INSTRUCTION MANUAL

# AM32 Multiplexer

Revision: 2/96

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# AM32 MULTIPLEXER MANUAL

## 1.0 FUNCTION

The AM32 multiplexer increases the number of sensors that may be scanned by the CR10(X), 21X, and CR7 dataloggers. Sensor leads are connected to the AM32. Mechanical relays are used to switch the sensor signal(s) to a cable connected to the datalogger. Two lines are switched simultaneously; a maximum of 32 sets of 2 lines (32 channels) may be scanned.

Signals from analog sensors are multiplexed into either a single-ended or a differential channel. For a discussion of single-ended versus differential analog measurements, please consult the Measurement Section of your datalogger manual.

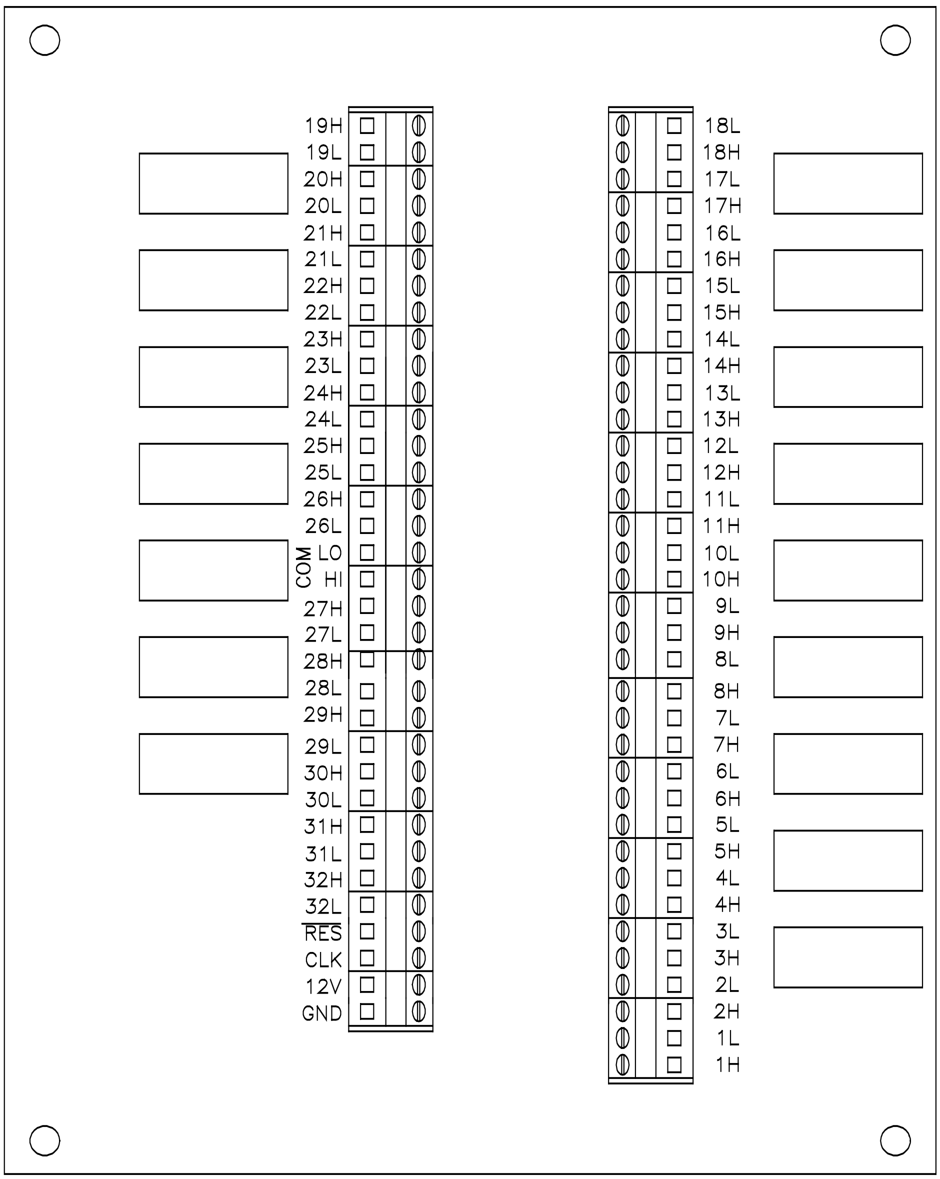


**FIGURE 1-1. Plan view of the AM32 Relay Multiplexer with cover plate removed.**

With limitations, it is possible to multiplex selected sensors of different types (e.g. thermocouples and soil moisture blocks, see example in section 7.3). In some cases, the AM32 is used to multiplex sensor excitation or continuous analog outputs.

An enclosure is required for field use. For thermocouples the AM-ENCT enclosure is recommended to reduce thermal gradients across the AM32. If thermocouples are not being measured, use the model AM-ENC enclosure.

## 2.0 SPECIFICATIONS

| | |
|---|---|
| **Power*** | unregulated 12 VDC (9.6 V to 16 V) - See Figure 4 for implications of low power to relay actuation. |
| **Current drain** | |
| **Quiescent** | < 15uA |
| **Active** | 25mA (average) |
| **Reset*** | > 3.5 V active; <1.5 V inactive |
| **Clock*** | Clocks on the rising edge from < 1.5V to > 3.5V, 5msec minimum pulse width. |
| **Operating Temp.** | -40°C to +65°C |
| **Operating humidity** | 0 - 95%, non-condensing |
| **Dimensions (L x W x D)** | |
| **Without field encl.** | 21.6 x 16.5 x 2.5 cm (8.5" x 6.5" x 1.0") |
| **Field enclosure** | 34.3 x 28.7 x 14.1 cm (13.5" x 11.3" x 5.5") |
| **Weight** | 2 lbs (approx.) |
| **in enclosure** | 12 lbs (approx.) |
| **Max switching cur.**** | 500mA |

* Reset, Clock and +12V inputs are limited to +16V by 1.5KE20A transzorbs.

** Switching currents greater than 30mA (occasional 50mA is acceptable) will degrade the contact surfaces of the mechanical relays, increasing their resistance. This process adversely affects the suitability of these relays to multiplex low voltage signals. Although a relay used in this manner will not be of use in future low voltage measurements, it may continue to be used for switching current in excess of 30mA.

CONTACT SPECIFICATIONS

| | |
|---|---|
| **Initial contact resistance** | .050 ohm max. |
| **Initial contact bounce** | 1ms max. |
| **Contact material** | Gold clad silver alloy |
| **Electrostatic capacitance** | 3pF |
| **Minimum expected life** | |
| **Mechanical (at 50cps)** | $10^8$ open |
| **Electrical (at 20cps)** | $10^5$ open at 4A 250V DC<br>$2 \times 10^5$ open at 3A 30V DC |

CHARACTERISTICS at 25°C, 50% RH

| | |
|---|---|
| **Operate time** | 8 to 15 ms (See Figure 4.) |
| **Release time** | 5 ms approx. |

## 3.0 OPERATION

### 3.1 THE CONTROL TERMINALS

The control terminals are located along the left terminal strip as shown in Figure 1-1.

The CR10(X), 21X and CR7 dataloggers are connected to the AM32 as shown in Figure 3-1.

The maximum terminal opening is 1.5 mm, about the size of a 12 gage wire.

The CR10(X) 12VDC supply and ground terminals are connected to the AM32 12V and ground terminals. One control port is used for clocking and one for reset.

With the CR7 and 21X, the 12V and ground terminals are connected to the AM32's 12V and GND terminals. One control port is used for reset, and one *switched excitation* channel is used for clock.

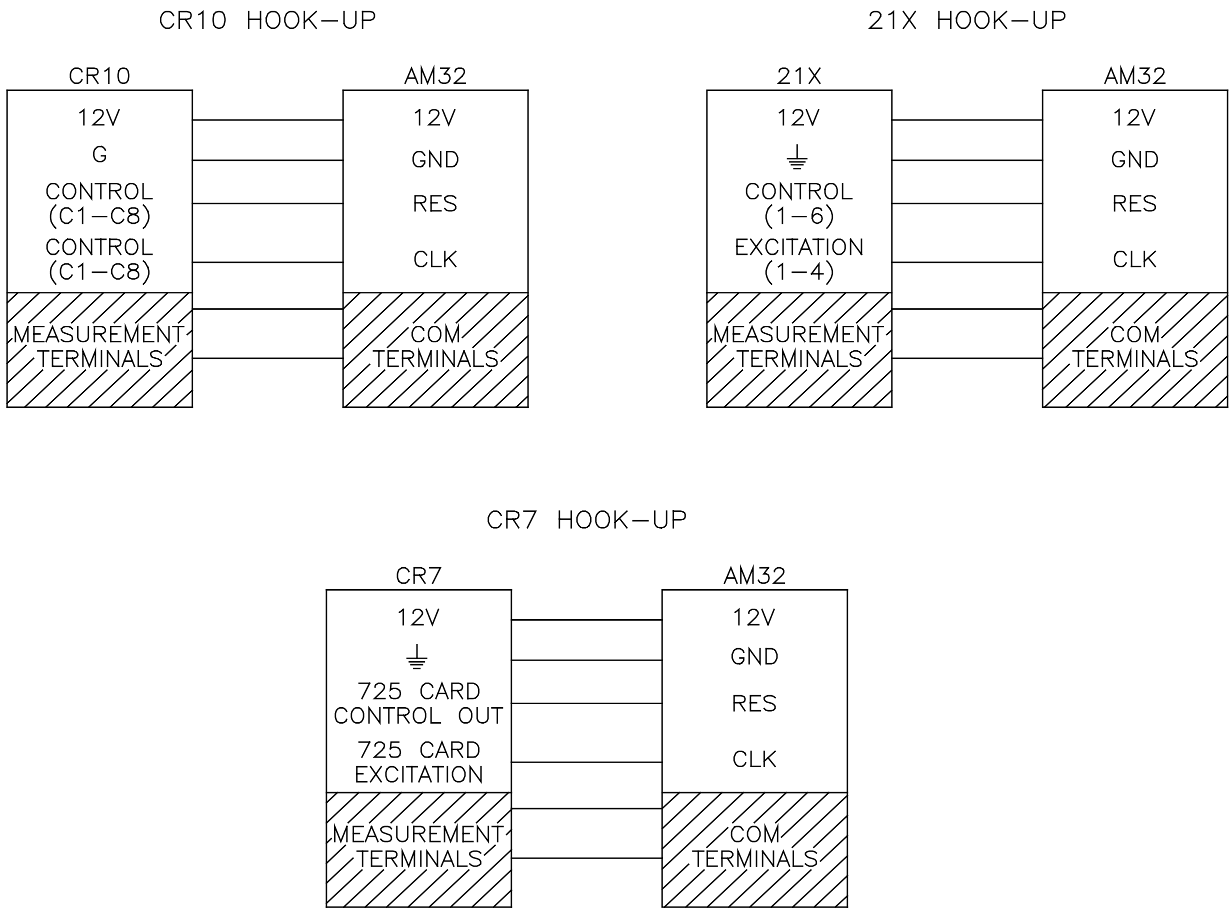


**FIGURE 3-1. Hook-up diagrams for datalogger to AM32 connections.**

### 3.1.1 RESET

Reset (RES) controls activation of the multiplexer. A voltage (3.5VDC < voltage < 16VDC) applied to this terminal activates the multiplexer. When this line is dropped to less than 0.9VDC, the multiplexer enters a low current drain state. Reset is connected to a datalogger control port. Instruction 86 with option code 41 - 48 (set port high) and 51 - 58 (set port low) is generally used to control the port.

With older CR7s or 21Xs that do not have Instruction 86 with port control capabilities, Instruction 20 is used to control the port.

### 3.1.2 CLOCK

The clock line CLK controls the multiplexer switching. When the multiplexer is activated with RES set high, the multiplexer's common lines (COM HI, COM LO) are not connected to any of the sensor input terminals. When the first clock pulse is received, the common lines are connected to multiplexer channel 1 (1H, 1L). When a second clock pulse is received, the common lines are connected to multiplexer channel 2 (2H, 2L); and so forth. The multiplexer is clocked on the leading edge of the voltage pulse, (i.e. voltage level must raise from 1.5VDC to above 3.5VDC to clock). The pulse width must be at least 5 ms. An additional delay is necessary before the measurement to ensure that the relay has adequate time to close.

With the CR10(X) a control port is generally used to clock the multiplexer. Instruction 86 with the pulse port option (command code 71 through 78 - pulse 10 ms) may be used to clock the multiplexer.

With the CR7 and 21X, one switched excitation channel is used to clock the multiplexer. Instruction 22 should be programmed to provide a 10ms delay with a 5000mV excitation. If switched excitation channels are unavailable, a control port may be used. However, the pulse port instruction of the CR7 and 21X has a fixed pulse time of 100msec. A 100msec delay per measurement may be unacceptable.

### 3.1.3 GROUND

If the AM32 is powered by the datalogger supply, then the multiplexer ground terminal is connected to datalogger power ground. If a separate supply is used to power the AM32, the ground of that supply should be connected to the datalogger power supply ground or directly to earth ground (Figure 3-2). The datalogger should always be earth grounded, and there should be only one earth ground per system. If several earth grounds exist, they should be tied together by a large diameter wire (12 AWG minimum).

### 3.1.4 POWER SUPPLY

The AM32 requires a continuous 9.6 to 16 VDC power supply for operation. The multiplexer's current drain is less than 15 microamps while quiescent and is typically 25 milliamps at 12 VDC when active. Power supply connections are made at the terminals labeled 12V and GND.

In many applications, it may be convenient to power the AM32 from the datalogger's battery. Campbell Scientific offers alkaline and sealed rechargeable power supplies with the 21X and CR10(X) dataloggers. The CR7 is available with a sealed rechargeable supply only. The datalogger alkaline supply (7.5 AmpHr) can be used to power the AM32 in applications where the system current drain is low or where frequently replacing the batteries is not a problem. Sealed rechargeable supplies are recommended where solar- or AC- charging sources are available. For power-intensive operations, a higher capacity, external, rechargeable, 12VDC source should be considered.

To determine the life of the power supply, calculate the system current drain and divide it into the power supply Amp-Hour rating. Table 3-1 provides CR10(X)/AM32 current drains for given scan rates and measurement integration times. At a minimum, the power supply must be able to sustain the system between site visits over the worst environmental extremes.

If a 21X power supply is used to power the AM32, all low level analog measurements (thermocouples, pyranometers, thermo-piles, etc.) must be made differentially. This procedure is required because slight ground potentials are created along the 21X analog terminal strip when the 12V supply is used to power peripherals. This limitation reduces the number of available analog input channels and may mandate the use of an external supply for the AM32 (Figure 3-2).

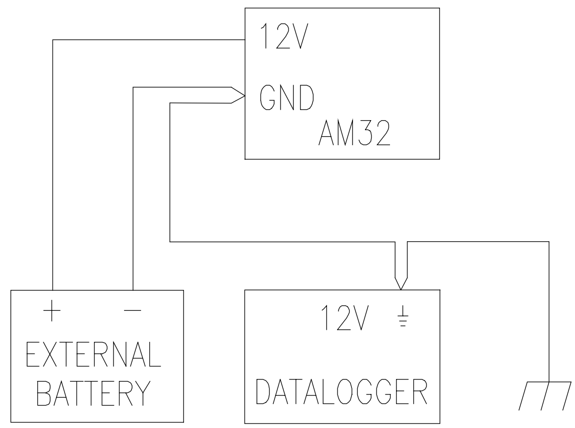


**FIGURE 3-2. Power and ground connections for external power supply.**

Low power and high ambient temperatures may affect the actuation time of the multiplexer relays (Figure 3-3). A measurement error will result if the relay is not closed when the measurement begins. To solve this problem, a delay can be programmed after the clocking instruction but, before the measurement instruction (refer to Section 4).

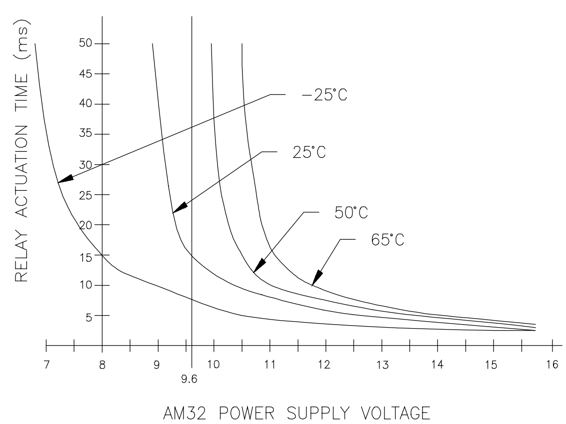


**FIGURE 3-3. Actuation time of relays versus temperature (°C) and battery voltage.**

**TABLE 3-1. CR10(X)/AM32 average current drain making differential measurements on 32 thermocouples.**

| | integration time | | |
|---|---|---|---|
| **SCAN RATE** | **SLOW** | **60 Hz REJECTION** | **FAST** |
| 2 MIN => | 0.9mA | 1.1mA | 0.8mA |
| 2 SEC => | 22mA | 39mA | 17mA |

### 3.2 THE MEASUREMENT TERMINALS

The COM terminals are where the datalogger connects to the multiplexer for signal transfer. The terminals labeled 1H, 1L...32H, 32L are for connecting sensors to the multiplexer (Figure 1-1). The sensor terminals are connected to the COM terminals on every clock pulse (clocking is explained in Section 4).

The 32 sensor terminals run the length of the multiplexer in two parallel groups. Each channel has two terminals labeled H and L, standing for High and Low. As the AM32 receives clock pulses from the datalogger, each channel is connected sequentially with COM terminals. For example, when the first clock pulse is received from the datalogger 1H is connected with COM HI and 1L with COM LO. When the second clock pulse is received the first channel is disconnected and the second channel is connected to the COM terminals.

## 4.0 DATALOGGER PROGRAMMING

When a number of similar sensors are being multiplexed, the Instructions to clock the AM32 and to measure the sensors are entered within a program loop. The generalized structure of a program loop is outlined below.

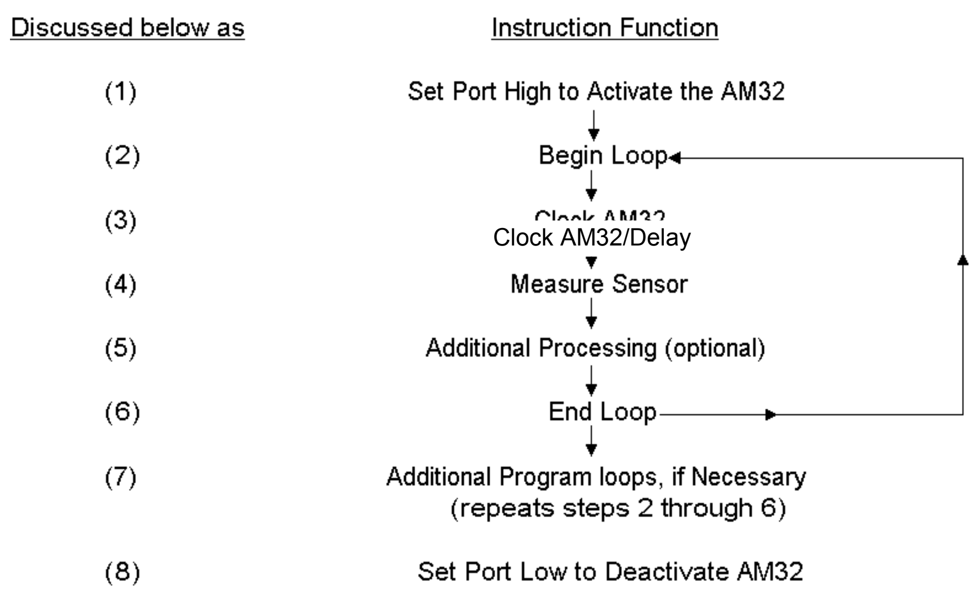


**FIGURE 4-1. Single loop instruction sequence**

## 4.1 SINGLE LOOP INSTRUCTION SEQUENCE

**(1 and 8) Activate/Deactivate AM32** - The control port connected to reset (RES) is set high to activate the AM32 prior to the measurement sequence and set low following the measurement loop(s). Instruction 86 with Port commands (41-48 set high, 51-58 set low) is used to set the port.

Instruction 20 is used to set the port in the pre OS7 CR7 or pre OSX-0.1, 1.1, or 2.1 21X dataloggers.

**(2 and 6) Loop and End Loop** - A programming loop is defined by Instruction 87 (Loop), and by Instruction 95 (End). Within Instruction 87, the 2nd parameter (iteration count) defines the number of times that the instructions within a loop are executed before the loop is exited. The iteration count is typically equal to the number of sensors to be read in the loop.

**(3) Clock/Delay** - With a CR10(X) the clock line is connected to a control port. Instruction 86 with the pulse port command (71 - 78), sets the clock line high for 10 ms. Instruction 22 is used to delay for an additional 10 ms.

When controlled by a 21X or CR7 datalogger, the clock line may be connected to either an excitation or a control port. Connection to an excitation channel is preferred because only one Instruction 22 is required to send the clock pulse. Instruction 22 should be programmed to provide a 10ms delay with a 5000mV excitation. A control port can be used to clock the AM32 if no excitation channels are available.

```
P22      Excitation with Delay
  01:       2         EX Chan 2
  02:       1         Delay w/EX (units=.01sec)
  03:       1         Delay after EX (units=.01sec)
  04:   5000          mV Excitation
```

The pre CR7 and 21X instruction sequence required to clock with a control port is as follows: Instruction 20 (set port high), then instruction 22 (delay of 20 ms without excitation) followed by instruction 20 (set port low).

**(4) Measure -** Enter the instruction needed to measure the sensor(s). Only one repetition is entered for the measurement instruction.

The Input Location in which to store the measurement is Indexed so that it is incremented by one with each pass through the loop.

**INDEXING**

An Input Location entered in an instruction that is in a loop may be Indexed by keying "C", before keying "A" to enter the Input location; two dashes (--) will appear at the right of the display. This causes the Location to be incremented with each pass through the loop. The loop counter is added to the indexed value to determine the actual Input Location the instruction acts on.

> **NOTE:** If more than 28 input locations are utilized, then additional input locations must be assigned using the datalogger *A mode. Consult your datalogger manual for details.

**(5) Optional Processing** - Additional processing is sometimes required to convert the reading to desired units. If it is important to make all the measurements as close to one point in time as possible, the optional processing should be done in a separate loop.

Indexing of input locations may be required during optional processing. The first program example demonstrates this technique.

**(7) Additional Loops** - Additional loops may be used if sensors that require different measurement instructions are connected to the same multiplexer. In this instance, sensors that are measured by the same instruction should be grouped in sequential input channels. Each group of sensors is measured in a separate loop (steps 2 through 6, Figure 4-1). Each loop contains clock and measurement instructions. All loops must reside between the instructions that activate and deactivate the AM32 (Steps 1 and 8).

## 4.2 MULTIPLE LOOP INSTRUCTION SEQUENCE

As shown in Table 5-1, the program to operate the AM32 is essentially the same for all Campbell Scientific dataloggers. To measure sensors of different types, different measurement instructions may be used within successive program loops.

The example in Section 7.3 is an example of a multiple loop instruction sequence where each loop is terminated with a P95 instruction  The multiplexer is not reset between loops.  Section 7.3 demonstrates measurement of two dissimilar sensor types (i.e. soil moisture blocks and thermocouples).

## 5.0 SENSOR HOOK-UP & MEASUREMENT EXAMPLES

This section covers sensor-AM32 connections as well as AM32-datalogger measurement connections.  The following are examples only and should not be construed as the only way to make a particular measurement.  See the Measurement Section of your datalogger manual for more information on the basic measurements.

### 5.1 SINGLE-ENDED ANALOG MEASUREMENTS

**Sensor to Multiplexer wiring** - One single-ended analog signal can be connected to each AM32 input channel for measurement.

Multiplexer to Datalogger wiring - Signal lines from the COM terminals are input into one single-ended channel and ground.  Signal grounds are tied to analog ground (AG) for the CR10(X) and datalogger ground for the 21X and CR7.  Up to 32 single-ended measurements can be made using one single-ended datalogger channel.

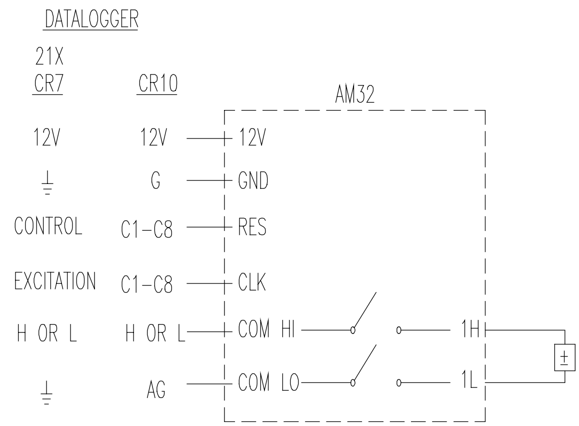


**FIGURE 5-1.  Single-Ended Measurement**

**TABLE 5-1. EXAMPLE PROGRAMS - GENERALIZED PROGRAM LOOPS FOR THE 21X, CR10(X), AND CR7.**

## 21X SAMPLE PROGRAM

| | | |
|---|---|---|
| * | 1 | Table 1 Programs |
| 01: | 60 | Sec. Execution Interval |
| ACTIVATES MULTIPLEXER | | |
| 01: | P20 | Set Port |
| 01: | 1 | Set high |
| 02: | 1 | Port Number |
| BEGINS MEASUREMENT LOOP | | |
| 02: | P87 | Beginning of Loop |
| 01: | 0 | Delay |
| 02: | 32 | Loop Count |
| CLOCK PULSE/DELAY | | |
| 03: | P22 | Excitation with delay |
| 01: | 1 | EX Chan |
| 02: | 1 | Delay w/EX (units= .01 sec) |
| 03: | 1 | Delay after EX (units= .01 sec) |
| 04: | 5000 | mV Excitation |
| 04: USER SPECIFIED MEASUREMENT INSTRUCTION | | |
| ENDS MEASUREMENT LOOP | | |
| 05: | P95 | End |
| DEACTIVATES MULTIPLEXER | | |
| 06: | P20 | Set Port |
| 01: | 0 | Set low |
| 02: | 1 | Port Number |

## CR7 SAMPLE PROGRAM

| | | |
|---|---|---|
| * | 1 | Table 1 Programs |
| 01: | 60 | Sec. Execution Interval |
| ACTIVATES MULTIPLEXER | | |
| 01: | P20 | Set Port |
| 01: | 1 | Set high |
| 02: | 1 | EX Card |
| 03: | 1 | Port No. |
| BEGINS MEASUREMENT LOOP | | |
| 02: | P87 | Beginning of Loop |
| 01: | 0 | Delay |
| 02: | 32 | Loop Count |
| CLOCK PULSE/DELAY | | |
| 03: | P22 | Excitation with delay |
| 01: | 1 | EX Chan |
| 02: | 2 | EX Chan |
| 03: | 1 | Delay w/EX (units= .01 sec) |
| 04: | 1 | Delay after EX (units= .01 sec) |
| 05: | 5000 | mV Excitation |
| 04: USER SPECIFIED MEASUREMENT INSTRUCTION | | |
| ENDS MEASUREMENT LOOP | | |
| 05: | P95 | End |
| DEACTIVATES MULTIPLEXER | | |
| 06: | P20 | Set Port |
| 01: | 0 | Set low |
| 02: | 1 | EX Card |
| 03: | 1 | Port No. |

## CR10(X) SAMPLE PROGRAM

| | | |
|---|---|---|
| * | 1 | Table 1 Programs |
| 01: | 60 | Sec. Execution Interval |
| ACTIVATES MULTIPLEXER | | |
| 01: | P86 | Do |
| 01: | 41 | Set high Port 1 |
| BEGINS MEASUREMENT LOOP | | |
| 02: | P87 | Beginning of Loop |
| 01: | 0 | Delay |
| 02: | 32 | Loop Count |
| CLOCK PULSE | | |
| 03: | P86 | Do |
| | 72 | Pulse Port 2 |
| DELAY | | |
| 04: | P22 | Excitation with delay |
| 01: | 1 | EX Chan |
| 02: | 0 | Delay w/EX (units=.01 sec) |
| 03: | 1 | Delay after EX (units=.01 sec) |
| 04: | 0 | mV Excitation |
| 05: USER SPECIFIED MEASUREMENT INSTRUCTION | | |
| ENDS MEASUREMENT LOOP | | |
| 06: | P95 | End |
| DEACTIVATES MULTIPLEXER | | |
| 07: | P86 | Do |
| 01: | 51 | Set low Port 1 |

### 5.2 DIFFERENTIAL MEASUREMENTS

**Sensor to Multiplexer wiring** - One differential analog signal can be connected to each AM32 input channel for measurement.

**Multiplexer to Datalogger wiring** - Signal lines from the COM terminals are connected to a differential analog input. Up to 32 differential measurements can be made using one differential datalogger channel.

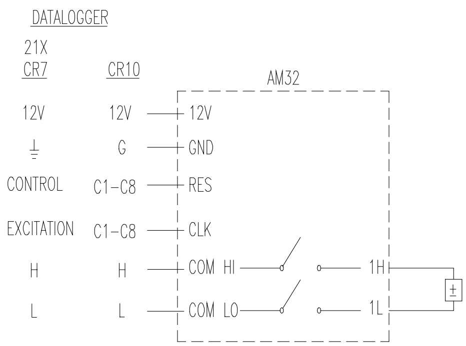


**FIGURE 5-2. Differential measurement.**

### 5.3 HALF BRIDGE MEASUREMENTS

#### 5.3.1 HALF BRIDGE MEASUREMENT WITH COMPLETION RESISTOR AT DATALOGGER

Sensor to Multiplexer wiring - A half bridge measurement can be made by connecting the sensor resistance to an AM32 input channel.

Multiplexer to Datalogger wiring - Signal lines from the multiplexer COM terminals are input to an Excitation channel and a single-ended input. A precision completion-resistor ties the analog input channel to analog ground in the CR10(X) or to datalogger ground in the 21X or CR7.

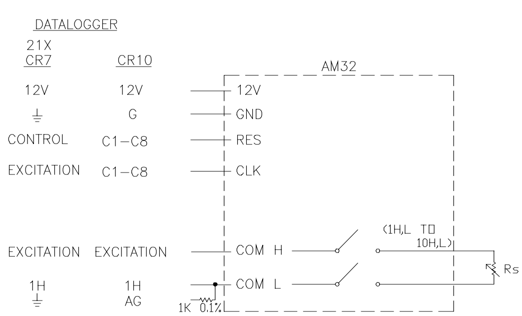


**FIGURE 5-3. Half Bridge measurement with resistor at the datalogger.**

### 5.4 MIXED SENSOR TYPES

In applications where sensors types are mixed, multiple hook-up configurations and programming sequences are possible.

Section 7.3 contains an example of multiplexing soil moisture blocks and thermocouples. If you need assistance in multiplexing markedly different sensor types, please contact Campbell Scientific for support.

## 6.0 THERMOCOUPLE WIRING AND MEASUREMENT CONSIDERATIONS

This section contains considerations for multiplexing thermocouple measurements. The Measurement Section of your datalogger manual contains a thorough discussion of thermocouple measurement and error analysis; these topics will not be covered here.

### 6.1 REFERENCE JUNCTIONS

Thermocouple measurements must always be referenced to a known temperature. As shown in Figure 6-1 and 6-2, two configurations are possible, reference at the datalogger or reference at the AM32. If the multiplexer is enclosed in an AM-ENCT, the recommended reference junction location is at the multiplexer.

**DATALOGGER REFERENCE** - The 21X and the CR7 723-T (Analog Input card with RTD) have built-in temperature references. For the CR10(X), the 10TCRT Thermocouple Reference may be purchased and installed on the wiring panel between the two analog input terminal strips.

A reference temperature sensor at the datalogger should be insulated to minimize thermal gradients. When using the 21X, the terminal strip cover, supplied with datalogger, should be in place. When using the CR7, its cover-plate should be attached. When using the CR10(X), the user may insulate the datalogger.

When the reference junction is located at the datalogger, the signal wires between the datalogger and the AM32 must be of the same wire type as the thermocouple (Figure 6-1). The 21X and CR7 have reference temperature sensors installed under differential input channels 5 and 7, respectively. To reduce reference temperature errors, measure the thermocouples on these channels when using the datalogger reference. Figures 6-1 and 6-2 depict type T thermocouple applications, but other thermocouple types (e.g. E, J, and K) may also be measured and linearized by the dataloggers. Also, type R, S, and B thermocouples can be read with Library Special software installed in the datalogger.

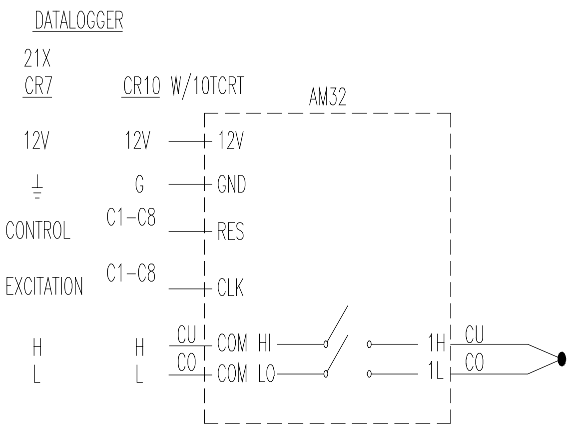


**FIGURE 6-1. Differential thermocouple measurement with reference junction at the datalogger.**

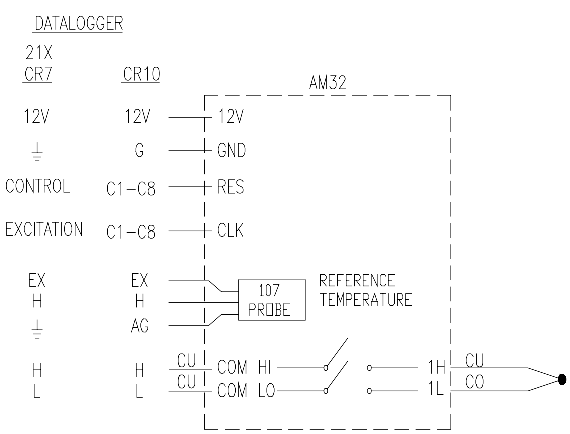


**FIGURE 6-2. Differential thermocouple measurement with reference junction at the AM32.**

If the thermocouple reference is at the datalogger (i.e. thermocouple lead is used to connect the datalogger and multiplexer), concurrent measurement of other low level signals is not recommended. Two problems will be encountered if this is done. Both problems result from the compositional differences of the thermocouple wires.

1. An extraneous thermocouple voltage will be added to the non-thermocouple signal at the junction of dissimilar metals (e.g. the multiplexer COM terminals). The magnitude of this signal will vary with the temperature difference between the datalogger and the AM32.

2. Some thermocouple wires have a greater resistance than copper, thus adding resistance to the non-thermocouple sensor circuit. For example, constantan is approximately 26 times more resistive than copper.

If a mix of TC's and other low level signals are multiplexed through the AM32, it is generally best to locate the reference junction on the AM32, as shown in Figure 6-2. So that copper wire, instead of thermocouple wire, can be run between the AM32 and datalogger. If the other sensors have larger outputs (e.g. soil moisture blocks, Figure 7-3) these problems are negligible.

**AM32 REFERENCE -** An external reference, usually a 107 Temperature Probe, may be located at the AM32 as shown in Figure 6-2. This approach requires an additional single-ended analog input to measure the reference. Locate the reference between the terminal strips, near the COM terminals and, when practical, measure the thermocouples on channels that are in close proximity to the COM terminals in order to minimize thermal gradients. For best results, the AM32 should be shielded and insulated from thermal sources in an AM-ENCT.

## 6.2 THERMAL GRADIENTS

Thermal gradients between the AM32's sensor input terminals and its COM terminals can cause errors in thermocouple readings. For example, with type T thermocouples, a one degree gradient between input terminals and the COM terminals will result in a one degree measurement error (approximately). The aluminum cover plate helps to minimize gradients.

When an enclosure is used, gradients induced from heat conducted along the thermocouple wire can be minimized by coiling some wire inside the enclosure. This procedure allows the heat to dissipate before it reaches the terminal.

Some consideration should be made as to what type of thermocouple wire to use. Different types and sizes of wires, or metals, have different characteristics including thermal conductivity.

# 7.0 PROGRAMMING EXAMPLES

## 7.1 CR10(X) PROGRAMMING EXAMPLE: 32 SOIL MOISTURE BLOCKS, MODEL 223

This example will use a CR10(X) datalogger to measure Model 223 Soil Moisture blocks.

This program samples the 32 soil moisture potentials every 6 hours (360 minutes).

The leads from the block electrodes are connected directly to the AM32; the lead from the center electrode attaches to high and the lead from the outer electrode to low. It is imperative that this wiring convention remains consistent so that current flow is confined to the interior of the block minimizing ground loops.

A 1k ohm resistor between the input and excitation channel is used to complete the half bridge as shown in Figure 7-1.

Instruction 5 (AC Half Bridge) is used to excite and measure the 223. The output from Instruction 5 is the ratio of signal voltage to excitation voltage.

Following the measurement, the Bridge Transform Instruction, P59, is used to calculate the block resistances in kohms. To avoid overranging, a multiplier of 1 is used to output sensor resistance (RS) in terms of k ohms.

Soil water potential (in bars) is calculated from RS using a fifth order polynomial (Instruction 55). Depending on the value of RS, one of two polynomials is selected to convert RS to soil water potential. If RS is greater than 17.009k ohms, soil water potential is not calculated, the value of RS is output.

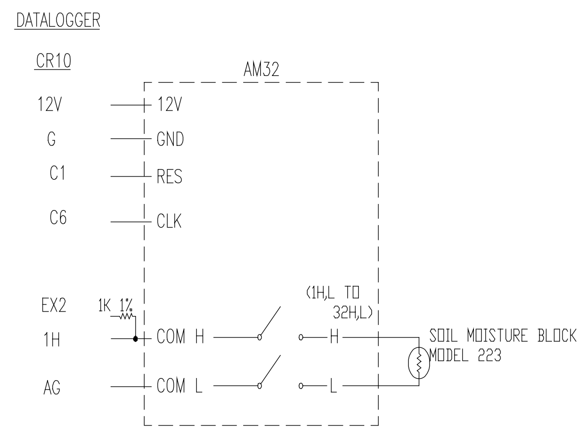


**FIGURE 7-1. Wiring Diagram for CR10(X), AM32 and 223 Soil Moisture Block example.**

**EXAMPLE PROGRAM FOR CR10(X)**
(35 locations allotted to Input Storage)

**A PROGRAM TO MEASURE 32 SOIL MOISTURE BLOCKS.**

```
*           1        Table 1 Programs
  01:       1        Sec. Execution Interval

01:       P92        If time is                       measure every
  01:       0        minutes into a                   6 hours
  02:     360        minute interval
  03:      30        Then Do

02:       P86        Do                               activate the AM32
  01:      41        Set high Port 1

03:       P87        Beginning of Loop                start the loop to
  01:       0        Delay                            measure and clock
  02:      32        Loop Count

04:       P86        Do                               clock the AM32
  01:      76        Pulse Port 6

05:       P22        Excitation with delay
  01:       1        EX Chan
  02:       0        Delay w/EX (units=/.01 sec)
  03:       1        Delay after EX (units=.01 sec)
  04:       0        mV Excitation

06:        P5        AC Half Bridge                   measure moisture
  01:       1        Rep                              blocks
  02:      14        250 mV fast Range
  03:       1        IN Chan
  04:       2        Excite all reps w/EXchan 2
  05:     250        mV Excitation
  06:       1--      Loc : [SM Bars#1]
  07:       1        Mult
  08:       0        Offset

07:       P59        BR Transform Rf[X/(1-X)]
  01:       1        Rep                              convert to
  02:       1--      Loc : [SM Bars#1]                resistance (Rs)
  03:       1        Multiplier (Rf)

08:       P89        If X<=>F                         If Rs < 17k ohms
  01:       1--      X Loc SM Bars#1
  02:       4        <
  03:      17.009    F
  04:      30        Then Do

09:       P89        If X<=>F                         If Rs < 5k ohms
  01:       1--      X Loc SM Bars#1
  02:       4        <
  03:       5        F
  04:      30        Then Do
```

```
10:         P55         Polynomial               0.1 to 2 Bar
  01:         1         Rep                      coversion
  02:         1--       X Loc SM Bars#1
  03:         1--       F(X) Loc : [SM Bars#1]
  04:          .06516     C0
  05:          .95117     C1
  06:         -.25159     C2
  07:         -.03736     C3
  08:          .03273     C4
  09:         -.00394     C5

11:         P94         Else

12:         P37         Z=X*F                    divide by 10 to
  01:         1--       X Loc SM Bars#1          fit polynomial
  02:         0.1       F
  03:         1--       Z Loc : [SM Bars#1]

13:         P55         Polynomial               2 to 10 Bars
  01:         1         Rep
  02:         1--       X Loc SM Bars#1
  03:         1--       F(X) Loc : [SM Bars#1]
  04:          .15836     C0
  05:         6.1445      C1
  06:        -8.4189      C2
  07:         9.2493      C3
  08:        -3.1685      C4
  09:          .3392      C5

14:         P94         Else

15:         P95         End                      2 to 10 Bars

16:         P95         End                      0.1 to 2 Bars

17:         P95         End                      Loop

18:         P86         Do                       deactivate AM32
  01:        51         Set low Port 1

19:         P86         Do
  01:        10         Set high Flag 0 (output)

20:         P77         Real Time
  01:      1110         Year,Day,Hour-Minute

21:         P70         Sample
  01:        32         Reps
  02:         1         Loc SM Bars#1

22:         P95         End                      6 hour then do

23:           P         End Table 1
```

| | | |
|---|---|---|
| * | A | Mode 10 Memory Allocation |
| 01: | 40 | Input Locations |
| 02: | 64 | Intermediate Locations |
| 03: | 0.0000 | Final Storage Area 2 |

Input Location Labels:

| | | | |
|---|---|---|---|
| 1:SM Bars#1 | 10:SM Bar#10 | 19:SM Bar#19 | 28:SM Bar#28 |
| 2:SM Bars#2 | 11:SM Bar#11 | 20:SM Bar#20 | 29:SM Bar#29 |
| 3:SM Bars#3 | 12:SM Bar#12 | 21:SM Bar#21 | 30:SM Bar#30 |
| 4:SM Bars#4 | 13:SM Bar#13 | 22:SM Bar#22 | 31:SM Bar#31 |
| 5:SM Bars#5 | 14:SM Bar#14 | 23:SM Bar#23 | 32:SM Bar#32 |
| 6:SM Bars#6 | 15:SM Bar#15 | 24:SM Bar#24 | 33:_________ |
| 7:SM Bars#7 | 16:SM Bar#16 | 25:SM Bar#25 | 34:_________ |
| 8:SM Bars#8 | 17:SM Bar#17 | 26:SM Bar#26 | 35:_________ |
| 9:SM Bars#9 | 18:SM Bar#18 | 27:SM Bar#27 | 36:_________ |

## 7.2 21X PROGRAMMING EXAMPLE: THERMOCOUPLES WITH REFERENCE AT THE DATALOGGER

The following example explains the wiring and programming necessary to make measurements of 10 copper-constantan thermocouples (type T) using the AM32 multiplexer.

The AM32 should be enclosed in an AM-ENCT enclosure.

In the example program, thermocouple temperature measurements are made on the first 10 AM32 channels.

This program makes thermocouple measurements with instruction P14 (Thermocouple Temperature, Differential Measurement).

The thermocouple temperature reference is made at the datalogger.

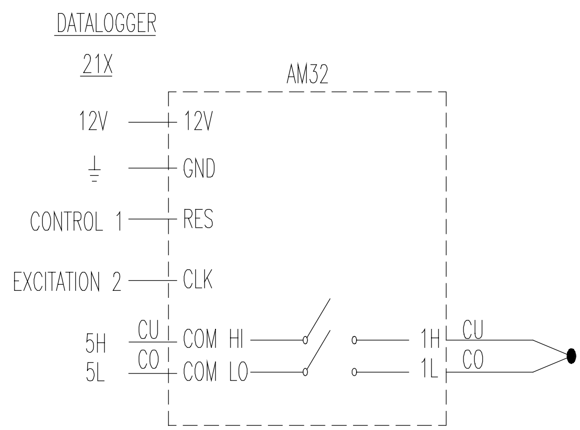


**FIGURE 7-2. Wiring Diagram for 21X and Thermocouples with reference at the datalogger.**

## EXAMPLE PROGRAM FOR 21X
## A PROGRAM TO MEASURE 10 TCs

| | | | |
|---|---|---|---|
| * | 1 | Table 1 Programs | |
| 01: | 5 | Sec. Execution Interval | |
| | | | |
| 01: | P17 | Panel Temperature | *measure reference* |
| 01: | 11 | Loc [:ref temp ] | *temp* |
| | | | |
| 02: | P86 | Do | *enable AM32* |
| 01: | 41 | Set high Port 1 | |
| | | | |
| 03: | P87 | Beginning of Loop | *start loop to* |
| 01: | 0 | Delay | *clock and measure* |
| 02: | 10 | Loop Count | |
| | | | |
| 04: | P22 | Excitation with Delay | *clock AM32* |
| 01: | 2 | EX Chan | |
| 02: | 1 | Delay w/ EX (units=.01sec) | |
| 03: | 1 | Delay after EX (units=.01sec) | |
| 04: | 5000 | mV Excitation | |
| | | | |
| 05: | P14 | Thermocouple Temp (DIFF) | |
| 01: | 1 | Rep | *measure TC* |
| 02: | 1 | 5 mV slow Range | |
| 03: | 5 | IN Chan | |
| 04: | 1 | Type T (Copper-Constantan) | |
| 05: | 11 | Ref Temp Loc ref temp | |
| 06: | 1-- | Loc [:TC temp#1] | |
| 07: | 1 | Mult | |
| 08: | 0 | Offset | |
| | | | |
| 06: | P95 | End | *end loop* |
| | | | |
| 07: | P86 | Do | *disable AM32* |
| 01: | 51 | Set low Port 1 | |
| | | | |
| 08: | P | End Table 1 | |
| | | | |
| * | A | Mode 10 Memory Allocation | |
| 01: | 28 | Input Locations | |
| 02: | 64 | Intermediate Locations | |

Input Location Labels:

| | | | |
|---|---|---|---|
| 1:TC temp#1 | 4:TC temp#4 | 7:TC temp#7 | 10:TC tem#10 |
| 2:TC temp#2 | 5:TC temp#5 | 8:TC temp#8 | 11:ref temp |
| 3:TC temp#3 | 6:TC temp#6 | 9:TC temp#9 | 12:_________ |

## 7.3 CR10(X) PROGRAMMING EXAMPLE: 223 MOISTURE BLOCKS AND TYPE T THERMOCOUPLES WITH REFERENCE AT THE MULTIPLEXER

The AM32 is used to switch the inputs from 16 soil moisture blocks into the hi side of a differential channel to make a single-ended measurement, it then switches thermocouples to be measured differentially .

The signal leads are connected to a differential input channel to make differential measurements on thermocouples. The low side of the differential channel is jumped to ground so single-ended soil moisture block measurements can be made between hi and ground.

A 1k ohm 1% resistor must be placed between the input and excitation channel used to complete the resistance measurement.

It is assumed that the AM32 is isothermal so that any thermocouple effects between the thermocouple wire and the AM32 circuitry are negligible. The thermocouple reference junction is at the AM32; it is measured using the 107 temperature probe with Instruction 11.

A thermocouple reference temperature could also be made at the datalogger. Thermocouple wire would have to be run from the AM32 to the datalogger. The use of constantan wire as the low common lead has no effect on the moisture block measurement.

The impedance of the switched excitation port is great enough that when off the thermocouple measurement is not affected by the connection to the excitation port. Because the circuit between a gypsum block and ground is closed only when measurements are being made, capacitors are not necessary to block DC current (created by galvanic action between block electrode and datalogger ground) which, if allowed to flow, would degrade the block. In the example program, the reference temperature measurement is made with a 107 temperature probe. AC resistance of 16 gypsum moisture blocks are measured on the first 16 AM32 channels, thermocouple temperature measurements are made on channels 17-32. The soil moisture readings (Bars) are stored in Input Storage locations 1-16 and the temperatures (°C) are in locations 17-32.

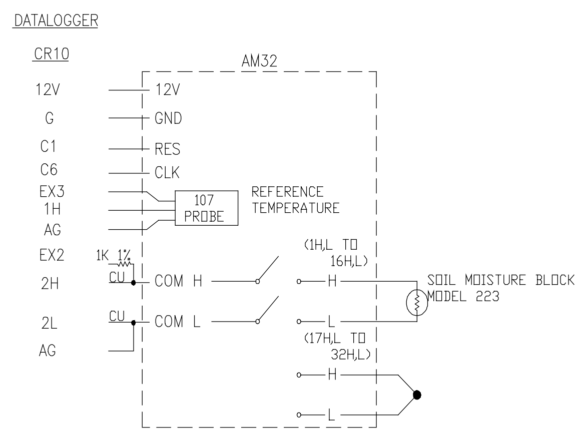


**FIGURE 7-3. Wiring Diagram for example of CR10(X) measuring soil moisture blocks and thermocouples with reference temperature at the AM32.**

## EXAMPLE PROGRAM FOR CR10(X)
## A PROGRAM TO MEASURE SOIL MOISTURE BLOCKS AND THERMOCOUPLES.

(40 locations allocated to Input Storage)

```
*           1       Table 1 Programs
  01:       1       Sec. Execution Interval

01:         P11     Temp 107 Probe
  01:       1       Rep
  02:       1       IN Chan
  03:       3       Excite all reps w/EXchan 3
  04:       33      Loc : [ref temp]
  05:       1       Mult
  06:       0       Offset

02:         P92     If time is                         measure every 6
  01:       0       minutes into a                     hours
  02:       360     minute interval
  03:       30      Then Do

03:         P86     Do                                 enable the AM32
  01:       41      Set high Port 1

04:         P87     Beginning of Loop                  start loop to
  01:       0       Delay                              measure and clock
  02:       16      Loop Count

05:         P86     Do                                 clock the AM32
  01:       76      Pulse Port 6

06:         P22     Excitation with delay
  01:       1       EX Chan
  02:       0       Delay w/EX (units=/.01 sec)
  03:       1       Delay after EX (units=.01 sec)
  04:       0       mV Excitation

07:         P5      AC Half Bridge                     measure moisture
  01:       1       Rep                                blocks
  02:       14      250 mV fast Range
  03:       3       IN Chan
  04:       2       Excite all reps w/EXchan 2
  05:       250     mV Excitation
  06:       1--     Loc : [SM Bars#1]
  07:       1       Mult
  08:       0       Offset

08:         P59     BR Transform Rf[X/(1-X)]
  01:       1       Rep                                convert to
  02:       1--     Loc : [SM Bars#1]                  resistance (Rs)
  03:       1       Multiplier (Rf)

09:         P89     If X<=>F                           if Rs < 17k ohms
  01:       1--     X Loc SM Bars#1
  02:       4       <
  03:       17.009  F
  04:       30      Then Do
```

```
10:      P89        If X<=>F                       if Rs < 5k ohms
  01:       1--     X Loc SM Bars#1
  02:       4       <
  03:       5       F
  04:      30       Then Do

11:      P55        Polynomial                     0.1 to 2 Bars
  01:       1       Rep                            conversion
  02:       1--     X Loc SM Bars#1
  03:       1--     F(X) Loc : [SM Bars#1]
  04:     .06516      C0
  05:     .95117      C1
  06:    -.25159      C2
  07:    -.03736      C3
  08:     .03273      C4
  09:    -.00394      C5

12:      P94        Else

13:      P37        Z=X*F                          divide by 10 to
  01:       1--     X Loc SM Bars#1                fit polynomial
  02:      0.1      F
  03:       1--     Z Loc : [SM Bars#1]

14:      P55        Polynomial                     2 to 10 Bars
  01:       1       Rep
  02:       1--     X Loc SM Bars#1
  03:       1--     F(X) Loc : [SM Bars#1]
  04:     .15836      C0
  05:     6.1445      C1
  06:    -8.4189      C2
  07:     9.2493      C3
  08:    -3.1685      C4
  09:     .33392      C5

15:      P94        Else

16:      P95        End                            2 to 10 Bars

17:      P95        End                            0.1 to 2 Bars

18:      P95        End                            loop

19:      P87        Beginning of Loop              start loop for TC
  01:       0       Delay
  02:      16       Loop Count

20:      P86        Do                             clock AM32
  01:      76       Pulse Port 6

21:      P22        Excitation with delay
  01:       1       EX Chan
  02:       0       Delay w/EX (units=/.01 sec)
  03:       1       Delay after EX (units=.01 sec)
  04:       0       mV Excitation
```

```
22:       P14      Thermocouple Temp (DIFF)
  01:        1     Rep                              measure TCs
  02:        1     2.5 mV slow Range
  03:        2     IN Chan
  04:        1     Type T (Copper-Constantan)
  05:       33     Ref Temp Loc
  06:       17--   Loc : [TCtemp#1]
  07:        1     Mult
  08:        0     Offset

23:       P95      End                              loop for TCs

24:       P86      Do                               deactivate the
  01:       51     Set low Port 1                   AM32

25:       P86      Do
  01:       10     Set high Flag 0 (output)

26:       P77      Real Time
  01:     1110     Year,Day,Hour-Minute

27:       P70      Sample
  01:       32     Reps
  02:        1     Loc SM Bars#1

28:       P95      End                              6 hour if-then do

29:         P      End Table 1


*           A      Mode 10 Memory Allocation
  01:       40     Input Locations
  02:       64     Intermediate Locations
  03:        0.0000 Final Storage Area 2
```

Input Location Labels:

| | | | |
|---|---|---|---|
| 1:SM bars#1 | 10:SM bar#10 | 19:TCtemp#3 | 28:TCtemp#12 |
| 2:SM bars#2 | 11:SM bar#11 | 20:TCtemp#4 | 29:TCtemp#13 |
| 3:SM bars#3 | 12:SM bar#12 | 21:TCtemp#5 | 30:TCtemp#14 |
| 4:SM bars#4 | 13:SM bar#13 | 22:TCtemp#6 | 31:TCtemp#15 |
| 5:SM bars#5 | 14:SM bar#14 | 23:TCtemp#7 | 32:TCtemp#16 |
| 6:SM bars#6 | 15:SM bar#15 | 24:TCtemp#8 | 33:ref temp |
| 7:SM bars#7 | 16:SM bar#16 | 25:TCtemp#9 | 34:_________ |
| 8:SM bars#8 | 17:TCtemp#1 | 26:TCtemp#10 | 35:_________ |
| 9:SM bars#9 | 18:TCtemp#2 | 27:TCtemp#11 | 36:_________ |

### 7.4 21X PROGRAMMING EXAMPLE: HALF BRIDGE MEASUREMENT WITH COMPLETION RESISTOR(S) AT THE DATALOGGER - 107 TEMPERATURE PROBES

The 107 temperature probe can be multiplexed with the AM32. The following diagram and program depicts the setup required to make temperature measurements. A similar program could be used to measure other half-bridge sensors.

The 107 probe does not need to be physically modified to work with the AM32. The black (excitation) lead is attached to LO and the red (signal) lead is attached to HI at the multiplexer. Insulate the white (ground) lead and tape it out of the way.

At the datalogger, a 1k ohm 0.1% precision completion resister is attached from the analog input to ground. Sensor shields should be tied together at the multiplexer and brought back to earth ground at the datalogger.

COM HI is tied to an excitation channel and COM LO to a single ended analog channel.

Instruction 22 is used to clock the AM32 with an excitation channel.

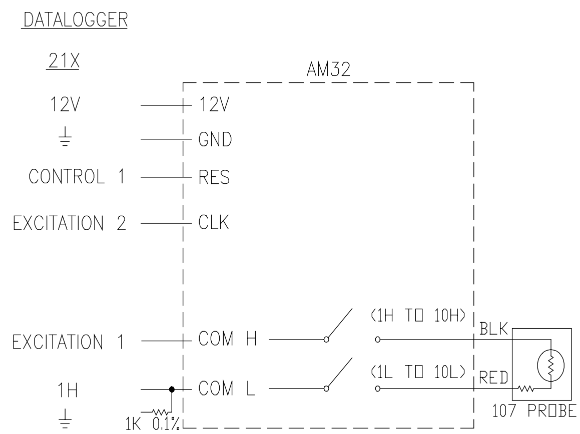


**FIGURE 7-4. Wiring diagram for example using 21X datalogger to measure 107 temperature probes.**

> **NOTE:** Tape the ground lead from the sensor out of the way. Wiring is for pre OSX-0.1, 1.1, 2.1 dataloggers

**EXAMPLE PROGRAM FOR 21X**

A PROGRAM TO MEASURE 107 TEMPERATURE PROBES.

| | | | |
|---|---|---|---|
| * | 1 | Table 1 Programs | |
| 01: | 5 | Sec. Execution Interval | |
| | | | |
| 01: | P20 | Set Port | *enable the AM32* |
| 01: | 1 | Set high | |
| 02: | 1 | Port Number | |
| | | | |
| 02: | P87 | Beginning of Loop | *start loop to* |
| 01: | 0 | Delay | *measure* |
| 02: | 10 | Loop Count | |
| | | | |
| 03: | P22 | Excitation with Delay | |
| 01: | 2 | EX Chan | *clock the AM32* |
| 02: | 1 | Delay w/EX (units=.01sec) | |
| 03: | 1 | Delay after EX (units=.01sec) | |
| 04: | 5000 | mV Excitation | |

```
04:        P11      Temp 107 Probe                  measure the 107
  01:        1      Rep
  02:        1      IN Chan
  03:        1      Excite all reps w/EXchan 1
  04:        1--    Loc : [temp #1 ]
  05:        1      Mult
  06:        0      Offset

05:        P95      End                             end loop

06:        P20      Set Port                        deactivate the
  01:        0      Set low                         AM32
  02:        1      Port Number

07:          P      End Table 1

*            A      Mode 10 Memory Allocation
  01:       28      Input Locations
  02:       64      Intermediate Locations
```

## 8.0 GENERAL MEASUREMENT CONSIDERATIONS

1. Long lead lengths - long lead lengths contribute to the formation of induced and capacitive voltages within the sensor and AM32 lead wires. To minimize this affect, CSI recommends use of Teflon, polyethylene, or polypropylene insulation around individual conductors. Do not use PVC insulation on conductors, although it may be used as a cable jacket. It may also be necessary to program a delay within the measurement instruction in order to allow the capacitance of the lead wires to discharge before measurement. Please consult the Measurement section of your datalogger manual for more information.

2. Common Earth Ground - A connection to earth ground should be made at the datalogger. The lead wire that connects the datalogger power ground to the AM32 power ground establishes a common ground. The Installation/Maintenance Section of your datalogger manual has more information on grounding procedures.

3. Completion resistors - In some applications it may be advisable to place completion resistors at the datalogger terminal strips. In some cases, sensors specific to the use of multiplexers are available from CSI. Examples include soil moisture probes and thermistors. Please consult CSI for ordering and pricing information.

4. Contact degradation - Once excitation in excess of 30 mA has been multiplexed, that set of contacts may be rendered unsuitable for later low voltage measurement. To prevent undue degradation, it is advisable to reserve certain channels for sensor excitations and other channels for sensor signals.

5. Sticky Relays - After extended periods of operation the relays may tend to become "sticky", resulting in switch bounce while the measurement is made. If this occurs, program in a delay after the clock pulse but before the measurement to allow time for the relay to settle.

## 9.0 INSTALLATION

The standard AM32 may be operated in an indoor, non-condensing environment. If condensing humidity is a problem or if the multiplexer might be exposed to liquids, a water-resistant enclosure is required. Desiccant should be used in enclosures to eliminate moisture build-up.

Several enclosures may be purchased through Campbell Scientific which offer a degree of protection against dust, spraying water, oil, falling dirt, or dripping noncorrosive liquids (Models AM-ENC, AM-ENCT, ENC-24, ENC-30). All the enclosures contain mounting plates for the multiplexer and conduit bushings for cable entry. These standard enclosures are rain-tight, but not water-proof.

The AM32 is attached to the mounting plate inside the enclosure with four screws.

The enclosure lids are gasketed. In high humidity environments, putty (or a similar substance) helps to reduce the passage of moisture into the enclosure via the cable conduits. The enclosure kit supplied with the enclosure contains putty and desiccant.

> **CAUTION:** Air movement should not be restricted into any enclosure containing batteries that may produce explosive or noxious gases (e.g. lead-acid cells).

U-bolts are provided to attach the enclosure to a 1.25" diameter pipe. The enclosure may also be lag-bolted to a wall or similar flat surface.

### 9.1 ENVIRONMENTAL CONSTRAINTS

The AM32 operating temperature range is -40°C. to +65°C. The multiplexer is susceptible to corrosion at high relative humidity.

Desiccant packs are available and they should be used inside the enclosure to remove water vapor.

## 10.0 DIFFERENCES BETWEEN THE AM32 AND THE AM416

The AM32 differs from the AM416 multiplexer in the following ways:

1. The AM32 switches thirty-two channels of two lines at a time (2 x 32). The AM416 switches sixteen sets of four lines at a time (4 x 16).

2. The AM32 comes as a circuit board that needs to be mounted in an enclosure. The AM416 is packaged in an aluminum case designed to decrease temperature gradients across the multiplexer terminal strips.

3. The AM32 requires one single-ended or one differential input. The AM416 requires two single-ended or two differential inputs.

4. The AM416 is more flexible in mix-and-matching sensor applications. The AM416 can accept a larger variety of sensors.

## Campbell Scientific Companies


**Campbell Scientific, Inc. (CSI)**
815 West 1800 North
Logan, Utah 84321
UNITED STATES
www.campbellsci.com
info@campbellsci.com

**Campbell Scientific Africa Pty. Ltd. (CSAf)**
PO Box 2450
Somerset West 7129
SOUTH AFRICA
www.csafrica.co.za
sales@csafrica.co.za

**Campbell Scientific Australia Pty. Ltd. (CSA)**
PO Box 444
Thuringowa Central
QLD 4812 AUSTRALIA
www.campbellsci.com.au
info@campbellsci.com.au

**Campbell Scientific do Brazil Ltda. (CSB)**
Rua Luisa Crapsi Orsi, 15 Butantã
CEP: 005543-000 São Paulo SP BRAZIL
www.campbellsci.com.br
suporte@campbellsci.com.br

**Campbell Scientific Canada Corp. (CSC)**
11564 - 149th Street NW
Edmonton, Alberta T5M 1W7
CANADA
www.campbellsci.ca
dataloggers@campbellsci.ca

**Campbell Scientific Ltd. (CSL)**
Campbell Park
80 Hathern Road
Shepshed, Loughborough LE12 9GX
UNITED KINGDOM
www.campbellsci.co.uk
sales@campbellsci.co.uk

**Campbell Scientific Ltd. (France)**
Miniparc du Verger - Bat. H
1, rue de Terre Neuve - Les Ulis
91967 COURTABOEUF CEDEX
FRANCE
www.campbellsci.fr
campbell.scientific@wanadoo.fr

**Campbell Scientific Spain, S. L.**
Psg. Font 14, local 8
08013 Barcelona
SPAIN
www.campbellsci.es
info@campbellsci.es


*Please visit www.campbellsci.com to obtain contact information for your local US or International representative.*