

# INSTRUCTION MANUAL



## *AM416 Relay Multiplexer*

Revision: 2/96

Copyright (c) 1987-1996  
Campbell Scientific, Inc.

# **Warranty and Assistance**

---

The **AM416 RELAY MULTIPLEXER** is warranted by CAMPBELL SCIENTIFIC, INC. to be free from defects in materials and workmanship under normal use and service for twelve (12) months from date of shipment unless specified otherwise. Batteries have no warranty. CAMPBELL SCIENTIFIC, INC.'s obligation under this warranty is limited to repairing or replacing (at CAMPBELL SCIENTIFIC, INC.'s option) defective products. The customer shall assume all costs of removing, reinstalling, and shipping defective products to CAMPBELL SCIENTIFIC, INC. CAMPBELL SCIENTIFIC, INC. will return such products by surface carrier prepaid. This warranty shall not apply to any CAMPBELL SCIENTIFIC, INC. products which have been subjected to modification, misuse, neglect, accidents of nature, or shipping damage. This warranty is in lieu of all other warranties, expressed or implied, including warranties of merchantability or fitness for a particular purpose. CAMPBELL SCIENTIFIC, INC. is not liable for special, indirect, incidental, or consequential damages.

Products may not be returned without prior authorization. The following contact information is for US and International customers residing in countries served by Campbell Scientific, Inc. directly. Affiliate companies handle repairs for customers within their territories. Please visit [www.campbellsci.com](http://www.campbellsci.com) to determine which Campbell Scientific company serves your country. To obtain a Returned Materials Authorization (RMA), contact CAMPBELL SCIENTIFIC, INC., phone (435) 753-2342. After an applications engineer determines the nature of the problem, an RMA number will be issued. Please write this number clearly on the outside of the shipping container. CAMPBELL SCIENTIFIC's shipping address is:

**CAMPBELL SCIENTIFIC, INC.**

RMA# \_\_\_\_\_

815 West 1800 North

Logan, Utah 84321-1784

CAMPBELL SCIENTIFIC, INC. does not accept collect calls.

# AM416 RELAY MULTIPLEXER MANUAL

## TABLE OF CONTENTS

*PDF viewers note: These page numbers refer to the printed version of this document. Use the Adobe Acrobat® bookmarks tab for links to specific sections.*

	<b>PAGE</b>
<b>1. FUNCTION</b>	
1.1 Typical Applications.....	1
1.2 Compatibility.....	1
<b>2. PHYSICAL DESCRIPTION.....</b>	<b>1</b>
<b>3. AM416 SPECIFICATIONS.....</b>	<b>3</b>
<b>4. OPERATION.....</b>	<b>3</b>
4.1 The Control Terminals.....	3
4.2 The Measurement Terminals.....	6
<b>5. DATALOGGER PROGRAMMING</b>	
5.1 Single Loop Instruction Sequence.....	6
5.2 Multiple Loop Instruction Sequence.....	9
5.3 General Programming Considerations.....	10
<b>6. SENSOR HOOK-UP AND MEASUREMENT EXAMPLES</b>	
6.1 Single-Ended Analog Measurement without Sensor Excitation.....	10
6.2 Differential Analog Measurement without Sensor Excitation.....	11
6.3 Half Bridge Measurements.....	11
6.4 Full Bridge Measurements.....	13
6.5 Full Bridges with Excitation Compensation.....	13
6.6 Thermocouple Measurement.....	14
6.7 Mixed Sensor Types.....	16
<b>7. GENERAL MEASUREMENT CONSIDERATIONS.....</b>	<b>18</b>
<b>8. INSTALLATION</b>	
8.1 Environmental Constraints.....	18
<b>APPENDIX A. AM416 STUFFING CHART AND SCHEMATICS.....</b>	<b>A-1</b>
<b>APPENDIX B. DIFFERENCES BETWEEN THE AM416 AND AM32.....</b>	<b>B-2</b>

### LIST OF FIGURES

1. Plan View of the AM416 Relay Multiplexer.....	2
2. Hook-up Diagrams for Datalogger - AM416 Connections.....	4
3. Power and Ground Connections for External Power Supply.....	5
4. Actuation Time of Relays vs. Temperature (°) and Battery Voltage.....	6
5. Single Loop Instruction Sequence.....	6
6. Example Program Loops for CR10(X), 21X, and CR7 Dataloggers.....	8

7.	Wiring Diagram for Strain Gages and Potentiometers.....	9
8.	Single-ended Measurement without Excitation .....	11
9.	Differential Measurement without Excitation .....	11
10.	Half Bridge (Modified 107 Temperature Probe) Hook-up and Measurement .....	12
11.	Potentiometer Hook-up and Measurement .....	12
12.	Four Wire Half Bridge Hook-up and Measurement.....	13
13.	Differential Measurement with Sensor Excitation.....	13
14.	Full Bridge Measurement with Excitation Compensation.....	14
15.	Differential Thermocouple Measurement with Reference Junction at the Datalogger.....	15
16.	Differential Thermocouple Measurement with Reference Junction at the AM416.....	15
17.	Thermocouple and Soil Block Measurement .....	16

## CAUTIONARY NOTES

The AM416 is not designed to multiplex power. Its intended function is to switch low level analog signals. Switched current in excess of 30 mA will degrade contacts and render them unsuitable for future low level analog measurements. Customers who need to switch power are directed to CSI's A6REL-12 or A21REL-12 relays.

Adjacent AM416 channels may be shorted together for up to 5 ms during the clocking procedure. Users should consider this when assigning AM416 input channels. Sensors that are capable of sourcing current should not be assigned input terminals adjacent to sensors that can sink current.



# AM416 RELAY MULTIPLEXER

## 1. FUNCTION

The primary function of the AM416 Multiplexer is to increase the number of sensors that may be scanned by Campbell's CR10(X), 21X and CR7 dataloggers. The AM416 is positioned between the sensors and the datalogger; mechanical relays are used to switch the desired sensor signal(s) through the system. Most commonly, users will multiplex signals from analog sensors into single-ended or differential datalogger channels. Four lines are switched simultaneously; a maximum of sixteen sets of (four) lines may be scanned, hence the name **A**(nalog) **M**(ultiplexer) **4**(lines x) **16**(sets). Therefore, a total of 64 lines may be multiplexed.

The maximum number of sensors that can be multiplexed through one AM416 depends primarily upon the type(s) of sensors to be scanned. Some examples (assuming identical sensors) follow:

1. Up to 32 single-ended or differential sensors that do not require excitation (e.g. pyranometers, thermocouples; Sections 6.1, 6.2, and 6.6).
2. Up to 48 single-ended sensors that require excitation (e.g. some half bridges; Section 6.3.1).
3. Up to 16 single-ended or differential sensors that require excitation (e.g. full bridges, four-wire half bridge with measured excitation; Section 6.3.3 and 6.4).
4. In conjunction with an AM32 multiplexer, up to 16 six-wire full bridges (Section 6.5).

### 1.1. TYPICAL APPLICATIONS

The AM416 is intended for use in applications where the number of required sensors exceeds the number of datalogger input channels. Most commonly, the AM416 is used to multiplex analog sensor signals, although it also may be used to multiplex switched excitations, continuous analog outputs, or even certain pulse counting measurements (i.e. those that require only intermittent sampling). It is also possible to multiplex sensors of different, but compatible, types (e.g. thermocouples and soil moisture blocks, see Section 6.6).

**NOTE:** For a discussion of single-ended versus differential analog measurements, please consult the Measurement Section of your datalogger manual.

As purchased, the AM416 is intended for use in indoor, non-condensing environments. An enclosure is required for field use. In non-thermocouple applications where a single multiplexer is deployed, the AM-ENC enclosure is recommended. In thermocouple applications, CSI recommends use of the AM-ENCT enclosure. If several multiplexers are deployed at the same site in a non-thermocouple application, the 024 or 030 enclosures provide cost-effective housing options.

### 1.2 COMPATIBILITY

The AM416 is compatible with Campbell's CR10(X), 21X or CR7 dataloggers.

The AM416 is compatible with a wide variety of commercially available sensors. As long as current limitations are not exceeded, and no more than four lines are switched at a time, system compatibility for a specific sensor is determined by sensor-datalogger compatibility.

In CR10(X) applications, the AM416 may be used to multiplex up to 16 Geokon vibrating wire sensors through one AVW-1 vibrating wire interface.

## 2. PHYSICAL DESCRIPTION

The AM416 is housed in a 21 cm x 16.5 cm x 3.5 cm (8.2" x 6.5" x 1.5") anodized aluminum case (Figure 1). The aluminum case is intended to reduce temperature gradients across the AM416's terminal strips. This is extremely important when thermocouples are being multiplexed (Section 6.6). The case may be opened by removing the four #1 phillips-head screws located at the corners of the case. Disassembly of the case may be required to mount the AM416 to a plate or an enclosure (Section 8).

A strain-relief flange is located along the lower edge of the top panel of the case. Several plastic wire ties are included with the AM416 to attach wires to this flange.

## AM416 RELAY MULTIPLEXER

Wires from sensors and datalogger are connected to the gray terminal strips. The set of four terminals located near the strain-relief flange are the connections for datalogger control of the AM416 (Section 4.1). The terminal strips that run the length of the AM416 are for measurement connections (Section 4.2).

The sensor inputs are not spark gapped. All terminals accept stripped and tinned lead wires up to 1.5 mm in diameter. The datalogger is connected to the AM416 through a minimum of seven, but generally nine, individually insulated lead wires.

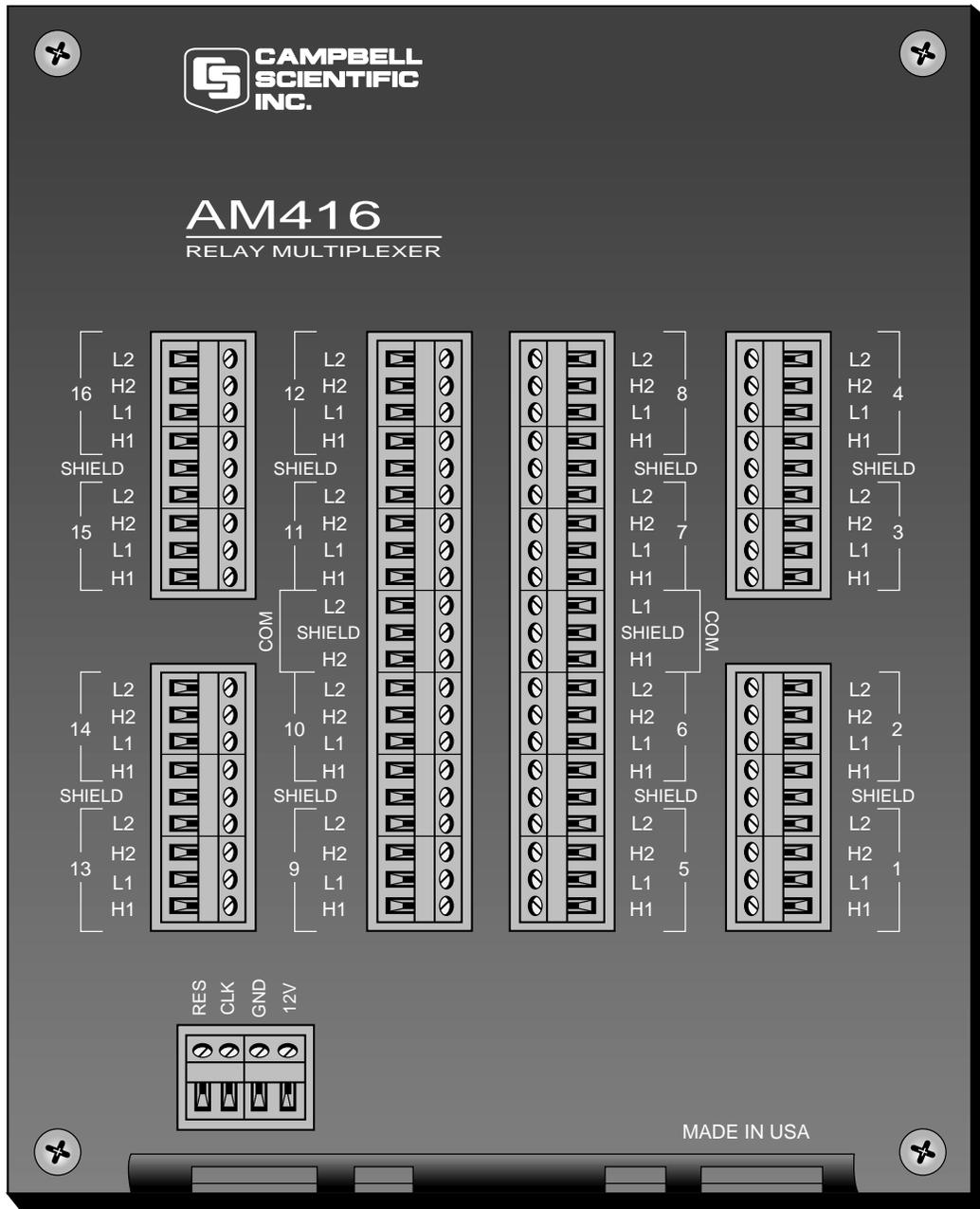


FIGURE 1. Plan View of the AM416 Relay Multiplexer

### 3. AM416 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: < 100 uA  
 Active: 17 mA (typical)

**RESET\***: a continuous signal of 3.5VDC  $\leq$  voltage  $\leq$  16 VDC holds AM416 in an active state (i.e. a clock pulse can trigger a scan advance). A signal voltage of < 0.9VDC deactivates the AM416 (clock pulse will not trigger a scan advance; AM416 is also reset).

**CLOCK\***: on the transition from <1.5 V to >3.5 V, scan advance is actuated on the leading edge of the clock signal; clock signal must be a minimum of 5 ms in width.

**OPERATIONAL TEMPERATURE:** -40°C to +65°C

**OPERATIONAL HUMIDITY:** 0 - 95%, non-condensing

**DIMENSIONS** (without field enclosure):  
 length - 21 cm (8.2")  
 width - 16.5 cm (6.5")  
 depth - 3.5 cm (1.5")

(with field enclosure i.e. box size):  
 length - 25.4 cm (10.0")  
 width - 20.3 cm (8.0")  
 depth - 10.2 cm (4.0")

**WEIGHT:** 1.5 lbs (approx.)  
 (in enclosure): 10.0 lbs (approx.)

**EXPANDABILITY\*\***(nominal):  
 3 AM416'S/CR10(X)  
 4 AM416'S/21X  
 8 AM416's/CR7 725 Card

**MAXIMUM CABLE LENGTH:** sensor & scan rate dependent (in general, longer lead lengths necessitate longer measurement delays. Refer to datalogger manual for additional details).

**MAXIMUM SWITCHING CURRENT\*\*\***: 500 mA

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

\*\* Assumes sequential activation of multiplexers and that each datalogger channel is uniquely dedicated. If your application requires additional multiplexing capability, please consult CSI for application assistance.

\*\*\* Switching currents greater than 30 mA (occasional 50 mA is acceptable) will degrade the contact surfaces of the mechanical relays (i.e. increase their resistance). This process will adversely affect 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 30 mA.

#### CONTACT SPECIFICATIONS

Initial contact resistance: 50 mohm max.  
 Initial contact bounce: 1 ms max.  
 Contact material: Gold clad silver alloy  
 Electrostatic capacitance: 3pF  
 Minimum expected life:  
     Mechanical (at 50cps):  $10^8$  open  
     Electrical (at 20cps):  $2 \times 10^5$

#### CHARACTERISTICS (at 25°C, 50% Relative Humidity)

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

### 4. OPERATION

Subsection 4.1 discusses the use of the terminals that control operation of the multiplexer. These terminals are located along the lower left side of the multiplexer as shown in Figure 1. Subsection 4.2 discusses the use of terminals used in sensor measurement.

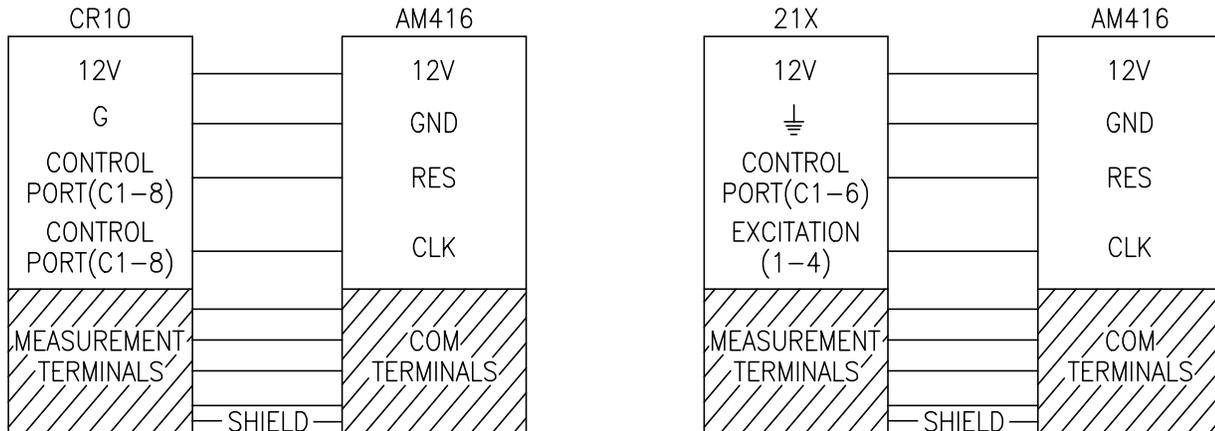
#### 4.1. THE CONTROL TERMINALS

The CR10(X), 21X and CR7 dataloggers should be connected to the AM416 as shown in Figure 2. This figure depicts control connections; measurement connections are discussed in Section 6. The power, ground, reset, and clock connections remain essentially the same regardless of datalogger used.

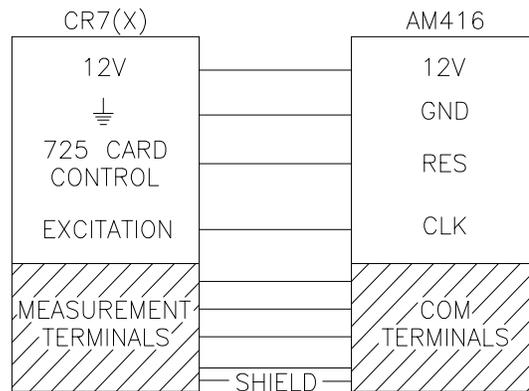
In a CR10(X) application, the datalogger 12VDC supply and ground terminals are connected to the AM416 12V and ground terminals. Two control ports are used for clock and reset.

## AM416 RELAY MULTIPLEXER

**FIGURE 2. Hook-up Diagrams for Datalogger - AM416 Connections**



**CR10(X) Hook-up 21X Hook-up**



**CR7 Hook-up**

The 21X or CR7 (with a 725 Card) can be used to connect 12VDC supply and ground to the AM416. One control port is used for reset, and one switched excitation channel is used for clock. If switched excitations are unavailable, a control port may be used to provide clock pulses to the multiplexer.

### 4.1.1 RESET

Reset (RES) controls activation of the multiplexer. A voltage ( $3.5\text{VDC} \leq \text{voltage} \leq 16\text{VDC}$ ) applied to this terminal activates the multiplexer. When this line is dropped to  $<0.9\text{VDC}$ , the multiplexer enters a quiescent, low current drain state. Reset is always connected to a datalogger control port. Instruction 86 (option code 41 - 48 [activate] and 51 - 58 [deactivate]) is generally used. With a 21X or CR7 with older PROMS, Instruction 20 is commonly used to activate and deactivate the multiplexer (set port high to

activate the multiplexer or low to enter quiescent mode).

### 4.1.2 CLOCK

The multiplexer clock line (CLK) controls the switching between sequential sets of relays. When reset is set high and the multiplexer is activated, the multiplexer's common lines (COM H1, COM L1, COM H2, COM L2) are not connected to any of the sensor input terminals. When the first clock pulse is received, the common lines are switched into connection with multiplexer channel 1 (H1,L1,H2,L2). When a second clock pulse is received, the common lines are connected to multiplexer channel 2 (H1,L1,H2,L2). Adjacent Multiplexer input channels are momentarily shorted to each other during the switch (e.g. channel 1 H1 to channel 2 H1, channel 1 L1 to channel 2 L1, etc. See Cautionary Notes). The multiplexer is clocked on the leading edge of the voltage pulse. The

voltage level must fall below 1.5VDC then exceed 3.5VDC to clock. Pulse width must be at least 5 ms. An additional delay is required before the measurement to ensure adequate time for the relay to close.

In the 21X and CR7 dataloggers, a switched excitation is generally used to clock the multiplexer (Instruction 22 - 5,000 mV excitation). If no switched excitation channels are available it is possible to clock using control ports. See Section 5.1 for additional details.

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

**4.1.3 GROUND**

The multiplexer ground terminal is connected to datalogger power ground. If a separate power supply is used, AM416 ground is also connected to the power supply ground (Figure 3). The datalogger should always be tied to earth ground by one of the methods described in the Installation/Maintenance Section of your datalogger manual.

**4.1.4 POWER SUPPLY**

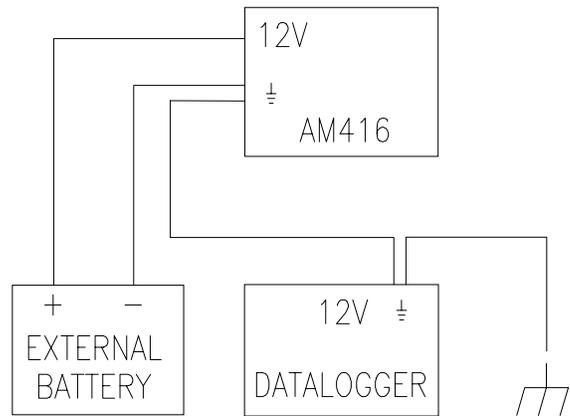
The AM416 requires a continuous 9.6 to 16 VDC power supply for operation. The multiplexer's current drain is less than 100 microamps while quiescent and is typically 17 milliamps at 12 VDC when active. Power supply connections are made at the terminals labeled 12V and GND.

In many applications, it may be convenient to power the AM416 from the datalogger's battery. For more power-intensive operations, an external, rechargeable, 12VDC, 60-AmpHr source may be advisable. Because of their ability to be recharged, lead-acid supplies are recommended where solar- or AC- charging sources are available. The datalogger alkaline supply (7.5 AmpHr) can be used to power the AM416 in applications where the system current drain is low, or where frequently replacing the batteries is not a problem. It is advisable to calculate the total power requirements of the system and the expected longevity of the power supply based on the system current drains (e.g. the datalogger, multiplexer, other peripherals

and sensors) and the expected ambient temperatures.

The power required to operate an AM416 depends on the percentage of time it is active. For example, if a CR10(X) makes differential measurements on 32 thermocouples every minute, the average current drain due to the AM416 is about 0.3 mA. Under the same conditions, a 2 second scan rate increases the average system current drain to about 8.5 mA. At a minimum, the power supply must be able to sustain the system between site visits over the worst environmental extremes.

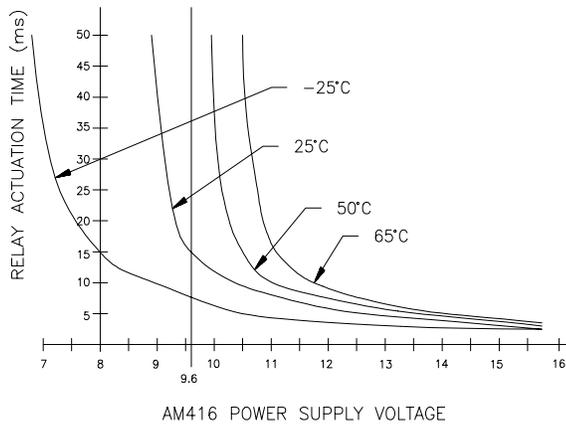
If a 21X power supply is used to power the AM416, all low level analog measurements (thermocouples, pyranometers, thermo-piles, etc.) must be made differentially. This procedure is required because slight ground potentials are created along the 21X analog terminal strip when the 12V supply is used to power peripherals. This limitation reduces the number of available analog input channels and may mandate the use of an external supply for the AM416 (Figure 3).



**FIGURE 3. Power and Ground Connections for External Power Supply.**

Low power and high ambient temperatures may affect the actuation time of the multiplexer relays (Figure 4). If the relay is not closed when a measurement is started, the result will be an inaccurate or overranged value.

## AM416 RELAY MULTIPLEXER



**FIGURE 4. Actuation Time of Relays vs. Temperature (°C) and Battery Voltage.**

### 4.2 THE MEASUREMENT TERMINALS

The terminals that run the length of the AM416 are dedicated to the connection of sensors to the datalogger (Figure 1). The 16 groups of 4-terminal inputs allow attachment of stripped and tinned sensor leads. The terminals marked COM allow attachment of the common signal leads that carry the sensor's signal between multiplexer and datalogger. The shield lines allow sensor shields to be routed through the multiplexer and back to datalogger ground.

#### 4.2.1 THE COM TERMINALS

The multiplexer terminals dedicated to multiplexer-datalogger signal transfer are located within the silk screened brackets labeled COM (common; see Figure 1). The four individual COM lines are labeled: H1 (common high #1), L1 (common low #1), H2 (common high #2), and L2 (common low #2). The circuitry of each COM line is isolated from the other three.

A shield terminal is also located within each COM bracket. All shield terminals are in electrical continuity at all times (i.e. they are not switched). Their function is to provide a path to ground for sensor cable shields. The shield terminals within the COM bracket should be tied to datalogger earth ground either directly or through a busbar.

#### 4.2.2 THE SENSOR INPUT TERMINALS

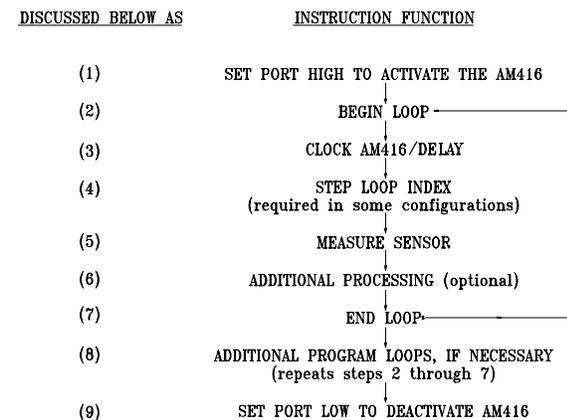
The input terminals for sensor attachment run the length of the multiplexer and are subdivided into 16 labeled groups. Each group consists of four Simultaneously Enabled Terminals (SET).

Within each SET, the four terminals are labeled H1, L1, H2, L2. As the AM416 receives clock pulses from the datalogger, each SET is switched sequentially into contact with the COM terminals. For example, when the first clock pulse is received from the datalogger, SET 1 (bracket annotated with a number 1) is connected with the COM lines. Terminal H1 is connected to COM H1, terminal L1 to COM L1, terminal H2 to COM H2, and terminal L2 to COM L2. When the second clock pulse is received, the first SET is switched out (becomes an open circuit) and the second SET (bracket annotated with a number 2) is connected to the COM terminals.

## 5. DATALOGGER PROGRAMMING

When a number of similar sensors are multiplexed and measured, the Instructions to clock the AM416 and to measure the sensors are entered within a program loop. The generalized structure of a program loop is outlined below:

### 5.1 SINGLE LOOP INSTRUCTION SEQUENCE



**FIGURE 5. Single Loop Instruction Sequence**

(1 and 9) Activate/Deactivate AM416 - The control port connected to reset (RES) is set high to activate the AM416 prior to the measurement sequence and set low following the measurement loop(s). Instruction 86 is used to set the port. (With the CR10(X), 21X, and CR7 without OS series PROMS, Instruction 20 is used.)

(2 and 7) Loop - A loop is defined by Instruction 87 (begin loop), and by an end instruction, 95. Within Instruction 87, the 2nd parameter (iteration count) defines the number of times that the instructions within a loop are executed before the program exits the loop.

(3) Clock/Delay - With the 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 an additional 10 ms.

When controlled by the 21X or CR7, the clock line may be connected to either an excitation or a control port. Connection to an excitation port 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 AM416 if no excitation ports are available. The 21X and CR7 instruction sequence required to clock with a control port is: Instruction 20 (set port high), Instruction 22 (delay of 20 ms without excitation) followed by Instruction 20 (set port low).

(4) Step Loop Index - This instruction is used when a measurement instruction within that loop has more than one repetition. It allows each measurement value to occupy a sequentially assigned input location without being overwritten by subsequent passes through the loop. Without this instruction, each indexed input location within the loop will advance by only one location per loop iteration.

For Example: 2 sensors per SET, 6 sensors total; two reps in measurement instruction; two measurement values assigned to indexed input locations (--); P90 step of 2. Loop count of three.

	Input locations						
	1	2	3	4	5	6	
First pass:	1	2					
Second pass:			3	4			sensor
Third pass:					5	6	numbers

Given the same program without a step loop instruction, the following situation results:

	Input locations						
	1	2	3	4	5	6	
First pass:	1	2					
Second pass:			3	4			sensor
Third pass:					5	6	numbers

The measurement values for the 2nd and 4th sensors will be overwritten in their input locations. The 1st, 3rd, 5th, and 6th measurement values will reside in the first 4 input locations.

The Step Loop Instruction 90 is available in CR10(X)s, CR7s, and 21Xs with a third PROM. For 21X dataloggers without a third prom (i.e. without Instruction 90), a separate measurement instruction (with one rep) is required for each sensor measured within the loop. The input location parameter within both measurement instructions is indexed.

For Example: 2 sensors per SET; one rep in each of two measurement instructions; two measurement values assigned to indexed input locations (--), one begins with input location 1, the other with input location 4; no P90. A total of six sensors to be measured; loop count is three.

	Input locations						
	1	2	3	4	5	6	
First pass:	1			2			
Second pass:			3		4		sensor
Third pass:					5	6	numbers

A potential drawback of this technique is that sequential sensors (i.e. those input to the same SET) will not have sequential input locations.

(5) Measure - Enter the instruction needed to measure the sensor(s) [see Section 6, Sensor Hook-Up & Measurement Examples]. The input location parameter of a measurement instruction is indexed if a (--) appears to the right of the input location. Index an input location by pressing "C" after keying the location. Indexing causes the input location to be incremented by 1 with each pass through the loop. This allows the measurement value to be stored in sequential input locations. Instruction 90, as explained above, allows the indexed input location to be incremented in integer steps greater than 1.

**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.

(6) Optional Processing - Additional processing is sometimes required to convert the reading to the desired units. It may be more efficient or reduce measurement time if this processing is done outside the measurement loop. A second loop can be used for processing, if necessary.

**AM416 RELAY MULTIPLEXER**

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

<b>21X SAMPLE PROGRAM</b>			<b>CR7 SAMPLE PROGRAM</b>			<b>CR10(X) SAMPLE PROGRAM</b>		
*	1	Table 1	*	1	Table 1	*	1	Table 1
		Programs			Programs			Programs
01:	60	Sec.	01:	60	Sec.	01:	60	Sec.
		Execution			Execution			Execution
		Interval			Interval			Interval
ACTIVATES MULTIPLEXER			ACTIVATES MULTIPLEXER			ACTIVATES MULTIPLEXER		
01:	P20	Set Port	01:	P20	Set Port	01:	P86	Do
01:	1	Set high	01:	1	Set high	01:	41	Set high
02:	1	Port	02:	1	EX Card			Port 1
		Number	03:	1	Port No.			
BEGINS MEASUREMENT LOOP			BEGINS MEASUREMENT LOOP			BEGINS MEASUREMENT LOOP		
02:	P87	Beginning of Loop	02:	P87	Beginning of Loop	02:	P87	Beginning of Loop
01:	0	Delay	01:	0	Delay	01:	0	Delay
02:	16	Loop Count	02:	16	Loop Count	02:	16	Loop Count
CLOCK PULSE AND DELAY			CLOCK PULSE AND DELAY			CLOCK PULSE		
03:	P22	Excitation with Delay	03:	P22	Excitation with Delay	03:	P86	Do
01:	1	EX Chan	01:	1	EX Card	01:	72	Pulse Port 2
02:	1	Delay w/EX (units=.01 sec)	02:	2	EX Chan			
03:	1	Delay after EX (units=.01 sec)	03:	1	Delay w/EX (units=.01 sec)	DELAY		
04:	5000	mV Excitation	04:	1	Delay after EX (units=.01 sec)		P22	Excitation with Delay
			05:	5000	mV Excitation	01:	1	EX Chan
						02:	0	Delay w/EX
						03:	1	Delay after EX
						04:	0	mV Excitation
04: USER SPECIFIED MEASUREMENT INSTRUCTION			04: USER SPECIFIED MEASUREMENT INSTRUCTION			04: USER SPECIFIED MEASUREMENT INSTRUCTION		
ENDS MEASUREMENT LOOP			ENDS MEASUREMENT LOOP			ENDS MEASUREMENT LOOP		
05:	P95	End	05:	P95	End	05:	P95	End
DEACTIVATES MULTIPLEXER			DEACTIVATES MULTIPLEXER			DEACTIVATES MULTIPLEXER		
06:	P20	Set Port	06:	P20	Set Port	06:	P86	Do
01:	0	Set low	01:	0	Set low	01:	51	Set low
02:	1	Port	02:	1	EX Card			Port 1
		Number	03:	1	Port No.			

**FIGURE 6. Example Program Loops for CR10(X), 21X and CR7 Dataloggers.**

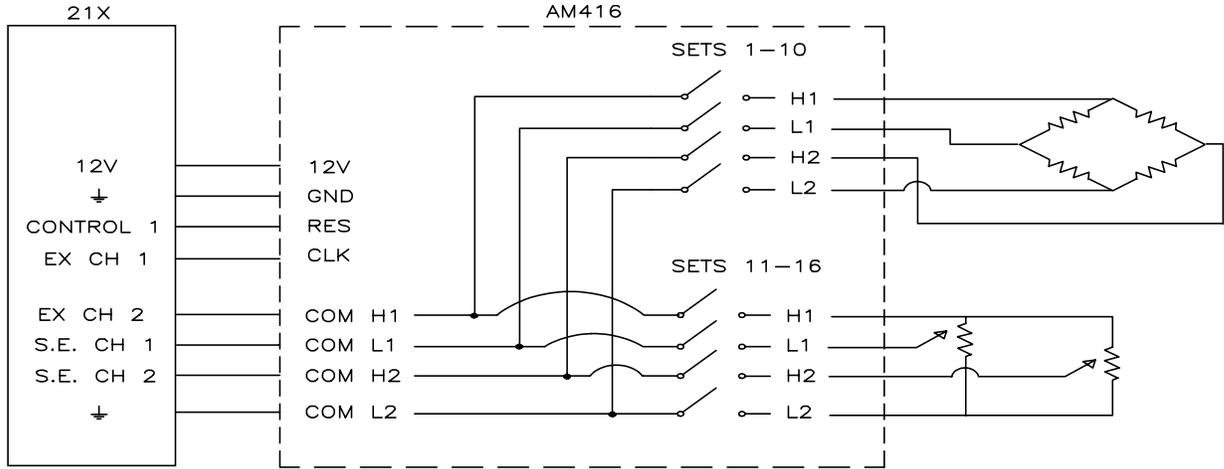


FIGURE 7. Wiring Diagram for Strain Gages and Potentiometers

(8) Additional Loops - Additional loops may be used if sensors that require different measurement instructions are connected to the same multiplexer. In this instance, like sensors are assigned to sequential input SETS. Each group of sensors is measured in a separate loop (steps 2 through 7, Figure 4). Each loop contains clock and measurement instructions, and all loops must reside between the instructions that activate and deactivate the AM416 (Steps 1 and 9).

The instruction sequence for control of an AM416 is given on the following page. The Program format is a product of EDLOG, a datalogger program editor contained in CSI's PC208 Datalogger Support Software.

5.2 MULTIPLE LOOP INSTRUCTION SEQUENCE

As shown above, the program for operation of the AM416 is essentially the same for all CSI dataloggers. To measure sensors of different types, different measurement instructions may be used within successive program loops. In the following example, each loop is terminated with Instruction 95, and the multiplexer is not reset between loops. The following example demonstrates measurement of two dissimilar sensor types (i.e. strain gages and potentiometers).

The program and accompanying wiring diagram are intended as examples only; users will find it necessary to modify both for specific applications.

```

*          1          Table 1 Programs
01:       60          Sec. Execution Interval

ENABLES MULTIPLEXER
01:       P20        Set Port
01:       1          Set high
02:       1          Port Number

BEGINS STRAIN GAGE MEASUREMENT LOOP
02:       P87        Beginning of Loop
01:       0          Delay
02:       10         Loop Count

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

FULL BRIDGE MEASUREMENT INSTRUCTION
04:       P6         Full Bridge
01:       1          Rep
02:       3          50 mV slow Range
03:       1          IN Chan
04:       2          Excite all reps w/EXchan 2
05:       5000       mV Excitation
06:       1--       Loc [:STRAIN #1]
07:       1          Mult
08:       0          Offset

END OF STRAIN GAGE MEASUREMENT LOOP
05:       P95        End
    
```

## AM416 RELAY MULTIPLEXER

### BEGINNING OF POTENTIOMETER MEASUREMENT LOOP

06: P87 Beginning of Loop  
01: 0 Delay  
02: 6 Loop Count

07: P90 Step Loop Index (Extended)  
01: 2 Step

### CLOCK PULSE

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

### POTENTIOMETER MEASUREMENT INSTRUCTION

09: P4 Excite,Delay,Volt(SE)  
01: 2 Repts  
02: 5 5000 mV slow Range  
03: 1 IN Chan  
04: 2 Excite all reps w/EXchan 2  
05: 1 Delay (units .01sec)  
06: 5000 mV Excitation  
07: 11-- Loc [:POT #1 ]  
08: 1 Mult  
09: 0 Offset

### END OF POTENTIOMETER MEASUREMENT LOOP

10: P95 End

### DISABLES MULTIPLEXER

11: P20 Set Port  
01: 0 Set low  
02: 1 Port Number

12: P End Table 1

### INPUT LOCATION LABELS:

1:STRAIN #1	13:POT #3
2:STRAIN #2	14:POT #4
3:STRAIN #3	15:POT #5
4:STRAIN #4	16:POT #6
5:STRAIN #5	17:POT #7
6:STRAIN #6	18:POT #8
7:STRAIN #7	19:POT #9
8:STRAIN #8	20:POT #10
9:STRAIN #9	21:POT #11
10:STRAIN#10	22:POT #12
11:POT #1	23:_____
12:POT #2	24:_____

## 5.3 GENERAL PROGRAMMING CONSIDERATIONS

The excitation voltage, integration and delay times associated with reading the signal, and the speed with which the channels are switched may be varied with the datalogger program. In general, longer delay times are necessary when the sensor and datalogger are separated by long lead lengths. Consult your datalogger manual for additional information on these topics.

## 6. SENSOR HOOK-UP AND MEASUREMENT EXAMPLES

This section covers sensor-AM416 connections as well as AM416-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 bridge measurements. Most of the following examples do not depict datalogger-AM416 control connections (Section 4), but their presence is implied and required. CSI recommends that only sensor shield (drain) wires be connected to AM416 shield terminals.

### 6.1 SINGLE-ENDED ANALOG MEASUREMENT WITHOUT SENSOR EXCITATION

Sensor to Multiplexer wiring - up to two single-ended sensors that don't require excitation may be connected to one AM416 input SET.

Multiplexer to Datalogger wiring - Signal lines from COM terminals are input into two consecutive single-ended analog input channels. Signal ground lines are tied to analog ground (AG) in the CR10(X), datalogger ground in the 21X and CR7. The COM shield line is tied to datalogger earth ground. Up to 32 single-ended sensors may be used by two single-ended datalogger channels in this manner.

**NOTE:** Low level single-ended measurements are not recommended in a 21X application in which the 21X's internal 12VDC supply is being used to power the multiplexer or other peripherals (Section 4.1.4).

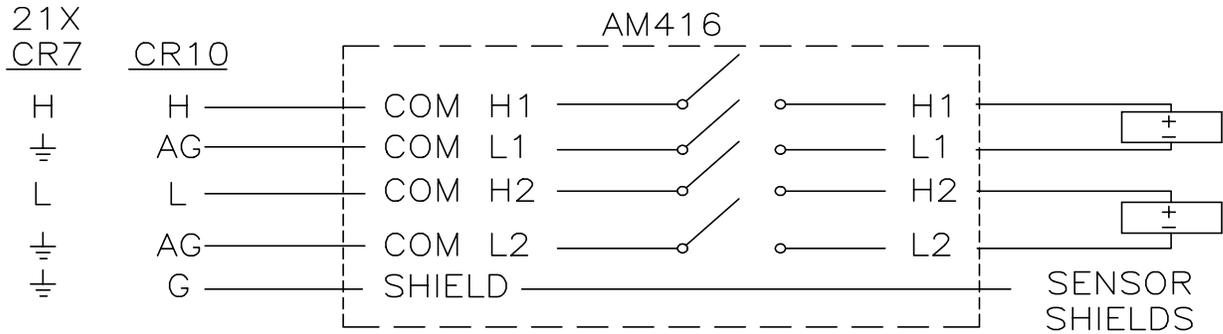


FIGURE 8. Single-ended Measurement Without Excitation

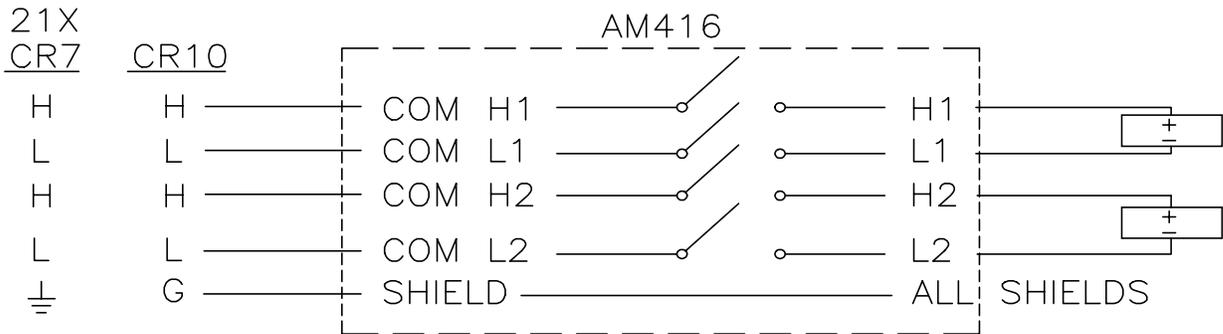


FIGURE 9. Differential Measurement Without Excitation

**6.2 DIFFERENTIAL ANALOG MEASUREMENT WITHOUT SENSOR EXCITATION**

Sensor to Multiplexer wiring - Up to two differential sensors that don't require excitation may be connected to one input SET. Sensor shields are routed through shield terminals.

Multiplexer to Datalogger wiring - A pair of COM terminals (e.g. COM H1 and COM L1) is connected to a differential analog input at the datalogger. Up to 32 differential sensors may be measured by two differential datalogger channels in this way.

**6.3 HALF BRIDGE MEASUREMENTS**

Measurements of this type may be subdivided into three categories based on completion resistance and the presence or absence of measured excitation. If the sensor's completion resistor(s) are installed at the datalogger panel (e.g. a CSI 107 probe modified for multiplexer use), then three probes per SET may be excited and measured (Figure 10). However, if the circuit is completed within the sensor (e.g.

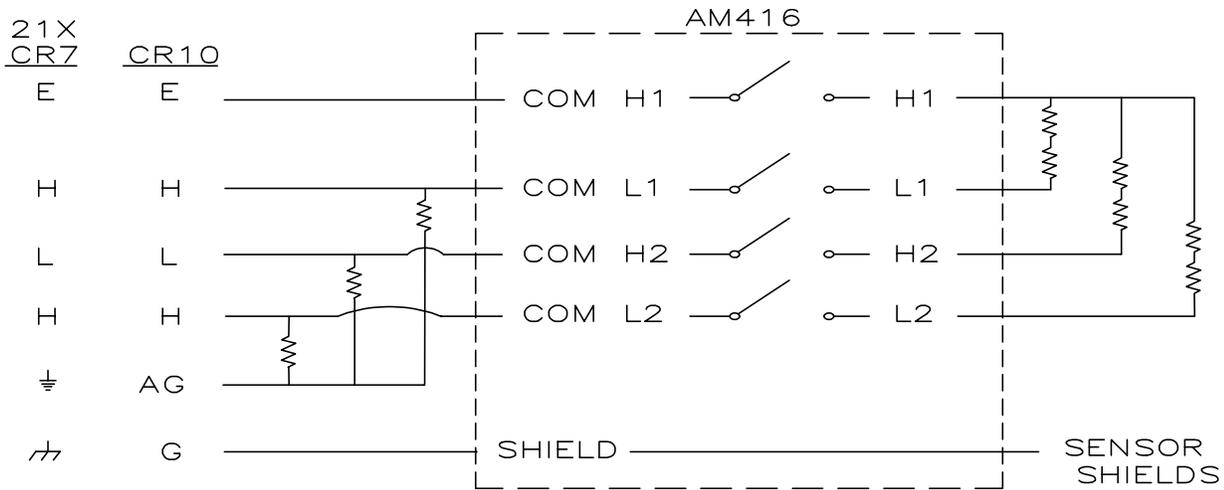
potentiometers), then excitation, wiper signal, and ground must be multiplexed. Because excitation and ground may be multiplexed in common, up to two sensors per SET may be measured (Figure 11). If measured excitation is required (i.e. four wire half-bridge), then only one sensor per SET may be measured (Figure 12).

**6.3.1 HALF BRIDGE MEASUREMENT WITH COMPLETION RESISTOR(S) AT DATALOGGER**

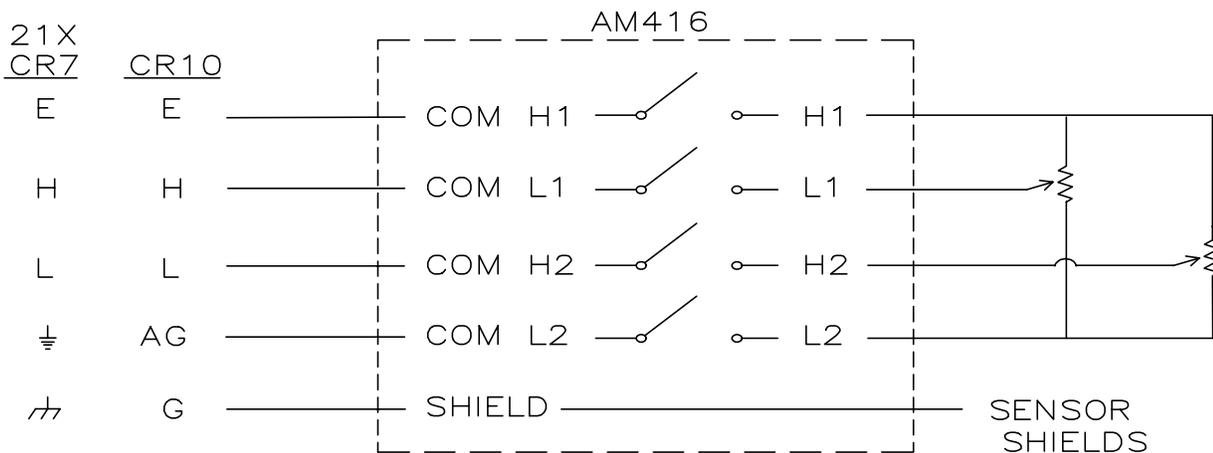
Sensor to Multiplexer wiring - up to three half bridges may be connected to one input SET, provided that the sensor's completion resistors are located at the datalogger (Figure 10).

Multiplexer to Datalogger wiring - Signal lines from the multiplexer COM terminals are input into three consecutive single-ended analog input channels. 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.

## AM416 RELAY MULTIPLEXER



**FIGURE 10. Half Bridge (Modified 107 Temperature Probe) Hook-up and Measurement.**



**FIGURE 11. Potentiometer Hook-up and Measurement**

### 6.3.2 POTENTIOMETER MEASUREMENT

Sensor to Multiplexer wiring - up to two potentiometers may be connected to one input SET. Excitation and ground leads may be common; signal leads must be routed separately (Figure 11).

Multiplexer to Datalogger wiring - Signal lines from two COM terminals are connected to two consecutive single-ended analog input channels. One COM terminal is connected to a datalogger switched excitation channel, and the remaining COM line connects to datalogger ground. Up to 32 potentiometers may be measured by two single-ended datalogger channels.

### 6.3.3 FOUR WIRE HALF BRIDGE WITH MEASURED EXCITATION

Sensor to Multiplexer Wiring - one sensor per input SET.

Multiplexer to Datalogger Wiring - One COM line is tied to a datalogger excitation channel, and two COM lines to a differential analog input. The remaining COM line is connected to the high side of a differential channel along with a fixed resistor. The other side of the resistor connects to the low side of the channel, then ground (Figure 12). Up to 16 four wire half-bridges may be measured by two differential datalogger channels in this manner.

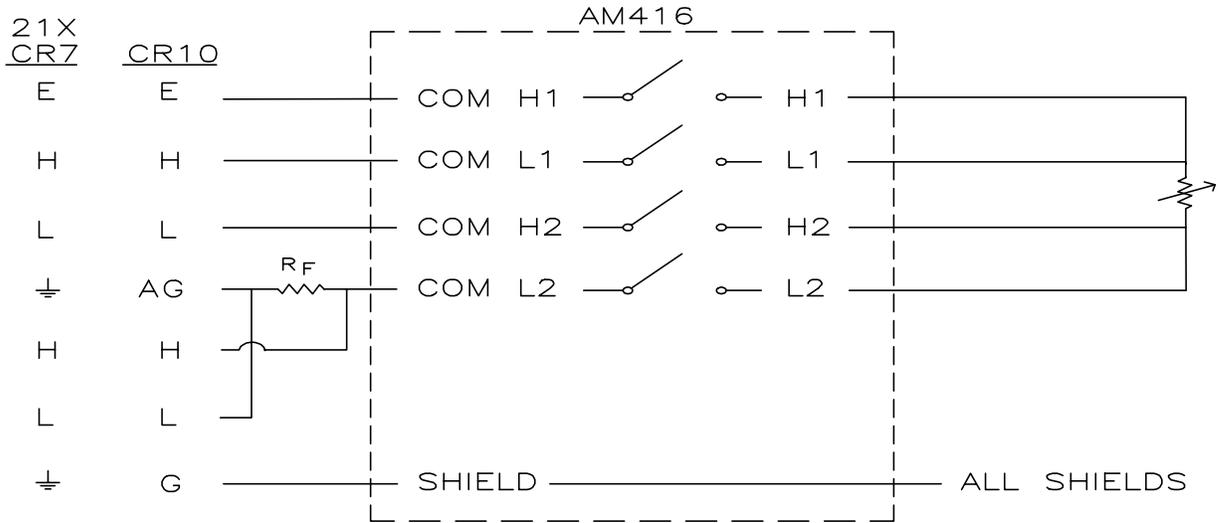


FIGURE 12. Four Wire Half Bridge Hook-up and Measurement

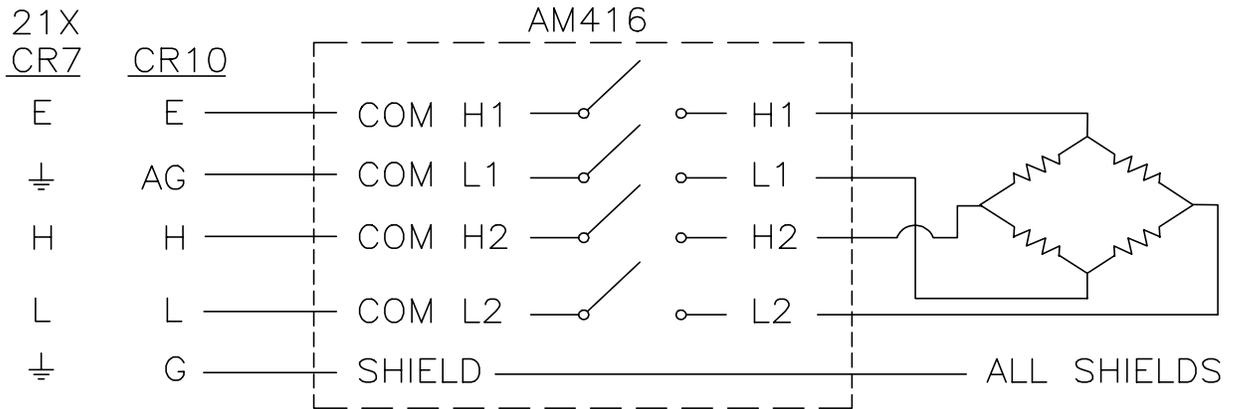


FIGURE 13. Differential Measurement with Sensor Excitation

**6.4 FULL BRIDGE MEASUREMENTS**

Sensor to Multiplexer wiring - Excitation, ground, and the two signal leads may be connected to one input SET (Figure 13).

Multiplexer to Datalogger wiring - COM terminals are connected to a datalogger excitation channel, a differential analog input channel, and analog ground. Up to sixteen full bridges may be multiplexed through the AM416.

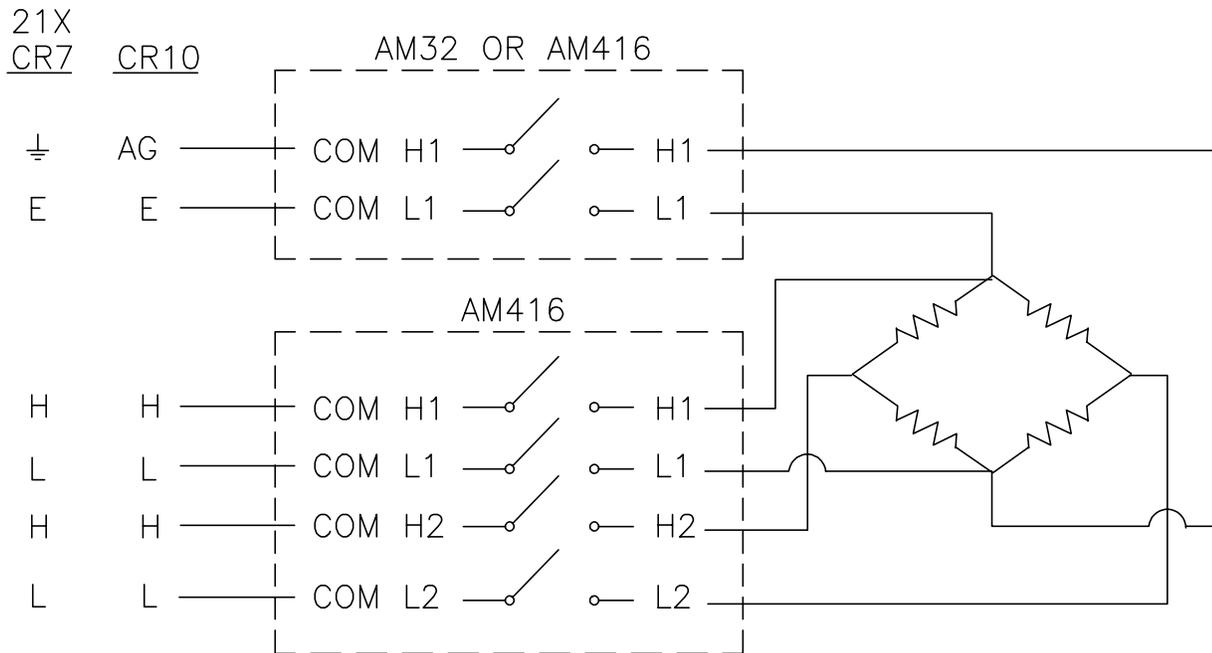
**6.5 FULL BRIDGES WITH EXCITATION COMPENSATION**

Sensor to Multiplexer wiring - In a six wire measurement, two wires must bypass the AM416. One solution is to multiplex the four signal wires through the AM416, but bypass the

AM416 with excitation and ground. This means that the sensors will be excited in common, which causes a higher current drain, possibly exceeding the current available from the datalogger's excitation channels. Alternatively, the excitation and ground leads may be multiplexed through either an AM32 multiplexer or an additional AM416. This allows the sensors to be excited one at a time (Figure 14).

Multiplexer to Datalogger wiring - Four leads from the COM terminals to two sequential differential analog channels in the datalogger. Excitation and ground are multiplexed by a AM32 or AM416. Both multiplexers can be reset and clocked by the same control ports and/or excitation channels, which simplifies programming.

## AM416 RELAY MULTIPLEXER



**FIGURE 14. Full Bridge Measurement with Excitation Compensation**

### 6.6 THERMOCOUPLE MEASUREMENT

The datalogger manuals contain thorough discussions of thermocouple measurement and error analysis. These topics will not be covered here.

#### 6.6.1 MEASUREMENT CONSIDERATIONS

**Reference Junction** - As shown in Figure 15 and 16, two reference junction configurations are possible: reference at the datalogger or reference at the AM416.

**Datalogger Reference** - The 21X and the CR7 723-T Analog Input card with RTD have built-in temperature references. The 10TCRT Thermocouple Reference (not standard with CR10(X) purchase), is installed on the wiring panel between the two analog input terminal strips.

When the reference junction is located at the datalogger, the signal wires between the datalogger and the AM416 must be of the same wire type as the thermocouple (Figure 15). The "polarity" of the thermocouple wire must be maintained on either side of the multiplexer (e.g. if constantan wire is input to a L1 terminal, then a constantan wire should run between the

multiplexer's COM L1 terminal and the datalogger measurement terminal). Figures 15 & 16 depict type T thermocouple applications, but other thermocouple types (e.g. E, J, and K) may also be measured and linearized by the dataloggers.

If thermocouples are measured with respect to the datalogger reference, then concurrent measurement of any other sensor type through the AM416 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 AM416.
2. Some thermocouple wires have a greater resistance than copper, which adds resistance to the non-thermocouple sensor circuit. For example, constantan is approximately 26 times more resistive than copper.



## AM416 RELAY MULTIPLEXER

### 6.6.2 SINGLE-ENDED THERMOCOUPLE MEASUREMENT

In single-ended thermocouple measurement, the following precautions must be taken to ensure accurate measurement:

1. Only shielded thermocouple wire should be used; the sensor shields should be tied to datalogger earth ground through the multiplexer shield terminals.
2. The exposed end of the thermocouple should be electrically insulated to prevent differences in ground potential from causing an error in the measured temperature.

Sensor to Multiplexer wiring - up to three thermocouples per SET; the high side of each thermocouple is input into terminals H1, L1, and H2. The low sides of each thermocouple are multiplexed in common through terminal L2.

Multiplexer to Datalogger wiring - If the reference junction is at the datalogger, then the wire that connects the COM H1, COM L1, and COM H2 terminals to the datalogger should be the same composition as the high side of the thermocouples. Also, the wire that connects COM L2 to datalogger ground should be the same composition as the low side of the thermocouples.

If the reference junction is at the AM416 (CSI 107 thermistor, RTD, etc.), then copper wire is used to connect all COM terminals to the datalogger.

### 6.6.3 DIFFERENTIAL THERMOCOUPLE MEASUREMENT

Sensor to Multiplexer wiring - up to two thermocouples per input SET.

Multiplexer to Datalogger wiring - The wires here can be handled in one of two ways. If a reference junction (107 thermistor, RTD, etc.) is at the AM416, then two pair of copper wires may be run between the COM terminals of the multiplexer and two differential input channels.

If the reference junction is at the datalogger, then two pairs of thermocouple wire should be run between the COM terminals of the multiplexer and two differential input channels.

## 6.7 MIXED SENSOR TYPES

In applications where sensors types are mixed, multiple hook-up configurations and programming sequences are possible. Please consult CSI for application assistance if you intend to multiplex markedly different sensor types in your application.

### 6.7.1 MIXED SENSOR EXAMPLE: SOIL MOISTURE BLOCKS AND THERMOCOUPLES

In this example, 16 thermocouples and 16 soil moisture blocks will be multiplexed through the AM416. One thermocouple and one soil moisture block are input into each SET.

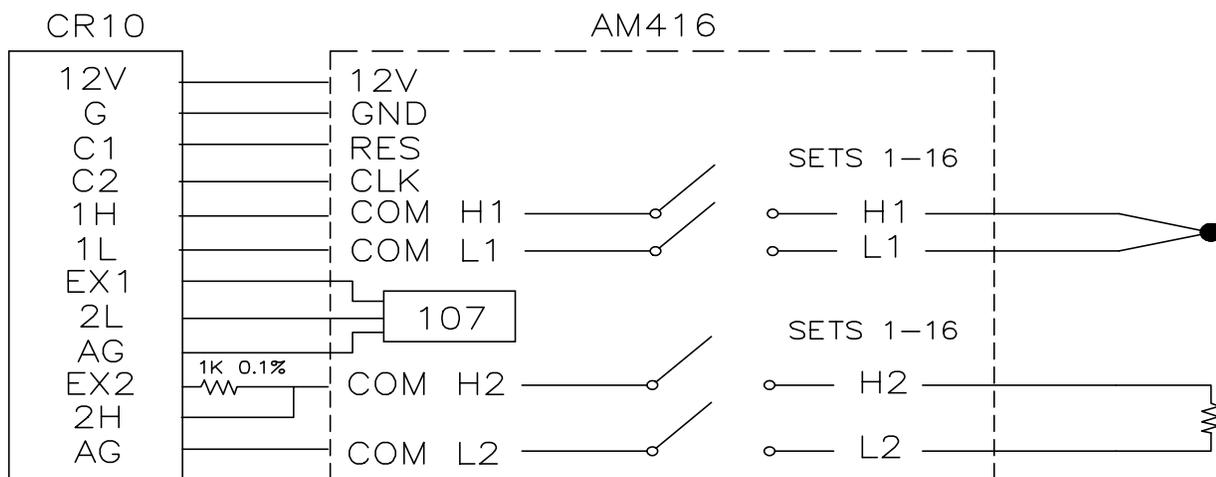


FIGURE 17. Thermocouple and Soil Block Measurement

**EXAMPLE PROGRAM - THERMOCOUPLE AND SOIL BLOCK MEASUREMENT**

(PROGRAM IS FOR CR10(X) - 33 LOCATIONS ALLOCATED TO INPUT STORAGE)

\* 1 Table 1 Programs  
01: 60 Sec. Execution Interval

REFERENCE TEMPERATURE FOR THERMOCOUPLES

01: P11 Temp 107 Probe  
01: 1 Rep  
02: 4 IN Chan  
03: 1 Excite all reps w/EXchan 1  
04: 1 Loc [:REFTEMP ]  
05: 1 Mult  
06: 0 Offset

ENABLES MULTIPLEXER

02: P86 Do  
01: 41 Set high Port 1

BEGINS MEASUREMENT LOOP

03: P87 Beginning of Loop  
01: 0 Delay  
02: 16 Loop Count

CLOCK PULSE

04: P86 Do  
01: 72 Pulse Port 2  
05: P22 Excitation with Delay  
01: 1 EX Chan  
02: 2 Delay w/EX (units=.01 sec)  
03: 0 Delay after EX (units=.01 sec)  
04: 1 mV Excitation  
05: 0

MEASURES 1 THERMOCOUPLE PER LOOP

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

MEASURES 1 SOIL MOISTURE BLOCK PER LOOP

07: P5 AC Half Bridge  
01: 1 Rep  
02: 14 250 mV fast Range  
03: 3 IN Chan  
04: 2 Excite all reps w/EXchan 2  
05: 250 mV Excitation  
06: 18-- Loc [:SOIL M #1]  
07: 1 Mult  
08: 0 Offset

ENDS MEASUREMENT LOOP

08: P95 End

DISABLES MULTIPLEXER

09: P86 Do  
01: 51 Set low Port 1

CALCULATES BRIDGE TRANSFORM ON SOIL MOISTURE BLOCKS

10: P59 BR Transform  $Rf[X/(1-X)]$   
01: 16 Reps  
02: 18 Loc [:SOIL M #1]  
03: 1 Multiplier (Rf)

11: P End Table 1

INPUT LOCATION LABELS:

1:REFTEMP	19:SOIL M #2
2:TC #1	20:SOIL M #3
3:TC #2	21:SOIL M #4
4:TC #3	22:SOIL M #5
5:TC #4	23:SOIL M #6
6:TC #5	24:SOIL M #7
7:TC #6	25:SOIL M #8
8:TC #7	26:SOIL M #9
9:TC #8	27:SOIL M#10
10:TC #9	28:SOIL M#11
11:TC #10	29:SOIL M#12
12:TC #11	30:SOIL M#13
13:TC #12	31:SOIL M#14
14:TC #13	32:SOIL M#15
15:TC #14	33:SOIL M#16
16:TC #15	34:_____
17:TC #16	35:_____
18:SOIL M #1	36:_____

### 7. GENERAL MEASUREMENT CONSIDERATIONS

1. Long lead lengths - long lead lengths contribute to the formation of induced and capacitive voltages within the sensor and AM416 lead wires. To minimize this phenomenon, CSI recommends use of Teflon, polyethylene, or polypropylene insulation around individual conductors. Do not use PVC insulation as conductor insulation, 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 theory of operation 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 AM416 power ground establishes a common ground. The Installation/Maintenance Section of your datalogger manual has more for 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.

### 8. INSTALLATION

The standard AM416 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.

Several enclosures may be purchased through CSI 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 AM416 is attached to the mounting plate inside the enclosure with two screws. To expose these screws, the top plate of the multiplexer (four #1 phillips screws at the corners) and the printed circuit board (two straight-slot screws near the center of the board) must be removed. Care must be taken when removing the upper plate of the multiplexer. It is generally easiest to lift the edge opposite the strain relief flange up first, then slide the upper plate out. Make sure to clear the terminal strips.

The enclosure lids are gasketed. The screws on the outside of the enclosure should be tightened to form a restrictive seal. In high humidity environments, user supplied foam or putty (or a similar substance) helps to reduce the passage of moisture into the enclosure via the cable conduits. **[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.

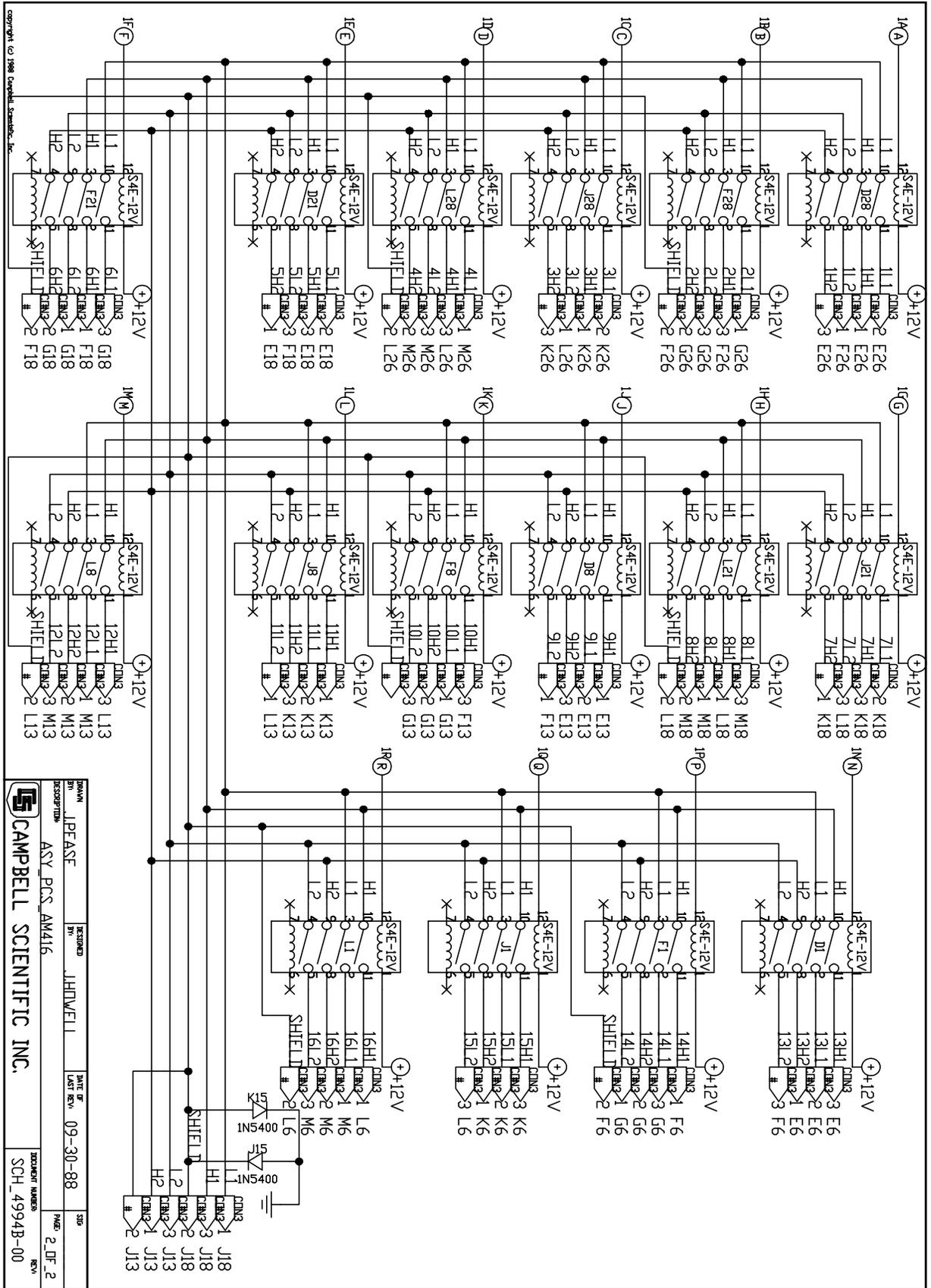
#### 8.1 ENVIRONMENTAL CONSTRAINTS

The AM416 has an operable temperature range of -40°C. to +65°C. The multiplexer is susceptible to corrosion at high relative humidity. Desiccant packs are available from CSI and they should be used inside the enclosure to remove water vapor.





APPENDIX A. AM416 STUFFING CHART AND SCHEMATICS



DESIGNER	J.P. FASE	DESIGNED BY	J.H. HOWELL	DATE OF LAST REV.	09-30-88	SHEET	2 OF 2
DESCRIPTION	ASY. PCS. AM416	REVISION				INCHMENT NUMBER	SCH_4994B-00
							REV.

Copyright © 1988 Campbell Scientific, Inc.

**APPENDIX A. AM416 STUFFING CHART AND SCHEMATICS**

## APPENDIX B. DIFFERENCES BETWEEN THE AM416 AND THE AM32

The AM416 differs from Campbell Scientific's AM32 multiplexer in the following ways:

1. The AM416 switches sixteen sets of four lines at a time (4 x 16). The AM32 switches thirty-two sets of two lines at a time (2 x 32).
2. The AM416 is packaged in an aluminum case that should decrease temperature gradients across the multiplexer terminal strips.
3. The AM416 is smaller.
4. The AM416 contains terminals and circuitry for sensor shield wires. This circuitry allows sensor shield wires to be routed through the multiplexer and grounded at the datalogger.
5. The packaging of the AM416 allows for strain relief of lead wires on the multiplexer's case.
6. The AM416 contains diodes between shields and power ground for transient protection.





## **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