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1 Introduction to SmartReader Data Loggers

SmartReaders are easy-to-use battery-powered data loggers. Pocket-sized and rugged, they can be used in a wide range of environmental and industrial applications. Different SmartReader models are available to directly measure and record variables such as temperature, relative humidity, pressure, electric current, analog voltage, current loop and pulse. Each model can reliably record time-based data for later analysis, by TrendReader software and any 100% PC-compatible computer.

TrendReader software must be installed on your computer prior to use of any SmartReader Data Logger described in this Reference Guide.

1.1 Features

SmartReader data loggers share many common features that make them outstanding tools for data collection:

- Pocket-sized.
- Internal components consist of all solid-state construction with no moving parts.
- Microprocessor controlled circuitry includes solid-state memory that can store data over a long time period.
- Precision on-board thermistor temperature sensor.
- Lithium high capacity battery.
- High-accuracy clock crystal.
- Magnetic backing and locking hole for easy and secure in-field mounting.
- Rugged custom-molded Noryl® case.
- Easy-to-use terminal block connector for reliable external connections.

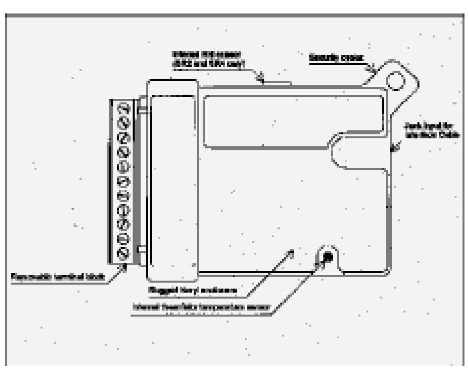

Figure 1

1.2 Description

SmartReader data loggers run continuously - constantly measuring and recording readings from any enabled channel. Self-powered by a long life lithium battery that will provide years of reliable operation, your SmartReader can work completely independently from any external power supply or computer. When you're ready to look at the data it has collected, it can transfer all information to your computer through the use of TrendReader software.

Main Components

The main components on the SmartReader data loggers include:

- a memory chip that has the capacity to store up to 32,768 readings.
- a microprocessor with an eight-bit analog-to-digital converter (A/D) that converts all input signals into digital values.
- a clock crystal that accurately keeps track of time and regulates the taking of readings.
- an accurate on-board thermistor that the logger uses to measure ambient temperature via changes in resistance. a lithium battery that provides power to the logger and internal or external sensors.
- a lithium battery that provides power to the logger and internal or external sensors.

1.3 Programmed Operation

SmartReader data loggers run continuously according to settings that you can program. These pre-selected settings are stored in the logger's memory chip and instruct it to:

- take data readings at regularly-spaced intervals.
- take readings from specific channels that you have enabled.
- associate each data-gathering channel with a special equation in TrendReader software.

1.4 How SmartReader Data Loggers Take Readings

Each SmartReader data logger has an on-board thermistor that you can use to record ambient temperature. You can turn this temperature-monitoring capability on or off through software. Depending on which SmartReader model you have, you can also record other information by connecting sensors, transducers or external circuitry to the plug-in terminal block.

SmartReaders can record up to 32,768 readings. When the memory is full (if "Stop When Full" is not selected), the logger continues to take readings (to make room it discards the oldest reading every time it adds a new one). Thus, when the memory is full, it will hold a "sliding window" of information spanning 32,768 readings.

You can set the frequency at which your logger takes readings through software. The sampling rate you select will apply to all enabled channels. At a sample rate of eight seconds, one reading is taken every eight seconds and saved to memory. As you slow the sample rate the logger begins to average readings before saving them to memory. To do this the logger takes a reading every eight seconds, but instead of transferring this directly to the logger's memory, it stores the readings in a buffer (a temporary memory) where it is retained until the sampling interval is over.

When you backup a logger's data into your computer, the correct time and date are referenced to each reading. All readings are then individually time and date stamped and processed by an equation associated with the data logger channel. The result is a collection of accurate time-based temperature data ready for detailed graphing and analysis.

1.5 How to Use SmartReaders

Using your SmartReader data logger for most applications is a simple process. With proper planning, setup, and installation of your data logger, you can be assured that the information you collect will be both correct and useful. This section provides general procedures for using SmartReader data loggers. For additional and specific information on these steps, refer to the chapter in this manual that deals with the particular SmartReader model you have.

Planning
Proper planning is the key to successful data logging. Time spent in this stage will help you save time and frustration later. To help you plan, answer these questions:

- *What exactly do I want to measure?*
- *Where is the best place to measure?*
- *How long do I want to monitor for?*
- *Should other variables be monitored simultaneously?*

Setup
To set up your SmartReader data logger you must first have TrendReader software installed and running on your computer. You can then configure your logger with various options by talking to it via the interface cable.

Set Sampling Rate
Always confirm the sampling rate (how often the logger takes readings) to make sure it will be acceptable for your application. You can alter the frequency at which your SmartReader data logger records readings by changing the sample rate. You can choose sample rates from 8 seconds to 5 days using TrendReader for Windows. The sampling rate you choose will apply to all the active channels on your SmartReader logger.

To help determine which sampling rate you should choose, answer these questions:

- *How long do I need to record data?*
- *How much time will elapse between when I retrieve the logger(s) and download the data to my computer (i.e. the trip back to the office)?*
- *How often do readings need to be taken?*

Making External Connections
If you are using your SmartReader data logger to monitor external modules, sensors, or circuitry, make sure the connections are secure. Also, make sure the terminal block is *snapped* securely into the logger.

Enable Channels
Always make sure that you have enabled and verified the correct channels for your application. This is very important as it can be very distressing to find out later that the information you hoped to collect was from an inactive channel. You can selectively enable additional channels in your SmartReader as required. However, in order to avoid using logger memory unnecessarily, disable any channels which are not required.

Clear Memory
Before sending your logger out into the field to collect data, clear the logger memory. This will help to keep the collected files smaller as well as decrease the time needed to backup the logger later. Note that clearing your SmartReader's memory is automatic if you save setup changes (i.e. assign different

equations, change sample rate, etc.)

Test
You can directly read the values that your SmartReader data logger is sensing, on a reading-by-reading basis, by using the real-time capability of TrendReader software. Data from any of the enabled channels can be instantly displayed. Make sure that the proper channels are enabled. This test gives you the opportunity to check your logger setup and make necessary changes before the logger is placed on location for data collection.

Label
If you're working with more than one data logger, label each, identifying the task and location before you distribute them throughout a building or system. To do this, you can simply use a shipping tag. Later, when you retrieve them to graph their data, you'll know what each graph refers to.

Mounting
Use the magnetic backing to conveniently mount your logger on metal surfaces like ductwork or electrical control cabinets. If you're concerned about theft, lock your logger to a permanent fixture using the special locking tab, or take advantage of its small size and hide it completely out of view. Because SmartReader loggers are so light, you can use special mounting methods like Velcro® fasteners to secure them to just about any surface. Make sure your logger is securely mounted to last the full length of your data logging session.

Do not rely on the logger's magnetic strip for secure mounting if the mounting surface is uneven, unstable or above 150°F (65C).

Cold or Humid Environments
Make sure that the environment you will be placing your logger into will be acceptable by referring to the *Specifications* section in this chapter. If conditions are not acceptable for the logger, consider using a protective enclosure. For humid environments, you can protect your logger simply by placing it in a zip-lock plastic bag.

When you place your SmartReader logger in a cold environment, make sure condensation will not settle on the logger when you bring it back into a warmer environment, like the office. The best way of preventing condensation is to place the logger in a plastic zip-lock bag and include a dessicant (a material that absorbs moisture). When you bring your logger back to your computer, leave the logger in the plastic bag (with the dessicant) until the logger has had a chance to warm up to the surrounding temperature. You can then take it out and analyze the data it has stored.

Keep Track
Be sure to keep a record of *where* you've placed each logger on a plan of the building or system. That way you'll save time in looking for them when your data-gathering session is over. Also, keep track of *when* you placed the loggers in the area you're monitoring. It will help when producing graphs on your computer.

Retrieval
After sufficient time has passed for you to obtain a representative profile of data, retrieve the logger and bring it back *immediately* to your computer for analysis. Make sure that each logger has a label (shipping tag) on it so you can properly identify and differentiate it from other loggers.

Analysis
To analyze the data your SmartReader logger has stored, you must first transfer a backup copy of the data into your computer. To do this, see Backup in the TrendReader Reference Guide. After transferring the data to the computer, the data is automatically copied to disk and time and date-stamped. You'll be able to copy just a portion, or the entire data set, as you require, to disk.

Refer to the chapter dealing with the particular model you have to find out how to differentiate the data from different channels on your logger. Each channel will initially have the same descriptive title, but you can alter these accordingly.

You can find detailed instructions for viewing graphs, and all other software functions, in the TrendReader Reference Guide.

1.6 General Specifications

General

Size:	107 x 74 x 22mm (4.2" x 2.9" x 0.9")
Weight:	110g (3.75 oz.)
Case Material:	Noryl® Plastic
Operating Limits:	-40 to 70°C (-40 to 158°F) and 0 to 95% Relative Humidity (non-condensing)
Clock Accuracy:	±2 seconds/day
Battery:	3.6 Volt Lithium, 1 Amp-hour
Power Consumption:	5 to 10 microamps (continuous)
Battery Life:	Ten years (Factory replaceable)
Memory Size:	32,768 readings
Sampling Methods:	**1**. Continuous (First-in, First-out) **2**. Stop when full (Windows)
Sample Rates:	User selectable rates between 8 seconds to once every 5 days.
Resolution:	8 bits (1 part in 256)
Resistance to X-rays:	Tested for protection against a 160kV dose @ 5 mA for 30 seconds (150 mA-sec) @ 38 in. F.F.D. (about 100 times that of an airport X-ray machine). Tested for protection against Gamma Ray (equivalent to 0.137 - 1.38 mega volts) IR 192 - 28 curies @ 30 second exposure source to object distance 5".
PC Requirements:	100% PC-compatible computer, with at least one unused serial port.

Internal Temperature Sensor

Type:	NTC thermistor; 10k ohms at 25°C (77°F)
Range:	-40 to 70°C (-40 to 158°F)
Accuracy:	±0.2°C between 0 and 70°C (±0.3°F between 32° and 158°F) ±0.5°C between -40° and 0°C (±0.9°F between -40° and 32°F)
Resolution:	0.4C at 25C (77°F) Better than 1.0°C between -25C (-13°F) and 70C (158°F) Better than 2.0C (3.6°F) between -40C (-40°F) and -25C (-13°F)
Equation:	Use Equation #45 in TrendReader software

Specifications are subject to change without notice.

1.7 Approvals

Meets Part 15 for Digital Devices of the Code of Federal Regulations of the Federal Communications Commission (FCC). Meets Class A radiated and conducted emission requirements of Section 2 of the Radio Interference Regulations of Communications Canada. IEC801-2, 3, 4 and EN55011 covering ESD, RFI Immunity, EFT/Burst and Radiated Emissions respectively for the Commission of the European Communities (CE).

2 SmartReader 1 Temperature Logger

SmartReader 1 is an easy-to-use logger for recording temperature in a wide range of applications such as HVAC testing and balancing, transportation, and energy management studies.

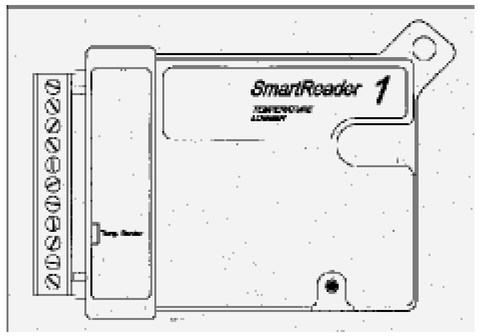

Figure 1.1: SmartReader 1

2.1 Description

The SmartReader 1 has an on-board thermistor temperature sensor and an external temperature sensor channel for remote measurements with an optional probe.

2.2 Setup

Make sure you have enabled the channels you want to use. If you are not using a channel, disable it to save logger memory.

Channel	Description	Equation
0	Internal Temperature	45
1	External Temperature	Appendix C

Accessories

The SmartReader 1 Temperature Logger can be used with ET series temperature probes (refer to the *Thermistor Temperature Probes* in Appendix C or any NTC thermistor data). To use an external temperature probe, simply connect the two wires to the terminals marked "Temp. Sensor" and activate the external temperature channel. Note that polarity does not matter when connecting thermistor leads. If you are using shielded cable, terminate the shield wire by connecting it to the *lower* of the two "Temp. Sensor" terminals (the *common* terminal).

Other Applications

For information on how you can monitor resistance or switch status with your SmartReader 1, refer to the chapter entitled *Measuring Resistance and Switch Status* in Appendix A.

3 SmartReader 2 Temperature & Humidity Logger

A self-contained "air-quality" logger, the SmartReader 2 can be used easily in a wide variety of applications to collect important temperature and relative humidity data.

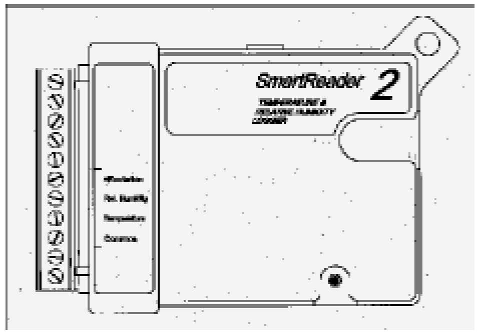

Figure 2-1: SmartReader 2

3.1 Description

SmartReader 2 includes an on-board thermistor temperature sensor and a plug-in RH Sensor plus two input channels for an optional remote temperature and relative humidity probe.

How It Works
The relative humidity sensor in the SmartReader 2 is a processed plastic wafer. This wafer is actually a laser-trimmed, capacitive thin-film relative humidity sensor.

Changes in relative humidity cause the surface capacitance of the polymer film to vary. The SmartReader 2 gauges this capacitance by passing a small electric current through it and measuring the relative voltage drop. Because the response of the sensor is slightly temperature dependent, a temperature reading is always taken at the same time as the humidity reading. That way, when the logger's information is backed up into your computer, TrendReader software can automatically factor in the right compensation values when it calculates the percentage of Relative Humidity (in % RH). The result is an accurate set of automatically-generated and temperature-compensated relative humidity readings.

3.2 Setup

Make sure you have enabled the channels you want to use. If you are not using a channel, disable it to save logger memory.

Channel	Description	Equation
0	Internal Temperature	45
1	Internal Relative Humidity	71
2	External Temperature	Appendix C
3	External Relative Humidity	71

NOTE: When you activate either RH channel, you must also enable its corresponding temperature channel, as well, in order to temperature compensate the RH sensors.

Precautions
The SmartReader 2's RH Sensor is designed for long-term trouble-free performance, but there are a few precautions to keep in mind to maximize the benefit it can give you.

- Always return your SmartReader Plus 2 to a resealable plastic bag during non-use to maximize the in-calibration life of the RH sensor.

3.3 Accessories

You can obtain replacement RH Sensors, remote temperature probes, temperature and relative humidity probes for use with your SmartReader 2.

ET Series Temperature Sensors
The ET Series Temperature sensors are thermistor probes that can be used easily with your SmartReader 2 for remote temperature measurements. The advantage of these probes is they can be used for a wider range of temperatures, are more versatile (they can be used to record fluid temperatures) and their small size permits them to be easily inserted in hard-to-get-at-locations (such as in ductwork or under pipe insulation).

To use an ET Temperature probe with your SmartReader 2 you must first enable the logger's external temperature channel. Connect the remote temperature probe by connecting one wire (of the two-wire probe) to the channel marked **Temperature** and the other wire to the terminal marked **Common.** For more information on ET series thermistor probes, refer to the appendix titled *Thermistor Temperature Probes.*

EH-020A Temperature and Relative Humidity Probe
The EH-020A is a four-wire probe with an on-board temperature and relative humidity sensor. For field-mounting convenience it also has a magnetic backing and a security eyelet. To use the EH-020A with your SmartReader 2, you must enable the logger's external temperature and humidity channels. To connect the EH-020A probe to your SmartReader 2, follow instruction notes packed with each RH probe set -- see Figure 2-2.

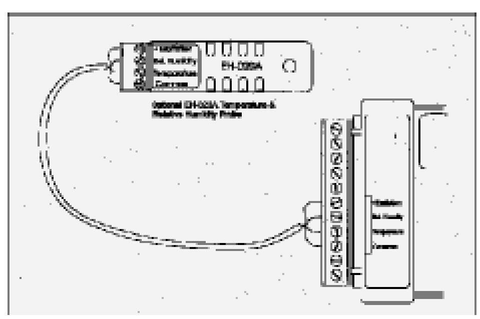

Figure 2-2: Connecting the EH-020A Temperature and RH Probe

The EH-020A is applicable for measurements between -20 and 40C (-4 and 104°F) and 10 to 90% RH.

> NOTE: *The EH-020A probe is compatible with loggers that have serial numbers above 20,000 only.*

The accurate measurement of temperature and humidity depends primarily on the information supplied by a particular sensor. SmartReader 2 data loggers use temperature and humidity sensors with rugged qualities designed for minimal or no maintenance (under normal operating conditions).

The SmartReader 2's on-board thermistor is chemically stable and not significantly affected by aging. It will typically drift less than 0.1C over a period of several years. The relative humidity sensor, although subject to accuracy degradation when exposed to contaminants and/or extreme environmental conditions, will drift typically less than 1% per year (under clean conditions). You should check your RH Sensor periodically. We recommend to recalibrate the loggers at least once every year.

Troubleshooting

If you are getting what appear to be wrong readings, consider the following before recalibrating the sensors. Sensors sample the atmosphere (or medium) only in the immediate vicinity of the sensors themselves. The physical state of the atmosphere and its degree of uniformity and turbulence will limit the validity of a measurement at some distance from the sensor. This becomes especially apparent for the measurement of ambient temperature and relative humidity.

In a room, temperature and RH levels may vary dramatically from location to location. Such factors as air stratification, drafts, and proximity to heat or humidity sources (people, equipment, moisture, solar gain, etc.) can contribute to a wide variance in conditions even within a small, confined area. The individual sensors associated with your SmartReader 2 measure and record temperature and RH only in one location. They do not, in any way, represent an overall reading.

If you decide to check the calibration of your SmartReader 2 RH Module using a Sling Psychrometer, keep in mind the following:

- Any instrument that requires a person to be present at, or in very close proximity to the R.H. sensor, in order to get a reading, will have a measurement error introduced to it. That is because the body readily gives off heat and moisture that is especially noticeable at lower RH levels.

- The time taken between slinging the psychrometer and reading it can exhibit several degrees of inaccuracy in the wet bulb reading. Air currents around the body, whether it is slung in the shade of a building or in sunlight, not knowing how to tie the wet sock, its condition, and the purity of water used, all contribute to error. In addition, interpolating the data from a psychrometric chart can add another 2 to 4% to the accumulative error.

3.4 Relative Humidity Calibration

Each relative humidity sensor has been individually calibrated in an environmental chamber with standards traceable in relative humidity to the National Institute of Standards and Technology (NIST).

The SmartReader 2 and the EH-020A probe are supplied with a calibration card which provides calibration values. These calibration values must be entered in and stored in the logger during initial setup. If your RH sensor is out of calibration, you can simply replace it with a new one.

In the event that you wish to confirm the RH calibration of your sensor, you can perform your own field test. Refer to the chapter entitled *Temperature and Relative Humidity Calibrations* in Appendix B for more information on RH testing.

3.5 Specifications

Relative Humidity Sensor & EH-020A

Type:	Capacitive thin polymer film
Range:	0 to 95% (non-condensing)
Accuracy:	±4% from 10 to 90% RH (-20 to 40°C [-4 to 104°F])
Resolution:	Better than 0.4% RH between 25 and 60% RH at 25°C (77°F)
Response Time:	Adequate ventilation reduces the response time which is approximately 5 minutes in still air and at constant temperature.

Environmental Conditions: The RH sensor is relatively immune to chemical contamination but when exposed to extreme environmental conditions, accuracy degradation could result. For long-term stability and reliable readings, the sensor should not be subjected to liquid immersion or exposed to high concentrations of organic solvents, corrosive agents, sulfur gases and strong acids or bases. Dust settling on the sensor surface will not affect sensor performance except possibly to decrease the speed of response.

Chemical Tolerances: Limits for different chemical groups

1. Organic solvents typically 1,000...10,000 ppm
2. Corrosive agents (strong acids S02, H2SO4, Cl2, HCl, H2S etc.) typically 1...10 ppm
3. Weak acids typically 100...1,000 ppm
4. Bases typically 10,000...100,000 ppm

Specifications are subject to change without notice.

4 SmartReader 3 Electric Current and Temperature Logger

SmartReader 3 is a versatile equipment performance logger. It can simultaneously monitor and record up to three external channels of alternating current without having to interrupt circuitry under test.

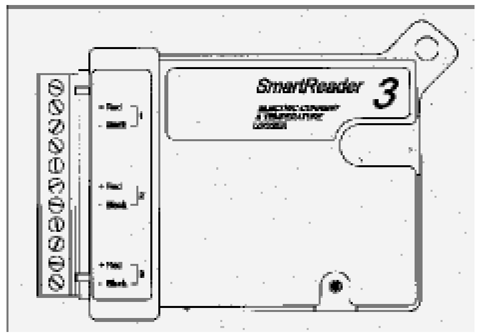

Figure 3-1: SmartReader 3

4.1 Description

SmartReader 3 has three current monitoring channels and one internal thermistor temperature channel. The current monitoring channels are used with external clamp-on probes to measure and record alternating current.

The following current probes from Amprobe Instruments are compatible with the SmartReader 3:

- A60FL and A70FL probes for 60Hz power systems
- A65FL and A75FL for 50Hz power systems

Use of these probes allows you to measure alternating current of conductors without the need for breaking circuitry. For information on current ranges and resolutions refer to the SmartReader 3 *Specifications* section.

How It Works

SmartReader 3 measures electric current through external current probes. Each current probe is basically a transformer with its internal coil serving as the secondary winding and the current-carrying conductor being measured serving as the primary winding. The output of the probe (which is the input to the SmartReader 3) is conditioned through internal circuitry. The probe produces an output of approximately 260 microamps full scale for each range available on the current probe. Readings from the current probe are scaled into amperage units through equations (in TrendReader software) that match the current probe and its range setting.

4.2 Setup and Use

The basic procedure for setting up your SmartReader 3 is as follows:

1. Connect one or more current probes, specified above, to the current channel inputs on your SmartReader. Make sure to observe polarity when making connections. Connect the current probe's red (+) wire to the channel's "**+ Red**" input. Connect the current probe's black wire to the channel's "**- Black**" input.

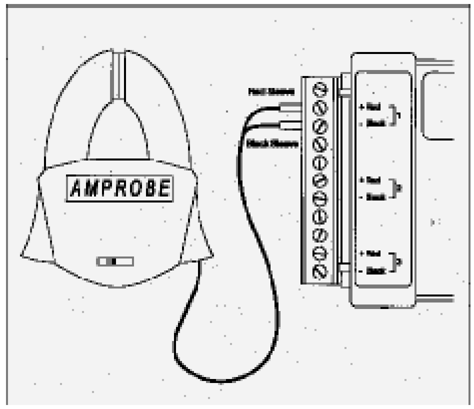

Figure 3-2: Connecting an external current probe

2. Adjust the range setting on the current probe(s) to suit your application. A good way to verify a conductor's maximum range is to check the circuit breaker or fuse rating. Then set the range on your current probe to suit. To maximize the resolution of your readings, always choose the lowest range possible that will encompass the full range of data you want to record.

3. Make sure you have enabled the channels you want to use. If you are not using a channel, disable it to save logger memory.

Channel	Description	Equation
0	Internal Temperature	45
1	Current 1	as below
2	Current 2	as below
3	Current 3	as below

	A60FL / A65FL	
Switch	**Range**	**Equation**
5	0.5 to 5 A	63
25	2.5 to 25 A	64
100	10 to 100 A	65
250	25 to 250 A	66

	A70FL / A75FL	
Switch	**Range**	**Equation**
10	1 to 10 A	67
50	5 to 50 A	68
250	25 to 250 A	69
500	50 to 500 A	70

Precautions

1. DANGER: Do not clamp a current probe around a conductor without a load connected to it. High voltage may be present! When logging current, always plug the external Current Probes into the SmartReader 3 before clamping it around any power wires. This avoids sparking and prevents the connectors from prematurely deteriorating.

2. The SmartReader 3 is to be used only with approved current probes from Amprobe Instruments (A60FL, A70FL, A65FL, and A75FL). DO NOT use any other probe unless approved by ACR in writing.

3. The SmartReader 3 can record current in accordance with the ranges available on the A60FL, A65FL, A70FL and A75FL probes. Always make sure the current you will be recording will fall into the appropriate range you set on the current probe.

4.3 Current Probes and Accessories

Each SmartReader 3 has three pairs of input connections for use with the Current Probes from Amprobe Instruments.

Low Currents

To log very low currents (such as when monitoring the operation of electrical appliances), SmartReader 3 can be used with a Line Splitter. The Amprobe A47L Energizer multiplies the signal to the logger by ten times over a range of 0.1 to 15A. It also allows you to effectively split a two-line conductor, allowing measurements without the need to enter electrical panels or junction boxes.

For European applications, Amprobe's model A47CL is available with screw-in European round prongs, two extra British-type prongs and British fuse plug adapter. Contact your local ACR representative for pricing and delivery of this product.

High Currents

You can monitor current ranges higher than those available on your Ampprobe probes by using them with an additional transformer. For this purpose Amprobe Instruments has available their Amptran® CT50-2 a 50-to-1 transformer (to monitor currents up to 3000 amps). Contact your ACR representative for pricing and availability on this probe.

4.4 Specifications

Output Current:	260 μA DC full scale into 400 ohms.
Lead Length:	1.5m (5 ft.)
Accuracy:	±4% FS above 10% of range.
Ranges:	A60FL / A65FL: 5, 25, 100, 250A A70FL / A75FL: 10, 50, 250, 500A
Maximum Voltage:	1500 Vrms secondary to core 3000 Vrms (4200 Vpeak) lamination to case

4.5 Troubleshooting

My SmartReader 3 is giving me wrong readings. What's wrong?

- If your *graphs* seem incorrect, check the equation number assigned to the graph file. This equation number **must** correspond to the model number and setting of the current probe you used to create the graph file. Refer to the *Specifications* section for a table of equations to use with the various current probes and settings.

- If your *realtime readings* seem incorrect, check the equation number assigned to the logger channel you are viewing. Make sure it corresponds to the model number and active setting of the current probe you are using.

- If your equation numbers are correctly assigned and you are still getting incorrect readings, it may be because of poor resolution. To correct this, make sure the current range setting on your current probe is at the lowest possible setting that will encompass the readings you are interested in. For example, do not use the 250 amp range on the A60FL current probe for recording currents you know will not exceed 5 amps. Use the 5 amp setting instead (it offers fifty times the resolution of the 250 amp setting).

- If the current traverses a wide range (for example, the difference between day and night time power consumption), it may be necessary to attach two probes - one on a high range and the other on a low range.

5 SmartReader 4 Pressure & Temperature Logger

The SmartReader 4 is a general purpose logger that can monitor pressure, temperature and relative humidity.

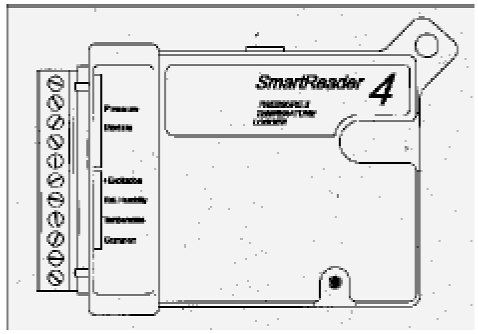

Figure 4-1: SmartReader 4

5.1 Description

SmartReader 4 is a five-channel logger designed to work with external pressure, temperature, and relative humidity sensors that you can order separately. The plug-in Pressure Module is available in several different ranges. The internal RH sensor allows you to record relative humidity. The EH-020A Temperature & Relative Humidity probe allows you to do remote temperature and RH sensing.

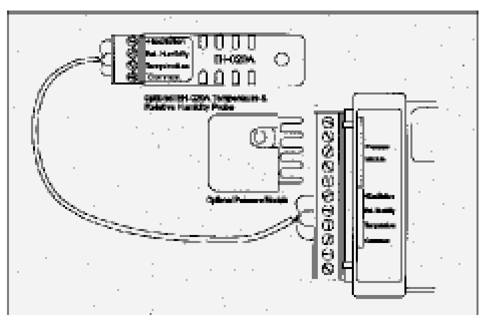

Figure 4-2: SmartReader 4 Accessories

5.2 Setup

Using the Pressure Modules

1. If you are going to measure pressure, you'll need a Pressure Module and a length of plastic tubing and appropriate fittings to tie into the system or equipment you intend to monitor.

2. To connect the Pressure Module, plug it into the five terminals as shown in Figure 4-2. Make sure it is properly plugged in and secured to the terminal block.

3. Use TrendReader software to enable the pressure channel. Then assign the correct pressure equation for the model of Pressure Module you are using. If you want to switch from one Pressure Module to another all you have to do is change the equation number assigned to the pressure channel.

Module	Range	Type	Resolution	Equation
PM-005-G	0 to 5 PSI (30 kPa)	Gauge	0.03 PSI (0.2 kPa)	20
PM-030-G	0 to 30 PSI (200 kPa)	Gauge	0.15 PSI (1.0 kPa)	8
PM-100-G	0 to 100 PSI (700 kPa)	Gauge	0.5 PSI (3.5 kPa)	22
PM-150-G	0 to 150 PSI (1000 kPa)	Gauge	0.5 PSI (3.5 kPa)	22
PM-030-A	0 to 30 PSI (200 kPa)	Absolute	0.15 PSI (1.0 kPa)	8
PM-100-A	0 to 100 PSI (700 kPa)	Absolute	0.5 PSI (3.5 kPa)	22

Pressure Measurement Precautions

The SmartReader 4 is designed for long-term trouble-free performance but there are a few precautions to keep in mind to maximize the benefit it can give you.

- The pressure sensor in the Pressure Module is compatible with non-corrosive gases and dry air. It is **not** to be used for liquid pressure measurements.

- Always try to make your pressure connections separate from the Pressure Module and logger. To do this, leave a short length of tubing continually attached to the input port. Overstressing the input connection may cause it to break and thus cause erroneous readings.

EH-020A Remote Temperature & RH Probe

1. Connect the EH-020A probe to the terminal block as shown in Figure 4-2. For wire colour coding, follow instructions supplied with each probe.

2. Use TrendReader software to activate the External temperature and RH channel. You must enable the External Temperature channel first, otherwise you will receive an error message.

Remote Thermistor Temperature Probe

You can monitor temperatures remotely using an ET temperature probe with your SmartReader 4 by connecting the probe's two wires to the *Temperature* and *Common* terminals. Make sure the External Temperature channel is activated and proper equation is selected.

5.3 Pressure Calibration

The pressure sensor (in the Pressure Module), although subject to accuracy degradation when exposed to contaminants and/or extreme environmental conditions, will drift typically less than 1%/year (under clean conditions). You should check your SmartReader 4 periodically and, if necessary, recalibrate or replace the Pressure Module. In the event that you wish to confirm the pressure calibration of your SmartReader 4 Logger, you can perform your own field test using the special adjustment provisions in TrendReader software.

The recommended method of calibration is to use a pneumatic pressure calibrator with a preferred accuracy of 0.1% F.S. or better. All the pressure modules can be calibrated with an offset and a gain up to ±5% of full scale.

Procedure

The **Low** calibration value is a zero adjustment and the **Mid** calibration value compensates for span. The calibration procedure is as follows:

1. Turn "ON" the pressure and temperature channels of SmartReader 4, if they are not already enabled.

2. Set all calibration values to Zero.

3. Ensure that the correct equation is selected.

4. Set pressure unit to PSI (Go to Option-Units-Pressure).

5. With the input port unconnected (open to ambient), view the real-time pressure reading and record it as (A). The reading should be close to zero if you are using a gauge sensor, or close to ambient pressure (AP) if you are using an absolute sensor.

6. Enter a Low calibration value using:
   - For absolute sensor: -(A-AP)*100/FS
   - For gage sensor: -(A*100/FS)

   Where:
   A = The real-time reading in PSI observed in previous step.
   AP = Ambient pressure.
   FS = Full scale rating of the logger.

   Note: Make sure you enter the **Low** calibration value before going to the next step.

7. Connect the input port of the logger to the calibrator, ensuring all connections are completely airtight.

8. Adjust the calibrator to produce a test pressure equal to the full scale (FS) range of the logger. View the real-time pressure reading and record it as B.

9. Enter a Mid calibration value using this formula (FS/B-1)*100
   Where:
   FS = Full scale range of the logger.
   B = The real-time reading

10. Save the calibration changes to the logger.

5.4 Specifications

The following specifications apply to the pressure sensors used in the SmartReader 4:

Type:	Silicon piezoresistive strain gauge
Max. Pressure:	4 x FS
Media:	Noncorrosive gases and dry air
Temp. Range:	
Operating:	-40 to 70°C (-40 to 158°F)
Compensated:	0 to 70°C (32 to 158°F)
Accuracy:	
Calibrated:	0.5% FS @ 25C (77°F)
Thermal:	over Compensated Range
5 PSI	±1.5% FS
30 PSI	±0.5% FS
100 PSI	±0.5% FS
Linearity:	best fit straight line
5 PSI	±0.25% FS
30 PSI	±0.1% FS
100 PSI	±0.1% FS

Specifications are subject to change without notice.

6 SmartReader 5 Thermocouple Logger

SmartReader 5 Thermocouple Logger can monitor and record from type J, K, T, or S thermocouples.

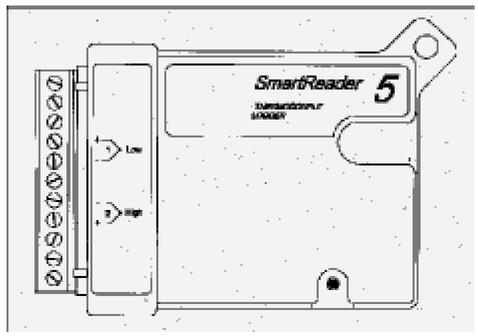

Figure 5-1: SmartReader 5

6.1 Description

SmartReader 5 has two external thermocouple temperature channels and one internal thermistor temperature channel. There are two different temperature ranges:

- Channel 1 (Low) is suited for use over a relatively narrow temperature range. It provides the best resolution readings.
- Channel 2 (High) is useful over a much wider temperature range thus offering greater application flexibility. Resolution is coarser using this channel.

For information on temperature ranges and resolutions applicable for the different types of thermocouples and channels you want to use, refer to the *Specifications* section.

6.2 Setup and Use

The internal thermistor temperature channel for the SmartReader 5 is used to simulate a reference junction for the thermocouples -- it must always be enabled.

1. Connect a J, K, T, or S-type thermocouple to one or both channels. Make sure that you observe polarity when making connections. To do this, connect a thermocouple's negative wire (usually red) to the "-" terminal of the channel you want to use. Connect the other (positive) wire to the "+" terminal. The following table lists the ANSI color code for the thermocouple wires:

Thermocouple Type	Positive (+) Wire	Negative (-) Wire
J	White	Red
K	Yellow	Red
T	Blue	Red
S	Black	Red

2. Connect the logger to your computer and run TrendReader software. Select the equation number for each activated thermocouple channel (refer to the specifications section.)

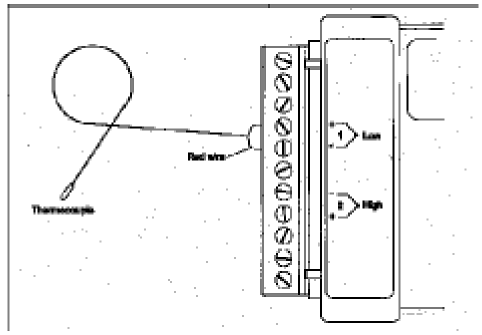

Figure 5-2: SmartReader 5 with a Thermocouple

3. Check that you have the thermocouple's polarity correct by warming its tip. You will see the realtime temperature reading increase if the wires are connected correctly. If the temperature decreases, reverse the connections.

6.3 Specifications

Type **J** Thermocouple Inputs

Thermocouple	Equation	Range	Resolution
1 (Narrow)	49	-20 to 190°C (0 to 370°F)	1.4°C (2.5°F)
2 (Wide)	50	-50 to 600°C (-55 to 1100°F)	5°C (9°F)

Type **K** Thermocouple Inputs

Thermocouple	Equation	Range	Resolution
1 (Narrow)	51	-25 to 230°C (-10 to 440°F)	1.7°C (3°F)
2 (Wide)	52	-100 to 900°C (-145 to 1650°F)	6.7°C (12°F)

Type **S** Thermocouple Inputs

Thermocouple	Equation	Range	Resolution
1 (Narrow)	73	0 to 960°C (32 to 1750°F)	7°C (12.6°F)
2 (Wide)	74	0 to 1760°C (32 to 3200°F)	23°C (41.5°F)

Type **T** Thermocouple Inputs

Thermocouple	Equation	Range	Resolution
1 (Narrow)	53	-35 to 200°C (-30 to 390°F)	1.7°C (3°F)
2 (Wide)	54	-200 to 400°C (-325 to 750°F)	6.7°C (12°F)

Low, Mid and High Calibration Values

The **Low** calibration value compensates for offset; **Mid** compensates for span. These values are set at the factory using an accurate millivolt reference. The following procedure may be used if you want to calibrate each channel to a specific piece of thermocouple wire:

1. Change the equation number of the channel you want to calibrate to 38, and replace any previous Low, Mid and High calibration values with zero (0). If you are using TrendReader for Windows, make sure you have selected **Byte Count** data units.

2. Short the "+" and "-" terminals of the channel with a piece of wire. Observe the Realtime value for the channel.

3. Enter a **Low** calibration value of 50 - R, where R = *the realtime value observed in the previous step*.

4. Change the equation number to the correct one for your thermocouple type, and connect the highest possible temperature reference to the channel. Make sure you have selected **Celsius** temperature units. Observe the Realtime values for the thermocouple channel and the internal temperature channel (Channel 0.)

5. Calculate the **Mid** calibration value using this formula:
   100 x ((A - C) - (B - C)) / (A - C)

   where:
   A = *thermocouple channel reading*
   B = *high reference temperature*
   C = *internal temperature channel reading*

   For example, if your thermocouple channel reads 502C at a high reference of 500C, and the internal temperature channel reads 25C, the **Mid** calibration value is equal to:
   100 x ((502 - 25) - (500 - 25)) / (502 - 25) = 0.419

6. Enter the Mid calibration value obtained in the previous step and save the setup to the logger.

7 SmartReader 6 Thermocouple Logger

The SmartReader 6 Thermocouple Logger can monitor and record readings from type J, K, S, and T thermocouples.

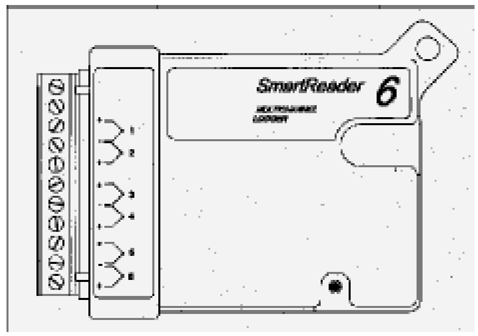

Figure 6-1: SmartReader 6

7.1 Description

SmartReader 6 has six external thermocouple temperature channels and one internal thermistor temperature channel for a cold-junction reference.

There are two basic models of SmartReader 6:

- SmartReader 6 N has all channels set for use over a narrow temperature range.
- SmartReader 6 W has all channels set for use over a wider temperature range but resolution is coarse.

For information on temperature ranges and resolution for the different types of thermocouple, refer to the *Specifications* section.

7.2 Setup

The internal thermistor temperature channel for the SmartReader 6 is used to simulate a reference junction for the thermocouples and it must always be enabled.

1. Connect a J, K, T, or S-type thermocouple to one or more channels. Make sure that you observe polarity when making connections. To do this, connect the thermocouple's negative wire (usually red) to the "-" terminal of the channel you want to use. Connect the other (positive) wire to the "+" terminal. The following table lists the ANSI color code for thermocouple wires:

Thermocouple Type	Positive (+) Wire	Negative (-) Wire
J	White	Red
K	Yellow	Red
T	Blue	Red
S	Black	Red

2. Connect the logger to your computer and run TrendReader software. Select the equation number for each activated thermocouple channel (refer to the Specifications section).

3. Check that you have the thermocouple's polarity correct by warming its tip. You will see the realtime temperature reading increase if the wires are connected correctly. If the temperature decreases, reverse the connections.

7.3 Specifications

Refer to SmartReader 5.

7.4 Calibration

Refer to SmartReader 5.

8 SmartReader 7 Process Signal Logger

A multi-channel, multi-purpose logger, the SmartReader 7 provides a versatile means of logging a wide variety of measurement parameters. It features seven input channels configured for easy interface with common transducer and transmitter outputs.

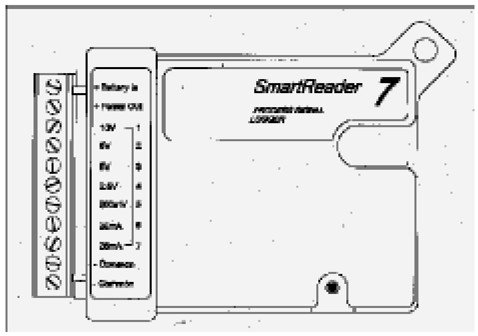

Figure 7-1: SmartReader 7

8.1 Description

SmartReader 7 can measure and record data from five separate channels of analog DC voltage covering the ranges of 0 to 200 millivolts, 0 to 2.5 volts 0 to 5 volts, and 0 to 10 volts and from two DC current channels covering the range of 0 to 25 mA.

How the SmartReader 7 Works

The 200 mV channel uses a pre-amplifier to magnify the signal ten times for maximum resolution by the A/D converter. The 5 and 10 volt channels are converted to a 0 to 2.5 volt signal by internal resistive divider circuits. All digital values are converted to their proper voltage values by individual equations in TrendReader software.

Current flow through a loop is logged by measuring the voltage drop across an internal 100 ohm input resistor. This voltage drop is accurately gauged by comparing it to a highly-stable voltage reference before conversion to a digital value by the A/D converter. The digital values are then processed into 0 to 25 mA values by an equation in TrendReader software.

8.2 Setup

This section provides guidelines to follow to get you started with your SmartReader 7.

1. The first step in using your SmartReader 7 is to decide what information, or parameters, you want to log. For example, you may simply wish to replace an existing hard-wired 4-20 mA chart recorder or, instead, monitor from a special multiple-transducer circuit that you have assembled (see the Applications section later in this chapter).

2. Determine what sensors, transducers, or transmitters you need to do the job (if not already present). Compatible transducers for monitoring temperature, humidity, pressure, wind speed, PH, AC voltage, and many more variables are available through a wide variety of vendors (see *Choosing Transducers and Transmitters*).

3. Modify the channels, externally (using resistors), if required, for maximum resolution (see *Customizing Input Ranges*).

4. Write an equation to convert the raw readings from the transducer or circuit you want to monitor (for

example, 0 to 2.5 volts) into the proper engineering units you require (for example, 0 to 100% Relative Humidity). For help in writing these equations refer to your TrendReader software manual.

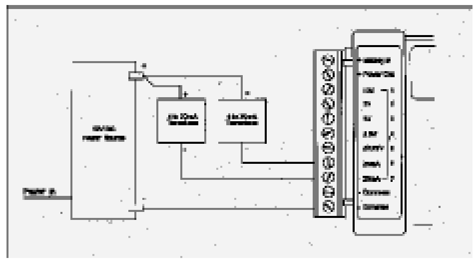

Figure 7-2: Using Transducers with a Power Supply

5. Decide how you are going to power your transducers (if required). You can either use a standard power supply, creating a circuit like that shown in Figure 7-2 or use batteries, producing your own self-contained logging assembly (Figure 7-3). For this application you must activate the battery switch (see *External Battery Control*).

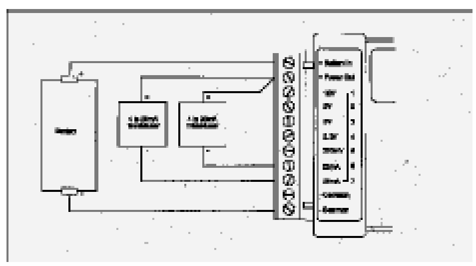

Figure 7-3: Using Transducers with a Battery

6. Connect your transducers or transmitters and check operation by observing the realtime values displayed by TrendReader software. If you can, try to exercise your transducers (make them change their output) to ensure that everything works properly. If it does, then you're ready to place your assembly in the field to start logging.

Avoiding Ground Loop Problems

Take special care to avoid ground loop problems when you use your SmartReader 7. A ground loop can occur when there is more than one path to ground in your logger-transducer circuit. Ground loops can damage your SmartReader 7 as well as your transducers. To avoid ground-loop problems in your SmartReader 7 circuit:

1. Do not use more than one grounded power supply to power your transducers.

2. Do not connect your logger to your computer for realtime readings unless:

    - your computer is battery-operated (i.e. not grounded); or
    - your transducer power supply is not grounded.

If you must use more than one grounded power supply in your SmartReader 7 circuit, *each* transducer you use must be isolated. If you must use non-isolated transducers, then you must use a Signal Repeater/Loop Isolator between the transducer output and the SmartReader 7 input.

Wiring Notes and Considerations

1. SmartReader 7 has two common inputs (labeled " - Common"). These are not isolated from each other and can be used as the "-" connection for the power supply (or battery) and any of the transducers being logged by the SmartReader 7.

2. For permanent applications, wiring connections can first be made to the SmartReader 7's removable terminal block. The terminal block can then be attached (with glue, for example) to a permanent fixture. When it comes time to analyze the data, the SmartReader 7 can simply be unplugged from the terminal block and brought back to your computer. After backing up the data, the logger can be returned and plugged back into the terminal block. Logging will then automatically continue. Extra terminal blocks are available from your sales representative.

3. The 2.5V and 200mV channels "float" when no connections are made to them. They can thus be expected to read a positive voltage when left unconnected. When connected, however, they will read the correct input voltage.

4. The "25mA" channels read positive current only. *Make sure to observe polarity*. If you are using both channels simultaneously, ensure that both 4-20mA transmitters provide a positive current to the logger inputs, while operating with their negative (-) terminals tied together.

8.3 Choosing Input Channels

To choose which of the SmartReader 7's seven external input channels to use for your particular applications, an understanding of *resolution* is required.

Maximizing Resolution

The resolution of your SmartReader 7 Logger is eight bits. This means that it can resolve analog signals, with a defined range, to 256 discrete steps (2 to the power of 8). When logging from the 2.5V channel, for example, the SmartReader 7 will record digital values in increments of 2.5 volts divided by 256, or approximately 10 millivolts.

Resolution is usually not a significant factor until you have logging applications that will produce input signals far less than that of the range of the logger's channel itself.

The 2.5V channel will have a resolution of 0.4% over a range of 0 to 2.5 volts (.01/2.5 x 100) which should be more than adequate for most applications. If, however, you are intending to measure signals ranging from 50 to 150 millivolts (with the same 2.5V channel), resolution will be much coarser (10%). By switching the 50 to 150 millivolt input to the 200mV channel, resolution can be improved to approximately 1%.

Choosing Input Channels

It is important to maximize resolution when measuring and recording from the SmartReader 7's current and voltage channels. Usually you can do this simply by choosing the channels that match or approximate the input signals you will be using. The table below lists several possible input signal ranges and the recommended channels to use. It also lists alternative channels that can be used to add additional simultaneous monitoring capability. These alternative channels will, however, require addition of external resistors (see *Customizing Input Ranges*).

Range of Input	Standard Solution	Alternative Solution(s)
0 to 500 millivolts	2.5	200
0 to 1.0 volt	2.5	200
0 to 2.0 volts	2.5	200
0 to 3.0 volts	5	2.5, 200
0 to 6.0 volts	10	5, 2.5, 200
0 to 20 volts	N / A	10, 5, 2.5, 200
0 to 2.0 milliamps	25	200
4 to 20 milliamps	25	2.5, 200
0 to 50 milliamps	N / A	25, 5
0 to 100 milliamps	N / A	25, 10

In the above table, the *Range of Input Column* lists examples of input signals that you may wish to monitor using your SmartReader 7. The *Standard Solution* column lists the channel you would normally choose to monitor that particular signal.

In this table, **200** refers to the 200mV channel, 2.5 to the 0 to 2.5V channel, **5** to either of the two 0 to 5V channels, **10** to the 0 to 10V channel, and **25** to either of the two 0 to 25mA channels. The *Alternative Solution* column lists other channels that can be used to monitor the same input signals. In most cases, these channels will need to be fitted with external resistors.

Non-Standard Ranges

You may want to use a special transducer or tie into an existing process signal loop that does not match the SmartReader 7's standard input ranges. The following step-by-step procedure will help you choose which channel is best:

1. Determine the maximum output signal (**M**) and the zero offset signal (**Z**) of the transmitter or circuit you wish to tie into. For example, a transducer with a specified range of 1 to 6 volts DC will have a maximum output signal of 6 volts and a zero offset signal of **1 volt**. A 4 to 20 milliamp transmitter will have a maximum output signal of **20 mA** and a zero offset signal of **4 mA**.

2. Determine the transducer's full scale output (F). You can do this simply by subtracting **Z from M**. The full scale output of the 1 to 6 volt transducer is thus **5 volts**. The full scale output of the 4-20mA transmitter is **16 mA**.

3. Compare **M** with the channels available on the SmartReader 7 and choose a channel with an input equal or greater to this value (if available). If no such channel exists, then modify one to suit by referring to the *Customizing Input Ranges* section.

4. Determine if the resolution (**R**) of the channel you chose in Step #2 will be adequate. You can determine this, in percent, by using the following equation:

$$R = C * 0.4 / F$$

Where:

C = the input range of the channel you chose to use (in units of either millivolts, volts or milliamps).
F = the full scale output of your transducer (M - Z) measured in the same units as for C.
R = the resolution expressed in a percentage (%) of full scale output.

For example, a 0.5 to 2.5 volt transducer connected to the 2.5V channel will be logged with a resolution of **0.5%**. A 4 to 20mA transducer hooked up to the 25mA channel will log with a resolution of **0.6%**.

Generally, it is good practice to keep resolution to within 1% for most applications. However, you might accept far coarser resolution in some applications and, in others, require far better. You'll be able to determine your own requirements after you've become familiar with the results you can expect with different arrangements. If your requirements demand greater resolution than what you calculated, then you should set up your inputs with resistors as described in the ***Customizing Input Ranges*** *section in this chapter.*

5. To find out in what actual steps (**S**) your logger will collect data, first determine the *input* (**I**) of your transducer or transmitter. You can do this by subtracting the lowest level input from the high. A thermocouple transmitter, for example, with a range of -20° to 600° will have an input span of **620**° (600-(-20)). A pressure transducer with a range of 0 to 100 psi will have an input span of **100 psi**.

6. To calculate **S**, measured in the same units as the input span (**I**) above, use this equation:

   $$S = R * I / 100$$

   For example, a 4 to 20mA Relative Humidity transmitter with an input span (**I**) of 90% RH and a calculated resolution (**R**) of 0.6% will record data in steps of **0.54% RH**.

8.4 Customizing Input Ranges

The standard input ranges on the SmartReader 7 should be suitable for most process signal applications, but occasionally you may require measurement of non-standard input levels where resolution is a primary concern (see the Choosing Input Channels section in this chapter). Ranges can be adapted easily by using either one or two external resistors. TrendReader software's custom equations can then be used to scale the data to the new input levels.

The resistor value that you will require to modify each SmartReader 7 input channel is selected by inserting your special input requirements into a simple equation. The following sections detail these equations and the method of tying in these resistors.

10 Volt Channel

The 10 volt channel can be modified to span higher ranges (greater than 10 volts DC) by adding a single resistor to the "10V" terminal shown in Figure 7-4. The value of the resistor "**R**" must be calculated by the following formula based on the desired voltage input range (**E_{in}**):

R = 4,090 x Ein - 40,900

For example, if you wish to measure up to 20 volts, the resistor value should be:

4,090 x 20 - 40,900 = 40,900 *ohms*

Since you won't always be able to get the exact resistor value that you calculated, you can determine the logger's actual input range by plugging the value of the resistor (R) you obtain back into the equation. For example, if the closest resistor you could obtain was 42K ohms, then the actual voltage input range would be:

Ein = (R + 40,900) / 4,090

(42,000 + 40,900) / 4,090 = 20.27 *volts*

This value will be needed when it comes time to create your own custom equation using TrendReader software.

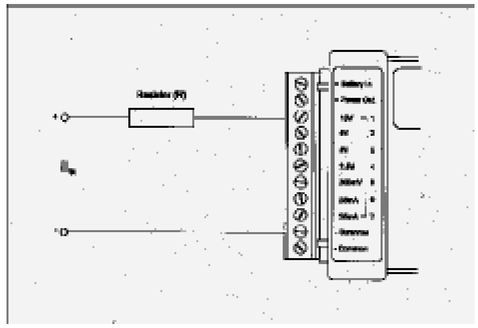

Figure 7-4: Modifying the 10 Volt Channel for Extended Voltage Range

You can also easily convert the 10V channel to measure 0 to 100mA current simply by putting a 100 ohm resistor (minimum rating: 2 watts) between the "10V" and "Common" terminals.

5 Volt Channels

The two 5 volt channels can be modified to span higher ranges (greater than 5V DC) by adding a single resistor, in the same way as shown for the 10V channel in Figure 7-4, to either, or both, of the two "5V" terminals. The value of the resistor "**R**" must be calculated by the following equation based on the desired voltage input range (**E**in):

$$R = 4{,}000 * Ein - 20{,}000$$

For example, if you wish to measure up to 20 volts, the resistor value should be:

$$4{,}000 * 20 - 20{,}000 = 60{,}000 \text{ ohms}$$

Since you won't always be able to get the exact resistor value that you calculated, you can determine the actual input range you'll have by plugging the value of the resistor back into the formula:

$$E_{in} = R + 20{,}000 / 4{,}000$$

You can easily convert either or both 5V channels to measure 0 to 50 mA current by wiring a 100 ohm resistor (minimum rating: 0.5 watts) from the "5V" terminals to common.

2.5 Volt Channel

The 2.5 volt channel can be modified to span higher ranges (greater than 2.5V DC) by adding *two* resistors to the input terminals as shown in Figure 7-5. The value of the resistor marked "10K" must be 10,000 ohms +/-1%. The value of the resistor marked "R" must be calculated by the following equation based on the desired voltage input range (Ein):

$$R = 4{,}000 * E_{in} - 10{,}000$$

For example, if you wish to measure up to 20 Volts, the resistor value should be:

$$4{,}000 * 20 - 10{,}000 = 70{,}000 \textit{ ohms}$$

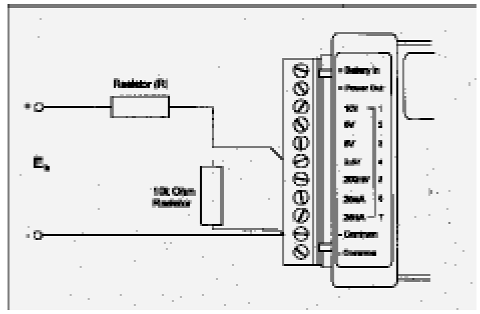

Figure 7-5: Modifying the 2.5 volt channel

Since you won't always be able to get the exact resistor value that you calculated, you can determine the actual input range you'll have by plugging the value of the resistor back into the formula:

$$E_{in} = R + 10{,}000 / 4{,}000$$

This value will be needed when it comes time to create your own custom equation using TrendReader software.

You can easily convert the 2.5V channel to measure 0 to 25 mA current by wiring a 100 ohm resistor from the "2.5V" terminal to common.

200 millivolt Channel

The 200 millivolt channel can be modified to span higher ranges (greater than 200 mV DC) by also adding two resistors, in the same way as shown for the 2.5V channel in Figure 7-5. The value of the resistor marked "10K" must be 10,000 ohms +/-1%. The value of the resistor "R" must be calculated by the following formula based on the desired voltage input range (E_{in}):

$$R = 50{,}000 * Ein - 10{,}000$$

You can also modify the 200 mV channel to log current loop signals with greater sensitivity than the two 25 mA channels. To do this, put a 100 ohm resistor across the "200mV" and "- Common" terminals and you will be able to log currents from 0 to 2.0 mA with approximately ten times the resolution of the 25mA channels. The equation to use to determine other current (**I**in) ranges, in milliamps, is:

$$R = 200 / Iin$$

25 milliamp Channel

The 25 milliamp channel can be modified to span higher ranges (greater than 25mA DC) by also adding a single resistor across the input terminals as shown in Figure 7-6. The value of the resistor (R) must be calculated by the following formula based on the desired current input range (I_{in}):

$$R = 2{,}500 / (I_{in} - 25)$$

Make sure the resistor can withstand at least twice the power you will be sending it. To calculate this, use the following equation:

$$P = 2 \times I_{in}^2 \times R$$

Where:

P = Minimum Power Rating of resistor (in watts)
I_{in} = Maximum amperage expected through resistor (in Amps)
R = Resistance of Resistor (in ohms)

For example, a 50 ohm resistor calculated to measure currents up to 75mA will require a power rating greater or equal to 0.56 watts. Therefore, a one watt resistor will be fine.

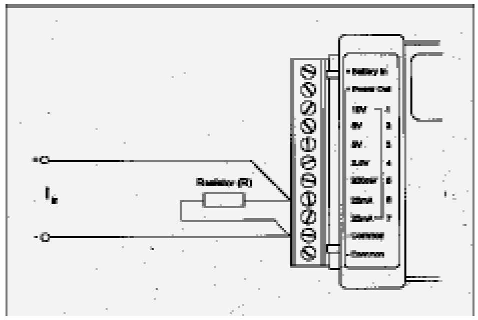

Figure 7-6: Modifying a 25mA Channel

For increased sensitivity at lower current ranges down to 2.5 milliamps, refer to the section for modifying the 200 mV channel.

Resistors

Resistors that can be used with the SmartReader 7 are readily available at most electronic parts supply stores. The most common ones are quite small and made in the form of a little cylinder. To clearly show the value of the resistor, regardless of the orientation of the cylinder, a color code is painted on each resistor in the form of rings around the cylinder.

For resistors with a tolerance rating of 2% or looser, the first ring, nearest one end, gives the first digit of the resistor's value; the second ring gives the second digit of the resistor's value; the third ring gives the number of zeroes to be added; and the fourth ring gives the manufacturer's tolerance of the resistor.

Color	First Two Bands (Significant Digit)	Third Band (Multiplier)	Fourth Band (Tolerance)
Black	0	* 1	1% tolerance
Brown	1	* 10	1% tolerance
Red	2	* 10^2	
Orange	3	* 10^3	
Yellow	4	* 10^4	
Green	5	* 10^5	
Blue	6	* 10^6	
Violet	7		
Grey	8		
White	9		
Gold		* 0.1	5% tolerance
Silver		* 0.01	10% tolerance
No fourth band			20% tolerance

Resistors which have a tolerance of 1% usually have five color bands. The difference with them is the addition of a third band for an extra significant digit of the resistor's value. Some 1% resistors may also use actual numbers instead of colored bands. For example, a 30.9K ohm resistor would be shown as "3092."

Metal film resistors with good long-term drift and temperature coefficient characteristics should be used. When choosing resistors, pick ones with a 1% tolerance or use your own ohmmeter to confirm the exact resistance of the resistors you intend to use. Using resistors with tolerances looser than 1%, without confirming their actual resistance, will create undesirable measurement errors.

8.5 External Battery Control

You can activate a special switch on the SmartReader 7 designed to optimize the use of battery-powered sensors while out in the field. The battery-saving contacts can provide switching capability to draw power from the battery only when needed, thus maximizing its life for extended field applications.

The battery switch allows you to power external transducers with a separate battery pack. This capability makes it easy for you to assemble your own self-contained data logging kit for long-term in-field use where there is no convenient power supply receptacle.

The battery switch is enabled or disabled using TrendReader software. If you are using TrendReader for Windows refer its Reference Guide for further information.

In TrendReader for DOS, you can activate the battery switch when you exit a setup session, and check its status in the setup menu. If the switch is activated, "Hi Cal" for channel 7 (25 mA) will read -5. If the switch is not activated, this value will be 0.

The switch works by closing eight seconds prior to a reading, remaining closed until the reading is taken, then immediately opening again before repeating the cycle (Figure 7-7).

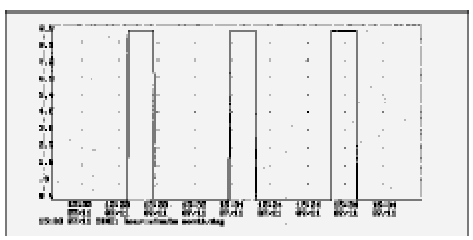

Figure 7-7: Battery Voltage Profile at 32 sec. Sampling

It extends battery life by only drawing power, when necessary, to meet the input requirements of the transducer or transmitter circuit that you want to monitor (Figure 7-8).

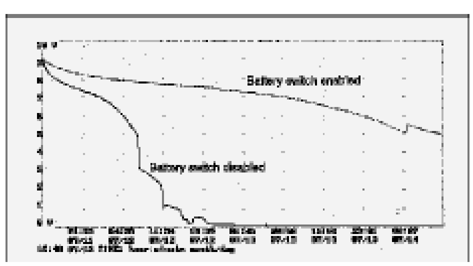

Figure 7-8: How the Battery Switch Extends Battery Life

To use the battery switch, the battery's positive (+) terminal must be wired to the "+ Battery In" terminal on the SmartReader 7 (refer to Figure 7-9). The power to your external transducers will then be available from the "+ Power Out" terminal. The battery's negative (-) terminal can then be wired to either of the "- Common" terminals.

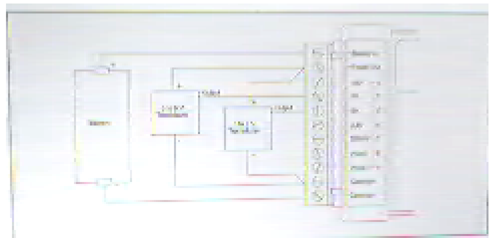

Figure 7-9: Using the Battery Switch

The maximum current that the battery switch can source is 100mA. Battery supply voltage can be from 9 to 25 volts. Short circuit protection is continuous at 9 volts, but only one second at higher voltages.

Things you should know about batteries

When using batteries for powering your external sensors and transducers, you should keep in mind these key points:

1. The rated voltage of a battery only applies to initial use. Once under load, the voltage will decrease gradually until completely drained (refer to Figure 7-8). By knowing how the battery voltage is affected through use you can make sure that the voltage requirements of your external transducers will be met. A good rule of thumb to follow is to exceed the minimum required input voltage for your transducers by at least two times (where acceptable).
2. Nickel-Cadmium (rechargeable) batteries self-discharge at a rate approximating 1% of their remaining capacity per day. This should be taken into account for extended logging sessions.

Determining how long your batteries will last

To estimate how long your batteries will successfully power your external sensors and transducers, you will need to know both the capacity of the batteries as well as the proposed resistance presented to them by the load (your own transducers).

Battery capacity, usually expressed in milliampere-hours (mAh), is the total amount of electrical charge a cell can store or deliver. Unfortunately, most commercially-available batteries are sold without any of this capacity information listed. To get it, though, you can usually call one of their local representatives.

As a general guide, most good quality nine volt batteries (such as Duracell or Eveready Energizers) have a capacity of approximately 500 mAh. This means, at an average *continuous* current draw of 50mA, it will deliver approximately ten hours of service.

The load you impose on your battery will depend on how many transducers you intend to have in your logging circuit. The greater the number of transducers, the greater the power draw from the battery. If you are logging from a 4 to 20mA transducer, the maximum current it will draw will be approximately 20mA. If you power it continuously, your 500 mAh battery should not run out until you've had at least twenty-five hours of service. Since your transducer probably will not always draw maximum current (12mA might be a more reasonable figure), you can probably expect up to forty-two hours of service.

The battery-saving switch contacts can increase the lifetime of your external batteries significantly. Since the batteries will be powered only for eight seconds out of every logging interval, the power draw on the battery will be reduced considerably.

Example

Problem: *You want to log pressure once every thirty minutes from a 0 to 300 psig transducer. The* *output of the transducer is 4 to 20mA. The excitation voltage is listed at between 9 and 40 volts DC.*

Solution: From this information we know that a 4 mA signal will represent 0 psig and a 20 mA signal will represent 300 psig. Since the minimum excitation voltage is 9 volts, we should supply at least 18 volts initially from our batteries. We can do this by simply connecting two nine volt 500 mAh batteries in series.

Without the battery-saving switch enabled, our minimum expected battery life would be approximately twenty-five hours. With the switch enabled, and thus closing only eight out of every 1,800 seconds (or thirty minutes), the life will be extended by a factor of 225 (or 1800/8). This means that we should be able to log from this transducer for over 5,625 hours, or over 234 days. Actual life may even be higher depending on what pressures are actually recorded (the lower the pressure, the lower the power draw).

Regulated Voltages

The unstable voltage characteristics of batteries makes them, by themselves, incompatible for use with transducers that require a regulated voltage supply. You can, however, add your own voltage regulator to your transducer circuit to compensate for this instability (see Figure 7-10). Voltage regulators are readily available at most electronic parts supply stores (such as Radio Shack).

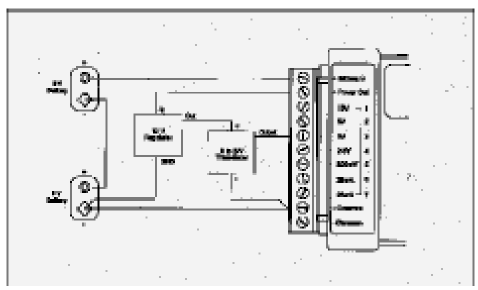

Figure 7-10: Regulating Battery Supply Voltage

Make sure that your supply voltage to your regulator is at least two volts higher than the level to which you want to regulate to. To do this, you can easily increase the voltage of your batteries by hooking them up in series as shown in Figure 7-10.

If the wires between the voltage regulator, batteries, and transducers are long (more than a few inches), the regulator may oscillate and produce an unstable voltage. You can correct for this by connecting one 0.1 microfarad capacitor to each of the regulator's outside pins then wiring them to the regulator's center pin. Make sure to keep the capacitor leads as short as possible.

8.6 Choosing Transducers and Transmitters

A *transducer* is defined as a device that receives energy from one system and retransmits it, in a different form, to another system. A *transmitter* is a term usually reserved for transducers in a current loop circuit. In this section, the terms transducer and transmitter will be used interchangeably.

For a transducer to be useful, the retransmitted signal must be compatible with standard instrumentation. For the SmartReader 7 Logger, this can be either in the form of an analog DC voltage or current.

In the case of the SmartReader 7 Process Signal Logger, many compatible transducers exist for measuring such variables as temperature, relative humidity, pressure, current, voltage, wind speed, PH, and much more. You can obtain these from a wide variety of manufacturers or distributors. An exhaustive listing of sensors and companies is published yearly by *Sensors* Magazine.

To discern what to look for when choosing transducers, it is helpful to know a few technical terms and how they relate to use with your SmartReader 7 logger.

Excitation Voltage

This term refers to the input voltage that a transducer requires in order for it to work properly. It is either specified as a range (for example, 9 to 30 volts DC) or as a specific voltage (for example, 10 volts DC). When a range is specified, it means you can use an unregulated power supply (such as battery) as long as voltages within the range are provided. Usually, if a specific voltage is required, it means you require a regulated power supply.

When an unregulated power supply is specified for the excitation voltage, a regulated one may also be used. The reverse, however, is not true. Millivolt pressure transducers, for example, usually require regulated power supplies.

Maximum Impedance

An important consideration when choosing transducers is the requirement for input or loop impedance. This simply refers to how much resistance your instrumentation (for example, the SmartReader 7) can have before it will begin to cause problems. For voltage inputs, a very high impedance is usually required (usually greater than 10K ohms). This prevents the unnecessary draining of current from the transducer circuit. The SmartReader 7's voltage inputs are all high impedance (greater than 20K ohms).

For current loop inputs, it is advantageous to have a very low impedance (the SmartReader 7's current channels have a low 100 ohm impedance). This helps to minimize the voltage requirements and power consumption of the circuit. Check the specifications for the transducers you intend to use to ensure the SmartReader 7's input impedances are acceptable.

Two-Wire Transmitters

Two-wire transmitters are transducers that form part of a current loop circuit. They vary the current flow in accordance with changes in the variable which they are sensing. Most two-wire transmitters have a 4-20mA output.

Three-Wire Transducers

Three-wire transducers have three connections: a supply (excitation) voltage input (V+IN), an output voltage (V+OUT) and a common (COM-). You can usually tell if a transducer is 3-wire by reviewing the wiring diagram and looking for a *single* common connection. These types of transducers are the most popular and are recommended for use with the SmartReader 7.

Four-Wire Transducers

Four-wire transducers fall into two categories: line-type and Wheatstone bridge types. No more than one line-type transducer can be attached to a SmartReader Plus 7 unless it has an isolated output (no electrical connection to the line). Bridge-type transducer can only be hooked to a SmartReader 7 if they are signal conditioned.

Output

The specified output of a transducer or transmitter will determine whether it is compatible for use with your SmartReader 7. Some of the most popular transducer outputs (such as 0 to 2.5V or 0 to 5V DC) are directly compatible with your SmartReader 7. The most popular transmitter output is 4 to 20 mA which can be easily used with either of SmartReader 7's 0 to 25 mA channels.

8.7 Specifications

Voltage and Current Inputs

Standard Ranges:	0 to 2.5 volts DC (1 channel) 0 to 5 volts DC (2 channels) 0 to 10 volts DC (1 channel)

	0 to 200mV DC (1 channel) 0 to 25mA (2 channels)
Accuracy:	±1% F.S.
Input Impedance:	>1 M ohms (0 to 200 mV channel) >1 M ohms (0 to 2.5 V channel) 20 K ohms (0 to 5.0 V channels) 40.9 K ohms (0 to 10.0 V channel) 100 ohms (0 to 25 mA channels)
Maximum Input Voltage:	Voltage channels: ±40 V (reverse polarity protected) Current channels: ±70 mA (reverse polarity protected)
Connections:	Removable screw-type terminal strip

Specifications are subject to change without notice.

8.8 Applications

The SmartReader 7 Logger can be used for a wide variety of data recording applications. You may decide to use it as a direct replacement for your existing analog voltage or current loop strip chart recorders. That way you'll be able to easily get valuable data into your computer, instead of always being restricted to just the charts.

You may also want to set up your own self-contained logging stations for monitoring commercially available transducers and transmitters (for example: temperature, pressure, humidity, wind speed, flow, level, pH, position, and much more). That way you will be able to easily set up your SmartReader 7 in the field with a minimum of trouble.

Application Example

Here is an example to guide you in your own SmartReader 7 applications:

Problem: *You want to monitor static pressure in a duct, over a period of about a week, to determine how a fan is performing in an air conditioning system. The location you want to monitor is not very accessible and there is no nearby power supply. It is estimated that the pressure in the system will vary as much as 3 to 4" W.C. (.75-1.00 kPa)*.

Solution: You decide a self-contained logging station is the best solution. For the pressure measurements you choose a Model 264 0 to 5" (0 to 1.25 kPa) unidirectional transducer from Setra Systems. The 264 requires an unregulated excitation of 12 to 28 volts DC to produce a linear 0 to 5 volt DC output signal.

Figure 7-11 illustrates the setup of this logging station using two 9 volt batteries wired in series (to produce an initial eighteen volt supply).

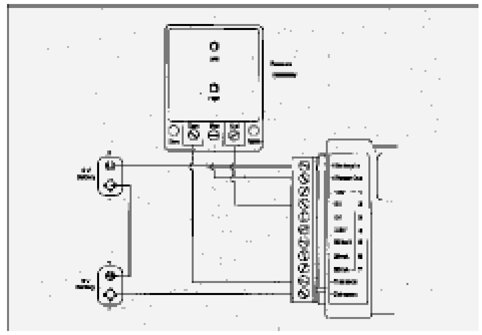

Figure 7-11: Using Voltage Channels with a Power Supply

To set up the SmartReader 7 you first disable all the input channels except for one of the 5V channels. You set this channel with a sampling rate of 2 minutes and activate the battery switch. That way you'll minimize battery consumption and maximize memory, allowing you to collect over forty-five days of data. It will also leave plenty of time for you to retrieve the logger after the logging session and transfer the data to your computer.

Before heading out into the field, write a simple equation converting the 0 to 5 volt signals into the 0 to 5" W.C. pressures. See your TrendReader software Reference Guide for information on writing custom equations. After saving the equation to the 5V channel, you can then test the logger's operation by viewing channel's realtime reading using TrendReader software.

9 SmartReader 8 Eight-Channel Temperature Logger

SmartReader 8 is a versatile logger for recording temperature in a wide range of environmental and industrial applications. It can record from up to eight temperature channels simultaneously.

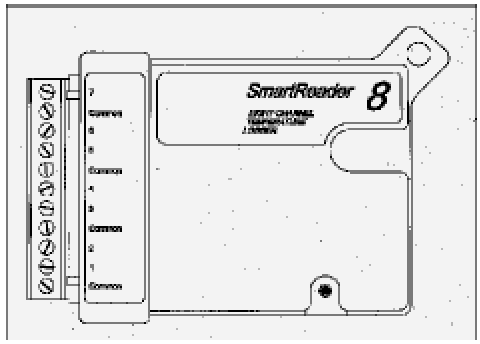

Figure 8-1: SmartReader 8

9.1 Description

SmartReader 8 has seven external temperature channels (for remote temperature probes) and one internal thermistor sensor.

9.2 Setup and Use

The following procedure will help you prepare your SmartReader 8 for temperature monitoring applications.

1. Connect your SmartReader 8 to your computer and run TrendReader software.

2. Activate only the channels you intend to monitor. Disable any channels you do not intend to use (to conserve memory).

3. If you are using external channels, make sure to use thermistor sensors appropriate for the measurements you want to take (see *Thermistor Temperature Probes* in this Reference Guide). Also, confirm that the equation number you are using for each of your probes is correct.

4. To connect remote temperature (two-wire) probes, simply wire one lead into a channel input (labeled 1 to 7) and the other into a terminal marked **Common**. It doesn't matter which lead goes to which terminal. You can also connect more than one thermistor probe to the same **Common** terminal. For example, Figure 8-2 shows two external probes connected to channels 2 and 3 sharing the same **Common** terminal. If you are using a thermistor probe with shielded cable, terminate the shield wire by connecting it to any **Common** terminal.

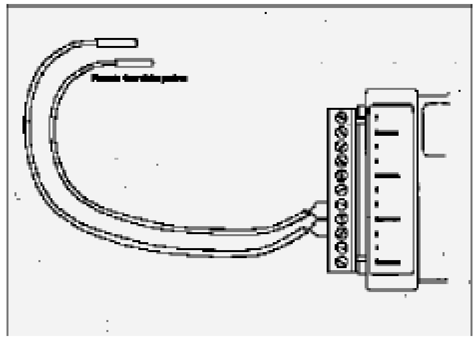

Figure 8-2: Connecting External Temperature Probes

Accessories

The ET Series Temperature sensors are thermistor probes that can be used easily with your SmartReader 8 for remote temperature measurements. The advantage of these probes is that they can be used for a wider range of temperatures, are more versatile (they can be used to record fluid temperatures), and their small size permits them to be easily inserted in hard-to-get-at locations such as in ductwork or under pipe insulation.

For more information on choosing and using thermistor probes, refer to the chapter entitled *Thermistor Temperature Probes* in Appendix C.

You can also purchase additional screw-type terminal block connectors for your SmartReader 8. These make it easy for you to permanently install sensors around buildings and systems and wire them to the unconnected blocks. When you're ready to collect data, you can simply plug in your SmartReader 8 logger. For analysis, you can just unplug it again without having to disconnect any sensors.

Other Applications

For information on how you can monitor resistance or switch status with your SmartReader 8, refer to the chapter entitled *Measuring Resistance and Switch Status* in Appendix A.

10 SmartReader 9 Pulse Logger

The SmartReader 9 is a three-channel, multi-purpose counter and logger. With it you can monitor a wide variety of measurement parameters.

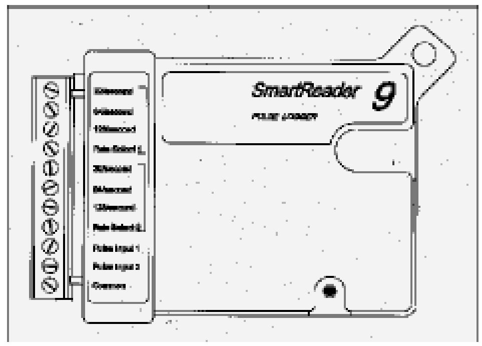

Figure 9-1: SmartReader 9

10.1 Description

Featuring two input channels configured for easy interface with common switch and transducer outputs, SmartReader 9 has the capability to count, totalize, and record voltage pulses and switch contact closure frequency as well as monitor ambient temperature from -40 to 75°C (-40 to 158°F).

10.2 How the SmartReader 9 Counts

The SmartReader 9 can count and log data from either of its two external input channels. The input channels can count the opening and closing of external switch contacts and/or the occurrence of DC voltage pulses.

SmartReader 9 keeps track of the number of times a switch opens and closes by maintaining a voltage potential across the input terminals on a continual basis. Figure 9-3 shows a simple circuit for monitoring such a switch. Every time the voltage potential changes from high to low (i.e. switch opening) and back to high again (i.e. switch closing) the logger registers a count of '1.'

Using the standard 32/sec. counting channel in the Normal Rate mode, the logger can count up to 256 switch contact closures over any eight second period (or an average of 32 closures per second). At the end of every eight second period the total number of counts is stored in a memory buffer. If the logger's sampling rate is set for eight seconds this total is immediately saved to memory as a reading. If the sampling rate is more infrequent than eight seconds the total number of counts for each eight-second period is added up and then averaged for the amount of the sampling rate.

Counting voltage pulses (also called logic inputs) is similar to counting switch contacts, only instead of having to rely on the change in internally-generated potential, the logger counts based on the voltage level of the pulse input. This pulse input must have a low level voltage less than 0.5 volts DC and the high level voltage must be from 4.5 to 24 volts DC.

Minimum pulse length and minimum interval between pulses must be 4 milliseconds. For the SmartReader 9 to register a count of '1,' the input voltage must go from a low level to a high level and back again to a low level.

You can configure each of two counting channels for any one of three possible rates: 32, 64, and 128 Hz (pulses per second). When the rate select jumper is attached to the 32/sec. setting, the logger can count up to 256 pulses every eight seconds. If the number of counts exceeds 256, the counting will restart from zero thereby producing an incorrect reading.

10.3 Quick-Start Tutorial

By setting up the following simple application, you can gain a basic understanding of how this logger works. The concepts learned here will help you use your SmartReader 9 correctly for your own applications.

This section assumes you are familiar with the basic operation of TrendReader software. If you need help, please refer to the *TrendReader software Reference Guide*.

1. Start TrendReader software and connect the SmartReader 9 to your PC via the interface cable.

2. Select equation 34 for the Pulse 1 channel, ensure that the channel is enabled, and choose Normal counting mode (do not activate the logger's Accumulate mode). Save the setup to the logger.

3. Enable realtime and observe the realtime reading. It should be 0.0 Hz.

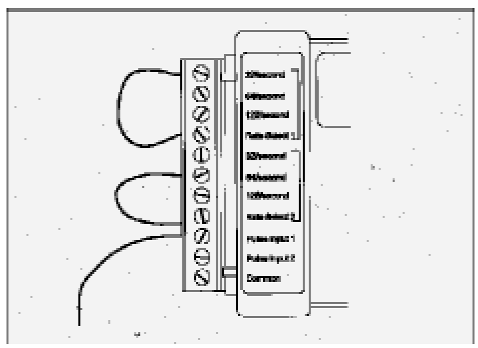

Figure 9-2: SmartReader 9 Test Configuration

4. Connect the three wires to your logger as shown in Figure 9-2 with one wire going from "Rate Select 1" to "32/second," one wire from "Rate Select 2" to "64/second" and the third wire from "Pulse Input 1" left unconnected.

5. Now tap (touch and release) the third wire to the screw head of the terminal marked "Common." Do this continuously at a rate of about once per second. The reading from the "Pulse 1" channel on your realtime screen should read close to "1.0 Hz" depending on how accurately and steadily you are tapping.

6. Try varying the rate at which you tap to see how the realtime display changes.

Each time you tap the wire to the "Common" terminal you are simulating a switch opening and closing. Note that these readings are in Hertz (Hz) which refers to the number of pulses or switch contact closures the logger detects per second. This is because the logger totalizes the number of contact closures (or pulses) it detects in periods of eight seconds at a time. It then expresses this in Hertz (or pulses per second).

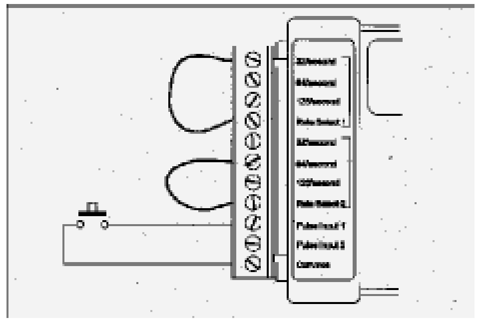

Figure 9-3: Counting Switch Contact Closures

10.4 Using Your SmartReader 9

Make sure to read the chapter entitled *Introduction to SmartReader Data Loggers* for general guidelines on how to set up your SmartReader data logger. Then read the following special notes that pertain to SmartReader 9.

1. Always make sure that the circuit you want to monitor will be compatible for use with your SmartReader 9. Refer to the *Specifications* section at the end of this chapter for details on the type of switches and logic signals that will work. Key things to note are:

   - If you are going to be monitoring the opening and closing of switches, then there must be no power source connected to the contacts (the contacts must be "dry").

   - If you wish to monitor a circuit that produces pulsed signals, then the low pulsed signal must fall between 0 and 0.5 volts DC and the high pulsed signal must be between 4.5 volts and 24 volts DC.

   - The frequency of the pulses or contact closures that you want to monitor must not exceed the maximum capability of the SmartReader 9 which is 1024 over any eight second period (using the 128 pulses/sec. channel).

2. Decide which mode you want to have your SmartReader 9 count in. For more information on the two choices you have (**Normal Rate** mode and **Accumulate** mode) refer to the Counting Modes and Equations section in this chapter.

3. Connect the Rate Select jumpers to the correct positions for your application, and choose the corresponding equation or write your own custom equation. Custom equations allow you to convert raw readings from a circuit (in Hz) to the units you require (for example, litres per second). See your *TrendReader* software *Reference Guide* for more information on custom equations).

4. Connect your transducers or transmitters and check operation through the realtime function in TrendReader software. If you can, try and exercise your transducers (make them change their output) to ensure that everything works properly. If it does, then you're ready to place your assembly in the field to start logging your data.

Wiring Notes and Considerations

For permanent applications, wiring connections can first be made to the SmartReader 9's removable terminal block. The terminal block can then be attached (with glue, for example) to a permanent fixture. When it comes time to analyze the data, the SmartReader 9 can simply be unplugged from the terminal block and brought back to your computer. After backing up the data, the logger can be returned and plugged back into the terminal block. Extra terminal blocks are available from your sales representative. When unplugging the terminal block from your logger, use care and make sure to pull it straight out so as not to break the plastic casing.

10.5 Rate Select Connections

The maximum number of pulses the logger can count in any eight-second period is 255, or about 32 pulses per second. To count more than this, you need to divide the pulse rate down to less than 32 pulses per second. This can be done by altering the Rate Select jumper connections.

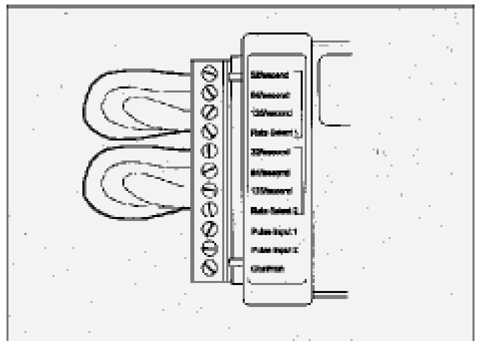

Figure 9-4: Setting the Rate Select Jumpers

For each pulse channel, the rate select terminal should connect to the 32/sec. terminal (to count every pulse), to the 64/sec. terminal (to count every second pulse) or to the 128/sec. terminal (to count every fourth pulse). Do not connect any external device to the 32/sec., 64/sec., 128/sec. or rate select terminals. These connections are only for selecting internal rate. For each channel, make sure that one of the 32, 64, or 128/sec. terminals is connected to its own rate select terminal. If you connect more than one of these at a time for each channel, the logger won't count pulses. If you don't connect any of these, the logger also won't count pulses.

10.6 Counting Modes and Equations

There are two counting modes for the SmartReader 9, **Normal Rate** and **Accumulate** mode. These modes are selected using TrendReader software. The mode you select applies to both logger channels. Make sure you choose equations for both channels that match the counting mode.

Normal Rate Mode

The **Normal Rate** mode counts and records a totalized reading in a buffer, then restarts counting at a fixed rate of once every eight seconds. The logger uses these eight-second totals to determine the actual reading it records in memory. Depending on how you set up your logger's sampling rate, the readings you obtain may be calculated by averaging the eight-second counts that make up the logger's sampling rate. For example, if your logger is set to take a reading every two minutes, then each reading the logger stores will consist of the average of fifteen eight-second intervals. If the logger counts 150
pulses in the first eight-second interval, and there are no pulses during the other fourteen eight-second intervals, your logger will average all fifteen intervals and store a raw byte value of 10. This indicates that during the two-minute interval there were an average of ten pulses per eight-second time period. The Normal Rate mode equations read out directly in Hz (pulses per second) both in realtime display and during graphing.

Accumulate Mode

The **Accumulate** mode counts and records a totalized reading to memory at a frequency matching the sampling rate that you have set for your logger. For example, if your logger is set to take a reading every two minutes, then each reading the logger stores will consist of the total of all the pulses that occurred during the two minutes. The **Accumulate** mode equations read out in pulses per logger time interval during graphing. In realtime mode, TrendReader software displays pulses per eight-second period.

Equations

There are six possible methods of operation for each of the SmartReader 9's two pulse channels. That's because there are three rate select jumper settings and two counting modes, **Normal Rate** mode and **Accumulate** mode. To collect correct data, you must select the equation that relates to your logger settings. The Rate Select Table provides you with a summary of these equations.

For each equation number listed in the following table, the corresponding information is provided:

- The counting mode the logger has been set to operate in ("A" for Accumulate mode, "N" for Normal Rate mode).
- The required setting for the rate select jumper on your logger. The maximum number of pulses that this configuration can count up to during an eight-second period (for normal rate mode) or the logger's sampling rate (for accumulate mode).
- The contents of the equation itself which you can use to create custom equations in your own choice of engineering units (i.e. flow rate in gpm, traffic in cars/minute, or speed in km/hour).

Equation Number	Counting Mode	Rate Select Setting (Pulse/Sec.)	Maximum Pulses	Equation Coding
31	A	32	256	answer0 = source0
32	A	64	512	answer0 = source0 * 2
33	A	128	1024	answer0 = source0 * 4
34	N	32	256	answer0 = source0 / 8
35	N	64	512	answer0 = source0 / 4
36	N	128	1024	answer0 = source0 / 2

Rate Select Table

10.7 Specifications

Pulse Inputs (General)

Standard Ranges: 32, 64, and 128 pulses/second.

Resolution: 8 bits

Accuracy: 32 Hz Channel: ±1 pulse/8 seconds
64 Hz Channel: ±2 pulses/8 seconds
128 Hz Channel: ±4 pulses/8 seconds

Maximum Voltage: ±40 volts (reverse polarity protected)

Connections: Removable screw-type terminal strip with single common (-) connection

Totalizing: Eight seconds. Average pulse frequency over this period must not exceed the channel range or counting will restart from zero.

Minimum Pulse width: 4 milliseconds

Input Types:

Contact: Uncommitted ("dry") switch or relay contacts (internally generated pulses). Switches with gold-plated sealed contacts recommended.

Excitation:	5 microamps contact current, 3.5 volts open circuit
Logic:	Active logic signals
Input Voltage	Low = 0 to 0.5 volts (DC) High = 4.5 to 24 volts (DC)
Input Impedance:	750K ohms

Specifications are subject to change without notice.

11 APPENDIX A Measuring Resistance and Switch Status

Measuring
Resistance
and
Switch Status

11.1 Monitoring Resistance

You can also use your SmartReader 1, 2, 4 or 8 model loggers to monitor resistance, instead of just temperature. This capability allows you to monitor devices other than just thermistors (for example, potentiometers, level indicators, or any other device that varies resistance in accordance with a known parameter).

To use the thermistor temperature channel on your SmartReader data logger to measure resistance, you must change the channel's equation number to the one for resistance. To do this, choose **Equation 44 - Resistance**, then save the changes to the logger.

Highest resolution of your resistance measurements occurs at a 10,000 ohm midpoint.

11.2 Monitoring the Status of Switches

You can also use your SmartReader 1, 2, 4 or 8 model loggers to record the status of uncommitted mechanical switch contacts (see Figure A-1). The switch you want to monitor must be a "dry" contact, which means that it must have no connection to any type of voltage, power or ground.

To use the thermistor temperature channel on your SmartReader data logger to monitor switch status, you must change the channel's equation number to the one for switch status. Then save the changes to the logger.

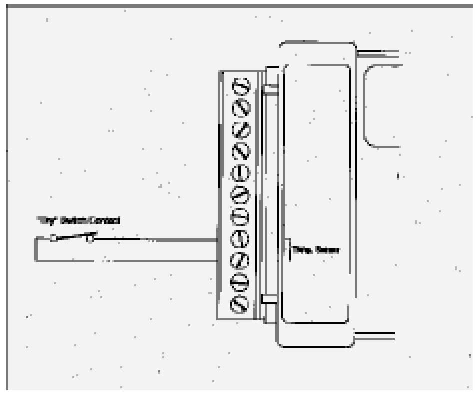

Figure A-1: Monitoring Switch Status

When monitoring the status of a switch with your data logger, keep in mind that the logger will not detect more than one change per sample period. For this reason, use a fast sample rate if you expect the switch to open and close frequently (up to a maximum of one change/eight seconds).

The type of graph produced when monitoring switch status is a square-wave (ON/OFF).

12 APPENDIX B Temperature and Relative Humidity Calibration

Temperature
and
Relative Humidity
Calibration

12.1 Temperature and Relative Humidity Calibration

This chapter provides instructions on how you can recalibrate your RH modules, EH-020A External Temperature and Relative Humidity probes and any thermistor temperature probes.

12.2 Relative Humidity Calibration

If you wish to confirm the calibration of your RH module or EH-020A Temperature and Relative Humidity probe, you can perform your own field test using the special adjustment provisions in TrendReader Software.

Recommended methods of calibration include using an accurate relative humidity test chamber or by mixing saturated salt solutions. Tests are performed at an ambient room temperature of 20 to 25C (68 to 77°F).

Calibration Chamber Test
If you intend to use a Relative Humidity Test Chamber for your calibration, make sure it has been recently tested to within ±1%. The procedure to calibrate is as follows:

1. Set up your humidity data logger with a sampling rate of 32 seconds and equation 38 on the RH channels. If you are calibrating an EH-020A probe, make sure it is properly connected to your humidity data logger and the external RH and temperature channels are enabled.

2. Start the test chamber at 5% RH and place your logger (SmartReader 2 or 4) or EH-020A probe into the test chamber. Wait 20 minutes.

3. Adjust the chamber to 20% RH and wait another 20 minutes. The wait is necessary to ensure the chamber has adequate time to settle in at the desired level.

4. Adjust the chamber to 80% RH and wait an additional 20 minutes.

5. Remove your logger or RH module from the test chamber and backup the recorded information onto your computer. If you are working with more than one logger, use the serial number as the file

name to help match the data with the logger when you make calibration adjustments.

6. Call up the logger file on your computer using TrendReader. The profile you see should reflect the test you have just performed.

7. Zoom in on the section that relates to the 20% RH level in the test chamber. Use the pointer (a mouse is best for this) and find what byte value was recorded during the latter part of the test (refer to step #3). Record this as the "b_L" reading.

8. Zoom in on the section that relates to the 80% RH level in the test chamber. Again, use the pointer to find what byte value was recorded at the end of the test (refer to step 4). Record this value as the "b_H" reading.

9. In TrendReader software, access the Low, Mid and High values for the RH channel you want to calibrate.

10. Use the following equation to calculate the "**Low**" calibration adjustment value:
    Low = $(63 \times b_L - 170 \times b_H) / 428$

11. For the "**High**" calibration adjustment value use the following equation:
    High = $40 \times (-107 / (b_H - b_L) - 1)$

12. Now enter the same values by revising the logger file and view the corrected graphs.

13. If the results are satisfactory, save the calibration changes to the logger (remember to set the RH channel's equation number back to 71).

Saturated Salt Test

Using saturated salt solutions is the most accurate *field* technique for RH calibration.

To check your humidity data logger with saturated salt solutions, gather the following equipment and materials:

- Wide mouth canning jars, 1000ml with metal lids
- #9 stoppers (Fisher #14-130N)
- Powder Funnel (Fisher #10-346-5B)
- Long Stem Funnel (Fisher #10-325D)
- Cardboard or wooden box
- Styrofoam chips (or other insulating material)
- Reagent grade salts:
  1. LiCl (anhydrous), 75gm (Fisher #L-121)
  2. $MgCl_2 \times 6H_2O$, 150gm (Fisher #M-33)
  3. NaCl, 50gm (Fisher #S-271)
- De-ionized or distilled water, 75ml for each solution

Prepare for the saturated salt test by following these steps:

1. Use the powder funnel to carefully place the salt into the center of the jar bottom.

2. Slowly pour the water onto the mound of salt, using the long stem funnel, taking care not to splash any water or salt onto the inner walls of the jar.

3. Gently swirl the saturated solution. If the salt dissolves entirely, with no crystals remaining on the bottom, the solution is not saturated and more salt must be added. There must be crystals remaining on the bottom but they must not be exposed above the water level.

4. Put a nail through the jar lid and bend into a small hook. Tape the head of the nail (or use rubber cement) to create an airtight seal of the opening. The logger with RH sensor (or EH-020A) can be inserted into the jar by first hanging it on the nail loop then screwing on the lid to the jar.

5. The saturated salt solutions should be kept in a well insulated environment to dampen any temperature changes. The equilibrium RH over saturated salt solutions is only slightly temperature dependent. However, for close calibration work to 5% RH or better, it is important to keep the temperature of the salt solution and the air space above it identical. To ensure this, the temperature of the lab should be constant.

To perform the saturated salt test, follow these steps:

1. Setup your relative humidity logger with a sampling rate of 32 seconds and equation 38 on the RH channel(s).

2. Place the jars into the box with 1 to 2 inches of Styrofoam chips on the bottom, then fill all remaining air spaces between the jars and the interior spaces of the box with the chips.

3. Cover the box with cardboard in which 6cm (2.5") diameter holes have been cut to allow access to the tops of the jars for insertion of the logger or RH module.

4. Place the logger with sensor or EH-020A module into the jar containing the **LiCl** solution (RH = 11%) **overnight** to eliminate any hysteresis effects.

5. Quickly insert the logger (or module) into the next solution by swapping the lids. Transfers should always be made **in the direction of higher RH conditions**. The jar should be well sealed. Allow at least two hours to get within three percent of the equilibrium RH. Repeat for next solution.

Salt	RH
$MgCl_2$	33%
NaCl	75%

6. Call up the graph on your computer using TrendReader software. The profile you see should reflect the test you have just performed.

7. Zoom in on the section that relates to the 33% RH level in the test chamber. Use the pointer (a mouse is best for this) and find what byte value was recorded during the latter part of the minimum two hour test portion (refer to step 5). Record this as the "b_L" reading.

8. Zoom in on the section that relates to the 75% RH level in the test chamber. Again, use the pointer to find what byte value was recorded at the end of the minimum two hour test (refer to step 5). Record this value as the "b_H" reading.

9. In TrendReader software, access the Low, Mid and High values for the RH channel you want to calibrate.

10. Use the following equation to calculate the "**Low**" calibration adjustment value:
    Low = $(71 \times b_L - 145 \times b_H) / 296$

11. For the "**High**" calibration adjustment value use the following equation:
    High = $40 \times (-74 / (b_H - b_L) - 1)$

12. Now enter the same values by revising the logger file and view the corrected graphs.

13. Save the calibration changes to the logger if the results are satisfactory (remember to set the RH channel's equation number back to 71).

12.3 Thermistor Calibration

If you do not have accurate resistance-temperature data on your thermistors (available with all interchangeable types), and want to calibrate your own, or simply want to confirm accuracies of the sensors you have, you can perform a simple calibration procedure that will give you the right information.

Items You'll Need

- an accurate thermometer, preferably one with 0.1C increments or better
- a bucket
- crushed or chipped ice
- a pot of boiling water
- a digital multimeter, preferably one with 0.1% resolution, or better

Test Procedure

Make sure the thermistors and leads you want to test are properly potted (waterproofed), insulated or otherwise protected against moisture. You should not dip an unprotected thermistor in water since the water will short the leads and produce false readings.

1. Label each thermistor sensor so that later you may easily match it to the calibration equations you produce.

2. Fill the bucket with the crushed or chipped ice. Then add water to an overflow condition. Add more ice until it is tightly packed right to the bottom of the bucket (allowing water to overflow).

3. Insert the thermometer and the thermistor probe(s) into the bucket ensuring that neither the probes nor the thermometer touch the side or bottom of the bucket. Make sure the thermistor probes' leads are long enough for you to easily take resistance readings.

4. Cover the bucket with foam chips or another suitable insulating material. Let sit for at least five minutes while the temperature stabilizes and the thermistor has a chance to respond. If the test is to continue for more than a few minutes, add more ice periodically, as before, insuring that it is tightly packed to the bottom of the bucket each time. The goal is to ensure that the thermistors are always in contact with an ice / water mixture over their entire surface.

5. Measure the temperature of the water (it should be very close to 0C) and the resistance of the thermistor. This set of readings comprises all the data we need for our *low temperature calibration point*.

6. Next, fill up a pot of water and heat it up till it reaches approximately 50°C. Once the temperature and thermistor have stabilized, again take an accurate reading of both the temperature and the thermistor's resistance, and record. This set of readings comprises our *mid temperature calibration point*.

7. Now heat the water so it boils. Record the temperature (100°C) and the resistance again. This set of readings comprises our *high calibration point*.

8. Use the calibration points obtained in the previous steps to create a thermistor equation using TrendReader software.

Note that the accuracy of the above test procedure is primarily limited by the cumulative accuracy of the
instruments you are using and how carefully you carry out the procedure. You should, however, be able to achieve accuracies within +/-1.0°C under most circumstances for thermistors with R_{25} values of between 10,000 and 100,000 ohms. You can perform tests with thermistors of other R25 values by using dry ice (for very low temperatures down to -70°C) or an oven (for temperatures up to a maximum

of 450°C).

To avoid damaging your thermistors, when calibrating, make sure to note the following:

- do not exceed the upper temperature limit rating for your high calibration point, and
- do not introduce the sensors to rapid changes in temperature (for example, from the ice bucket right into the boiling water).

13 APPENDIX C Thermistor Temperature Probes

Thermistor Temperature Pobes

13.1 Thermistor Temperature Probes

The SmartReader 1, 2, 4 and 8 data loggers can record temperature from a wide variety of external *thermistor* temperature probes. You can use the standard thermistor probes ACR makes available or you can use your own.

What are Thermistors?
Thermistors are temperature-sensitive resistors. The most common are those classified as the NTC (Negative Temperature Coefficient) type, which, at high temperatures, have a relatively low electrical resistance. At low temperatures their resistance is much higher. In between, the resistance varies with temperature at a predictable rate that can be approximated by a mathematical equation (refer to your *TrendReader Software Reference Guide*).

Thermistors provide a rugged, highly stable, and accurate means of measuring temperature. They can be used for very low temperature applications down to -80°C (-112°F) or with special probe configurations, in environments all the way up to 250°C (482°F).

In the past, thermistors have been difficult to work with because of lack of uniformity between ones of a given type. Each had to be calibrated and treated individually. A thermistor calibrated for use on one instrument or channel could not be accurately used on another, without recalibration. Now, however, interchangeable thermistors are readily available due to improved manufacturing techniques. They can be readily substituted without recalibration on a variety of channels and loggers.

13.2 ET Series Temperature Probes

The ET Series External Temperature Probes provide added versatility to the temperature measuring capabilities of your SmartReader 1, 2, 4 and 8 data loggers. Accurate, interchangeable and suitable for various defined temperature ranges, they interface easily to the terminal connector block on each logger. Each ET Series Temperature Probe consists of a *negative temperature coefficient* (NTC) Thermistor potted into the tip of a short length of stainless steel tubing.

Equations
Each ET series thermistor probe is associated with a standard linearizing equation in TrendReader Software. The equation converts the resistance values of the thermistor to accurate temperature readings depending on the specific characteristics of the thermistor type. When you load your SmartReader logger's data onto your computer it automatically accesses the equation you assigned it and the data is accurately, and automatically, scaled to suit.

Why the Different Types?
Individual thermistor types are most effectively used over specific and defined temperature ranges in

order to maximize measurement accuracy and resolution. In addition, some thermistor probes are constructed to accommodate special environmental or application conditions.

There are six different types of ET Series temperature probes available that cover a wide range of operation. The **ET-016 General Purpose Temperature Probe** is best suited for general purpose temperature measurements centered on ambient room temperature. The **ET-004 Low Temperature Probe** is ideal for low temperature measurements and comes complete with a handle and a sharp-ended stainless steel *penetration* probe so you can use it, among other applications, to monitor semi-solid frozen foods. The **ET-081 High Temperature Probe** is best suited for higher temperature measurements centered on 77C (170°F). The **ET-086 Oven Temperature Probe** is designed for even higher measurements centered on 150C (302°F). The **ET-016-STP** is used to monitor skin temperature on human and animals. The **ET-016-SMP** is used to measure pipe surface temperature. It wraps around any pipe less than 2" in diameter.

If your need for temperature measuring doesn't quite fit with the ET series probes, you may consider using a different type of probe. The *Custom Probes* section in this chapter describes how you can work with other commercially-available thermistor probes from many different suppliers.

13.3 Setup and Use

ET series thermistor probes are easy to use and setup with your loggers. To make a probe work with your particular logger, follow the instructions for using remote thermistor probes in the chapter that deals with your SmartReader model. After connecting your thermistor, make sure:

- The proper temperature equation is loaded for each enabled channel. Refer to the *Specifications* section in this chapter for the equation to use for the probe you will be working with. **Remember that if you do not use the correct equation you will end up producing misleading readings!**

- To check operation of your external probes before heading out in the field by observing realtime readings. If your probe does not appear to be reading the correct temperature, make sure it is isolated from any possible heat source that may be incorrectly affecting the reading.

Extending Cable Lengths

If you find the standard length of your ET Series Temperature Probe is not long enough for your intended application, you can extend the cable yourself up 100 ft. (30m). To prevent measurement errors, make sure the connections are properly insulated and well protected from moisture.

Applications

The ET Series Temperature Probes lend themselves to a wide range of applications. For example, to log temperatures from pipes you can insert your ET Probe in an existing thermometer well or strap the tip of the probe to pipe for a surface conduction temperature (for best thermal conductivity, epoxy the probe tip directly to the pipe and replace the pipe insulation back over top). You can also easily measure duct temperatures by simply drilling a hole in the duct and inserting your ET probe in.

13.4 Specifications

ET-016 General Purpose Probe

Description:	NTC thermistor and cable potted into the end of a 1" (25mm) long by 3/16" (5mm) diameter cylindrical stainless steel tip.
R_{25} Value:	10,000 ohms
Range:	-35 to 95°C (-30 to 200°F)
Resolution:	Refer to Figure C-1

Accuracy:	±0.2C (±0.36°F) from the temperature values listed in Table C-1 over the range of 0 to 70°C (32 to 158°F). ±0.5°C (±0.9°F) from -35 to 0°C (-30 to 32°F). ±0.5°C (±0.9°F) from 70 to 120°C (158 to 248°F)
Max. Temp.:	150°C (300°F)
Cable:	6 m (20ft) standard length with a white Teflon® protective jacket and red and black stripped and tinned leads.
Equation:	Use equation #45 in TrendReader software.

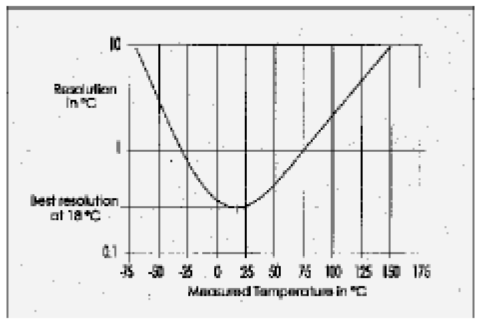

Figure C-1: Resolution Chart for the ET-016 Probe

ET-004 Low Temperature Probe

Description:	NTC thermistor and cable potted into the end of a 3 1/2" (89mm) long tapered stainless steel penetration tip with C-8_C-9 3 1/2" (89mm) long by 3/4" (19mm) diameter tapered plastic handle.
R25 Value:	2,252 ohms
Range:	-60 to 55°C (-75 to 130°F)
Max Temp:	150C (300°F)
Resolution:	Refer to Figure C-2
Accuracy:	±0.2°C (±0.4°F) from 0 to 55°C (32 to 113°F). ±0.6°C (±1.1°F) from -50 to -30°C (-58 to -22°F). ±0.3°C (±0.54°F) from -30 to 0°C (-22 to 32°F).
Cable:	3 m (10 ft), 2-wire, white Teflon® jacket, and red and black stripped and tinned leads
Equation:	Use equation #46 in TrendReader software.

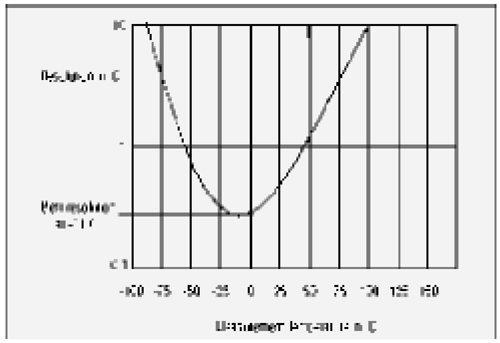

Figure C-2: Resolution Chart for the ET-004 Probe

ET-081 High Temperature Probe

Description: NTC thermistor and cable potted into the end of a 1" (25mm) long by 3/16" (5mm) diameter nickel-plated eyelet.

R_{25} Value: 100,000 ohms

Range: 10 to 170°C (50 to 335°F)

Max. Temp.: 190°C (375°F)

Resolution: Refer to Figure C-3

Accuracy: 0.5°C (0.9°F) from the temperature values listed in Table C-1 over the range of 10 to 170°C (50 to 335°F).

Cable: 6 m (20 ft.), 2-wire, individually Teflon® jacketed (one white/red lead, one yellow) and stripped ends

Equation: Use equation #47 in TrendReader software

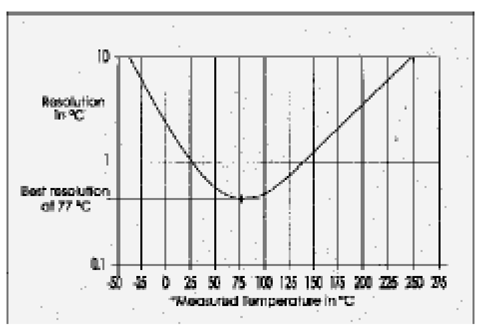

Figure C-3: Resolution Chart for the ET-081 Probe

ET-086 Oven Temperature Probe

Description: NTC thermistor and cable potted into the end of a 1" (25mm) long by 3/16" (5mm) diameter nickel-plated eyelet.

R_{125} Value: 26,266 ohms (at 125C)

Range:	70 to 255°C (155 to 490°F)
Max. Temp.:	275°C (525°F)
Resolution:	Refer to Figure C-4
Interchangeability:	±1°C (1.8°F) from the temperature values listed in Table C-1 over the range of 70 to 255°C (155 to 490°F)
Cable:	6 m (20 ft.), 2-wire, with stripped leads. The jacket of the individually-protected leads consists of a wall of Teflon®- coated glass yarn and an impregnation of chemical moisture barrier with a white Teflon® finish
Equation:	Use equation #48 in TrendReader software

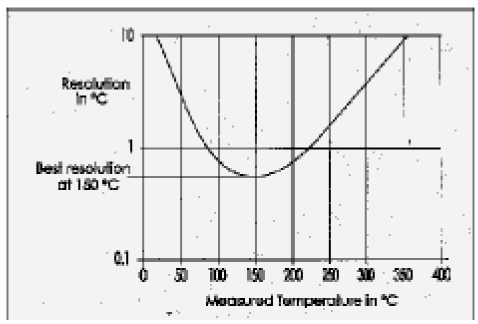

Figure C-4: Resolution Chart for the ET-086 Probe

13.5 Resistance vs. Temperature Tables

The following table lists the Resistance vs. Temperature characteristics of the ET series thermistor probes as they relate to use with the SmartReader 1, 2, 4 and 8 loggers.

For each thermistor probe model the table documents the complete set of temperature readings and corresponding thermistor resistances possible from the logger's eight-bit processor (256 byte values).

Table C-1: Temperature-Resistance Values for ET Series Probes

	Probe Model Number	ET-016	ET-004	ET-081	ET-086	ET-016	ET-004	ET-081	ET-086
Byte Number	Resistance (ohms)	ºC	ºC	ºC	ºC	ºF	ºF	ºF	ºF
255	5,000,000								
254	2,540,000	-67.5	-84.7	-35.3	6.0	-89.4	-120.5	-31.6	42.8
253	1,265,000	-58.6	-76.9	-24.2	20.0	-73.5	-106.5	-11.6	68.0
252	840,000	-53.1	-72.2	-17.3	28.8	-63.6	-97.9	0.9	83.8
251	627,500	-49.1	-68.6	-12.1	35.3	-56.3	-91.5	10.2	95.5
250	500,000	-45.8	-65.8	-8.0	40.5	-50.5	-86.5	17.7	104.9
249	415,000	-43.1	-63.5	-4.5	44.9	-45.6	-82.3	23.9	112.8
248	354,286	-40.8	-61.5	-1.5	48.7	-41.4	-78.6	29.4	119.7
247	308,750	-38.7	-59.7	1.2	52.1	-37.7	-75.4	34.2	125.8
246	273,333	-36.8	-58.1	3.6	55.2	-34.3	-72.5	38.5	131.3
245	245,000	-35.1	-56.6	5.8	57.9	-31.3	-69.9	42.5	136.3
244	221,818	-33.6	-55.3	7.8	60.5	-28.5	-67.5	46.1	140.9
243	202,500	-32.2	-54.1	9.7	62.9	-25.9	-65.3	49.5	145.2
242	186,154	-30.8	-52.9	11.5	65.1	-23.5	-63.2	52.6	149.2
241	172,143	-29.6	-51.8	13.1	67.2	-21.2	-61.3	55.6	152.9
240	160,000	-28.4	-50.8	14.7	69.2	-19.1	-59.5	58.4	156.5
239	149,375	-27.2	-49.8	16.1	71.0	-17.0	-57.7	61.0	159.9
238	140,000	-26.2	-48.9	17.5	72.8	-15.1	-56.1	63.6	163.1
237	131,667	-25.2	-48.1	18.9	74.5	-13.3	-54.5	66.0	166.1
236	124,211	-24.2	-47.2	20.2	76.1	-11.5	-53.0	68.3	169.1
235	117,500	-23.3	-46.4	21.4	77.7	-9.9	-51.6	70.5	171.9
234	111,429	-22.4	-45.7	22.6	79.2	-8.3	-50.2	72.6	174.6
233	105,909	-21.5	-44.9	23.7	80.7	-6.7	-48.9	74.7	177.2
232	100,870	-20.7	-44.2	24.8	82.1	-5.2	-47.6	76.7	179.7
231	96,250	-19.9	-43.5	25.9	83.4	-3.7	-46.4	78.6	182.1
230	92,000	-19.1	-42.9	26.9	84.7	-2.3	-45.2	80.5	184.5
229	88,077	-18.3	-42.2	27.9	86.0	-1.0	-44.0	82.3	186.8
228	84,444	-17.6	-41.6	28.9	87.2	0.3	-42.9	84.0	189.0
227	81,071	-16.9	-41.0	29.9	88.5	1.6	-41.8	85.7	191.2
226	77,931	-16.2	-40.4	30.8	89.6	2.9	-40.7	87.4	193.3
225	75,000	-15.5	-39.8	31.7	90.8	4.1	-39.7	89.0	195.4
224	72,258	-14.8	-39.3	32.6	91.9	5.3	-38.7	90.6	197.4
223	69,688	-14.2	-38.7	33.4	93.0	6.5	-37.7	92.2	199.4
222	67,273	-13.6	-38.2	34.3	94.1	7.6	-36.7	93.7	201.4
221	65,000	-12.9	-37.7	35.1	95.1	8.7	-35.8	95.2	203.2
220	62,857	-12.3	-37.2	35.9	96.2	9.8	-34.9	96.7	205.1
219	60,833	-11.7	-36.7	36.7	97.2	10.9	-34.0	98.1	206.9
218	58,919	-11.2	-36.2	37.5	98.2	11.9	-33.1	99.5	208.7
217	57,105	-10.6	-35.7	38.3	99.1	12.9	-32.2	100.9	210.5
216	55,385	-10.0	-35.2	39.0	100.1	14.0	-31.4	102.2	212.2
215	53,750	-9.5	-34.7	39.8	101.1	14.9	-30.5	103.6	213.9
214	52,195	-8.9	-34.3	40.5	102.0	15.9	-29.7	104.9	215.6
213	50,714	-8.4	-33.8	41.2	102.9	16.9	-28.9	106.2	217.2
212	49,302	-7.9	-33.4	41.9	103.8	17.8	-28.1	107.4	218.8
211	47,955	-7.4	-32.9	42.6	104.7	18.8	-27.3	108.7	220.4
210	46,667	-6.8	-32.5	43.3	105.6	19.7	-26.5	109.9	222.0
209	45,435	-6.3	-32.1	44.0	106.4	20.6	-25.8	111.2	223.6
208	44,255	-5.8	-31.7	44.6	107.3	21.5	-25.0	112.4	225.1
207	43,125	-5.4	-31.3	45.3	108.1	22.4	-24.3	113.5	226.6
206	42,041	-4.9	-30.9	46.0	109.0	23.2	-23.5	114.7	228.1
205	41,000	-4.4	-30.5	46.6	109.8	24.1	-22.8	115.9	229.6

204	40,000	-3.9	-30.1	47.2	110.6	24.9	-22.1	117.0	231.1
203	39,038	-3.5	-29.7	47.9	111.4	25.8	-21.4	118.2	232.5
202	38,113	-3.0	-29.3	48.5	112.2	26.6	-20.7	119.3	233.9
201	37,222	-2.5	-28.9	49.1	113.0	27.4	-20.0	120.4	235.3
200	36,364	-2.1	-28.5	49.7	113.8	28.2	-19.3	121.5	236.8
199	35,536	-1.7	-28.1	50.3	114.5	29.0	-18.6	122.6	238.1
198	34,737	-1.2	-27.8	50.9	115.3	29.8	-18.0	123.7	239.5
197	33,966	-0.8	-27.4	51.5	116.0	30.6	-17.3	124.7	240.9
196	33,220	-0.3	-27.0	52.1	116.8	31.4	-16.7	125.8	242.2
195	32,500	0.1	-26.7	52.7	117.5	32.2	-16.0	126.9	243.6
194	31,803	0.5	-26.3	53.3	118.3	32.9	-15.4	127.9	244.9
193	31,129	0.9	-26.0	53.8	119.0	33.7	-14.7	128.9	246.2
192	30,476	1.4	-25.6	54.4	119.7	34.4	-14.1	130.0	247.5
191	29,844	1.8	-25.3	55.0	120.5	35.2	-13.5	131.0	248.8
190	29,231	2.2	-24.9	55.5	121.2	35.9	-12.9	132.0	250.1
189	28,636	2.6	-24.6	56.1	121.9	36.7	-12.2	133.0	251.4
188	28,060	3.0	-24.2	56.7	122.6	37.4	-11.6	134.0	252.7
187	27,500	3.4	-23.9	57.2	123.3	38.1	-11.0	135.0	253.9
186	26,957	3.8	-23.6	57.8	124.0	38.8	-10.4	136.0	255.2
185	26,429	4.2	-23.2	58.3	124.7	39.5	-9.8	136.9	256.4
184	25,915	4.6	-22.9	58.8	125.4	40.3	-9.2	137.9	257.7
183	25,417	5.0	-22.6	59.4	126.1	41.0	-8.6	138.9	258.9
182	24,932	5.4	-22.2	59.9	126.8	41.7	-8.0	139.8	260.2
181	24,459	5.8	-21.9	60.4	127.4	42.4	-7.5	140.8	261.4
180	24,000	6.1	-21.6	61.0	128.1	43.1	-6.9	141.8	262.6
179	23,553	6.5	-21.3	61.5	128.8	43.7	-6.3	142.7	263.8
178	23,117	6.9	-21.0	62.0	129.4	44.4	-5.7	143.6	265.0
177	22,692	7.3	-20.6	62.5	130.1	45.1	-5.1	144.6	266.2
176	22,278	7.7	-20.3	63.1	130.8	45.8	-4.6	145.5	267.4
175	21,875	8.0	-20.0	63.6	131.4	46.5	-4.0	146.4	268.6
174	21,481	8.4	-19.7	64.1	132.1	47.1	-3.5	147.4	269.8
173	21,098	8.8	-19.4	64.6	132.8	47.8	-2.9	148.3	271.0
172	20,723	9.2	-19.1	65.1	133.4	48.5	-2.3	149.2	272.1
171	20,357	9.5	-18.8	65.6	134.1	49.1	-1.8	150.1	273.3
170	20,000	9.9	-18.5	66.1	134.7	49.8	-1.2	151.0	274.5
169	19,651	10.3	-18.2	66.6	135.4	50.5	-0.7	152.0	275.6
168	19,310	10.6	-17.8	67.1	136.0	51.1	-0.1	152.9	276.8
167	18,977	11.0	-17.5	67.7	136.6	51.8	0.4	153.8	278.0
166	18,652	11.4	-17.2	68.2	137.3	52.4	1.0	154.7	279.1
165	18,333	11.7	-16.9	68.7	137.9	53.1	1.5	155.6	280.3
164	18,022	12.1	-16.6	69.2	138.6	53.7	2.1	156.5	281.4
163	17,717	12.4	-16.3	69.7	139.2	54.4	2.6	157.4	282.6
162	17,419	12.8	-16.0	70.1	139.8	55.0	3.1	158.3	283.7
161	17,128	13.2	-15.7	70.6	140.5	55.7	3.7	159.2	284.8
160	16,842	13.5	-15.4	71.1	141.1	56.3	4.2	160.1	286.0
159	16,563	13.9	-15.1	71.6	141.7	57.0	4.7	160.9	287.1
158	16,289	14.2	-14.8	72.1	142.4	57.6	5.3	161.8	288.3
157	16,020	14.6	-14.6	72.6	143.0	58.2	5.8	162.7	289.4
156	15,758	14.9	-14.3	73.1	143.6	58.9	6.3	163.6	290.5
155	15,500	15.3	-14.0	73.6	144.3	59.5	6.9	164.5	291.7
154	15,248	15.6	-13.7	74.1	144.9	60.2	7.4	165.4	292.8
153	15,000	16.0	-13.4	74.6	145.5	60.8	7.9	166.3	293.9
152	14,757	16.3	-13.1	75.1	146.1	61.4	8.5	167.1	295.1
151	14,519	16.7	-12.8	75.6	146.8	62.1	9.0	168.0	296.2
150	14,286	17.1	-12.5	76.1	147.4	62.7	9.5	168.9	297.3
149	14,057	17.4	-12.2	76.6	148.0	63.3	10.0	169.8	298.5
148	13,832	17.8	-11.9	77.0	148.7	64.0	10.6	170.7	299.6
147	13,611	18.1	-11.6	77.5	149.3	64.6	11.1	171.6	300.7
146	13,394	18.5	-11.3	78.0	149.9	65.2	11.6	172.4	301.8
145	13,182	18.8	-11.0	78.5	150.5	65.9	12.1	173.3	303.0
144	12,973	19.2	-10.7	79.0	151.2	66.5	12.7	174.2	304.1
143	12,768	19.5	-10.4	79.5	151.8	67.1	13.2	175.1	305.2
142	12,566	19.9	-10.2	80.0	152.4	67.8	13.7	176.0	306.4
141	12,368	20.2	-9.9	80.5	153.1	68.4	14.2	176.9	307.5
140	12,174	20.6	-9.6	81.0	153.7	69.0	14.8	177.7	308.6
139	11,983	20.9	-9.3	81.5	154.3	69.7	15.3	178.6	309.8
138	11,795	21.3	-9.0	82.0	155.0	70.3	15.8	179.5	310.9
137	11,610	21.6	-8.7	82.4	155.6	70.9	16.3	180.4	312.1
136	11,429	22.0	-8.4	82.9	156.2	71.6	16.9	181.3	313.2
135	11,250	22.3	-8.1	83.4	156.9	72.2	17.4	182.2	314.3

134	11,074	22.7	-7.8	83.9	157.5	72.8	17.9	183.1	315.5
133	10,902	23.0	-7.5	84.4	158.1	73.5	18.5	184.0	316.6
132	10,732	23.4	-7.2	84.9	158.8	74.1	19.0	184.9	317.8
131	10.565	23.7	-6.9	85.4	159.4	74.7	19.5	185.8	318.9
130	10,400	24.1	-6.6	85.9	160.0	75.4	20.0	186.7	320.1
129	10,238	24.5	-6.3	86.4	160.7	76.0	20.6	187.6	321.2
128	10,079	24.8	-6.1	86.9	161.3	76.7	21.1	188.5	322.4
127	9,922	25.2	-5.8	87.4	162.0	77.3	21.6	189.4	323.6
126	9,767	25.5	-5.5	87.9	162.6	78.0	22.2	190.3	324.7
125	9,615	25.9	-5.2	88.4	163.3	78.6	22.7	191.2	325.9
124	9,466	26.3	-4.9	88.9	163.9	79.3	23.2	192.1	327.1
123	9,318	26.6	-4.6	89.5	164.6	79.9	23.8	193.0	328.2
122	9,173	27.0	-4.3	90.0	165.2	80.6	24.3	193.9	329.4
121	9,030	27.3	-4.0	90.5	165.9	81.2	24.9	194.9	330.6
120	8,889	27.7	-3.7	91.0	166.5	81.9	25.4	195.8	331.8
119	8,750	28.1	-3.4	91.5	167.2	82.5	25.9	196.7	333.0
118	8,613	28.4	-3.1	92.0	167.9	83.2	26.5	197.7	334.2
117	8,478	28.8	-2.8	92.5	168.5	83.8	27.0	198.6	335.4
116	8,345	29.2	-2.5	93.1	169.2	84.5	27.6	199.5	336.6
115	8,214	29.5	-2.2	93.6	169.9	85.2	28.1	200.5	337.8
114	8,085	29.9	-1.8	94.1	170.6	85.8	28.7	201.4	339.0
113	7,958	30.3	-1.5	94.7	171.2	86.5	29.2	202.4	340.2
112	7,832	30.7	-1.2	95.2	171.9	87.2	29.8	203.3	341.5
111	7,708	31.0	-0.9	95.7	172.6	87.9	30.3	204.3	342.7
110	7,586	31.4	-0.6	96.3	173.3	88.5	30.9	205.3	343.9
109	7,466	31.8	-0.3	96.8	174.0	89.2	31.5	206.2	345.2
108	7,347	32.2	0.0	97.3	174.7	89.9	32.0	207.2	346.4
107	7,230	32.6	0.3	97.9	175.4	90.6	32.6	208.2	347.7
106	7,114	32.9	0.7	98.4	176.1	91.3	33.2	209.2	349.0
105	7,000	33.3	1.0	99.0	176.8	92.0	33.7	210.1	350.2
104	6,887	33.7	1.3	99.5	177.5	92.7	34.3	211.1	351.5
103	6,776	34.1	1.6	100.1	178.2	93.4	34.9	212.1	352.8
102	6,667	34.5	1.9	100.6	178.9	94.1	35.5	213.2	354.1
101	6,558	34.9	2.3	101.2	179.7	94.8	36.1	214.2	355.4
100	6,452	35.3	2.6	101.8	180.4	95.5	36.7	215.2	356.7
99	6,346	35.7	2.9	102.3	181.1	96.2	37.2	216.2	358.0
98	6,242	36.1	3.2	102.9	181.9	97.0	37.8	217.2	359.4
97	6,139	36.5	3.6	103.5	182.6	97.7	38.4	218.3	360.7
96	6,038	36.9	3.9	104.1	183.4	98.4	39.0	219.3	362.0
95	5,938	37.3	4.2	104.7	184.1	99.2	39.6	220.4	363.4
94	5,839	37.7	4.6	105.2	184.9	99.9	40.3	221.4	364.8
93	5,741	38.1	4.9	105.8	185.6	100.7	40.9	222.5	366.1
92	5,644	38.6	5.3	106.4	186.4	101.4	41.5	223.6	367.5
91	5,549	39.0	5.6	107.0	187.2	102.2	42.1	224.7	368.9
90	5,455	39.4	6.0	107.7	188.0	102.9	42.7	225.8	370.3
89	5,361	39.8	6.3	108.3	188.8	103.7	43.4	226.9	371.8
88	5,269	40.3	6.7	108.9	189.5	104.5	44.0	228.0	373.2
87	5,179	40.7	7.0	109.5	190.3	105.2	44.6	229.1	374.6
86	5,089	41.1	7.4	110.1	191.2	106.0	45.3	230.2	376.1
85	5,000	41.6	7.7	110.8	192.0	106.8	45.9	231.4	377.6
84	4,912	42.0	8.1	111.4	192.8	107.6	46.6	232.5	379.0
83	4,826	42.5	8.5	112.1	193.6	108.4	47.2	233.7	380.5
82	4,740	42.9	8.8	112.7	194.5	109.3	47.9	234.9	382.1
81	4,655	43.4	9.2	113.4	195.3	110.1	48.6	236.1	383.6
80	4,571	43.8	9.6	114.0	196.2	110.9	49.3	237.3	385.1
79	4,489	44.3	10.0	114.7	197.0	111.7	49.9	238.5	386.7
78	4,407	44.8	10.4	115.4	197.9	112.6	50.6	239.7	388.3
77	4,326	45.2	10.7	116.1	198.8	113.4	51.3	240.9	389.8
76	4,246	45.7	11.1	116.8	199.7	114.3	52.0	242.2	391.4
75	4,167	46.2	11.5	117.5	200.6	115.2	52.8	243.4	393.1
74	4,088	46.7	11.9	118.2	201.5	116.1	53.5	244.7	394.7
73	4,011	47.2	12.3	118.9	202.4	116.9	54.2	246.0	396.4
72	3,934	47.7	12.7	119.6	203.4	117.8	54.9	247.3	398.1
71	3,859	48.2	13.2	120.3	204.3	118.8	55.7	248.6	399.8
70	3,784	48.7	13.6	121.1	205.3	119.7	56.4	250.0	401.5
69	3,710	49.2	14.0	121.8	206.2	120.6	57.2	251.3	403.2
68	3,636	49.7	14.4	122.6	207.2	121.5	58.0	252.7	405.0
67	3,564	50.3	14.8	123.4	208.2	122.5	58.7	254.1	406.8
66	3,492	50.8	15.3	124.2	209.2	123.5	59.5	255.5	408.6
65	3,421	51.4	15.7	124.9	210.3	124.4	60.3	256.9	410.5

64	3,351	51.9	16.2	125.7	211.3	125.4	61.1	258.3	412.3
63	3,281	52.5	16.6	126.6	212.3	126.4	61.9	259.8	414.2
62	3,212	53.0	17.1	127.4	213.4	127.5	62.8	261.3	416.1
61	3,144	53.6	17.6	128.2	214.5	128.5	63.6	262.8	418.1
60	3,077	54.2	18.0	129.1	215.6	129.5	64.5	264.3	420.1
59	3,010	54.8	18.5	129.9	216.7	130.6	65.3	265.9	422.1
58	2,944	55.4	19.0	130.8	217.9	131.7	66.2	267.5	424.1
57	2,879	56.0	19.5	131.7	219.0	132.8	67.1	269.1	426.2
56	2,814	56.6	20.0	132.6	220.2	133.9	68.0	270.7	428.3
55	2,750	57.2	20.5	133.6	221.4	135.0	68.9	272.4	430.5
54	2,687	57.9	21.0	134.5	222.6	136.2	69.8	274.1	432.7
53	2,624	58.5	21.6	135.4	223.8	137.4	70.8	275.8	434.9
52	2,562	59.2	22.1	136.4	225.1	138.5	71.8	277.6	437.2
51	2,500	59.9	22.6	137.4	226.4	139.8	72.7	279.4	439.5
50	2,439	60.6	23.2	138.4	227.7	141.0	73.7	281.2	441.8
49	2,379	61.3	23.8	139.5	229.0	142.3	74.8	283.0	444.3
48	2,319	62.0	24.3	140.5	230.4	143.5	75.8	284.9	446.7
47	2,260	62.7	24.9	141.6	231.8	144.9	76.9	286.9	449.2
46	2,201	63.4	25.5	142.7	233.2	146.2	77.9	288.9	451.8
45	2,143	64.2	26.1	143.8	234.7	147.6	79.0	290.9	454.4
44	2,085	65.0	26.8	145.0	236.2	149.0	80.2	293.0	457.1
43	2,028	65.8	27.4	146.2	237.7	150.4	81.3	295.1	459.8
42	1,972	66.6	28.1	147.4	239.3	151.8	82.5	297.2	462.7
41	1,916	67.4	28.7	148.6	240.9	153.3	83.7	299.5	465.5
40	1,860	68.3	29.4	149.9	242.5	154.9	84.9	301.8	468.5
39	1,806	69.1	30.1	151.2	244.2	156.4	86.2	304.1	471.5
38	1,751	70.0	30.8	152.5	245.9	158.0	87.5	306.5	474.7
37	1,697	70.9	31.6	153.9	247.7	159.7	88.8	309.0	477.9
36	1,644	71.9	32.3	155.3	249.5	161.4	90.2	311.5	481.2
35	1,591	72.9	33.1	156.7	251.4	163.1	91.6	314.1	484.6
34	1,538	73.9	33.9	158.2	253.4	164.9	93.1	316.8	488.1
33	1,486	74.9	34.7	159.8	255.4	166.8	94.5	319.6	491.7
32	1,435	76.0	35.6	161.4	257.5	168.7	96.1	322.5	495.5
31	1,384	77.1	36.5	163.1	259.6	170.7	97.7	325.5	499.4
30	1,333	78.2	37.4	164.8	261.9	172.7	99.3	328.6	503.4
29	1,283	79.4	38.3	166.6	264.2	174.9	101.0	331.8	507.5
28	1,233	80.6	39.3	168.4	266.6	177.1	102.8	335.1	511.9
27	1,184	81.9	40.3	170.3	269.1	179.3	104.6	338.6	516.4
26	1,135	83.2	41.4	172.3	271.7	181.7	106.5	342.2	521.1
25	1,087	84.5	42.5	174.4	274.4	184.2	108.5	346.0	526.0
24	1,039	86.0	43.6	176.6	277.3	186.8	110.5	349.9	531.1
23	991	87.5	44.8	178.9	280.3	189.5	112.7	354.0	536.5
22	944	89.1	46.1	181.3	283.4	192.3	114.9	358.4	542.2
21	897	90.7	47.4	183.8	286.7	195.3	117.3	362.9	548.1
20	851	92.4	48.8	186.5	290.2	198.4	119.8	367.7	554.4
19	805	94.3	50.2	189.4	293.9	201.7	122.4	372.8	561.1
18	759	96.2	51.8	192.4	297.9	205.2	125.2	378.3	568.2
17	714	98.3	53.4	195.6	302.1	208.9	128.1	384.0	575.7
16	669	100.5	55.1	199.0	306.6	212.9	131.3	390.2	583.8
15	625	102.9	57.0	202.7	311.4	217.2	134.6	396.9	592.5
14	581	105.4	59.0	206.7	316.7	221.8	138.2	404.1	602.0
13	537	108.2	61.2	211.1	322.4	226.7	142.2	411.9	612.2
12	494	111.2	63.6	215.8	328.6	232.2	146.4	420.5	623.5
11	451	114.5	66.2	221.1	335.5	238.1	151.1	429.9	635.9
10	408	118.2	69.1	226.9	343.2	244.8	156.3	440.5	649.8
9	366	122.3	72.3	233.5	351.9	252.2	162.1	452.4	665.5
8	324	127.0	75.9	241.1	361.9	260.7	168.7	466.0	683.4
7	282	132.5	80.2	249.9	373.5	270.4	176.3	481.8	704.4
6	241	138.9	85.1	260.4	387.4	282.0	185.2	500.7	629.4
5	200	146.7	91.1	273.3	404.5	296.0	196.0	523.9	760.2
4	159	156.6	98.7	289.8	426.6	313.8	209.7	553.6	799.8
3	119	169.9	108.9	312.5	457.0	337.9	228.0	594.5	854.5
2	79	190.1	124.1	347.6	504.2	374.2	255.4	657.7	939.5
1	39	228.8	152.9	417.8	599.8	443.9	307.1	784.0	1111.6
0	10								

13.6 Custom Probes

Obtaining thermistors through specialty suppliers allows you wide flexibility in the number of possible probe assemblies for your specific applications. That way, if you have special surface, penetration, pipe well, or immersion sensing applications, for example, you can usually get off-the-shelf or even custom probes to suit.

Contact your ACR representative for recommendations.

Writing Your Own Thermistor Equations

Each thermistor temperature probe you use with SmartReader data loggers must be associated with a standard or custom equation in the TrendReader software. This equation helps TrendReader software relate to the specific characteristics of the thermistor, or thermistor type, that you are using. That way, when you load your SmartReader data logger's data onto your computer, it can automatically produce temperature data that is not only highly accurate, but scaled into the units of your choice (e.g., in degrees Celsius, Fahrenheit, Kelvin, etc.).

TrendReader software includes a function that can automatically create custom equations for use with your own thermistors. To access this function,follow the instructions provided in the *TrendReader software Reference Guide*.

When you go out to the field you must make sure that you are using the correct thermistor probe with the channel that has the right equation assigned to it. If you don't, the data you collect will be incorrect. If you accidentally apply the wrong equation or use the wrong thermistor with a graphing file, you can correct it later. To do this, simply change the equation number for the file to the one that applies.

To avoid confusion over using many different equations and thermistor probes (on many different channels), make sure to label each of your probes with a number that relates to the right equation number. Also, try to use interchangeable thermistors wherever possible.

13.7 Where to Get Thermistors

Thermistor temperature sensors and probe assemblies are available from several different sources in a wide variety of configurations. You can obtain thermistors just by themselves and assemble them into your own probes, or order them completely pre-assembled. Some manufacturers will have off-the-shelf availability of products (or be able to guide you to one of their distributors who does) or else provide you with a custom probe configuration to suit your specific need.

13.8 How to Choose Thermistors

Obtaining thermistors can be confusing. To help, here are a variety of terms and how they relate to using them with your SmartReader data loggers.

Interchangeable

Interchangeable is a term that refers to sensors that can be freely used with the same linearizing equation (the type of equation that TrendReader software uses to convert resistance readings into temperature) and still produce accurate readings within a certain degree of accuracy (tolerance). For example, five thermistors with an interchangeability tolerance of ±0.2C should be able to produce readings within ±0.2C. Most interchangeable thermistors are available in tolerances ranging from ±1.0 down to ±0.05C within a defined temperature range (for example, 0 to 70C). This interchangeability can usually be extended well beyond this range, however, the tolerance degrades.

Interchangeable thermistors are strongly recommended if the sensors are intended for use on more than one SmartReader channel or data logger. When acquiring interchangeables, make sure to request the specific resistance-temperature data that you will need for calibration purposes.

Tolerance

Tolerance refers to the amount of uncertainty (expressed as either a percentage of the resistance value or as a temperature) to expect from a particular type of thermistor. For interchangeable thermistors, tolerance is given over a specific range of temperatures (for example, ± *1%, or* ± *0.2C over a range of 0 to 70C*).

You can also use non-interchangeable thermistors with far looser tolerances (for example, 5% or 20%), however, then you will be required to perform your own temperature calibration (see *Calibrating Thermistors*) and each one must be associated with a particular unique equation. Note that non-interchangeable thermistors are specified with a tolerance applicable at a single reference point only.

NTC and PTC

By far the most common types of thermistors have a negative temperature coefficient (NTC). These are the types that you should obtain for accurate temperature sensing. Positive Temperature Coefficient (PTC) thermistors are not applicable for use with SmartReader data loggers.

Linear Thermistors

Linear thermistors are actually two or more separate thermistors, combined together, for use with a resistor set. The result is a "thermistor" with a response curve that approaches a straight line. Because TrendReader software can accurately linearize the thermistor curve using the Steinhard-Hart equation, linear thermistors are not necessary, nor applicable, for use with SmartReader data loggers.

Resistance at 25C

One of the main considerations when choosing a thermistor is its resistance characteristics. Selecting the right one will help you maximize the resolution and accuracy of your SmartReader data logger measurements.

Your goal here should be to choose a thermistor that has a resistance of approximately 10,000 ohms at the midpoint of the temperature range in which you want to monitor. The graph in Figure C-5 shows how the temperature resolution from your loggers changes at different resistance values. From the graph you can see that the best resolution occurs at 10,000 ohms.

A good indicator of this is the thermistor's $\mathbf{R}_{25}$ rating which is a standard value identifying its resistance measured at 25°C. To decide which $\mathbf{R}_{25}$ value is best for your applications first determine the midpoint of the temperature range you want to monitor. Then refer to Figure C-6 which shows the best $\mathbf{R}_{25}$ values for different temperature midpoints.

If you wish to measure temperature centered on the boiling point of water (100°C), for example, the best thermistor to use would have a resistance of approximately 300,000 ohms at 25C (and thus approximately 10,000 ohms at 100C).

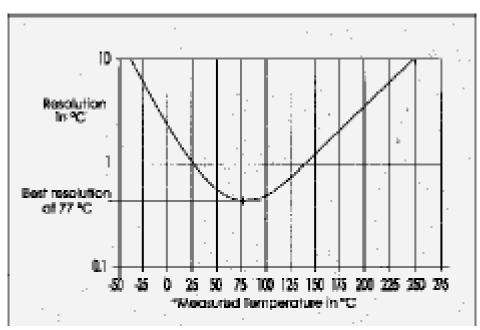

Figure C-5: Thermistor Resolution Chart

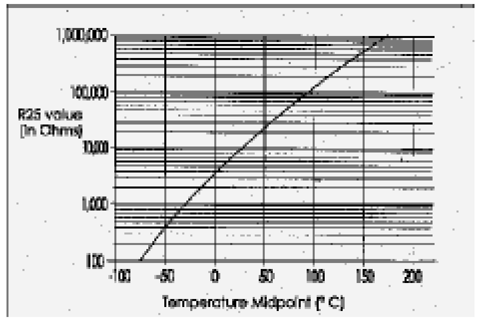

Figure C-6: Choosing an R_{25} Value

Resistance Curves

Always request the Resistance-Temperature data of the thermistors you obtain. If you are getting "interchangeable" sensors, this data will make initial calibration very easy.

13.9 Probe Assemblies

Because unprotected thermistors are poorly suited to most temperature measurements, they must be mounted in some type of probe assembly.

A probe may simply be a thermistor on the end of a cable protected by a special potting compound, or a drilled-out bolt for installation into a tapped hole or pipe well. An ET Series Temperature Probe is simply a thermistor attached to the end of a length of high-temperature cable, then mounted, with special potting, into the end of a short length of stainless steel tubing. Endless possibilities exist. Many thermistor manufacturers offer custom probe assemblies to fit specific applications. Thermistor distributors such as Omega® usually have standard thermistor probe assemblies.

When making a probe, the thermistor should be soldered to a length of wire or cable and inserted into the probe, generally with epoxy in the probe tip to give mechanical strength and to create better thermal contact with the probe. Additional epoxy is used to seal the back end. Make sure not to get any air bubbles into the probe or the pressure resulting from high temperature monitoring may destroy the potting.

Types of Cables

Thermistors require two-conductor cables. There are no limitations here which cable you can use as long as the environment you intend to use the probes in will not exceed the specific temperature ratings of the cable itself. A good cable to use is 22 gauge stranded with high-temperature Teflon® or Kynar™ insulated leads.

Shielded cable is not usually required unless the sensors will be used in an environment with high electromagnetic interference (EMI). Then we suggest running the sensors in a metal sheath or conduit that is grounded to a suitable point outside the area of EMI. The sheath should extend entirely over the end of the thermistor. If shielded cable is used, then the shield should be grounded to the **Common** connection directly on your data logger.

Cable Lengths

The high resistivity of thermistors affords them a distinct measurement advantage over other methods when using long lengths of cable. For example, a thermistor probe that has a typical value of 10K ohms at 25C will change its resistance about 4% per degree C. Even with 100 ft. (30m) leads (which may add an extra 10 ohm resistance) an error of less than 0.025C will be introduced. The higher the resistance of the thermistor, the more negligible this error will become.

Keeping this in mind you will be able to run cables up to 100 feet (30 meters) without appreciable accuracy degradation. If you intend on using longer cables, such factors as electrical noise and capacitance must be considered.