or the **PUBLIC** statement) allows an optional type descriptor **AS** that specifies the data type. The default data type, without a descriptor, is IEEE4 floating point (FLOAT). Variable data types are STRING and three numeric types: **FLOAT**, **LONG**, and **BOOLEAN.** Stored data has additional data type options FP2, UINT2, BOOL8, and NSEC. EXAMPLE 9.6-3 shows these in use in the declarations and output sections of a CRBASIC program.

EXAMPLE 9.6-3. CRBASIC Code: Data Type Declarations

```
'Float Variable Examples
Public Z
Public X As Float
Public CR1000Time As Long

'Long Variable Example
Public PosCounter As Long
Public PosNegCounter As Long

'Boolean Variable Examples
Public Switches(8) As Boolean
Public FLAGS(16) As Boolean

'String Variable Example
Public FirstName As String * 16 'allows a string up to 16 characters long

DataTable (TableName,True,-1)
    'FP2 Data Storage Example
    Sample (1,Z,FP2)

    'IEEE4 / Float Data Storage Example
    Sample (1,X,IEEE4)

    'UINT2 Data Storage Example
    Sample (1,PosCounter,UINT2)
    'LONG Data Storage Example
    Sample (1,PosNegCounter,Long)

    'STRING Data Storage Example
    Sample (1,FirstName,String)

    'BOOLEAN Data Storage Example
    Sample (8,Switches(),Boolean)

    'BOOL8 Data Storage Example
    Sample (2,FLAGS(),Bool8)

    'NSEC Data Storage Example
    Sample (1,CR1000Time,Nsec)
EndTable
```

TABLE 9.6-1 lists details of available data types.

TABLE 9.6-1. Data Types

Code	Data Format	Where Used	Word Size	Range	Resolution
FP2	Campbell Scientific Floating Point	Output Data Storage Only	2 bytes	±7999	13 bits (about 4 digits)
IEEE4 or FLOAT	IEEE 4 Byte Floating Point	Output Data Storage / Variables	4 bytes	$\pm 1.4 \times 10^{-45}$ to $\pm 3.4 \times 10^{38}$	24 bits (about 7 digits)
LONG	4 Byte Signed Integer	Output Data Storage / Variables	4 bytes	-2,147,483,648 to +2,147,483,647	1 bit (1)
UINT2	2 Byte Unsigned Integer	Output Data Storage Only	2 bytes	0 to 65535	1 bit (1)
BOOLEAN	4 byte Signed Integer	Output Data Storage / Variables	4 bytes	0, -1	True or False (-1 or 0)
BOOL8	1 byte Boolean	Output Data Storage Only	1 byte	0, -1	True or False (-1 or 0)
NSEC	Time Stamp	Output Data Storage Only	8 byte	seconds since 1990	4 bytes of nanoseconds in the second
STRING	ASCII String	Output Data Storage / Variables	Set by program		

9.6.1.4 Data Type Operational Detail

FP2 Default CR1000 data type for stored data. While IEEE 4 byte floating point is used for variables and internal calculations, FP2 is adequate for most stored data. FP2 provides 3 or 4 significant digits of resolution, and requires half the memory as IEEE 4.

TABLE 9.6-2. Resolution and Range Limits of FP2 Data

Zero	Minimum Magnitude	Maximum Magnitude
0.000	±0.001	±7999.

The resolution of FP2 is reduced to 3 significant digits when the first (left most) digit is 8 or greater (TABLE 9.6-2). Thus, it may be necessary to use IEEE4 format or an offset to maintain the desired resolution of a measurement. For example, if water level is to be measured and stored to the nearest 0.01 foot, the level must be less than 80 feet for low-resolution format to display the 0.01-foot increment. If the water level is expected to range from 50 to 90 feet the data can be formatted as IEEE4.

TABLE 9.6-3. FP2 Decimal Location	
Absolute Value	**Decimal Location**
0 - 7.999	X.XXX
8 - 79.99	XX.XX
80 - 799.9	XXX.X
800 - 7999.	XXXX.

IEEE4 IEEE Standard 754.

Advantages: Industry standard.

Disadvantages: Uses twice the storage space of FP2. See Section 9.13.1 for limitations in using IEEE4 in arithmetic.

LONG Advantages: Speed -- the CR1000 can do math on integers faster than with floats. Resolution-- LONG has 31 bits compared to 24-bits in IEEE4.

Disadvantages: In most applications, it is not suitable for stored output data since any fractional portion of the value is lost.

UINT2 Typical uses are for efficient storage of totalized pulse counts, port status (e.g. 16 ports on an SDM-IO16 stored in one variable) or integer values that store binary flags.

Float values are converted to integer UINT2 values as if using the INT function. Values may need to be range checked since values outside the range of 0-65535 will yield UINT2 data that is probably unusable. NAN values are stored as 65535.

Boolean Boolean variables are typically used for flags and to represent conditions or hardware that have only two states such as flags and control ports. A Boolean variable uses the same 4-byte integer format as a LONG but can be set to only one of two values. To save memory space, consider using BOOL8 format instead.

BOOL8 A one byte variable that hold 8 bits (0 or 1) of information. BOOL8 uses less space than 32-bit BOOLEAN data type, since 32 bits of information are stored in four 8-bit Boolean bytes. Repetitions in output processing data table instructions must be divisible by two, since an odd number of bytes cannot be stored in a data table. When converting from a LONG or a FLOAT to a BOOL8, only the least significant 8 bits are used, i.e., only the modulo 256 is used. When LoggerNet retrieves a BOOL8 data type, it splits it apart into 8 fields of true or false when displaying or storing to an ASCII file. Consequently, more computer memory is consumed by the datalogger support software, but CR1000 memory is conserved. Conservation of memory in the CR1000 also results in less band width being used when data are collected via telecommunications.

Read more! Bool8 data type is discussed in depth, with examples, in Section 11.13.

NSEC 8 bytes divided up as 4 bytes of seconds since 1990 and 4 bytes of nanoseconds into the second. Used when a LONG variable being sampled is the result of the RealTime() instruction or when the sampled variable is a LONG storing time since 1990, such as when time of maximum or time of minimum is asked for. Alternatively, if the variable array (must be FLOAT or LONG) is dimensioned to 7, the values stored will be year, month, day of year, hour, minutes, seconds, and milliseconds. If the variable array (must be LONG) is dimensioned to two, the instruction assumes that the first element holds seconds since 1990 and the second element holds microseconds into the second. If the variable array (must be LONG) is dimensioned to 1, the instruction assumes that the variable holds seconds since 1990 and microseconds into the second is 0. In this instance, the value stored is a standard datalogger timestamp rather than the number of seconds since January 1990.

Read more! NSEC data type is discussed in depth, with examples, in Section 11.12.

String ASCII String; size defined by the CR1000 CRBASIC program. The minimum string datum size (regardless of word length), and the default if size is not specified, is 16 bytes or characters. A string conveniently handles alphanumeric variables associated with serial sensors, dial strings, text messages, etc.

9.6.2 Constants

A constant can be declared at the beginning of a program to assign an alphanumeric name to be used in place of a value so the program can refer to the name rather than the value itself. Using a constant in place of a value can make the program easier to read and modify, and more secure against unintended changes. Constants can be changed while the program is running if they are declared using the ConstTable/EndConstTable instruction.

Programming Tip: Using all uppercase for constant names may make them easier to recognize.

EXAMPLE 9.6-4. CRBASIC Code: Using the Const Declaration.

```
Public PTempC, PTempF
Const CtoF_Mult = 1.8
Const CtoF_Offset = 32

BeginProg
    Scan (1,Sec,0,0)
        PanelTemp (PTempC,250)
        PTempF = PTempC * CtoF_Mult + CtoF_Offset
    NextScan
EndProg
```

9.6.2.1 Predefined Constants

Several words are reserved for use by CRBASIC. These words cannot be used as variable or table names in a program. Predefined constants include some instruction names, as well as valid alphanumeric names for instruction parameters. In general, instruction names should not be used as variable, constant, or table names in a datalogger program, even if they are not specifically listed as a predefined constant. If predefined constant is used in a program, an error similar to that shown in FIGURE 9.6-1 may, but not always, be displayed. TABLE 9.6-4 lists predefined constants.

```
STRING is already in use as a predefined CONST
```

FIGURE 9.6-1. Predefined CONST Error

TABLE 9.6-4. Predefined Constants and Reserved Words

_50hz	_60hz	Auto	Autoc
AutoRange	AutoRangec	BOOL8	BOOLEAN
CAO1	CAO2	Case	Com1
Com2	Com3	Com310	Com4
ComME	ComRS232	ComSDC10	ComSDC11
ComSDC7	ComSDC8	CR1000	CR3000
CR5000	CR800	CR9000X	day
DO	EVENT	FLOAT	FOR
hr	FALSE	If	IX1
IX2	IEEE4	IX4	LoggerType
LONG	IX3	msec	mv1000
mv1000C	min	mv1000R	mv2_5
mv2_5c	mv1000cR	mv200	mv200c
mv200cR	mv20	mv20c	mv25
mv250	mv200R	mv2500c	mv250c
mv25c	mv2500	mv500	mv5000
mv5000	mv50	mv5000C	mv5000cR
mv5000R	mv5000c	mv50c	mv50c
mv50cR	mv500c	mv7_5	mv7_5c
mvX10500	mv50R	NSEC	PROG
SCAN	mvX1500	Select	STRING
SUB	sec	TABLE	TRUE
TypeB	SUBSCAN	TypeJ	TypeK
TypeN	TypeE	TypeS	TypeT
UINT2	TypeR	usec	v10
v2	Until	v2c	v50
v60	v20	VX1 (VX1 (EX1))	vX15
VX2	VX1	vX105	VX2 (EX2)
VX3 (EX3)	VX3	VX4	While

9.6.3 Flags

Flags are a useful program control tool. While any variable of any data type can be used as a flag, using Boolean variables, especially variables named "Flag", works best. EXAMPLE 9.6-5 shows an example using flags to change the word in string variables.

EXAMPLE 9.6-5. CRBASIC Code: Flag Declaration and Use

```
Public Flag(2) As Boolean
Public FlagReport(2) As String

BeginProg
    Scan (1,Sec,0,0)
        If Flag(1) = True Then
            FlagReport(1) = "High"
        Else
            FlagReport(1) = "Low"
        EndIf
        If Flag(2) = True Then
            FlagReport(2) = "High"
        Else
            FlagReport(2) = "Low"
        EndIf
    NextScan
EndProg
```

9.7 Data Tables

Data are stored in tables as directed by the CRBASIC program. A data table is created by a series of CRBASIC instructions entered after variable declarations but before the BeginProg instruction. These instructions include:

```
DataTable ()
    Output Trigger Condition(s)
    Output Processing Instructions
EndTable
```

A data table is essentially a file that resides in CR1000 memory. The file is written to each time data are directed to that file. The trigger that initiates data storage is tripped either by the CR1000's clock, or by an event, such as a high temperature. Up to 30 data tables can be created by the program. The data tables may store individual measurements, individual calculated values, or summary data such as averages, maxima, or minima to data tables.

Each data table is associated with overhead information that becomes part of the ASCII file header when data are downloaded to a PC. Overhead information includes:

- table format
- datalogger type and operating system version,
- name of the CRBASIC program running in the datalogger
- name of the data table (limited to 20 characters)
- alphanumeric field names to attach at the head of data columns

This information is referred to as "table definitions."

TABLE 9.7-1 shows a data file as it appears after the associated data table has been downloaded from a CR1000 programmed with the code in EXAMPLE 9.7-1. "TIMESTAMP", "RECORD", "Batt_Volt_Avg", "PTemp_C_Avg", "TempC_Avg(1)", and "TempC_Avg(2)" are default fieldnames.

Default fieldnames are a combination of the variable names (or alias) from which data are derived with a three letter suffix. The suffix is an abbreviation of the data process that output the data to storage. For example, "Avg" is the abbreviation for average. If the default fieldnames are not acceptable to the programmer, FieldNames () instruction can be used to customized fieldnames.

Read more! See TABLE 9.14-1 for a list of default field names.

The third row of the data table header lists units for the stored values. These units are declared in the "Define Units" section of the program, as shown in EXAMPLE 9.7-1. Units are strictly for documentation. The CR1000 makes neither use of units nor checks on their accuracy.

TABLE 9.7-1. Typical Data Table

TOA5	CR1000	CR1000	1048	CR1000.Std.13.06	CPU:Data.CR1	35723	OneMin
TIMESTAMP	RECORD	Batt_Volt_Avg	PTemp_C_Avg	Temp_C_Avg(1)	Temp_C_Avg(2)		
TS	RN	Volts	Deg C	Deg C	Deg C		
		Avg	Avg	Avg	Avg		
7/11/2007 16:10	0	13.18	23.5	23.54	25.12		
7/11/2007 16:20	1	13.18	23.5	23.54	25.51		
7/11/2007 16:30	2	13.19	23.51	23.05	25.73		
7/11/2007 16:40	3	13.19	23.54	23.61	25.95		
7/11/2007 16:50	4	13.19	23.55	23.09	26.05		
7/11/2007 17:00	5	13.19	23.55	23.05	26.05		
7/11/2007 17:10	6	13.18	23.55	23.06	25.04		

EXAMPLE 9.7-1. CRBASIC Code: Definition and Use of a Data Table

```
'CR1000

'Declare Variables
Public Batt_Volt
Public PTemp_C
Public Temp_C(2)

'Define Units
Units Batt_Volt=Volts
Units PTemp_C=Deg C
Units Temp_C(2)=Deg C

'Define Data Tables
DataTable (OneMin,True,-1)
    DataInterval (0,1,Min,10)
    Average (1,Batt_Volt,FP2,False)
    Average (1,PTemp_C,FP2,False)
    Average (2,Temp_C(1),FP2,False)
EndTable
```

```
DataTable (Table1,True,-1)
    DataInterval (0,1440,Min,0)
    Minimum (1,Batt_Volt,FP2,False,False)
EndTable

'Main Program
BeginProg
    Scan (5,Sec,1,0)

        'Default Datalogger Battery Voltage measurement Batt_Volt:
        Battery (Batt_Volt)

        'Wiring Panel Temperature measurement PTemp_C:
        PanelTemp (PTemp_C,_60Hz)

        'Type T (copper-constantan) Thermocouple measurements Temp_C:
        TCDiff (Temp_C(),2,mV2_5C,1,TypeT,PTemp_C,True,0,_60Hz,1,0)

        'Call Data Tables and Store Data
        CallTable (OneMin)
        CallTable (Table1)

    NextScan
EndProg
```

9.7.1 Data Table Programming

As shown in EXAMPLE 9.7-1, data table declaration begins with the DataTable () instruction and ends with the EndTable () instruction. Between DataTable () and EndTable () are instructions that define what data to store and under what conditions data are stored. A data table must be called by the CRBASIC program for data storage processing to occur. Typically, data tables are called by the CallTable () instruction once each Scan.

9.7.1.1 DataTable () and EndTable () Instructions

The DataTable instruction has three parameters: a user-specified alphanumeric name for the table (e.g., "OneMin"), a trigger condition (e.g., "True"), and the size to make the table in RAM (e.g., auto allocated).

- Name -- The table name can be any combination of numbers and letters up to 20 characters in length. The first character must be a letter.

- TrigVar – Controls whether or not data records are written to storage. Data records are written to storage if TrigVar is true and if other conditions, such as DataInterval (), are met. Default setting is -1 (True). TrigVar may be a variable, expression, or constant. TrigVar does not control intermediate processing. Intermediate processing is controlled by the disable variable, DisableVar, which is a parameter in all output processing instructions (see Section 9.7.1.4).

Read more! Section 11.10 discusses the use of TrigVar and DisableVar in special applications.

- Size – Table size is the number of records to store in a table before new data begins overwriting old data. If "-1" is entered, memory for the table is determined (auto-allocated) by the CR1000. Auto allocation is preferred in most applications since the datalogger sizes all tables such that they will begin overwriting the oldest data at about the same time.

EXAMPLE 9.7-1 creates a data table named "OneMin", stores data once a minute as defined by DataInterval (), and retains the most recent records in RAM, up to an automatically allocated memory limit.

9.7.1.2 DataInterval () Instruction

DataInterval () programs the CR1000 to both write data records at the specified interval and to recognize when a record has been skipped. Sometimes, program logic prevents a record from being written. If a record is not written, the CR1000 recognizes the omission as a "lapse" and increments a SkippedRecord counter in the status table. Lapses waste significant memory in the data table and may cause the data table to fill sooner than expected. DataInterval () parameter "Lapses" controls the CR1000's response to a lapse. TABLE 9.7-2 lists Lapses parameter options and concomitant functions.

TABLE 9.7-2. DataInterval () Lapse Parameter Options

DataInterval () Lapse Parameter	Effect
X > 0	If table record number is fixed, X data frames (1 kbyte per data frame) added to data table if memory is available. If record number is auto-allocated, no memory is added to table. When lapse occurs, new data frame created for next record. Unused memory in previous data frame remains unused.
X = 0	Timestamp always stored with each record.
X < 0	When lapse occurs, no new data frame created. Record timestamps calculated at data extraction may be in error.

NOTE Program logic that results in lapses includes scan intervals inadequate to the length of the program (skipped scans), the use of DataInterval() in event driven data tables, logic that directs program execution around the CallTable() instruction, or temporary loss of power.

A data table consists of successive 1 kilobyte data frames. Each data frame contains a timestamp, frame number, and one or more records. By default, a timestamp and record number are not stored with each record. Rather, the data extraction software uses the frame timestamp and frame number to timestamp and number each record when it is stored to computer memory. This technique saves telecommunications bandwidth and 16 bytes of CR1000 memory per record. However, when a record is skipped, or several records are skipped contiguously, a lapse occurs, the SkippedRecords status entry is incremented, and a new data frame is created. Since the previous data frame is not

completely filled before a new one is created, programs that lapse frequently under default settings waste significant memory.

If the Lapses parameter is set to 20, the memory allocated for the data table is increased by 20 frames (20 kbytes). If more than 20 lapses occur, the actual number of records that will be written to the data table before the oldest is overwritten (ring memory) may be less than what was specified in the DataTable () or CardOut () instructions.

If a program is planned to experience multiple lapses, and if telecommunications bandwidth is not a consideration, a more efficient use of memory may be to timestamp every record (Lapses parameter = 0) rather than sacrificing the unused memory of multiple data frames.

9.7.1.3 OpenInterval () Instruction

By default, the CR1000 uses closed intervals. Data output to a data table based on DataInterval () include measurements only from the current interval. Intermediate memory that contains measurements is cleared at the top of the next interval regardless of whether a record was written to the data table.

If OpenInterval () is programmed into the data table declaration, intermediate memory is not cleared. This results in all measurements since the last time data were stored being included in the data table. So, with an open interval, data that span multiple output intervals may be summarized in a single record.

Historical Note: Array based datalogger, i.e. those dataloggers manufactured prior to the CR1000 series dataloggers, e.g. the CR10X, use open intervals.

9.7.1.4 Output Processing Instructions

Data storage processing ("output processing") instructions determine what data are stored in the data table. When a data table is called in the CRBASIC program, data storage processing instructions process variables holding current inputs or calculations. If trigger conditions are true, e.g. the required interval has expired, processed values are stored ("output") in the data table. In EXAMPLE 9.7-1, three averages are stored.

Consider the Average () instruction as an example of output processing instructions. Average () stores the average of a variable over the data storage output interval. Its parameters are:

- Reps -- number of elements in the variable array for which to calculate averages. In EXAMPLE 9.7-1, reps is set to 1 to average PTemp, and set to 2 to average 2 thermocouple temperatures, both of which reside in the variable array "Temp_C".
- Source -- variable array to average. In EXAMPLE 9.7-1, variable arrays PTemp_C (an array of 1) and Temp_C() (an array of 2) are used.
- DataType -- Data type for the stored average.
- EXAMPLE 9.7-1 uses data type FP2, which is Campbell Scientific's 2 - byte floating point data type.

Read more! See Section 9.6.1.3 for more information on available data types.

- DisableVar – controls whether or not a measurement or value is included in an output processing function. A measurement or value will not be included if the disable variable is true (≠ 0). For example, in the case of an Average () output processing instruction, if, on a particular pass through the data table, the Average () disable variable true, the value resident in the variable to be averaged with not be included in the average. Program EXAMPLE 9.7-2 has "False" entered for the disable variable, so all readings are included in the averages. In Program EXAMPLE 9.7-2, the average of variable "Oscillator" does not include samples occurring when Flag 1 is high, producing an average of 2, whereas, when Flag 1 is low (all samples used), an average of 1.5 is calculated.

Read more! Section 11.10 discusses the use of TrigVar and DisableVar in special applications.

EXAMPLE 9.7-2. CRBASIC Code: Use of the Disable Variable.

```
'Declare Variables and Units
Public Oscillator As Long
Public Flag(1) As Boolean
Public DisableVar As Boolean

'Define Data Tables
DataTable (OscAvgData,True,-1)
    DataInterval (0,1,Min,10)
    Average (1,Oscillator,FP2,DisableVar)
EndTable

'Main Program
BeginProg
    Scan (1,Sec,1,0)

        'Reset and Increment Counter
        If Oscillator = 2 Then Oscillator = 0
        Oscillator = Oscillator + 1

        'Process and Control
        If Oscillator = 1
            If Flag(1) = True Then
                DisableVar = True
            End If
        Else
            DisableVar = False
        EndIf

        'Call Data Tables and Store Data
        CallTable (OscAvgData)

    NextScan
EndProg
```

Read more! For a complete list of output processing instructions, see Section 10.2.3 Data Storage Output Processing.

9.8 Subroutines

Read more! See Section 11.4 Subroutines for more information on programming with subroutines.

Subroutines allow a section of code to be called by multiple processes in the main body of a program. Subroutines are defined before the main program body (Section 11.4 Subroutines) of a program.

NOTE A particular subroutine can be called by multiple program sequences simultaneously. To preserve measurement and processing integrity, the CR1000 queues calls on the subroutine, allowing only one call to be processed at a time in the order calls are received. This may cause unexpected pauses in the conflicting program sequences.

9.9 Program Timing: Main Scan

As shown in EXAMPLE 9.9-1, aside from declarations, the CRBASIC program may be relatively short. Executable code begins with **BeginProg** and ends with **EndProg**. Measurements, processing, and calls to data tables within the Scan / NextScan loop determine the sequence and timing of program functions.

EXAMPLE 9.9-1. CRBASIC Code: BeginProg / Scan / NextScan / EndProg Syntax

```
BeginProg
Scan (1,Sec,3,0)
    PanelTemp (RefTemp, 250)
    TCDiff (TC(),6,mV2_5C,1,TypeT,RefTemp,RevDiff,Del,Integ,Mult,Offset)
    CallTable Temp
NextScan
EndProg
```

Scan determines how frequently instructions in the program are executed:

EXAMPLE 9.9-2. CRBASIC Code: Scan Syntax

```
'Scan (Interval, Units, BufferSize, Count)
Scan (1,Sec,3,0)
.
.
.
ExitScan
```

Scan has four parameters:

Interval is the interval between scans.

Units is the time unit for the interval. Interval is 10 ms < = Interval < = 1 day.

BufferSize is the size (number of scans) of a buffer in RAM that holds the raw results of measurements. When running in Pipline mode, using a buffer allows

the processing in the scan to lag behind measurements at times without affecting measurement timing. Use of the CRBASIC Editor default size is normal. Refer to Section 19.1.1.2 for troubleshooting tips.

Count is number of scans to make before proceeding to the instruction following NextScan. A count of 0 means to continue looping forever (or until ExitScan). In the example in EXAMPLE 9.9-2, the scan is 1 second, three scans are buffered, and measurements and data storage continue indefinitely.

9.10 Program Timing: Slow Sequence Scans

Instructions in a slow sequence scan are executed whenever the main scan is not active. When running in pipeline mode, slow sequence measurements will be spliced in after measurements in the main program, as time allows. Because of this splicing, the measurements in a slow sequence may actually span across multiple main program scan intervals. When no measurements need to be spliced, the scan will run independent of the fast scan, so slow sequences with no measurements can run at intervals ≤ main scan interval (still in 100 ms increments) without skipping scans. When splicing, checking for skipped slow scans is done after the first splice is complete rather than immediately after the interval comes true.

In sequential mode, all instructions in the slow sequences are executed as they occur in the program according to task priority.

Slow sequence scans are declared with the SlowSequence instruction and run outside the main program scan. They typically run at a slower rate than the main scan. Up to four slow sequences scans can be defined in a program.

Background calibration is an automatic slow sequence scan.

Read more! Section 06 Self-Calibration.

9.11 Program Execution and Task Priority

Execution of program instructions is prioritized among three tasks: measurement / control, SDM, and processing. Processes of each task are listed in TABLE 9.11-1.

The **measurement / control task** is a rigidly timed sequence that measures sensors and outputs control signals for other devices.

The **SDM task** manages measurement and control of SDM devices (Campbell Scientific's **S**ynchronous **D**evices for **M**easurement).

The **processing task** converts analog and digital measurements to numbers represented by engineering units, performs calculations, stores data, makes decisions to actuate controls, and performs serial I/O communication.

TABLE 9.11-1. Task Processes

Measurement Task	SDM Task	Processing Task
• Analog Measurements • Excitation • Read Pulse Counters • Read Control Ports (GetPort) • Set Control Ports (SetPort • VibratingWire • PeriodAvg • CS616 • Calibrate	• All SDM instructions, except SMDSIO4 and SDMIO16	• Processing • Output • Serial I/O • SDMSIO4 • SDMIO16 • ReadIO • WriteIO • Expression evaluation and variable setting in measurement and SDM instructions

The CR1000 executes these tasks in either **pipeline** or **sequential** mode. When a program is compiled, the CR1000 evaluates the program and determines which mode to use. Mode information is included in a message returned by the datalogger, which is displayed by the support software. The CRBASIC Editor precompiler returns a similar message.

NOTE A program can be forced to run in sequential or pipeline modes by placing the SequentialMode or PipelineMode instruction in the declarations section of the program.

Some tasks in a program may have higher priorities than other tasks. Measurement tasks generally take precedence over all others. Priority of tasks is different for pipeline mode and sequential mode.

9.11.1 Pipeline Mode

Pipeline Mode handles measurement, most SDM, and processing tasks separately, and possibly simultaneously. Measurements are scheduled to execute at exact times and with the highest priority, resulting in more precise timing of measurements, and usually more efficient processing and power consumption.

Pipeline scheduling requires that the program be written such that measurements are executed every scan. Because multiple tasks are taking place at the same time, the sequence in which the instructions are executed may not be in the order in which they appear in the program. Therefore, conditional measurements are not allowed in pipeline mode. Because of the precise execution of measurement instructions, processing in the current scan (including update of public variables and data storage) is delayed until all measurements are complete. Some processing, such as transferring variables to control instructions, such as PortSet () and ExciteV (), may not be completed until the next scan.

When a condition is true for a task to start, it is put in a queue. Because all tasks are given the same priority, the task is put at the back of the queue. Every 10 msec (or faster if a new task is triggered) the task currently running is paused and put at the back of the queue, and the next task in the queue begins running. In this way, all tasks are given equal processing time by the datalogger.

All tasks are given the same general priority. However, when a conflict arises between tasks, program execution adheres to the priority schedule in TABLE 9.11-2.

TABLE 9.11-2. Pipeline Mode Task Priorities
1) Measurements in main program
2) Background calibration
3) Measurements in slow sequences
4) Processing tasks

9.11.2 Sequential Mode

Sequential mode executes instructions in the sequence in which they are written in the program. Sequential mode may be slower than pipeline mode since it executes only one line of code at a time. After a measurement is made, the result is converted to a value determined by processing included in the measurement instruction, and then execution proceeds to the next instruction. This line-by-line execution allows writing conditional measurements into the program.

NOTE The exact time at which measurements are made in sequential mode may vary if other measurements or processing are made conditionally, if there is heavy communications activity, or if other interrupts such as inserting a CF card occur.

When running in sequential mode, the datalogger uses a queuing system for processing tasks similar to the one used in pipeline mode. The main difference when running a program in sequential mode is that there is no prescheduled timing of measurements; instead, all instructions are executed in their programmed order.

A priority scheme is used to avoid conflicting use of measurement hardware. The main scan has the highest priority and prevents other sequences from using measurement hardware until the main scan, including processing, is complete. Other tasks, such as processing from other sequences and communications, can occur while the main sequence is running. Once the main scan has finished, other sequences have access to measurement hardware with the order of priority being the background calibration sequence followed by the slow sequences in the order they are declared in the program.

NOTE Measurement tasks have priority over other tasks such as processing and communication to allow accurate timing needed within most measurement instructions.

9.12 Instructions

In addition to BASIC syntax, additional instructions are included in CRBASIC to facilitate measurements and store data. Section 10 contains a comprehensive list of these instructions.

9.12.1 Measurement and Data Storage Processing

CRBASIC instructions have been created for making measurements and storing data. Measurement instructions set up CR1000 hardware to make measurements and store results in variables. Data storage instructions process measurements into averages, maxima, minima, standard deviation, FFT, etc.

Each instruction is a keyword followed by a series of informational parameters needed to complete the procedure. For example, the instruction for measuring CR1000 panel temperature is:

PanelTemp *(Dest, Integ)*

"PanelTemp" is the keyword. Two parameters follow: *Dest*, a **dest**ination variable name in which the temperature value is stored; and *Integ,* a length of time to **integ**rate the measurement. To place the panel temperature measurement in the variable RefTemp, using a 250 microsecond integration time, the syntax is:

EXAMPLE 9.12-1. CRBASIC Code: Measurement Instruction Syntax

```
PanelTemp (RefTemp, 250)
```

9.12.2 Parameter Types

Many instructions have parameters that allow different types of inputs. Common input type prompts are listed below. Allowed input types are specifically identified in the description of each instruction in CRBASIC Editor Help.

Constant, or Expression that evaluates as a constant
Variable
Variable or Array
Constant, Variable, or Expression
Constant, Variable, Array, or Expression
Name
Name or list of Names
Variable, or Expression
Variable, Array, or Expression

9.12.3 Names in Parameters

TABLE 9.12-1 lists the maximum length and allowed characters for the names for Variables, Arrays, Constants, etc. The CRBASIC Editor pre-compiler will identify names that are too long or improperly formatted.

TABLE 9.12-1. Rules for Names		
Name for	**Maximum Length (number of characters)**	**Allowed characters**
Variable or Array	39	Letters A-Z, upper or lower. case, underscore "_", and numbers 0-9. The name must start with a letter. CRBASIC is not case sensitive
Constant	38	
Alias	39	
Data Table Name	20	
Field name	39	
Field Name Description	64	

9.12.4 Expressions in Parameters

Read more! See Section 9.13 for more information on expressions.

Many parameters allow the entry of expressions. If an expression is a comparison, it will return -1 if the comparison is true and 0 if it is false (Section 9.13.4 Logical Expressions). EXAMPLE 9.12-2 shows an example of the use of expressions in parameters in the DataTable instruction, where the trigger condition is entered as an expression. Suppose the variable TC is a thermocouple temperature:

EXAMPLE 9.12-2. CRBASIC Code: Use of Expressions in Parameters

```
'DataTable (Name, TrigVar, Size)
DataTable (Temp, TC > 100, 5000)
```

When the trigger is "TC > 100", a TC temperature > 100 will set the trigger to true and data is stored.

9.12.5 Arrays of Multipliers and Offsets

A single measurement instruction can measure a series of sensors and apply individual calibration factors to each sensor as shown in EXAMPLE 9.12-3. Storing calibration factors in variable arrays, and placing the array variables in the multiplier and offset parameters of the measurement instruction, makes this possible. The measurement instruction uses repetitions to implement this feature by stepping through the multiplier and offset arrays as it steps through the measurement input channels. If the multiplier and offset are not arrays, the same multiplier and offset are used for each repetition.

EXAMPLE 9.12-3. CRBASIC Code: Use of Arrays as Multipliers and Offsets

```
Public Pressure(3), Mult(3), Offset(3)

DataTable (AvgPress,1,-1)
    DataInterval (0,60,Min,10)
    Average (3,Pressure(),IEEE4,0)
EndTable

BeginProg
    'Calibration Factors:
    Mult(1)=0.123 : Offset(1)=0.23
    Mult(2)=0.115 : Offset(2)=0.234
    Mult(3)=0.114 : Offset(3)=0.224

    Scan (1,Sec,10,0)
        'VoltSe instruction using array of multipliers and offsets:
        VoltSe (Pressure(),3,mV5000,1,True,0,_60Hz,Mult(),Offset())
        CallTable AvgPress
    NextScan
EndProg
```

Read more! More information is available in CRBASIC Editor Help topic "Multipliers and Offsets with Repetitions".

9.13 Expressions

An expression is a series of words, operators, or numbers that produce a value or result. Expressions are evaluated from left to right, with deference to precedence rules. The result of each stage of the evaluation is of type Long (integer) if the variables are of type Long (constants are integers) and the functions give integer results, such as occurs with INTDV (). If part of the equation has a floating point variable or constant, or a function that results in a floating point, the rest of the expression will be evaluated using floating point math, even if the final function is to convert the result to an integer; e.g. INT ((rtYear-1993)*.25). This is a critical feature to consider when 1) trying to use Long integer math to retain numerical resolution beyond the limit of floating point variables (24 bits), or 2) if the result is to be tested for equivalence against another value (see Section 9.13.1 for limits of floating point precision).

Two types of expressions, mathematical and programming, are used in CRBASIC. A useful property of expressions in CRBASIC is that they are equivalent to and often interchangeable with their results.

Consider the expressions:

x = (z * 1.8) + 32 (a mathematical expression)
If x = 23 then y = 5 (programming expression)

The variable x can be omitted and the expressions combined and written as:

If (z * 1.8 + 32 = 23) then y = 5

Replacing the result with the expression should be done judiciously and with the realization that doing so may make program code more difficult to decipher.

9.13.1 Floating Point Arithmetic

Variables and calculations are performed internally in single precision IEEE4 byte floating point with some operations calculated in double precision.

NOTE Single precision float has 24 bits of mantissa. Double precision has a 32-bit extension of the mantissa, resulting in 56 bits of precision. Instructions that use double precision are AddPrecise, Average, AvgRun, AvgSpa, CovSpa, MovePrecise, RMSSpa, StdDev, StdDevSpa, and Totalize.

Floating point arithmetic is common in many electronic computational systems, but it has pitfalls high-level programmers should be aware of. Several sources discuss floating point arithmetic thoroughly. One readily available source is the topic "Floating Point" at Wikipedia.org. In summary, CR1000 programmers should consider at least the following:

- Floating point numbers do not perfectly mimic real numbers.
- Floating point arithmetic does not perfectly mimic true arithmetic.
- Avoid use of equality in conditional statements. Use >= and <= instead. For example, use "If X => Y, then do" rather than using, "If X = Y, then do".
- When programming extended cyclical summation of non-integers, use the AddPrecise() instruction. Otherwise, as the size of the sum increases, fractional addends will have ever decreasing effect on the magnitude of the sum, because normal floating point numbers are limited to about 7 digits of resolution.

9.13.2 Mathematical Operations

Mathematical operations are written out much as they are algebraically. For example, to convert Celsius temperature to Fahrenheit, the syntax is:

TempF = TempC * 1.8 + 32

EXAMPLE 9.13-1 shows example code to convert twenty temperatures in a variable array from C to F:

EXAMPLE 9.13-1. CRBASIC Code: Use of variable arrays to save code space.

```
For I = 1 to 20
    TCTemp(I) = TCTemp(I) * 1.8 + 32
Next I
```

9.13.3 Expressions with Numeric Data Types

FLOATs, LONGs and Booleans are cross-converted to other data types, such as FP2, by using "="

9.13.3.1 Boolean from FLOAT or LONG

When a FLOAT or LONG is converted to a Boolean as shown in EXAMPLE 9.13-2, zero becomes False (0) and non-zero becomes True (-1).

EXAMPLE 9.13-2. CRBASIC Code: Conversion of FLOAT / LONG to Boolean

```
Public Fa AS FLOAT
Public Fb AS FLOAT
Public L AS LONG
Public Ba AS Boolean
Public Bb AS Boolean
Public Bc AS Boolean

BeginProg
    Fa = 0
    Fb = 0.125
    L = 126
    Ba = Fa                    'This will set Ba = False (0)
    Bb = Fb                    'This will Set Bb = True (-1)
    Bc = L                     'This will Set Bc = True (-1)
EndProg
```

9.13.3.2 FLOAT from LONG or Boolean

When a LONG or Boolean is converted to FLOAT, the integer value is loaded into the FLOAT. Booleans will be converted to -1 or 0 depending on whether the value is non-zero or zero. LONG integers greater than 24 bits (16,777,215; the size of the mantissa for a FLOAT) will lose resolution when converted to FLOAT.

9.13.3.3 LONG from FLOAT or Boolean

Booleans will be converted to -1 or 0. When a FLOAT is converted to a LONG, it is truncated. This conversion is the same as the INT function (Section 10.6.4 Arithmetic Functions). The conversion is to an integer equal to or less than the value of the float (e.g., 4.6 becomes 4, -4.6 becomes -5).

If a FLOAT is greater than the largest allowable LONG (+2,147,483,647), the integer is set to the maximum. If a FLOAT is less than the smallest allowable LONG (-2,147,483,648), the integer is set to the minimum.

9.13.3.4 Integers in Expressions

LONGs are evaluated in expressions as integers when possible. EXAMPLE 9.13-3 illustrates evaluation of integers as LONGs and FLOATs.

EXAMPLE 9.13-3. CRBASIC Code: Evaluation of Integers

```
Public X, I AS Long
BeginProg
    I = 126
    X = (I+3) * 3.4
        'I+3 is evaluated as an integer,
        'then converted to FLOAT before
        'it is multiplied by 3.4
EndProg
```

9.13.3.5 Constants Conversion

Constants are not declared with a data type, so the CR1000 assigns the data type as needed. If a constant (either entered as a number or declared with CONST) can be expressed correctly as an integer, the compiler will use the type that is most efficient in each expression. The integer version will be used if possible, i.e., if the expression has not yet encountered a float. EXAMPLE 9.13-4 lists a programming case wherein a value normally considered an integer (10) is assigned by the CR1000 to be As Float.

EXAMPLE 9.13-4. CRBASIC Code: Constants to LONGs or FLOATs

```
Public I AS Long
Public A1, A2
CONST ID = 10
BeginProg


    A1 = A2 + ID

    I = ID * 5

EndProg
```

In EXAMPLE 9.13-4, I is an integer. A1 and A2 are Floats. The number 5 is loaded As Float to add efficiently with constant ID, which was compiled As Float for the previous expression to avoid an inefficient run time conversion from integer to float before each floating point addition.

9.13.4 Logical Expressions

Measurements made by the CR1000 can indicate the absence or presence of certain conditions. For example, an RH measurement of 100% indicates a condensation event such as fog, rain, or dew. CR1000's can render events into a binary form for further processing, i.e., events can either be TRUE[1] (equal to

[1] Several words are commonly interchanged with True / False such as High / Low, On / Off, Yes / No, Set / Reset, Trigger / Do Not Trigger. The CR1000 understands only True / False or -1 / 0, however. The CR1000 represents "true" with "-1" because AND / OR operators are the same for logical statements and binary bitwise comparisons.

-1 in the CR1000)[2], indicating the condition occurred or is occurring, or FALSE (0), indicating the condition has not yet occurred or is over.

The CR1000 is able to translate the conditions listed in TABLE 9.13-1 to binary form (-1 or 0), using the listed instructions and saving the binary form in the memory location indicated.

TABLE 9.13-1. Binary Conditions of TRUE and FALSE

Condition	CRBASIC Instruction(s) Used	Memory Location of Binary Result
Time	TimeIntoInterval () IfTime ()	Variable, System Variable, System
Control Port Trigger	WaitDigTrig ()	System
Communications	VoiceBeg () ComPortIsActive () PPPClose ()	System Variable Variable
Measurement Event	DataEvent ()	System

Using TRUE or FALSE conditions with logic operators such as AND and OR, logical expressions can be encoded into a CR1000 to perform three general logic functions, facilitating conditional processing and control applications.

1. Evaluate an expression, take one path or action if the expression is true (= -1), and / or another path or action if the expression is false (= 0).
2. Evaluate multiple expressions linked with **AND** or **OR**.
3. Evaluate multiple and / or links.

The following commands and logical operators are used to construct logical expressions. EXAMPLE 9.13-5 a - f demonstrate some logical expressions.

IF
AND
OR
NOT
XOR
IMP
IIF

[2] In the binary number system internal to the CR1000, "-1" is expressed with all bits equal to 1 (11111111). "0" has all bits equal to 0 (00000000). When -1 is ANDed with any other number, the result is the other number. This ensures that if the other number is non-zero (true), the result will be non-zero.

EXAMPLE 9.13-5. Logical Expression Examples

a. If X >= 5 then Y = 0

Sets the variable Y to 0 if the expression "X >= 5" is true, i.e. if X is greater than or equal to 5. The CR1000 evaluates the expression (X >= 5) and registers in system memory a -1 if the expression is true, or a 0 if the expression is false.

b. If X >= 5 AND Z = 2 then Y = 0

Sets Y = 0 only if both X >= 5 and Z = 2 are true.

c. If X >= 5 OR Z = 2 then Y = 0

Sets Y = 0 if either X >= 5 or Z = 2 is true.

d. If 6 then Y = 0.

"If 6" is true since "6" (a non-zero number) is returned, so Y will be set to 0 every time the statement is executed. Likewise, consider the equally impractical statement

e. If 0 then Y = 0.

"If 0" is false since "0" is returned, so Y will never be set to 0 by this statement.

f. Z = (X > Y).

Z will equal -1 if X > Y, or Z will equal 0 if X <= Y.

g. The NOT operator simply complements every bit in the word. A Boolean can only be 0 or have all of its bits set to 1. Complementing a Boolean will turn TRUE (all bits set) to FALSE (all bits complemented to 0).

Example: (a AND b) = (26 AND 26) = (&b11010 AND &b11010) = &b11010. NOT (&b11010) yields &b00101. This is non-zero, so when converted to a BOOLEAN, it becomes TRUE.

```
Public a AS Long
Public b AS Long
Public is_true AS Boolean
Public not_is_true AS Boolean
Public not_a_and_b AS Boolean

BeginProg
    a = 26
    b = a
    Scan (1,Sec,0,0)
        is_true = a AND b                 'This evaluates to TRUE.
        not_is_true = NOT (is_true)       'This evaluates to FALSE.
        not_a_and_b = NOT (a AND b)       'This evaluates to TRUE!
    NextScan
EndProg
```

9.13.5 String Expressions

CRBASIC allows the addition or concatenation of string variables to variables of all types using & and + operators. To ensure consistent results, use "&" when concatenating strings. Use "+" when concatenating strings to other variable types. EXAMPLE 9.13-6 demonstrates CRBASIC code for concatenating strings and integers.

EXAMPLE 9.13-6. CRBASIC Code: String and Variable Concatenation

```
'Declare Variables
Dim Wrd(8) As String * 10
Public Phrase(2) As String * 80
Public PhraseNum(2) As Long

'Declare Data Table
DataTable (Test,1,-1)
    DataInterval (0,15,Sec,10)

    'Write phrases to data table "Test"
    Sample (2,Phrase,String)

EndTable

'Program
BeginProg
    Scan (1,Sec,0,0)

        'Assign strings to String variables
        Wrd(1) = " ":Wrd(2) = "Good":Wrd(3) = "morning":Wrd(4) = "Don't"
        Wrd(5) = "do":Wrd(6) = "that":Wrd(7) = ",":Wrd(8) = "Dave"

        'Assign integers to Long variables
        PhraseNum(1) = 1:PhraseNum(2) = 2

        'Concatenate string "1 Good  morning, Dave"
        Phrase(1) = PhraseNum(1)+Wrd(1)&Wrd(2)&Wrd(1)&Wrd(3)&Wrd(7)&Wrd(1)&Wrd(8)

        'Concatenate string "2 Don't do that, Dave"
        Phrase(2) = PhraseNum(2)+Wrd(1)&Wrd(4)&Wrd(1)&Wrd(5)&Wrd(1)&Wrd(6)&Wrd(7)&Wrd(1)&Wrd(8)

        CallTable Test

    NextScan
EndProg
```

9.14 Program Access to Data Tables

CRBASIC has syntax provisions facilitating access to data in tables or information relating to a table. Except when using the GetRecord () instruction (Section 10.15 Data Table Access and Management), the syntax is entered directly into the CRBASIC program through a variable name. The general form is:

"TableName.FieldName_Prc (Fieldname Index, Records Back)".

Where:

TableName = name of the data table

FieldName = name of the variable from which the processed value is derived

Prc = Abbreviation of the name of the data process used. See TABLE 9.14-1 for a complete list of these abbreviations – not needed for values from Status or Public tables.

Fieldname Index = Array element number (optional)

Records Back = How far back into the table to go to get the value (optional)

TABLE 9.14-1. Abbreviations of Names of Data Processes

Abbreviation	Process Name
Tot	Totalize
Avg	Average
Max	Maximum
Min	Minimum
SMM	Sample at Max or Min
Std	Standard Deviation
MMT	Moment
	Sample
Hst	Histogram
H4D	Histogram4D
FFT	FFT
Cov	Covariance
RFH	RainFlow Histogram
LCr	Level Crossing
WVc	WindVector
Med	Median
ETsz	ET
RSo	Solar Radiation (from ET)
TMx	Time of Max
TMn	Time of Min

For instance, to access the number of watchdog errors, use the "status.watchdogerrors," where "status" is the table name, and "watchdogerrors" is the field name.

Seven special variable names are used to access information about a table:

EventCount
EventEnd
Output
Record
TableFull
TableSize
TimeStamp

Consult CRBASIC Editor Help Index topic “DataTable access” for complete information.

Section 10. CRBASIC Programming Instructions

Read more! Parameter listings, application information, and code examples are available in CRBASIC Editor Help. CRBASIC Editor is part of PC400, LoggerNet, and RTDAQ.

Select instructions are explained more fully, some with example code, in Section 11 Programming Resource Library. Example code is throughout the CR1000 manual. Refer to the table of contents Example index.

10.1 Program Declarations

Alias
Assigns a second name to a variable.
Syntax
Alias [variable] = [alias name]

AngleDegrees
Sets math functions to use degrees instead of radians.
Syntax
AngleDegrees

As
Sets data type for DIM or PUBLIC variables.
Syntax
Dim [variable] AS [data type]

Const
Declares symbolic constants for use in place of numeric entries.
Syntax
Const [constant name] = [value or expression]

ConstTable … EndConstTable
Declares constants that can be changed using the datalogger keyboard or terminal 'C' option. The program is recompiled with the new values when values change.
Syntax
ConstTable
[constant a] = [value]
[constant b] = [value]
[constant c] = [value]
EndConstTable

Dim
Declares and dimensions private variables. Dimensions are optional.
Syntax
Dim [variable name (x,y,z)]

ESSVariables
Automatically declares all the variables required for the datalogger when used in an Environmental Sensor Station application. Used in conjunction with ESSInitialize.

Syntax

ESSVariables

PipelineMode
Configures datalogger to perform measurement tasks separate from, but concurrent with, processing tasks.

Syntax

PipelineMode

PreserveVariables
Retains values in Dim or Public variables when program restarts after a power failure or manual stop.

Syntax

PreserveVariables

Public
Declares and dimensions public variables. Dimensions are optional.

Syntax

Public [variable name (x,y,z)]

SetSecurity
Sets numeric password for datalogger security levels 1, 2, and 3. Security[I] are constants. Executes at compile time.

Syntax

SetSecurity (security[1], security[2], security[3])

SequentialMode
Configures datalogger to perform tasks sequentially.

Syntax

SequentialMode

Station Name
Sets the station name internal to the CR1000. Does not affect data files produced by support software.

Syntax

StationName (name of station)

Sub, Exit Sub, End Sub
Declares the name, variables, and code that form a Subroutine. Argument list is optional. Exit Sub is optional.

Syntax

```
Sub subname (argument list)
        [ statement block ]
        Exit Sub
        [ statement block ]
End Sub
```

Units
Assigns a unit name to a field associated with a variable.

Syntax

Units [variable] = [unit name]

WebPageBegin / WebPageEnd
See Section 11.2 Information Services.

10.2 Data Table Declarations

DataTable … EndTable
Mark the beginning and end of a data table.

Syntax

```
DataTable (Name, TrigVar, Size)
    [data table modifiers]
    [on-line storage destinations]
    [output processing instructions]
EndTable
```

10.2.1 Data Table Modifiers

DataEvent
Sets triggers to start and stop storing records within a table. One application is with WorstCase.

Syntax

```
DataEvent (RecsBefore, StartTrig, StopTrig, RecsAfter)
```

DataInterval
Sets the time interval for an output table.

Syntax

```
DataInterval (TintoInt, Interval, Units, Lapses)
```

FillStop
Sets a data table to fill and stop.

Syntax

```
FillStop
```

NOTE To reset a table after it fills and stops, use ResetTable () instruction or LoggerNet | Connect | Datalogger | View Station Status | Table Fill Times | Reset Tables.

OpenInterval
Sets time series processing to include all measurements since the last time data storage occurred.

Syntax

```
OpenInterval
```

10.2.2 On-Line Data Destinations

CardOut
Send output data to a CF card module.

Syntax

```
CardOut (StopRing, Size)
```

DSP4
Send data to the DSP4 display

Syntax

```
DSP4 (FlagVar, Rate)
```

TableFile
Writes a file from a data table to the datalogger CPU, user drive, or a compact flash card.

Syntax

TableFile ("FileName", Options, MaxFiles, NumRecs / TimeIntoInterval, Interval, Units, OutStat, LastFileName)

10.2.3 Data Storage Output Processing

FieldNames
Immediately follows an output processing instruction to change default field names.

Syntax

FieldNames ("Fieldname1 : Description1, Fieldname2 : Description2…")

10.2.3.1 Single-Source

Average
Stores the average value over the output interval for the source variable or each element of the array specified.

Syntax

Average (Reps, Source, DataType, DisableVar)

Covariance
Calculates the covariance of values in an array over time.

Syntax

Covariance (NumVals, Source, DataType, DisableVar, NumCov)

FFT
Performs a Fast Fourier Transform on a time series of measurements stored in an array.

Syntax

FFT (Source, DataType, N, Tau, Units, Option)

Maximum
Stores the maximum value over the output interval.

Syntax

Maximum (Reps, Source, DataType, DisableVar, Time)

Median
Stores the median of a dependant variable over the output interval

Syntax

Median (Reps, Source, MaxN, DataType, DisableVar)

Minimum
Stores the minimum value over the output interval.

Syntax

Minimum (Reps, Source, DataType, DisableVar, Time)

Moment
Stores the mathematical moment of a value over the output interval.

Sytnax

Moment (Reps, Source, Order, DataType, DisableVar)

PeakValley
Detects maxima and minima in a signal.
Syntax
PeakValley (DestPV, DestChange, Reps, Source, Hysteresis)

Sample
Stores the current value at the time of output.
Syntax
Sample (Reps, Source, DataType)

SampleFieldCal
Writes field calibration data to a table.
See Section 6.19 Calibration Functions.

SampleMaxMin
Samples a variable when another variable reaches its maximum or minimum for the defined output period.
Syntax
SampleMaxMin (Reps, Source, DataType, DisableVar)

StdDev
Calculates the standard deviation over the output interval.
Syntax
StdDev (Reps, Source, DataType, DisableVar)

Totalize
Sums the total over the output interval.
Syntax
Totalize (Reps, Source, DataType, DisableVar)

10.2.3.2 Multiple-Source

ETsz
Stores evapotranspiration (ETsz) and solar radiation (RSo).
Syntax
ETsz (Temp, RH, uZ, Rs, Longitude, Latitude, Altitude, Zw, Sz, DataType, DisableVar)

WindVector

Read more! See Section 11.5 Wind Vector.

Processes wind speed and direction from either polar or orthogonal sensors. To save processing time, only calculations resulting in the requested data are performed.
Syntax
WindVector (Repetitions, Speed/East, Direction/North, DataType, DisableVar, Subinterval, SensorType, OutputOpt)

10.2.4 Histograms

Histogram
Processes input data as either a standard histogram (frequency distribution) or a weighted value histogram.

Syntax

Histogram (BinSelect, DataType, DisableVar, Bins, Form, WtVal, LoLim, UpLim)

Histogram4D
Processes input data as either a standard histogram (frequency distribution) or a weighted value histogram of up to 4 dimensions.

Syntax

Histogram4D (BinSelect, Source, DataType, DisableVar, Bins1, Bins2, Bins3, Bins4, Form, WtVal, LoLim1, UpLim1, LoLim2, UpLim2, LoLim3, UpLim3, LoLim4, UpLim4)

LevelCrossing
Processes data into a one or two dimensional histogram using a level crossing counting algorithm.

Syntax

LevelCrossing (Source, DataType, DisableVar, NumLevels, 2ndDim, CrossingArray, 2ndArray, Hysteresis, Option)

RainFlow
Creates a rainflow histogram.

Syntax

RainFlow (Source, DataType, DisableVar, MeanBins, AmpBins, Lowlimit, Highlimit, MinAmp, Form)

10.3 Single Execution at Compile

Reside between BeginProg and Scan Instructions.

ESSInitialize
Placed after the BeginProg instruction but prior to the Scan instruction to initialize ESS variables at compile time.

Syntax

ESSInitialize

MovePrecise
Used in conjunction with AddPrecise, moves a high precision variable into another input location.

Syntax

MovePrecise (PrecisionVariable, X)

PulseCountReset
Resets the pulse counters and the running averages used in the pulse count instruction.

Syntax

PulseCountReset

10.4 Program Control Instructions

10.4.1 Common Controls

BeginProg … EndProg
Mark the beginning and end of a program.

Syntax

```
BeginProg
    Program Code
EndProg
```

Call
Transfers program control from the main program to a subroutine.

Syntax

```
Call subname (list of variables)
```

CallTable
Calls a data table, typically for output processing.

Syntax

```
CallTable [TableName]
```

Delay
Delays the program.

Syntax

```
Delay (Option, Delay, Units)
```

Do … Loop
Repeats a block of statements while a condition is true or until a condition becomes true.

Syntax

```
Do [{While | Until} condition]
    [statementblock]
    [ExitDo]
    [statementblock]
Loop

-or-

Do
    [statementblock]
    [ExitDo]
    [statementblock]
Loop [{While | Until} condition]
```

Exit
Exit program.

Syntax

```
Exit
```

For ... Next
Repeats a group of instructions a specified number of times.

Syntax

```
For counter = start To end [ Step increment ]
    [statementblock]
    [ExitFor]
    [statementblock]
Next [counter [, counter][, ...]]
```

If ... Then ... Else … ElseIf ... EndIf

NOTE EndSelect and EndIf call the same CR1000 function

Allows conditional execution, based on the evaluation of an expression. Else is optional. ElseIf is optional.

Syntax

```
If [condition] Then [thenstatements] Else [elsestatements]

-or-

If [condition 1] Then
    [then statements]
ElseIf [condition 2] Then
    [elseif then statements]
Else
    [else statements]
EndIf
```

Scan … ExitScan … NextScan
Establishes the program scan rate. ExitScan is optional.

Syntax

```
Scan (Interval, Units, Option, Count)
    ...
Exit Scan
    ...
Next Scan
```

Select Case … Case … Case Is … Case Else … EndSelect

NOTE EndSelect and EndIf call the same CR1000 function

Executes one of several statement blocks depending on the value of an expression. CaseElse is optional

Syntax

```
Select Case testexpression
Case      [expression 1]
          [statement block 1]
Case      [expression 2]
          [statement block 2]
Case Is   [expression fragment]
Case Else
          [statement block 3]
EndSelect
```

Slow Sequence
Marks the beginning of a section of code that will run concurrently with the main program.

Syntax

```
SlowSequence
```

SubScan … NextSubScan
Controls a multiplexer or measures some analog inputs at a faster rate than the program scan.

Syntax

```
SubScan (SubInterval, Units, Count)
    Measurements and processing
NextSubScan
```

TriggerSequence
Used with WaitTriggerSequence to control the execution of code within a slow sequence.

Syntax

```
TriggerSequence (SequenceNum, Timeout)
```

WaitTriggerSequence
Used with TriggerSequence to control the execution of code within a slow sequence.

Syntax

```
WaitTriggerSequence
```

WaitDigTrig
Triggers a measurement scan from an external digital trigger.

Syntax

```
WaitDigTrig (ControlPort, Option)
```

While…Wend
Execute a series of statements in a loop as long as a given condition is true.

Syntax

```
While Condition
    [StatementBlock]
Wend
```

10.4.2 Advanced Controls

Data … Read … Restore
Defines a list of Float constants to be read (using Read) into a variable array later in the program.

Syntax

```
Data [list of constants]

Read [VarExpr]

Restore
```

DataLong … Read … Restore
Defines a list of Long constants to be read (using Read) into a variable array later in the program.

Syntax

DataLong [list of constants]

Read [VarExpr]

Restore

Read
Reads constants from the list defined by Data or DataLong into a variable array.

Syntax

Read [VarExpr]

Restore
Resets the location of the Read pointer back to the first value in the list defined by Data or DataLong.

10.5 Measurement Instructions

Read more! For information on recording data from RS-232 and TTL output sensors, see Section 10.11 Serial Input / Output and Section 11.8 Serial I/O.

10.5.1 Diagnostics

Battery
Measures input voltage.

Syntax

Battery (Dest)

ComPortIsActive
Returns a Boolean value, based on whether or not activity is detected on the specified COM port.

Syntax

variable = ComPortIsActive (ComPort)

InstructionTimes
Returns the execution time of each instruction in the program.

Syntax

InstructionTimes (Dest)

MemoryTest
Performs a test on the datalogger's CPU and Task memory and store the results in a variable.

Syntax

MemoryTest (Dest)

PanelTemp
This instruction measures the panel temperature in °C.

Syntax

PanelTemp (Dest, Integ)

RealTime
Derives the year, month, day, hour, minute, second, microsecond, day of week, and day of year from the datalogger clock and stores the results in an array.
Syntax
RealTime (Dest)

Signature
Returns the signature for program code in a datalogger program.
Syntax
variable = Signature

10.5.2 Voltage

VoltDiff
Measures the voltage difference between H and L inputs of a differential channel
Syntax
VoltDiff (Dest, Reps, Range, DiffChan, RevDiff, SettlingTime, Integ, Mult, Offset)

VoltSe
Measures the voltage at a single-ended input with respect to ground.
Syntax
VoltSe (Dest, Reps, Range, SEChan, MeasOfs, SettlingTime, Integ, Mult, Offset)

10.5.3 Thermocouples

Read more! See Section 4.34 Thermocouple Measurements.

TCDiff
Measures a differential thermocouple.
Syntax
TCDiff (Dest, Reps, Range, DiffChan, TCType, TRef, RevDiff, SettlingTime, Integ, Mult, Offset)

TCSe
Measures a single-ended thermocouple.
Syntax
TCSe (Dest, Reps, Range, SEChan, TCType, TRef, MeasOfs, SettlingTime, Integ, Mult, Offset)

10.5.4 Bridge Measurements

Read more! See Section 4.3 Bridge Resistance Measurements.

BrHalf
Measures single-ended voltage of a 3 wire half bridge. Delay is optional.
Syntax
BrHalf (Dest, Reps, Range, SEChan, Vx/ExChan, MeasPEx, ExmV, RevEx, SettlingTime, Integ, Mult, Offset)

BrHalf3W
Measures ratio of R_s / R_f of a 3 wire half bridge.
Syntax
BrHalf3W (Dest, Reps, Range, SEChan, Vx/ExChan, MeasPEx, ExmV, RevEx, SettlingTime, Integ, Mult, Offset)

BrHalf4W
Measures ratio of R_s / R_f of a 4 wire half bridge.
Syntax
BrHalf4W (Dest, Reps, Range1, Range2, DiffChan, Vx/ExChan, MeasPEx, ExmV, RevEx, RevDiff, SettlingTime, Integ, Mult, Offset)

BrFull
Measures ratio of Vdiff / Vx of a 4 wire full bridge. Reports 1000 * (V_{diff} / V_x).
Syntax
BrFull (Dest, Reps, Range, DiffChan, Vx/ExChan, MeasPEx, ExmV, RevEx, RevDiff, SettlingTime, Integ, Mult, Offset)

BrFull6W
Measures ratio of V_{diff2} / V_{diff1} of a 6 wire full bridge. Reports 1000 * (V_{diff2} / V_{diff1}).
Syntax
BrFull6W (Dest, Reps, Range1, Range2, DiffChan, Vx/ExChan, MeasPEx, ExmV, RevEx, RevDiff, SettlingTime, Integ, Mult, Offset)

10.5.5 Excitation

ExciteV
This instruction sets the specified switched voltage excitation channel to the voltage specified.
Syntax
ExciteV (Vx/ExChan, ExmV, XDelay)

SW12
Sets a switched 12-volt supply high or low.
Syntax
SW12 (State)

10.5.6 Pulse

Read more! See Section 4.5 Pulse Count Measurement.

NOTE Pull-up resistors are required when using digital I/O (control) ports for pulse input (Section 4.5.2).

PulseCount
Measures number or frequency of voltages pulses on a pulse channel.
Syntax
PulseCount (Dest, Reps, PChan, PConfig, POption, Mult, Offset)

10.5.7 Digital I/O

Read more! See Section 11.11 Programming for Control.

CheckPort
Returns the status of a control port.
Syntax
CheckPort (Port)

PeriodAvg
Measures the period of a signal on any single-ended voltage input channel.
Syntax
PeriodAvg (Dest, Reps, Range, SEChan, Threshold, PAOption, Cycles, Timeout, Mult, Offset)

PortsConfig
Configure control ports as input or output.
Syntax
PortsConfig (Mask, Function)

PortGet
Reads the status of a control port.
Syntax
PortGet (Dest, Port)

PortSet
Sets the specified port high or low.
Syntax
PortSet (Port, State)

PulsePort
Toggles the state of a control port, delays the specified amount of time, toggles the port, and delays a second time.
Syntax
PulsePort (Port, Delay)

PWM
Performs a pulse width modulation on a control I/O port.
Syntax
PWM (Source,Port,Period,Units)

ReadIO
Reads the status of selected control I/O ports.
Syntax
ReadIO (Dest, Mask)

TimerIO
Measures interval or frequency on a digital I/O port.
Syntax
TimerIO (Dest, Edges, Function, Timeout, Units)

VibratingWire
The VibratingWire instruction is used to measure a vibrating wire sensor with a swept frequency (from low to high).

Syntax

VibratingWire (Dest, Reps, Range, SEChan, Vx/ExChan, StartFreq, EndFreq, TSweep, Steps, DelMeas, NumCycles, DelReps, Multiplier, Offset)

WriteIO
WriteIO is used to set the status of selected control I/O channels (ports) on the CR1000.

Syntax

WriteIO (Mask, Source)

10.5.8 SDI-12

Read more! See Section 11.3 SDI-12 Support.

SDI12Recorder
The SDI12Recorder instruction is used to retrieve the results from an SDI-12 sensor.

Syntax

SDI12Recorder (Dest, SDIPort, SDIAddress, SDICommand, Multiplier, Offset)

SDI12SensorSetup
Sets up the datalogger to act as an SDI12 sensor

SDI12SensorResponse
Holds the source of the data to send to the SDI12 recorder.

Syntax

SDI12SensorSetup (Repetitions, SDIPort, SDIAddress, ResponseTime)

SDI12SensorResponse (SDI12Source)

10.5.9 Specific Sensors

CS110
Measures electric field by means of a CS110 electric field meter.

Syntax

CS110 (Dest, Leakage, Status, Integ, Mult, Offset)

CS110Shutter
Controls the shutter of a CS110 electric field meter.

Syntax

CS110Shutter (Status, Move)

CS616
Enables and measures a CS616 water content reflectometer.

Syntax

CS616 (Dest, Reps, SEChan, Port, MeasPerPort, Mult, Offset)

CS7500
Communicates with the CS7500 open path CO_2 and H_2O sensor.
Syntax
CS7500 (Dest, Reps, SDMAddress, CS7500Cmd)

CSAT3
Communicates with the CSAT3 three-dimensional sonic anemometer.
Syntax
CSAT3 (Dest, Reps, SDMAddress, CSAT3Cmd, CSAT3Opt)

HydraProbe
Reads the Stevens Vitel SDI-12 Hydra Probe sensor.
Syntax
HydraProbe (Dest, SourceVolts, ProbeType, SoilType)

TGA
Measures a TGA100A trace gas analyzer system.
Syntax
TGA (Dest, SDMAddress, DataList, ScanMode)

Therm107
Measures a Campbell Scientific 107 thermistor.
Syntax
Therm107 (Dest, Reps, SEChan, Vx/ExChan, SettlingTime, Integ, Mult, Offset)

Therm108
Measures a Campbell Scientific 108 thermistor.
Syntax
Therm108 (Dest, Reps, SEChan, Vx/ExChan, SettlingTime, Integ, Mult, Offset)

Therm109
Measures a Campbell Scientific 109 thermistor.
Syntax
Therm109 (Dest, Reps, SEChan, Vx/ExChan, SettlingTime, Integ, Mult, Offset)

10.5.10 Peripheral Device Support

Multiple SDM instructions can be used within a program.

AM25T
Controls the AM25T Multiplexer.
Syntax
AM25T (Dest, Reps, Range, AM25TChan, DiffChan, TCType, Tref, ClkPort, ResPort, VxChan, RevDiff, SettlingTime, Integ, Mult, Offset)

AVW200
Enables CR1000 to get measurements from an AVW200 Vibrating Wire Spectrum Analyzer.
Syntax
AVW200 (Result, ComPort, NeighborAddr, PakBusAddr, Dest, AVWChan, MuxChan, Reps, BeginFreq, EndFreq, ExVolt, Therm50_60Hz, Multiplier, Offset)

SDMAO4
Sets output voltage levels in an SDM-AO4 analog output device.
Syntax
SDMAO4 (Source, Reps, SDMAdress)

SDMCAN
Reads and controls an SDM-CAN interface.
Syntax
SDMCAN (Dest, SDMAddress, TimeQuanta, TSEG1, TSEG2, ID, DataType,

SDMCD16AC
Controls an SDM-CD16AC, SDM-CD16, or SDM-CD16D control device.
Syntax
SDMCD16AC (Source, Reps, SDMAddress)

SDMCVO4
Control the SDM-CVO4 four channel current/voltage output device.
Syntax
SDMCVO4 (CVO4Source, CVO4Reps, SDMAddress, CVO4Mode)

SDMINT8
Controls and reads an SDM-INT8.
Syntax
SDMINT8 (Dest, Address, Config8_5, Config4_1, Funct8_5, Funct4_1, OutputOpt, CaptureTrig, Mult, Offset)

SDMIO16
Sets up and measures an SDM-IO16 control port expansion device.
Syntax
SDMIO16 (Dest, Status, Address, Command, Mode Ports 16-13, Mode Ports 12-9, Mode Ports 8-5, Mode Ports 4-1, Mult, Offset)

SDMSIO4
Controls and transmits / receives data from an SDM-SIO4 Interface.
Syntax
SDMSIO4 (Dest, Reps, SDMAddress, Mode, Command, Param1, Param2, ValuesPerRep, Multiplier, Offset)

SDMSpeed
Changes the rate the CR1000 uses to clock SDM data.
Syntax
SDMSpeed (BitPeriod)

SDMSW8A
Controls and reads an SDM-SW8A.
Syntax
SDMSW8A (Dest, Reps, SDMAddress, FunctOp, SW8AStartChan, Mult, Offset)

SDMTrigger
Synchronize when SDM measurements on all SDM devices are made.
Syntax

SDMX50
Allows individual multiplexer switches to be activated independently of the TDR100 instruction.

Syntax

SDMX50 (SDMAddress, Channel)

TDR100
Directly measures TDR probes connected to the TDR100 or via an SDMX50.

Syntax

TDR100 (Dest, SDMAddress, Option, Mux/ProbeSelect, WaveAvg, Vp, Points, CableLength, WindowLength, ProbeLength, ProbeOffset, Mult, Offset)

TimedControl
Allows a sequence of fixed values and durations to be controlled by the SDM task sequencer enabling SDM-CD16 control events to occur at a precise time.

Syntax

TimedControl (Size, SyncInterval, IntervalUnits, DefaultValue, CurrentIndex, Source, ClockOption)

10.6 Processing and Math Instructions

10.6.1 Mathematical Operators

NOTE Program declaration AngleDegrees (Sec 12.1) sets math functions to use degrees instead of radians.

^ Raise to PowerResult is always promoted to a float to avoid problems that may occur when raising an integer to a negative power. However, loss of precision occurs if result is > 24 bits.

For example:

(46340 ^ 2) will yield 2,147,395,584 (not precisely correct)

whereas

(46340 * 46340) will yield 2,147,395,600 (precisely correct)

Simply use repeated multiplications instead of ^ operators when full 32-bit precision is required.

Same functionality as PWR instruction (12.6.4).

* Multiply
/ Divide
Use INTDV to retain 32-bit precision
\+ Add
\- Subtract
= Equals
<> Not Equal
> Greater Than

< Less Than
>= Greater Than or Equal
<= Less Than or Equal

Bit Shift Operators

Bit shift operators (<< and >>) allow the program to manipulate the positions of patterns of bits within an integer (CRBASIC Long type). Here are some example expressions and the expected results:

&B00000001 << 1 produces &B00000010 (decimal 2)
&B00000010 << 1 produces &B00000100 (decimal 4)
&B11000011 << 1 produces &B10000110 (decimal 134)
&B00000011 << 2 produces &B00001100 (decimal 12)
&B00001100 >> 2 produces &B00000011 (decimal 3)

The result of these operators is the value of the left hand operand with all of its bits moved by the specified number of positions. The resulting "holes" are filled with zeroes.

Consider a sensor or protocol that produces an integer value that is a composite of various "packed" fields. This approach is quite common in order to conserve bandwidth and/or storage space. Consider the following example of an eight byte value:

bits 7-6: value_1
bits 5-4: value_2
bits 3-0: value_3

Code to extract these values is shown in EXAMPLE 10.6-1.

EXAMPLE 10.6-1. CRBASIC Code: Using bit shift operators.

```
Dim input_val as LONG
Dim value_1 as LONG
Dim value_2 as LONG
Dim value_3 as LONG

'read input_val somehow
value_1 = (input_val AND &B11000000) >> 6
value_2 = (input_val AND &B00110000) >> 4

'note that value_3 does not need to be shifted
value_3 = (input_val AND &B00001111)
```

With unsigned integers, shifting left is the equivalent of multiplying by two and shifting right is the equivalent of dividing by two.

<<
Bit shift left
Syntax
Variable = Numeric Expression >> Amount

>>
Bit shift right
Syntax
Variable = Numeric Expression >> Amount

10.6.2 Logical Operators

AND
Used to perform a logical conjunction on two expressions.
Syntax
result = expr1 AND expr2

NOT
Performs a logical negation on an expression.
Syntax
result = NOT expression

OR
Used to perform a logical disjunction on two expressions.
Syntax
result = expr1 OR expr2

XOR
Performs a logical exclusion on two expressions.
Syntax
result = expr1 XOR expr2

IIF
Evaluates a variable or expression and returns one of two results based on the outcome of that evaluation.
Syntax
Result = IIF (Expression, TrueValue, FalseValue)

IMP
Performs a logical implication on two expressions.
Syntax
result = expression1 IMP expression2

10.6.3 Trigonometric Functions

10.6.3.1 Derived Functions

TABLE 10.6-1 is a list of trigonometric functions that can be derived from functions intrinsic to CRBASIC.

TABLE 10.6-1. Derived Trigonometric Functions

Function	CRBASIC Equivalent
Secant	Sec = 1 / Cos(X)
Cosecant	Cosec = 1 / Sin(X)
Cotangent	Cotan = 1 / Tan(X)
Inverse Secant	Arcsec = Atn(X / Sqr(X * X - 1)) + Sgn(Sgn(X) - 1) * 1.5708
Inverse Cosecant	Arccosec = Atn(X / Sqr(X * X - 1)) + (Sgn(X) - 1) * 1.5708
Inverse Cotangent	Arccotan = Atn(X) + 1.5708
Hyperbolic Secant	HSec = 2 / (Exp(X) + Exp(-X))
Hyperbolic Cosecant	HCosec = 2 / (Exp(X) - Exp(-X))
Hyperbolic Cotangent	HCotan = (Exp(X) + Exp(-X)) / (Exp(X) - Exp(-X))
Inverse Hyperbolic Sine	HArcsin = Log(X + Sqr(X * X + 1))
Inverse Hyperbolic Cosine	HArccos = Log(X + Sqr(X * X - 1))
Inverse Hyperbolic Tangent	HArctan = Log((1 + X) / (1 - X)) / 2
Inverse Hyperbolic Secant	HArcsec = Log((Sqr(-X * X + 1) + 1) / X)
Inverse Hyperbolic Cosecant	HArccosec = Log((Sgn(X) * Sqr(X * X + 1) + 1) / X)
Inverse Hyperbolic Cotangent	HArccotan = Log((X + 1) / (X - 1)) / 2

10.6.3.2 Intrinsic Functions

ACOS
Returns the arc cosine of a number.

Syntax

```
x = ACOS(source)
```

ASIN
The ASIN function returns the arc sin of a number.

Syntax

```
x = ASIN(source)
```

ATN
Returns the arctangent of a number.

Syntax

```
x = ATN(source)
```

ATN2
Returns the arctangent of y / x.

Syntax

```
x = ATN(y , x)
```

COS
Returns the cosine of an angle specified in radians.
Syntax
x = COS(source)

COSH
Returns the hyperbolic cosine of an expression or value.
Syntax
x = COSH(source)

SIN
Returns the sine of an angle.
Syntax
x = SIN(source)

SINH
Returns the hyperbolic sine of an expression or value.
Syntax
x = SINH(Expr)

TAN
Returns the tangent of an angle.
Syntax
x = TAN(source)

TANH
Returns the hyperbolic tangent of an expression or value.
Syntax
x = TANH(Source)

10.6.4 Arithmetic Functions

ABS
Returns the absolute value of a number.
Syntax
x = ABS(source)

Ceiling
Rounds a value to a higher integer.
Syntax
variable = Ceiling(Number)

EXP
Returns e (the base of natural logarithms) raised to a power
Syntax
x = EXP(source)

Floor
Rounds a value to a lower integer.
Syntax
variable = Floor(Number)

FRAC
Returns the fractional part of a number.
Syntax
x = FRAC(source)

INT or FIX
Return the integer portion of a number.
Syntax
x = INT(source)
x = Fix(source)

INTDV
Performs an integer division of two numbers.
Syntax
X INTDV Y

LN or LOG
Returns the natural logarithm of a number. Ln and Log perform the same function.
Syntax
x = LOG(source)
x = LN(source)

NOTE LOGN = LOG(X) / LOG(N)

LOG10
The LOG10 function returns the base 10 logarithm of a number.
Syntax
x = LOG10 (number)

MOD
Divides two numbers and returns only the remainder.
Syntax
result = operand1 MOD operand2

PWR
Performs an exponentiation on a variable. Same functionality as ^ operator (6.6.1).
Syntax
PWR (X, Y)

RectPolar
Converts from rectangular to polar coordinates.
Syntax
RectPolar (Dest, Source)

Round
Rounds a value to a higher or lower number.
Syntax
variable = Round (Number, Decimal)

SGN
Finds the sign value of a number.
Syntax
x = SGN(source)

Sqr
Returns the square root of a number.
Syntax
x = SQR(number)

10.6.5 Integrated Processing

DewPoint
Calculates dew point temperature from dry bulb and relative humidity.
Syntax
DewPoint (Dest, Temp, RH)

PRT
Calculates temperature from the resistance of an RTD.
Syntax
PRT (Dest, Reps, Source, Mult, Offset)

SatVP
Calculates saturation vapor pressure (kPa) from temperature.
Syntax
SatVP (Dest, Temp)

StrainCalc
Converts the output of a bridge measurement instruction to microstrain.
Syntax
StrainCalc (Dest, Reps, Source, BrZero, BrConfig, GF, v)

VaporPressure
Calculates vapor pressure from temperature and relative.
Syntax
VaporPressure (Dest, Temp, RH)

WetDryBulb
Calculates vapor pressure (kPa) from wet and dry bulb temperatures and barometric pressure.
Syntax
WetDryBulb (Dest, DryTemp, WetTemp, Pressure)

10.6.6 Spatial Processing

AvgSpa
Computes the spatial average of the values in the source array.
Syntax
AvgSpa (Dest, Swath, Source)

CovSpa
Computes the spatial covariance of sets of data.
Syntax
CovSpa (Dest, NumOfCov, SizeOfSets, CoreArray, DatArray)

FFTSpa
Performs a Fast Fourier Transform on a time series of measurements.
Syntax
FFTSpa (Dest, N, Source, Tau, Units, Option)

MaxSpa
Finds the maximum value in an array.
Syntax
MaxSpa (Dest, Swath, Source)

MinSpa
Finds the minimum value in an array.
Syntax
MinSpa (Dest, Swath, Source)

RMSSpa
Computes the RMS (root mean square) value of an array.
Syntax
RMSSpa (Dest, Swath, Source)

SortSpa
Sorts the elements of an array in ascending order.
Syntax
SortSpa (Dest, Swath, Source)

StdDevSpa
Used to find the standard deviation of an array.
Syntax
StdDevSpa (Dest, Swath, Source)

10.6.7 Other Functions

AddPrecise
Used in conjunction with MovePrecise, allows high precision totalizing of variables or manipulation of high precision variables.
Syntax
AddPrecise (PrecisionVariable, X)

AvgRun
Stores a running average of a measurement.
Syntax
AvgRun (Dest, Reps, Source, Number)

Randomize
Initializes the random-number generator.
Syntax
Randomize (source)

RND
Generates a random number.
Syntax
RND (source)

10.7 String Functions

& Concatenates string variables
+ Concatenates string and numeric variables
- Compares two strings, returns zero if identical

10.7.1 String Operations

String Constants

Constant strings can be used in expressions using quotation marks, i.e.

FirstName = “Mike”

String Addition

Strings can be concatenated using the ‘+’ operator, i.e

FullName = FirstName + “ “ + MiddleName + “ “ + LastName

String Subtraction

String1-String2 results in an integer in the range of -255..+255.

String Conversion to / from Numeric

Conversion of Strings to Numeric and Numeric to Strings is done automatically when an assignment is made from a string to a numeric or a numeric to a string, if possible.

String Comparison Operators

The comparison operators =, >,<,<>, >= and <= operate on strings.

String Output Processing

The Sample () instruction will convert data types if source data type is different than the Sample () data type. Strings are disallowed in all output processing instructions except Sample ().

10.7.2 String Commands

ASCII

Returns the ASCII / ANSI code of a character in a string.

Syntax

Variable = ASCII (ASCIIString(1,1,X))

CHR

Insert an ANSI character into a string.

Syntax

CHR (Code)

CheckSum

Returns a checksum signature for the characters in a string.

Syntax

Variable = CheckSum (ChkSumString, ChkSumType, ChkSumSize)

FormatFloat

Converts a floating point value into a string.

Syntax

String = FormatFloat (Float, FormatString)

HEX
Returns a hexadecimal string representation of an expression.
Syntax
Variable = HEX (Expression)

HexToDec
Converts a hexadecimal string to a float or integer.
Syntax
Variable = HexToDec (Expression)

InStr
Find the location of a string within a string.
Syntax
Variable = InStr (Start, SearchString, FilterString, SearchOption)

LTrim
Returns a copy of a string with no leading spaces.
Syntax
variable = LTrim (TrimString)

Left
Returns a substring that is a defined number of characters from the left side of the original string.
Syntax
variable = Left (SearchString, NumChars)

Len
Returns the number of bytes in a string.
Syntax
Variable = Len (StringVar)

LowerCase
Converts a string to all lowercase characters.
Syntax
String = LowerCase (SourceString)

Mid
Returns a substring that is within a string.
Syntax
String = Mid (SearchString, Start, Length)

RTrim
Returns a copy of a string with no trailing spaces.
Syntax
variable = RTrim (TrimString)

Right
Returns a substring that is a defined number of characters from the right side of the original string.
Syntax
variable = Right (SearchString, NumChars)

Replace
Searches a string for a substring, and replace that substring with a different string.

Syntax

variable = Replace (SearchString, SubString, ReplaceString)

StrComp
Compares two strings by subtracting the characters in one string from the characters in another

Syntax

Variable = StrComp (String1, String2)

SplitStr
Splits out one or more strings or numeric variables from an existing string.

Syntax

SplitStr (SplitResult, SearchString, FilterString, NumSplit, SplitOption)

Trim
Returns a copy of a string with no leading or trailing spaces.

Syntax

variable = Trim (TrimString)

UpperCase
Converts a string to all uppercase characters

Syntax

String = UpperCase (SourceString)

10.8 Clock Functions

Within the CR1000, time is stored as integer seconds and nanoseconds into the second since midnight, January 1, 1990.

ClockReport
Sends the datalogger clock value to a remote datalogger in the PakBus network.

Syntax

ClockReport (ComPort, RouterAddr, PakBusAddr)

ClockSet
Sets the datalogger clock from the values in an array

Syntax

ClockSet (Source)

DaylightSaving
Defines daylight saving time. Determines if daylight saving time has begun or ended. Optionally advances or turns-back the datalogger clock one hour.

Syntax

variable = DaylightSaving (DSTSet, DSTnStart, DSTDayStart, DSTMonthStart, DSTnEnd, DSTDayEnd, DSTMonthEnd, DSTHour)

DaylightSavingUS
Determine if US daylight saving time has begun or ended. Optionally advance or turn-back the datalogger clock one hour.

Syntax

variable = DaylightSavingUS (DSTSet)

IfTime
Returns a number indicating True (-1) or False (0) based on the datalogger's real-time clock.

Syntax

If (IfTime (TintoInt, Interval, Units)) Then
-or-
Variable = IfTime (TintoInt, Interval, Units)

PakBusClock
Sets the datalogger clock to the clock of the specified PakBus device.

Syntax

PakBusClock (PakBusAddr)

RealTime
Parses year, month, day, hour, minute, second, micro-second, day of week, and/or day of year from the datalogger clock.

Syntax

RealTime (Dest)

SecsSince1990
Returns seconds elapsed since 1990. DataType is LONG. Used with GetRecord ().

Syntax

SecsSince1990 (date,option)

TimeIntoInterval
Returns a number indicating True (-1) or False (0) based on the datalogger's real-time clock.

Syntax

Variable = TimeIntoInterval (TintoInt, Interval, Units)
-or-
If TimeIntoInterval (TintoInt, Interval, Units)

Timer
Returns the value of a timer.

Syntax

variable = Timer (TimNo, Units, TimOpt)

10.9 Voice Modem Instructions

Refer to the Campbell Scientific voice modem manuals for complete information.

DialVoice
Defines the dialing string for a COM310 voice modem.

Syntax

DialVoice (DialString)

VoiceBeg, EndVoice
Mark the beginning and ending of voice code executed when the datalogger detects a ring from a voice modem.

Syntax

```
VoiceBeg
    voice code to be executed
EndVoice
```

VoiceHangup
Hangs up the voice modem.

Syntax

```
VoiceHangup
```

VoiceKey
Recognizes the return of characters 1 - 9, *, or #. VoiceKey is often used to add a delay, which provides time for the message to be spoken, in a VoiceBegin/EndVoice sequence.

Syntax

```
VoiceKey (TimeOut*IDH_Popup_VoiceKey_Timeout)
```

VoiceNumber
Returns one or more numbers (1 - 9) terminated by the # or * key.

Syntax

```
VoiceNumber (TimeOut*IDH_POPUP_VoiceKey_Timeout)
```

VoicePhrases
Provides a list of phrases for VoiceSpeak

Syntax

```
VoicePhrases (PhraseArray, Phrases)
```

VoiceSetup
Controls the hang-up of the COM310 voice modem.

Syntax

```
VoiceSetup (HangUpKey, ExitSubKey, ContinueKey, SecsOnLine,
UseTimeout, CallOut)
```

VoiceSpeak
Defines the voice string that should be spoken by the voice modem.

Syntax

```
VoiceSpeak ( "String" + Variable + "String"…, Precision)
```

10.10 Custom Keyboard and Display Menus

```
Note that custom menus are constructed with the following syntax before the
BeginProg instruction.
DisplayMenu ("MenuName", AddToSystem)
    MenuItem ("MenuItemName", Variable)
    MenuPick (Item1, Item2, Item3...)
    DisplayValue ("MenuItemName", tablename.fieldname)
    SubMenu (MenuName)
    MenuItem ("MenuItemName", Variable)
    EndSubMenu
EndMenu

BeginProg
    (Program Body)
EndProg
```

DisplayMenu … EndMenu
Marks the beginning and ending of a custom menu.

Syntax

```
DisplayMenu ("MenuName", AddToSystem)
    menu definition
EndMenu
```

MenuItem
Defines the name and associated measurement value for an item in a custom menu.

Syntax

```
MenuItem ("MenuItemName", Variable)
```

MenuPick
Creates a list of selectable options that can be used when editing a MenuItem value.

Syntax

```
MenuPick (Item1, Item2, Item3...)
```

DisplayValue
Defines the name and associated data table value or variable for an item in a custom menu.

Syntax

```
DisplayValue ("MenuItemName", Expression)
```

SubMenu … EndSubMenu
Defines the beginning and ending of a second level menu for a custom menu.

Syntax

```
DisplayMenu ("MenuName", 100)
    SubMenu ("MenuName")
        menu definition
    EndSubMenu
EndMenu
```

10.11 Serial Input / Output

Read more! See Section Error! Reference source not found. **Serial Input.**

MoveBytes
Moves binary bytes of data into a different memory location when translating big endian to little endian data.

Syntax

MoveBytes (Destination, DestOffset, Source, SourceOffset, NumBytes)

SerialClose
Closes a communications port that was previously opened by SerialOpen.

Syntax

SerialClose (ComPort)

SerialFlush
Clears any characters in the serial input buffer.

Syntax

SerialFlush (ComPort)

SerialIn
Sets up a communications port for receiving incoming serial data.

Syntax

SerialIn (Dest, ComPort, TimeOut, TerminationChar, MaxNumChars)

SerialInBlock
Stores incoming serial data. This function returns the number of bytes received.

Syntax

SerialInBlock (ComPort, Dest, MaxNumberBytes)

SerialInChk
Returns the number of characters available in the datalogger serial buffer.

Syntax

SerialInChk (ComPort)

SerialInRecord
Reads incoming serial data on a COM port and stores the data in a destination variable.

Syntax

SerialInRecord (COMPort, Dest, SyncChar, NBytes, EndWord, RecsBack)

SerialOpen
Sets up a datalogger port for communication with a non-PakBus device.

Syntax

SerialOpen (ComPort, BaudRate, Format, TXDelay, BufferSize)

SerialOut
Transmits a string over a datalogger communication port.

Syntax

SerialOut (ComPort, OutString, WaitString, NumberTries, TimeOut)

SerialOutBlock
Send binary data out a communications port. Used to support a transparent serial talk-through mode.

Syntax

SerialOutBlock (ComPort, Expression, NumberBytes)

10.12 Peer-to-Peer PakBus Communications

Read more! See Section 12 PakBus Overview for more information. Also see Campbell Scientific PakBus Networking Guide available at www.campbellsci.com.

Peer-to-peer PakBus instructions enable the datalogger to communicate with other PakBus devices. Instructions specify a COM port and a PakBus address. If the route to the device is not yet known, a direct route through the specified COM port is first tried. If the route is through a PakBus neighbor that must first be dialed, use DialSequence () to define and establish the route.

The PakBus Address is a variable that can be used in CRBASIC like any other variable.

The ComPort parameter sets a default communications port when a route to the remote node is not known. Enter one of the following commands:

ComRS-232
ComME
Com310
ComSDC7
ComSDC8
ComSDC10
ComSDC11
Com1 (C1,C2)
Com2 (C3,C4)
Com3 (C5,C6)
Com4 (C7,C8)
Com32 – Com46 (using SDM-SI01)

Baud rate on asynchronous ports (ComRS-232, ComME, Com1, Com2, Com3, and Com4) will default to 9600 unless set otherwise by SerialOpen (), or if the port is opened by an incoming PakBus packet at some other baud rate.

The baud rate parameter on asynchronous ports is restricted to 300, 1200, 4800, 9600, 19200, 38400, 57600, 115200, with 9600 the default.

In general, PakBus instructions write a result code to a variable indicating success or failure. Success sets the result code to 0. Otherwise, the result code increments. If communication succeeds but an error is detected, a negative result code is set. See CRBASIC Editor Help for an explanation of error codes.

The Timeout parameter in these instructions is in units of 0.01 seconds. If 0 is used, then the default timeout defined by the time of the best route is used. Use PakBusGraph “Hop Metrics” to calculate this time.

For instructions returning a result code, retries can be coded with CRBASIC logic as shown in the GetVariables example in EXAMPLE 10.12-1:

EXAMPLE 10.12-1. CRBASIC Code: Programming for retries in PakBus peer-to-peer communications.

```
For I = 1 to 3
    GetVariables (ResultCode,….)
    if ResultCode = 0 Exit For
Next
```

These communication instructions wait for a response or timeout before the program moves on to the next instruction. However, they can be used in a SlowSequence scan, which will not interfere with the execution of other program code. Optionally, the ComPort parameter can be negated, which will cause the instruction not to wait for a response or timeout. This will make the instruction execute faster but any data that it retrieves and the result code will be set when the communication is complete.

Broadcast
Sends a broadcast message to a PakBus network.

Syntax

```
Broadcast (ComPort, Message)
```

ClockReport
Sends the datalogger clock value to a remote datalogger in the PakBus network.

Syntax

```
ClockReport (ComPort, RouterAddr, PakBusAddr)
```

DataGram
Initializes a SerialServer / DataGram / PakBus application in the datalogger when a program is compiled.

Syntax

```
DataGram (ComPort, BaudRate, PakBusAddr, DestAppID,
SrcAppID)
```

DialSequence … EndDialSequence
Defines the code necessary to route packets to a PakBus device.

Syntax

```
DialSequence (PakBusAddr)

DialSuccess =  DialModem (ComPort, DialString, ResponseString)

EndDialSequence (DialSuccess)
```

GetDataRecord
Retrieves the most recent record from a data table in a remote PakBus datalogger and stores the record in the CR1000.

Syntax

```
GetDataRecord (ResultCode, ComPort, NeighborAddr, PakBusAddr,
Security, Timeout, Tries, TableNo, DestTableName)
```

GetFile
Gets a file from another PakBus datalogger.

Syntax

GetFile (ResultCode, ComPort, NeighborAddr, PakBusAddr, Security, TimeOut, "LocalFile", "RemoteFile")

GetVariables
Retrieves values from a variable or variable array in a data table of a PakBus datalogger.

Syntax

GetVariables (ResultCode, ComPort, NeighborAddr, PakBusAddr, Security, TimeOut, "TableName", "FieldName", Variable, Swath)

Network
In conjunction with SendGetVariables, configures destination dataloggers in a PakBus network to send and receive data from the host.

Syntax

Network (ResultCode, Reps, BeginAddr, TimeIntoInterval, Interval, Gap, GetSwath, GetVariable, SendSwath, SendVariable)

PakBusClock
Sets the datalogger clock to the clock of the specified PakBus device.

Syntax

PakBusClock (PakBusAddr)

Route
Returns the neighbor address of (or the route to) a PakBus datalogger.

Syntax

variable = Route (PakBusAddr)

Routes
Returns a list of known dynamic routes for a PakBus datalogger that has been configured as a router in a PakBus network.

Syntax

Routes (Dest)

SendData
Sends the most recent record from a data table to a remote PakBus device.

Syntax

SendData (ComPort, RouterAddr, PakBusAddr, DataTable)

SendFile
Sends a file to another PakBus datalogger.

Syntax

SendFile (ResultCode, ComPort, NeighborAddr, PakBusAddr, Security, TimeOut, "LocalFile", "RemoteFile")

SendGetVariables
Sends an array of values to the host PakBus datalogger, and / or retrieve an array of data from the host datalogger.

Syntax

SendGetVariables (ResultCode, ComPort, RouterAddr, PakBusAddr, Security, TimeOut, SendVariable, SendSwath, GetVariable, GetSwath)

SendTableDef
Sends the table definitions from a data table to a remote PakBus device.
Syntax
SendTableDef (ComPort, RouterAddr, PakBusAddr, DataTable)

SendVariables
Sends value(s) from a variable or variable array to a data table in a remote datalogger.
Syntax
SendVariables (ResultCode, ComPort, RouterAddr, PakBusAddr, Security, TimeOut, "TableName", "FieldName", Variable, Swath)

StaticRoute
Defines a static route to a PakBus datalogger.
Syntax
StaticRoute (ComPort, NeighborAddr, PakBusAddr)

TimeUntilTransmit
The TimeUntilTransmit instruction returns the time remaining, in seconds, before communication with the host datalogger.
Syntax
TimeUntilTransmit

10.13 Variable Management

FindSpa
Searches a source array for a value and returns the value's position in the array.
Syntax
FindSpa (SoughtLow, SoughtHigh, Step, Source)

Move
Moves the values in a range of variables into difference variables or fills a range of variables with a constant.
Syntax
Move (Dest, DestReps, Source, SourceReps)

10.14 File Management

Commands to access and manage files stored in CR1000 memory.

CalFile
Stores variable data, such as sensor calibration data, from a program into a non-volatile CR1000 memory file (CRD, CPU:drive, or USR: drive). CalFile pre-dates and is not used with the FieldCal function.
Syntax
CalFile (Source/Dest, NumVals, "Device:filename", Option)

FileCopy
Copies a file from one drive to another.
Syntax
FileCopy (FromFileName, ToFileName)

FileClose
Closes a FileHandle created by FileOpen.
Syntax
FileClose (FileHandle)

FileList
Returns a list of files that exist on the specified drive.
Syntax
FileList (Drive,DestinationArray)

FileManage
Manages program files from within a running datalogger program.
Syntax
FileManage ("Device: FileName", Attribute)

FileOpen
Opens an ASCII text file or a binary file for writing or reading.
Syntax
FileHandle = FileOpen ("FileName", "Mode", SeekPoint)

FileRead
Reads a file referenced by FileHandle and stores the results in a variable or variable array.
Syntax
FileRead (FileHandle, Destination, Length)

FileReadLine
Reads a line in a file referenced by a FileHandle and stores the result in a variable or variable array.
Syntax
FileReadLine (FileHandle, Destination, Length)

FileRename
Changes the name of file on the CR1000's CPU:, USR:, or CRD: drives.
Syntax
FileRename (drive:OldFileName, drive:NewFileName)

FileSize
Returns the size of the file in the previously opened file referenced by the FileHandle parameter.
Syntax
FileSize (FileHandle)

FileTime
Returns the time the file specified by the FileHandle was created.
Syntax
Variable = FileTime (FileHandle)

FileWrite
Writes ASCII or binary data to a file referenced in the program by FileHandle.
Syntax
FileWrite (FileHandle, Source, Length)

Include
Inserts code from a file (Filename) at the position of the Include () instruction at compile time. Include cannot be nested.

Syntax

Include ("Device:Filename")

NewFile
Determines if a file stored on the datalogger has been updated since the instruction was last run. Typically used with image files.

Syntax

NewFile (NewFileVar, “FileName”)

RunProgram
Runs a datalogger program file from the active program file.

Syntax

RunProgram ("Device:FileName", Attrib)

10.15 Data Table Access and Management

Commands to access and manage data stored in data tables, including Public and Status tables.

FileMark
Inserts a filemark into a data table.

Syntax

FileMark (TableName)

GetRecord
Retrieves one record from a data table and stores the results in an array. May be used with SecsSince1990 ().

Syntax

GetRecord (Dest, TableName, RecsBack)

ResetTable
Used to reset a data table under program control.

Syntax

ResetTable (TableName)

SetStatus ("FieldName", Value)
Changes the value for a setting in the datalogger Status table.

Syntax

SetStatus ("FieldName", Value)

TableName.FieldName
Accesses a specific field from a record in a table

Syntax

TableName.FieldName (FieldNameIndex, RecordsBack)

TableName.Output
Determine if data was written to a specific DataTable the last time the DataTable was called.

Syntax

TableName.Output (1,1)

TableName.Record
Determines the record number of a specific DataTable record.
Syntax
TableName.Record (1,n)

TableName.TableSize
Returns the number of records allocated for a data table
Syntax
TableName.TableSize (1,1)

TableName.TableFull
Indicates whether a fill and stop table is full or whether a ring-mode table has begun overwriting its oldest data.
Syntax
TableName.TableFull (1,1)

TableName.TimeStamp
Returns the time into an interval or a timestamp for a record in a specific DataTable.
Syntax
TableName.TimeStamp (m,n)

TableName.EventCount
Returns the number of data storage events that have occurred for an event driven data table.
Syntax
TableName.EventCount (1,1)

WorstCase
Saves one or more "worst case" data storage events into separate tables. Used in conjunction with DataEvent.
Syntax
WorstCase (TableName, NumCases, MaxMin, Change, RankVar)

10.16 Information Services

Email, IP SMS, and Web Page Services.

Read more! See Section 11.2 Information Services.

EMailRecv
Polls an SMTP server for email messages and store the message portion of the email in a string variable.
Syntax
variable = EMailRecv ("ServerAddr", "ToAddr", "FromAddr", "Subject", Message, "Authen", "UserName", "PassWord", Result)

EMailSend
Sends an email message to one or more email addresses via an SMTP server.
Syntax
variable = EMailSend ("ServerAddr", "ToAddr", "FromAddr", "Subject", "Message", "Attach", "UserName", "PassWord", Result)

FTPClient
Sends or retrieves a file via FTP.

Syntax

```
Variable = FTPClient ("IPAddress", "User", "Password",
"LocalFileName", "RemoteFileName", PutGetOption)
```

HTTPOut
Defines a line of HTML code to be used in a datalogger generated HTML file.

Syntax

```
WebPageBegin ("WebPageName", WebPageCmd)
    HTTPOut ("<p>html string to output " + variable + " additional
    string to output</p>")
    HTTPOut ("<p>html string to output " + variable + " additional
    string to output</p>")
WebPageEnd
```

IPTrace
Writes IP debug messages to a string variable.

Syntax

```
IPTrace (Dest)
```

NetworkTimeProtocol
Synchronizes the datalogger clock with an Internet time server.

Syntax

```
variable = NetworkTimeProtocol (NTPServer, NTPOffset,
NTPMaxMSec)
```

PPPOpen
Establishes a PPP connection with a server.

Syntax

```
variable = PPPOpen
```

PPPClose
Closes an opened PPP connection with a server.

Syntax

```
variable = PPPClose
```

TCPOpen
Sets up a TCP/IP socket for communication.

Syntax

```
TCPOpen (IPAddr, TCPPort, TCPBuffer)
```

TCPClose
Closes a TCPIP socket that has been set up for communication.

Syntax

```
TCPClose (TCPSocket)
```

UDPOpen
Opens a port for transferring UDP packets.

Syntax

```
UDPOpen (IPAddr, UDPPort, UDPBuffsize)
```

UDPDataGram
Sends packets of information via the UDP communications protocol.

Syntax

```
UDPDataGram(IPAddr, UDPPort, SendVariable, SendLength,
RcvVariable, Timeout)
```

WebPageBegin … WebPageEnd
Declare a web page that will be displayed when a request for the defined HTML page comes from an external source.

Syntax

```
WebPageBegin ("WebPageName", WebPageCmd)
    HTTPOut ("<p>html string to output " + variable + " additional
    string to output</p>")
    HTTPOut ("<p>html string to output " + variable + " additional
    string to output</p>")
WebPageEnd
```

10.17 Modem Control

Read more! For help on datalogger initiated telecommunication, see Section 11.9 Callback.

DialModem
Sends a modem dial string out a datalogger communications port.

Syntax

```
DialModem (ComPort, BaudRate, DialString, ResponseString)
```

ModemCallback
Initiates a call to a computer via a phone modem.

Syntax

```
ModemCallback (Result, COMPort, BaudRate, Security, DialString,
ConnectString, Timeout, RetryInterval, AbortExp)
```

ModemHangup … EndModemHangup
Enclose code that should be run when a COM port hangs up communication.

Syntax

```
ModemHangup (ComPort)
    instructions to be run upon hang-up
EndModemHangup
```

10.18 SCADA

Read more! See Sections 15.1 DNP3 and 15.2 Modbus.

ModBusMaster
Sets up a datalogger as a ModBus master to send or retrieve data from a ModBus slave.

Syntax

```
ModBusMaster (ResultCode, ComPort, BaudRate, ModBusAddr,
Function, Variable, Start, Length, Tries, TimeOut)
```

ModBusSlave
Sets up a datalogger as a ModBus slave device.
Syntax
ModBusSlave (ComPort, BaudRate, ModBusAddr, DataVariable, BooleanVariable)

DNP
Sets up a CR1000 as a DNP slave (outstation/server) device.
Syntax
DNP (ComPort, BaudRate, Addr)

DNPUpdate
Determines when the DNP slave will update arrays of DNP elements.
Specifies the address of the DNP master to send unsolicited responses.
Syntax
DNPUpdate (DNPAddr)

DNPVariable
Sets up the DNP implementation in a DNP slave CR1000.
Syntax
DNPVariable (Array, Swath, Object, Variation, Class, Flag, Event Expression, Number of Events)

10.19 Calibration Functions

Calibrate
Used to force calibration of the analog channels under program control.
Syntax
Calibrate (Dest, Range) (parameters are optional)

FieldCal
Sets up the datalogger to perform a calibration on one or more variables in an array.
Syntax
FieldCal (Function, MeasureVar, Reps, MultVar, OffsetVar, Mode, KnownVar, Index, Avg)

SampleFieldCal
Stores the values in the FieldCal file to a data table.
Syntax
DataTable (TableName, NewFieldCal, Size)
SampleFieldCal
EndTable

NewFieldCal
Triggers storage of FieldCal values when a new FieldCal file has been written.
Syntax
DataTable (TableName, NewFieldCal, Size)
SampleFieldCal
EndTable

LoadFieldCal
Loads values from the FieldCal file into variables in the datalogger.
Syntax
LoadFieldCal (CheckSig)

FieldCalStrain
Sets up the datalogger to perform a zero or shunt calibration for a strain measurement.

Syntax

FieldCalStrain (Function, MeasureVar, Reps, GFAdj, ZeromV/V, Mode, KnownRS, Index, Avg, GFRaw, uStrainDest)

10.20 Satellite Systems Programming

Instructions for GOES, ARGOS, INMARSAT-C, OMNISAT. Refer to satellite transmitter manuals available at www.campbellsci.com.

10.20.1 Argos

ArgosSetup
Sets up the datalogger for transmitting data via an Argos satellite.

Syntax

ArgosSetup (ResultCode, ST20Buffer, DecimalID, HexadecimalID, Frequency)

ArgosData
Specifies the data to be transmitted to the Argos satellite.

Syntax

ArgosData (ResultCode, ST20Buffer, DataTable, NumRecords, DataFormat)

ArgosTransmit
Initiates a single transmission to an Argos satellite when the instruction is executed.

Syntax

ArgosTransmit (ResultCode, ST20Buffer)

ArgosError
Sends a "Get and Clear Error Message" command to the transmitter.

Syntax

ArgosError (ResultCode, ErrorCodes)

ArgosDataRepeat
Sets the repeat rate for the ArgosData instruction.

Syntax

ArgosDataRepeat (ResultCode, RepeatRate, RepeatCount, BufferArray)

10.20.2 GOES

GOESData
Sends data to a CSI GOES satellite data transmitter.

Syntax

GOESData (Dest, Table, TableOption, BufferControl, DataFormat)

GOESGPS
Stores GPS data from the satellite into two variable arrays.

Syntax

GOESGPS (GoesArray1(6), GoesArray2(7))

GOESSetup
Programs the GOES transmitter for communication with the satellite.

Syntax

GOESSetup (ResultCode, PlatformID, MsgWindow, STChannel, STBaud, RChannel, RBaud, STInterval, STOffset, RInterval)

GOESStatus
Requests status and diagnostic information from a CSI GOES satellite transmitter.

Syntax

GOESStatus (Dest, StatusCommand)

10.20.3 OMNISAT

OmniSatSTSetup
Sets up the OMNISAT transmitter to send data over the GOES or METEOSAT satellite at a self-timed transmission rate.

Syntax

OmniSatSTSetup (ResultCodeST, ResultCodeTX, OmniPlatformID, OmniMsgWindow, OmniChannel, OmniBaud, STInterval, STOffset)

OmniSatRandomSetup
Sets up the OMNISAT transmitter to send data over the GOES or METEOSAT satellite at a random transmission rate.

Syntax

OmniSatRandomSetup (ResultCodeR, OmniPlatformID, OmniChannel, OmniBaud, RInterval, RCount)

OmniSatData
Sends a table of data to the OMNISAT transmitter for transmission via the GOES or METEOSAT satellite.

Syntax

OmniSatData (OmniDataResult, TableName, TableOption, OmniBufferCtrl, DataFormat)

OmniSatStatus
Queries the transmitter for status information.

Syntax

OmniSatStatus (OmniStatusResult)

10.20.4 INMARSAT-C

INSATSetup
Configures the OMNISAT-I transmitter for sending data over the INSAT-1 satellite.

Syntax

INSATSetup (ResultCode, PlatformID, RFPower)

INSATData
Sends a table of data to the OMNISAT-I transmitter for transmission via the INSAT-1 satellite.

Syntax

INSATData (ResultCode, TableName, TX_Window, TX_Channel)

INSATStatus

Queries the transmitter for status information.

Syntax

INSATStatus (ResultCode)

Section 11. Programming Resource Library

11.1 Field Calibration of Linear Sensors (FieldCal)

Calibration increases accuracy of a measurement device by adjusting its output, or the measurement of its output, to match independently verified quantities. Adjusting a sensor output directly is preferred, but not always possible or practical. By adding FieldCal () or FieldCalStrain () instructions to the CR1000 program, a user can easily adjust the measured output of linear sensors by modifying multipliers and offsets.

Once programmed in the CR1000, calibration functions are accessed through a software wizard (LoggerNet | Connect | Tools | Calibration Wizard) or through a numeric monitor procedure using keypad or software. The numeric monitor procedure, though somewhat arcane, is utilized in the examples below to illustrate calibration functions and procedures.

NOTE LoggerNet calibration wizard does not yet support FieldCalStrain ().

11.1.1 CAL Files

Calibration data are stored automatically in CAL files in CR1000 memory, which become the source for calibration factors when requested with the LoadFieldCal instruction.

A CAL file is created automatically on the same drive and given the same name (with .cal extension) as the program that creates and uses it, e.g., CPU:MyProg.CR1 generates CPU:MyProg.cal.

CAL files are created if a program using FieldCal () or FieldCalStrain () does not find an existing compatible CAL file. Files are updated with each successful calibration and contain multiplier and offset factors and information for the LoggerNet Calibration Wizard. If the user creates a data storage output table in the CR1000 program, a calibration history will be maintained.

NOTE CAL files created by FieldCal () and FieldCalStrain () differ from files created by the CalFile () instruction (Section 10.14 File Management).

11.1.2 CRBASIC Programming

Field calibration functionality is utilized through either:

FieldCal () -- the principal instruction used for non-strain gage type sensors. One instruction is entered for each sensor to be calibrated.

or

FieldCalStrain () -- the principal instruction used for strain gages measuring microstrain. One instruction is entered for each gage to be calibrated.

with two supporting instructions:

LoadFieldCal () -- an optional instruction that evaluates the validity of, and loads values from a CAL file.

SampleFieldCal -- an optional data storage output instruction that writes the latest calibration values to a data table (not to the CAL file).

and a reserved Boolean variable:

NewFieldCal -- a reserved Boolean variable under CR1000 control used to optionally trigger a data storage output table after a calibration has succeeded.

See CRBASIC Editor Help for operational details on CRBASIC instructions.

11.1.3 Calibration Wizard Overview

The LoggerNet Field Calibration Wizard steps through the calibration process by performing the mode variable changes and measurements automatically. The user sets the sensor to known values and inputs those values into the Wizard.

When a program with FieldCal ()instructions is running, select "LoggerNet | Connect | Tools | Calibration Wizard" to start the wizard. A list of measurements utilized in any FieldCal instruction in the program is shown.

11.1.4 Manual Calibration Overview

Manual calibration is accomplished by changing the value of the FieldCal () or FieldCalStrain () mode variable through the CR1000KD keyboard display or LoggerNet numeric monitor. The datalogger does not check for out of bounds values in mode variables. Normal mode variable entries are restricted to "1" or "4".

11.1.4.1 Single-point Calibrations (zero or offset)

Use the following general procedure to adjust offsets (y-intercepts) with single-point calibrations:

1) Ensure mode variable = 0 or 6 before starting.
2) Place the sensor into zeroing or offset condition
3) Set mode variable = 1 to start calibration

Mode Variable	Interpretation
> 0 and ≠ 6	calibration in progress
< 0	calibration encountered an error
2	calibration in process
6	calibration complete.

11.1.4.2 Two-point Calibrations (multiplier / gain)

Use the following general procedure to adjust multipliers (slopes) and offsets (y-intercepts) with two-point calibrations:

Ensure mode variable = 0 or 6 before starting.
If Mode variable > 0 and ≠ 6 then calibration in progress.
If Mode variable < 0 then calibration encountered an error.

1) Place sensor into first known point condition.
2) Set Mode variable = 1 to start first part of calibration.

Mode variable = 2 during the first point calibration.
Mode variable = 3 when the first point is completed.

3) Place sensor into second known point condition.
4) Set Mode variable = 4 to start second part of calibration.

Mode variable = 5 during second point calibration.
Mode variable = 6 when calibration process completes.

11.1.5 FieldCal () Demonstration Programs

FieldCal () has the following calibration options:

Zero
Offset
Two Point Slope and Offset
Two Point Slope Only

Demonstration programs are provided as a way to become familiar with the FieldCal () features at the test bench without actual sensors. Sensor signals are simulated by a CR1000 excitation channel. To reset tests, go to LoggerNet | Connect | Tools | File Control and delete .cal files, then send the demonstration program again to the CR1000.

11.1.5.1 Zero (Option 0)

Case: A sensor measures the relative humidity of air. Multiplier is known to be stable, but sensor offset drifts and requires regular zeroing in a desiccated

chamber. The following procedure zeros the RH sensor to obtain the calibration report shown.

Calibration Report for Air RH Sensor		
	Initial Calibration	**1 Month Calibration**
mV Output	1000	1050
Desiccated Chamber	0 %	0 %
Multiplier	.05 % / mV	.05 % / mV
Offset	-50 %	-52.5 %
Reading	%	0 %

Send the program in EXAMPLE 11.1-1 to the CR1000. To simulate the RH sensor, place a jumper wire between channels VX1 (VX1 (EX1)) and SE8 (4L).

Using the CR1000KD keyboard or software numeric monitor, change the value in variable CalibMode to 1 to start calibration. When CalibMode increments to 6, calibration is complete.

mV	1,000.00
KnownRH	0.00
CalMode	6.00
Multiplier	0.05
Offset	-50
RH	0

Change the mV variable to 1050, then repeat the calibration to see how drift is easily zeroed.

EXAMPLE 11.1-1. FieldCal zeroing demonstration program.

```
'Jumper VX1 (VX1 (EX1)) to SE8(4L) to simulate a sensor

Public mV                    'Excitation mV Output
Public KnownRH               'Known Relative Humidity
Public CalMode               'Calibration Trigger

Public Multiplier            'Multiplier (Starts at .05 mg / liter / mV, does not change)
Public Offset                'Offset (Starts at zero, not changed)
Public RH                    'Measured Relative Humidity

'Data Storage Output of Calibration Data -- stored whenever a calibration occurs
DataTable (CalHist,NewFieldCal,200)
    SampleFieldCal
EndTable
```

```
BeginProg

    Multiplier = .05
    Offset = 0
    KnownRH = 0

    LoadFieldCal (true) 'Load the CAL File, if possible

    Scan (100,mSec,0,0)

        'Simulate measurement by exciting channel Vx/VX1 (EX1)
        ExciteV (Vx1,mV,0)

        'Make the calibrated measurement
        VoltSE (RH,1,mV2500,8,1,0,250,Multiplier,Offset)

        'Perform a calibration if CalMode = 1
        FieldCal (0,RH,1,Multiplier,Offset,CalMode,KnownRH,1,30)

        'If there was a calibration, store it into a data table
        CallTable (CalHist)

    NextScan

EndProg
```

11.1.5.2 Offset (Option 1)

Case: A sensor measures the salinity of water. Multiplier is known to be stable, but sensor offset drifts and requires regular offset correction using a standard solution. The following procedure offsets the measurement to obtain the calibration report shown.

Calibration Report for Salinity Sensor		
	Initial Calibration	**1 week Calibration**
mV Output	1350 mV	1345 mV
Standard Solution	30 mg/l	30 mg/l
Multiplier	.05 mg/l/mV	.05 mg/l/mV
Offset	-37.50 mg/l	-37.23 mg/l
Reading	30 mg/l	30 mg/l

Send the program in EXAMPLE 11.1-2 to the CR1000. Put a jumper wire between channels Vx/VX1 (EX1) and SE8 (4L).

Using the CR1000KD keyboard or software numeric monitor, change the value in variable CalibMode to 1 to start calibration. When CalibMode increments to 6, the calibration is complete.

EXAMPLE 11.1-2. FieldCal offset demonstration program.

```
'Jumper VX1 (EX1) to SE8(4L) to simulate a sensor

Public mV                   'Excitation mV Output
Public KnownSalt            'Known Salt Concentration
Public CalMode              'Calibration Trigger

Public Multiplier           'Multiplier (Starts at .05 mg / liter / mV, does not change)
Public Offset               'Offset (Starts at zero, not changed)
Public SaltContent          'Salt Concentration

'Data Storage Output of Calibration Data -- stored whenever a calibration occurs
DataTable (CalHist,NewFieldCal,200)
    SampleFieldCal
EndTable

BeginProg

    Multiplier = .05
    Offset = 0
    KnownSalt = 0

    LoadFieldCal (true)     'Load the CAL File, if possible

    Scan (100,mSec,0,0)

        'Simulate measurement by exciting channel VX1 (EX1)
        ExciteV (Vx1,mV,0)

        'Make the calibrated measurement
        VoltSE (SaltContent,1,mV2500,8,1,0,250,Multiplier,Offset)

        'Perform a calibration if CalMode = 1
        FieldCal (1,SaltContent,1,Multiplier,Offset,CalMode,KnownSalt,1,30)

        'If there was a calibration, store it into a data table
        CallTable (CalHist)

    NextScan

EndProg
```

11.1.5.3 Two Point Slope and Offset (Option 2)

Case: A meter measures the volume of water flowing through a pipe. Multiplier and offset are known to drift, so a two-point calibration is required periodically at known flow rates. The following procedure adjusts multiplier and offset to correct for meter drift as shown in the calibration report below. Note that the flow meter outputs milliVolts inversely proportional to flow.

Calibration Report for Y Flow Meter		
	Initial Calibration	**1 Week Calibration (5% Drift)**
Output @ 30 l/s	300 mV	285 mV
Output @ 10 l/s	550 mV	522 mV
Multiplier	-0.0799 l/s/mV	-.0841 l/s/mV
Offset	53.90 l	53.92 l

Send the program in EXAMPLE 11.1-3 to the CR1000. Put a jumper wire between channels Vx/VX1 (EX1) and SE8 (4L). Using the CR1000KD keyboard or software numeric monitor, change variables as indicated below:

mV = 300
KnownFlow = 30
CalibMode = 1

mV	300.00
KnownFlow	30.00
CalMode	3.00
Multiplier	1.0000
Offset	0.00
WaterFlow	299.13

When CalibMode increments to 3, the first step of the calibration is complete. Change variables as indicated below to complete the second step:

mV = 550
KnownFlow = 10
CalibMode = 4

mV	550.00
KnownFlow	10.00
CalMode	6.00
Multiplier	-0.0798
Offset	53.88
WaterFlow	10.00

When CalibMode has incremented to 6, the calibration is finished. Repeat the procedure using the 5% shift values from the calibration report.

EXAMPLE 11.1-3. FieldCal multiplier and offset demonstration program.

```
'Jumper Vx/VX1 (EX1) to SE8(4L) to simulate a sensor

Public mV                       'Excitation mV Output
Public KnownFlow                'Known Water Flow
Public CalMode                  'Calibration Trigger

Public Multiplier               'Sensitivity
Public Offset                   'Offset (Starts at zero, not changed)
Public WaterFlow                'Water Flow

'Data Storage Output of Calibration Data -- stored whenever a calibration occurs
DataTable (CalHist,NewFieldCal,200)
    SampleFieldCal
EndTable

BeginProg

    Multiplier = 1
    Offset = 0
    KnownFlow = 0

    LoadFieldCal (true)         'Load the CAL File, if possible

    Scan (100,mSec,0,0)

        'Simulate measurement by exciting channel Vx/VX1 (EX1)
        ExciteV (Vx1,mV,0)

        'Make the calibrated measurement
        VoltSE (WaterFlow,1,mV2500,8,1,0,250,Multiplier,Offset)

        'Perform a calibration if CalMode = 1
        FieldCal (2,WaterFlow,1,Multiplier,Offset,CalMode,KnownFlow,1,30)

        'If there was a calibration, store it into a data table
        CallTable (CalHist)

    NextScan

EndProg
```

11.1.5.4 Two Point Slope Only (Option 3)

Some measurement applications do not require determination of offset. Wave form analysis, for example, may only require relative data to characterize change.

Case: A soil water sensor is to be use to detect a pulse of water moving through soil. To adjust the sensitivity of the sensor, two soil samples, with volumetric water contents of 10 and 35, will provide two known points.

The following procedure sets the sensitivity of a simulated soil water content sensor.

Send the program in EXAMPLE 11.1-4. Start the first step of the simulated calibration by entering:

mV = 175 mV
KnownWC = 10
CalibMode = 1

The first step is complete when CalibMode increments to 3.

mV	175.00
KnownWC	10.00
CalMode	3.00
Multiplier	1.0000
Offset	0.00
RelH2OContent	174.21

Calibration continues when starting the second step by entering:

mV = 700
KnownWC = 35
CalibMode = 4

mV	700.00
KnownWC	35.00
CalMode	6.00
Multiplier	0.0476
Offset	0.00
RelH2OContent	33.29

Sensitivity calibration is complete when CalibMode increments automatically to 6.

EXAMPLE 11.1-4. FieldCal multiplier only demonstration program.

```
'Jumper Vx/VX1 (EX1) to SE8(4L) to simulate a sensor

Public mV                   'Excitation mV Output
Public KnownWC              'Known Water Content
Public CalMode              'Calibration Trigger

Public Multiplier           'Sensitivity
Public Offset               'Offset (Starts at zero, not changed)
Public RelH2OContent        'Relative Water Content

'Data Storage Output of Calibration Data -- stored whenever a calibration occurs
DataTable (CalHist,NewFieldCal,200)
    SampleFieldCal
EndTable
```

```
BeginProg

    Multiplier = 1
    Offset = 0
    KnownWC = 0

    LoadFieldCal (true)          'Load the CAL File, if possible

    Scan (100,mSec,0,0)

        'Simulate measurement by exciting channel Vx/VX1 (EX1)
        ExciteV (Vx1,mV,0)

        'Make the calibrated measurement
        VoltSE (RelH2OContent,1,mV2500,8,1,0,250,Multiplier,Offset)

        'Perform a calibration if CalMode = 1
        FieldCal (3,RelH2OContent,1,Multiplier,Offset,CalMode,KnownWC,1,30)

        'If there was a calibration, store it into a data table
        CallTable (CalHist)

    NextScan

EndProg
```

11.1.6 FieldCalStrain () Demonstration Program

Strain gage systems consist of one or more strain gages, a Wheatstone bridge in which the gage resides, and a measurement device such as the CR1000 datalogger. The FieldCalStrain () instruction facilitates shunt calibration of strain gage systems, and is designed exclusively for strain applications wherein microstrain is the unit of measure. The FieldCal () instruction (Section 11.1.5 FieldCal () Demonstration Programs) is typically used in non-microstrain applications.

Shunt calibration of strain gage systems is common practice. However, the technique provides many opportunities for misapplication and misinterpretation. This section is not intended to be a primer on shunt calibration theory, but only to introduce use of the technique with the CR1000 datalogger. Campbell Scientific strongly urges users to study shunt calibration theory from other sources. A thorough treatment of strain gages and shunt calibration theory is available from Vishay at:

http://www.vishay.com/brands/measurements_group/guide/indexes/tn_index.htm

Campbell Scientific applications engineers also have resources that may assists users with strain gage applications.

FieldCalStrain () Shunt Calibration Concepts:

1) Shunt calibration does not calibrate the strain gage itself.

2) Shunt calibration does compensate for long leads and non-linearity in the Wheatstone bridge. Long leads reduce sensitivity because of voltage drop.

FieldCalStrain uses the known value of the shunt resistor to adjust the gain (multiplier / span) to compensate. The gain adjustment (S) is incorporated by FieldCalStrain with the manufacturer's gage factor (GF), becoming the adjusted gage factor (GF_{adj}), which is then used as the gage factor in StrainCalc (). GF is stored in the CAL file and continues to be used in subsequent calibrations. Non-linearity of the bridge is compensated for by selecting a shunt resistor with a value that best simulates a measurement near the range of measurements to be made. Strain gage manufacturers typically specify and supply a range of resistors available for shunt calibration.

3) Shunt calibration verifies the function of the CR1000.

4) The zero function of FieldCalStrain() allows the user to set a particular strain as an arbitrary zero, if desired. Zeroing is normally done after the shunt cal.

Zero and shunt options can be combined through a single CR1000 program.

The following program is provided to demonstrate use of FieldCalStrain () features. If a strain gage configured as shown in FIGURE 11.1-1 is not available, strain signals can be simulated by building the simple circuit shown in FIGURE 11.1-1, substituting a 1000 Ω potentiometer for the strain gage. To reset calibration tests, go to LoggerNet | Connect | Tools | File Control and delete .cal files, then send the demonstration program again to the CR1000.

Case: A 1000 Ω strain gage is placed into a Wheatstone bridge at position R1 as shown in FIGURE 11.1-1. The resulting circuit is a quarter bridge strain gage with alternate shunt resistor (Rc) positions shown. Gage specifications indicate that the gage factor is 2.0, and that with a 249 kΩ shunt, measurement should be about 2000 microstrain.

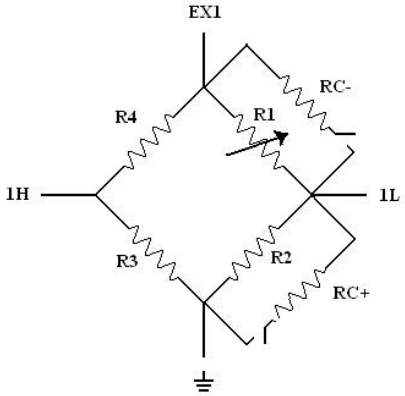


FIGURE 11.1-1. Quarter bridge strain gage schematic with RC resistor shunt locations shown.

Send Program EXAMPLE 11.1-5 to a CR1000 datalogger.

EXAMPLE 11.1-5. FieldCalStrain () calibration demonstration.

```
'Program to measure quarter bridge strain gage
'Measurements
Public Raw_mVperV
Public MicroStrain

'Variables that are arguments in the Zero Function
Public Zero_Mode
Public Zero_mVperV

'Variables that are arguments in the Shunt Function
Public Shunt_Mode
Public KnownRes
Public GF_Adj
Public GF_Raw

'---------------------------- Tables----------------------------
DataTable (CalHist,NewFieldCal,50)
  SampleFieldCal
EndTable

'\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\ PROGRAM ////////////////////////////

BeginProg

  'Set Gage Factors
  GF_Raw = 2.1
  GF_Adj = GF_Raw 'The adj Gage factors are used in the calculation of uStrain

  'If a calibration has been done, the following will load the zero or Adjusted GF from the Calibration file
  LoadFieldCal (True)

  Scan (100,mSec,100,0)
    'Measure Bridge Resistance
    BrFull (Raw_mVperV,1,mV25,1,Vx1,1,2500,True ,True ,0,250,1.0,0)

    'Calculate Strain for 1/4 Bridge (1 Active Element)
    StrainCalc (microStrain,1,Raw_mVperV,Zero_mVperV,1,GF_Adj,0)

    'Steps (1) & (3): Zero Calibration
    'Balance bridge and set Zero_Mode = 1 in numeric monitor.  Repeat after shunt calibration.
    FieldCalStrain (10,Raw_mVperV,1,0,Zero_mVperV,Zero_Mode,0,1,10,0,microStrain)

    'Step (2) Shunt Calibration
    'After zero calibration, and with bridge balanced (zeroed), set KnownRes = to gage resistance
    '(resistance of gage at rest), then set Shunt_Mode = 1.  When Shunt_Mode increments to 3,
    'position shunt resistor and set KnownRes = shunt resistance, then set Shunt_Mode = 4.
    FieldCalStrain (13,MicroStrain,1,GF_Adj,0,Shunt_Mode,KnownRes,1,10,GF_Raw,0)

    CallTable CalHist
  Next Scan
EndProg
```

11.1.6.1 Quarter bridge Shunt (Option 13)

With EXAMPLE 11.1-5 sent to CR1000, and with strain gage stable, use the CR1000KD keyboard or software numeric monitor to change the value in variable KnownRes to the nominal resistance of the gage, 1000 Ω. Set Shunt_Mode to 1 to start the two-point shunt calibration. When Shunt_Mode increments to 3, the first step is complete.

To complete the calibration, shunt R1 with the 249 kΩ resistor. Set variable KnownRes to 249,000. Set variable Shunt_mode to 4. When variable Shunt_mode = 6, shunt calibration is complete.

Raw mVperV	-1.109
MicroStrain	2,117
Zero Mode	0
Zero mVperV	0.0000
Shunt Mode	1
KnownRes	1,000
GF Adj	2.100
GF Raw	2.100

FIGURE 11.1-2. Strain gage shunt calibration started.

Raw mVperV	-1.109
MicroStrain	-2,215
Zero Mode	0
Zero mVperV	0.0000
Shunt Mode	6
KnownRes	249,000
GF Adj	-2.008
GF Raw	2.000

FIGURE 11.1-3. Strain gage shunt calibration finished.

11.1.6.2 Quarter bridge Zero (Option 10)

Continuing from 9.8.6.1, keep the 249 kΩ resistor in place to simulate a strain. Using the CR1000KD keyboard or software numeric monitor, change the value in variable Zero_Mode to 1 to start the zero calibration as shown if FIGURE 11.1-4. When Zero_Mode increments to 6, zero calibration is complete as shown in FIGURE 11.1-5.

Raw mVperV	-1.110
MicroStrain	-2,214
Zero Mode	1
Zero mVperV	0.0000
Shunt Mode	6
KnownRes	249,000
GF Adj	-2.010
GF Raw	2.000

FIGURE 11.1-4. Starting zero procedure.

Raw mVperV	-1.110
MicroStrain	0
Zero Mode	6
Zero mVperV	-1.1096
Shunt Mode	6
KnownRes	249,000
GF Adj	-2.010
GF Raw	2.000

FIGURE 11.1-5. Zero procedure finished.

11.2 Information Services

Read More! Specific information concerning the use of digital cellular modems for information services can often be found in CSI manuals for those modems for sale through Campbell Scientific.

When used in conjunction with an NL115 network link interface, or a cell modem with the PPP/IP key enabled, the CR1000 has TCP/IP functionality. This provides the following capabilities:

- PakBus communication over TCP/IP with LoggerNet or PC400 software.
- Callback (datalogger initiated communication) using the CRBASIC TCPOpen() function.
- Datalogger-to-datalogger communication.
- HTTP protocol and Web Server.
- FTP Server and Client for transferring files to and from the datalogger.
- TelNet Server for debugging and entry into terminal mode.
- SNMP for NTCIP and RWIS applications.

- PING.
- Micro-serial server using CRBASIC Serial I/O functions with TCP sockets as “COM Ports”.
- Modbus/TCP/IP, Master and Slave.
- DHCP Client to obtain an IP address.
- DNS Client to query a DNS server to map a name into an IP address.
- SMTP to send email messages.

For additional information, see the NL115 manual and CRBASIC Editor Help.

11.2.1 PakBus Over TCP/IP and Callback

Once the hardware has been configured, basic PakBus communication over TCP/IP is possible. These functions include sending and retrieving programs, setting the datalogger clock, collecting data, and displaying at the most current record from the CR1000 data tables.

Data callback and datalogger-to-datalogger communications are also possible over TCP/IP. For details and example programs for callback and datalogger-to-datalogger communications, see the NL115 manual.

11.2.2 HTTP Web Server

The CR1000 has a default home page built into the operating system. As shown in FIGURE 11.2-1, this page provides links to the newest record in all tables, including the status table, public table, and data tables. Links are also provided for the last 24 records in each data table. If fewer than 24 records have been stored in a data table, the link will display all data in that table.

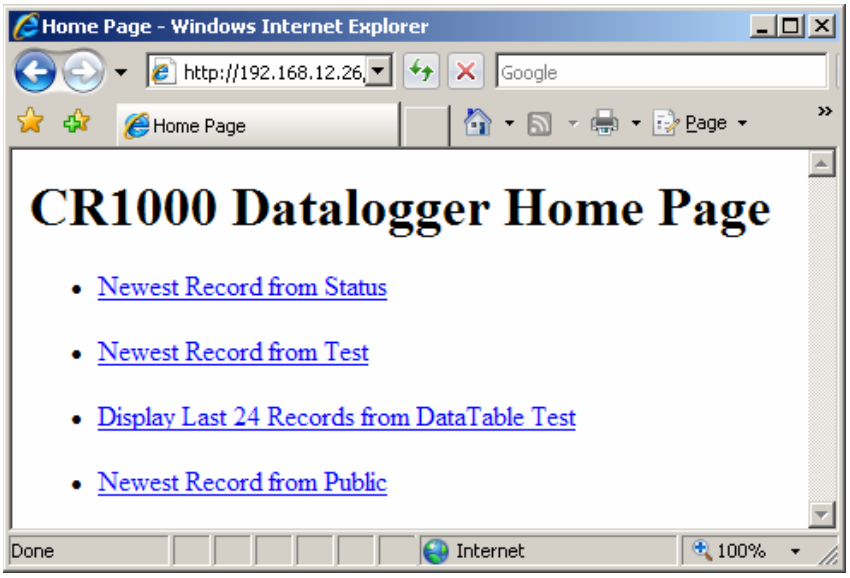


FIGURE 11.2-1. CR1000 Default Home Page

Newest Record links refresh automatically every 10 seconds. Last 24 Records link must be manually refreshed to see new data.

Links will also be created automatically for any HTML, XML, and JPEG files found on the datalogger in the CPU:, USR:, and CRD: drives. To copy files to these drives, choose File Control from the Tools menu found in PC400 or in the Connect screen of LoggerNet.

Although the default home page cannot be accessed by the user for editing, it can be replaced with HTML code to customize the look of the home page. To replace the default home page, save the new home page under the name *default.html* and copy it to the datalogger. It can be copied to the CPU:, USR:, or CRD: drive with File Control. Deleting *default.html* from the datalogger will cause the CR1000 to use its original default home page.

The CR1000 can be programmed to generate HTML or XML code that can be viewed by the web browser. EXAMPLE 11.2-1 shows how to use the CRBASIC keywords WebPageBegin/WebPageEnd and HTTPOut to create HTML code. Note that for HTML code requiring the use of quote marks, CHR(34) is used, while regular quote marks are used to define the beginning and end of alphanumeric strings inside the parentheses of the HTTPOut instruction. For additional information, see the CRBasic editor Help.

EXAMPLE 11.2-1. CRBASIC Code. HTML

```
'CR1000 Series Datalogger
Dim Commands As String * 200
Public Time(9), RefTemp,
Public Minutes As String, Seconds As String, Temperature As String

DataTable (CR1Temp,True,-1)
   DataInterval (0,1,Min,10)
   Sample (1,RefTemp,FP2)
   Average (1,RefTemp,FP2,False)
EndTable

'Default HTML Page
WebPageBegin ("default.html",Commands)
   HTTPOut ("<html>")
   HTTPOut ("<style>body {background-color: oldlace}</style>")
   HTTPOut ("<body><title>Campbell Scientific CR1000 Datalogger</title>")
   HTTPOut ("<h2>Welcome To the Campbell Scientific CR1000 Web Site!</h2>")
   HTTPOut ("<tr><td style="+ CHR(34) +"width: 290px"+ CHR(34) +">")
   HTTPOut ("<a href="+ CHR(34) +"http://www.campbellsci.com"+ CHR(34) +">")
   HTTPOut ("<img src="+ CHR(34) +"/CPU/SHIELDWEB2.jpg"+ CHR(34) + "width="+ CHR(34) +"128"+CHR(34)+"height="+
      CHR(34)+"155"+ CHR(34) + "class="+ CHR(34) +"style1"+ CHR(34) + "/></a></td>")
   HTTPOut ("<p><h2> Current Data:</h2></p>")
   HTTPOut ("<p>Time: " + time(4) + ":" + minutes + ":" + seconds + "</p>")
   HTTPOut ("<p>Temperature: " + Temperature + "</p>")
   HTTPOut ("<p><h2> Links:</h2></p>")
   HTTPOut ("<p><a href="+ CHR(34) +"monitor.html"+ CHR(34)+">Monitor</a></p>")
   HTTPOut ("</body>")
   HTTPOut ("</html>")
WebPageEnd

'Monitor Web Page
WebPageBegin ("monitor.html",Commands)
   HTTPOut ("<html>")
   HTTPOut ("<style>body {background-color: oldlace}</style>")
   HTTPOut ("<body>")
   HTTPOut ("<title>Monitor CR1000 Datalogger Tables</title>")
   HTTPOut ("<p><h2>CR1000 Data Table Links</h2></p>")
```

```
    HTTPOut ("<p><a href="+ CHR(34) + "command=TableDisplay&table=CR1Temp&records=10"+ CHR(34)+">Display Last 10
       Records from DataTable CR1Temp</a></p>")
    HTTPOut ("<p><a href="+ CHR(34) + "command=NewestRecord&table=CR1Temp"+ CHR(34) + ">Current Record from
       CR1Temp Table</a></p>")

       HTTPOut ("<p><a href="+ CHR(34) + "command=NewestRecord&table=Public"+ CHR(34)+">Current Record from Public
       Table</a></p>")
    HTTPOut ("<p><a href="+ CHR(34) + "command=NewestRecord&table=Status"+ CHR(34)+">Current Record from Status
       Table</a></p>")
    HTTPOut ("<br><p><a href="+ CHR(34) +"default.html"+CHR(34)+">Back to the Home Page</a></p>")
    HTTPOut ("</body>")
    HTTPOut ("</html>")
WebPageEnd

BeginProg
   Scan (1,Sec,3,0)
      PanelTemp (RefTemp,250)
      RealTime (Time())
      Minutes = FormatFloat (Time(5),"%02.0f")
      Seconds = FormatFloat (Time(6),"%02.0f")
      Temperature = FormatFloat (RefTemp, "%02.02f")
      CallTable (CR1Temp)
   NextScan
EndProg
```

In this example program, the default home page was replaced by using WebPageBegin to create a file called default.html. The new default home page created by the program appears as shown in FIGURE 11.2-2 looks like this:

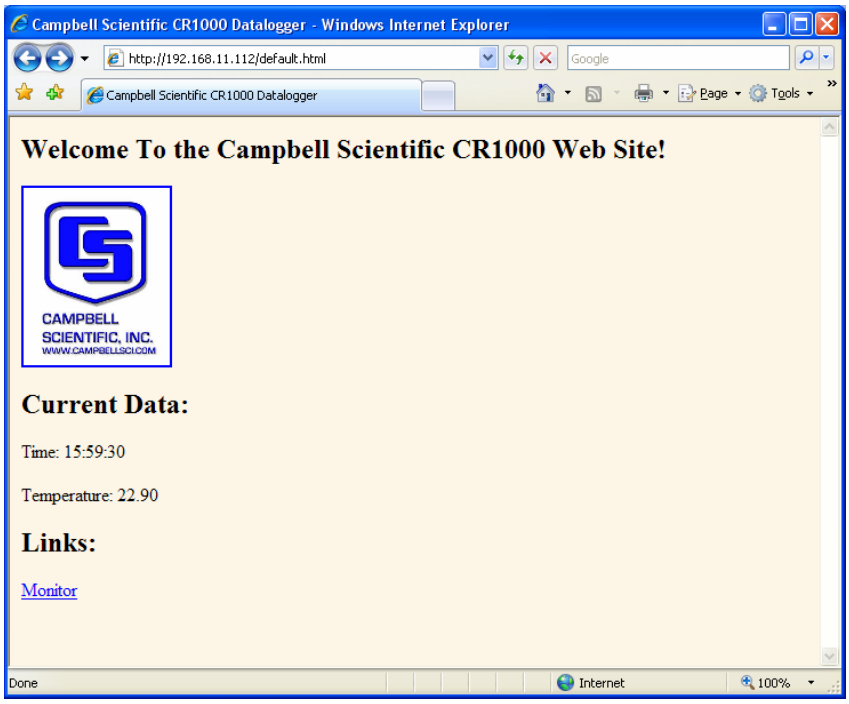


FIGURE 11.2-2. Home Page Created using WebPageBegin () Instruction

The Campbell Scientific logo in the web page comes from a file called SHIELDWEB2.JPG. That file must be transferred to the datalogger's CPU drive using File Control. The datalogger can then access the graphic for display on the web page.

A second web page, shown in FIGURE 11.2-3 called monitor.html was created by the example program that contains links to the CR1000 data tables:

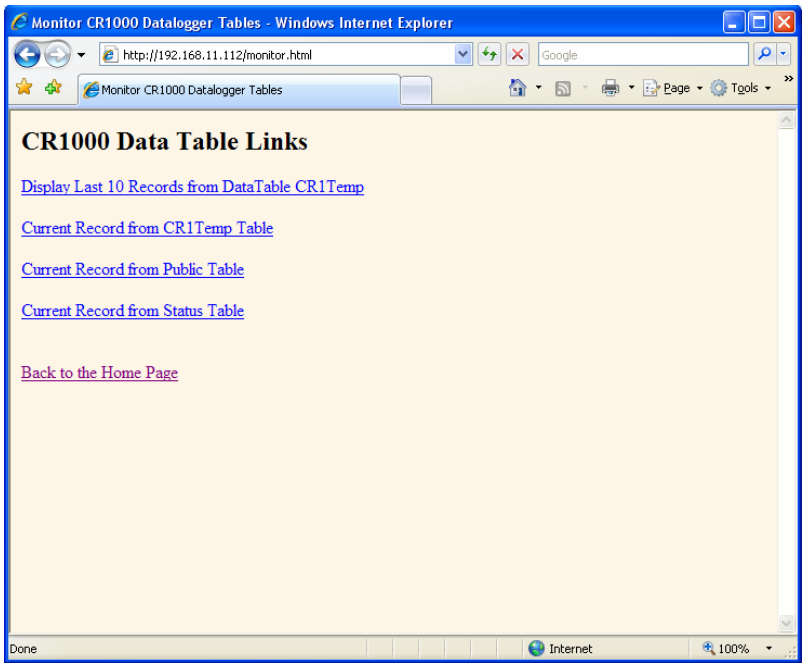


FIGURE 11.2-3. Monitor Web Page Generated By Datalogger Program

11.2.3 FTP Server

The CR1000 automatically runs an FTP server. This allows Windows Explorer to access the CR1000 file system via FTP, with the "drives" on the CR1000 being mapped into directories or folders. The "root directory" on the CR1000 can include CPU, USR or CRD. USR is a user defined directory that is created by allocating memory for it in the USRDriveSize field of the Status table. If a compact flash card is present in the NL115 and the CR1000 program uses the CardOut instruction in one or more data tables, then the CRD directory will be mapped.

The files on the CR1000 will be contained in one of these directories. Files can be pasted and copied to and from the datalogger "drives" as is they were drives on the PC. Files can also be deleted through FTP.

11.2.4 FTP Client

The CR1000 can act as an FTP Client to send a file or get a file from an FTP server, such as another datalogger or web camera. This is done using the CRBASIC FTPClient () instruction. See the NL115 manual or CRBASIC Editor Help for details and sample programs.

11.2.5 Telnet

Telnet can be used to access the same commands as the Terminal Emulator in the LoggerNet Connect screen's Tools menu and the PC400. Start a Telnet session by opening a command prompt and type in:

Telnet xxx.xxx.xxx.xxx <Enter>

where xxx.xxx.xxx.xxx is the IP address of the network device connected to the CR1000.

11.2.6 SNMP

Simple Network Management Protocol (SNMP) is a part of the IP suite used by NTCIP and RWIS for monitoring road conditions. The CR1000 supports SNMP when a network device is attached.

11.2.7 Ping

Ping can be used to verify that the IP address for the network device connected to the CR1000 is reachable. To use the Ping tool, open a command prompt on a computer connected to the network and type in:

ping xxx.xxx.xxx.xxx <Enter>

where xxx.xxx.xxx.xxx is the IP address of the network device connected to the CR1000.

11.2.8 Micro-Serial Server

The CR1000 can be configured to allow serial communication over a TCP/IP port. This is useful when communicating with a serial sensor. See the NL115 manual and the CRBASIC Editor Help for the TCPOpen () instruction for more information.

11.2.9 Modbus TCP/IP

The CR1000 can perform Modbus communication over TCP/IP using the Modbus TCP/IP interface. To set up Modbus TCP/IP, specify port 502 as the ComPort in the ModBusMaster () and ModBusSlave () instructions. See the CRBASIC Editor Help for more information.

11.2.10 DHCP

When connected to a server with a list of IP addresses available for assignment, the CR1000 will automatically request and obtain an IP address through the Dynamic Host Configuration Protocol (DHCP). Once the address is assigned, use DevConfig, PakBus Graph, Connect, or a CR1000KD to look in the CR1000 Status table to see the assigned IP address. This is shown under the field name IPInfo.

11.2.11 DNS

The CR1000 provides a Domain Name Server (DNS) client that can query a DNS server to determine if an IP address has been mapped to a hostname. If it has, then the hostname can be used interchangeably with the IP address in some datalogger instructions.

11.2.12 SMTP

Simple Mail Transfer Protocol (SMTP) is the standard for e-mail transmissions. The CR1000 can be programmed to send e-mail messages on a regular schedule or based on the occurrence of an event.

11.3 SDI-12 Sensor Support

Using the SDI12Recorder () instruction, the CR1000 interrogates SDI-12 sensors attached to terminals C1, C3, C5, and C7. Several SDI-12 probes can be wired to each terminal so long as each probe has a unique address and its own SDI12Recorder instruction.

11.3.1 SDI-12 Transparent Mode

System operators can manually interrogate and enter settings in probes using SDI-12 Transparent Mode. Transparent mode is useful in troubleshooting SDI-12 systems because it allows direct communication with SDI-12 probes.

Transparent mode may need to wait for programmed datalogger commands to finish before sending responses. While in the transparent mode, datalogger programs may not execute. Datalogger security may need to be unlocked before transparent mode can be activated.

Transparent mode is entered while the PC is in telecommunications with the datalogger through a terminal emulator program. It is most easily accessed through Campbell Scientific datalogger support software, but is also accessible with terminal emulator programs such as Windows Hyperterminal. Datalogger keyboards and displays cannot be used.

To enter the SDI-12 transparent mode, enter Terminal Emulator from LoggerNet, PC400 or PC200W datalogger support software. A terminal emulator screen is displayed. Click the “Open Terminal” button. A green “Active” indicator appears as shown in FIGURE 11.3-1. Press <Enter> until the CR1000 responds with the prompt “CR1000>”. Type “SDI12” at the prompt (without the quotes) and press <Enter>. In response, the query “Enter Cx Port 1, 3, 5 or 7” will appear. Enter the control port integer to which the SDI-12 sensor is connected. An “Entering SDI12 Terminal” response indicates that SDI-12 Transparent Mode is active.

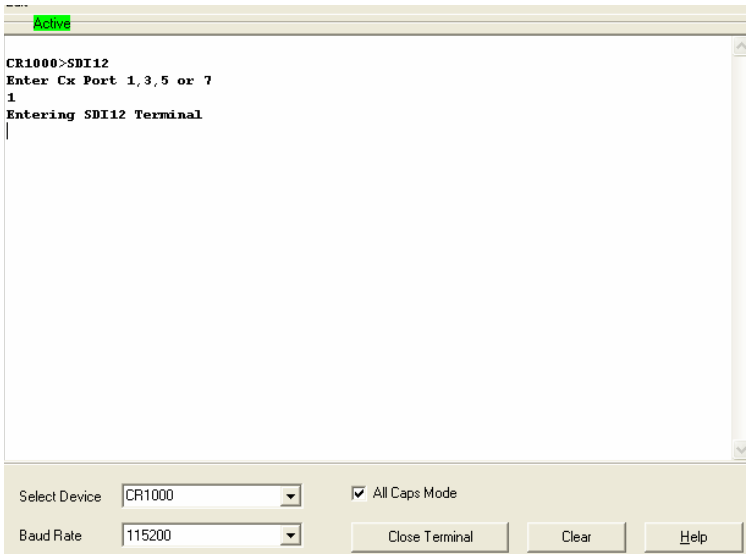


FIGURE 11.3-1. Entering SDI-12 Transparent Mode through LoggerNet Terminal Emulator

11.3.2 SDI-12 Command Basics

All commands can be issued through SDI-12 transparent mode.

All commands have three components: sensor address, command body, and command termination.

Sensor address is a single character, and is always the first character of the command or the subsequent response from the sensor. Usually, sensors are shipped from the factory with a default address of zero.

Command body and subsequent responses are shown as a combination of upper and lower case letters. The upper case letters are the fixed portion of the command, while the lower case letters are the variables or values. All commands use an exclamation point (!) as command terminator.

The CR1000 datalogger supports the entire suite of SDI-12 instructions as summarized in TABLE 11.3-1, and defined by the SDI-12 Support Group (www.sdi-12.org). Manufacturers establish the command set a specific sensor will respond. This section discusses the most common commands including: address query, address change, and sensor acknowledgment and identification. Various ways to initiate measurement and report data are also discussed. For assistance with other commands contact a Campbell Scientific Applications Engineer.

11.3.3 Addressing

Wiring more than one SDI-12 probe to a single port requires that each probe have a unique address. Since the default address on most probes is 0, additional probes will need the address changed. All SDI-12 version 1.3 probes accept an address of 0 - 9. If more than ten probes are connected to a common port, lower case “a-z”, and upper case “A-Z” may also be used as addresses.

11.3.3.1 *Address Query* Command

If the address of a particular sensor is unknown, use the *Address Query* command to request the sensor identify itself. Get Unknown Address syntax is "?!" (without the quotation marks), where the question mark is used as a wildcard for the address, followed by the command terminator. The sensor replies to the query with the address, "a". Carriage-return <CR> and line-feed <LF> are appended to all responses, although these are transparent to the user.

When using Get Unknown Address command, only one sensor can be connected to the SDI-12 / control port.

11.3.3.2 *Change Address* Command

The command body for changing the sensor address is "Ab", where "b" is the desired new address. Thus the total command string is "aAb!", where the lower case "a" is the current address, which is followed by the command body and then the command terminator. For example, to change an address from the default address 0, to address 2, the command is "0A2!" In response, the sensor responds with the "new" address "a", or in this case "2".

To subsequently change the address of this sensor to 4, the command is "2A4!"

11.3.3.3 *Send Identification* Command

Verify what sensor is being communicated with by using the *Send Identification* command "I". If using the default address of zero, the entire command structure is: "0I!" The specific reply from a sensor will be defined by the manufacturer, but will include the sensor's address, the SDI-12 version, and typically the manufacturer's name, the sensor's model number and version number. Optionally it may also contain the serial number or other sensor specific information.

An example of a response from the aI! command is:

013NRSYSINC1000001.2101 <CR><LF>

where,
Address = 0
SDI-12 version =1.3
Manufacturer = NRSYSINC
Sensor model = 100000
Sensor version = 1.2
Serial number = 101

11.3.4 Making Measurements

There are two ways to command sensors to take measurements. A standard measurement has the command body of M[v], and the *concurrent* measurement is initiated with C[v], where "v" is an optional number that allows for variations to the measurement command. For either measurement command, the response from the sensor will be in the form of "atttnn", where

a = the sensor address

ttt = the time, in seconds, until the sensor will have the measurement(s) ready

nn = the number of values will be returned in one or more subsequent D commands

The difference between the two commands is with what happens after the response is returned to the logger. When running CRBASIC code, with the standard M[v] command, the datalogger pauses its operations until the time "ttt" expires, after which it immediately polls the sensor for those values, and then continues with the remainder of its program. With the C[v] command, the datalogger continues with its program without pausing, and queries the sensor for its values on subsequent passes through its program (i.e., those that occur after the time "ttt" expires). The datalogger immediately issues another C[v] command to request a measurement, data from which will be requested on the next scan. Note that these subsequent scans should be rapid enough that the sensor is still holding those values in its registers before the sensor times out and discards the data. This "time out" period is fixed by the sensor manufacturer. In normal operations of the logger, for either measurement command set, the datalogger issues the subsequent aD0! *send data* request, without the user needing to request it. In transparent mode, however, the *send data* command will need to be issued to see the values returned. The *send data* command is discussed more fully below.

11.3.4.1 *Start Measurement* Command

The command body that tells a sensor to make measurements is in the form M[v]. The [v] is an optional number, between 1 and 9, and if supported by the sensor's manufacturer will give variants of the basic measurement instruction. Variants might include a way to change the units that the values are reported (e.g., English standard to metric), or perhaps additional values (level *and temperature*), or maybe a diagnostic of the sensor's internal battery's condition. As mentioned before the response is in the form of "atttnn".

An example of the entire syntax, for a sensor with the address of 5, might be:

5M! 500410

The response ("atttnn") indicates that address 5 will have data ready in 4 seconds, and will report 10 values.

Using a variation of the measurement command might be 5M7! 500201 For this hypothetical sensor, with [v] = 7, the sensor returns its internal battery voltage. The response could be read as "address 5 will have data ready in 2 seconds, reporting one value."

11.3.4.2 *Start Concurrent Measurement* Command

This command is new to Version 1.2 or higher of the SDI-12 Specification. Older sensors, older loggers, or new sensors that do not meet v1.2 specifications will likely not support this command

The command body is C[v]. The interpretation of "v" is the same as in the standard measurement command.

After retrieving data from a previous C! command whose timeout for getting data has expired, the CR1000 will immediately issue another C! command instead of waiting to do so in the next scan. By doing so, if the sensor timeout is < the datalogger's scan interval, the C! command will be able to retrieve data

every scan, i.e., it will pick up the data from the measurement command issued during the previous scan and, when the timeout has expired, issue the measurement command whose data will be retrieved on the subsequent scan.

11.3.4.3 *Aborting a Measurement* Command

If after sending any measurement command (aM[v]! or aC[v]!) to a sensor, but before it issues a response indicating that the data values are ready, a user can abort the measurement by issuing any other valid command to the sensor.

11.3.5 Obtaining Measurement Values

11.3.5.1 *Send Data* Command

This command is used to get groups of data from the sensor. D0! is normally issued automatically by the datalogger after any measurement command. In transparent mode, the user asserts this command to obtain data. If the expected number of data values are not returned in response to a D0! command, the data logger issues D1!, D2!, etc., until all measurement values are received. The limiting constraint is that the total number of characters that can be returned to a D0! command is 35 characters (or 75 characters for a concurrent command). If the number of characters exceed this limit, then the remainder of the response are obtained with D1!. If that cannot capture the remainder of the response within the 35 character limit, then D2! is issued, and so on.

11.3.5.2 *Continuous Measurements* Command

Sensors that are able to continuously monitor the phenomena to be measured, such as a shaft encoder, do not require a *measurement* command (e.g., M!). They can be read directly with the R commands (R0!... R9!) If a sensor cannot perform continuous measurements, then it will only respond with the sensor's address, acknowledging that it has received but cannot comply with the instruction.

TABLE 11.3-1. The SDI-12 basic command / response set.
Courtesy SDI-12 Support Group.

Name	Command[1]	Response[2]
Break	Continuous spacing for at least 12 milliseconds	None
Acknowledge Active	a!	a<CR><LF>
Send Identification	aI!	allccccccccmmmmmmmvvvxxx...xx<CR><LF>
Change Address	aAb!	b<CR><LF> (support for this command is required only if the sensor supports software changeable addresses)
Address Query	?!	a<CR><LF>
Start Measurement[3]	aM!	atttn<CR><LF>
Start Measurement and Request CRC[3]	aMC!	atttn<CR><LF>
Send Data	aD0! . . . aD9!	a<values><CR><LF> or a<values><CRC><CR><LF> a<values><CR><LF> or a<values><CRC><CR><LF> a<values><CR><LF> or a<values><CRC><CR><LF> a<values><CR><LF> or a<values><CRC><CR><LF> a<values><CR><LF> or a<values><CRC><CR><LF>
Additional Measurements[3]	aM1! . . . aM9!	atttn<CR><LF> atttn<CR><LF> atttn<CR><LF> atttn<CR><LF> atttn<CR><LF>
Additional Measurements and Request CRC[3]	aMC1! ... aMC9!	atttn<CR><LF>
Start Verification[3]	aV!	atttn<CR><LF>
Start Concurrent Measurement	aC!	atttnn<CR><LF>
Additional Concurrent Measurements	aC1! . . . aC9!	atttnn<CR><LF> atttnn<CR><LF> atttnn<CR><LF> atttnn<CR><LF> atttnn<CR><LF>
Additional Concurrent Measurements and Request CRC	aCC1! ... aCC9!	atttnn<CR><LF>
Continuous Measurements	aR0! ... aR9!	a<values><CR><LF> (formatted like the D commands)
Continuous Measurements and Request CRC	aRC0! ... aRC9!	a<values><CRC><CR><LF> (formatted like the D commands)

[1] If the command terminator '!' is not present in the command parameter, a measurement command will not be issued. The SDI12Recorder () instruction, however, will still pick up data resulting from a previously issued "C!" command.

[2] Complete response string can be obtained when using the SDIRecorder () instruction by declaring the Destination variable as String.

[3]This command may result in a service request.

11.3.6 SDI-12 Power Considerations

When a command is sent by the datalogger to an SDI-12 probe, all probes on the same SDI-12 port will wake up. Only the probe addressed by the datalogger will respond, however, all other probes will remain active until the timeout period expires.

Example

Probe: Water Content

Power Usage:
Quiescent: 0.25 mA
Measurement: 120 mA
Measurement Time: 15 s
Active: 66 mA
Timeout: 15 s

Probes 1, 2, 3, and 4 are connected to SDI-12 / Control Port 1.

The time line in TABLE 11.3-2 shows a 35 second power usage profile example.

TABLE 11.3-2. Example Power Usage Profile for a Network of SDI-12 Probes

Sec	Command	All Probes Awake	Time Out Expires	milliAmps 1	2	3	4	Total mA
1	1M!	Yes		120	66	66	66	318
2				120	66	66	66	318
•				•	•	•	•	•
•				•	•	•	•	•
•				•	•	•	•	•
14				120	66	66	66	318
15			Yes	120	66	66	66	318
16	1D0!	Yes		66	66	66	66	264
17				66	66	66	66	264
•				•	•	•	•	•
•				•	•	•	•	•
•				•	•	•	•	•
29				66	66	66	66	264
30			Yes	66	66	66	66	264
31				0.25	0.25	0.25	0.25	1
•				•	•	•	•	•
•				•	•	•	•	•
•				•	•	•	•	•
35				0.25	0.25	0.25	0.25	1

For most applications, total power usage of 318 mA for 15 seconds is not excessive, but if 16 probes were wired to the same SDI-12 port, the resulting power draw would be excessive. Spreading sensors over several SDI-12 terminals will help reduce power consumption.

11.4 Subroutines

This section is not yet available.

11.5 Wind Vector

11.5.1 OutputOpt Parameters

In the CR1000 WindVector () instruction, the OutputOpt parameter is used to define the values which will be stored. All output options result in an array of values, the elements of which have "_WVc(n)" as a suffix, where n is the element number. The array uses the name of the Speed/East variable as its base. TABLE 11.5-1 lists and describes OutputOpt options.

TABLE 11.5-1. OutputOpt Options

Option	Description
0	WVc(1) = Mean horizontal wind speed (S)
	WVc(2) = Unit vector mean wind direction (Θ1)
	WVc(3) = Standard deviation of wind direction σ(Θ1). Standard deviation is calculated using the Yamartino algorithm. This option complies with EPA guidelines for use with straight-line Gaussian dispersion models to model plume transport.
1	WVc(1) = Mean horizontal wind speed (S)
	WVc(2) = Unit vector mean wind direction (Θ1)
2	WVc(1) = Resultant mean horizontal wind speed ($\overline{U}$)
	WVc(2) = Resultant mean wind direction (Θu)
	WVc(3) = Standard deviation of wind direction σ(Θu). This standard deviation is calculated using Campbell Scientific's wind speed weighted algorithm. Use of the resultant mean horizontal wind direction is not recommended for straight-line Gaussian dispersion models, but may be used to model transport direction in a variable-trajectory model.
3	WVc(1) = Unit vector mean wind direction (Θ1)
4	WVc(1) = Unit vector mean wind direction (Θ1)
	WVc(2) = Standard deviation of wind direction σ(Θu). This standard deviation is calculated using Campbell Scientific's wind speed weighted algorithm. Use of the resultant mean horizontal wind direction is not recommended for straight-line Gaussian dispersion models, but may be used to model transport direction in a variable-trajectory model.

11.5.2 Wind Vector Processing

WindVector () processes wind speed and direction measurements to calculate mean speed, mean vector magnitude, and mean vector direction over a data storage interval. Measurements from polar (wind speed and direction) or orthogonal (fixed East and North propellers) sensors are accomodated. Vector direction and standard deviation of vector direction can be calculated weighted or unweighted for wind speed.

When a wind speed measurement is zero, WindVector () uses the measurement to process scalar or resultant vector wind speed and standard deviation, but not the computation of wind direction.

NOTE Cup anemometers typically have a mechanical offset which is added to each measurement. A numeric offset is usually encoded in the CRBASIC program to compensate for the mechanical offset. When this is done, a measurement will equal the offset only when wind speed is zero; consequently, additional code is often included to zero the measurement when it equals the offset so that WindVector () can reject measurements when wind speed is zero.

Standard deviation can be processed one of two ways: 1) using every sample taken during the data storage interval (enter 0 for the Subinterval parameter), or 2) by averaging standard deviations processed from shorter sub-intervals of the data storage interval. Averaging sub-interval standard deviations minimizes the effects of meander under light wind conditions, and it provides more complete information for periods of transition[3].

Standard deviation of horizontal wind fluctuations from sub-intervals is calculated as follows:

$$\sigma(\Theta) = [((\sigma\Theta_1)^2 + (\sigma\Theta_2)^2 \ldots + (\sigma\Theta_M)^2) / M]^{1/2}$$

where $\sigma(\Theta)$ is the standard deviation over the data storage interval, and $\sigma\Theta_1 \ldots \sigma\Theta_M$ are sub-interval standard deviations.

A sub-interval is specified as a number of scans. The number of scans for a sub-interval is given by:

Desired sub-interval (secs) / scan rate (secs)

For example if the scan rate is 1 second and the data interval is 60 minutes, the standard deviation is calculated from all 3600 scans when the sub-interval is 0. With a sub-interval of 900 scans (15 minutes) the standard deviation is the average of the four sub-interval standard deviations. The last sub-interval is weighted if it does not contain the specified number of scans.

[3] EPA On-site Meteorological Program Guidance for Regulatory Modeling Applications.

11.5.2.1 Measured Raw Data

S_i = horizontal wind speed
Θ_i = horizontal wind direction
Ue_i = east-west component of wind
Un_i = north-south component of wind
N = number of samples

11.5.2.2 Calculations

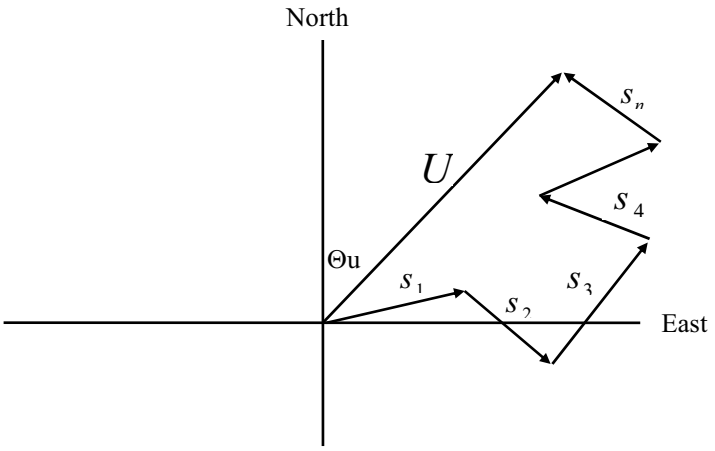


FIGURE 11.5-1. Input Sample Vectors

In FIGURE 11.5-1, the short, head-to-tail vectors are the input sample vectors described by s_i and Θ_i, the sample speed and direction, or by Ue_i and Un_i, the east and north components of the sample vector. At the end of data storage interval T, the sum of the sample vectors is described by a vector of magnitude U and direction Θu. If the input sample interval is t, the number of samples in data storage interval T is $N = T / t$. The mean vector magnitude is $\overline{U} = U / N$.

Scalar mean horizontal wind speed, S:

$$S = (\Sigma s_i) / N$$

where in the case of orthogonal sensors:

$$S_i = (Ue_i^2 + Un_i^2)^{1/2}$$

Unit vector mean wind direction, Θ1:

$$\Theta 1 = \text{Arctan } (Ux / Uy)$$

where

$$Ux = (\Sigma \sin \Theta_i) / N$$
$$Uy = (\Sigma \cos \Theta_i) / N$$

or, in the case of orthogonal sensors

$$Ux = (\Sigma(Ue_i / U_i)) / N$$
$$Uy = (\Sigma(Un_i / U_i)) / N$$
$$\text{where } U_i = (Ue_i^2 + Un_i^2)^{1/2}$$

Standard deviation of wind direction, σ(Θ1), using Yamartino algorithm:

$$\sigma(\Theta 1) = \arcsin(\varepsilon)[1 + 0.1547\ \varepsilon^3]$$

where,

$$\varepsilon = [1-((Ux)^2 + (Uy)^2)]^{1/2}$$

and Ux and Uy are as defined above.

Resultant mean horizontal wind speed, $\overline{U}$:

$$\overline{U} = (Ue^2 + Un^2)^{1/2}$$

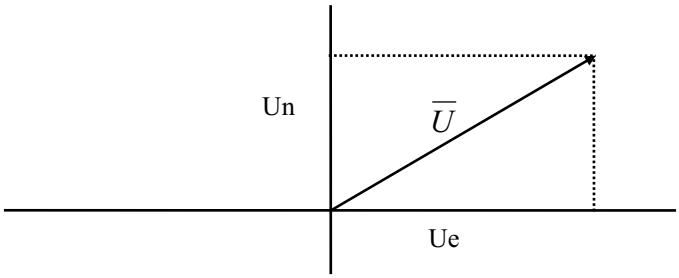


FIGURE 11.5-2. Mean Wind Vector

where for polar sensors:

$$Ue = (\Sigma S_i \text{ Sin } \Theta_i) / N$$
$$Un = (\Sigma S_i \text{ Cos } \Theta_i) / N$$

or, in the case of orthogonal sensors:

$$Ue = (\Sigma Ue_i) / N$$
$$Un = (\Sigma Un_i) / N$$

Resultant mean wind direction, Θu:

$$\Theta u = \text{Arctan } (Ue / Un)$$

Standard deviation of wind direction, σ(Θu), using Campbell Scientific algorithm:

$$\sigma(\Theta u) = 81(1 - \overline{U} / S)^{1/2}$$

The algorithm for σ(θu) is developed by noting (FIGURE 11.5-2) that

$$\mathrm{Cos}\,(\Theta_i') = U_i/s_i;\ \text{where}\ \Theta_i' = \Theta_i - \Theta u$$

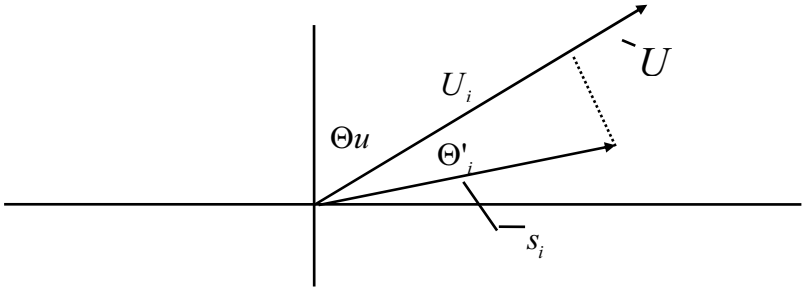


FIGURE 11.5-3. Standard Deviation of Direction

The Taylor Series for the Cosine function, truncated after 2 terms is:

$$\mathrm{Cos}\,(\Theta_i') \cong 1 - (\Theta_i')^2 / 2$$

For deviations less than 40 degrees, the error in this approximation is less than 1%. At deviations of 60 degrees, the error is 10%.

The speed sample can be expressed as the deviation about the mean speed,

$$s_i = s_i' + S$$

Equating the two expressions for Cos (θ‘) and using the previous equation for s_i;

$$1 - (\Theta_i')^2 / 2 = U_i /(s_i' + S)$$

Solving for $(\Theta_i')^2$, one obtains;

$$(\Theta_i')^2 = 2 - 2U_i / S - (\Theta_i')^2 s_i' / S + 2s_i' / S$$

Summing $(\Theta_i')^2$ over N samples and dividing by N yields the variance of Θu. Note that the sum of the last term equals 0.

$$(\sigma(\Theta u))^2 = \sum_{i=1}^{N} (\Theta_i')^2 / N = 2(1 - \overline{U} / S) - \sum_{i=1}^{N} ((\Theta_i')^2 s_i') / NS$$

The term, $\sum ((\Theta_i')^2 s_i') / NS$, is 0 if the deviations in speed are not correlated with the deviation in direction. This assumption has been verified in tests on wind data by CSI; the Air Resources Laboratory, NOAA, Idaho Falls, ID; and MERDI, Butte, MT. In these tests, the maximum differences in

$$\sigma(\Theta u) = (\sum (\Theta_i')^2 / N)^{1/2} \text{ and } \sigma(\Theta u) = (2(1 - \overline{U} / S))^{1/2}$$

have never been greater than a few degrees.

The final form is arrived at by converting from radians to degrees (57.296 degrees/radian).

$$\sigma(\Theta u) = (2(1-\overline{U}/S))^{1/2} = 81(1-\overline{U}/S)^{1/2}$$

11.6 Custom Menus

CR1000 Keyboard / Display menus can be customized to simplify routine operations. Viewing data, toggling control functions, or entering notes are common applications. Individual menu screens support up to eight lines of text with up to 7 variables.

11.6.1 Programming

Use the following CRBASIC instructions. Refer to CRBASIC Editor Help for complete information.

DisplayMenu()

Marks the beginning and end of a custom menu. Only one allowed per program. Note: label must be at least 6 characters long to mask default display clock.

EndMenu

Marks the end of a custom menu. Only one allowed per program.

DisplayValue()

Defines a label and displays a value (variable or data table value) not to be edited, such as a measurement.

MenuItem()

Defines a label and displays a variable to be edited by typing or from a pick list defined by MenuPick().

MenuPick()

Creates a pick list from which to edit a MenuItem() variable. Follows immediately after MenuItem(). If variable is declared As Boolean, MenuPick() allows only True or False or declared equivalents. Otherwise, many items are allowed in the pick list. Order of items in list is determined by order in instruction; however, item displayed initially in MenuItem() is determined by the value of the item.

SubMenu()/EndSubMenu

Defines the beginning and end of a second level menu. Note: SubMenu() label must be at least 6 characters long to mask default display clock.

11.6.2 Programming Example

EXAMPLE 11.6-1 lists CRBASIC programming for a custom menu that facilitates viewing data, entering notes, and controlling a device. FIGURE 11.1-1 through FIGURE 11.6-9 show the organization of the custom menu.

```
**CUSTOM MENU DEMO**
                    >
View Data           >
Make Notes          >
Control             >
```

FIGURE 11.6-1. Custom Menu Home from Example 18.6-1

```
View Data :
Ref  Temp C  |25.7643
TC 1 Temp C  |24.3663
TC 2 Temp C  |24.2643
```

FIGURE 11.6-2. View Data Window from Example 18.6-1

```
Make Notes :
Predefined  |  _____
Free Entry  |
Accept/Clear| ??????
```

FIGURE 11.6-3. Make Notes Sub Menu from Example 18.6-1

```
Predefined
 Cal_Done
 Offset_Changed
 ______
```

FIGURE 11.6-4. Predfined Notes Pick List from Example 18.6-1

```
Modify Value
 Free Entry

   Current Value:

   New Value:
```

FIGURE 11.6-5. Free Entry Notes Window from Example 18.6-1

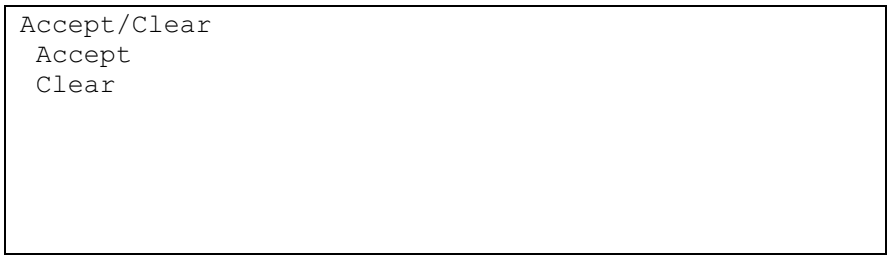


FIGURE 11.6-6. Accept / Clear Notes Window from Example 18.6-1

FIGURE 11.6-7. Control Sub Menu from Example 18.6-1

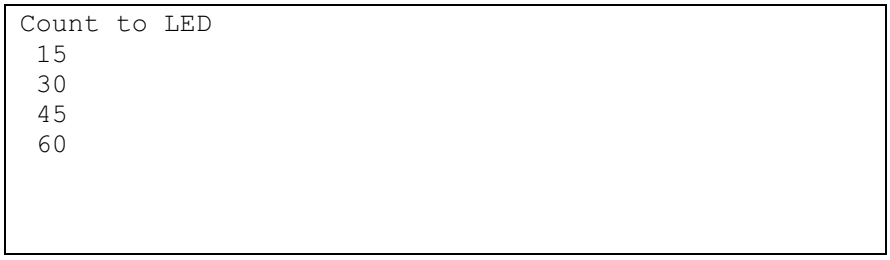


FIGURE 11.6-8. Control LED Pick List from Example 18.6-1

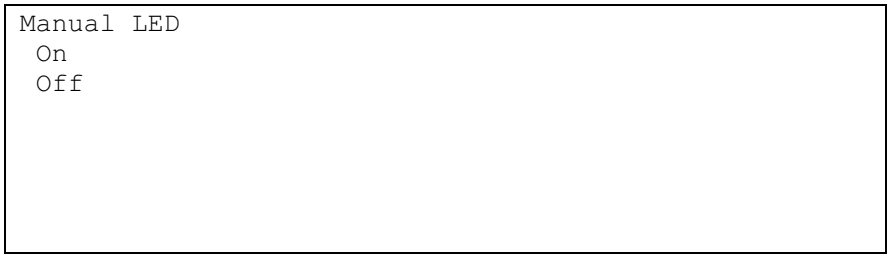


FIGURE 11.6-9. Control LED Manual Boolean Pick List from Example 18.6-1

EXAMPLE 11.6-1. CRBASIC Code: Custom menus as shown in Figs 18.6-1 to 18.6-9.

```
'CR1000 Series Datalogger
'Custom Menu Example

'Declarations supporting View Data menu item
Public RefTemp                                  'Declare Reference Temp Variable
Public TCTemp(2)                                'Declare Thermocouple Temp Array

'Delarations supporting blank line menu item
Const Escape = "Hit Esc"                        'Word to indicate action to get out of a dead end

'Declarations supporting Enter Notes menu item
Public SelectNote As String * 20                'Variable to hold predefined pick list note
Const Cal_Done = "Cal Done"                     'Word stored when Cal_Don selected from pick list
Const Offst_Chgd = "Offset Changed"             'Word stored when Offst_Chgd selected from pick list
Const _______ = ""                              'Word stored when blank _______ selected from pick list
Public EnterNote As String * 30                 'Variable to hold free entry note
Public CycleNotes As String * 20                'Variable to hold notes control word
Const Accept = "Accept"                         'Notes control word
Const Clear = "Clear" 'Notes control word

'Declarations supporting Control menu item
Const On = true                                 'Assign "On" as Boolean True
Const Off = false                               'Assign "Off" as Boolean False
Public StartFlag As Boolean                     'LED Control Process Variable
Public CountDown As Long                        'LED Count Down Variable
Public ToggleLED As Boolean                     'LED Control Variable

'Define Note DataTable                          'Set up Notes data table, written to only when
DataTable (Notes,1,-1)                          'a note is accepted
    Sample (1,SelectNote,String)                'Sample Pick List Note
    Sample (1,EnterNote,String)                 'Sample Free Entry Note
EndTable

'Define temperature DataTable                   'Set up temperature data table.  Written to
DataTable (TempC,1,-1)                          'every 60 seconds with:
    DataInterval (0,60,Sec,10)
    Sample (1,RefTemp,FP2)                      'Sample of reference temperature
    Sample (1,TCTemp(1),FP2)                    'Sample of thermocouple 1
    Sample (1,TCTemp(2),FP2)                    'Sample of thermocouple 2
EndTable

'Custom Menu Declarations
DisplayMenu("**CUSTOM MENU DEMO**",-3)          'Create Menu; Upon power up, the custom menu is
                                                'displayed. The system menu is hidden from the user.

    SubMenu("")                                 'Dummy Sub menu to write a blank line
      DisplayValue("",Escape)                   '
    EndSubMenu'End of dummy submenu

    SubMenu("View Data ")                       'Create Submenu named PanelTemps
      DisplayValue("Ref  Temp C",RefTemp)       'Item for Submenu from Public Table
      DisplayValue("TC 1 Temp C",TCTemp(1))     'Item for Submenu - TCTemps(1)
      DisplayValue("TC 2 Temp C",TCTemp(2))     'Item for Submenu - TCTemps(2)
    EndSubMenu'End of Submenu

    SubMenu("Make Notes ")                      'Create Submenu named PanelTemps
      MenuItem ("Predefined",SelectNote)        'Choose predefined notes Menu Item
      MenuPick (Cal_Done,Offset_Changed,_____)  'Create pick list of predfined notes
      MenuItem ("Free Entry",EnterNote)         'User entered notes Menu Item
      MenuItem ("Accept/Clear",CycleNotes)
      MenuPick (Accept,Clear)
    EndSubMenu
```

```
    SubMenu("Control ")                                  'Create Submenu named PanelTemps
      MenuItem ("Count to LED",CountDown)                'Create menu item CountDown
      MenuPick(15,30,45,60)                              'Create a pick list for CountDown
      MenuItem ("Manual LED",toggleLED)                  'Manual LED control Menu Item
      MenuPick (On,Off)
    EndSubMenu

EndMenu                                                  'End custom menu creation

'Main Program
BeginProg

    CycleNotes = "??????"                                'Initializes Notes Sub Menu, write ????? as a null prompt
    Scan (1,Sec,3,0)

      'Measurements
      PanelTemp (RefTemp,250)                            'Measure Reference Temperature
                                                         'Measure Two Thermocouples
      TCDiff (TCTemp(),2,mV2_5C,1,TypeT,RefTemp,True,0,250,1.0,0)
      CallTable TempC                                    'Call data table

      'Menu Item "Make Notes" Support Code
      If CycleNotes = "Accept" Then
        CallTable Notes                                  'Write data to Notes data table
        CycleNotes = "Accepted"                          'Write "Accepted" after written to data table
        Delay (1,500,mSec)                               'Pause so user can read "Accepted"
        SelectNote = ""                                  'Clear pick list note
        EnterNote = ""                                   'Clear free entry note
        CycleNotes = "??????"                            'Write ????? as a null prompt
      EndIf
      If CycleNotes = "Clear" Then                       'Clear notes when requested
        SelectNote = ""                                  'Clear pick list note
        EnterNote = ""                                   'Clear free entry note
        CycleNotes = "??????"                            'Write ????? as a null prompt
      EndIf

      'Menu Item "Control" Menu Support Code
      CountDown = CountDown - 1                          'Count down by 1
      If CountDown <= 0                                  'Stop count down from passing 0
        CountDown = 0
      EndIf
      If CountDown > 0 Then
        StartFlag = True                                 'Indicate that a count down has started
      EndIf
      If StartFlag = True AND CountDown = 0 Then         'Interprocess count down and manual LED
        ToggleLED = True
        StartFlag = False
      EndIf
      If StartFlag = True AND CountDown <> 0 Then        'Interprocess count down and manual LED
        ToggleLED = False
      EndIf
      PortSet (4,ToggleLED)                              'Set control port according to result of processing

    NextScan
EndProg
```

11.7 Conditional Compilation

CRBASIC allows definition of conditional code that the compiler interprets and includes at compile time. This feature is useful when the same program code is to be used across multiple datalogger types, e.g., in both the CR1000 and CR3000. Pseudocode for this feature can be written as...

```
#Const Destination = “CR3000”
#If Destination = “CR3000” Then
      <code specific to the CR3000>
#ElseIf Destination = “CR1000” Then
      <code specific to the CR1000>
 #Else
      <code to include otherwise>
#EndIf
```

which allows the simple change of a constant to include the appropriate measurement instructions.

All CRBASIC dataloggers accept program or Include () files with a .DLD extension, which makes it possible to write a single file with conditional compile statements to run in multiple loggers.

Code EXAMPLE 11.7-1 shows a sample program which demonstrates the use of conditional compilation features in CRBASIC using the #If, #ElseIf, #Else and #EndIf commands. Within the program are examples showing the use of the predefined LoggerType constant and associated predefined logger constants (CR3000, CR1000 etc...). The program can be loaded into a CR3000 / CR1000 / CR800 series logger.

EXAMPLE 11.7-1. Use of Conditional Compile Instructions #If, #ElseIf, #Else and #EndIf

```
'Conditional Compilation Example for CR3000 / CR1000 / CR800 Series Dataloggers

'Here we choose to set program options based on the
'setting of a constant in the program.
Const ProgramSpeed = 2

#If ProgramSpeed = 1
   Const ScanRate = 1                '1 Second
   Const Speed = "1 Second"
#ElseIf ProgramSpeed = 2
   Const ScanRate = 10               '10 Seconds
   Const Speed = "10 Second"
#ElseIf ProgramSpeed = 3
   Const ScanRate = 30               '30 Seconds
   Const Speed = "30 Second"
#Else
   Const ScanRate = 5                '5 Seconds
   Const Speed = "5 Second"
#EndIf

'Here we choose a COM port depending on which
'logger type the program is running in.
#If LoggerType = CR3000
   Const SourcSerialPort = Com3
#ElseIf LoggerTypes = CR1000
   Const SourcSerialPort = Com2
#ElseIf LoggerType = CR800
   Const SourcSerialPort = Com1
```

```
#Else
  Const SourcSerialPort = Com1
#EndIf

'Public Variables.
Public ValueRead, SelectedSpeed As String * 50

'Main Program
BeginProg

  'Return the selected speed and logger type for display.
  #If LoggerType = CR3000
    SelectedSpeed = "CR3000 running at " & Speed & " intervals."
  #ElseIf LoggerTypes = CR1000
    SelectedSpeed = "CR1000 running at " & Speed & " intervals."
  #ElseIf LoggerType = CR800
    SelectedSpeed = "CR800 running at " & Speed & " intervals."
  #Else
    SelectedSpeed = "Unknown Logger " & Speed & " intervals."
  #EndIf

  'Open the serial port.
  SerialOpen (SourcSerialPort,9600,10,0,10000)

  'Main Scan.
  Scan (ScanRate,Sec,0,0)
    'Here we make a measurement using different parameters and a different
    'SE channel depending on the logger type the program is running in.
    #If LoggerType = CR3000
      VoltSe (ValueRead,1,mV1000,22,0,0,_50Hz,0.1,-30)   'This instruction is used if the logger is a CR3000
    #ElseIf LoggerType = CR1000
      VoltSe (ValueRead,1,mV2500,12,0,0,_50Hz,0.1,-30)   'This instruction is used if the logger is a CR1000
    #ElseIf LoggerType = CR800
      VoltSe (ValueRead,1,mV2500,3,0,0,_50Hz,0.1,-30)    'This instruction is used if the logger is a CR800 Series
    #Else
      ValueRead = NaN
    #EndIf
  NextScan

EndProg
```

11.8 Serial I/O

This section introduces procedures and CRBASIC programming to enable CR1000 communications with devices through non-standard serial protocols.

Read More! See Section 13. Telecommunication and Data Retrieval for background on CR1000 serial communications.

11.8.1 Introduction

Serial denotes transmission of bits (1s and 0s) sequentially, or "serially", on a single wire. A byte is a packet of sequential bits. RS-232 and TTL standards use bytes containing eight bits each. Imagine that an instrument transmits the

byte 11001010 to the CR1000. The instrument does this by translating 11001010 into a series of higher and lower voltages, which it transmits to the CR1000. The CR1000 receives and reconstructs these voltage levels as 11001010. Because an RS-232 or TTL standard was adhered to by both the instrument and the CR1000, the byte successfully passes between them.

If the byte is displayed on a terminal as it was received, it will appear as an ASCII / ANSI character or control code. TABLE 11.8-1 shows a sample of ASCII / ANSI character and code equivalents.

TABLE 11.8-1. ASCII / ANSI Equivalents

Byte Received	ASCII Character Displayed	Decimal ASCII Code	Hex ASCII Code
00110010	2	50	32
1100010	b	98	62
00101011	+	43	2b
00001101	cr	13	d
00000001	☺	1	1

Read More! See Appendix D for a complete list of ASCII / ANSI codes and their binary and hex equivalents.

The byte's face value, however, is not what is usually of interest. The manufacturer of the instrument must specify what information in the byte is of interest. For instance, two bytes may be received, one for character 2, the other for character b. The pair of characters together, 2b, is the hexadecimal code for "+", "+" being the information of interest. Or, perhaps, the leading bit, the MSB, on each of two bytes is dropped, the remaining bits combined, and the resulting "superbyte" translated from the remaining bits into a decimal value. The variety of protocols is limited only by the number of instruments on the market. For one in-depth example of how bits may be translated into useable information, see Appendix E. FP2 Data Format.

Tip: ASCII / ANSI control character ff -- form feed (binary 00001100) causes a terminal screen to clear. This can be frustrating for a developer. Some third party terminal emulator programs, such as Procomm, are useful tools in serial I/O development since they handle this and other idiosyncrasies of serial communication.

When a standardized protocol is used, such as PakBus or Modbus, translation of bytes is relatively easy and transparent. However, when bytes require specialized translation, specialized code is required in the user entered CRBASIC program, and development time can extend into several hours and days.

11.8.2 Serial Ports

The CR1000 supports two-way serial communication with other instruments through ports listed in TABLE 11.8-2.

TABLE 11.8-2. CR1000 Serial Ports

Serial Port	Voltage Level	Logic
RS-232 (9-pin)	RS-232	Full duplex asynchronous RS-232
CS I/O (9-pin)	TTL	Full duplex asynchronous RS-232
COM1 (C1 – C2)	TTL	Full duplex asynchronous RS-232/TTL
COM2 (C3 – C4)	TTL	Full duplex asynchronous RS-232/TTL
COM3 (C5 – C6)	TTL	Full duplex asynchronous RS-232/TTL
COM4 (C7 – C8)	TTL	Full duplex asynchronous RS-232/TTL
C1	5 VDC	SDI-12
C3	5 VDC	SDI-12
C5	5 VDC	SDI-12
C7	5 VDC	SDI-12
C1, C2, C3	5 VDC	SDM (used with CSI peripherals only)

11.8.3 Serial Protocols

PakBus is the protocol native to the CR1000 and transparently handles routine point-to-point and network communications among CSI dataloggers and PCs. Modbus and DNP3 are standard networking SCADA protocols that optionally operate in the CR1000 with minimal configuration by the user. PakBus, Modbus, and DNP3 operate on the RS-232, CS I/O, and four COM ports. SDI-12 is a protocol used by some smart sensors that requires minimal configuration by the user.

Read More! See Sections 4.7 SDI-12 Measurements, 11.3 SDI-12 Sensor Support, 14 PakBus Overview, 15.1 DNP3, and 15.2 Modbus.

Many instruments require non-standard protocols to communicate with the CR1000.

Programming Tip! If an instrument or sensor supports SDI-12, Modbus or DNP3, consider using these protocols before programming a custom protocol. These higher level protocols are standardized and, relative to a custom protocol, easy to use. SDI-12, Modbus, and DNP3 also support addressing systems that allow multiplexing of several sensors on a single communications port, which makes for more efficient use of resources.

11.8.4 Terms

Asynchronous indicates the sending and receiving devices are not synchronized using a clock signal.

Baud rate is the rate at which data, plus the start and stop bits, are transmitted. Bits Per Second (BPS) does not account for the start and stop bits.

Big Endian "Big end first." Placing the most significant integer at the beginning of a numeric word, reading left to right.

cr Carriage Return

Data bits is the number of bits used to describe the data, and fit between the start and stop bits. Sensors typically use 7 or 8 data bits.

Duplex can be half or full. Full duplex is simultaneous, bidirectional data.

lf Line Feed

Little Endian "Little end first." Placing the most significant integer at the end of a numeric word, reading left to right.

LSB Least significant bit

Marks and Spaces RS232 signal levels are inverted logic compared to TTL. The different levels are called marks and spaces. When referenced to signal ground, the valid RS232 voltage level for a mark is -3 to -25, and for a space is +3 to +25 with -3 to + 3 considered the transition range and meaningless. A mark is a logic 1 and negative voltage. A space is a logic 0 and positive voltage.

MSB Most significant bit

RS-232C refers to the standard used to define the hardware signals and voltage levels. The CR1000 supports several options of serial logic and voltage levels including RS-232 logic at TTL levels and TTL logic at TTL levels.

RX Receive

SP Space

Start bit is the bit used to indicate the beginning of data.

Stop bits is the end of the data bits. The stop bit can be 1, 1.5 or 2.

TX Transmit

11.8.5 CRBASIC Programming

To transmit or receive RS-232 or TTL signals, a serial port (see TABLE 11.8-2) must be opened and configured through CRBASIC with the SerialOpen() instruction. The SerialClose() instruction can be used to close the serial port. Below is practical advice regarding the use of SerialOpen() and

SerialClose. Program EXAMPLE 11.8-1 and EXAMPLE 11.8-2 show their use. Consult CRBASIC Editor Help for more information.

SerialOpen (COM Port , Baud Rate , Format , TX Delay , Buffer Size)

Baud rate – baud rate mismatch is frequently a problem when developing a new application. Check for matching baud rates. Some developers prefer to use a fixed baud rate during initial development. When set to a negative value, auto-baud rate detect will be enabled. Auto-baud is useful when using the CS I/O and RS232 ports since it will allow the ports to also be used for PC telecommunications.

Format -- determines data type and if PakBus communications can occur on the COM port. If the port is expected to read sensor data and support normal PakBus telemetry operations, use the auto-baud rate option and ensure the format option supports PakBus communications.

Buffer size -- The buffer holds data received until it is removed. SerialIn(), SerialInRecord(), and SerialInBlock() instructions are used to read data from the buffer to variables. Once the data is in variables, string manipulation instructions are used to format and parse the data.

SerialClose() must be used before SerialOpen() can be used again to reconfigure the same serial port, or before the port can be used to communicate with a PC.

11.8.5.1 Serial Input Instruction Set Basics

SerialOpen[1]

- Be aware of buffer size (ring memory)
- Closes PPP (if active)
- Returns TRUE or FALSE when set equal to a Boolean variable

SerialClose

- Examples of when to close
  - Reopen PPP
  - Finished setting new settings in a Hayes modem
  - Finished dialing a modem
- Returns TRUE or FALSE when set equal to a Boolean variable

SerialFlush

- Puts the read and write pointers back to the beginning
- Returns TRUE or FALSE when set equal to a Boolean variable

SerialIn[1]

- Can wait on the string until it comes in
- Timeout is renewed after each character is received
- SerialInRecord tends to obsolete SerialIn.
- Buffer size margin (1 extra record + 1 byte).

SerialInBlock[1]
- For binary data (perhaps integers, floats, data with NULL characters).
- Destination can be of any type.
- Buffer size margin (1 extra record + 1 byte).

SerialOutBlock[1,3]
- Binary
- Can run in pipeline mode inside the digital measurement task (along with SDM instructions) if COM1..COM4 and the number of bytes is a constant.

SerialOut
- Handy for ASCII command and a known response, e.g., Hayes modem commands.
- Returns 0 if not open else the number of bytes sent.

SerialInRecord[2]
- Can run in pipeline mode inside the digital measurement task (along with SDM instructions) if COM1..COM4 and the number of bytes is a constant.
- Simplifies synchronization with one way.
- Simplifies working with protocols that send a "record" of data with known start and/or end characters, or a fixed number of records in response to a poll command.
- If a start and end word is not present, then a time gap is the only remaining separator of records. Using Com1..Com4 coincidentally detects a time gap of >100 bits as long as the records are less than 256 bytes.
- Buffer size margin (1 extra record + 1 byte).

[1] Processing instructions
[2] Measurement instruction in the pipeline mode

[3] Measurement instruction if expression evaluates to a constant

11.8.5.2 Serial Input Programming Basics

Applications with the purpose of receiving data from another device usually include the following procedures. Other procedures may be required depending on the application.

1. Know what the sensor supports and exactly what the data is. Most sensors work well with TTL voltage levels and RS232 logic. Some things to consider:
   - Become thoroughly familiar with the data to be captured
   - Can the sensor be polled?
   - Does the sensor send data on its own schedule?
   - Are there markers at the beginning or end of data? Markers are very useful for identifying a variable length record.
   - Does the record have a delimiter character, e.g. ",", spaces or tabs? These delimeters are useful for parsing the record into usable numbers.
   - Will the sensor be sending multiple data strings? Multiple strings usually require filtering before parsing.
   - How fast will data be sent to the datalogger?
   - Is power consumption critical?
   - Does the sensor compute a checksum? Which type? A checksum is useful to test for data corruption.

2. Open a serial port (CRBASIC SerialOpen() command)
   - Example: SerialOpen(Com1,9600,0,0,10000)
   - Designate the correct port in CRBASIC
   - Correctly wire the device to the CR1000
   - Match the port's baud rate to the baud rate of the device in CRBASIC.
     - Use a fixed baud rate (rather than autobaud) when possible.

3. Receive serial data as a string (CRBASIC SerialIn() or SerialInRecord() command)
   - Example: SerialInRecord(Com2,SerialInString,42,0,35,"",01)
   - Declare the string variable large enough to accept the string.
     - Example: Public SerialInString As String * 25
   - Observe the input string in the input string variable in software numeric monitor.
   - NOTE: SerialIn() and SerialInRecord() receive the same data. SerialInRecord() is generally used for data streaming into the CR1000, while SerialIn is used for data that is received in discrete blocks.

4. Parse (split up) the serial string (CRBASIC SplitStr() Command)
   - Separates string into numeric and / or string variables.
   - Example: SplitStr(InStringSplit,SerialInString,"",2,0)
   - Declare an array to accept the parsed data
     - Example: Public InStringSplit(2) As String
     - Example: Public SplitResult(2) As Float

11.8.5.3 Serial Output Programming Basics

Applications with the purpose of transmitting data to another device usually include the following procedures. Other procedures may be required depending on the application.

1. Open a serial port (SerialOpen() command) to configure it for communications.
   - Parameters are set according to the requirements of the communications link and the serial device.
   - Example: SerialOpen (Com1,9600,0,0,10000)
   - Designate the correct port in CRBASIC
   - Correctly wire the device to the CR1000
   - Match the port's baud rate to the baud rate of the device in CRBASIC.
   - Use a fixed baud rate (rather than auto baud) when possible.

2. Build the output string
   - Example: SerialOutString = "*" & "27.435" & "," & "56.789" & "#"
   - Tip: concatenate (add) strings together using & instead of +
   - Tip: CHR() instruction is used to insert ASCII / ANSI characters into a string

3. Output string via the serial port (SerialOut() or SerialOutBlock() command)
   - Example: SerialOut (Com1,SerialOutString,"",0,100)
   - Declare the output string variable large enough to hold the entire concatenation.
   - Example: Public SerialOutString As String * 100

- SerialOut() and SerialOutBlock() output the same data, except that SerialOutBlock transmits null values while SerialOut() strings are terminated by a null value.

11.8.5.4 Translating Bytes

One or more of three principle data formats may end up in the SerialInString variable (see examples in Sec. 11.8.3.2). Data may be combinations or variations of all of these. The manufacturer of the instrument must provide the rules by which data are to be decoded.

Alpha-numeric – each digit represents its own alpha-numeric value, i.e., R = the letter R, and 2 = decimal 2. This is the easiest protocol to translate since literal translation arrives complete from the transmitting instrument. It remains to the CRBASIC program to parse (split) the string up and place the values in CR1000 variables.

Example (humidity, temperature, and pressure sensor):

```
SerialInString = "RH= 60.5 %RH T= 23.7 'C Tdf= 15.6 'C Td= 15.6 'C
a= 13.0 g/m3   x=   11.1  g/kg    Tw= 18.5  'C H2O=  17889 ppmV
pw=17.81 hPa pws   29.43 hPa h= 52.3 kJ/kg   dT= 8.1 'C"
```

Hex Pairs – Bytes are translated to hex pairs, consisting of digits 0 - 9 and letters a – f. Each pair describes a hexadecimal ASCII / ANSI code. Some codes translate to alpha-numeric values, others to symbols or non-printable control characters.

Example (Temperature Sensor):

```
SerialInString = "23 30 31 38 34 0D" (translates to #01 84 cr)
```

Binary – Bytes are processed on a bit-by-bit basis. Character 0 (Null, &b00) is a valid part of binary data streams. However, the CR1000 uses Null terminated strings, so anytime a Null is received, a string is terminated. The termination is usually premature when reading binary data. To remedy this problem, the SerialInBlock() or SerialInRecord() instruction is required when reading binary data from the serial port buffer to a variable. The variable must be an array set As Long data type, as in,

Dim SerialInString As Long

11.8.5.5 Memory Considerations

Several points regarding memory should be considered when receiving and processing serial data.

1) Serial buffer. The serial port buffer, which is declared in the SerialOpen() instruction, must be large enough to hold all the data a device will send. The buffer holds the data for subsequent transfer to variables. Allocate extra memory to the buffer when needed, but recognize that added memory to the buffer reduces memory available for long term data storage.

NOTE SerialInRecord running in pipeline mode, with the number of bytes parameter = 0. For the digital measurement sequence to know how much room to allocate in the Scan() instruction buffers (default of 3), SerialInRecord has to allocate itself the buffer size specified by SerialOpen (default 10,000, an overkill), or default 3*10,000 = 30K of buffer space. So, while making sure enough bytes are allocated in SerialOpen (the number of bytes per record * ((records/Scan)+1) + at least one extra byte), there is reason not to make the buffer size too large. (Note that if the number of bytes parameter is non-zero, then SerialInRecord needs to allocate itself only this many bytes instead of the number of bytes specified by SerialOpen.)

2) Variable declarations. Variables used to receive data from the serial buffer can be declared as Public or Dim. DIMing variables has the effect of consuming less telecommunications bandwidth. When Public variables are viewed in software, the entire Public table is transferred at the update interval. If the Public table is large, telecommunications bandwidth can be taxed such that other data tables are not collected.

3) String declarations. String variables are memory intensive. Determine how large strings will be and declare variables just large enough to hold the string. If the sensor sends multiple strings at once, consider declaring a single string variable and read incoming strings one at a time.

4) The CR1000 adjusts the declared size of strings. One byte is always added to the declared length, which is then increased by up to another 3 bytes to make length divisible by 4.

5) When strings are written to memory, declared string length, not number of characters, determines the memory consumed. Consequently, large strings not filled with characters waste significant memory.

11.8.6 Demonstration Programs

Program Examples 11.8-1 through 11.8-3 are provided as exercises in serial input / output programming. The examples only require the CR1000 and a single wire jumper between COM1 Tx and COM2 Rx. The programs simulate a temperature and relative humidity sensor transmitting RS-232 data out COM1. EXAMPLE 11.8-1 outputs data as an alpha-numeric string.

EXAMPLE 11.8-2 outputs data as hex pairs. EXAMPLE 11.8-3 outputs data in a binary format. The input side acts as an RS-232 receiver, which receives the simulated sensor output on COM2, parses it, and places the parsed data into temperature and relative humidity variables.

EXAMPLE 11.8-1. CRBASIC Code: Serial I/O program to receive a simulated RS-232 sensor string. Output string is simulated by the program.

```
'RS-232 Demonstration Program

'Receive data from a simulated RS-232 sensor to demonstrate RS-232 input / output on a single CR800.  Simulated
'air temperature = 27.435 F, relative humidity 56.789 %.

'Wiring:
'COM1 TX (C1) ----- COM2 RX (C4)

'Serial Out Declarations
Public TempOut As Float
Public RhOut As Float
Public SerialOutString As String * 25                    'Declare a string variable large enough to
                                                         'hold the output  string.
'Serial In Declarations
Public SerialInString As String * 25                     'Declare a string variable large enough to
                                                         'hold the output string
Public InStringSplit(2) As String                        'Declare strings to accept parsed data.
                                                         'If parsed data is strictly numeric, this array
                                                         'can be declared as Float or Long
Alias InStringSplit(1) = TempIn
Alias InStringSplit(2) = RhIn

'Main Program
BeginProg

    'Simulate temperature and RH sensor
    TempOut = 27.435                                     'Set simulated temperature to transmit
    RhOut = 56.789                                       'Set simulated relative humidity to transmit

    Scan(5,Sec, 3, 0)

      'Serial Out Code
      'Transmits string "*27.435,56.789#" out COM1
      SerialOpen (Com1,9600,0,0,10000)                   'Open a serial port
      SerialOutString = "*" & TempOut & "," & RhOut & "#"  'Build the output string
      SerialOut (Com1,SerialOutString,"",0,100)          'Output string via the serial port

      'Serial In Code
      'Receives string "27.435,56.789" via COM2
      'Uses * and # character as filters
      SerialOpen (Com2,9600,0,0,10000)                   'Open a serial port
      SerialInRecord (Com2,SerialInString,42,0,35,"",01)  'Receive serial data as a string
      SplitStr (InStringSplit(),SerialInString,"",2,0)   'Parse the serial string

    NextScan
EndProg
```

11.8.7 Testing Serial I/O Applications

A common problem when developing a serial I/O application is the lack of an immediately available serial device with which to develop and test programs. Using HyperTerminal, a developer can simulate the output of a serial device or capture serial input.

NOTE HyperTerminal automatically converts binary data to ASCII on the screen. Binary data can be captured, saved to a file, and then viewed with a hexadecimal editor. Other terminal emulators are available from third party vendors that facilitate capture of binary or hex data.

11.8.7.1 Configure HyperTerminal

Create a HyperTerminal instance file by clicking Start | All Programs | Accessories | Communications | HyperTerminal. The windows in FIGURE 11.8-1 through FIGURE 11.8-4 will be presented. Enter an instance name and click OK.

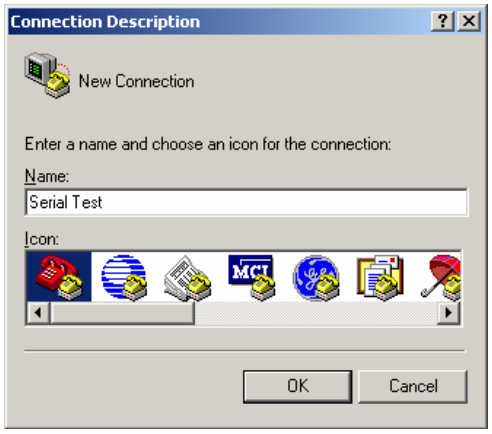


FIGURE 11.8-1. HyperTerminal Connection Description

FIGURE 11.8-2. HyperTerminal Connect To Settings

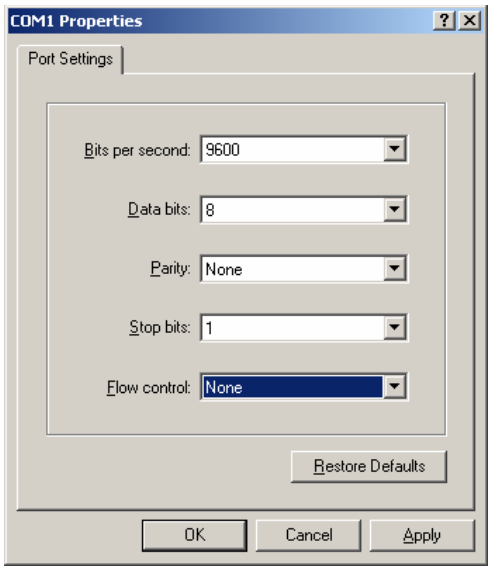


FIGURE 11.8-3. HyperTerminal COM Port Settings

Click File | Properties | Settings | ASCII Setup... and set as shown.

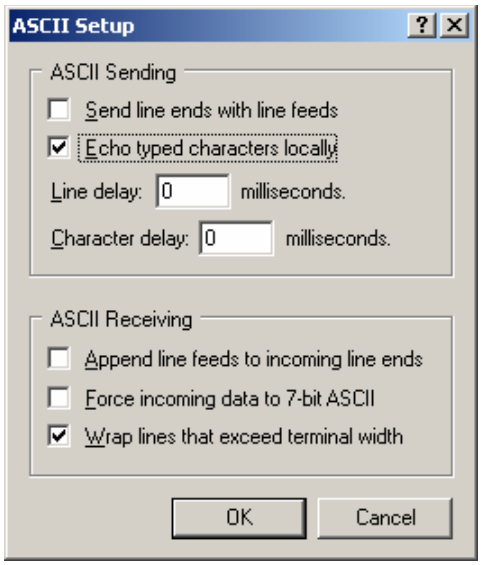
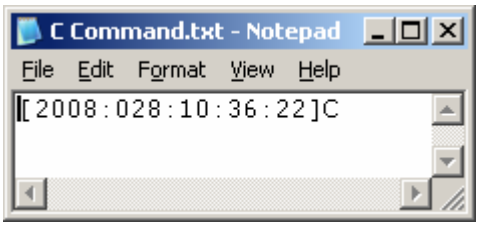


FIGURE 11.8-4. HyperTerminal ASCII Setup

11.8.7.2 Create Send Text File

Create a file from which to send a serial string. The file shown in EXAMPLE 11.8-2 will send the string "[2008:028:10:36:22]C" to the CR1000. Use Notepad or some other text editor that will not place unexpected hidden characters in the file.

EXAMPLE 11.8-2. HyperTerminal Send Text File Example

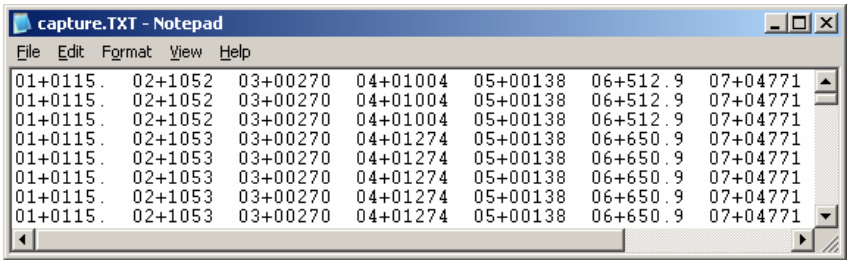


To send the file, click Transfer | Send Text File | Browse for file, then click OK.

11.8.7.3 Create Text Capture File

EXAMPLE 11.8-3 shows a HyperTerminal capture file with some data. The file is empty before use commences.

EXAMPLE 11.8-3. HyperTerminal Text Capture File Example



Engage text capture by clicking on Transfer | Capture Text | Browse, select the file and click OK.

11.8.8 Example Test Program

The following test program solves a problem for a specific Campbell Scientific customer. It illustrates one use of CR1000 serial I/O features. The example allows the reader to program a CR1000 to gain experience with serial I/O applications.

Problem: An energy company has a large network of older CR510 dataloggers into which new CR1000 dataloggers are to be incorporated. The CR510 dataloggers are programmed to output data in the legacy Campbell Scientific Printable ASCII format, which satisfies requirements of the customer's data acquisition system. The network administrator also prefers to synchronize the CR510 clocks from a central computer using the legacy Campbell Scientific 'C' command. The CR510 datalogger is hard-coded to output Printable ASCII and recognize the 'C' command. CR1000 dataloggers, however, require custom programming to output and accept these same ASCII strings.

Solution: Programming EXAMPLE 11.8-4 imports and exports serial data via the CR1000 RS-232 port. Imported data is expected to have the form of the legacy Campbell Scientific time set 'C' command. Exported data has the form of the legacy Campbell Scientific Printable ASCII format.

NOTE The RS232 port can be used to download the datalogger program if the SerialOpen() baud rate matches that of CSI support software (PC400, LoggerNet, etc). However, two-way PakBus communications will cause the CR1000 to occasionally send unsolicited PakBus packets out the RS232 port for at least 40 seconds after the last PakBus communication. This will produce some "noise" on the intended data output signal.

Monitor the CR1000 RS232 port with the HyperTerminal instance described in Section 11.8.4.1. Send C command file to set the clock according to the text in the file.

NOTE The HyperTerminal file will not update automatically with actual time. The file only simulates a clock source.

EXAMPLE 11.8-4. CRBASIC Code: measures sensors and sends data out the RS-232 port in Printable ASCII format. Accepts "C" command to set the CR1000 clock.

```
'Declarations
'Visible Variables
Public StationID
Public KWH_In
Public KVarH_I
Public KWHHold
Public KVarHold
Public KWHH
Public KvarH
Public InString As String * 25
Public OutString As String * 100

'Hidden Variables
Dim i, rTime(9), OneMinData(6), OutFrag(6) As String
Dim InStringSize, InStringSplit(5) As String
Dim Date, Month, Year, DOY, Hour, Minute, Second, uSecond
Dim LeapMOD4, LeapMOD100, LeapMOD400
Dim Leap4 As Boolean, Leap100 As Boolean, Leap400 As Boolean,
Dim LeapYear As Boolean
Dim ClkSet(7) As Float

'One Minute Data Table
DataTable(OneMinTable,true,-1)
   OpenInterval 'sets interval same as found in CR510
   DataInterval(0,1,Min,10)
   Totalize(1, KWHH,FP2,0)
   Sample(1, KWHHold,FP2)
   Totalize(1, KvarH,FP2,0)
   Sample(1, KVarHold,FP2)
   Sample(1, StationID,FP2)
EndTable
```

```
'Clock Set Record Data Table
DataTable (ClockSetRecord,True,-1)
  Sample(7,ClkSet(),FP2)
EndTable

'Subroutine to convert date formats (day-of-year to month and date)
Sub DOY2MODAY

  'Store Year, DOY, Hour, Minute and Second to Input Locations.
  Year = InStringSplit(1)
  DOY = InStringSplit(2)
  Hour = InStringSplit(3)
  Minute = InStringSplit(4)
  Second = InStringSplit(5)
  uSecond = 0

  'Check if it is a leap year:
  'If Year Mod 4 = 0 and Year Mod 100 <> 0, then it is a leap year OR
  'If Year Mod 4 = 0, Year Mod 100 = 0, and Year Mod 400 = 0, then it is a leap year

  LeapYear = 0 'Reset leap year status location

  LeapMOD4 = Year MOD 4
  LeapMOD100 = Year MOD 100
  LeapMOD400 = Year MOD 400

  If LeapMOD4 = 0 Then Leap4 = True Else Leap4 = False
  If LeapMOD100 = 0 Then Leap100 = True Else Leap100 = False
  If LeapMOD400 = 0 Then Leap400 = True Else Leap400 = False

  If Leap4 = True Then
    LeapYear = True
    If Leap100 = True Then
      If Leap400 = True Then
        LeapYear = True
      Else
        LeapYear = False
      EndIf
    EndIf
  Else
    LeapYear = False
  EndIf

  'If it is a leap year, use this section.
  If (LeapYear = True) Then
    Select Case DOY
    Case Is < 32
      Month = 1
      Date = DOY
    Case Is < 61
      Month = 2
      Date = DOY + -31
    Case Is < 92
      Month = 3
      Date = DOY + -60
```

```
  Case Is < 122
      Month = 4
      Date = DOY + -91
    Case Is < 153
      Month = 5
      Date = DOY + -121
    Case Is < 183
      Month = 6
      Date = DOY + -152
    Case Is < 214
      Month = 7
      Date = DOY + -182
    Case Is < 245
      Month = 8
      Date = DOY + -213
    Case Is < 275
      Month = 9
      Date = DOY + -244
    Case Is < 306
      Month = 10
      Date = DOY + -274
    Case Is < 336
      Month = 11
      Date = DOY + -305
    Case Is < 367
      Month = 12
      Date = DOY + -335
    EndSelect
'If it is not a leap year, use this section.
  Else
    Select Case DOY
    Case Is < 32
      Month = 1
      Date = DOY
    Case Is < 60
      Month = 2
      Date = DOY + -31
    Case Is < 91
      Month = 3
      Date = DOY + -59
    Case Is < 121
      Month = 4
      Date = DOY + -90
    Case Is < 152
      Month = 5
      Date = DOY + -120
    Case Is < 182
      Month = 6
      Date = DOY + -151
    Case Is < 213
      Month = 7
      Date = DOY + -181
    Case Is < 244
      Month = 8
      Date = DOY + -212
```

```
   Case Is < 274
      Month = 9
      Date = DOY + -243
    Case Is < 305
      Month = 10
      Date = DOY + -273
    Case Is < 336
      Month = 11
      Date = DOY + -304
    Case Is < 366
      Month = 12
      Date = DOY + -334
    EndSelect
  EndIf
EndSub

'\\\\\\\\\\\\\\\\\\\\\\\\\\\\ PROGRAM ////////////////////////////

BeginProg
  StationID = 4771
  Scan(1,Sec, 3, 0)

    '////////////////Measurement Section//////////////////

    'PulseCount(KWH_In, 1, 1, 2, 0, 1, 0) 'Activate this line in working program
    KWH_In = 4.5 'Simulation -- delete this line from working program
    'PulseCount(KVarH_I, 1, 2, 2, 0, 1, 0) 'Activate this line in working program
    KVarH_I = 2.3 'Simulation -- delete this line from working program

    KWHH = KWH_In
    KvarH = KVarH_I
    KWHHold = KWHH + KWHHold
    KVarHold = KvarH + KVarHold

    CallTable OneMinTable

    '////////////////////Serial I/O Section/////////////////////

    SerialOpen (ComRS232,9600,0,0,10000)

    '///////////////Serial Time Set Input Section///////////////

    'Accept old C command -- [2008:028:10:36:22]C -- parse, process, set clock
    SerialInRecord (ComRS232,InString,91,0,67,InStringSize,01) 'Chr(91) = [, Chr(67) = C

    If InStringSize <> 0 Then
      SplitStr (InStringSplit,InString,"",5,0)

      Call DOY2MODAY 'Call subroutine to convert day-of-year to month & day

      ClkSet(1) = Year
      ClkSet(2) = Month
      ClkSet(3) = Date
      ClkSet(4) = Hour
      ClkSet(5) = Minute
      ClkSet(6) = Second
```

```
      ClkSet(7) = uSecond
      ClockSet (ClkSet()) 'Array requires year, month, date, hour, minute, second, microseconds
      CallTable (ClockSetRecord)

    EndIf

    '///////////////Serial Output Section///////////////
    'Construct old Campbell Scientific Printable ASCII data format and output to COM1

    'Read datalogger clock
    RealTime (rTime)

    If TimeIntoInterval (0,5,Sec) Then
      'Load OneMinData table data for processing into printable ASCII
      GetRecord (OneMinData(),OneMinTable,1)

      'Assign +/- Sign
      For i=1 To 6
        If OneMinData(i) < 0 Then
          OutFrag(i)=CHR(45) & FormatFloat (ABS(OneMinData(i)),"%05g") 'chr45 is - sign
        Else
          OutFrag(i)=CHR(43) & FormatFloat (ABS(OneMinData(i)),"%05g") 'chr43 is + sign
        EndIf
      Next i

      'Concatenate Printable ASCII string, then push string  out RS-232 (first 2 fields are ID, hhmm):
      OutString = "01+0115." & "  02+"  & FormatFloat(rTime(4),"%02.0f") & FormatFloat(rTime(5),"%02.0f")
      OutString = OutString & "  03" & OutFrag(1) & "  04" & OutFrag(2) & "  05" & OutFrag(3)
      OutString = OutString & "  06" & OutFrag(4) & "  07" & OutFrag(5) & CHR(13) & CHR(10) & "" 'add CR LF null

      'Send printable ASCII string out RS232 port
      SerialOut (ComRS232,OutString,"",0,220)

    EndIf

  NextScan
EndProg
```

11.8.9 Q & A

Q: I am writing a CR1000 program to transmit a serial command that contains a null character.

The string to transmit is:
CHR(02)+CHR(01)+"CWGT0"+CHR(03)+CHR(00)+CHR(13)+CHR(10)

How does the logger handle the null character?
Is there a way that we can get the logger to send this?

A: Strings created with CRBASIC are NULL terminated. Adding strings together means the 2nd string will start at the first null it finds in the first string.

Use SerialOutBlock() instruction, which lets you send null characters, as shown below.

```
SerialOutBlock (COMRS232, CHR(02) + CHR(01) + "CWGT0" +
CHR(03),8)
SerialOutBlock (COMRS232, CHR(0),1)
SerialOutBlock (COMRS232, CHR(13) + CHR(10),2)
```

Q: Please explain / summarize when the CR1000 powers the RS-232 port? I get that there is an "always on" setting. How about when there are beacons? Does the SerialOpen instruction cause other power cycles?

A: The RS-232 port is left on under the following conditions: 1) when the setting: RS232Power is set, or 2) when the SerialOpen() for COMRS232 is used in the program. Both of these conditions power up the interface and leave it on (with no timeout). If SerialClose is used after SerialOpen() then the port is powered down and in a state waiting for characters to come in.

Under normal operation the port is powered down waiting for input. Upon receiving input there is a 40 second software timeout that must expire before shutting down. The 40 second timeout is generally circumvented when communicating with LoggerNet because it sends information as part of the protocol that lets the CR1000 know that it can shut down the port.

When in the "dormant" state with the interface powered down, hardware is configured to detect activity and wake up, but there is a penalty of losing the first character of the incoming data stream. PakBus takes this into consideration in the "ring packets" that are preceded with extra sync bytes at the start of the packet. For this reason SerialOpen leaves the interface powered up so no incoming bytes will be lost.

When the CR1000 has data to send via the RS-232 port, if the data is not a response to a received packet, such as sending a beacon, then it will power up the interface, send the data and return to the "dormant" state with no 40 sec timeout.

11.9 TrigVar and DisableVar -- Controlling Data Output and Output Processing

TrigVar is the third parameter in the DataTable () instruction. It controls whether or not a data record is written to final storage. TrigVar control is subject to other conditional instructions such as the DataInterval () and DataEvent () instructions.

DisableVar is the last parameter in most output processing instructions, such as Average (), Maximum (), Minimum (), etc. It controls wheather or not a particular measurement or value is included in the affected output processing function.

> Flashback! Together, TrigVar and DataInterval grant functionality similar to Flag 0 in earlier generation CSI mixed-array dataloggers, such as the CR10X.

For individual measurements to affect summary data, output processing instructions such as Average () must be executed whenever the DataTable is called from the program – normally once each Scan. For example, for an average to be calculated for the hour, each measurement must be added to a total over the hour. This accumulation of data are not affected by TrigVar. TrigVar only controls the moment when the final calculation is performed and the processed data (the average) is written to the data table. For this summary moment to occur, TrigVar and all other conditions (i.e. DataInterval and DataEvent) must be true. To restate, when TrigVar is false, output processing instructions (e.g. Average ()) perform intermediate processing but not their final processing, and a new record will not be created.

Take Away: In many applications, output records are solely interval based and TrigVar is set to TRUE (-1) always. In these applications DataInterval () is the sole specifier of the output trigger condition.

EXAMPLE 11.9-1 lists CRBASIC code that uses TrigVar () rather than DataInterval () to trigger data storage. TABLE 11.9-1 shows data produced by the example code.

EXAMPLE 11.9-1. Using TrigVar to Trigger Data Storage

In this example, the variable "counter" is incremented by 1 each scan. The data table is called every scan, which includes the Sample (), Average (), and Totalize () instructions. TrigVar is true when counter = 2 or counter = 3. Data are stored when TrigVar is true. Data stored are the sample, average, and total of the variable counter, which is equal to 0, 1, 2, 3, or 4 when the data table is called.

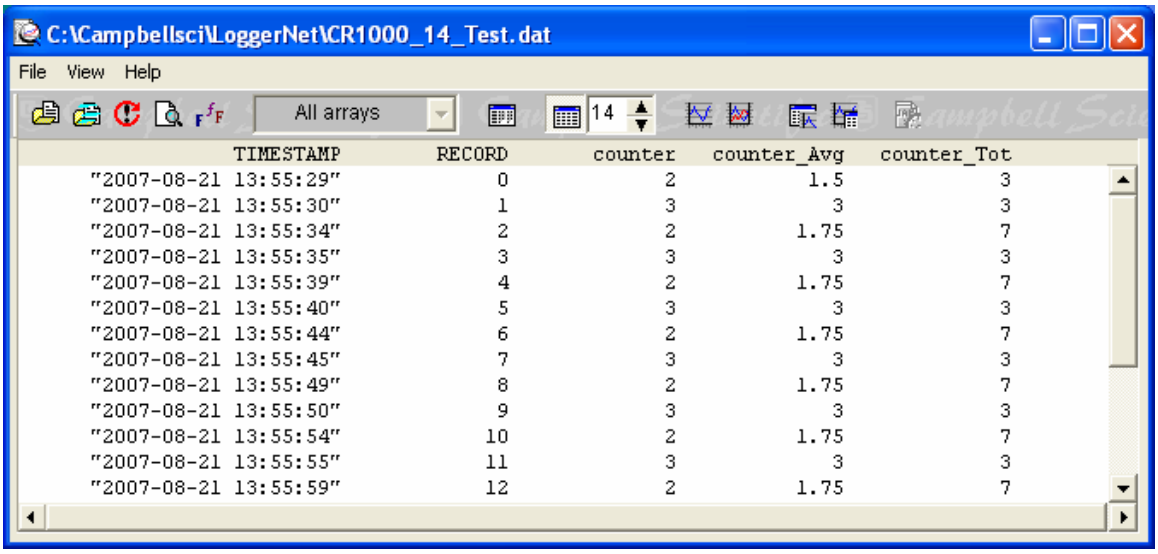
```
'CR1000 Series Datalogger

Public counter

DataTable (Test,counter=2 or counter=3,100)
    Sample (1,counter,FP2)
    Average (1,counter,FP2,False)
    Totalize (1,counter,FP2,False)
EndTable

BeginProg
    Scan (1,Sec,0,0)
        counter = counter+1
        If counter = 5 Then
            counter = 0
        EndIf
        CallTable Test
    NextScan
EndProg
```

TABLE 11.9-1. Data Generated by Code in EXAMPLE 11.9-1



C:\CampbellSci\LoggerNet\CR1000_14_Test.dat

File View Help

All arrays 14

TIMESTAMP	RECORD	counter	counter_Avg	counter_Tot
"2007-08-21 13:55:29"	0	2	1.5	3
"2007-08-21 13:55:30"	1	3	3	3
"2007-08-21 13:55:34"	2	2	1.75	7
"2007-08-21 13:55:35"	3	3	3	3
"2007-08-21 13:55:39"	4	2	1.75	7
"2007-08-21 13:55:40"	5	3	3	3
"2007-08-21 13:55:44"	6	2	1.75	7
"2007-08-21 13:55:45"	7	3	3	3
"2007-08-21 13:55:49"	8	2	1.75	7
"2007-08-21 13:55:50"	9	3	3	3
"2007-08-21 13:55:54"	10	2	1.75	7
"2007-08-21 13:55:55"	11	3	3	3
"2007-08-21 13:55:59"	12	2	1.75	7

11.10 Programming for Control

This section is not yet available.

11.11 NSEC Data Type

11.11.1 NSEC Application

NSEC data type consists of 8 bytes divided up as 4 bytes of seconds since 1990 and 4 bytes of nanoseconds into the second. NSEC is used when a LONG variable being sampled is the result of the RealTime () instruction, or when the sampled variable is a LONG storing time since 1990, such as results when time-of-maximum or time-of-minimum is requested.

Specific uses include:

- Placing a timestamp in a second position in a record.
- Accessing a timestamp from a data table and subsequently storing it as part of a larger data table. Maximum (), Minimum, and FileTime () instructions produce a timestamp that may be accessed from the program after being written to a data table. The time of other events, such as alarms, can be stored using the RealTime () instruction.
- Accessing and storing a timestamp from another datalogger in a PakBus network.

11.11.2 NSEC Options

NSEC is used in a CRBASIC program one of the following three ways. In all cases, the time variable is only sampled with Sample () instruction reps = 1.

- Time variable dimensioned to (1). If the variable array (must be LONG) is dimensioned to 1, the instruction assumes that the variable holds seconds since 1990 and microseconds into the second is 0. In this instance, the value stored is a standard datalogger timestamp rather than the number of seconds since January 1990. EXAMPLE 11.11-1 shows NSEC used with a time variable array of (1).

- Time variable dimensioned to (2). If the variable array (must be LONG) is dimensioned to two, the instruction assumes that the first element holds seconds since 1990 and the second element holds microseconds into the second. EXAMPLE 11.11-2 shows NSEC used with a time variable array of (2).

- Time variable dimensioned to (7). If the variable array (must be FLOAT or LONG) is dimensioned to 7, and the values stored are year, month, day of year, hour, minutes, seconds, and milliseconds. EXAMPLE 11.11-3 shows NSEC used with a time variable array of (7).

11.11.3 Example NSEC Programming

EXAMPLE 11.11-1. CRBASIC Code: Using NSEC data type on a 1 element array.

A timestamp is retrieved into variable TimeVar (1) as seconds since 00:00:00 1 January 1990. Because the variable is dimensioned to 1, NSEC assumes the value = seconds since 00:00:00 1 January 1990.

```
Public PTemp
Public TimeVar (1) As Long

DataTable (FirstTable,True,-1)
    DataInterval (0,1,Sec,10)
    Sample (1,PTemp,FP2)
EndTable

DataTable (SecondTable,True,-1)
    DataInterval (0,5,Sec,10)
    Sample (1,TimeVar,Nsec)
EndTable

BeginProg
    Scan (1,Sec,0,0)
        TimeVar = FirstTable.TimeStamp
        CallTable FirstTable
        CallTable SecondTable
    NextScan
EndProg
```

EXAMPLE 11.11-2. CRBASIC Code: Using NSEC data type on a 2 element array.

TimeStamp is retrieved into variables TimeOfMaxVar(1) and TimeOfMaxVar(2). Because the variable is dimensioned to 2, NSEC assumes TimeOfMaxVar(1) = seconds since 00:00:00 1 January 1990, and TimeOfMaxVar(2) = µsec into a second.

```
Public PTempC
Public MaxVar
Public TimeOfMaxVar(2) As Long

DataTable (FirstTable,True,-1)
    DataInterval (0,1,Min,10)
    Maximum (1,PTempC,FP2,False,True)
EndTable

DataTable (SecondTable,True,-1)
    DataInterval (0,5,Min,10)
    Sample (1,MaxVar,FP2)
    Sample (1,TimeOfMaxVar,Nsec)
EndTable

BeginProg
    Scan (1,Sec,0,0)
        PanelTemp (PTempC,250)
        MaxVar = FirstTable.PTempC_Max
        TimeOfMaxVar = FirstTable.PTempC_TMx
        CallTable FirstTable
        CallTable SecondTable
    NextScan
EndProg
```

EXAMPLE 11.11-3. CRBASIC Code: Using NSEC data type with a 7 element time array.

A timestamp is retrieved into variable rTime(1) through rTime(9) as year, month, day, hour, minutes, seconds, and microseconds using the RealTime () instruction. The first seven time values are copied to variable rTime2(1) through rTime2(7). Because the variables are dimensioned to 7 or greater, NSEC assumes the first seven time factors in the arrays are year, month, day, hour, minutes, seconds, and microseconds.

```
Public rTime(9) As Long          '(or Float)
Public rTime2(7) As Long         '(or Float)
Dim x

DataTable (SecondTable,True,-1)
    DataInterval (0,5,Sec,10)
    Sample (1,rTime,Nsec)
    Sample (1,rTime2,Nsec)
EndTable

BeginProg
    Scan (1,Sec,0,0)
        RealTime (rTime)
        For x = 1 To 7
            rTime2(x) = rTime(x)
```

```
        Next
        CallTable SecondTable
    NextScan
EndProg
```

11.12 Bool8 Data Type

Boolean variables are typically used to represent conditions or hardware that have only 2 states (high/low, on/off, true/false) such as flags and control ports. A BOOLEAN data type variable uses the same 4 byte integer format as a LONG data type, but it can be set to only one of two values. To save data storage space, and data transmission bandwidth, consider using BOOL8 format to store data in final storage data tables.

BOOL8 is a one byte variable that hold 8 bits (0 or 1) of information. BOOL8 uses less space than 32-bit BOOLEAN data type, since 32 bits of information are stored in four 8-bit Boolean bytes. Repetitions in output processing data table instructions must be divisible by two, since an odd number of bytes cannot be stored in a data table. When converting from a LONG or a FLOAT to a BOOL8, only the least significant 8 bits are used, i.e., only the modulo 256 is used. When LoggerNet retrieves a BOOL8 data type, it splits it apart into 8 fields of true or false when displaying or storing to an ASCII file. Consequently, more computer memory is consumed by the datalogger support software, but CR1000 memory is conserved. Conservation of memory in the CR1000 also results in less band width being used when data is collected via telecommunications.

EXAMPLE 11.12-1 programs the CR1000 to monitor the state of 32 ‘alarms’ as a tutorial exercise. The alarms are toggled by manually entering zero or non-zero (e.g., 0 or 1) in each public variable representing an alarm as shown in FIGURE 11.12-1. Samples of the four public variables FlagsBool(1), FlagsBool(2), FlagsBool(3), and FlagsBool(4) are stored in data table “Bool8Data” as four 1-byte values. As shown in FIGURE 11.12-2, when viewing data table “Bool8Data” in a CSI software numeric monitor, however, the data is conveniently translated into 32 values of True or False. As shown in FIGURE 11.12-3, when CSI software stores the data in an ASCII text file, the data is stored as 32 columns of either 0 or -1, each column representing 1 of 32 alarm states. When programming, remember that aliasing can be employed to make the program and data more understandable for a particular application.

EXAMPLE 11.12-1. Programming with Bool8 and a bit-shift operator.

```
Public Alarm(32)
Public Flags As Long
Public FlagsBool8(4) As Long

DataTable (Bool8Data,True,-1)
  DataInterval (0,1,Sec,10)
  Sample(2,FlagsBool8(1),Bool8) 'store bits 1 through 16 in columns 1 through 16 of data file
  Sample(2,FlagsBool8(3),Bool8) 'store bits 17 through 32 in columns 17 through 32 of data file
EndTable

BeginProg
  Scan (1,Sec,3,0)

    'Reset all bits each pass before setting bits selectively
    Flags = &h0
```

```
    'Set bits selectively.  Hex used to save space.


    'Logical OR bitwise comparison

    'If bit in OR bit in The result
    'Flags Is Bin/Hex Is Is
    '-------------------- ----------
    '0    0   0
    '0    1   1
    '1    0   1
    '1    1   1
    '                          Binary equivalent of Hex:
    If Alarm(1) Then Flags = Flags OR &h1          '                              &b10
    If Alarm(3) Then Flags = Flags OR &h4          '                             &b100
    If Alarm(4) Then Flags = Flags OR &h8          '                            &b1000
    If Alarm(5) Then Flags = Flags OR &h10         '                           &b10000
    If Alarm(6) Then Flags = Flags OR &h20         '                          &b100000
    If Alarm(7) Then Flags = Flags OR &h40         '                         &b1000000
    If Alarm(8) Then Flags = Flags OR &h80         '                        &b10000000
    If Alarm(9) Then Flags = Flags OR &h100        '                       &b100000000
    If Alarm(10) Then Flags = Flags OR &h200       '                      &b1000000000
    If Alarm(11) Then Flags = Flags OR &h400       '                     &b10000000000
    If Alarm(12) Then Flags = Flags OR &h800       '                    &b100000000000
    If Alarm(13) Then Flags = Flags OR &h1000      '                   &b1000000000000
    If Alarm(14) Then Flags = Flags OR &h2000      '                  &b10000000000000
    If Alarm(15) Then Flags = Flags OR &h4000      '                 &b100000000000000
    If Alarm(16) Then Flags = Flags OR &h8000      '                &b1000000000000000
    If Alarm(17) Then Flags = Flags OR &h10000     '               &b10000000000000000
    If Alarm(18) Then Flags = Flags OR &h20000     '              &b100000000000000000
    If Alarm(19) Then Flags = Flags OR &h40000     '             &b1000000000000000000
    If Alarm(20) Then Flags = Flags OR &h80000     '            &b10000000000000000000
    If Alarm(21) Then Flags = Flags OR &h100000    '           &b100000000000000000000
    If Alarm(22) Then Flags = Flags OR &h200000    '          &b1000000000000000000000
    If Alarm(23) Then Flags = Flags OR &h400000    '         &b10000000000000000000000
    If Alarm(24) Then Flags = Flags OR &h800000    '        &b100000000000000000000000
    If Alarm(25) Then Flags = Flags OR &h1000000   '       &b1000000000000000000000000
    If Alarm(26) Then Flags = Flags OR &h2000000   '      &b10000000000000000000000000
    If Alarm(27) Then Flags = Flags OR &h4000000   '     &b100000000000000000000000000
    If Alarm(28) Then Flags = Flags OR &h8000000   '    &b1000000000000000000000000000
    If Alarm(29) Then Flags = Flags OR &h10000000  '   &b10000000000000000000000000000
    If Alarm(30) Then Flags = Flags OR &h20000000  '  &b100000000000000000000000000000
    If Alarm(31) Then Flags = Flags OR &h40000000  ' &b1000000000000000000000000000000
    If Alarm(32) Then Flags = Flags OR &h80000000  '&b10000000000000000000000000000000

    'Note: &HFF = &B11111111.  By shifting at 8 bit increments along 32-bit 'Flags' (Long data
type),
    'the first 8 bits in the four Longs FlagsBool8(4) are loaded with alarm states.  Only the
first
    '8 bits of each Long 'FlagsBool8' are stored when converted to Bool8.

    'Logical AND bitwise comparison

    'If bit in OR bit in The result
    'Flags Is Bin/Hex Is Is
    '-------------------- ----------
    '0    0   0
    '0    1   0
    '1    0   0
    '1    1   1

    FlagsBool8(1) = Flags AND &HFF        'AND 1st 8 bits of "Flags" & 11111111
    FlagsBool8(2) = (Flags >> 8) AND &HFF     'AND 2nd 8 bits of "Flags" & 11111111
    FlagsBool8(3) = (Flags >> 16) AND &HFF    'AND 3rd 8 bits of "Flags" & 11111111
    FlagsBool8(4) = (Flags >> 24) AND &HFF    'AND 4th 8 bits of "Flags" & 11111111

    CallTable(Bool8Data)
  NextScan
EndProg
```

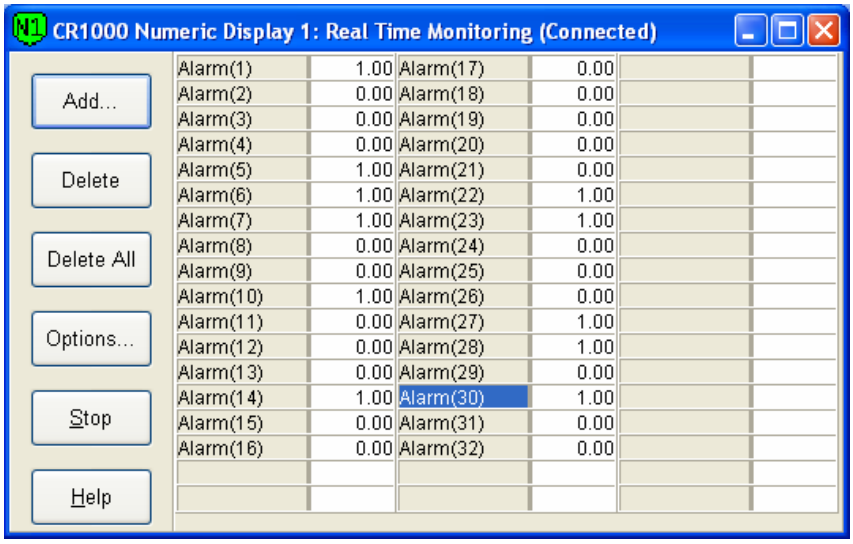


FIGURE 11.12-1. Alarms toggled in EXAMPLE 11.12-1

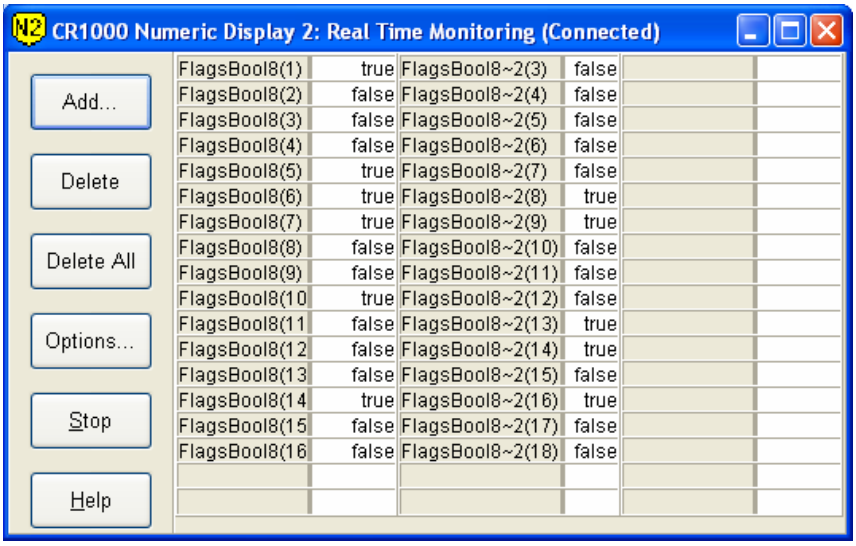


FIGURE 11.12-2. Bool8 data from EXAMPLE 11.12-1 displayed in a numeric monitor

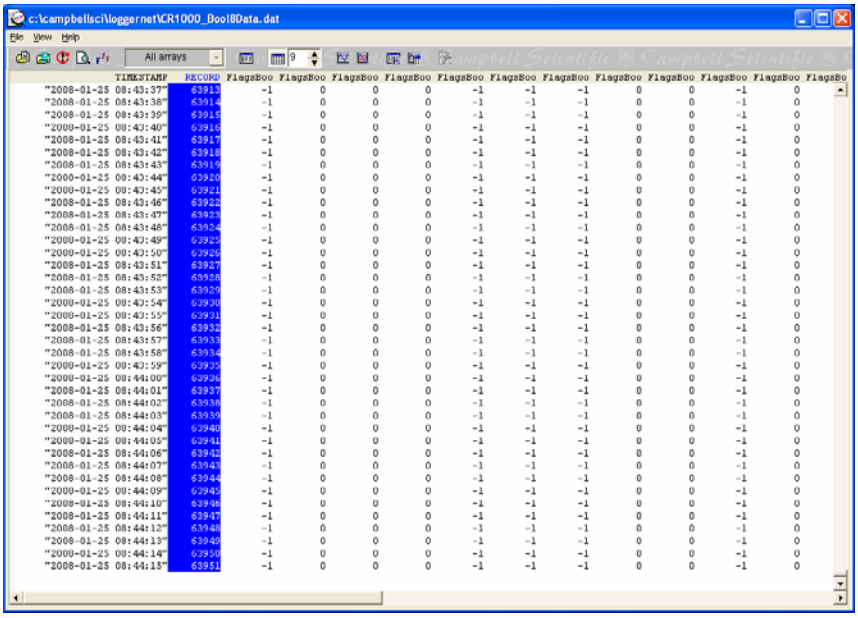


FIGURE 11.12-3. Bool8 data from EXAMPLE 11.12-1 stored in a computer data file

11.13 Burst Mode

Burst mode rapidly repeats measurements on a single-ended or differential voltage input channel. TABLE 11.13-1 summarizes burst mode specifications.

TABLE 11.13-1. Burst Mode Specifications

Burst mode enabled instructions	VoltSe(), VoltDiff(), TCSe(), TCDiff()
Maximum measurements per burst	65535
Maximum burst rate	2 kHz
Bridge excitation enabled with	ExciteV()

11.13.1 CR1000 Burst Mode

Burst mode is invoked in the VoltDiff() or VoltSE() instructions by entering a negative sign, "-", before the channel number in the DiffChan or SEChan parameter. Reps, SEChan, DiffChan, and SettlingTime parameters are used differently in burst mode. Special consideration also needs to be paid to the size of the Dest variable array. Parameter differences are summarized in TABLE.

TABLE 11.13-2. Burst Mode Parameter Changes for Burst Enabled Instructions

Parameter	Standard Analog Mode	Burst Analog Mode
Dest	Var DIMed (1) to (16)	Var DIMed (1) to (65535)
Reps	Sequential Channels	Number of Measurements (65535 Max)
Range	N/C	N/C
SEChan	1 to 16	-1 to -16
DiffChan	1 to 8	-1 to -8
RevDiff	N/C	N/C
SettlingTime	Settling Time	Interval (≥500 µs minimum)
Integ	N/C	N/C
Mult	N/C	N/C
Offset	N/C	N/C

11.13.2 Comparing CR1000 and CR10X Burst Modes

Historical Note: Burst mode was invoked in older array based CSI dataloggers using Instruction 23 Burst Measurement.

CR1000	CR10X
Channel sequence: 111…, 222…, 333…[1]	Channel sequence 1, 2, 3…, 1, 2, 3…, 1, 2, 3…[2]
2 kHz Max	750 Hz Max
Data output only to resident memory	Data to resident memory or out serial port
Raw A/D output not possible	Raw A/D output possible
Optional output to max 2G byte CF cards	Optional output to max 6M byte storage modules
Communications OK during burst	No communications during burst
Trigger using DataEvent()	Trigger from P23 parameters
All voltage ranges OK	Only voltage ranges 25mV and greater are practical

[1]A single VoltDiff or VoltSE instruction can burst on one channel only. To burst on multiple channels, multiple VoltDiff or VoltSE instruction are entered into the CRBASIC program. Burst on one channel completes before burst on the second channel begins.

[2]A single P23 instruction can burst on multiple channels, near simultaneously, by first measuring the channel programmed for first analog measurement, then the following channels sequentially, such that all channels complete at about the same time.

11.13.3 Burst Mode Programming

Program EXAMPLE 11.13-1 shows a simple program burst measuring a single-ended thermocouple, 100 measurements at a 2 kHz rate. Data is logged to memory between when the variable Seconds equaling 28 and 35.

EXAMPLE 11.13-1. Burst Mode Programming

```
Public Seconds
Public PanelT
Public ThCSe(100)                          'dimension variable for 100 measurements

DataTable (TestSE,1,-1)
  DataEvent (0,Seconds=28,Seconds=35, 0)   'log data only between seconds 28 and 35, inclusive
  Sample (1,Seconds,FP2)
  Sample (1,PanelT,FP2)
  Sample (100,ThCSe(),FP2)
EndTable

BeginProg
  Scan (1,Sec,0,0)
    PanelTemp (PanelT,250)
    TCSe (ThCSe(),100,mV2_5,-1,TypeT,PanelT,False,500,250,1.0,0) '100 measurements at 2 kHz
    Seconds = Seconds + 1
    CallTable TestSE
  NextScan
EndProg
```

11.14 String Operations

11.14.1 Operators

- Ampersand (&) -- forces numeric values to strings before concatenation
- Plus (+) -- adds values until a string is encountered
- Minus (-) – “subtracts” <NULL> from the end of ASCII characters for conversion to an ASCII code (Long data type). As with StrComp() instruction, (-) compares two strings. If the strings are identical, 0 is returned. If the strings are differenct, non-zero is returned. Starting from the first character in the two strings, the difference in their ASCII value is taken until either the difference is non-zero, or the end of both the strings is reached. The result is the difference.

11.14.2 Concatenation

Concatenation is the building of strings from other strings (“abc123”) or characters (“a” or chr()).

Examples:

Expression	Comments	Result
StringVar(1) = 5.4 + 3 + " Volts"	Add Floats, Concatenate String	“8.4 Volts”
StringVar(2) = 5.4 & 3 & " Volts"	Concatenate Floats and Strings	“5.43 Volts”
LongVar(1) = "123"	Convert String to Long	123
LongVar (2) = 1+2+"3"	Add Floats to String / convert to Long	33
LongVar (3) = "1"+2+3	Concatenate String and Floats	123
LongVar (4) = 1&2&"3"	Concatenate Floats and String	123

11.14.3 NULL Character

All strings are automatically NULL terminated. NULL, Chr(0) or “”, counts as one of the characters in the string. Assignment of just one character is that character followed by a NULL, unless the character is a NULL.

Examples:

Expression	Comments	Result
LongVar (5) = "#"-""	Subtract NULL, ASCII code results	35
LongVar (6) = StrComp("#","")	Also subtracts NULL	35

Example:

Objective:
Insert a NULL character into a string, then reconstitute the string

Given:
StringVar(3) = "123456789"

Execute:
StringVar(3,1,4) = "" “123<NULL>56789”

Results:
StringVar(4) = StringVar(3) “123”

But StringVar(3) still = “123<NULL>56789”, so:
StringVar(5) = StringVar(3,1,4+1) “56789”
StringVar(6) = StringVar(3) + 4 + StringVar(3,1,4+1) “123456789”

Some smart sensors send strings containing NULL characters. To manipulate a string that has NULL characters within it (in addition to being terminated with another NULL), use MoveBytes() instruction.

11.14.4 Inserting String Characters

Example:

Objective:
Using MoveBytes() to change “123456789” to “123A56789”

Given:
StringVar(7) = "123456789" “123456789”

Try (does not work):
StringVar(7,1,4) = "A" 123A<NULL>56789

Instead, use:
StringVar(7) = MoveBytes(Strings(7,1,4),0,"A",0,1) “123A56789”

11.14.5 Extracting String Characters

A specific character in the string can be accessed by using the “dimensional” syntax; that is, when the third dimension of a string is specified, the third dimension is the character position.

Examples:

Expression	Comments	Result
StringVar(3) = “Go Jazz”	Load sting into variable	
StringVar(4) = StringVar(3,1,4)	Extract single character	”J”

11.14.6 Use of ASCII / ANSII Codes

Examples:

Expression	Comments	Result
LongVar (7) = ASCII("#")		35
LongVar (8) = ASCII("*")		42
LongVar (9) = "#"	Cannot be converted to Long with NULL	NAN
LongVar (1) = "#"-""	Can be converted to Long without NULL	35

11.14.7 Formatting Strings

Example:

Objective:
Format the string “The battery is 12.4 Volts”

Use Expression:
StringVar(11) = Mid("The battery is 12.4 Volts",InStr(1,"The battery is 12.4 Volts"," is ",2)+3,Len("The battery is 12.4 Volts"))

Result:
12.4 Volts

Examples:

Expression	Result
StringVar(1) = 123e4	1230000
StringVar(2) = FormatFloat(123e4,"%12.2f")	1230000.00
StringVar(3) = FormatFloat(Values(2)," The battery is %.3g Volts ")	"The battery is 12.4 Volts"
StringVar(4) = Strings(3,1,InStr(1,Strings(3),"The battery is ",4))	12.4 Volts
StringVar(5) = Strings(3,1,InStr(1,Strings(3),"is ",2) + 3)	12.4 Volts
StringVar(6) = Replace("The battery is 12.4 Volts"," is "," = ")	The battery = 12.4 Volts
StringVar(7) = LTrim("The battery is 12.4 Volts")	The battery is 12.4 Volts
StringVar(8) = RTrim("The battery is 12.4 Volts")	The battery is 12.4 Volts
StringVar(9) = Trim("The battery is 12.4 Volts")	The battery is 12.4 Volts
StringVar(10) = UpperCase("The battery is 12.4 Volts")	THE BATTERY IS 12.4 VOLTS
StringVar(12) = Left("The battery is 12.4 Volts",7)	The b
StringVar(13) = Right("The battery is 12.4 Volts",7)	Volts

11.14.8 Formatting Hexadecimal Variables

Examples:

Expression	Comment	Result
CRLFNumeric(1) = &H0d0a	Add leading zero to hex step 1	3338
StringVar(20) = "0" & Hex(CRLFNumeric)	Add leading zero to hex step 2	0D0A
CRLFNumeric(2) = HexToDec(Strings(20))	Convert Hex string to Float	3338.00

11.15 Data Tables

11.15.1 Two Data Intervals – One Data Table

EXAMPLE 11.15-1. Programming for two data intervals in one data table

```
'CRBasic program To write To a single table with two different time intervals.
'Note: this Is a conditional table, check the Table Fill times in the Status Table.
'For programs with conditional tables AND other time driven tables it Is generally wise
'To NOT auto allocate the conditional table; set a specific number of records.

'date: February 2, 2006
'program author: Janet Albers

'Declare Public Variables
Public PTemp, batt_volt, airtempC, deltaT
Public int_fast As Boolean
Public int_slow As Boolean
Public counter(4) As Long

'Data Tables
'Table output on two intervals depending on condition.
'note the parenthesis around the TriggerVariable AND statements
'Status Table datafilldays field will be low
DataTable (TwoInt,(int_fast AND TimeIntoInterval (0,5,Sec)) OR (int_slow AND TimeIntoInterval
(0,15,sec)),-1)
   Minimum (1,batt_volt,FP2,0,False)
   Sample (1,PTemp,FP2)
   Maximum (1,counter(1),Long,False,False)
   Minimum (1,counter(1),Long,False,False)
```

```
   Maximum (1,deltaT,FP2,False,False)
   Minimum (1,deltaT,FP2,False,False)
   Average (1,deltaT,IEEE4,false)
EndTable

'Main Program
BeginProg
   Scan (1,Sec,0,0)

      PanelTemp (PTemp,250)
      Battery (Batt_volt)
      counter(1)=counter(1)+1

      'thermocouple measurement
      TCDiff (AirTempC,1,mV2_5C,1,TypeT,PTemp,True ,0,250,1.0,0)
      'calculate the difference in air temperature and panel temperature
      deltaT=airtempC-PTemp

      'when the the difference in air temperatures is >=3 turn LED on
      'and trigger the data table's faster interval
      If deltaT>=3 Then
         PortSet (4,true)
         int_fast=true
         int_slow=false
      Else
         PortSet (4,false)
         int_fast=false
         int_slow=true
      EndIf

      'Call Output Tables
      CallTable TwoInt
   NextScan
EndProg
```

Section 12. Memory and Data Storage

CR1000 memory consists of four storage media:

1. Internal Flash EEPROM
2. Internal Serial Flash
3. Internal SRAM
4. External Compact Flash (CF) (optional)

Table 10-1 illustrates the structure of CR1000 memory.

The CR1000 utilizes many memory features automatically. However, users control, and should monitor, those areas of memory wherein data tables, CRBASIC program files, and image files reside.

NOTE Data files should not be stored to the CPU: drive as it has a limited number of write cycles. It should be used exclusively for program files, calibration files, or files that will not be written too frequently.

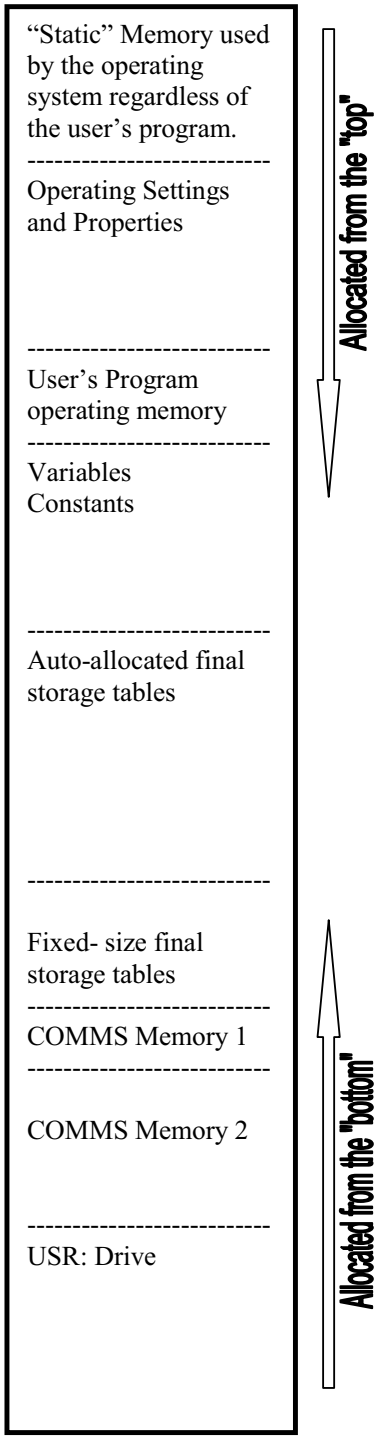
- Program files reside on Serial Flash CPU: drive or Compact Flash CRD: drive.
- Data tables reside in SRAM. Copies of data tables are maintained in data files on the CompactFlash CRD: drive when the CRBASIC program includes the CardOut () instructions. A CRBASIC program is limited to 30 data tables, depending on size and available memory. When a new program is compiled, the CR1000 checks that there is adequate space in memory it references for the programmed data tables; a program that requests more space than is available will not run.
- FieldCal files reside exclusively on the CPU: drive (Section 10.3.1).
- Image files reside exclusively on the USR: drive (Section 10.3.3).

TABLE 12-1. CR1000 Memory Allocation

NOTE: As of September 2007, all new CR1000s have 4 MB SRAM.

Internal Flash EEPROM SRAM 2 or 4 MB	**Notes**
	See Table 12-2.
Internal Serial Flash 128K or 512K	
Device Configuration Settings Backup ~ 1K	A backup of all the Device Configuration Settings, such as PakBus Address, Station Name, Beacon Intervals, Neighbor lists, etc., rebuilt approximately every hour.
"CPU" Drive for files ~ 98K	Serial flash is slower, but adequate for storing files. When a program is compiled and run in SRAM, a copy is also put here to be loaded on subsequent power-up. Users can also store files, including program files, here for future use. Shows up as "CPU:" in LoggerNet's File Control screen. Status Table field - CPUDriveFree
External Compact Flash (Variable size)	
"CRD" Drive for files	CRD: Drive resides on a Compact Flash (CF) card used in an optional accessory CF module, which attaches to the peripheral port. Cards should be industrial grade and must not exceed 2 Gbytes. If the DataTable declarations in the CR1000 program use the CardOut instruction, final storage data can also be stored to the CF card. The CR1000 provides data first from internal CPU memory and if additional records are needed (that have been overwritten in CPU, the CR1000 sends it from the CF card. Data as files can also be retrieved from the CF card with the File Control utility, in which case it is saved on the PC as a file in a binary format that must be converted using CardConvert software.

TABLE 12-2. CR1000 SRAM Memory



Notes
The operating system requires some memory in which to operate. This memory is rebuilt at power-up, program re-compile, and watchdog events.
Also known as the "Keep", memory used to store Device Configuration settings such as PakBus Address, Station Name, Beacon Intervals, Neighbor lists, etc, as well as dynamic properties such as the Routing Table, communications time outs, etc.
Compiled user program currently running; rebuilt on power-up, recompile, and watchdog events.
Memory for the public variables in the user's program. These values may persist across power-up, recompile, and watchdog events if the PreserveVariables instruction is in the running program.
Auto-allocated tables fill whatever memory is left over from all other demands.
Memory for user's fixed-size final storage tables. Compile error occurs if insufficient memory available.
Construction and temporary storage of PakBus packets.
Constructed Routing Table: List of known nodes and routing to them. Routers take more space than leaf nodes because must remember routers' neighbors. Increasing the PakBusNodes field in the Status Table will increase this allocation.
Memory manually allocated for use in storing files such as images and FileRead/FileWrite operations. Shows up as "USR:" in LoggerNet's File Control screen. Status Table field – USRDriveSize.

12.1 Internal SRAM

SRAM (2 or 4 Mbytes) is powered by the internal CR1000 battery when main power is disconnected so data remain in memory. SRAM data are erased when a program is sent to the CR1000. Some SRAM is used by the operating system.

The CR1000 can be programmed to store each measurement or, more commonly, to store processed values such as averages, maxima, minima, histograms, FFTs, etc. Storage can be programmed to occur periodically or conditionally. Data are stored in data tables in SRAM as directed by the CRBASIC program (Section 9.5 Structure). A data table can be configured as ring memory or fill-and-stop. Ring memory allows the CR1000 to overwrite the oldest data when the data table is full. Fill-and-stop configures the data table to be filled, then subsequent data discarded.

In a CRBASIC program, the DataTable () instruction sets the size of the data table or buffer area. A data file mirroring an SRAM data table can be stored on a CF card by including the **CardOut ()** instruction within the data table declaration. When a CF card is used, SRAM also acts as the buffer area for data written to the card.

12.2 CompactFlash® (CF)

CAUTION When installing or removing the CFM100 or NL115 module, first turn off CR1000 power.

Removing a card from the CFM100 or NL115 while the CF card is active can cause garbled data and can actually damage the card. Always press the button to disable the card for removal and wait for the green LED before switching off the CR1000 power.

To prevent losing data, collect data from the CF card before sending a program to the datalogger. When a program is sent to the datalogger all data on the CF card is erased.

CSI CF card modules connect to the CR1000 Peripheral Port. Each has a slot for a Type I or Type II CF card. A CF card expands the CR1000's storage capacity. A maximum of 30 data tables can be created on a CF card.

NOTE CardConvert software, included with LoggerNet, PC400, RTDAQ, and PC200W support software, converts CF card data to the standard Campbell Scientific data format.

When a data table is sent to a CF card, a data table of the same name in SRAM is used as a buffer for transferring data to the card. When the card is present, the status table will show the size of the table on the card. If the card is removed, the size of the table in SRAM will be shown.

When a new program is compiled that sends data to the CF card, the CR1000 checks if a card is present and if the card has adequate space for the data tables.

If the card has adequate space, the tables will be allocated and the CR1000 will start storing data to them. If there is no card or if there is not enough space, the CR1000 will warn that the card is not being used and will run the program, storing the data in SRAM only. When a card with enough available memory is inserted the CR1000 will create the data tables on the card and store the data that is accumulated in SRAM.

The CR1000 accepts cards formatted as FAT or FAT32. Older CR1000 operating systems formatted cards as FAT or FAT32. Newer operating systems always format cards as FAT32.

12.3 Memory Drives

12.3.1 CPU:

CPU: drive is the default drive in CR1000 memory for storing programs and calibration files. Currently about 100K when formatted.

12.3.2 CRD: (CF card memory)

CRD: drive is the default drive in CF memory used principally for storing data files.

12.3.3 USR:

CR1000 final data storage memory can be partitioned to create a FAT32 USR: drive, analogous to partitioning a second drive on a PC hard disk. The USR: drive stores certain types of files to conserve limited CPU memory, which should be reserved for datalogger programs, and to prevent interaction with memory used to store data tables. The USR: drive is configured using DevConfig settings or SetStatus () instruction in a CRBASIC program. Partition USR: drive to at least 11264 bytes in 512 byte increments. If the value entered is not a multiple of 512 bytes, the size will be rounded up.

Once partitioned, USR: memory is reserved for the USR: drive and is not affected by program recompilation or formatting of other drives. It will only be reset if the USR: drive is formatted, a new operating system is loaded, or the size of the USR: drive is changed. Size is changed manually or by loading a program with a different size entered in a SetStatus () command.

NOTE Settings in the program will over-ride attempts to change the size manually since the CR1000 restarts its program when the USR: drive size is changed.

The USR: drive holds virtually any file type within the constraints of the size of the drive and the limitations on filenames. Files stored on the USR: drive include image files from cameras, such as the CC640, ASCII files used to hold setup information for the logger program, or ASCII / binary files written by the datalogger for retrieval by ftp and html files for viewing via web access.

The CR1000 user must manage the use of the USR: drive, either manually or through a CRBASIC program, to ensure adequate space to store new files. Filemanage () command is used within the CRBASIC program to remove files from the USR: drive. Files are managed manually using the File Control tool

in LoggerNet. Files are collected by remote ftp connections (where there is a TCP/IP connection to the logger), manually using the file control tool in LoggerNet, or automatically using the LNCMD program supplied with LoggerNet.

Two status table registers are used to monitor use and size of the USR: drive. Bytes remaining are indicated in register "USRDriveFree." Total size is indicated in register "USRDriveSize." Memory allocated to USR: drive, less overhead for directory use, is shown in LoggerNet | Connect | File Control.

12.4 Memory Conservation

Each public variable in a CRBASIC program uses a little more than 200 bytes of memory. Memory intensive programs may need to employ one or more of the following memory saving techniques:

- Declaring variables using DIM instead of PUBLIC saves memory since DIM variables do not require buffer allocation for data retrieval.
- Reduce arrays to the minimum size needed. Each variable, whether or not part of an array, requires ≈250 fixed bytes of memory. Approximately 720 variables will fill all available memory.
- String concatenation should be confined to DIM variables when possible.
- Use variable arrays with aliases instead of individual Public statements for unique names. Aliases consume less memory than unique variable names.
- Dimension string variables only to the size required by the program.

12.5 Memory Reset

12.5.1 Full Memory Reset

The full CR1000 memory is reset by entering 98765 in the status table field "FullMemReset." Full memory reset performs the following functions:

Formats CPU:
    Deletes all program files
    Clears data tables
Restores all settings to default
Initializes system variables
Clears all communications memory

12.5.2 Data Table Reset

Data table memory (final storage memory) is reset during a full memory reset (Sec 12.5.1) or when a program is sent. Data table memory can also be reset from the CR1000KD keypad diplay or with LoggerNet / RTDAQ / PC400 file control.

Key / command sequences to reset data tables:

CR1000KD -- <Enter> | Data | Reset Data Tables

LoggerNet -- Connect | Datalogger | View Station Status | Table Fill Times | Reset Tables

12.6 File Management

Files in CR1000 memory (program, data, CAL, image) can be managed or controlled with Campbell Scientific support software as summarized in TABLE 12.6-1.

TABLE 12.6-1. File Control Functions

File Control Functions	Accessed Through
Sending programs to the CR1000.	Send[1], LN file control[2], DevConfig[3], CF manual[4], CF power-up[5]
Setting file attributes. See TABLE 12.6-2.	LN file control[2], CF power-up[5], FileManage ()[6].
Sending an OS to the CR1000. Reset settings.	LN file control[2], DevConfig[3], CF automatic[5]
Sending an OS to the CR1000. Preserve settings.	Send[1], LN file control with default.cr1[2], CF power-up with default.cr1[5]
Formatting CR1000 memory drives.	LN file control[2], CF power-up[5].
Retrieving programs from the CR1000.	Connect[7], LN file control[2], CF manual[4]
Setting disposition of old CF files	LN file control[2], CF power-up[5].
Deleting files from memory drives.	LN file control[2], CF power-up[5].
Stopping program execution.	LN file control[2].
Renaming a file.	FileRename ()[6]
Time stamping a file.	FileTime ()[6]
List files.	LN file control[2], FileList ()[6]
Create a data file from a data table	TableFile ()[6]
JPEG files manager	CR1000KD, PakBusGraph (LoggerNet)

[1]LoggerNet, PC400, PC200W Program Send Button. See software Help.

[2]LoggerNet | Connect | Datalogger | File Control. See LoggerNet Help & Section 8.1.

[3]Device Configuration Utility (DevConfig). See DevConfig Help & Section 8.1.

[4]Manual with CompactFlash®. See Section 12.2.

[5]Automatic with CompactFlash® and Powerup.ini. See Section 12.6.2.

[6]CRBASIC commands. See Sections 10.2.2 and 10.14 and CRBASIC Editor Help.

[7]LoggerNet | Connect | Receive Button. See LoggerNet Help.

12.6.1 File Attributes

A feature of program files is the file attribute. TABLE 12.6-2 lists available file attributes, their functions, and when attributes are typically used. For example, a program file sent via the Send option in LoggerNet, PC400, or PC200W, runs a) immediately and b) when power is cycled on the CR1000. This functionality is invoked because Send sets two CR1000 file attributes on the program file. These file attributes are "Run Now" and "Run on Power-up," together tagged as "Run Always."

NOTE Activation of the Run on Power-up file can be prevented by holding down the Del key on the keyboard / display while the CR1000 is being powered up.

TABLE 12.6-2. CR1000 File Attributes

Attribute	Function	Attribute for Programs Sent to CR1000 with:
Run Always (Run on Power-up + Run Now)	Runs now and on power-up	a) Send[1] b) LN file control[2] with Run Now & Run on Power-up checked. c) CF power-up[3] using commands 1 & 13 (see TABLE 12.6-3).
Run on Power-up	Runs only on power-up	a) LN file control[2] with Run on Power-up checked. b) CF power-up[3] using command 2 (see TABLE 12.6-3).
Run Now	Runs only when file sent to CR1000	a) LN file control[2] with Run Now checked. b) CF power-up[3] using commands 6 & 14 (see TABLE 12.6-3). But, if CF is left in, program loads again from CF.

[1]LoggerNet, PC400, PC200W Program Send Button. See software Help.

[2]LoggerNet | Connect | Datalogger | File Control. See LoggerNet Help & Section 8.1.

[3]Automatic on power-up of CR1000 with CompactFlash® and Powerup.ini. See Section 12.6.2.

Associated with file attributes are options to either erase CF (CompactFlash®) data files or not when the program is sent. Unlike data tables in the CR1000, CF data are stored as a discrete file. While data tables in the CR1000 are erased automatically when a program is received, their mirror image data files on the CF (when present) can be preserved. Depending on the application, retention of the CF data files may or may not be desirable. When sending a program with Send, CF data files are always deleted before the program runs. The pseudo code in FIGURE 12.6-1 summarizes the disposition of CR1000 data depending on the CF data file option used.

```
if "keep CF data"
      keep CF data from overwritten program
      if current program = overwritten program
            keep CPU data
            keep cache data
      else
            erase CPU data
            erase cache data
      end if
end if

if "erase CF data"
      erase CF data from overwritten program
      erase CPU data
      erase cache data
end if
```

FIGURE 12.6-1. Summary of the Effect of CF Data Options on CR1000 Data.

12.6.2 CF Power-up

Hard Knocks in a Real World

Uploading an OS or program in the field can be challenging, particularly during weather extremes. Heat, cold, snow, rain, altitude, sand in your eyes, distance to hike – all can influence how easily programming with a laptop or palm PC may be. One alternative is to simply carry a light weight CF card into the field, on which a program or OS is written. Inserting a properly configured CF card into a CR1000 CF module (CF100 or NL115), then cycling CR1000 power, will result in the OS or program automatically uploading and running without further input from the user. OS upload from a CF card is very fast. CAUTION. Test this option in the lab before going to the field to make sure you have it configured correctly. Carry your laptop or palm PC with you, but with CF Power-up, you will be overjoyed when you don't need to pull the computer out.

Power-up functions of CompactFlash® cards can include

a) Sending programs to the CR1000
b) Setting attributes of CR1000 program files
c) Setting disposition of old CF files
d) Sending an OS to the CR1000
e) Formatting memory drives
f) Deleting data files

"Oh, what a tangled web we weave..." – Sir Walter Scott.

Back in the old days of volatile RAM, life was simple. Nasty at times, but simple. You lose power, you lose program, variables, and data. Simple. You re-start from scratch. The advent of non-volatile memory has saved a lot of frustration in the field, but it requires thought in some applications. For instance, if the CR1000 loses power, do you want it to power back up with the same program, or another one? with variables intact or erased? with data intact or erased?

The key to the CF power-up function is the powerup.ini file, which contains a list of one or more command lines. At power-up, the powerup.ini command line is executed prior to compiling the program. Powerup.ini performs three operations:

1) Copies the specified program file to a specified memory drive.

2) Sets a file attribute on the program file

3) Optionally deletes CF data files from the overwritten (just previous) program.

Powerup.ini takes precedence during power-up. Though it sets file attributes for the programs it uploads, its presence on the CF does not allow those file attributes to control the power-up process. To avoid confusion, either remove the CF card or delete the powerup.ini file after the powerup.ini upload.

Creating and Editing Powerup.ini

Powerup.ini is created with a text editor, then saved as "powerup.ini".

NOTE Some text editors (such as WordPad) will attach header information to the powerup.ini file causing it to abort. Check the text of a powerup.ini file with the CR1000KD to see what the CR1000 actually sees.

Comments can be added to the file by preceding them with a single-quote character (‘). All text after the comment mark on the same line is ignored.

Syntax
Syntax allows functionality comparable to File Control in LoggerNet. Powerup.ini is a text file that contains a list of commands and parameters. The syntax for the file is:

Command,File,Device

where

Command = one of the numeric commands in Table 1.
File = file on CF associated with the action. Name can be up to 22 characters.
Device = the device to which the associated file will be copied to. Options are CPU:, USR:, and CRD:. If left blank or with invalid option, will default to CPU:.

TABLE 12.6-3. Powerup.ini Commands	
Command	**Description**
1	Run always, preserve CF data files
2	Run on power-up
5	Format
6	Run now, preserve CF data files
9	Load OS (File = .obj)
13	Run always, erase CF data files now
14	Run now, erase CF data files now

By using PreserveVariables () instruction in the CR1000 CRBASIC program, with options 1 & 6, data and variables can be preserved.

EXAMPLE 12.6-1. Powerup.ini code.

```
'Command = numeric power-up command
'File = file on CF associated with the action
'Device = the device to which File will be copied.  Defaults to CPU:

'Command,File,Device
13,Write2CRD_2.cr1,CPU:
```

Applications

- Commands 1, 2, 6, 13, and 14 (Run Now and / or Run On Power-up). If a device other than CRD: drive is specified, the file will be copied to that device.
- Command 1, 2, 13 (Run On Power-up). If the copy (first application, above) succeeds, the new Run On Power-up program is accepted. If the copy fails, no change will be made to the Run On Power-up program.
- Commands 1, 6, 13, and 14 (Run Now). The Run Now program is changed whether or not the copy (first application, above) occurs. If the copy does succeed, the Run Now program will be opened from the device specified.
- Commands 13 and 14 (Delete Associated Data). Since CRD:powerup.ini is only processed at power-up, there is not a compiled program to delete associated data for. The information from the last running program is still available for the CR1000 to delete the files used by that program.

Program Execution

After File is processed, the following rules determine what CR1000 program to run:

1) If the Run Now program is changed then it will be the program that runs.
2) If no change is made to Run Now program, but Run on Power-up program is changed, the new Run on Power-up program runs.
3) If neither Run on Power-up nor Run Now programs are changed, the previous Run on Power-up program runs.

Example Power-up.ini Files

EXAMPLE 12.6-2 through EXAMPLE 12.6-7 are example powerup.ini files.

EXAMPLE 12.6-2. Run Program on Power-up.

```
'Copy pwrup.cr1 to USR:, will run only when powered-up later
2,pwrup.cr1,usr:
```

EXAMPLE 12.6-3. Format the USR: drive.

```
'Format the USR: drive
5,,usr:
```

EXAMPLE 12.6-4. Send OS on Power-up.

```
'Load this file into FLASH as the new OS
9,CR1000.Std.04.obj
```

EXAMPLE 12.6-5. Run Program from CRD: drive.

```
'Leave program on CRD:, run always, erase CRD: data files
13,toobigforcpu.cr1,crd:
```

EXAMPLE 12.6-6. Run Program Always, Erase CF data.

```
'Run always, erase CRD: data files
13,pwrup_1.cr1,crd
```

EXAMPLE 12.6-7. Run Program Now, Erase CF data.

```
'Copy run.cr1 to CPU:, erase CF data, run CPU:run.cr1, but not if later powered-up
14,run.cr1,cpu:
```

12.7 File Names

The maximum size of the file name that can be stored, run as a program, or FTP transferred in the CR1000 is 59 characters. If the name is longer than 59 characters an "Invalid Filename" error is displayed. If several files are stored, each with a long filename, memory allocated to the root directory can be exceeded before the actual memory of storing files is exceeded. When this occurs, an “insufficient resources of memory full” error is displayed.

Section 13. Telecommunications and Data Retrieval

Telecommunications, in the context of CR1000 operation, is the movement of information between the CR1000 and another computing device, usually a PC. The information can be programs, data, files, or control commands.

Telecommunications systems require three principal components: hardware, carrier signal, and protocol. For example, a common way to communicate with the CR1000 is with PC200W software by way of a PC COM port. In this example, hardware are the PC COM port, the CR1000 RS-232 port, and a serial cable. The carrier signal is RS-232, and the protocol is PakBus. Of these three, a user most often must come to terms with only the hardware, since the carrier signal and protocol are transparent in most applications.

Systems usually require a single type of hardware and carrier signal. Some applications, however, require hybrid systems, which utilize two or more hardware and signal carriers.

Contact a Campbell Scientific applications engineer for assistance in configuring any telecommunications system.

13.1 Hardware and Carrier Signal

Campbell Scientific supplies or recommends a wide range of telecommunications hardware. TABLE 13.1-1 lists telecommunications destination device, path, and carrier options, which imply certain types of hardware, for use with the CR1000 datalogger. Information in TABLE 13.1-1 is generic. For specific model numbers and specifications, contact a Campbell Scientific applications engineer, or go to www.campbellsci.com.

TABLE 13.1-1. CR1000 Telecommunications Options

Destination Device / Portal	Communications Path	Carrier Signal
PC / COM or USB	Direct Connect	RS-232
PDA / COM Port	Direct Connect	RS-232
PC / COM Port	Digital Cellular	800 MHz RF
PC / COM Port	Multidrop	RS485
PC / Network Card	Ethernet / PPP	IP
PC / COM Port	Spread Spectrum RF	900 MHz RF
PC / COM Port	Licensed Frequency RF	UHF VHF RF
PC / COM Port	Short-haul Telephone	CCITT v.24
PC / COM Port	Land-line Telephone	CCITT v.92
PDA / Infrared Port	Infrared	SIR
Satellite System	Satellite Transceiver	RF
CompactFlash Card	Direct Connect	SRAM
Audible Report	Land-line Telephone	Voice
Heads-Up Display	Direct Connect	CS I/O
Digital Display	Direct Connect	CS I/O
Keyboard / Display	Direct Connect	CS I/O

13.2 Protocols

The primary telecommunication protocol for the CR1000 is PakBus (Section 14 PakBus Overview). ModBus and DNP3 are also supported on board (Section 15). CANBUS is also supported when using the Campbell Scientific CANBUS communications module.

13.3 Initiating Telecommunications

Telecommunications sessions are usually initiated by the user or PC. Once telecommunications is established, the CR1000 issues a series of commands to send programs, set clocks, and collect data. Because data retrieval is managed by the PC, several PC's can have access to a single CR1000 without disrupting the continuity of data. PakBus allows multiple PCs to communicate with the CR1000 simultaneously when the proper telecommunications networks are installed.

When using PC200W, PC400, and RTDAQ software, the user always initiates telecommunications. With LoggerNet software, the user or LoggerNet, by way of a scheduler, may initiate telecommunications. Some applications, however, require the CR1000 to initiate a telecommunications session. This feature of the CR1000 is known as Callback.

For example, if a fruit grower wants the CR1000 to contact him with a frost alarm, the CR1000 can instigate telecommunications. Telecommunications is often initiated by calling the PC, but can also be initiated through email / text messaging to the grower's cell phone, audible voice synthesized information over telephone, or by calling a pager. Callback has been utilized in applications including Ethernet, land-line telephone, digital cellular, and direct connection. Callback via telephone is well documented in CRBASIC Editor Help. For more information on other available Callback features, contact a Campbell Scientific applications engineer or search for "Callback" information in CRBASIC Editor Help.

CAUTION

When using the ComME communications port with non-PakBus protocols, incoming characters can be corrupted by concurrent use of the CS I/O for SDC communication. PakBus communication uses a low level protocol of a pause / finish / ready sequence to stop incoming data while SDC occurs.

Non-PakBus communication includes PPP protocol, ModBus, DNP3, and generic CRBASIC driven use of CS I/O.

Usually unnoticed, a short burst of SDC communication occurs at power up and other times when the datalogger is reset, such as when compiling a program or changing settings that require recompiling. This SDC activity is the datalogger querying the SDC to see if the CR1000KD Keyboard / Display, an SDC device, is attached.

When DevConfig and PakBus Graph retrieve settings, the CR1000 queries the SDC to determine what SDC devices are connected. Results of the query can be seen in the DevConfig and PakBus Graph settings tables. SDC queries occur whether or not an SDC device is attached.

13.4 Data Retrieval

Data tables are transferred to PC files through a telecommunications link (Section 13 Telecommunications and Data Retrieval) or by transporting the CF card to the PC.

13.4.1 Via Telecommunications

Data are usually transferred through a telecommunications link to an ASCII file on the supporting PC using Campbell Scientific datalogger support software (Section 16 Support Software). See also the manual and Help for the software package being used.

13.4.2 Via CF Card

CAUTION When installing a CF card module, first turn off the CR1000 power.

Before removing a CF card module from the datalogger, disable the card by pressing the "removal button" (NOT the eject button), wait for the green LED, then turn the CR1000 power off.

Removing a card or card module from the CR1000 while the CF card is active can cause garbled data and can damage the card.

Sending a program to the CR1000 may erase all SRAM and CF card data. To prevent losing data, collect data from the CF card before sending a program to the datalogger.

Data stored on CF cards are retrieved through a telecommunication link to the CR1000 or by removing the card and carrying it to a computer. Many varieties of CF adapters are available for computers and PCMCIA card slots. CF adaptors are much faster than telecommunications links, so, with large CF files, transferring data to a computer with an adaptor will be significantly faster.

The format of data files collected via a CF adaptor is different than the format created by Campbell Scientific telecommunications software. Data files read from the CF card via a CF adaptor can be converted to a Campbell Scientific format using CardConvert. CardConvert is included with most CSI software. Consult the software manual for more CardConvert information.

13.4.3 Data Format on Computer

CR1000 data stored on a PC via support software is formatted as either ASCII or Binary depending on the file type selected in the support software. Consult the software manual for details on the various available data file formats.

Section 14. PakBus Overview

Read more! This section is provided as a primer to PakBus communications. Complete information is available in Campbell Scientific's "PakBus Networking Guide."

The CR1000 communicates with computers or other dataloggers via PakBus. PakBus is a proprietary telecommunications protocol similar in concept to IP (Internet protocol). PakBus allows compatible Campbell Scientific dataloggers and telecommunications hardware to seamlessly link to a PakBus network.

14.1 PakBus Addresses

CR1000s are assigned PakBus address 1 as a factory default. Networks with more than a few stations should be organized with an addressing scheme that guarantees unique addresses for all nodes. One approach, demonstrated in Fig. 1, is to assign single-digit addresses to the first tier of nodes, multiples of tens to the second tier, multiples of 100s to the third, etc. Note that each node on a branch starts with the same digit. Devices, such as PCs, with addresses greater than 4000 are given special administrative access to the network

PakBus addresses are set using DevConfig, PakBusGraph, CR1000 status table, or with a CR1000KD Keyboard Display. DevConfig (Device Configuration Utility) is the primary settings editor for Campbell Scientific equipment. It requires a hardwire RS-232 connection to a PC and allows backup of settings on the PC hard drive. PakBusGraph is used over a telecommunications link to change settings, but has no provision for backup.

Caution. Care should be taken when changing PakBus addresses with PakBus Graph or in the status table. If an address is changed to an unknown value, a field visit with a laptop and DevConfig may be required to discover the unknown address.

14.2 Nodes: Leaf Nodes and Routers

- A PakBus network consists of 2 to 4093 linked nodes.
- One or more leaf nodes and routers can exist in a network.
- Leaf nodes are measurement devices at the end of a branch of the PakBus web.
    - Leaf nodes can be linked to any router.
    - A leaf node cannot route packets but can originate or receive them.
- Routers are measurement or telecommunications devices that route packets to other linked routers or leaf nodes.
    - Routers can be branch routers. Branch routers only know as neighbors central routers, routers in route to central routers, and routers one level outward in the network.

- Routers can be central routers. Central routers know the entire network. A PC running LoggerNet is typically a central router.

- Routers can be router-capable dataloggers or communications devices.

The CR1000 is a leaf node by factory default. It can be configured as a router by setting "IsRouter" in its status table to "1" or "True". The network shown in FIGURE 14.2-1 contains 6 routers and 8 leaf nodes.

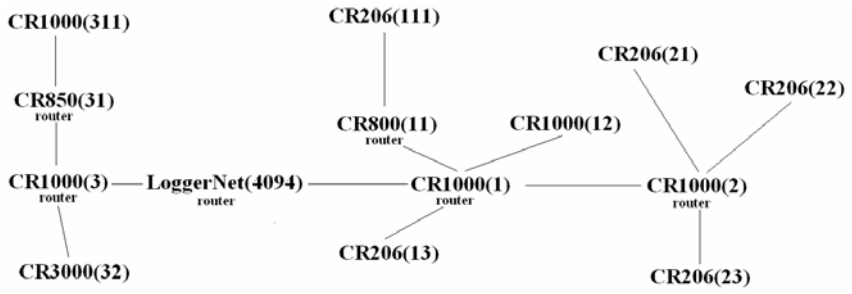


FIGURE 14.2-1. PakBus Network Addressing. PakBus addresses are shown in parentheses after each datalogger in the network.

LoggerNet is configured by default as a router and can route datalogger to datalogger communications.

14.3 Router and Leaf Node Configuration

TABLE 14.3-1 lists leaf node and router hardware.

TABLE 14.3-1. PakBus Leaf Node and Router Devices

Network Device	Description	PakBus Leaf Node	PakBus Router	PakBus Aware	Transparent
CR200	Datalogger	•			
CR800	Datalogger	•	•		
CR1000	Datalogger	•	•		
CR3000	Datalogger	•	•		
CR5000	Datalogger	•	•		
LoggerNet	Software		•		
NL100	Network Link		•		•
NL115	Network Link				•
MD485	Multidrop			•	•
RF401	Radio		•	•	•
CC640	Camera	•			
SC105	Serial Interface				•
SC32B	Serial Interface				•
SC932A	Serial Interface				•
COM220	Telephone Modem				•
COM310	Telephone Modem				•
SRM-5A	Short-haul Modem				•

14.4 Linking Nodes: Neighbor Discovery

To form a network, *nodes* must establish *links* with *neighbors* (adjacent nodes). *Links* are established through a process called *discovery*. *Discovery* occurs when *nodes* exchange *hellos*. A hello exchange occurs during a *hello-message* between two nodes.

14.4.1 Hello-message (two-way exchange)

A *hello-message* is an interchange between two nodes that negotiates a neighbor link. A *hello-message* is sent out in response to one or both of either a beacon or a hello-request.

14.4.2 Beacon (one-way broadcast)

A *beacon* is a broadcast sent by a node at a specified interval telling all nodes within hearing that a *hello-message* can be sent. If a node wishes to establish itself as a neighbor to the beaconing node, it will then send a *hello-message* to the beaconing node. Nodes already established as neighbors will not respond to a beacon.

14.4.3 Hello-request (one-way broadcast)

All nodes hearing a *hello-request* broadcast (existing and potential neighbors) will issue a *hello-message* to negotiate or re-negotiate a neighbor relationship with the broadcasting node.

14.4.4 Neighbor Lists

PakBus devices in a network can be configured with a neighbor list. The CR1000 sends out a *hello-message* to each node in the list whose verify interval has expired at a random interval*. If a node responds, a hello-message is exchanged and the node becomes a neighbor.

> *A random number of seconds between INTERVAL and (2 * INTERVAL), where INTERVAL is the Verify Interval setting if non-zero, or 30 seconds if the Verify Interval setting is zero.

Neighbor filters dictate which nodes are neighbors and force packets to take routes specified by the network administrator. LoggerNet (a PakBus node) derives its neighbor filter from link information in the Setup device map.

14.4.5 Adjusting Links

PakBusGraph, a client of LoggerNet, is particularly useful when testing and adjusting PakBus routes.

Paths established by way of beaconing may be redundant and vary in reliability. Redundant paths can provide backup links in the event the primary path fails. Redundant and unreliable paths can be eliminated by activating neighbor filters in the various nodes and by disabling some beacons.

14.4.6 Maintaining Links

Links are maintained by means of the CVI (communications verification interval). The CVI can be specified in each node with DevConfig. The following rules[1] apply:

If Verify Interval = 0, then CVI = 2.5 x beacon interval*

If Verify Interval = 60, then CVI = 60 seconds*

If Beacon Interval = 0 and Verify Interval = 0, then CVI = 300 seconds*

If the CR1000 does not hear from a neighbor for one CVI, it begins again to send a Hello message to that node at the random interval.

Users should base verification intervals on the timing of normal communications such as scheduled LoggerNet collections or datalogger to dataloggers communications. The idea is to not allow the verification interval to expire before normal communications. If the verification interval expires the devices will initiate hello exchanges in an attempt to regain neighbor status, increasing traffic in the network.

[1]During the hello-message, a CVI must be negotiated between two neighbors. The negotiated CVI will be the lesser of the first nodes CVI and 6/5ths of the neighbors CVI.

14.5 Troubleshooting

Various tools and methods have been developed to assist in troubleshooting PakBus networks.

14.5.1 Link Integrity

With beaconing or neighbor filter discovery, links are established and verified using relatively small data packets (Hello messages). When links are used for regular telecommunications, however, longer messages are used. Consequently, a link may be reliable enough for *discovery* but unreliable with larger packets. This condition is most common in radio networks, particularly when max packet size is >200.

PakBus communications over marginal links can often be improved by reducing the size of the PakBus packets. Best results are obtained when the maximum packet sizes in both nodes are reduced.

Automatic Packet Size Adjustment

The BMP5 file receive transaction allows the BMP5 client (LoggerNet) to specify the size of the next fragment of the file that the CR1000 sends.

NOTE The file receive transaction is used to get table definitions from the datalogger.

Because LoggerNet must specify a size for the next fragment of the file, it uses whatever size restrictions that apply to the link.

Hence, the size of the responses to the file receive commands that the CR1000 sends will be governed by the maxPacketSize setting for the datalogger as well as that of any of its parents in LoggerNet's network map. Note that this calculation also takes into account the error rate for devices in the link.

BMP5 data collection transaction does not provide any way for the client to specify a cap on the size of the response message. This is the main reason why the "Max Packet Size" setting exists in the CR1000. The CR1000 can look at this setting at the point where it is forming a response message and cut short the amount of data that it would normally send if the setting limits the message size.

14.5.2 Ping

Link integrity can be verified with the following procedure by using PakBusGraph | Ping Node. Nodes can be pinged with packets of 50, 100, 200 or 500 bytes.

NOTE Do not use packet sizes greater than 90 when pinging with RF400-series radios or CR200-series dataloggers.

Pinging with ten repetitions of each packet size will characterize the link. Before pinging, all other network traffic (scheduled data collections, clock checks, etc.) should be temporarily disabled. Begin by pinging the first layer of links (neighbors) from the PC, then proceed to nodes that are more than one hop away. TABLE 14.5-1 provides a link performance gage.

TABLE 14.5-1. PakBus Link Performance Gage

500 byte Ping Sent	Successes	Link Status
10	10	excellent
10	9	good
10	7-8	adequate
10	<7	marginal

14.5.3 Traffic Flow

Keep beacon intervals as long as possible with higher traffic (large numbers of nodes and / or frequent data collection). Long beacon intervals minimize collisions with other packets and resulting retries. The minimum recommended beacon interval is 60 seconds. If communications traffic is high, consider setting beacon intervals of several minutes. If data throughput needs are great, maximize data bandwidth by creating some branch routers, and / or by eliminating beacons altogether and setting up neighbor filters.

14.6 LoggerNet Device Map Configuration

As shown in FIGURE 14.6-1 and FIGURE 14.6-2, the essential element of a PakBus network device map in LoggerNet is the PakBusPort. After adding the root port (COM, IP, etc), add a PakBusPort and the dataloggers.

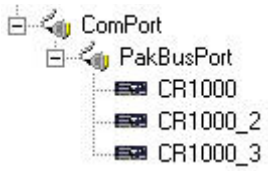


FIGURE 14.6-1. Flat Map

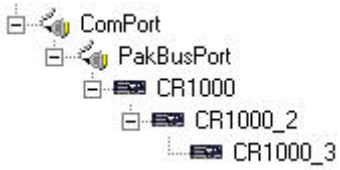


FIGURE 14.6-2. Tree Map

Use the 'tree' configuration of FIGURE 14.6-2 when communications requires routers. The shape of the map serves to disallow a direct LoggerNet connection to CR1000_2 and CR1000_3, and implies constrained routes that will probably be established by user-installed neighbor filters in the routers. This assumes that LoggerNet beacons are turned off. Otherwise, with a default address of 4094, LoggerNet beacons will penetrate the neighbor filter of any in-range node.

Section 15. Alternate Telecoms Resource Library

15.1 DNP3

15.1.1 Overview

The CR1000 is DNP3 SCADA compatible. DNP3 is a SCADA protocol primarily used by utilities, power generation and distribution networks, and the water and wastewater treatment industry.

Distributed Network Protocol (DNP) is an open protocol used in applications to ensure data integrity using minimal bandwidth. DNP implementation in the CR1000 is DNP3 level 2 Slave compliant with some of the operations found in a level 3 implementation. A standard CR1000 program with DNP instructions will take arrays of real time or processed data and map them to DNP arrays in integer or binary format. The CR1000 responds to any DNP master with the requested data or sends unsolicited responses to a specific DNP master. DNP communications are supported in the CR1000 through the RS-232 port, COM1 - COM4, or over TCP, taking advantage of multiple communications options compatible with the CR1000, e.g., RF, cellular phone, satellite.

DNP SCADA software enables CR1000 data to move directly into a database or display screens. Applications include monitoring weather near power transmission lines to enhance operational decisions, monitoring and controlling irrigation from a wastewater treatment plant, controlling remote pumps, measuring river flow, and monitoring air movement and quality at a power plant.

15.1.2 Programming for DNP3

EXAMPLE 15.1-1 lists CRBASIC code to take Iarray() analog data and Barray() binary data (status of control port 5) and map them to DNP arrays. The CR1000 responds to a DNP master with the specified data or sends unsolicited responses to DNP Master 3.

15.1.2.1 Declarations

TABLE 15.1-1 shows object groups supported by the CR1000 DNP implementation, and the required data types. A complete list of groups and variations is available in CRBASIC Help for DNPVariable().

TABLE 15.1-1. CRBASIC data types required to store data in the public table for each object group.		
Data Type	**Group**	**Description**
Boolean	1	Binary Input
	2	Binary Input Change
	10	Binary Output
	12	Control Block
Long	30	Analog Input
	32	Analog Change Event
	40	Analog Output Status
	41	Analog Output Block
	50	Time and Date
	51	Time and Date CTO

15.1.2.2 CRBASIC Instructions

Complete descriptions and options of commands are available in CRBASIC Editor Help.

DNP()

Sets the CR1000 as a DNP slave (outstation/server) with an address and DNP3 dedicated COM port. Normally resides between BeginProg and Scan(), so is executed only once. Example at Example 15.1-1, line 20.

Syntax

DNP (ComPort, BaudRate, DNPSlaveAddr)

DNPVariable()

Associates a particular variable array with a DNP object group. When the master polls the CR1000, it returns all the variables specified along with their specific groups. Also used to set up event data, which is sent to the master whenever the value in the variable changes. Example at Example 15.1-1, line 24.

Syntax

DNPVariable (Source, Swath, DNPObject, DNPVariation, DNPClass, DNPFlag, DNPEvent, DNPNumEvents)

DNPUpdate()

Determines when DNP slave (outstation/server) will update its arrays of DNP elements. Specifies the address of the DNP master to which are sent unsolicited responses (event data). Must be included once within a Scan/NextScan for the DNP slave to update its arrays. Typically placed in a

program after the elements in the array are updated. The CR1000 will respond to any DNP master regardless of its address.

Syntax
DNPUpdate (DNPMasterAddr)

15.1.2.3 Programming for Data Acquisition

To program the CR1000 to return data when polled by the DNP3 master,

- place DNP() at the beginning of the program between BeginProg and Scan(). Set COM port, baud rate, and DNP3 address.
- setup the variables to be sent to the master using DNPVariable(). Dual instructions cover static (current values) and event (previous ten records) data.
    - For analog measurements:
      DNPVariable(Variable_Name,Swath,30,2,0,&B00000000,0,0)
      DNPVariable(Variable_Name,Swath,32,2,3,&B00000000,0,10)
    - For digital measurements (control ports):
      DNPVariable(Variable_Name,Swath,1,2,0,&B00000000,0,0)
      DNPVariable(Variable_Name,Swath,32,2,3,&B00000000,0,10)
- place DNPUpdate() after Scan(), inside the main scan. The DNP3 master will be notified of any change in data each time DNPUpdate() runs; e.g for a 10 second scan, the master will be notified every 10 seconds.

15.1.2.4 Programming for Control

Variables inside the CR1000 can be set by the DNP3 master to setup the CR1000 to accept control commands.

- place DNP() at the beginning of the program between BeginProg and Scan(). Set COM port, baud rate, and DNP3 address.
- setup the variables to be set by the master using DNPVariable(). Dual instructions maintain compatibility with DNP3 implementations.
    - For analog variables:
      DNPVariable(Variable_Name,Swath,40,2,0,&B00000000,0,0)
      DNPVariable(Variable_Name,Swath,41,2,0,&B00000000,0,0)
    - For digital variables (control ports):
      DNPVariable(Variable_Name,Swath,10,1,0,&B00000000,0,0)
      DNPVariable(Variable_Name,Swath,12,1,0,&B00000000,0,0)
- place DNPUpdate() after Scan(), inside the main scan. Variables are updated each time this command runs.

15.1.2.5 Program Example

EXAMPLE 15.1-1. CRBASIC Code: Implementation of DNP3.

```
'CR1000
Public IArray(4) as Long
Public BArray(1) as Boolean

Public WindSpd
Public WindDir
Public Batt_Volt
Public PTemp_C

Units WindSpd=meter/Sec
Units WindDir=Degrees
Units Batt_Volt=Volts
Units PTemp_C=Deg C

'Main Program
BeginProg

  'DNP communication over the RS-232 port at 115.2kbps.  Datalogger DNP address is 1
  DNP(COMRS-232,115200,1)

  'DNPVariable (Source, Swath, DNPObject, DNPVariation, DNPClass, DNPFlag, DNPEvent, DNPNumEvents)

  DNPVariable (IArray,4,30,2,0,&B00000000,0,0)
  'Object group 30, variation 2 is used to return analog data when the CR1000 is polled.  Flag is set to an empty 8 bit number
  '(all zeros), DNPEvent is a reserved parameter and is currently always set to zero.  Number of events is only used for event
  'data.

  DNPVariable (IArray,4,32,2,3,&B00000000,0,10)
  DNPVariable (BArray,1,1,1,0,&B00000000,0,0)
  DNPVariable (Barray,1,2,1,1,&B00000000,0,1)

  Scan(1,Sec,1,0)

    'Wind Speed & Direction Sensor measurements WS_ms and WindDir:
    PulseCount(WindSpd,1,1,1,3000,2,0)
    IArray(1) = WindSpd * 100
    BrHalf(WindDir,1,mV2500,3,1,1,2500,True,0,_60Hz,355,0)
    If WindDir>=360 Then WindDir=0
    IArray(2) = WindDir * 100
    'Default Datalogger Battery Voltage measurement Batt_Volt:
    Battery(Batt_Volt)
    IArray(3) = Batt_Volt * 100
    'Wiring Panel Temperature measurement PTemp_C:
    PanelTemp(PTemp_C,_60Hz)
    IArray(1) =PTemp_C
    PortGet (Barray(1),5)

    'Update DNP arrays and send unsolicited requests to DNP Master address 3
    DNPUpdate(3)
  NextScan
```

15.2 Modbus

15.2.1 Overview

Modbus is a widely used SCADA communication protocol that facilitates exchange of information and data between computers / HMI software, instruments (RTUs) and Modbus compatible sensors. The CR1000 communicates via Modbus over RS-232, RS485 and TCP.

Modbus systems consist of a master (PC), RTU / PLC slaves, field instruments (sensors), and the communications network hardware. The communications port, baud rate, data bits, stop bits, and parity are set in the Modbus driver of the master and / or the slaves. The Modbus standard has two communications modes, RTU and ASCII. However, CR1000s communicate in RTU mode exclusively.

Field instruments can be queried by the CR1000. Because Modbus has a set command structure, programming the CR1000 to get data from field instruments is much simpler than from serial sensors. Because Modbus uses a common bus and addresses each node, field instruments are effectively multiplexed to a CR1000 without additional hardware.

A CR1000 goes into sleep mode after 40 seconds of communications inactivity. Once asleep, two packets are required before the CR1000 will respond. The first packet awakens the CR1000; the second packet is received as data. CR1000s, through DevConfig or the status table (Appendix B) can be set to keep communications ports open and awake, but at higher power usage.

15.2.2 Terminology

TABLE 15.2-1 lists terminology equivalents to aid in understanding how CR1000s fit into a SCADA system.

TABLE 15.2-1. Modbus to Campbell Scientific Equivalents

Modbus Domain	Data Form	Campbell Scientific Domain
Coils	Single Bit	Ports, Flags, Boolean Variables
Digital Registers	16-bit Word	Floating Point Variables
Input Registers	16-bit Word	Floating Point Variables
Holding Registers	16-bit Word	Floating Point Variables
RTU / PLC		CR1000
Master		Usually a computer
Slave		Usually a CR1000
Field Instrument		Sensor

15.2.2.1 Glossary of Terms

Coils (00001 to 09999)

Originally, "coils" referred to relay coils. In CR1000s, coils are exclusively ports, flags, or a Boolean variable array. Ports are inferred if parameter 5 of the ModbusSlave instruction is set to 0. Coils are assigned to Modbus registers 00001 to 09999.

Digital Registers 10001-19999

Hold values resulting from a digital measurement. Digital registers in the Modbus domain are read only. In the CSI domain, the leading digit in Modbus registers is ignored, and so are assigned together to a single Dim or Public variable array (read / write).

Input Registers 30001 - 39999
: Hold values resulting from an analog measurement. Input registers in the Modbus domain are read only. In the CSI domain, the leading digit in Modbus registers is ignored, and so are assigned together to a single Dim or Public variable array (read / write).

Holding Registers 40001 - 49999
: Hold values resulting from a programming action. Holding registers in the Modbus domain are read / write. In the CSI domain, the leading digit in Modbus registers is ignored, and so are assigned together to a single Dim or Public variable array (read / write).

RTU / PLC
: Remote Telemetry Units (RTUs) and Programmable Logic Controllers (PLCs) were at one time used in exclusive applications. As technology increases, however, the distinction between RTUs and PLCs becomes more blurred. A CR1000 fits both RTU and PLC definitions.

15.2.3 Programming for Modbus

15.2.3.1 Declarations

TABLE 15.2-2 shows the linkage between CR1000 ports, flags and Boolean variables and Modbus registers. Modbus does not distinguish between CR1000 ports, flags, or Boolean variables. By declaring only ports, or flags, or Boolean variables, the declared feature is addressed by default. A typical CRBASIC program for a Modbus application will declare variables and ports, or variables and flags, or variables and Boolean variables.

TABLE 15.2-2. Linkage between CR1000 Ports, Flags, and Variables and Modbus Registers.

CR1000 Feature	Example CRBASIC Declaration	Equivalent Example Modbus Register
Control Port (Port)	Public Port(8)	00001 to 00009
Flag	Public Flag(17)	00001 to 00018
Boolean Variable	Public ArrayB(56) as Boolean	00001 to 00057
Variable	Public ArrayV(20)*	40001 to 40041* or 30001 to 30041*

*Because of byte number differences, each CR1000 domain variable translates to two Modbus domain input / holding registers.

15.2.3.2 CRBASIC Instructions

Complete descriptions and options of commands are available in CRBASIC Editor Help.

ModbusMaster ()
Sets up a CR1000 as a Modbus master to send or retrieve data from a Modbus slave.

Syntax
ModbusMaster (ResultCode, ComPort, BaudRate, ModbusAddr, Function, Variable, Start, Length, Tries, TimeOut)

ModbusSlave ()
Sets up a CR1000 as a Modbus slave device.

Syntax
ModbusSlave (ComPort, BaudRate, ModbusAddr, DataVariable, BooleanVariable)

MoveBytes ()
Moves binary bytes of data into a different memory location when translating big endian to little endian data.

Syntax
MoveBytes (Dest, DestOffset, Source, SourceOffset, NumBytes)

15.2.3.3 Addressing (ModbusAddr)

Modbus devices have a unique address in each network. Addresses range from 1 to 247. Address 0 is reserved for universal broadcasts. When using the NL100, use the same number as the Modbus and Pakbus address.

15.2.3.4 Supported Function Codes (Function)

Modbus protocol has many function codes. CR1000 commands support the following.

01	Read Coil Status
02	Read Input Status
03	Read Holding Registers
04	Read Input Registers
05	Force Single Coil
15	Force Multiple Coils
16	Force Multiple Registers

15.2.3.5 Reading Inverse Format Registers

Some Modbus devices require reverse byte order words (CDAB vs. ABCD). This can be true for either floating point, or integer formats. Since a slave CR1000 uses the ABCD format, either the master has to make an adjustment, which is sometimes possible, or the CR1000 needs to output reverse byte order words. To reverse the byte order, use the MoveBytes () instruction as shown in the sample code below.

```
for i = 1 to k
   MoveBytes (InverseFloat(i),2,Float(i),0,2)
   MoveBytes (InverseFloat(i),0,Float(i),2,2)
next
```

In the example above InverseFloat(i) is the array holding the inverse byte ordered word (CDAB). Array Float(i) holds the obverse byte ordered word (ABCD).

15.2.4 Troubleshooting

Test Modbus functions on the CR1000 with third party Modbus software. Further information is available at the following links:

http://www.simplyModbus.ca/FAQ.htm
http://www.Modbus.org/tech.php
http://www.lammertbies.nl/comm/info/modbus.html

15.2.5 Modbus over IP with NL115

The NL115 supports networking of Modbus devices. When the ModbusSlave () COM port is set to 502, the CR1000 will listen on this port over TCP/IP for commands from a TCP Modbus Master device. If the ModbusMaster () COM port is a variable that is set by a TCPOpen () function, the CR1000 will use the TCP socket opened by TCPOpen () to communicate via Modbus TCP/IP to a slave.

15.2.6 Modbus Slave over IP with NL100

The NL100 can be used to support simultaneous networking of Modbus devices and PakBus devices (e.g. another CR1000 or LoggerNet). This feature allows for simultaneous real-time data viewing and collection of data. Correct operating systems (OS) for the CR1000 and NL100, as well as the correct settings are critical for success. The CR1000 OS should be version 9, or later, and the NL100 OS should be version rev7fix1 (nl100-r7fix1.os), or later. The CR1000 must be configured to respond to Modbus queries. Protocol used with the NL100 is Modbus / TCP, which enables communication options not available with serial connections (RS-232, RS485). When ModbusSlave () COM port is set to 0, the CR1000 will listen for TCP / Modbus commands.

15.2.6.1 Configuring the NL100

Connect to the NL100 with Device Configurator (DevConfig) software. DevConfig allows viewing and changing of device settings. Some settings, such as the IP address and PakBus address, are unique to each application. FIGURE 15.2-1 through FIGURE 15.2-6 depict DevConfig windows and settings to be set and verified to enable Modbus communication.

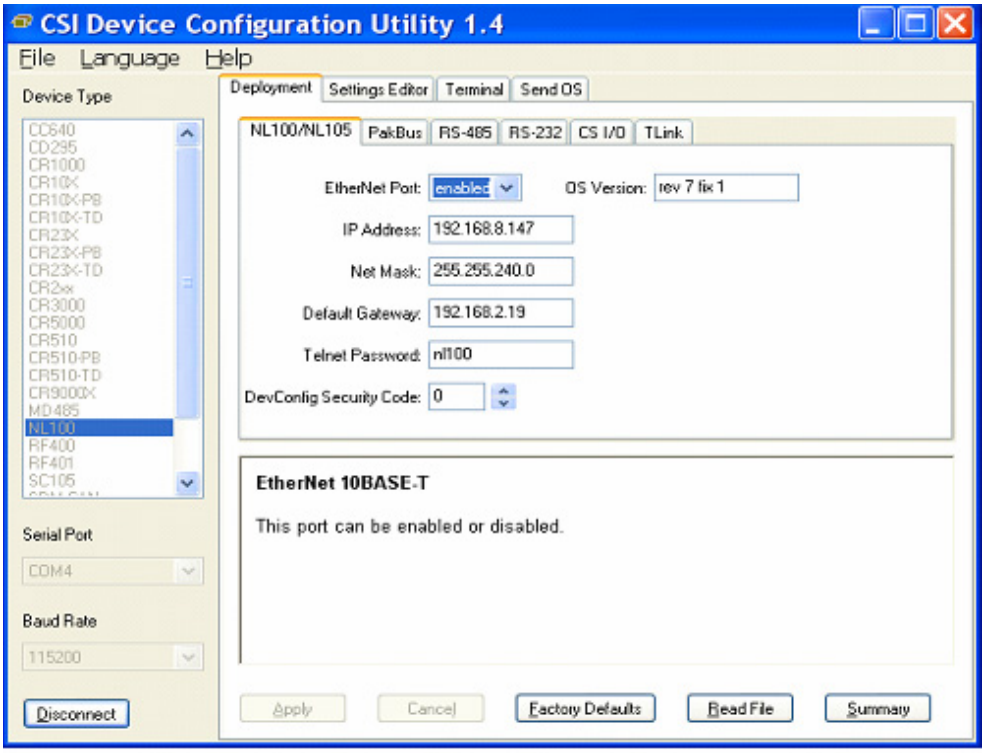


FIGURE 15.2-1. NL100/NL105 Settings.
Verify the correct OS version and enter IP address, net mask, and default gateway.

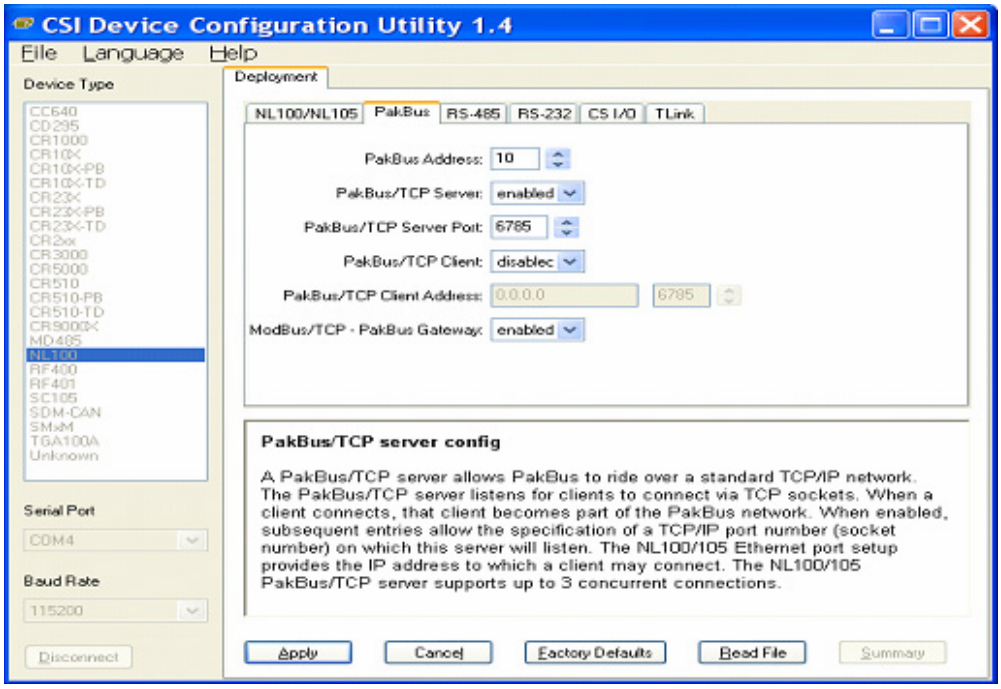


FIGURE 15.2-2. PakBus Settings. The PakBus address must be unique to the network. PakBus / TCP Server must be enabled. Pick a PakBus / TCP Server port number or use the default. PakBus / TCP Client should be disabled. Modbus / TCP – PakBus Gateway should be enabled.

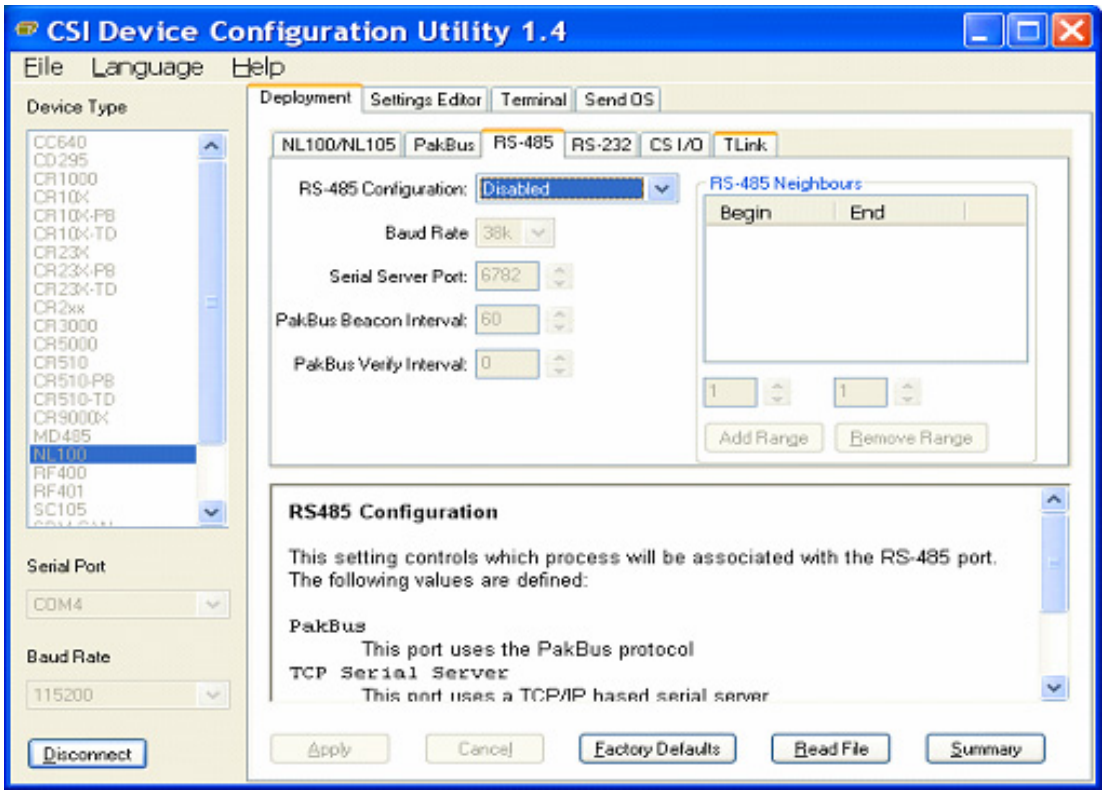


FIGURE 15.2-3. RS-485 Settings.
This port should be disabled, unless an RS485 connection is being used.

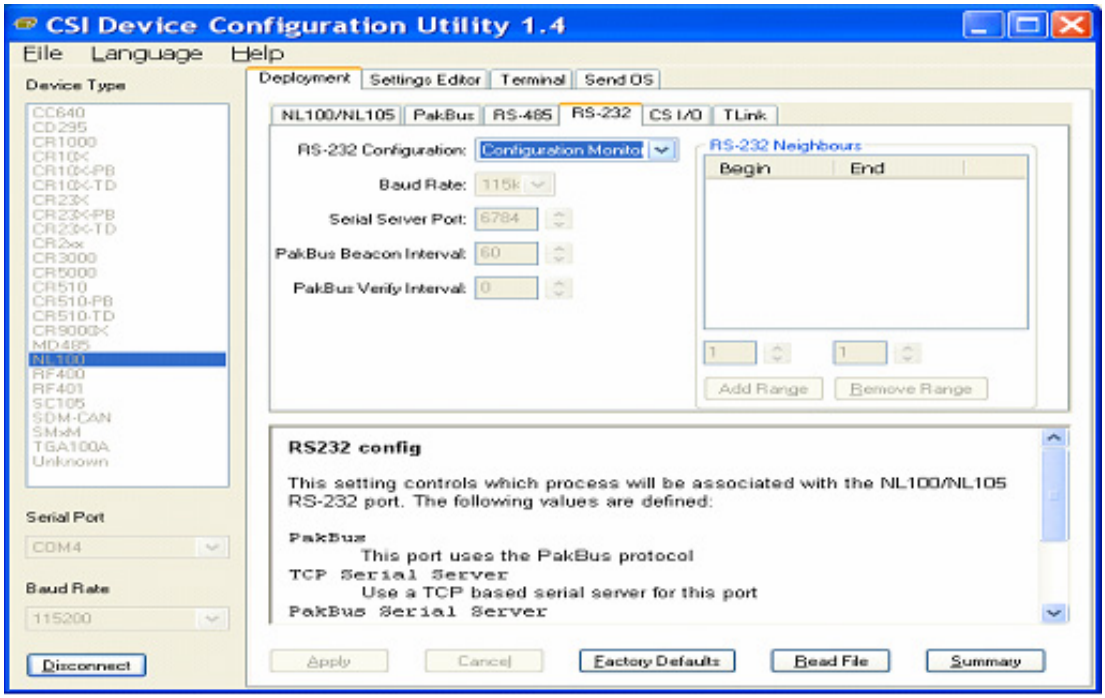


FIGURE 15.2-4. RS-232 Settings.
This port should be set to Configuration Monitor.

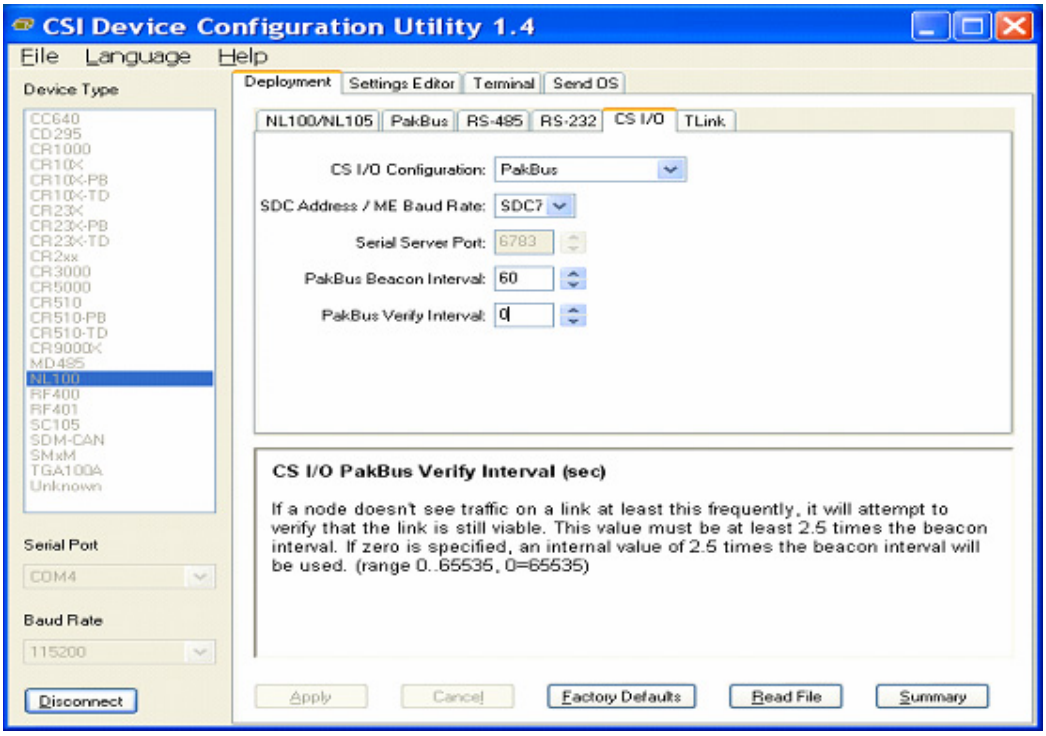


FIGURE 15.2-5. CS I/O Settings. The CS I/O Configuration should be set to PakBus. The SDC Address/Me Baud Rate should be set to SDC7 or SDC8. The Serial Server Port will not be active. PakBus Beacon Interval will probably be ok at 60 sec. As a result the PakBus verify Interval will be 0.

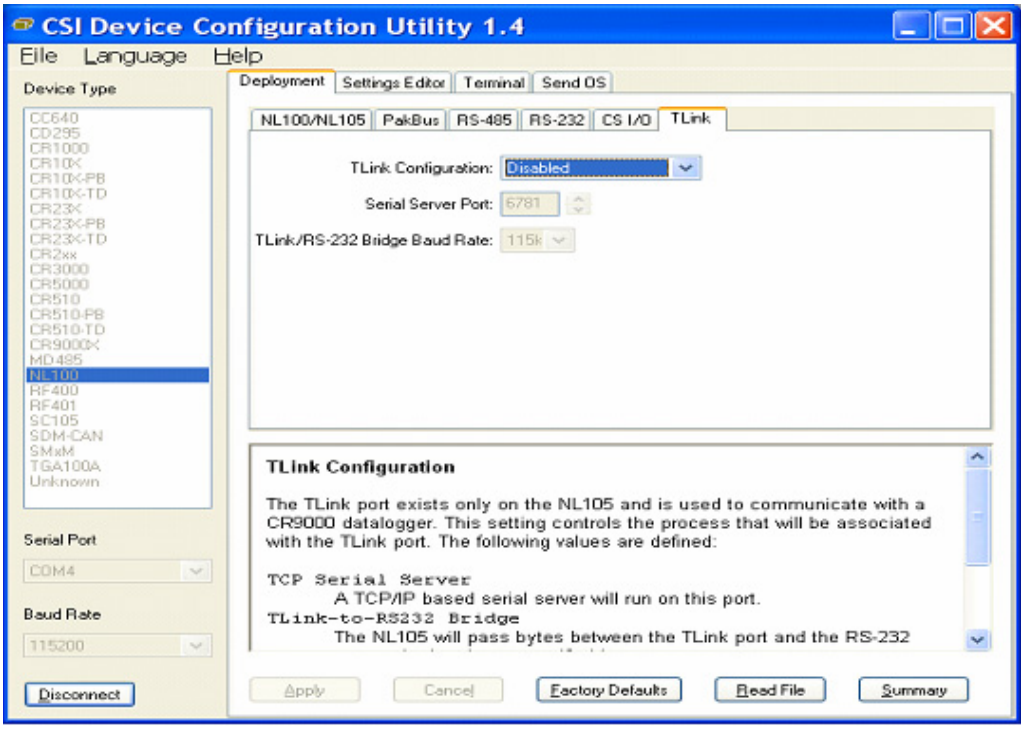


FIGURE 15.2-6. Tlink Settings.
This option is disabled.

15.2.6.2 Configuring the CR1000

The CR1000 program must include the ModbusSlave () instruction. ModbusSlave () defines what variables are accessible and the Modbus address of the device. ModbusSlave () does not need to be executed every time the program runs, but can be placed between the 'Begin Program' and 'Scan' instructions (see program example below). The Modbus address and the CR1000 PakBus address must be identical. COM port must be set for option 0 (ModBus/Pakbus). EXAMPLE 15.2-1 lists example CR1000 Modbus slave code.

EXAMPLE 15.2-1. CRBASIC Code: Modbus Slave

```
'Program for CR1000 Series Datalogger
'Declare Public Variables

preservevariables
Public PTempC, PTempF, Batt_Volts
Public Modbus(5)
Public modbdig(5) as Boolean

'Define Data Tables

DataTable (ModTest,1,-1)
    DataInterval (0,1,Min,10)
    Minimum (1,Batt_Volts,FP2,0,False)
    Sample (1,PTempC,FP2)
    sample (1,PTempF,FP2)
EndTable

'Main Program Array that holds
BeginProg

    ModbusSlave (0,-115200,1,Modbus(),modbdig())
    'parameter 1 must be 0 for NL100 & 502 for NL115
    'parameter 3 matches the CR1000 PakBus address -- recommended
    'parameter 4 Modbus registers array
    'parameter 5 Modbus coils array, if = 0 uses DL C1-C8

        Scan (1,Sec,0,0)

            PanelTemp (PTempC,250)
            PTempF = PTempC * 1.8 + 32
            Battery (Batt_Volts)

            Modbus(1) = Batt_Volts
            Modbus(2) = PTempC
            Modbus(3) = PtempF

            CallTable ModTest

        NextScan

EndProg
```

15.2.6.3 ModBus tidBytes

- Question:

  Can Modbus be used over an RS-232 link, 7 data bits, even parity, one stop bit?

  Answer:

  Yes. Precede ModBusMaster() / ModBusSlave() with SerialOpen() set the numeric format of the COM port with any of the available formats, including the option of 7 data bits, even parity. SerialOpen() and ModBusMaster() can be used once and placed before Scan().

- Concatenating two Modbus long 16-bit variables to one Modbus long 32 bit number.

```
'Requires CR1000 OS  v. 12 or higher
'CR1000 uses Big-Endien word order.

'Declarations
Public Combo As Long  'Combo is the variable that will hold the combined 32-bit
Public Register(2) As Long                    'Array holds two 16-bit ModBus long variables
                                              'Register(1) = Least Significant Word
                                              'Register(2) = Most Significant Word
Public Result                                 'Holds the result of the ModBus master query

'Aliases used for clarification
Alias Register(1) = Register_LSW              'Least significant word.
Alias Register(2) = Register_MSW              'Most significant word.

BeginProg

    'If you use the numbers below (un-comment them first) Combo will be read as 131073 decimal
    'Register_LSW=&h0001 'Least significant word.
    'Register_MSW=&h0002 ' Most significant word.

    Scan(1,Sec,0,0)

        'In the case of the CR1000 being the ModBus master then the ModbusMaster instruction would
        'be used (instead of fixing the variables as shown between the BeginProg and SCAN instructions).
        ModbusMaster (Result,COMRS232,-115200,5,3,-Register(1),1,2,3,100)

        'MoveBytes(DestVariable,DestOffset,SourceVariable,SourceOffSet,NumberOfBytes)
        MoveBytes(Combo,2, Register_LSW,2,2)
        MoveBytes(Combo,0, Register_MSW,2,2)

    NextScan

EndProg
```

Section 16. Support Software

PC / Windows® compatible software products are available from Campbell Scientific to facilitate CR1000 programming, maintenance, data retrieval, and data presentation. Short Cut, PC200W, and Visual Weather are designed for novice integrators, but have features useful in advanced applications. PC400 and LoggerNet provide increasing levels of power required for advanced integration, programming and networking applications. Support software for PDA and Linux applications are also available.

16.1 Short Cut

Short Cut utilizes an intuitive user interface to create CR1000 program code for common measurement applications. It presents lists from which sensors, engineering units, and data output formats are selected. It supports by name most sensors sold by Campbell Scientific. It features "generic" measurement routines, enabling it to support many sensors from other manufacturers. Programs created by Short Cut are automatically well documented and produce examples of CRBASIC programming that can be used as source or reference code for more complex programs edited with CRBASIC Editor.

Short Cut is included with PC200W, Visual Weather, PC400, RTDAQ, and LoggerNet and is available at no charge from the Campbell Scientific web site.

16.2 PC200W

PC200W utilizes an intuitive user interface to support direct serial communication to the CR1000 via COM / RS-232 ports. It sends programs, collects data, and facilitates monitoring of digital measurement and process values. PC200W is available at no charge from the Campbell Scientific web site.

16.3 Visual Weather

Visual Weather supports weather stations. It is recommended in applications wherein the user requires minimal control over programming and the pre-configured display and reporting features. Visual Weather is highly integrated and easy to use.

16.4 PC400

PC400 is a mid-level software suite. It includes CRBASIC Editor, point-to-point communications over several communications protocols, simple real-time digital and graphical monitors, and report generation. It does not support scheduled collection or multi-mode communication networks.

16.5 LoggerNet Suite

The LoggerNet suite utilizes a client-server architecture that facilitates a wide range of applications and enables tailoring software acquisition to specific requirements. TABLE 16.5-1 lists features of LoggerNet products that include

the LoggerNet server. TABLE 16.5-2 lists features of LoggerNet products that require the LoggerNet server as an additional purchase.

TABLE 16.5-1. LoggerNet Products that Include the LoggerNet Server

LoggerNet	Datalogger management, programming, data collection, scheduled data collection, network monitoring and troubleshooting, graphical data displays, automated tasks, data viewing and post-processing.
LoggerNet Admin	All LoggerNet features plus network security, manages the server from a remote PC, runs LoggerNet as a service, exports data to third party applications, launches multiple instances of the same client, e.g., two or more functioning Connect windows.
LoggerNet Remote	Allows management of an existing LoggerNet datalogger network from a remote location, without investing in another complete copy of LoggerNet Admin.
LoggerNet-SDK	Allows software developers to create custom client applications that communicate through a LoggerNet server with any datalogger supported by LoggerNet. Requires LoggerNet.
LoggerNet Server – SDK	Allows software developers to create custom client applications that communicate through a LoggerNet server with any datalogger supported by LoggerNet. Includes the complete LoggerNet Server DLL, which can be distributed with the custom client applications.
LoggerNet Linux	Includes LoggerNet Server for use in a Linux environments and LoggerNet Remote for managing the server from a Windows environment.

TABLE 16.5-2. LoggerNet Clients (require, but do not include, the LoggerNet Server)

Baler	Handles data for third-party application feeds.
RTMCRT	RTMC viewer only.
RTMC Web Server	Converts RTMC graphics to HTML.
RTMC Pro	Enhanced version of RTMC.
LoggerNetData	Displays / Processes real-time and historical data.
CSI OPC Server	Feeds data into third-party OPC applications.

16.6 PDA Software

PConnect Software supports PDAs with Palm Operating Systems. PConnectCE supports Windows Mobile and Pocket PC PDAs. Both support direct RS-232 connection to the CR1000 for sending programs, collecting data, and digital real-time monitoring.

Section 17. CR1000KD: Using the Keyboard Display

Read more! See Section 11.6 CR1000KD Custom Menus.

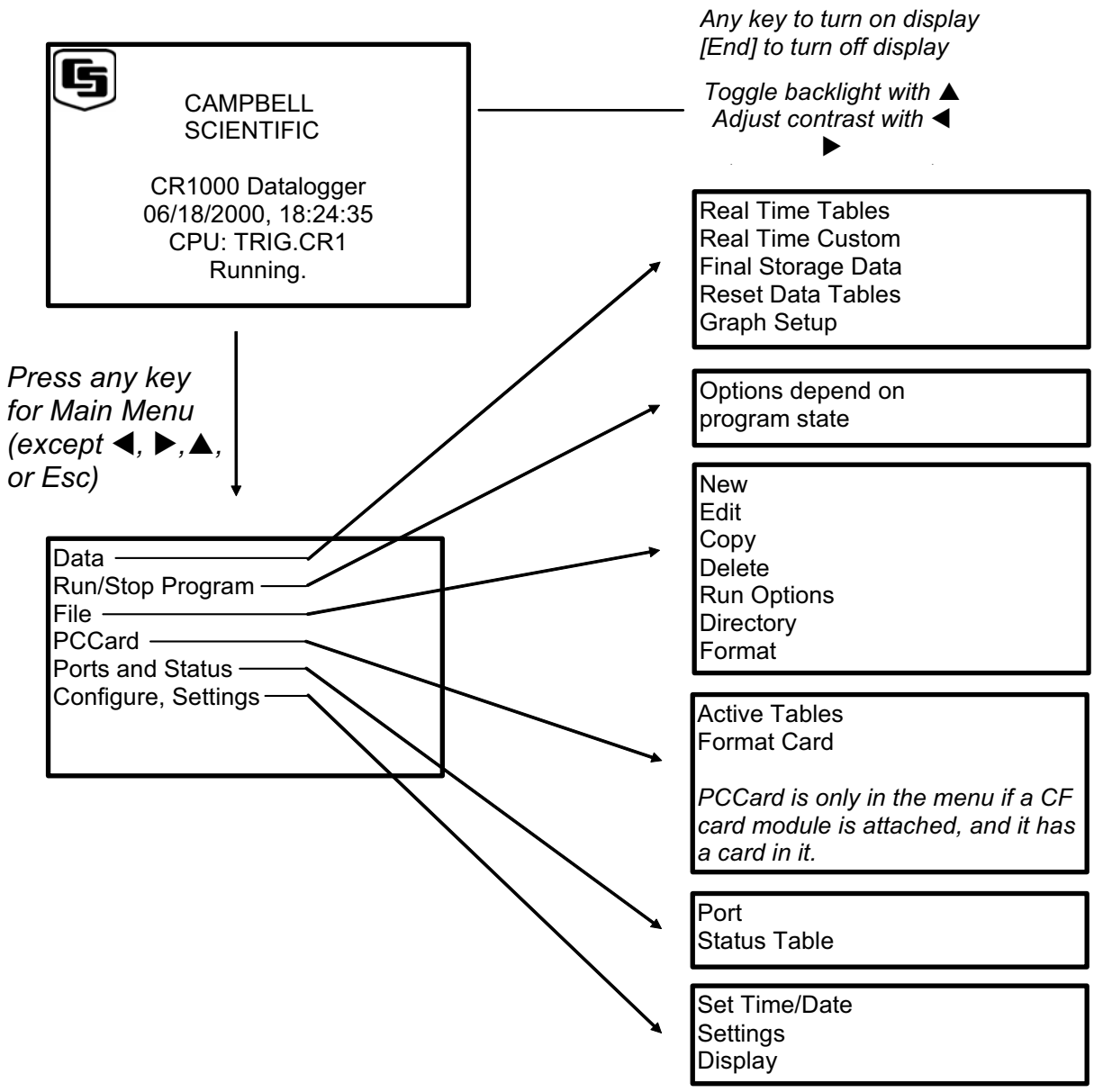
The CR1000 has an optional keyboard display, the CR1000KD. This section illustrates the use of the CR1000KD using its default menus. The CR1000KD has a few keys that have special functions which are listed below.

NOTE Although the CR1000KD is not required to operate or use the CR1000, it is a useful diagnostic and debugging tool.

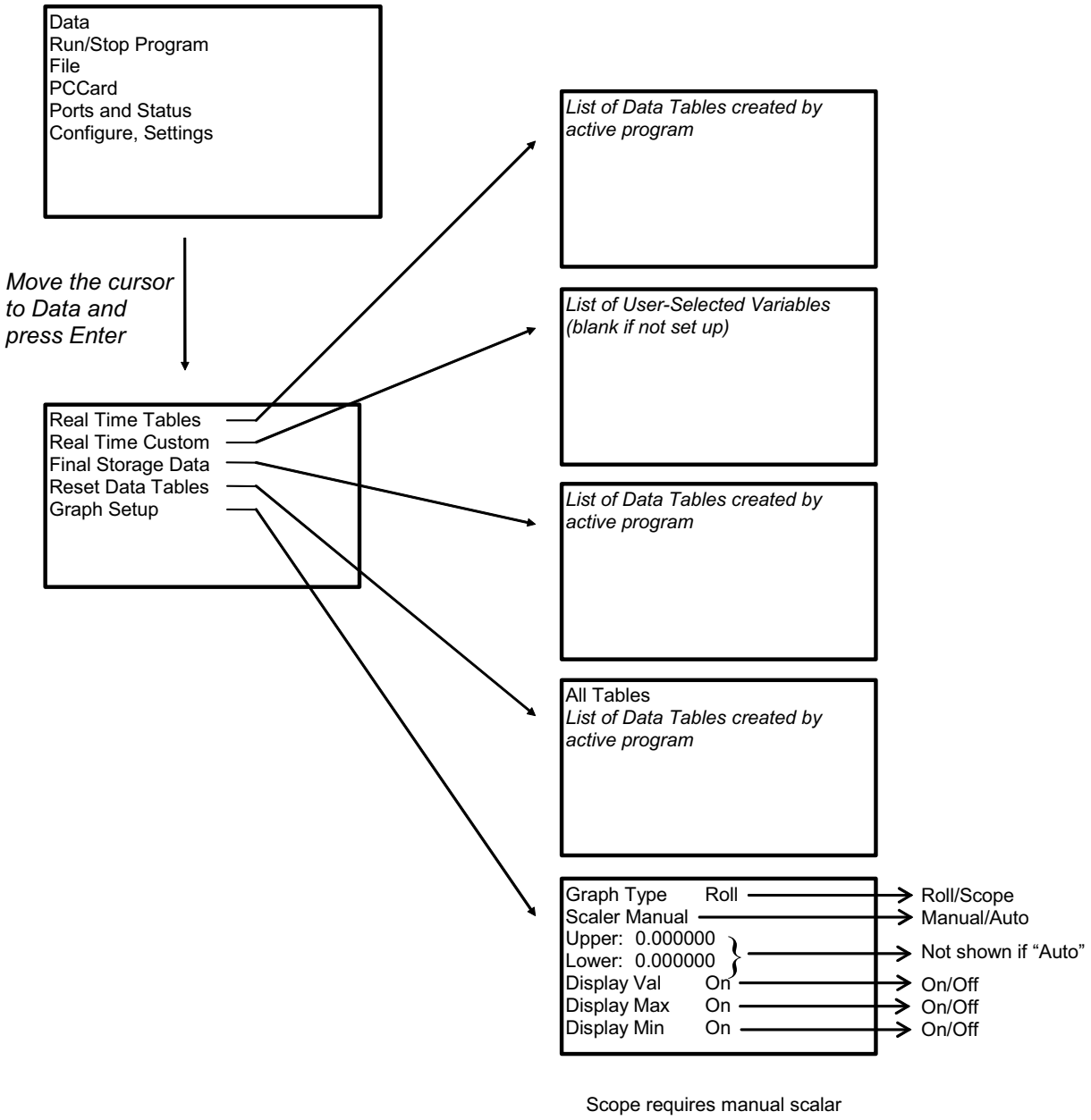
Key	Usage
[2] and [8]	To navigate up and down through the menu list one line at a time
[Enter]	Selects the line or toggles the option of the line the cursor is on
[Esc]	Back up one level in the menu
[Home]	Move cursor to top of the list
[End]	Move cursor to bottom of the list
[Pg Up]	Move cursor up one screen
[Pg Dn]	Move cursor down one screen
[BkSpc]	Delete character to the left
[Shift]	Change alpha character selected
[Num Lock]	Change to numeric entry
[Del]	Delete
[Ins]	Insert/change graph setup
[Graph]	Graph

Power Up Screen

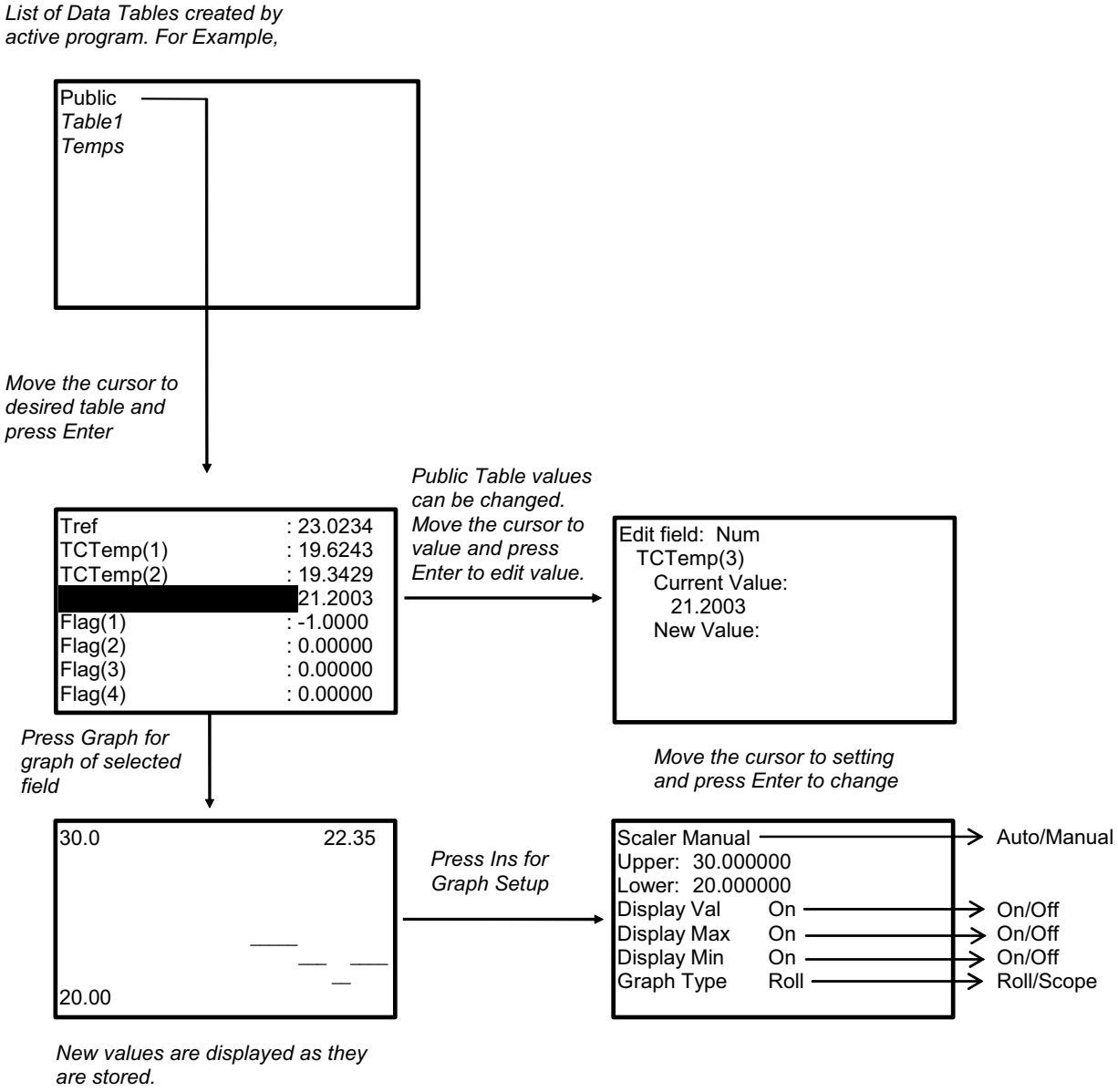
CR1000 Display



17.1 Data Display



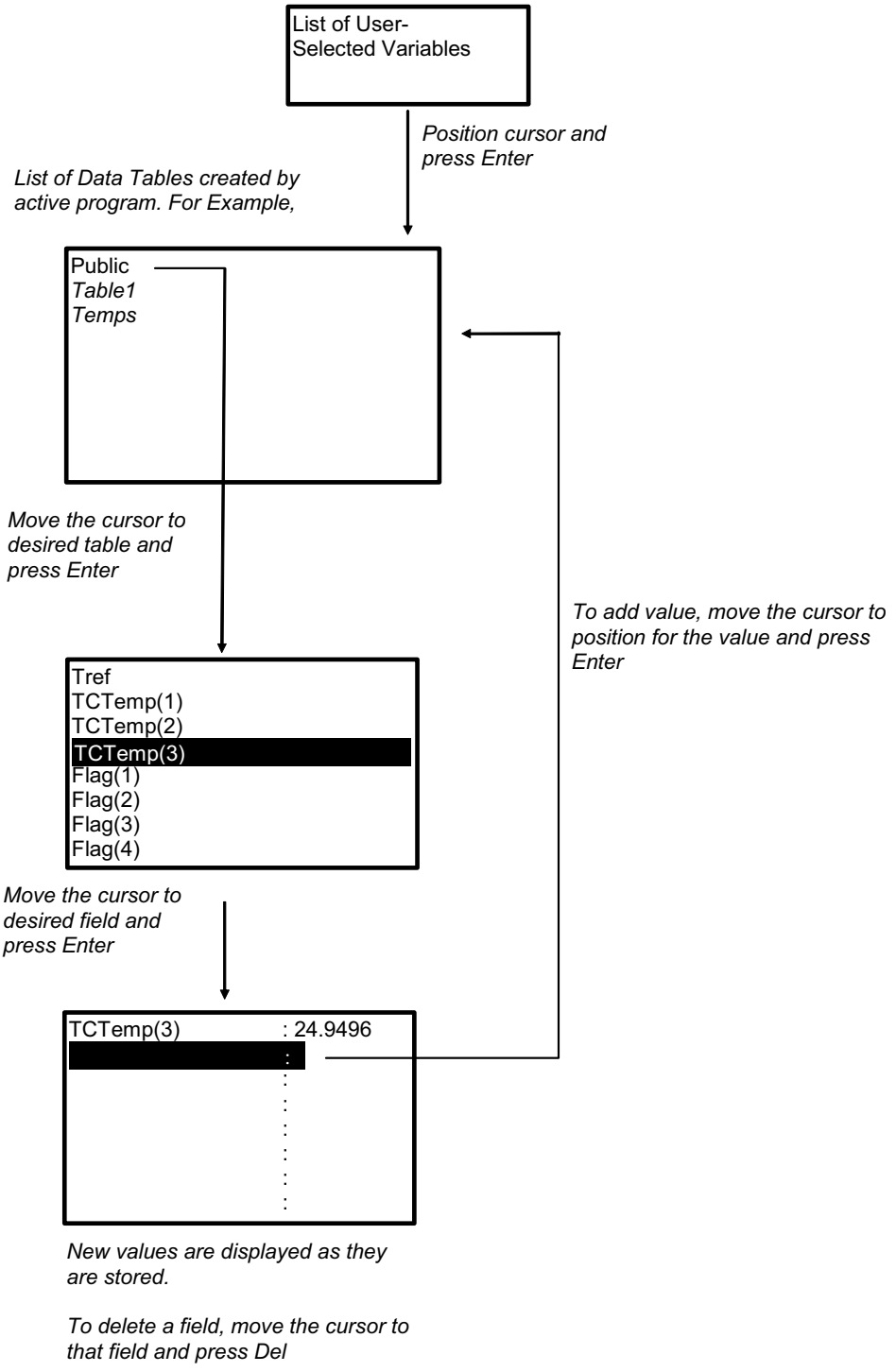
17.1.1 Real Time Tables



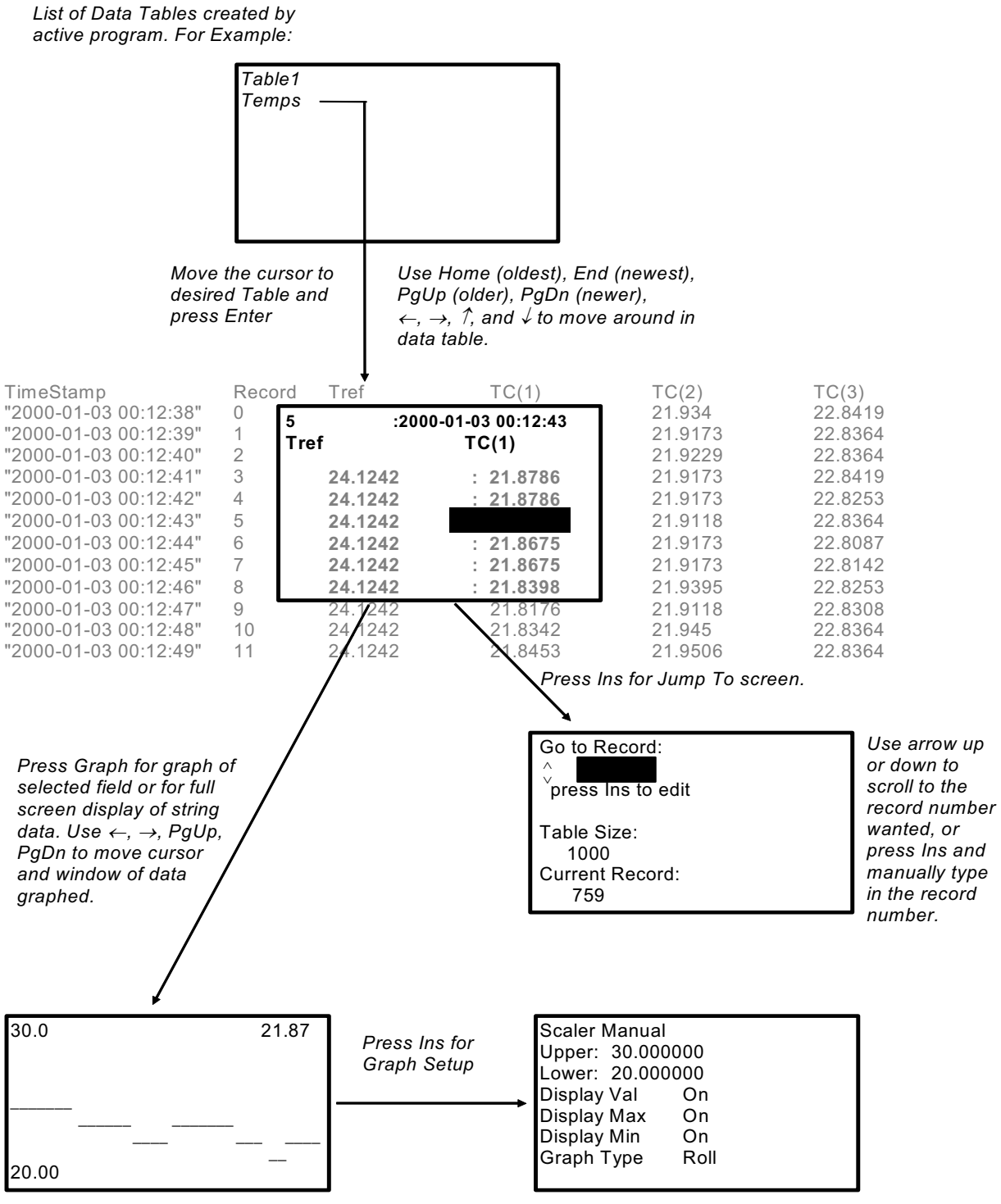
17.1.2 Real Time Custom

The CR1000KD can be configured with a user defined real-time display. The CR1000 will keep the setup as long as the same program is running, or it is changed by the user.

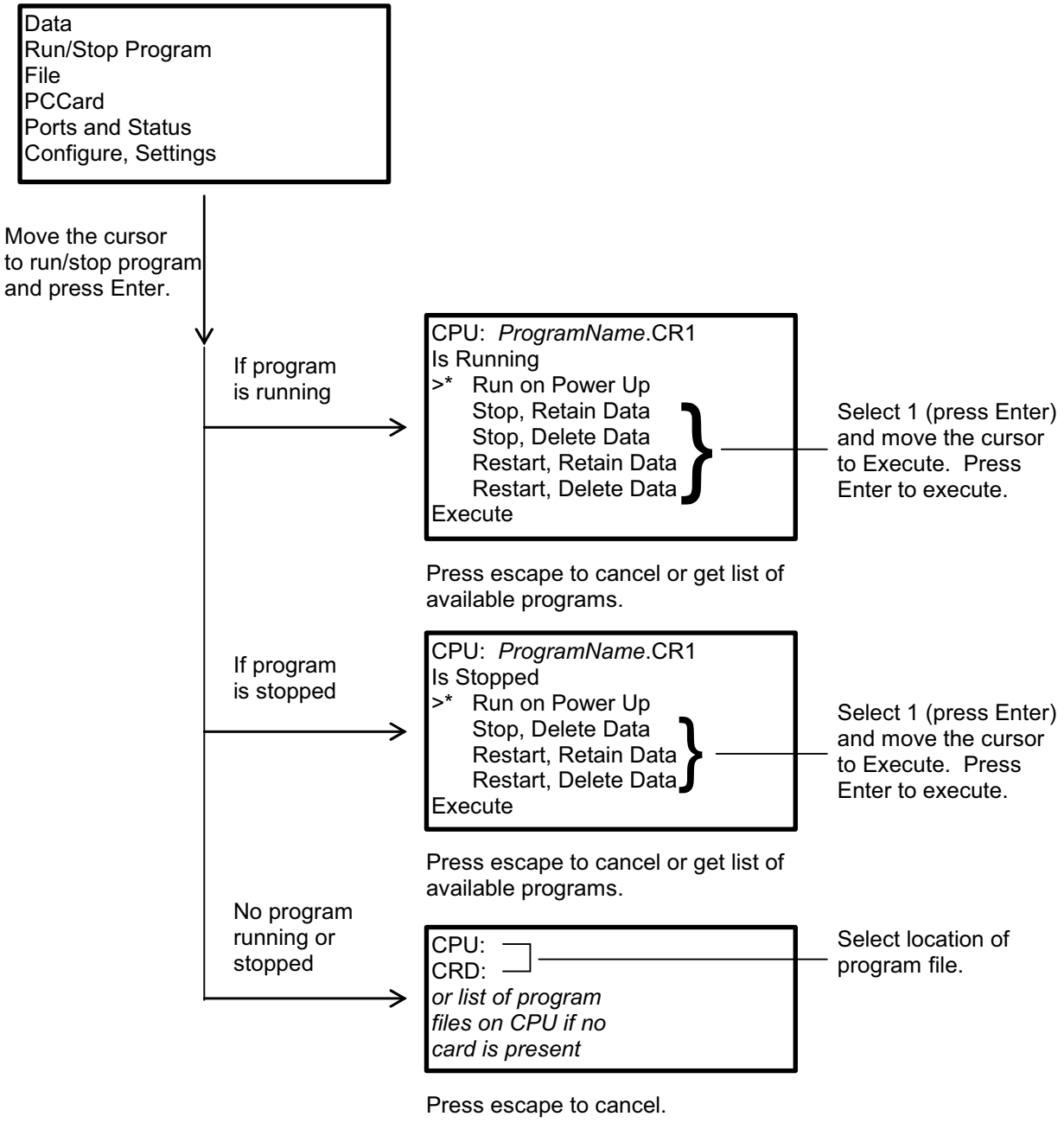
Read more! Custom menus can also be programmed. See Section 11.6 CR1000KD Custom Menus for more information.



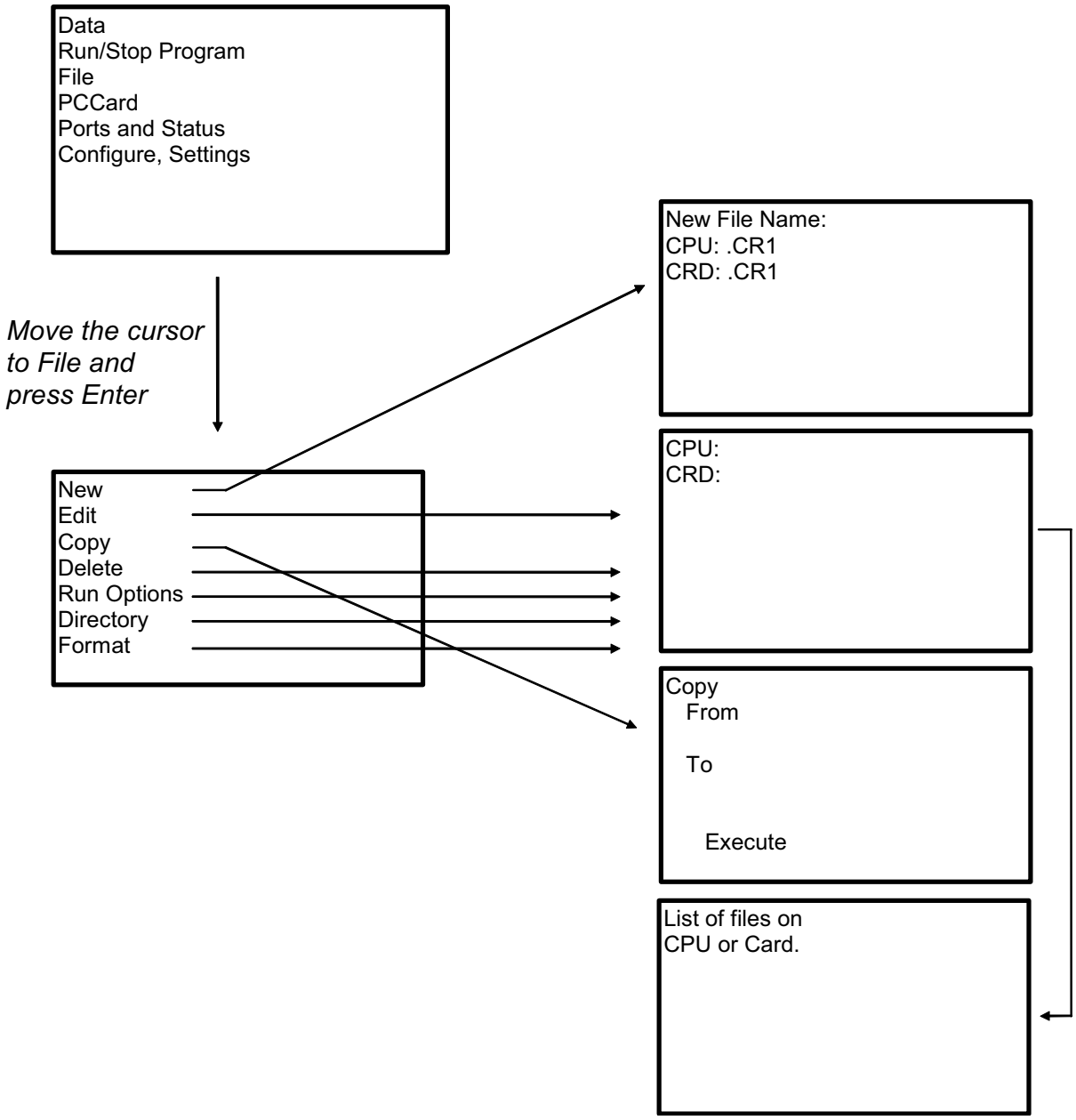
17.1.3 Final Storage Tables



17.2 Run/Stop Program

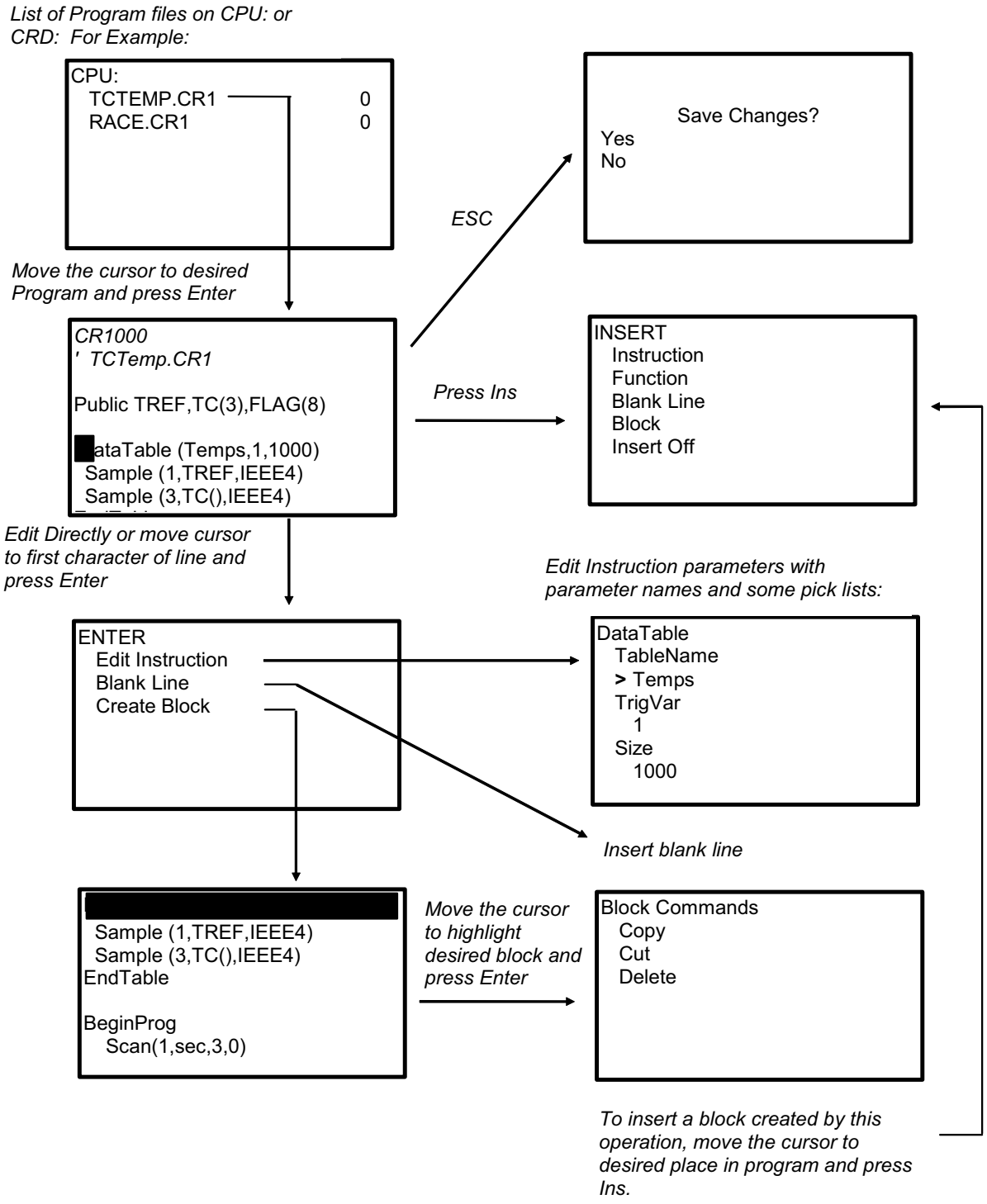


17.3 File Display

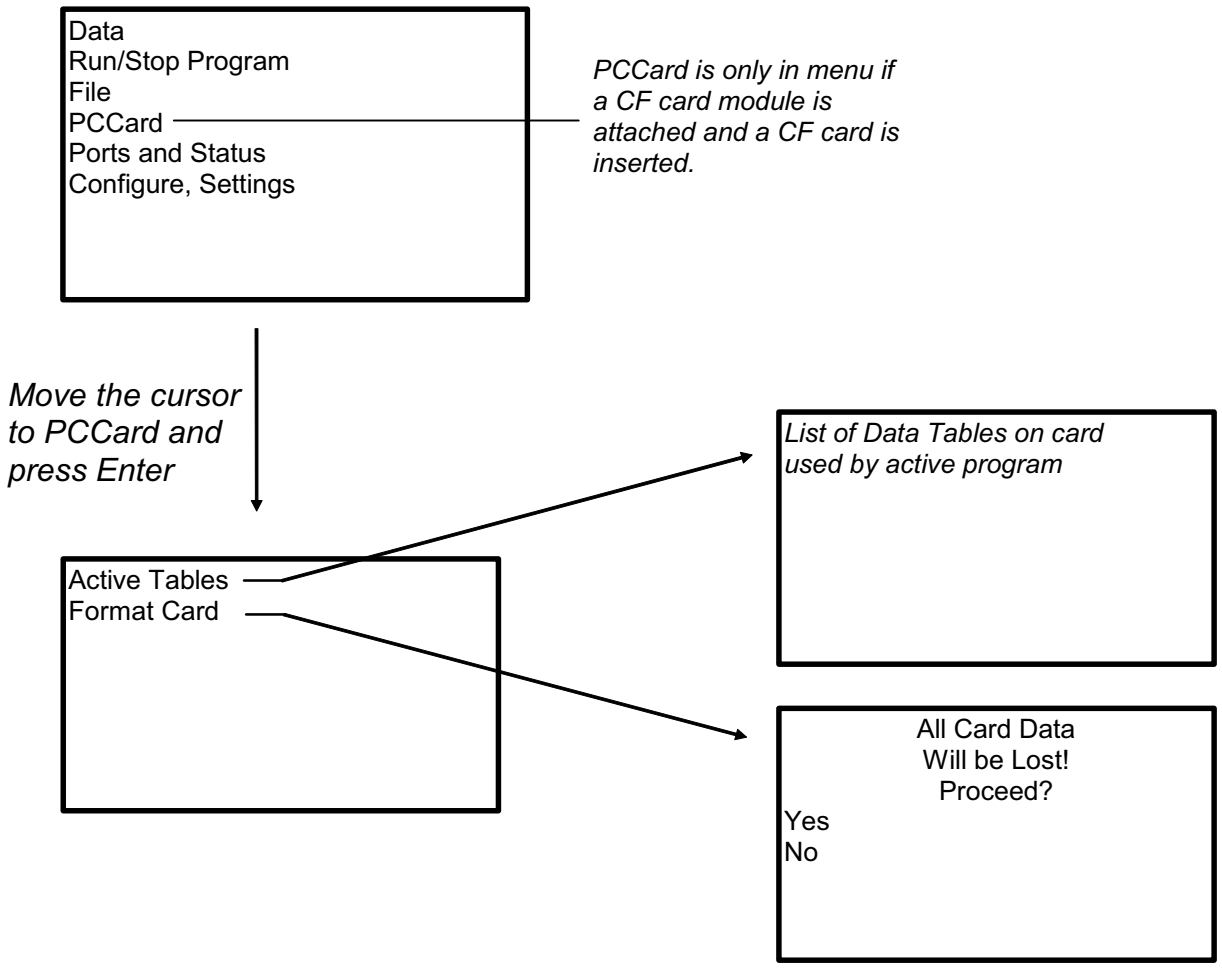


17.3.1 File: Edit

The CRBASIC Editor is recommended for writing and editing datalogger programs. Changes in the field can be made with the keyboard display. When making changes to the program with the CR1000KD, stop the program then restart it to active the changes.

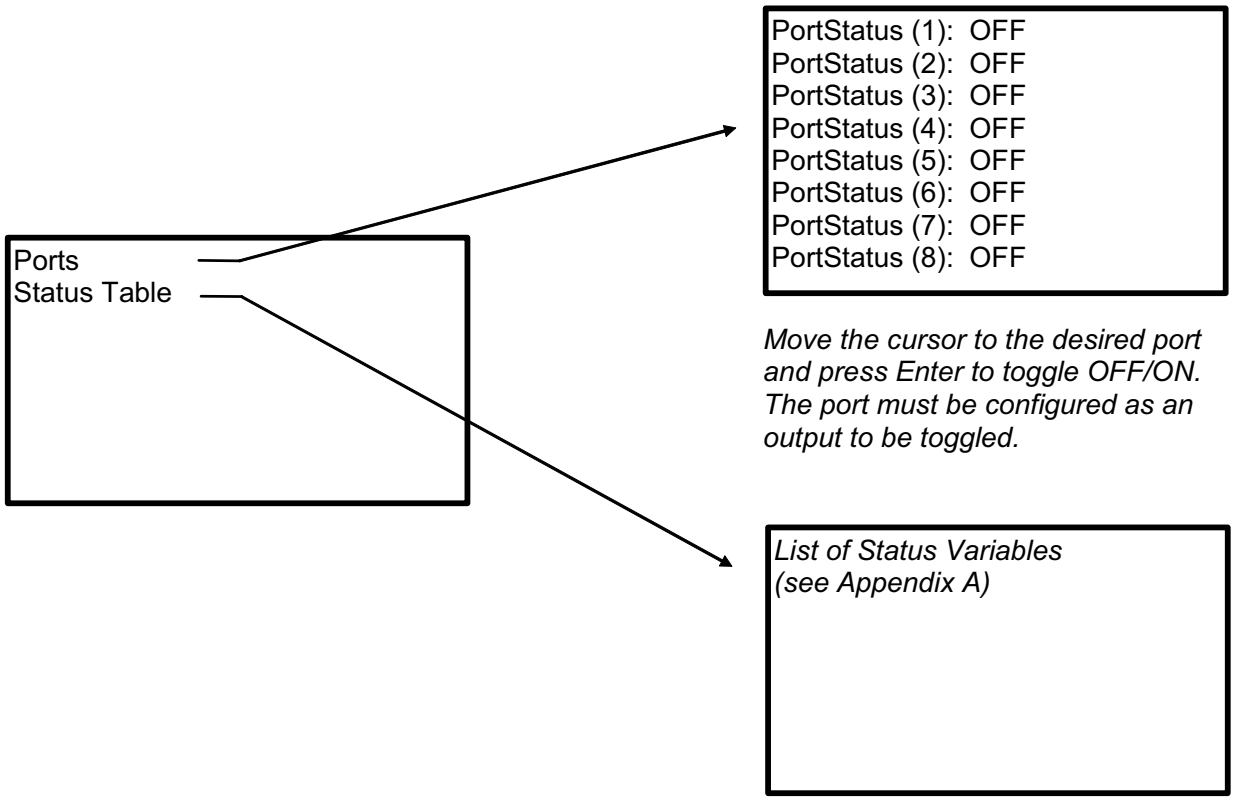


17.4 PCCard Display

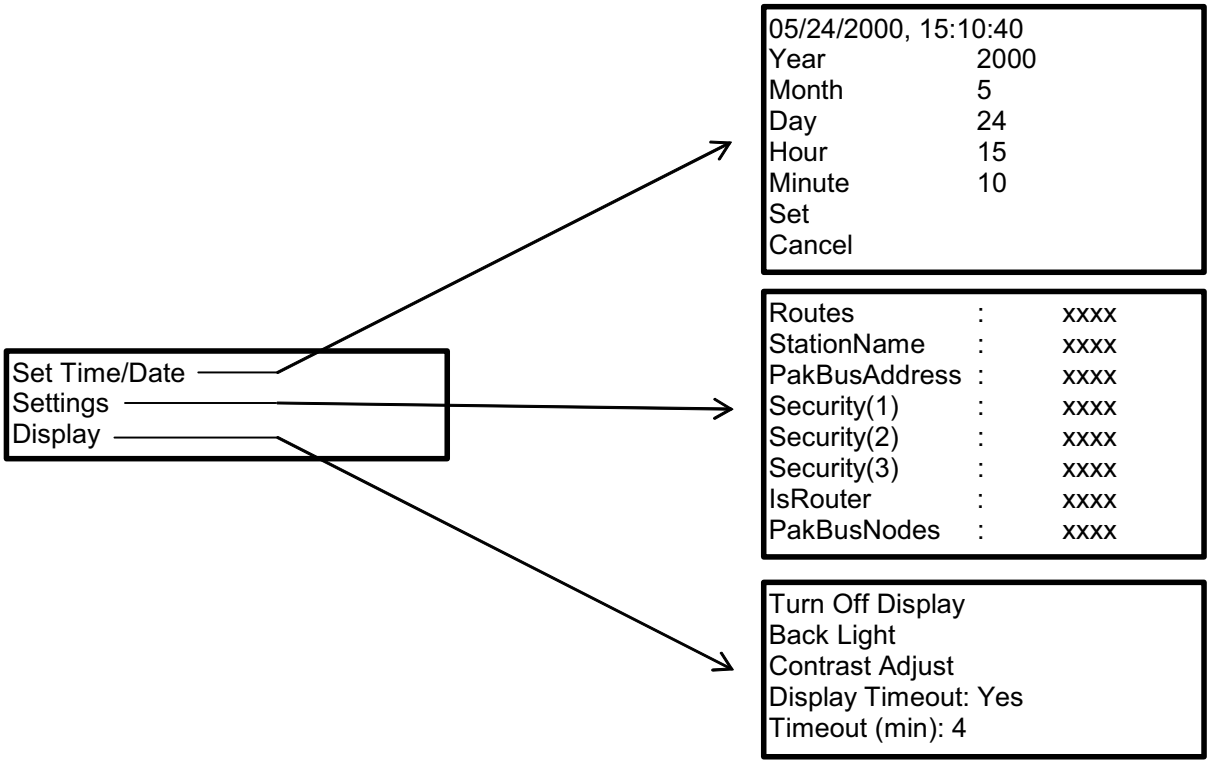


17.5 Ports and Status

Read more! See Appendix A Status Table



17.6 Settings



Move the cursor to time element and press Enter to change

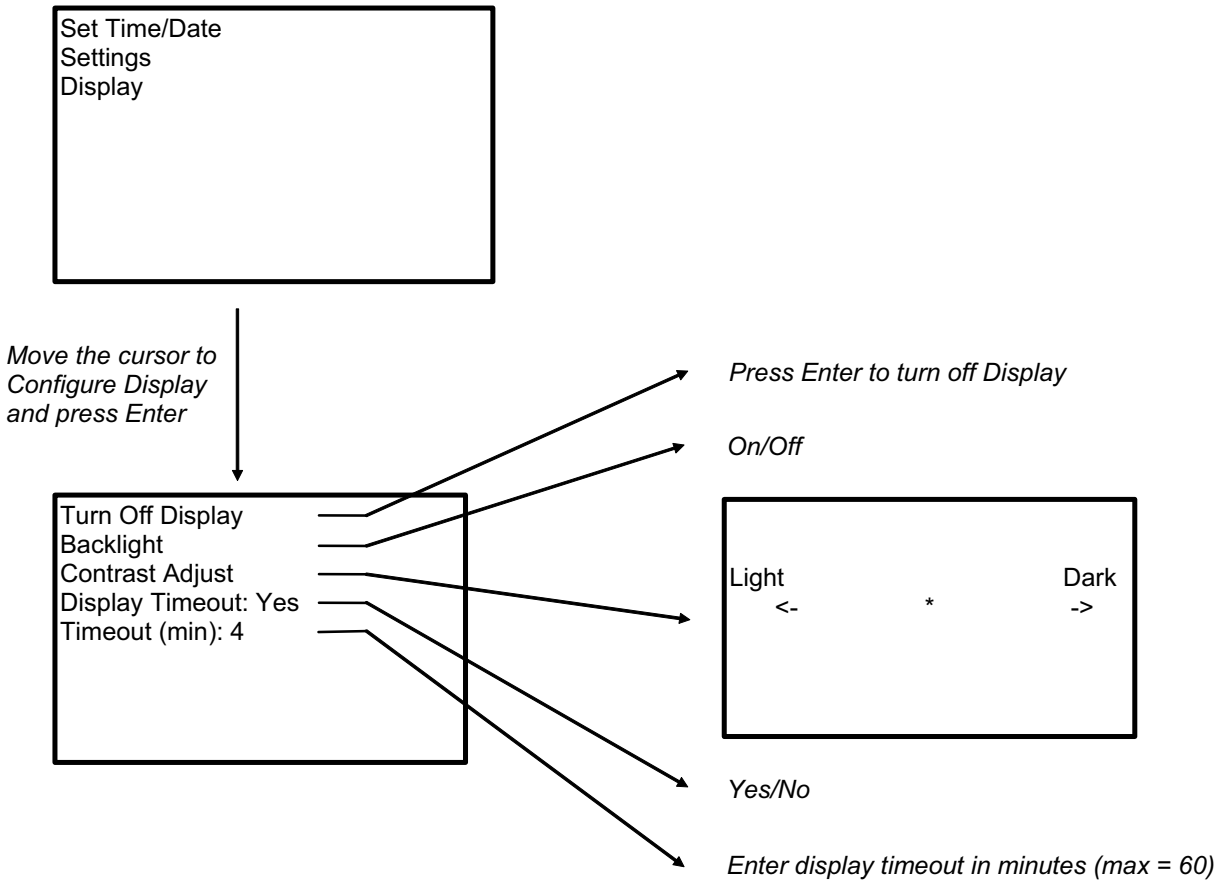
17.6.1 Set Time / Date

Move the cursor to time element and press Enter to change it. Then move the cursor to Set and press Enter to apply the change.

17.6.2 PakBus Settings

In the Settings menu, move the cursor to the PakBus element and press Enter to change it. After modifying, press Enter to apply the change.

17.6.3 Configure Display



Section 18. Care and Maintenance

Temperature and humidity can affect the performance of the CR1000. The internal lithium battery must be replaced periodically.

18.1 Temperature Range

The standard CR1000 is designed to operate reliably from -25 to +50°C (-40°C to +85°C, optional) in non-condensing humidity.

18.2 Moisture Protection

When humidity tolerances are exceeded and condensation occurs, damage to CR1000 electronics can result. Effective humidity control is the responsibility of the user.

Internal CR1000 module moisture is controlled at the factory by sealing the module with a packet of silica gel inside. The desiccant is replaced whenever the CR1000 is repaired at Campbell Scientific. The module should not be opened by the user except to replace the lithium coin cell providing back up power to the clock and SRAM. Repeated disassembly of the CR1000 will degrade the seal, leading to potential moisture problems.

Adequate desiccant should be placed in the instrumentation enclosure to prevent corrosion on the CR1000 wiring panel.

18.3 Enclosures

Campbell Scientific offers environmental enclosures for housing a CR1000 and peripherals. These enclosures are classified as NEMA 4X (watertight, dust-tight, corrosion-resistant, indoor and outdoor use).

18.4 Replacing the Internal Battery

CAUTION Misuse of the lithium battery or installing it improperly can cause severe injury. Fire, explosion, and severe burn hazard! Do not recharge, disassemble, heat above 100°C (212°F), solder directly to the cell, incinerate, nor expose contents to water. Dispose of spent lithium batteries properly.

The CR1000 contains a lithium battery that operates the clock and SRAM when the CR1000 is not powered. The CR1000 does not draw power from the lithium battery while it is powered by a 12 VDC supply. In a CR1000 stored at room temperature, the lithium battery should last approximately 10 years (less at temperature extremes). Where the CR1000 is powered most or all of the time the lithium cell should last much longer.

While powered from an external source, the CR1000 measures the voltage of the lithium battery daily. This voltage is displayed in the status table (Appendix A). A new battery will have approximately 3.6 volts. The CR1000 Status Table has a "Lithium Battery" field. This field shows lithium battery voltage. Replace the battery when voltage is approximately 2.7 V. If the lithium cell is removed or allowed to discharge below the safe level, the CR1000 will still operate correctly while powered. Without the lithium battery, the clock will reset and data will be lost when power is removed.

A replacement lithium battery can be purchased from Campbell (part number 13519). TABLE 18.4-1 lists the specifications of the battery.

TABLE 18.4-1. CR1000 Lithium Battery Specifications

Manufacturer	Tadiran
Model	TL-59025 (3.6 V)
Capacity	1.2 Ah
Self-discharge rate	1%/year @ 20°C
Operating temperature range	-55°C to 85°C

The CR1000 must be partially disassembled to replace the lithium cell.

FIGURE 18.4-1 through FIGURE 18.4-5 illustrate how to disassemble the CR1000. Reverse these steps to reassemble the CR1000.

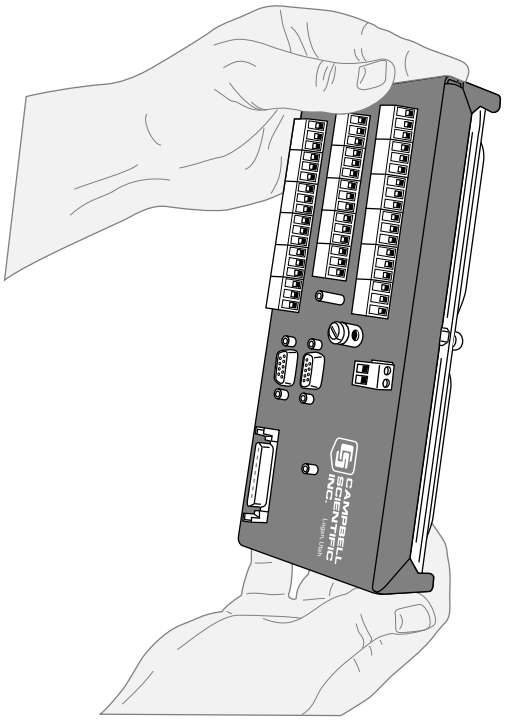


FIGURE 18.4-1. CR1000 with wiring panel.

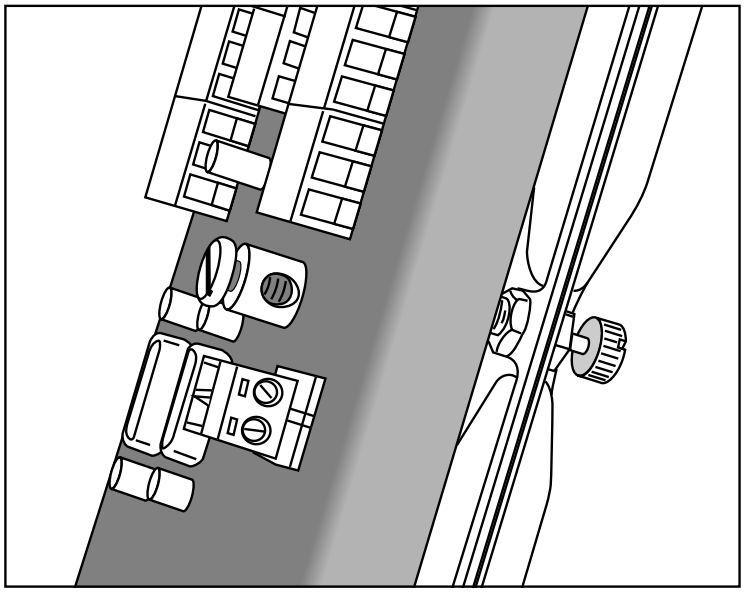


FIGURE 18.4-2. Loosen thumbscrew to remove CR1000 canister from wiring panel.

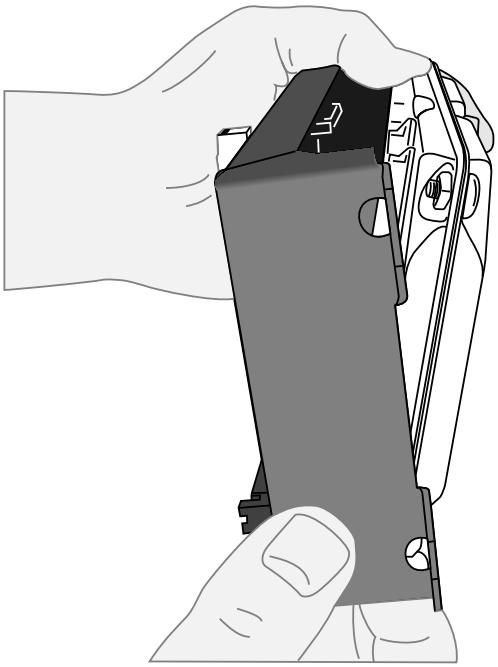


FIGURE 18.4-3. Pull edge with thumbscrew away from wiring panel.

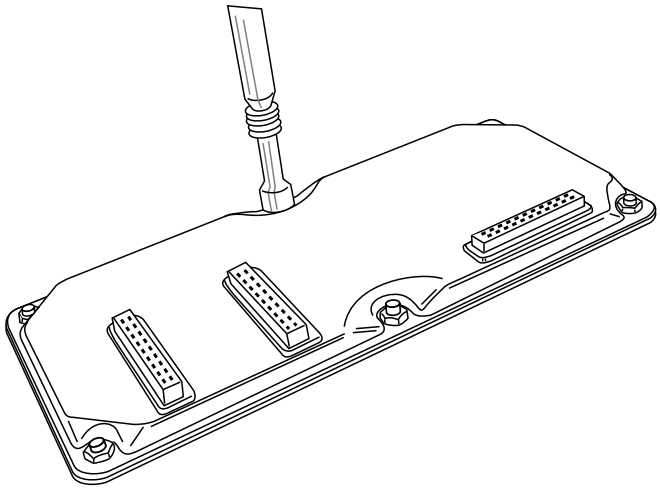


FIGURE 18.4-4. Remove nuts to disassemble canister.

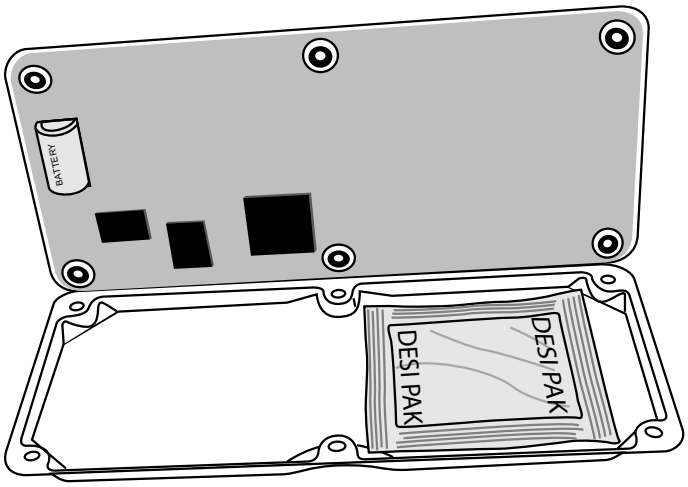


FIGURE 18.4-5. Remove and replace battery.

Section 19. Troubleshooting

NOTE If any component needs to be returned to the factory for repair or recalibration, remember that an RMA number is required. Contact a Campbell Scientific applications engineer to receive the RMA number.

19.1 Programming

19.1.1 Debugging Resources

A properly deployed CR1000 measures sensors accurately and stores all data as requested by the program. Experienced users analyze measurement data soon after deployment to ensure the CR1000 is measuring and storing data as desired by the programmer. Most measurement and data storage problems are a result of one or more instances of improper program code or "bugs."

Consult the CR1000 Status Table when a problem with a program is suspected. Critical Status Table registries to review include:

Read more! See Appendix A for a complete list of Status Table registers and hints on using the Status Table.

19.1.1.1 CompileResults

Reports messages generated by the CR1000 at program upload and compile-time. A message will report that the program compiled OK or that there are run-time errors. Error messages may not be obvious because the display column is too short. Messages report variables that caused out-of-bounds conditions, watchdog information, and memory errors. Messages may be tagged onto this line as the program runs.

A rare error is indicated by "**mem3 fail**" type messages. These messages can be caused by random internal memory corruption. When seen on a regular basis with a given program, an operating system error is indicated. "Mem3 fail" messages are not caused by user error, and only rarely by a hardware fault. Report any occurrence of this error to a Campbell Scientific applications engineer, especially if the problem is reproducible. Any program generating these errors is unlikely to be running correctly.

19.1.1.2 SkippedScan / SkippedSlowScan

Occasional skipped scans may be expected and acceptable. However, be careful that scans that store data are not skipped. The CR1000 automatically runs a slow sequence to update the calibration table. When the calibration slow sequence skips, the CR1000 will try to repeat that step of the calibration process next time around. This simply extends calibration time. If any scan skips repeatedly, optimization of the datalogger program or reduction of online processing may be necessary.

Skipped scans in Pipeline Mode indicate an increase in the maximum buffer depth is needed. Try increasing the number of scan buffers (third parameter of the Scan () instruction) to a value greater than that shown in the MaxBuffDepth register in the Status Table.

19.1.1.3 SkippedRecord

Increments normally caused by skipped scans, which occur when a table called by the skipped scan is supposed to store data. These counters are not incremented by all events that leave gaps in data, including the CR1000 powering down or the CR1000 clock being changed.

19.1.1.4 ProgErrors

If not zero, investigate

19.1.1.5 Memoryfree

A number less than 4 kbytes is too small and may lead to memory buffer related errors.

19.1.1.6 VarOutOfBound

The CR1000 tries to write which variable has gone out-of-bounds at the end of the CompileResults message. The CR1000 does not catch all out-of-bounds errors.

19.1.1.7 WatchdogErrors

Non-zero indicates the CR1000 has crashed, which can be caused by power or transient voltage problems, or an operating system or hardware problem. For many types of crashes the CR1000 will sometimes write information at the end of the CompileResults register indicating the nature of the last crash. Watchdog errors may cause telecommunications disruptions, which can make diagnosis and remediation difficult. The CR1000KD will often work as a user interface when telecommunications fail.

19.1.2 Program does not Compile

Although the PC CRBASIC compiler says a program compiles OK, it may not run or even compile in the CR1000. Reasons may include:

- The CR1000 has a different (usually older) operating system that is not compatible with the PC compiler. Check the two versions if in doubt (the PC version is shown on the first line of the compile results).
- The program has large memory requirements for data tables or variables and the CR1000 does not have adequate memory. This normally is flagged at compile time, in the compile results. If this sort of error occurs, check:
  a) For copies of old programs encumbering the CPU drive. The CR1000 will keep copies of all program files ever loaded unless they are deleted, the drive is formatted, or a new OS is loaded with DevConfig.
  b) That the USR: drive, if created, is not too large. The USR: drive may be using memory needed for the program.
  c) That a program written for a 4 MB CR1000 is not now being loaded into a 2MB CR1000.
  d) That a memory card is available if the program is attempting to access the CRD: drive.

19.1.3 Program Compiles / Does Not Run Correctly

If the program compiles but does not run correctly, timing discrepancies are often the cause. Neither CRBASIC Editor nor the CR1000 compiler attempt to check whether the CR1000 is fast enough to do all that the program specifies in the time allocated. If a program is tight on time, look further at the execution times. Check the measurement and processing times in the Status Table (MeasureTime, ProcessTime, MaxProcTime) for all scans, then try experimenting with the InstructionTimes () instruction in the program. Analyzing InstructionTimes () results can be difficult due to the multitasking nature of the logger, but it can be a powerful way to fine tune a program.

19.1.4 NAN and ±INF

NAN (not-a-number) and ±INF (infinite) are data words indicating an exceptional occurrence in datalogger function or processing. NAN is a constant that can be used in expressions such as in EXAMPLE 19.1-1 NAN can also be used in the disable variable (DisableVar) in output processing (data storage) instructions.

Read More! Use of NAN and the disable variable in advanced data table programming is discussed in Section 11.15.2 NAN and the Disable Variable.

EXAMPLE 19.1-1. Using NAN in an Expressions

```
If WindDir = NAN Then
    WDFlag = True
Else
    WDFlag=False
EndIf
```

19.1.4.1 Measurements and NAN

NAN results when an instruction fails to return a valid measurement.

Analog Measurements

When NAN results from analog voltage measurements, it indicates an overrange error wherein the input voltage exceeds the programmed input range. When NAN occurs with auto ranging, it indicates either the first or second measurement in the autorange sequence has overranged.

If an analog sensor is open (inputs not connected but "floating"), the inputs will remain floating near the voltage they were last connected to; a measurement on ±2.5 mV, ±7.5 mV, ±25 mV, or ±250 mV voltage range will overrange and return NAN.

To make a differential measurement, voltage inputs must be within the CR1000 common mode range of ±5 V. Otherwise, the CR1000 indicates the overrange by returning NAN.

SDI-12 Measurements

NAN is loaded into the first variable when the command issued by the SDI12Recorder () instruction fails to get a response from an SDI-12 probe.

19.1.4.2 Floating Point Math, NAN, and ±INF

TABLE 19.1-1 lists math expressions, their CRBASIC form, and IEEE floating point math result loaded into variables declared as FLOAT or STRING.

TABLE 19.1-1. Math Expressions and CRBASIC Results

Expression	CRBASIC Expression	Result
0 / 0	0 / 0	NAN
∞ - ∞	(1 / 0) - (1 / 0)	NAN
$(-1)^{\infty}$	-1 ^ (1 / 0)	NAN
0 * -∞	0 * (-1 * (1 / 0))	NAN
±∞ / ±∞	(1 / 0) / (1 / 0)	NAN
1^{∞}	1 ^ (1 / 0)	NAN
0 * ∞	0 * (1 / 0)	NAN
x / 0	1 / 0	INF
x / -0	1 / -0	INF
-x / 0	-1 / 0	-INF
-x / -0	-1 / -0	-INF
∞^0	(1 / 0) ^ 0	INF
0^{∞}	0 ^ (1 / 0)	0
0^0	0 ^ 0	1

19.1.4.3 Data Types, NAN, and ±INF

NAN and ±INF are presented differently depending on the declared variable data type. Further, they are recorded differently depending on the final storage data type chosen compounded with the declared variable data type used as the source (TABLE 19.1-2). For example, INF in a variable declared as LONG is represented by the integer -2147483648. When that variable is used as the source, the final storage word when sampled as UINT2 is stored as 0.

TABLE 19.1-2. Variable and FS Data Types with NAN and ±INF							
Test Expression	**Variable**	**FS FP2**	**FS IEEE4**	**FS UINT2**	**FS STRING**	**FS BOOL**	**FS LONG**
	As FLOAT						
Jan-00	INF	INF	INF	65535	+INF	TRUE	2,147,483,647
0 / 0	NAN	NAN	NAN	0	NAN	TRUE	-2,147,483,648
	As LONG						
1 / 0	2,147,483,647	7999	2.147484E+09	65535	2147483647	TRUE	2,147,483,647
0 / 0	-2,147,483,648	-7999	-2.147484E+09	0	-2147483648	TRUE	-2,147,483,648
	As Boolean						
1 / 0	TRUE	-1	-1	65535	-1	TRUE	-1
0 / 0	TRUE	-1	-1	65535	-1	TRUE	-1
	As STRING						
1 / 0	+INF	INF	INF	65535	+INF	TRUE	2,147,483,647
0 / 0	NAN	NAN	NAN	0	NAN	TRUE	-2,147,483,648

19.2 Communications

19.2.1 RS-232

Baud rate mis-match between the CR1000 and LoggerNet is often the root of communication problems through the RS-232 port. By default, the CR1000 attempts to adjust its baud rate to that of LoggerNet. However, settings changed in the CR1000 to accommodate a specific RS-232 device, such as a smart sensor, display or modem, may confine the RS-232 port to a single baud rate. If the baud rate can be guessed at and entered into LoggerNet Setup communications may be established. Once communications is established, CR1000 baud rate settings can be changed. Get clues as to what the baud rate may be set at by analyzing current and previous CR1000 programs for the SerialOpen () instruction, which specifies a baud rate. Documentation provided by the manufacturer of the previous RS-232 device may also hint at the baud rate.

19.2.2 Communicating with Multiple PC Programs

A common practice is to monitor the performance of a CR1000 using Devconfig or Loggernet while the CR1000 has an open connection to another copy of Loggernet. For example, the main connection can be via Internet while the performance monitoring is done via RS-232 port. This is a useful feature of the CR1000. A problem often arises, however, in that the CR1000 gets confused when attempting this via two different ports, from two different instances of the same PakBus address, i.e. if Loggernet and Devconfig have the same address.

NOTE Loggernet defaults to PakBus address 4094. Devconfig is fixed at PakBus address 4094.

The solution is to change the PakBus address in Loggernet | Setup | Options | Loggernet Pakbus Settings). If feasible, use PC200W or PC400 instead of Devconfig as each has a different default PakBus address from LoggerNet.

19.3 Memory Errors

CommsMemFree is a Status Table register. The first number (positive < 1000000) is the most useful. It should be around 30,000 when very little communication is happening. A lot of PakBus or TCP/IP communication will tend to drop this number. It should not drop down as low as 2,000. When it gets this low, comms will try to use non-existent memory. If this occurs too often, a watchdog will happen with a message "Out of Memory".

19.4 Power Supply

19.4.1 Overview

Power supply systems may include batteries, charger/regulators, and charging sources such as solar panels or transformers. All of these components may need to be checked if the power supply is not functioning properly.

Section 17.4.3 includes the following flowcharts:

- Battery Voltage Test
- Charging Circuit Test (when using an unregulated solar panel)
- Charging Circuit Test (when using a transformer)
- Adjusting Charging Circuit

If all of the power supply components are working properly and the system has peripheral(s) with high current drain(s) such as satellite transmitter, verify that the system's power supply provides enough power. For more information, refer to our Power Supply product literature or Application Note.

19.4.2 Troubleshooting at a Glance

Symptoms:

Possible symptoms include the CR1000 program not executing; Low12VCount of the Status table displaying a large number.

Affected Equipment:

Batteries, charger/regulators, solar panels, transformers

Likely Cause:

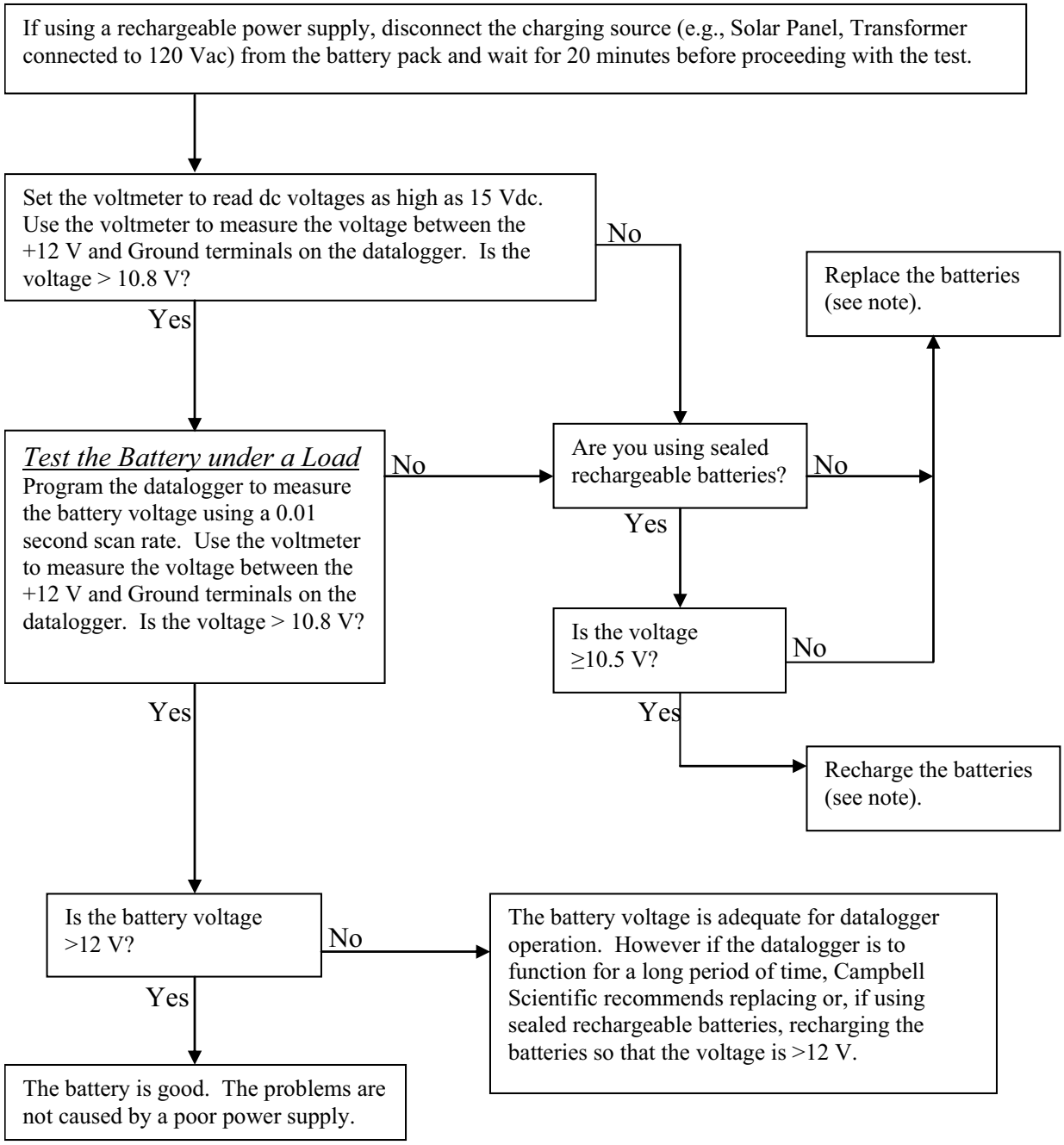
Batteries may need to be replaced or recharged; charger/regulators may need to be fixed or recalibrated; solar panels or transformers may need to be fixed or replaced.

Required Equipment:

Voltmeter; 5 kohm resistor and 50 ohm 1 W resistor for the charging circuit tests and to adjust the charging circuit voltage

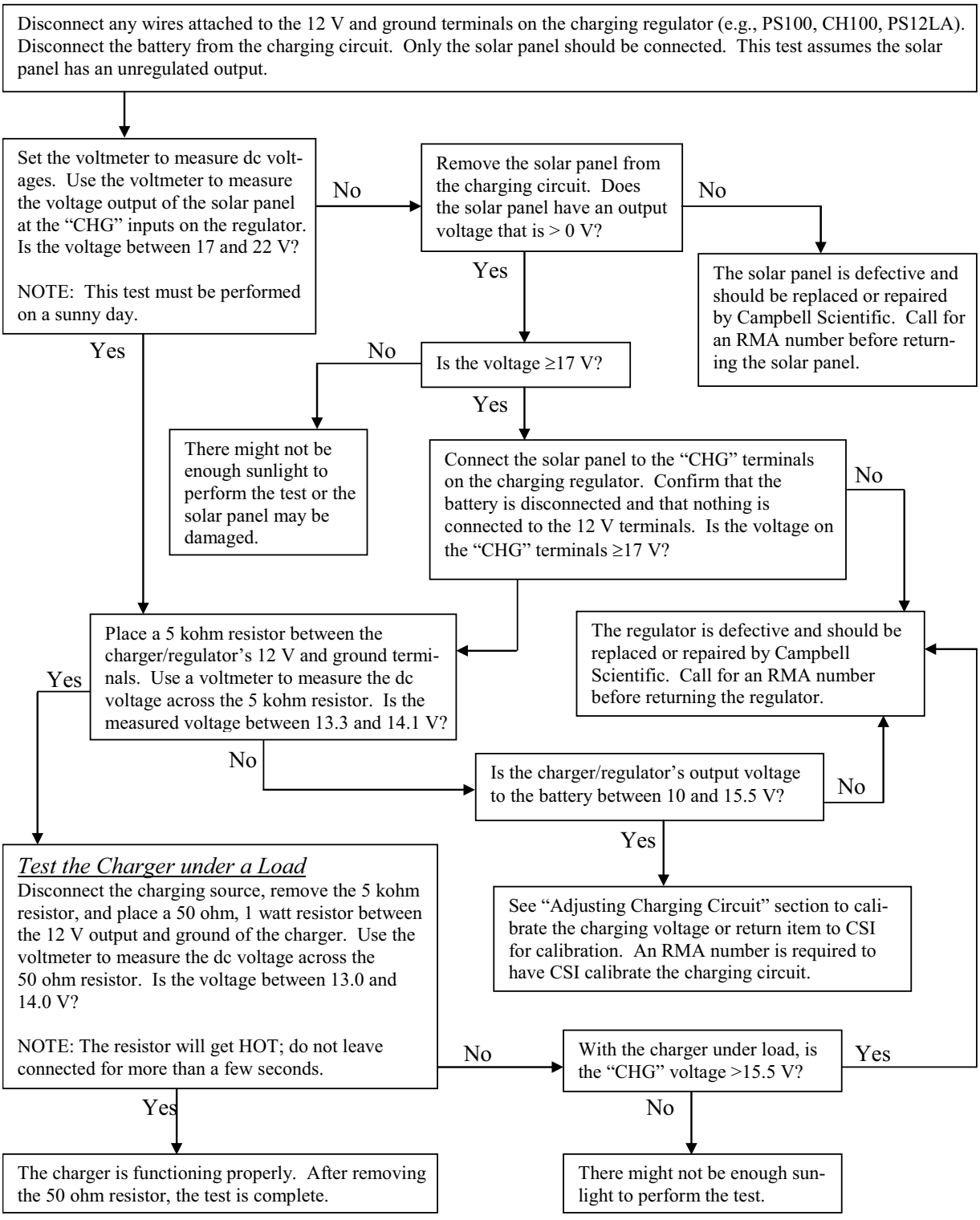
19.4.3 Diagnosis and Fix Procedures

19.4.3.1 Battery Voltage Test

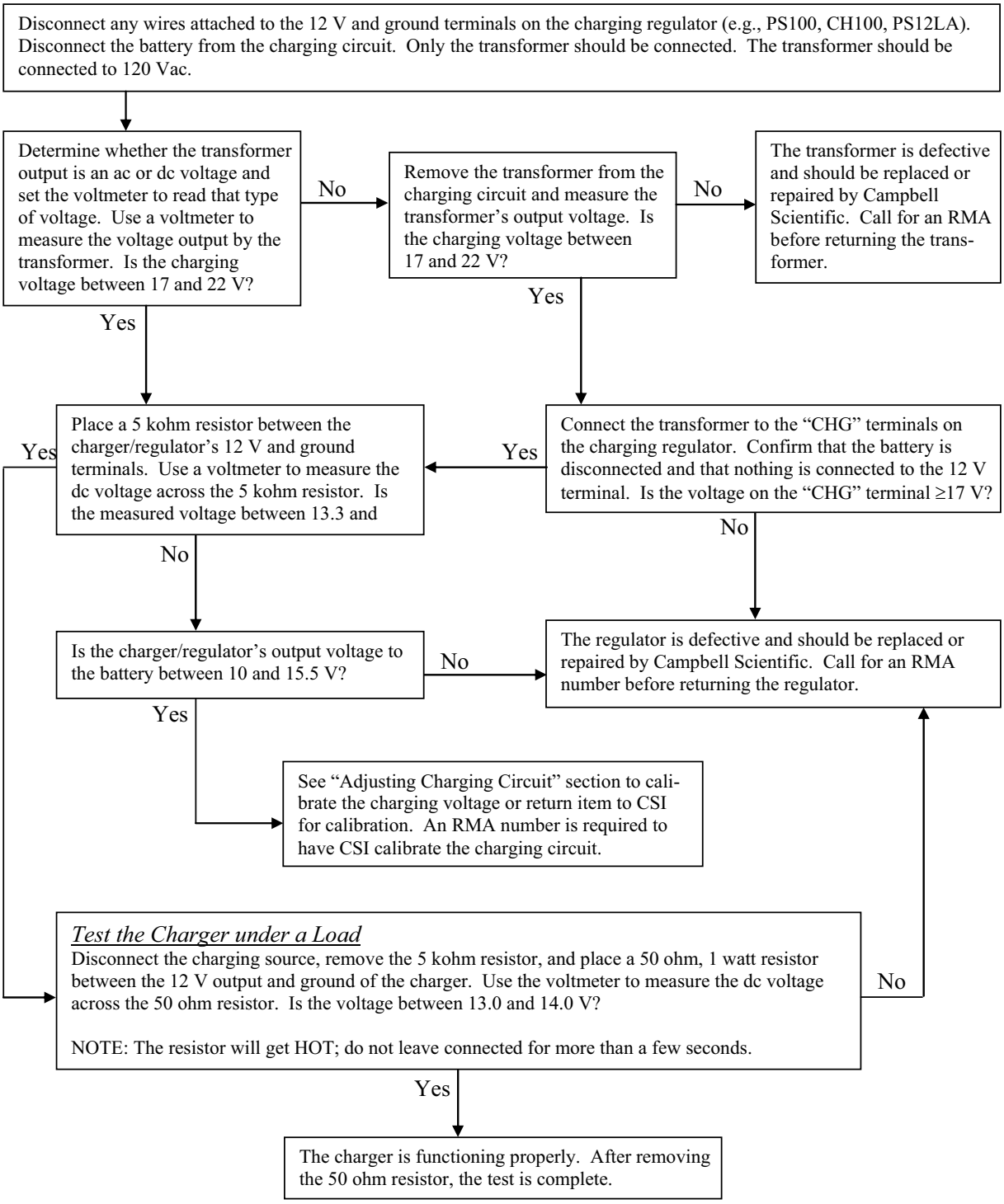


NOTE For customers using a sealed rechargeable battery that is recharged via an unregulated solar panel or a transformer, Campbell Scientific also recommends checking the charging circuit.

19.4.3.2 Charging Circuit Test — Solar Panel

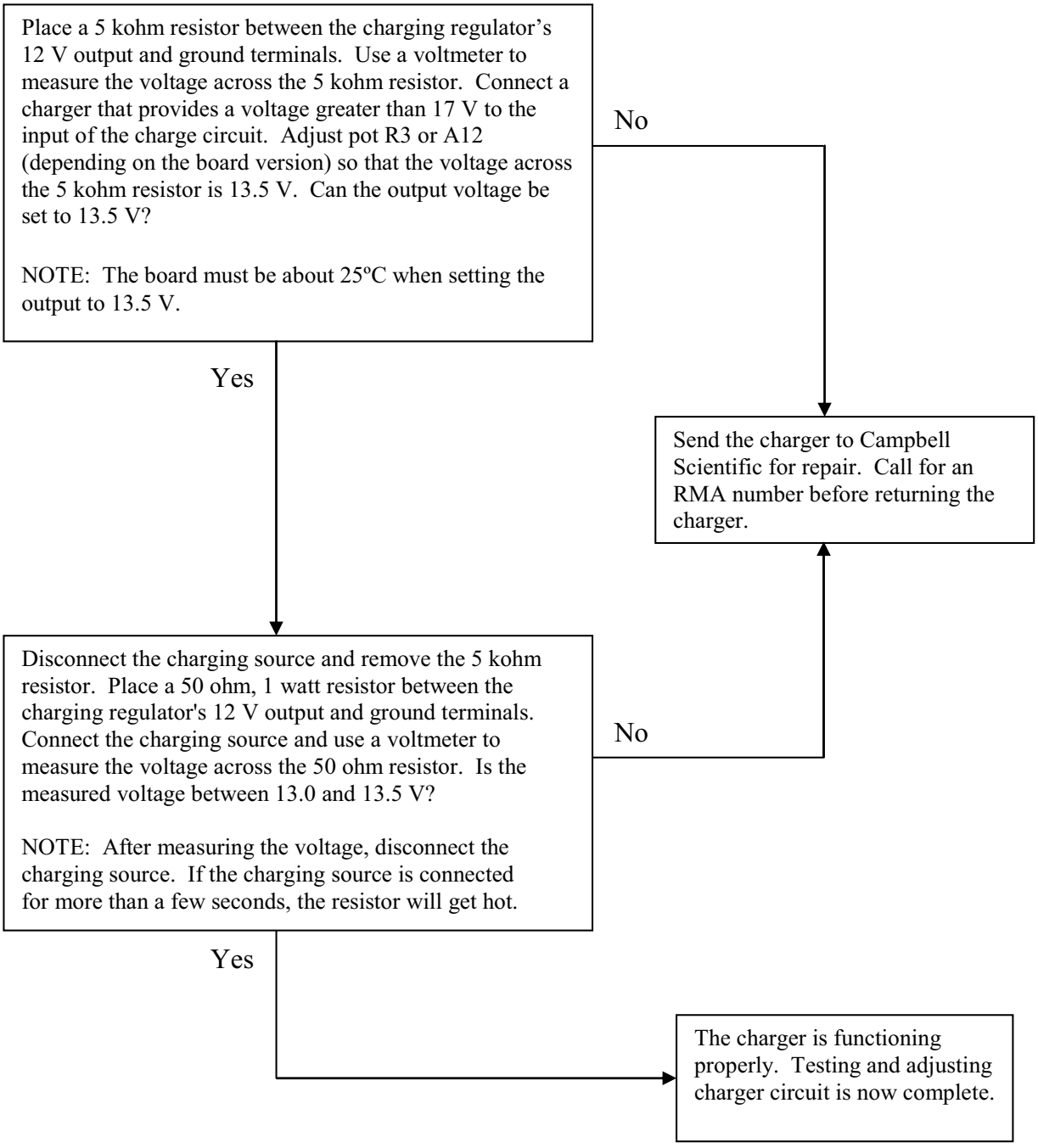


19.4.3.3 Charging Circuit Test — Transformer



19.4.3.4 Adjusting Charging Circuit Voltage

Campbell Scientific recommends that only a qualified electronic technician perform the following procedure.



Appendix A. Glossary

A.1 Terms

AC see VAC.

A/D analog-to-digital conversion. The process that translates analog voltage levels to digital values.

accuracy a measure of the correctness of a measurement. See also Section A.2.1 Accuracy, Precision, and Resolution.

Amperes (Amps) base unit for electric current. Used to quantify the capacity of a power source or the requirements of a power consuming device.

analog data presented as continuously variable electrical signals.

ASCII / ANSI abbreviation for American Standard Code for Information Interchange / American National Standards Institute. A specific binary code of 255 characters represented by 7 bit binary numbers.

asynchronous the transmission of data between a transmitting and a receiving device occurs as a series of zeros and ones. For the data to be "read" correctly, the receiving device must begin reading at the proper point in the series. In asynchronous communication, this coordination is accomplished by having each character surrounded by one or more start and stop bits which designate the beginning and ending points of the information (see Synchronous).

baud rate the speed of transmission of information across a serial interface, expressed in units of bits per second. For example, 9600 baud refers to bits being transmitted (or received) from one piece of equipment to another at a rate of 9600 bits per second. Thus, a 7 bit ASCII character plus parity bit plus 1 stop bit (total 9 bits) would be transmitted in 9/9600 sec. = .94 ms or about 1000 characters/sec. When communicating via a serial interface, the baud rate settings of two pieces of equipment must match each other.

Beacon a signal broadcasted to other devices in a PakBus® network to identify “neighbor” devices. A beacon in a PakBus network ensures that all devices in the network are aware of other devices that are viable. If configured to do so, a clock set command may be transmitted with the beacon. This function can be used to synchronize the clocks of devices within the PakBus network. See also PakBus and Neighbor Device.

binary describes data represented by a series of zeros and ones. Also describes the state of a switch, either being on or off.

Callback is a name given to a process by which the CR1000 initiates telecommunication with a PC running appropriate CSI datalogger support software. Also known as “Initiate Telecommunications.”

CF abbreviation for CompactFlash®, a data storage card that uses flash memory.

code a CRBASIC program, or a portion of a program.

constant a packet of CR1000 memory given an alpha-numeric name and assigned a fixed number.

control I/O Terminals C1 - C8 or processes utilizing these terminals.

CVI Communications Verification Interval. The interval at which a PakBus device verifies the accessibility of neighbors in its neighbor list. If a neighbor does not communicate for a period of time equal to 2.5 x the CVI, the device will send up to 4 Hellos. If no response is received, the neighbor is removed from the neighbor list.

CPU central processing unit. The brains of the CR1000.

CR10X older generation Campbell Scientific datalogger replaced by the CR1000.

CR1000KD an optional hand-held keyboard display for use with the CR1000 and CR800 dataloggers.

CRD a flash memory card or the memory drive that resides on the flash card.

CS I/O Campbell Scientific Input / Output. A proprietary serial communications protocol.

datalogger support software includes PC200W, PC400, RTDAQ, LoggerNet

data point a data value which is sent to Final Storage as the result of an output processing (data storage) instruction. Strings of data points output at the same time make up a record in a data table.

DC see VDC.

DCE data communications equipment. While the term has much wider meaning, in the limited context of practical use with the CR1000, it denotes the pin configuration, gender and function of an RS-232 port. The RS-232 port on the CR1000 and on many 3rd party telecommunications devices, such as a digital cellular modems, are DCE. To interface a DCE device to a DCE device requires a null-modem cable.

desiccant a material that absorbs water vapor to dry the surrounding air.

DevConfig Device Configuration Utility, available with LN, PC400, or from the CSI website.

DHCP Dynamic Host Configuration Protocol. A TCP/IP application protocol.

differential a sensor or measurement terminal wherein the analog voltage signal is carried on two leads. The phenomenon measured is proportional to the difference in voltage between the two leads.

digital numerically presented data.

Dim a CRBASIC command for declaring and dimensioning variables. Variables declared with DIM remain hidden during datalogger operation.

dimension to code for a variable array. DIM example(3) creates the three variables example(1), example(2), and example(3). DIM example(3,3) creates nine variables. DIM example (3,3,3) creates 27 variables.

DNS Domain Name System. A TCP/IP application protocol.

DTE data terminal equipment. While the term has much wider meaning, in the limited context of practical use with the CR1000, it denotes the pin configuration, gender and function of an RS-232 port. The RS-232 port on the CR1000 and on many 3rd party telecommunications devices, such as a digital cellular modems, are DCE. Attachment of a null-modem cable to a DCE device effectively converts it to a DTE device.

Earth Ground1) Using a grounding rod or another suitable device to tie a system or device to the earth at the datalogger site. Such a connection is used as a sink for electrical transients and possibly damaging potentials, such as those produced by a nearby lightning strike. 2) A reference potential for analog voltage measurements. Note that most objects have a "an electrical potential" and the potential at different places on the earth – even a few meters away – may be different. See ground loop.

engineering units units that explicitly describe phenomena, as opposed to the CR1000 measurement units of millivolts or counts.

ESD electrostatic discharge

ESS Environmental Sensor Station

excitation application of a precise voltage, usually to a resistive bridge circuit.

execution time time required to execute an instruction or group of instructions. If the execution time of a Program Table exceeds the table's Execution Interval, the Program Table will be executed less frequently than programmed (Section OV4.3.1 and 8.9).

expression a series of words, operators, or numbers that produce a value or result.

final storage that portion of memory allocated for storing Output Arrays. Final Storage may be viewed as a ring memory, with the newest data being written over the oldest. Data in Final Storage may be displayed using the Mode or sent to various peripherals (Sections 2, 3, and OV4.1).

FTP File Transfer Protocol. A TCP/IP application protocol.

full duplex definition

garbage the refuse of the data communication world. When data are sent or received incorrectly (and there are numerous reasons this happens) a string of invalid, meaningless characters (garbage) results. Two common causes are: 1) a baud rate mismatch and 2) synchronous data being sent to an asynchronous device and vice versa.

ground being or related to an electrical potential of 0 Volts.

half duplex definition

Handshake, Handshaking the exchange of predetermined information between two devices to assure each that it is connected to the other. When not used as a clock line, the CLK/HS (pin 7) line in the datalogger CS I/O port is primarily used to detect the presence or absence of peripherals.

Hello Exchange the process of verifying a node as a neighbor.

Hertz abbreviated Hz. Unit of frequency described as cycles or pulses per second.

HTML Hypertext Markup Language. A programming language used for the creation of web pages.

HTTP Hypertext Transfer Protocol. A TCP/IP application protocol.

INF infinite or undefined. A data word indicating the result of a function is infinite or undefined.

Initiate telecommunication is a name given to a processes by which the CR1000 initiates telecommunications with a PC running appropriate CSI datalogger support software. Also known as “Callback.”

input/output instructions used to initiate measurements and store the results in Input Storage or to set or read Control/Logic Ports.

integer a number written without a fractional or decimal component. 15 and 7956 are integers. 1.5 and 79.56 are not integers.

intermediate storage that portion of memory allocated for the storage of results of intermediate calculations necessary for operations such as averages or standard deviations. Intermediate storage is not accessible to the user.

IP Internet Protocol. A TCP/IP internet protocol.

IP Address A unique address for a device on the internet.

loop in a program, a series of instructions which are repeated a prescribed number of times, followed by an "end" instruction which exists the program from the loop.

loop counter increments by 1 with each pass through a loop.

manually initiated initiated by the user, usually with a keyboard, as opposed to occurring under program control.

milli the SI prefix denoting 1 / 1000s of a base SI unit.

Modbus communication protocol published by Modicon in 1979 for use in programmable logic controllers (PLCs).

modem/terminal any device which: 1) has the ability to raise the CR1000 ring line or be used with the SC32B to raise the ring line and put the CR1000 in the Telecommunications Command State and 2) has an asynchronous serial communication port which can be configured to communicate with the CR1000.

multi-meter an inexpensive and readily available device useful in troubleshooting data acquisition system faults.

mV the SI abbreviation for milliVolts.

NAN not a number. A data word indicating a measurement or processing error. Voltage overrange, SDI-12 sensor error, and undefined mathematical results can produce NAN.

Neighbor Device devices in a PakBus® network that can communicate directly with an individual device without being routed through an intermediate device. See also PakBus and Beacon Interval.

NIST National Institute of Standards and Technology

Node part of the description of a datalogger network when using LoggerNet. Each node represents a device that the communications server will dial through or communicate with individually. Nodes are organized as a hierarchy with all nodes accessed by the same device (parent node) entered as child nodes. A node can be both a parent and a child.

Null-modem a device, usually a multi-conductor cable, which converts an RS-232 port from DCE to DTE or from DTE to DCE.

Ohm the unit of resistance. Symbol is the Greek letter Omega (Ω). 1 Ω equals the ratio of 1 Volt divided by 1 Amp.

Ohms Law describes the relationship of current and resistance to voltage. Voltage equals the product of current and resistance (V = I*R).

on-line data transfer routine transfer of data to a peripheral left on-site. Transfer is controlled by the program entered in the datalogger.

output a loosely applied term. Denotes a) the information carrier generated by an electronic sensor, b) the transfer of data from variable storage to final storage, or c) the transfer of power from the CR1000 or a peripheral to another device.

output array a string of data points output to Final Storage. Output occurs when the data interval and data trigger are true. The data points which complete the Array are the result of the Output Processing Instructions which are executed while the Output Flag is set.

output interval the time interval between initiations of a particular data table record.

output processing instructions process data values and generate Output Arrays. Examples of Output Processing Instructions include Totalize, Maximize, Minimize, Average, etc. The data sources for these Instructions are values in Input Storage. The results of intermediate calculations are stored in Intermediate Storage. The ultimate destination of data generated by Output Processing Instructions is usually Final Storage but may be Input Storage for further processing. The transfer of processed summaries to Final Storage takes place when the Output Flag has been set by a Program Control Instruction.

PakBus is a proprietary telecommunications protocol similar in concept to internet protocol (IP). It has been developed by Campbell Scientific to facilitate communications between Campbell Scientific instrumentation.

parameter used in conjunction with CR1000 program Instructions, parameters are numbers or codes which are entered to specify exactly what a given instruction is to do. Once the instruction number has been entered in a Program Table, the CR1000 will prompt for the parameters by displaying the parameter number in the ID Field of the display.

period average a measurement technique utilizing a high-frequency digital clock to measure time differences between signal transitions. Sensors commonly measured with period average include vibrating wire transducers and water content reflectometers.

peripheral any device designed for use with, and requiring, the CR1000 (or another CSI datalogger) to operate.

Ping a software utility that attempts to contact another specific device in a network.

precision a measure of the repeatability of a measurement. See also Section A.2.1 Accuracy, Precision, and Resolution.

print device any device capable of receiving output over pin 6 (the PE line) in a receive-only mode. Printers, "dumb" terminals, and computers in a terminal mode fall in this category.

print peripheral see Print Device.

processing instructions these Instructions allow the user to further process input data values and return the result to Input Storage where it can be accessed for output processing. Arithmetic and transcendental functions are included in these Instructions.

program control instructions used to modify the sequence of execution of Instructions contained in Program Tables; also used to set or clear flags.

Poisson Ratio a ratio used in strain measurements equal to transverse strain divided by extension strain. $v = -(\varepsilon_{trans} / \varepsilon_{axial})$.

Public a CRBASIC command for declaring and dimensioning variables. Variables declared with PUBLIC can be monitored during datalogger operation.

pulse an electrical signal characterized by a sudden increase in voltage follow by a short plateau and a sudden voltage decrease.

regulator a device for conditioning an electrical power source. CSI regulators typically condition AC or DC voltages greater than 16 V to about 14 VDC.

resistance a feature of an electronic circuit that impedes or redirects the flow of electrons through the circuit.

resistor a device that provides a known quantity of resistance.

resolution a measure of the fineness of a measurement. See also Section A.2.1 Accuracy, Precision, and Resolution.

ring line (Pin 3) line pulled high by an external device to "awaken" the CR23X.

RMS root mean square or quadratic mean. A measure of the magnitude of wave or other varying quantities around zero.

RS-232 Recommended Standard 232. A loose standard defining how two computing devices can communicate with each other. The implementation of RS-232 in CSI dataloggers to PC communications is quite rigid, but transparent to most users. Implementation of RS-232 in CSI datalogger to RS-232 smart sensor communications is quite flexible.

sample rate the rate at which measurements are made. The measurement sample rate is primarily of interest when considering the effect of time skew (i.e., how close in time are a series of measurements). The maximum sample rates are the rates at which measurements are made when initiated by a single instruction with multiple repetitions.

scan (execution interval) is the time interval between initiating each execution of a given Scan interval. If the Execution Interval is evenly divisible into 24 hours (86,400 seconds), the Execution Interval will be synchronized with 24 hour time, so that the table is executed at midnight and every execution interval thereafter. The table will be executed for the first time at the first occurrence of the Execution Interval after compilation. If the Execution Interval does not divide evenly into 24 hours, execution will start on the first even second after compilation. See Section OV4.3.1 for information on the choice of an Execution Interval.

SDI-12 Serial/Digital Data Interface at 1200 bps. Communication protocol for transferring data between data recorders and sensors.

SDM Synchronous Device for Measurement. A processor based peripheral device or sensor that communicates with the CR1000 via hardwire over short distance using a proprietary CSI protocol.

Seebeck Effect induces microvolt level thermal electromotive forces (EMF) across junctions of dissimilar metals in the presence of temperature gradients. This is the principle behind thermocouple temperature measurement. It also causes small correctable voltage offsets in CR1000 measurement circuitry.

Send denotes the program send button in LoggerNet, PC400, and PC200W datalogger support software.

serial a loose term denoting output or a device that outputs an electronic series of alphanumeric characters.

SI Système Internationale The International System of Units.

signature a number which is a function of the data and the sequence of data in memory. It is derived using an algorithm which assures a 99.998% probability that if either the data or its sequence changes, the signature changes.

single-ended denotes a sensor or measurement terminal where in the analog voltage signal is carried on a single lead, which is measured with respect to ground.

skipped scans occur when the CR1000 program is too long for the scan interval. Skipped scans can cause errors in pulse measurements.

slow sequence is a usually slower secondary scan in the CR1000 CRBASIC program. The main scan has priority over a slow sequence.

SMTP Simple Mail Transfer Protocol. A TCP/IP application protocol.

SNP Snapshot File.

state whether a device is on or off.

string a datum consisting of alpha-numeric characters.

support software include PC200W, PC400, RTDAQ, LoggerNet

synchronous the transmission of data between a transmitting and receiving device occurs as a series of zeros and ones. For the data to be "read" correctly, the receiving device must begin reading at the proper point in the series. In synchronous communication, this coordination is accomplished by synchronizing the transmitting and receiving devices to a common clock signal (see Asynchronous).

task 1) grouping of CRBASIC program instructions by the CR1000. Tasks include measurement, SDM, and processing. Tasks are prioritized by a CR1000 operating in pipeline mode.

TCP/IP Transmission Control Protocol / Internet Protocol.

Telnet a software utility that attempts to contact and interrogate another specific device in a network.

throughput the throughput rate is the rate at which a measurement can be made, scaled to engineering units, and the reading stored in Final Storage. The CR23X has the ability to scan sensors at a rate exceeding the throughput rate (see SAMPLE RATE). The primary factor affecting throughput rate is the amount of processing specified by the user. In normal operation, all processing called for by an instruction must be completed before moving on the next instruction. The maximum throughput rate for a fast single-ended measurement is approximately 192 measurements per second (12 measurements, repeated 16 times per second). This rate is possible if the CR23X's self-calibration function is suspended (this is accomplished by entering Instruction 24 into Program Table 2 while leaving the Execution Interval 0 so Program Table 2 never executes).

When the self-calibration function is operating, the maximum throughput rate for a fast, single-ended measurement is 192 measurements per second (12 measurements, 16 times per second).

TLL Transistor – Transistor Logic. In the CR1000, TTL is a serial protocol using 0V and 5V as logic signal levels.

toggle to reverse the current power state.

USR: drive. A portion of CR1000 memory dedicated to the storage of image or other files.

UPS uninterruptible power supply. A UPS can be constructed for most datalogger applications using AC line power, an AC/AC or AC/DC wall adapter, a charge controller, and a rechargeable battery.

variable A packet of CR1000 memory given an alpha-numeric name, which holds a potentially changing number or string.

VAC Volts Alternating Current. Mains or grid power is high-level VAC, usually 110 VAC or 220 VAC at a fixed frequency of 50 Hz or 60 Hz. High-level VAC is used as a primary power source for Campbell Scientific power supplies. Do not connect high-level VAC directly to the CR1000. The CR1000 measures varying frequencies of low-level VAC in the range of ±20 VAC.

VDC Volts Direct Current. The CR1000 operates with a nominal 12 VDC power supply. It can supply nominal 12 VDC, regulated 5 VDC, and variable excitation in the ±2.5 VDC range. It measures analog voltage in the ±5.0 VDC range and pulse voltage in the ±20 VDC range.

volt meter an inexpensive and readily available device useful in troubleshooting data acquisition system faults.

Volts SI unit for electrical potential.

watch dog timer an error checking system that examines the processor state, software timers, and program related counters when the datalogger is running its program. If the processor has bombed or is neglecting standard system updates or if the counters are outside the limits, the watch dog timer resets the processor and program execution. Voltage surges and transients can cause the watch dog timer to reset the processor and program execution. When the watch dog timer resets the processor and program execution, an error count will be incremented in the watchdogtimer entry of the status table. A low number (1 to 10) of watch dog timer resets is of concern, but normally indicates the user should just monitor the situation. A large number (>10) of error accumulating over a short period of time should cause increasing alarm since it indicates a hardware or software problem may exist. When large numbers of watch dog timer resets occur, consult with a Campbell Scientific applications engineer.

weather tight describes an instrumentation enclosure impenetrable by common environmental conditions. During extraordinary weather events, however, seals on the enclosure may be breached.

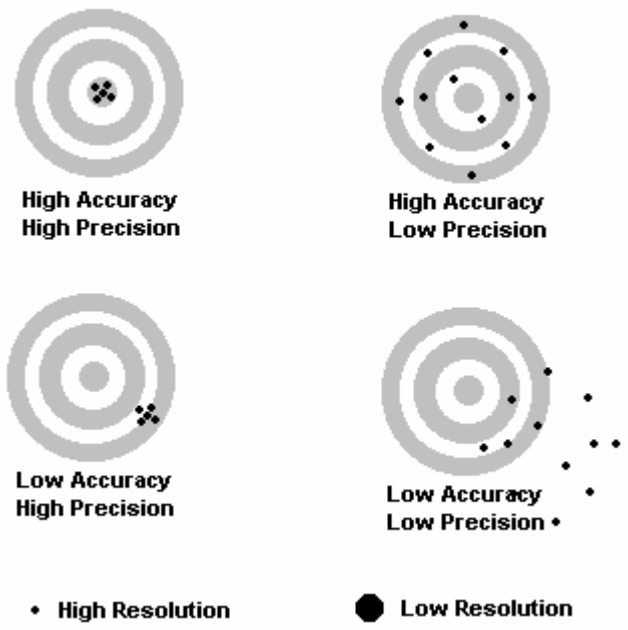
XML Extensible Markup Language.

A.2 Concepts

A.2.1 Accuracy, Precision, and Resolution

Three terms often confused are accuracy, precision, and resolution. **Accuracy** is a measure of the correctness of a single measurement, or the group of measurements in the aggregate. **Precision** is a measure of the repeatability of a group of measurements. **Resolution** is a measure of the fineness of a measurement. Together, the three define how well a data acquisition system performs. To understand how the three relate to each other, consider "target practice" as an analogy. The figure below shows four targets. The bull's eye

on each target represents the absolute correct measurement. Each shot represents an attempt to make the measurement. The diameter of the projectile represents resolution.



The objective of a data acquisition system should be high accuracy, high precision, and to produce data with resolution as high as appropriate for a given application.

Appendix B. Status Table and Settings

The CR1000 status table contains system operating status information accessible via CR1000KD keypad or PC software DevConfig, LoggerNet, or PC400. TABLE B-1 lists some of the more common uses of status table information. TABLE B-2 is a comprehensive list of status table variables with brief descriptions.

Status Table information is easily viewed by going to LoggerNet | Connect | Datalogger | View Station Status. However, be aware that information presented in View Station Status is not automatically updated. Click the refresh button each time an update is desired. Alternatively, use the Numeric displays of the connect screen to show critical values and have these update automatically, or use Devconfig, which polls the status table at regular intervals without use of a refresh button. Note that a lot of comms and other activity is needed to generate the Status Table, so if the CR1000 is very tight on time, just getting the Status Table itself repeatedly could push timing over the edge and cause skipped scans.

Through the continued development of the operating system, the status table has become quite large. A separate settings table has been introduced to slow the growth of the status table. To maintain backward compatibility, settings first included in the status table have been retained, but are also included in the settings editor.

TABLE B-1. Common Uses of the Status Table

Feature or Suspect Constituent	Status Field to Consult	Feature or Suspect Constituent	Status Field to Consult
Full Reset of CR1000	FullMemReset (Enter 98765)	PakBus	IsRouter
Program Execution	BuffDepth		
	MaxBuffDepth		
Operating System	OSVersion		PakBusNodes
	OSDate		CentralRouters
	OSSignature		Beacon
	WatchdogErrors		Verify
Power Supply	Battery		MaxPacketSize
	WatchdogErrors	CRBASIC Program	ProgSignature
	Low12VCount		Compile Results
	Low5VCount		ProgErrors
	StartUpCode		VarOutofBound
SRAM	LithiumBattery		SkippedScan
	MemorySize		SkippedSlowScan
	MemoryFree		PortStatus
Telecommunications	PakBusAddress		PortConfig
	Low5VCount	Measurements	ErrorCalib
	RS-232Handshaking	Data	SkippedRecord
	RS-232Timeout		DataFillDays
	CommActive		
	CommConfig		
	Baudrate		

TABLE B-2. Status / Setting Fields and Descriptions

Status Fieldname	Description	Variable Type	Default	Normal Range	User can change?	Info Type
Record NoNum	Record number for this set of data		_	_	_	
TimeStamp	Time the record was generated	Time	_	_	_	
OSVersion	Version of the Operating System	String	_	_	_	Status
OSDate	Date OS was released.	String	_	_	_	Status
OSSignature	Operating System Signature	Integer	_	_	_	Status
SerialNumber	CR1000 specific serial number. Stored in FLASH memory.	Integer	_	_	_	Status
RevBoard	Hardware revision number. Stored in FLASH memory.	Integer	_	_	_	Status
StationName[1]	Name of the CR1000. Stored in FLASH memory.	String	_		Yes	Config
PakBusAddress[2]	CR1000 PakBus address.	String	1	1 to 3999	Yes	Config PB
ProgName	Name of current (running) program.	String	_	_	_	Status
StartTime	Time the program began running.	Time	_	_	_	Status
RunSignature	Signature of the compiled binary data structure for the current program. Value is independent of comments added or non-functional changes to the program	Integer	_	_	_	Status
ProgSignature	Signature of the current running program file including comments.	Integer	_	_	_	Status
Battery	Current value of the battery voltage. Measurement is made in the background calibration.	Float	_	9.6-16 Volts	_	Measure
PanelTemp	Current wiring panel temperature. Measurement is made in the background calibration.	Float	_	_	_	Measure
WatchdogErrors[3]	Number of Watchdog errors that have occurred while running this program.	Integer	0	0	Can Reset = 0	Error
LithiumBattery[4]	Current voltage of the lithium battery. Measurement is updated in background calibration.	Float	_	2.7-3.6 Volts	_	Measure
Low12VCount[5]	Number of occurrences of the 12VLow signal being asserted. When this condition is detected, the CR1000 ceases measurements and goes into a low power mode until proper system voltage is restored.	Integer	0	0	Can Reset = 0	Error
Low5VCount	Number of occurrences of the 5VExtLow signal being asserted.	Integer	0	0	Can Reset = 0	Error
CompileResults	Contains error messages generated by compilation or during run time.	String	_	0	_	Error
StartUpCode6	A code variable that indicates how the system woke up from power off.	String	0	0	_	Status / Error
ProgErrors	The number of compile or runtime errors for the current program.	Integer	_	0	_	Error

Status Fieldname	Description	Variable Type	Default	Normal Range	User can change?	Info Type
VarOutOfBound[7]	Number of times an array was accessed out of bounds.	Integer	0	0	Can Reset = 0	Error
SkippedScan	Number of skipped scans that have occurred while running the current program instance.	Integer	0	_	Can Reset = 0	Error
SkippedSystemScan[8]	The number of scans skipped in the background calibration.	Integer array	0	_	Can Reset = 0	Error
SkippedSlowScan[9]	The number of scans skipped in a SlowSequence(s).	Interger array.	0	_	Can Reset = 0	Error
ErrorCalib[8]	The number of erroneous calibration values measured. The erroneous value is discarded (not included in the filter update).	Integer	0	0	_	Error
MemorySize	Total amount of SRAM (bytes) in this device.	_	_	2097152 (2M) 4194304 (4M)	_	Status
MemoryFree	Bytes of unallocated memory on the CPU (SRAM). All free memory may not be available for data tables. As memory is allocated and freed, holes of unallocated memory, which are unusable for final storage, may be created.	Integer	_	4 kbytes and higher	_	Status
CPUDriveFree	Bytes remaining on the CPU: drive. This drive resides in the serial FLASH and is always present. CRBASIC programs are normally stored here.	Integer				
USRDriveFree	Bytes remaining on the USR: drive. USR: drive is user-created and normally used to store .jpg and other files.	Integer			No	Mem
CommsMemFree	Array of two values. First value displays in sequence 1) comms memory free (+ number < 1000000), 2) main memory free (negative), 3) total of 1 and 2 (1,000,000 + total memory free. Second value is the number of small blocks available.	Integer array of 2	_	(1) 2000-15000	_	Status
FullMemReset	A value of 98765 written to this location will initiate a full memory reset. Full memory reset will reinitialize RAM disk, final storage, PakBus memory, and return parameters to defaults.	Integer	0	_	Enter 98765 to Reset	Config
DataTableName	Programmed name of data table(s). Each table has its own entry.	String array of number of data tables	_	_	_	Prog

Status Fieldname	Description	Variable Type	Default	Normal Range	User can change?	Info Type
SkippedRecord[10]	Variable array that posts how many records have been skipped for a given table. Each table has its own entry.	Integer array	0	0	Can Reset = 0	Error
DataRecordSize	Number of records in a table. Each table has its own entry in this array.	Integer array	_	_	_	
SecsPerRecord	Output interval for a given table. Each table has its own entry in this array.	Integer array	_	_	_	
DataFillDays	Time in days to fill a given table. Each table has its own entry in this array.	Integer array	_	_	_	
CardStatus	Contains a string with the most recent card status info.	String	_	_	_	Status
CardBytesFree[11]	Gives the number of bytes free on the CF card.	Integer	_	_	_	Status
MeasureOps	Number of task sequencer opcodes required to do all measurements in the system. This value includes the calibration opcodes (compile time) and the background calibration (system) slow sequence opcodes.	Integer	_	_	_	Status
MeasureTime	Time (µs) required to make the measurements in this scan, including integration and settling times. Processing occurs concurrent with this time so the sum of measure time and process time is not the time required in the scan instruction.	Integer	_	_	_	Status
ProcessTime	Processing time (µs) of the last scan. Time is measured from the end of the EndScan instruction (after the measurement event is set) to the beginning of the EndScan (before the wait for the measurement event begins) for the subsequent scan.	Integer	_	_	_	Status
MaxProcTime	Maximum time (µs) required to run through processing for the current scan. This value is reset when the scan exits.	Integer	_	_	Can Reset = 0	Status
BuffDepth	Shows the current Pipeline Mode processing buffer depth., which indicates how far processing is currently behind measurement.					
MaxBuffDepth	Gives the maximum number of buffers processing lagged measurement.					
LastSystemScan8	The last time the background calibration executed.	Integer array	_	_	_	Status
LastSlowScan9	The last time SlowSequence scan(s) executed.	Integer array	_	_	_	Status
SystemProcTime8,12	The time (µs) required to process the background calibration.	Integer array	_	_	_	Status

Status Fieldname	Description	Variable Type	Default	Normal Range	User can change?	Info Type
SlowProcTime[9,12]	The time (µs) required to process SlowSequence scan(s).	Integer array	_	_	_	Status
MaxSystemProcTime[8,13]	The maximum time (µs) required to process the background calibration.	Integer array	_	_	_	Status
MaxSlowProcTime[9,13]	The maximum time (µs) required to process SlowSequence scan(s).	Integer array	_	_	_	Status
PortStatus	Array of Boolean values posting the state of control ports. Values updated every 500 ms.	Boolean array of 8	False	True or False	Yes	Status
PortConfig	Array of strings explaining the use of the associated control port. Valid entries are: Input, Output, SDM, SDI-12, Tx, and Rx.	String array of 8	Input	Input or Output	_	Status
SW12Volts	Status of switched 12 V control port.	Boolean	False	True or False	Yes	Status
Security[14]	Array of the three security settings or codes. Will not be shown if security is enabled.	Integer array of 3	0, 0, 0	0 - 65535 (0 is no security)	Yes	Status
RS-232Power (RS-232 Always On)	Controls whether the RS-232 port will remain active even when communication is not taking place. If RS-232 handshaking is enabled (handshaking buffer size is non-zero), this setting must be set to yes	Boolean	0	0 or 1		
RS-232Handshaking (RS-232 Hardware Handshaking Buffer Size)	If non zero, hardware handshaking is active on the RS-232 port. This setting specifies the maximum packet size sent between checking for CTS.	Integer	0			
RS-232Timeout (RS-232 Hardware Handshaking Timeout)	For RS-232 hardware handshaking, this specifies in tens of ms the timeout that the datalogger will wait between packets if CTS is not asserted.	Integer	0			
CommActive15	Array of Boolean values telling if communications is currently active on the corresponding port. Aliased to CommActiveRS-232, CommActiveME, CommActiveCOM310, CommActiveSDC7, CommActiveSDC8, CommActiveSDC10 CommActiveSDC11 CommActiveCOM1, CommActiveCOM2, CommActiveCOM3, CommActiveCOM4	Boolean array of 9	False, except for the active COM	True or False	_	Status

Status Fieldname	Description	Variable Type	Default	Normal Range	User can change?	Info Type
CommConfig	Array of values telling the configuration of comm ports. Aliased to CommConfigRS-232, CommConfigME, CommConfigCOM310, CommConfigSDC7, CommConfigSDC8, CommConfigSDC10 CommConfigSDC11 CommConfigCOM1, CommConfigCOM2, CommConfigCOM3, CommConfigCOM4	Integer array of 9	RS-232-SDC8 = 4 COM1-4 = 0	0 or 4	_	Config
Baudrate[16]	Array of baudrates for comms. Aliased to: BaudrateRS-232, BaudrateME, BaudrateSDC BaudrateCOM1 BaudrateCOM2 BaudrateCOM3 BaudrateCOM4	Integer array of 9	RS-232=-115200 ME-SDC8 = 115200 COM1-4 = 0	1200, 2400, 4800, 9600, 19.2k, 38.4k, 57.6k, 115.2k	Yes, can also use SerialOut instruction to setup.	Config
IsRouter	Is the CR1000 configured to act as router	Boolean	False	0 or 1	Yes	Config PB
PakBusNodes	Number of nodes (approximately) that will exist in the PakBus network. This value is used to determine how much memory to allocate for networking.	Integer	50	>=50	Yes	Config PB
CentralRouters(1) - (8)[17]	Array of (8) PakBus addresses for central routers.	Integer array of 8	0	_	Yes	Config PB
Beacon	Array of Beacon intervals (in seconds) for comms ports. Aliased to BeaconRS-232, BeaconME, BeaconSDC7, BeaconSDC8, BeaconSDC10, BeaconSDC11, BeaconCOM1, BeaconCOM2, BeaconCOM3, BeaconCOM4	Integer array of 9	0	0 - approx. 65,500	Yes	Config PB

Status Fieldname	Description	Variable Type	Default	Normal Range	User can change?	Info Type
Verify	Array of verify intervals (in seconds) for com ports. Aliased to VerifyRS-232, VerifyME, VerifySDC7, VerifySDC8, VerifySDC10, VerifySDC11, VerifyCOM1, VerifyCOM2, VerifyCOM3, VerifyCOM4	Integer array of 9	0	0 - approx. 65,500	_	Status
MaxPacketSize	Maximum number of bytes per data collection packet.	_	1000	_	_	
USRDriveSize	Configures the USR: drive. If 0, the drive is removed. If non-zero, the drive is created.	Integer	0	8192 Min	Yes	Mem
IPInfo	Indicates current parameters for IP connection.	String				
IPAddressEth	Specifies the IP address for the Etnernet interface. If specified as zero, the address, net mask, and gateway will be configured automatically using DHCP.	Entered as String / Stored as 4 byte	0.0.0.0	All valid IP addresses	Yes	
IPGateway	Specifies the address of the IP router to which the CR1000 will forward all non-local IP packets for which it has no route.	Entered as String / Stored as 4 byte	0.0.0.0	All valid IP addresses	Yes	
TCPPort	Specifies the port used for ethernet socket communications.	Long	6785	0 - 65535	Yes	
pppInterface	Controls which datalogger port PPP service will be configured to use. Warning: If this value is set to CS I/O ME, do not attach any other devices to the CS I/O port.	Integer	0 (Inactive)			
pppIPAddr	Specifies the IP address that will be used for the PPP interface if that interface is active (the PPP Interface setting needs to be set to something other than Inactive).	String	0.0.0.0			
pppUsername	Specifies the user name that will be used to log in to the PPP server.	String	_			
pppPassword	Specifies the password that will be used to log in to the PPP server.	String	_			

Status Fieldname	Description	Variable Type	Default	Normal Range	User can change?	Info Type
pppDial	Specifies the dial string that follows ATD (e.g., #777 for Redwing CDMA) or a list of AT commands separated by ';' (e.g., ATV1; AT+CGATT=0;ATD*99***1#), that will be used to initialize and dial through a modem before a PPP connection is attempted. A blank string means that dialling is not necessary before a PPP connection is established.	String	_			
pppDialResponse	Specifies the response expected after dialing a modem before a PPP connection can be established.	String	connect	_	Yes	
Messages	Contains a string of messages that can be entered by the user.	String	_		Yes	
CalGain[18]	Calibration table of Gain values. Each integration / range combination has a gain associated with it. These numbers are updated by the background slow sequence if needed in the program.	Float array of 18	_	.	_	Calib
CalSeOffSet[18]	Calibration table of single ended offset values. Each integration / range combination has a single ended offset associated with it. These numbers are updated by the background slow sequence if needed in the program.	Integer array of 18	_	close to 0	_	Calib
CalDiffOffset[18]	Calibration table of differential offset values. Each integration / range combination has a differential offset associated with it. These numbers are updated by the background slow sequence if needed in the program.	Integer array of 18	_	close to 0	_	Calib

1 The StationName instruction can also be used in a program to write to this field. This is not the name used in the TOA data file header.

2 Pak Bus Addresses 1 to 4094 are valid. Addresses >= 4000 are generally used for a PC by PC200, PC400, or LoggerNet.

3 Watchdog errors are automatically reset upon compiling a new program.

4 Replace the lithium battery if <2.7V. See section 1.10.2 for replacement directions.

5 The 12V low comparator has some variation, but typically triggers at about 9.0 volts. The minimum specified input voltage of 9.6 V will not cause a 12 V low, but a 12 V low condition will stop the program execution before the CR1000 will give bad measurements due to low of supply voltage.

6 Currently not being used (12/1/2004)

7 The Variable out of Bounds error occurs when a program tries to write to an array variable outside of its declared size. It is a programming error that causes this, and should not be ignored. When the datalogger detects that a write outside of an array is being attempted it does not perform the write and increments the VOOB in the status table. The compiler and pre-compiler can only catch things like reps too large for an array etc. If an array is used in a loop or expression the pre-compiler does not (in most cases cannot) check to see if an array will be accessed out of bounds (i.e. accessing an array with a variable index such as arr(index) = arr(index-1), where index is a variable).

8 The background calibration runs automatically in a hidden SlowSequence scan (Section 3.8.).

9 If no user entered SlowSequence scans are programmed, this variable does not appear. If multiple user entered SlowSequence scans programmed, this variable becomes an array with a value for each scan.

10 The order of tables is the order in which they are declared.

11 Card bytes free is shown = -1 when no card is present.

12 Displays a large number until a SlowSequence scan runs.

13 Displays 0 until a SlowSequence scan runs.

14 Security can be changed via DeviceConfig, CR1000KD, PBGraph, StatusTable, and SetSecurity instruction. Shows -1 if security code has not been given / deactivated.

15 When the SerialOpen instruction is used CommsConfig is loaded with the format parameter of that instruction. Currently (11/2004), the only formatting option available is 0 = No error checking. PakBus communication can occur concurrently on the same port If the port was previously opened (in the case of the CP UARTS) for PakBus, or if the port is always opened (CS-9pin, and RS-232) for PakBus the code will be 4.

16 The value shown is the initial baud rate the CR1000 will use. A negative value will allow the CR1000 to auto baud but will dictate at which baud rate to begin.

17 A list of up to eight PB addresses for routers that can act as Central Routers. See CSI DevConfig (Device Configuration) software for more information.

18 (1) 5000 mV range 250 uS integration,
(2) 2500 mV range 250 uS integration,
(3) 250 mV range 250 uS integration,
(4) 25 mV range 250 uS integration,
(5) 7.5 mV range 250 uS integration,
(6) 2.5 mV range 250 uS integration,
(7) 5000 mV range 1/60 Hz integration,
(8) 2500 mV range 1/60 Hz integration,
(9) 250 mV range 1/60 Hz integration,
(10) 25 mV range 1/60 Hz integration,
(11) 7.5 mV range 1/60 Hz integration,
(12) 2.5 mV range 1/60 Hz integration,
(13) 5000 mV range 1/50 Hz integration,

(14) 2500 mV range 1/50 Hz integration,
(15) 250 mV range 1/50 Hz integration,
(16) 25 mV range 1/50 Hz integration,
(17) 7.5 mV range 1/50 Hz integration,
(18) 2.5 mV range 1/50 Hz integration

TABLE B-3. Settings

Settings are accessed through Campbell Scientific's Device Confituration Utility (DevConfig) for direct serial connection, or through PakBusGraph for most telecommunications options.

Setting	Description	Default Entry
OS Version	Specifies the version of the operating system currently in the datalogger.	
Serial Number	Specifies the datalogger serial number assigned by the factory when the datalogger was calibrated.	
Station Name	Specifies a name assigned to this station.	
PakBus Address	This setting specifies the PakBus address for this device. The value for this setting must be chosen such that the address of the device will be unique in the scope of the datalogger network. Duplication of PakBus addresses in two or more devices can lead to failures and unpredictable behavior in the PakBus network. The following values are the default addresses of various types of software and devices and should probably be avoided: LoggerNet 4094 PC400 4093 PC200 4092 Visual Weather 4091 RTDAQ 4090 DevConfig 4089 NL100 678 All other devices 1	1
Security Level 1	Specifies Level 1 Security. Zero disables all security. Range: 0 to 65535	0
Security Level 2	Specifies Level 2 Security. Zero disables levels 2 & 3. Range: 0 to 65535	0
Security Level 3	Specifies Level 3 Security. Zero disables level 3. Range: 0 to 65535	0
Is Router	This setting controls whether the datalogger is configured as a router or as a leaf node. If the value of this setting is non-zero, the datalogger will be configured to act as a PakBus router. That is, it will be able to forward PakBus packets from one port to another. In order to perform its routing duties, a datalogger configured as a router will maintain its own list of neighbors and send this list to other routers in the PakBus network. It will also obtain and receive neighbor lists from other routers. If the value of this setting is zero, the datalogger will be configured to act as a leaf node. In this configuration, the datalogger will not be able to forward packets from one port to another and it will not maintain a list of neighbors. Under this configuration,	0

	the datalogger can still communicate with other dataloggers and wireless sensors. It cannot, however, be used as a means of reaching those other dataloggers.	
PakBus Nodes Allocation	Specifies the amount of memory that the datalogger allocates for maintaining PakBus routing information. This value represents roughly the maximum number of PakBus nodes that the datalogger will be able to track in its routing tables.	50
Route Filters	This setting configures the datalogger to restrict routing or processing of some PakBus message types so that a "state changing" message can only be processed or forwarded by this datalogger if the source address of that message is in one of the source ranges and the destination address of that message is in the corresponding destination range. If no ranges are specified (the default), the datalogger will not apply any routing restrictions. "State changing" message types include set variable, table reset, file control send file, set settings, and revert settings. For example, if this setting was set to a value of (4094, 4094, 1, 10), the datalogger would only process or forward "state changing" messages that originated from address 4094 and were destined to an address in the range between one and ten. This is displayed and parsed using the following formal syntax: route-filters := { "(" source-begin "," source-end "," dest-begin "," dest-end ")" }. source-begin := uint2. ; 1 < source-begin <= 4094 source-end := uint2. ; source-begin <= source-end <= 4094 dest-begin := uint2. ; 1 < dest-begin <= 4094 dest-end := uint2. ; dest-begin <= dest-end <= 4094	
Baud Rate RS232 ME SDC7 SDC8 SDC10 SDC11 COM1 COM2 COM3 COM4	This setting governs the baud rate that the datalogger will use for a given port in order to support PakBus or PPP communications. For some ports (COM1 through COM4), this setting also controls whether the port will be enabled for PakBus or PPP communications. Some ports (RS-232 and CS I/O ME) support auto-baud synchronisation while the other ports support only fixed baud. With auto-baud synchronisation, the datalogger will attempt to match the baud rate to the rate used by another device based upon the receipt of serial framing errors and invalid packets.	115200 Auto 115200 Auto 115200 Fixed 0 0 0 0
Beacon Interval RS232 ME SDC7 SDC8 SDC10 SDC11 COM1 COM2	This setting, in units of seconds, governs the rate at which the datalogger will broadcast PakBus messages on the associated port in order to discover any new PakBus neighboring nodes. It will also govern the default verification interval if the value of the Verify Interval XXX setting for the associated port is zero.	0

COM3 COM4		
Verify Interval RS232 ME SDC7 SDC8 SDC10 SDC11 COM1 COM2 COM3 COM4	This setting specifies the interval, in units of seconds, that will be reported as the link verification interval in the PakBus hello transaction messages. It will indirectly govern the rate at which the datalogger will attempt to start a hello transaction with a neighbor if no other communication has taken place within the interval.	0
Neighbors Allowed RS232 ME SDC7 SDC8 SDC10 SDC11 COM1 COM2 COM3 COM4	This setting specifies, for a given port, the explicit list of PakBus node addresses that the datalogger will accept as neighbors. If the list is empty (the default value) any node will be accepted as a neighbor. This setting will not effect the acceptance of a neighbor if that neighbor's address is greater than 3999. The formal syntax for this setting follows: neighbor := { "(" range-begin "," range-end ")" }. range-begin := pakbus-address. ; range-end := pakbus-address. pakbus-address := number. ; 0 < number < 4000	
Central Routers	This setting specifies a list of up to eight PakBus addresses for routers that are able to work as Central Routers. By specifying a non-empty list for this setting, the datalogger will be configured as a Branch Router meaning that it will not be required to keep track of neighbors of any routers except those in its own branch. Configured in this fashion, the datalogger will ignore any neighbor lists received from addresses in the central routers setting and will forward any messages that it receives to the nearest default router if it does not have the destination address for those messages in its routing table. Each entry in this list is expected to be formatted with a comma separating individual values.	
Routes	This read-only setting lists the routes in the case of a router or the router neighbors in the case of a leaf node that were known to the datalogger at the time that the setting was read. Each route known to the logger will be represented by the following four components separated by commas and enclosed in parentheses. The description of each component follows: Port Number Specifies a numeric code for the port that the router will use. Will correspond with one of the following: 1. RS-232 2. CS I/O Modem Enable 3. CS I/O COM310 4. CS I/O SDC7	(1, 4089, 4089, 1000)

	5. CS I/O SDC8 6. COM1 7. COM2 8. COM3 9. COM4 10. PakBus/TCP Connection If the value ofthe port number is 100 or greater, the connection is made through PakBus/TCP either by the datalogger executing a TCPOpen() instruction or by having a connection made to the PakBus/TCP logger service. Via Neighbor Address Specifies the address of the neighbor/router that will be used to send messages for this route. If the route is for a neighbor, this value will be the same as the address. PakBus Address For a router, specifies the address that the route will reach. In the case of a leaf node, this will be 0. Response Time For a router, specifies the amount of time (in milli-seconds) that will be allowed for the route. For a leaf node, this will be 0.	
USR: Drive Size	Specifies the size in bytes allocated for the "USR:" ram disk drive.	0
Files Manager	This setting specifies the number of files of a designated type that will be saved when received from a specified node. There can be up to 4 such settings. The files will be renamed by using the specified file name optionally altered by a serial number inserted before the file type. This serial number is used by the datalogger to know which file to delete after the serial number exceeds the specified number of files to retain. If the number of files is 0, then the serial number is not inserted. A special node id of 3210 can be used if the files will be sent via FTP protocol or 3211 if the files will be written via CRBasic. Note that this setting will operate only on files whose name is not a null string. Example: (129,CPU:NorthWest.JPG,2) (130,CRD:SouthEast.JPG,20) (130,CPU:Message.TXT,0) In the example above, *.JPG files from node 129 are named CPU:NorthWestnnn.JPG and 2 files are retained, and *.JPG files from node 130 are named CRD:SouthEastnnn.JPG, while 20 files are retained. The nnn serial number starts at 1 and will advance beyond 9 digits. In this example, all *.TXT files from node 130 will be stored with the name CPU:Message.Txt, with no serial number inserted.	

	FilesManager := { "(" pakbus-address "," name-prefix "," number-files ")" }. pakbus-address := number. ; 0 < number < 4095 name-prefix := string. number_files := number. ; 0 <= number < 10000000	
Include File Name	This setting specifies the name of a file to be implicitly included at the end of the current CRBasic program or can be run as the default program. This setting must specify both the name of the file to run as well as on the device (CPU:, USR:, or CRD:) on which the file is located. The extension of the file must also be valid for a datalogger program (.dld, .cr1 (CR1000), .cr3 (CR3000), or .cr8 (CR800 Series)). Consider the following example: CPU:pakbus_broker.dld The rules used by the datalogger when it starts are as follows: 1. If the logger is starting from power-up, any file that is marked as the run on power-up program will be the "current program". Otherwise, any file that is marked as run now will be selected. This behaviour has always been present and is not effected by this setting. 2. If there is a file specified by this setting, it will be incorporated into the program selected above. 3. If there is no current file selected or if the current file cannot be compiled, the datalogger will run the program given by this setting as the current program. 4. If the program run by this setting cannot be run or if no program is specified, the datalogger will attempt to run the program named default.cr1 on its CPU: drive. 5. If there is no default.cr1 file or if that file cannot be compiled, the datalogger will not run any program. The datalogger will now allow a SlowSequence statement to take the place of the BeginProg statement. This feature allows the specified file to act both as an include file and as the default program. The formal syntax for this setting follows: include-setting := device-name ":" file-name "." file-extension. device-name := "CPU" | "USR" | "CRD".	

	File-extension := "dld" | "cr1" | "cr3" | "cr8".	
Max Packet Size	Specifies the maximum number of bytes per data collection packet.	1000
RS232 Always On	Controls whether the RS-232 port will remain active even when communication is not taking place. Note that if RS232 handshaking is enabled (handshaking buffer size is non-zero), that this setting must be set to yes	No
RS232 Hardware Handshaking Buffer Size	If non zero, hardware handshaking is active on the RS232 port. This setting specifies the maximum packet size sent between checking for CTS.	0
RS232 Hardware Handshaking Timeout	For RS232 hardware handshaking, this specifies in tens of msecs the timeout that the datalogger will wait between packets if CTS is not asserted.	0
Ethernet IP Address	Specifies the IP address for the Ethernet Interface. If specified as zero, the address, net mask, and gateway will be configured automatically using DHCP.	0.0.0.0
Ethernet Subnet Mask	Specifies the subnet mask for the Ethernet interface.	255.255.255.0
Default Gateway	Specifies the address of the IP router to which the datalogger will forward all non-local IP packets for which it has no route.	0.0.0.0
Name Servers	This setting specifies the addresses of up to two domain name servers that the datalogger can use to resolve domain names to IP addresses. Note that if DHCP is used to resolve IP information, the addresses obtained via DHCP will be appended to this list.	0.0.0.0 0.0.0.0
PPP Interface	This setting controls which datalogger port PPP service will be configured to use. Warning: If this value is set to CS I/O ME, you must not attach any other devices to the CS I/O port	Inactive
PPP IP Address	Specifies the IP address that will be used for the PPP interface if that interface is active (the PPP Interface setting needs to be set to something other than Inactive). The syntax for this setting is nnn.nnn.nnn.nnn. A value of 0.0.0.0 or an empty string will indicate that DHCP must be used to resolve this address as well as the subnet mask.	0.0.0.0
Reserved	This field reserved. Do not edit.	
PPP User Name	Specifies the user name that will be used to log in to the PPP server.	
PPP Password	Specifies the password that will be used to log in to the PPP server when the PPP Interface setting is set to one of the client selections. Also specifies the password that must be provided by the PPP client when the PPP Interface setting is set to one of the server selections.	
PPP Dial	Specifies the dial string that would follow ATD (e.g., #777 for Redwing CDMA) or a list of AT commands seperated by ';' (e.g., ATV1;AT+CGATT=0;ATD*99***1#) that will be used to initialise and dial through a modem before a PPP connection is attempted. A blank string indicates that no dialing will take place and will configure the	

	datalogger to "listen" for PPP connections (basically to act as a server). A value of "PPP" will indicate to the datalogger that no modem dialing should take place but that it should PPP communication.	
PPP Dial Response	Specifies the response expected after dialing a modem before a PPP connection can be established.	CONNECT
PakBus/TCP Server Port	This setting specifies the TCP service port for PakBus communications with the datalogger. Unless firewall issues exist, this setting probably does not need to be changed from its default value. This setting will only be effective if there is an EtherNet interface installed via the NL115 or if the PPP service is enabled.	6785
PakBus/TCP Client Connections	This setting specifies outgoing PakBus/TCP connections that the datalogger should maintain. Up to four addresses can be specified. An example specifying two connections follows: (192.168.4.203, 6785) (JOHN_DOE.server.com, 6785) The following is a formal syntax of the setting: TCP Connections := 4{ address_pair }. address_pair := "(" address "," tcp-port ")". address := domain-name | ip-address.	
PakBus/TCP Password	This setting specifies a password that, if empty, allows the CR1000 to authenticate any incoming or outgoing PakBus/TCP connection.	
HTTP Server Port	Configures the TCP port on which the HTTP (web server) service will be offered. Generally the default value is sufficient unless a different value needs to be specified in order to accomodate port mapping rules in a network address translation firewall.	80
FTP Server Port	Configures the TCP port on which the FTP service will be offered. Generally the default value is sufficient unless a different value needs to be specified in order to accomodate port mapping rules in a network address translation firewall.	21
FTP User Name	Specifies the user name that will be used to log in to the FTP server. An empty string (the default) inactivates the FTP server.	anonymous
FTP Password	Specifies the password that will be used to log in to the FTP server.	*
Ping Enabled	Set to one if the ICMP ping service should be enabled. This service is disabled by default.	1
FTP Enabled	Set to one if the FTP service should be enabled. This service is disabled by default	1
Telnet Enabled	Set to one if the Telnet service should be enabled. This service is disabled by default.	1
HTTP Enabled	Set to one if the HTTP (web server) service should be enabled. This service is disabled by default.	1
IP Trace COM Port	This setting specifies whether, and on what port TCP/IP trace information will be sent. The type of	Inactive

	information that will be sent is controlled by the IP Trace Code setting.	
IP Trace Code	This setting controls what type of information will be sent on the port specified by IP Trace Port and via Telnet. Useful values are: 0 Trace is inactive 1 Startup and watchdog only 2 Verbose PPP 4 Print general informational messages 16 Display net interface error messages 256 Transport protocol (UDP/TCP/RVD) trace 8192 FTP trace 65535 Trace everything	0
TCP/IP Info	Currently DHCP assigned addresses, Domain Name Servers, etc.	MAC: 00d02c042ccb eth IP: 192.168.1.99 eth mask: 255.255.240.0 eth gw: 192.168.2.19 dns svr1: 192.168.2.25 dns svr2: 192.168.2.16

Appendix C. Serial Port Pin Outs

C.1 CS I/O Communications Port

Pin configuration for the CR1000 CS I/O port is listed in TABLE C-1.

TABLE C-1. CS I/O Pin Description

ABR = Abbreviation for the function name.
PIN = Pin number.
O = Signal Out of the CR1000 to a peripheral.
I = Signal Into the CR1000 from a peripheral.

PIN	ABR	I/O	Description
1	5 V	O	5V: Sources 5 VDC, used to power peripherals.
2	SG		Signal Ground: Provides a power return for pin 1 (5V), and is used as a reference for voltage levels.
3	RING	I	Ring: Raised by a peripheral to put the CR1000 in the telecommunications mode.
4	RXD	I	Receive Data: Serial data transmitted by a peripheral are received on pin 4.
5	ME	O	Modem Enable: Raised when the CR1000 determines that a modem raised the ring line.
6	SDE	O	Synchronous Device Enable: Used to address Synchronous Devices (SDs), and can be used as an enable line for printers.
7	CLK/HS	I/O	Clock/Handshake: Used with the SDE and TXD lines to address and transfer data to SDs. When not used as a clock, pin 7 can be used as a handshake line (during printer output, high enables, low disables).
8	+12 VDC		
9	TXD	O	Transmit Data: Serial data are transmitted from the CR1000 to peripherals on pin 9; logic low marking (0V) logic high spacing (5V) standard asynchronous ASCII, 8 data bits, no parity, 1 start bit, 1 stop bit, 300, 1200, 2400, 4800, 9600, 19,200, 38,400, 115,200 baud (user selectable).

C.2 RS-232 Communications Port

C.2.1 Pin-Out

Pin configuration for the CR1000 RS-232 9-pin port is listed in TABLE C-2. Information for using a null modem with the RS-232 9-pin port is given in TABLE C-3.

The Datalogger RS-232 port can function as either a DCE (Data Communication Equipment) or DTE (Data Terminal Equipment) device. For the Datalogger RS-232 port to function as a DTE device, a null modem cable is required. The most common use of the Datalogger's RS-232 port is a connection to a computer DTE device. A standard DB9-to-DB9 cable can connect the computer DTE device to the Datalogger DCE device. The following table describes the Datalogger's RS-232 pin function with standard DCE naming notation. Note that pins 1, 4, 6 and 9 function differently than a standard DCE device, this is to accommodate a connection to a modem or other DCE device via a null modem.

TABLE C-2. Datalogger RS-232 Pin-Out

PIN = Pin number

O = Signal Out of the CR1000 to a RS-232 device

I = Signal Into the CR1000 from a RS-232 device

X = Signal has no connection (floating)

PIN	DCE Function	Logger Function	I/O	Description
1	DCD	DTR (tied to pin 6)	O*	Data Terminal Ready
2	TXD	TXD	O	Asynchronous data Transmit
3	RXD	RXD	I	Asynchronous data Receive
4	DTR	N/A	X*	Not Connected
5	GND	GND	GND	Ground
6	DSR	DTR	O*	Data Terminal Ready
7	CTS	CTS	I	Clear to send
8	RTS	RTS	O	Request to send
9	RI	RI	I*	Ring

* Different pin function compared to a standard DCE device. These pins will accommodate a connection to modem or other DCE devices via a null modem cable.

C.2.2 Power States

The RS-232 port is powered under the following conditions: 1) when the setting RS232Power is set or 2) when the SerialOpen for COMRS232 is used in the program. These conditions leave the RS-232 port on with no timeout. If SerialClose is used after SerialOpen then the port is powered down and left in a sleep mode waiting for characters to come in.

Under normal operation, the port is powered down waiting for input. Upon receiving input there is a 40 second software timeout before shutting down. The 40 second timeout is generally circumvented when communicating with LoggerNet because it sends information as part of the protocol that lets the CR1000 know it can shut down the port.

When in sleep mode, hardware is configured to detect activity and wake up. Sleep mode has the penalty of losing the first character of the incoming data stream. PakBus takes this into consideration in the "ring packets" that are preceded with extra sync bytes at the start of the packet. SerialOpen leaves the interface powered up so no incoming bytes will be lost.

When the logger has data to send via the RS-232 port, if the data are not a response to a received packet, such as sending a beacon, then it will power up the interface, send the data, and return to sleep mode with no 40 second timeout.

TABLE C-3. Standard Null Modem Cable or Adapter Pin Connections*

DB9		***DB9***
pin 1 & 6	----------	pin 4
pin 2	----------	pin 3
pin 3	----------	pin 2
pin 4	----------	pin 1 & pin 6
pin 5	----------	pin 5
pin 7	----------	pin 8
pin 8	----------	pin 7
pin 9	XXXXX	pin 9 (Most null modems have NO connection)

* If the null modem cable does not connect pin 9 to pin 9, then the modem will need to be configured to output a RING (or other characters previous to the DTR being asserted) on the modem's TX line to wake the datalogger and activate the DTR line or enable the modem.

Appendix D. ASCII / ANSI Table

American Standard Code for Information Interchange (ASCII) / American National Standards Institute (ANSI)
Decimal and Hexadecimal Codes and Characters

Dec	Hex	Keypad Char	LoggerNet Char	HyperTerminal Char	Dec	Hex	Keypad Char	LoggerNet Char	HyperTerminal Char
0	0		NULL	NULL	128	80		€	Ç
1	1			☺	129	81			ü
2	2			☻	130	82		‚	é
3	3			♥	131	83		*ƒ*	â
4	4			♦	132	84		„	ä
5	5			♣	133	85		…	à
6	6			♠	134	86		†	å
7	7			•	135	87		‡	ç
8	8			◘	136	88		ˆ	ê
9	9			ht	137	89		‰	ë
10	a		lf	lf	138	8a		Š	è
11	b			vt	139	8b		‹	ï
12	c			ff	140	8c		Œ	î
13	d		cr	cr	141	8d			ì
14	e			♫	142	8e		Ž	Ä
15	f			☼	143	8f			Å
16	10			►	144	90			É
17	11			◄	145	91		‘	æ
18	12			↕	146	92		’	Æ
19	13			‼	147	93		“	ô
20	14			¶	148	94		”	ö
21	15			§	149	95		•	ò
22	16			▬	150	96		–	û
23	17			↨	151	97		—	ù
24	18			↑	152	98		˜	ÿ
25	19			↓	153	99		™	Ö
26	1a			→	154	9a		š	Ü
27	1b				155	9b		›	¢
28	1c			∟	156	9c		œ	£
29	1d			↔	157	9d			¥
30	1e			▲	158	9e		ž	Pt
31	1f			▼	159	9f		Ÿ	*ƒ*
32	20		SP	SP	160	a0			á

Dec	Hex	Keypad Char	LoggerNet Char	HyperTerminal Char
33	21	!	!	!
34	22	"	"	"
35	23	#	#	#
36	24	$	$	$
37	25	%	%	%
38	26	&	&	&
39	27	'	'	'
40	28	(	(	(
41	29	)	)	)
42	2a	*	*	*
43	2b	+	+	+
44	2c	,	,	,
45	2d	-	-	-
46	2e	.	.	.
47	2f	/	/	/
48	30	0	0	0
49	31	1	1	1
50	32	2	2	2
51	33	3	3	3
52	34	4	4	4
53	35	5	5	5
54	36	6	6	6
55	37	7	7	7
56	38	8	8	8
57	39	9	9	9
58	3a	:	:	:
59	3b	;	;	;
60	3c	<	<	<
61	3d	=	=	=
62	3e	>	>	>
63	3f	?	?	?
64	40	@	@	@
65	41	A	A	A
66	42	B	B	B
67	43	C	C	C
68	44	D	D	D
69	45	E	E	E
70	46	F	F	F
71	47	G	G	G
72	48	H	H	H
73	49	I	I	I

Dec	Hex	Keypad Char	LoggerNet Char	HyperTerminal Char
161	a1		¡	í
162	a2		¢	ó
163	a3		£	ú
164	a4		¤	ñ
165	a5		¥	Ñ
166	a6		¦	ª
167	a7		§	º
168	a8		¨	¿
169	a9		©	⌐
170	aa		ª	¬
171	ab		«	½
172	ac		¬	¼
173	ad			¡
174	ae		®	«
175	af		¯	»
176	b0		°	░
177	b1		±	▒
178	b2		²	▓
179	b3		³	│
180	b4		´	┤
181	b5		µ	╡
182	b6		¶	╢
183	b7		·	╖
184	b8		¸	╕
185	b9		¹	╣
186	ba		º	║
187	bb		»	╗
188	bc		¼	╝
189	bd		½	╜
190	be		¾	╛
191	bf		¿	┐
192	c0		À	└
193	c1		Á	┴
194	c2		Â	┬
195	c3		Ã	├
196	c4		Ä	─
197	c5		Å	┼
198	c6		Æ	╞
199	c7		Ç	╟
200	c8		È	╚
201	c9		É	╔

Dec	Hex	Keypad Char	LoggerNet Char	HyperTerminal Char	Dec	Hex	Keypad Char	LoggerNet Char	HyperTerminal Char
74	4a	J	J	J	202	ca		Ê	╩
75	4b	K	K	K	203	cb		Ë	╦
76	4c	L	L	L	204	cc		Ì	╠
77	4d	M	M	M	205	cd		Í	═
78	4e	N	N	N	206	ce		Î	╬
79	4f	O	O	O	207	cf		Ï	╧
80	50	P	P	P	208	d0		Ð	╨
81	51	Q	Q	Q	209	d1		Ñ	╤
82	52	R	R	R	210	d2		Ò	╥
83	53	S	S	S	211	d3		Ó	╙
84	54	T	T	T	212	d4		Ô	╘
85	55	U	U	U	213	d5		Õ	╒
86	56	V	V	V	214	d6		Ö	╓
87	57	W	W	W	215	d7		×	╫
88	58	X	X	X	216	d8		Ø	╪
89	59	Y	Y	Y	217	d9		Ù	┘
90	5a	Z	Z	Z	218	da		Ú	┌
91	5b	[	[	[	219	db		Û	█
92	5c	\	\	\	220	dc		Ü	▄
93	5d	]	]	]	221	dd		Ý	▌
94	5e	^	^	^	222	de		Þ	▐
95	5f	_	_	_	223	df		ß	▀
96	60	`	`	`	224	e0		à	α
97	61	a	a	a	225	e1		á	ß
98	62	b	b	b	226	e2		â	Γ
99	63	c	c	c	227	e3		ã	π
100	64	d	d	d	228	e4		ä	Σ
101	65	e	e	e	229	e5		å	σ
102	66	f	f	f	230	e6		æ	µ
103	67	g	g	g	231	e7		ç	τ
104	68	h	h	h	232	e8		è	Φ
105	69	i	i	i	233	e9		é	Θ
106	6a	j	j	j	234	ea		ê	Ω
107	6b	k	k	k	235	eb		ë	δ
108	6c	l	l	l	236	ec		ì	∞
109	6d	m	m	m	237	ed		í	φ
110	6e	n	n	n	238	ee		î	ε
111	6f	o	o	o	239	ef		ï	∩
112	70	p	p	p	240	f0		ð	≡
113	71	q	q	q	241	f1		ñ	±
114	72	r	r	r	242	f2		ò	≥

Dec	Hex	Keypad Char	LoggerNet Char	HyperTerminal Char	Dec	Hex	Keypad Char	LoggerNet Char	HyperTerminal Char
115	73	s	s	s	243	f3		ó	≤
116	74	t	t	t	244	f4		ô	⌠
117	75	u	u	u	245	f5		õ	⌡
118	76	v	v	v	246	f6		ö	÷
119	77	w	w	w	247	f7		÷	≈
120	78	x	x	x	248	f8		ø	°
121	79	y	y	y	249	f9		ù	∙
122	7a	z	z	z	250	fa		ú	·
123	7b	{	{	{	251	fb		û	√
124	7c	|	|	|	252	fc		ü	ⁿ
125	7d	}	}	}	253	fd		ý	²
126	7e	~	~	~	254	fe		þ	■
127	7f			⌂	255	ff		ÿ	

Appendix E. FP2 Data Format

FP2 data are two byte big endian values. The FP2 data format is nearly equivalent to the low resolution data format in older array based CSI dataloggers. Representing bits in each byte pair as ABCDEFGH IJKLMNOP, bits are described in Table E-1.

TABLE E-1. FP2 Data Format Bit Descriptions

Bit	Description
A	Polarity, 0 = +, 1 = -
B, C	Decimal locators as defined in Table C-2
D - P	13 bit binary value, D being the MSB. Largest 13-bit magnitude is 8191, but CSI defines the largest allowable magnitude as 7999

Decimal locators can be viewed as a negative base 10 exponent with decimal locations as shown in Table E-2.

TABLE E-2. FP2 Decimal Locator Bits

B	C	Decimal Location
0	0	XXXX.
0	1	XXX.X
1	0	XX.XX
1	1	X.XXX

Index to Sections

The index lists page numbers to headings of sections containing desired information. Consequently, sought after information may be on pages subsequent to those listed in the index.

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