AM416
Relay Multiplexer

User Guide

Issued 5.11.98

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AM416 Relay Multiplexer

The main function of the AM416 Multiplexer is to increase the number of sensors that may be scanned by most Campbell Scientific 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 analogue sensors into single-ended or differential datalogger channels. Four lines are switched simultaneously; a maximum of sixteen sets of (four) lines can be scanned, hence the name ***A****(nalogue)* ***M****(ultiplexer)* ***4****(lines x)* ***16****(sets). Therefore, a total of 64 lines can be multiplexed.*

1. Introduction

The maximum number of sensors that can be multiplexed through one AM416 depends on 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; see Sections 6.1, 6.2, and 6.6).
2. Up to 48 single-ended sensors that require excitation (e.g. some half bridges; see 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; see Section 6.3.3 and 6.4).
4. In conjunction with an AM32 multiplexer, up to 16 six-wire full bridges (see 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 analogue sensor signals, although it may also be used to multiplex switched excitations, continuous analogue 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 6.7).

NOTE A discussion of single-ended and differential analogue measurements is given in the datalogger manual.

As purchased, the AM416 is intended for use in indoor, non-condensing environments. An enclosure such as the AM-ENC is required for field use. In thermocouple applications, the AM-ENCT enclosure should be used.

1.2 Compatibility

The AM416 is compatible with the CR10/10X, CR23X, 21X and CR7 dataloggers. It can *not* be used with the CR500 datalogger.

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 CR10/10X and CR23X applications, the AM416 may be used to multiplex up to 16 Geokon (or similar) vibrating wire sensors through one AVW1 vibrating wire interface.

2. Physical Description

The AM416 is housed in a 210 x 165 x 35mm anodised aluminium case (Figure 1). The aluminium case reduces temperature gradients across the AM416's terminal strips. This is extremely important when thermocouples are being multiplexed (see Section 6.6). The case can be opened by removing the four 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 (see Section 8).

A strain-relief flange is located along the lower edge of the top panel of the case. Wires can be attached to this flange with standard cable ties.

Wires from sensors and the datalogger are connected to the grey terminal strips. The four terminals near the strain-relief flange are the connections for datalogger control of the AM416 (see Section 4.1). The terminal strips that run the length of the AM416 are for measurement connections (see Section 4.2). Note that these sensor inputs do *not* have spark gaps. All terminals accept stripped and tinned lead wires up to 1.5mm in diameter. The datalogger is connected to the AM416 through a minimum of seven, but generally nine, individually insulated wires.

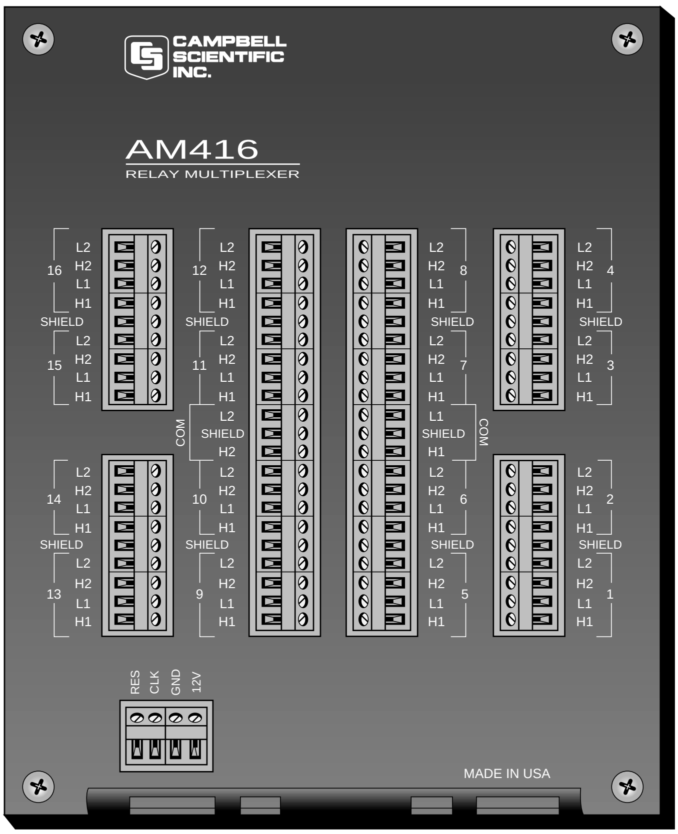


Figure 1 Plan View of the AM416 Relay Multiplexer

3. AM416 Specifications

Power*: Unregulated 12V DC (9.6V to 16V) – See Figure 4 for effect of low voltage on relay actuation time.

Current Drain: Quiescent: <100µA
Active: 17mA (typical)

Reset*: A continuous signal between 3.5V DC and16V DC holds the AM416 in an active state (i.e. a clock pulse can trigger a scan advance). A signal voltage less than 0.9V DC deactivates the AM416 (a clock pulse will not trigger a scan advance and the AM416 is reset).

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

Operational Temperature: -40°C to +65°C

Operational Humidity: 0 - 95%, non-condensing

Dimensions: length: 210mm
width: 165mm
depth: 35mm
(without field enclosure)

Weight: 0.7kg

Expandability:**
3 AM416s per CR10/10X
4 AM416s per CR23X
4 AM416s per 21X
8 AM416s per CR7 (725 Card)
(nominal maximum; number of AM416s may be increased depending on specific site requirements and configuration)

Maximum Cable Length: Sensor and scan rate dependent (in general, longer lead lengths necessitate longer measurement delays; refer to datalogger manual for additional details).

Maximum Switching Current*:** 500mA

* 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 Campbell Scientific for application assistance.

CAUTION *** Switching currents greater than 30mA (occasional 50mA 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 30mA.

Contact Specifications

Initial contact resistance:	50mΩ max.
Initial contact bounce:	1ms max.
Contact material:	Gold clad silver alloy
Electrostatic capacitance:	3pF

Minimum expected life

Mechanical (at 50Hz):	10^8 operations
Electrical (at 20Hz):	2 x 10^5 operations at 3A 30V DC

Speed (At 25°C, 50% RH)

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

4. Operation

Section 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. Section 4.2 discusses the use of terminals used in sensor measurement.

4.1 Control Terminals

The dataloggers should be connected to the AM416 as shown in Figure 2. The power, ground, reset and clock connections remain essentially the same regardless of the datalogger type used.

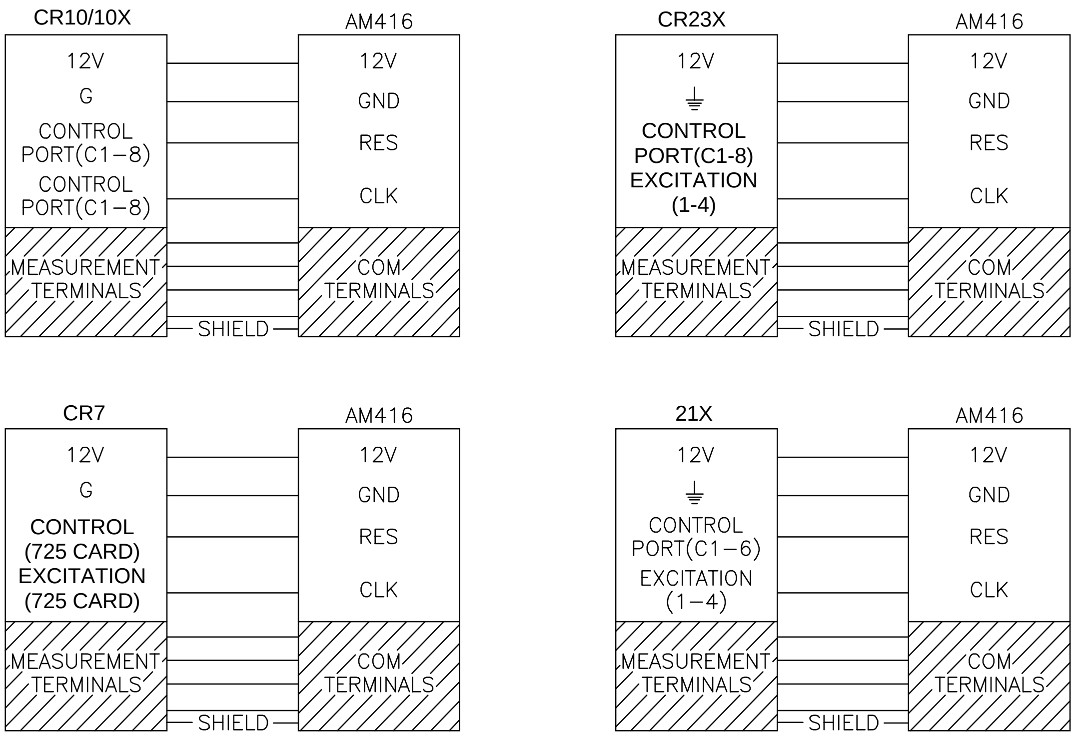


Figure 2 Datalogger to AM416 Connections

In a CR10/10X application, connect the datalogger 12V DC supply and ground terminals to the AM416 12V and ground terminals. Use two control ports for Clock and Reset.

With the CR23X, 21X or CR7 (with 725 Card) you can use one control port for Reset, and one switched excitation channel 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 between 3.5 and 16V DC applied to this terminal activates the multiplexer. When this line is dropped to <0.9V DC, the multiplexer enters a quiescent, low current drain state. Reset is always connected to a datalogger control port. Instruction 86 (option codes 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).

CAUTION Adjacent multiplexer input channels may be shorted to each other for up to 5ms during the transition between channels (e.g. channel 1 H1 to channel 2 H1, channel 1 L1 to channel 2 L1, etc.). For this reason, sensors that are capable of sourcing current should not be assigned input terminals adjacent to sensors that can sink current.

The multiplexer is clocked on the leading edge of the voltage pulse. The voltage level must fall below 1.5V DC then exceed 3.5V DC to register a clock pulse. Pulse width must be at least 5ms.

With the CR23X, 21X and CR7 dataloggers, a switched excitation is generally used to clock the multiplexer (Instruction 22 with 5000mV excitation). If no switched excitation channels are available it is possible to clock using control ports. See Section 5.1 for additional details.

With the CR10/10X datalogger, a control port is used to clock the multiplexer. Instruction 86 with the pulse port option (command codes 71 to 78 generate a pulse 10ms 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 (see Figure 3). The datalogger should always be tied to earth ground by one of the methods described in the Installation/ Maintenance section of the datalogger manual.

4.1.4 Power Supply

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

In many applications it may be convenient to power the AM416 from the data-logger's battery. For more power-intensive operations, an external, rechargeable, 12V DC, 60Ah 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 can be used to power the AM416 in applications where the system current drain is low, or where replacing the batteries frequently is not a problem. It is advisable to calculate the total power requirements of the system and the expected battery life 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 CR10/10X makes differential measurements on 32 thermocouples every minute, the average current drain due to the AM416 is about 0.3mA. Under the same conditions, a 2 second scan rate increases the average system current drain to about 8.5mA. 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 analogue measurements (thermocouples, pyranometers, thermopiles, etc.) must be made differentially. This procedure is required because small ground potentials are created along the 21X analogue terminal strip when the 12V supply is used to power peripherals. This limitation reduces the number of available analogue input channels and so may make the use of an external supply essential for the AM416 (Figure 3).

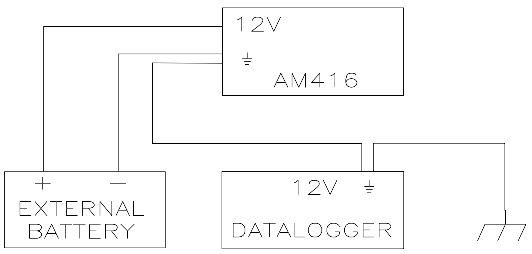


Figure 3 Power and Ground Connections for External Power Supply

CAUTION Low power and high ambient temperatures may affect the actuation time of the multiplexer relays (see Figure 4). If the relay is not closed when a measurement is started, the result will be an inaccurate or over-ranged value. Extra delay (e.g. an extra 10ms) can be introduced in a CR10/10X program, if necessary, by using Instruction 22 after Instruction 86 (see Datalogger Program Examples, in Section 5). Depending on the programming method used, the extra delay can b added in other datalogger programs by simply increasing the value of parameter 2 in Instruction 22.

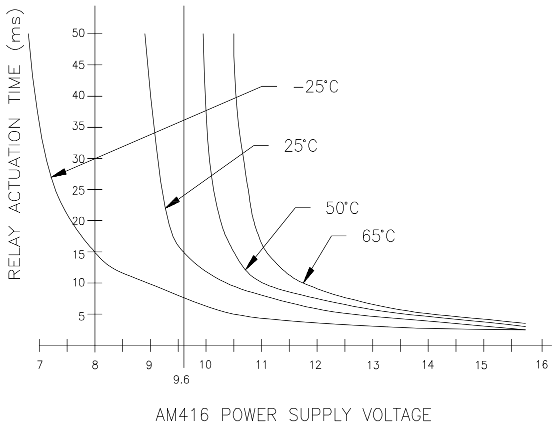


Figure 4 Actuation Time of Relays vs. Temperature (°C) and Battery Voltage

4.2 Measurement Terminals

The terminals that run the length of the AM416 are dedicated to the connection of sensors to the datalogger (see 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 the multiplexer and the datalogger. The shield lines allow sensor shields to be routed through the multiplexer and back to datalogger ground.

4.2.1 COM Terminals

The multiplexer terminals dedicated to multiplexer-datalogger signal transfer are labelled COM (common; see Figure 1). The four individual COM lines are labelled: 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.

Shield terminals are provided with the COM terminals. 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 next to the COM terminals should be tied to datalogger earth ground either directly or through a busbar.

4.2.2 Sensor Input Terminals

The input terminals for sensor attachment run the length of the multiplexer and are subdivided into 16 labelled groups. Each group consists of four Simultaneously Enabled Terminals (referred to collectively as a SET). Within each SET, the four terminals are labelled H1, L1, H2 and 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 output of the sensors are entered in a program loop. The *generalised* structure of a program loop is outlined below. More complete example programs are shown in Section 5.2.

5.1 Single Loop Instruction Sequence

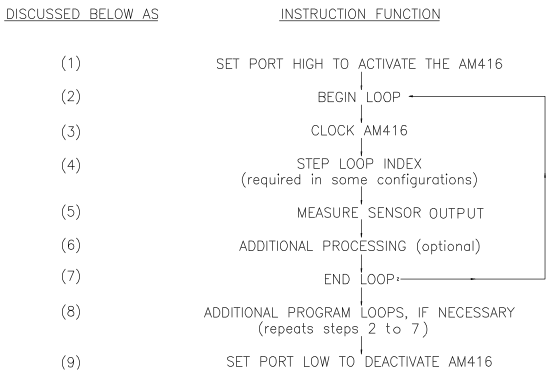


Figure 5 Generalised Single Loop Instruction Sequence

5.1.1 Steps 1 and 9 – Activate / Deactivate AM416

The control port connected to Reset (RES) is set high to activate the AM416 before the measurement sequence and set low following the measurement loop(s). Instruction 86 is used to set the port. (With older CR10, 21X and CR7s without OS series PROMs, Instruction 20 is used.)

5.1.2 Steps 2 and 7 – Loop

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

5.1.3 Step 3 – Clock / Delay

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

When controlled by the CR23X, CR7 or 21X, the Clock line may be connected to an excitation channel or a control port. When using an excitation channel only one instruction (22) is required to send the clock pulse. Instruction 22 should be programmed to provide a 20ms delay with a 5000mV excitation (10ms with the excitation, 10ms after the excitation). A control port can be used to clock the AM416 if required if no excitation ports are available. The CR7 and 21X instruction sequence required to clock with a control port is: Instruction 20 (set port high), 22 (delay of 20ms without excitation, i.e. parameter 3=2) followed by 20 (set port low). The program for the CR23X when using a control port is similar to that for the CR10/10X shown in the program examples in Section 5.3.

NOTE With the 21X or CR7, the 'pulse port' command can be used for clocking the AM416, but the fixed 100ms pulse width may be too long in some applications.

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

Extra delay can be introduced if necessary by increasing the value of parameter 3 in Instruction 22.

5.1.4 Step 4 – Step Loop Index

This instruction is used when a measurement instruction in the 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.

Example: two sensors per SET, six sensors total; two repetitions in measurement instruction; two measurement values assigned to indexed input locations (indicated by --); P90 used with a step of two, loop count of three.

	Input Locations						
	1	2	3	4	5	6	
First Pass	1	2					Sensor Numbers
Second Pass			3	4			
Third Pass					5	6	

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					Sensor Numbers
Second Pass		3	4				
Third Pass			5	6			

The measurement values for the second and fourth sensors are overwritten in their input locations. The first, third, fifth, and sixth measurement values are stored in the first four input locations.

The Step Loop Index is available in the CR10/10X, CR23X and CR7 dataloggers as standard, and also in the 21X 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: two 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			Sensor Numbers
Second Pass		3			4		
Third Pass			5			6	

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

5.1.5 Step 5 – Measure

Enter the instruction(s) needed to measure the output of the sensor(s). 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' or F4 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 needed, assign more input locations using the datalogger *A Mode.

5.1.6 Step 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.

5.1.7 Step 8 – Additional Loops

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

The program instruction sequences for control of an AM416 with different dataloggers are given in the examples below.

5.2 Simple Program Loop Examples

The example programs shown below are typical for a particular datalogger model with the AM416 muliplexer. They are not definitive, as the datalogger can be programmed in more than one way to achieve the desired result. In particular, while the *excitation voltage* produced by the CR10/10X datalogger is unsuitable for clocking the AM416, so necessitating the use of a control port, the CR23X, CR7 and 21X models can clock the multiplexer using *either* control ports *or* excitation ports, depending on the number of ports available and the programmer's preferences.

5.2.1 CR10/10X

```
*Table 1 Program
  01:  60       Execution Interval (seconds)
```

Activate Multiplexer

```
1:  Do (P86)
 1: 41       Set Port 1 High
```

Begin Measurement Loop

```
2:  Beginning of Loop (P87)
 1: 0        Delay
 2: 16       Loop Count
```

Clock Pulse

```
3:  Do (P86)
 1: 72       Pulse Port 2
```

Delay

```
4:  Excitation with Delay (P22)
 1: 1        Ex Channel
 2: 0        Delay W/Ex (units = 0.01 sec)
 3: 1        Delay After Ex (units = 0.01 sec)
 4: 0        mV Excitation
```

5: *User-Specified Measurement Instructions*

End Measurement Loop

```
6:  End (P95)
```

Deactivate Multiplexer

```
7:  Do (P86)
 1: 51       Set Port 1 Low

*Table 2 Program
  02: 0.0000    Execution Interval (seconds)

*Table 3 Subroutines

End Program
```

5.2.2 CR23X (Using Excitation Ports)

```
*Table 1 Program
  01: 600       Execution Interval (seconds)
```

Activate Multiplexer

```
1:  Do (P86)
 1: 41       Set Port 1 High
```

Begin Measurement Loop

```
2:  Beginning of Loop (P87)
 1: 0        Delay
 2: 16       Loop Count
```

Clock Pulse and Delay

```
3:  Excitation with Delay (P22)
 1: 1        Ex Channel
 2: 1        Delay W/Ex (units = 0.01 sec)
 3: 1        Delay After Ex (units = 0.01 sec)
 4: 5000     mV Excitation
```

4: *User-Specified Measurement Instructions*

End Measurement Loop

```
5:  End (P95)
```

Deactivate Multiplexer

```
6:  Do (P86)
 1: 51       Set Port 1 Low

*Table 2 Program
  02: 0.0000    Execution Interval (seconds)

*Table 3 Subroutines

End Program
```

5.2.3 21X (Using Excitation Ports)

```
*Table 1 Program
  01: 60          Execution Interval (seconds)
```

Activate Multiplexer

```
1:  Set Port (P20)
 1: 1        Set High
 2: 1        Port Number
```

Begin Measurement Loop

```
2:  Beginning of Loop (P87)
 1: 0        Delay
 2: 16       Loop Count
```

Clock Pulse and Delay

```
3:  Excitation with Delay (P22)
 1: 1        Ex Channel
 2: 1        Delay w/Ex (units = 0.01 sec)
 3: 1        Delay After Ex (units = 0.01 sec)
 4: 5000     mV Excitation
```

4: *User-Specified Measurement Instructions*

End Measurement Loop

```
5:  End (P95)
```

Deactivate Multiplexer

```
6:  Set Port (P20)
 1: 0        Set Low
 2: 1        Port Number

*Table 2 Program
  02: 0.0000    Execution Interval (seconds)

*Table 3 Subroutines
End Program
```

5.2.4 CR7 (Using Excitation Ports)

```
*Table 1 Program
  01: 60          Execution Interval (seconds)
```

Activate Multiplexer

```
1:  Set Port(s) (P20)
 1: 1        Set High
 2: 1        Ex Card
 3: 1        Port Number
```

Begin Measurement Loop

```
2:  Beginning of Loop (P87)
 1: 0        Delay
 2: 16       Loop Count
```

Clock Pulse and Delay

```
3:  Excitation with Delay (P22)
 1: 1        Ex Card
 2: 2        Ex Channel
 3: 1        Delay w/Ex (units = 0.01 sec)
 4: 1        Delay After Ex (units = 0.01 sec)
 5: 5000     mV Excitation
```

4: *User-Specified Measurement Instructions*

End Measurement Loop

```
5:  End (P95)
```

Deactivate Multiplexer

```
6:  Set Port(s) (P20)
 1: 0        Set Low
 2: 1        Ex Card
 3: 1        Port Number

*Table 2 Program
  02: 0.0000    Execution Interval (seconds)

*Table 3 Subroutines

End Program
```

5.3 Multiple Loop Instruction Sequence

The program for operation of the AM416 is essentially the same for all 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 example demonstrates measurement of two dissimilar sensor types (i.e. strain gauges and potentiometers).

The program and accompanying wiring diagram (Figure 6) are intended as examples only; users will find it necessary to modify the program both for specific dataloggers and applications.

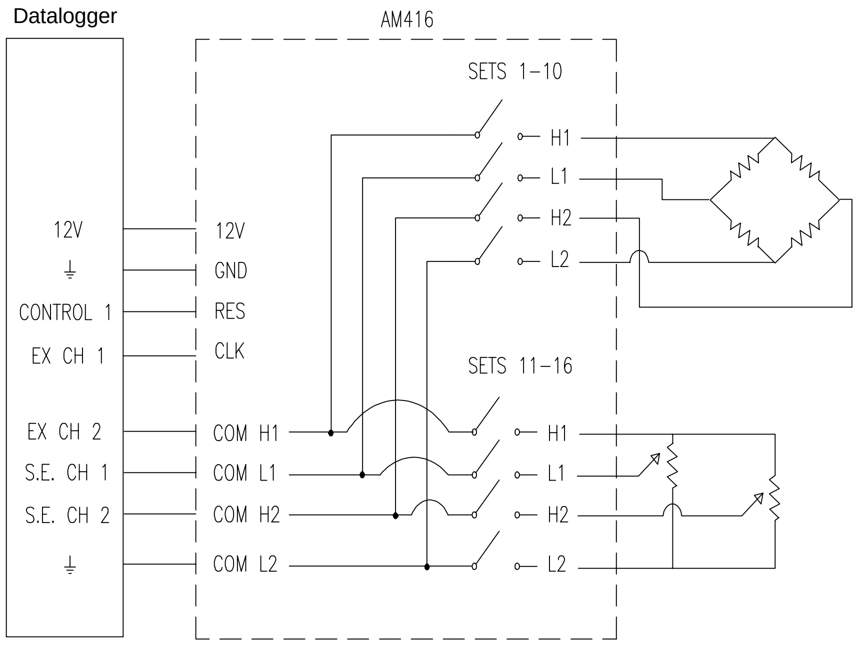


Figure 6 Wiring Diagram for Strain Gauges and Potentiometers

Example program for measuring strain gauges and potentiometers

```
*Table 1 Program
  01: 60        Execution Interval (seconds)
```

Enable Multiplexer

```
1:  Set Port (P20)
 1: 1         Set High
 2: 1         Port Number
```

Begin Strain Gauge Measurement Loop

```
2:  Beginning of Loop (P87)
 1: 0         Delay
 2: 10        Loop Count
```

Clock Pulse

```
3:  Excitation with Delay (P22)
 1: 1         Ex Channel
 2: 1         Delay w/Ex (units = 0.01 sec)
 3: 1         Delay After Ex (units = 0.01 sec)
 4: 5000      mV Excitation
```

Full Bridge Measurement Instruction

```
4:  Full Bridge (P6)
 1: 1         Reps
 2: 3         50 mV Slow Range
 3: 1         DIFF Channel
 4: 2         Excite all reps w/Exchan 2
 5: 5000      mV Excitation
 6: 1      -- Loc [ Strain____ ]
 7: 1         Mult
 8: 0         Offset
```

End of Strain Gauge Measurement Loop

```
5:  End (P95)
```

Beginning of Potentiometer Measurement Loop

```
6:  Beginning of Loop (P87)
 1: 0         Delay
 2: 6         Loop Count

7:  Step Loop Index (P90)
 1: 2         Step
```

Clock Pulse

```
8:  Excitation with Delay (P22)
 1: 1         Ex Channel
 2: 1         Delay w/Ex (units = 0.01 sec)
 3: 1         Delay After Ex (units = 0.01 sec)
 4: 5000      mV Excitation
```

Potentiometer Measurement Instruction

```
9:  Excite Delay Volt (SE) (P4)
 1: 2         Reps
 2: 5         5000 mV Slow Range
 3: 1         SE Channel
 4: 2         Excite all reps w/Exchan 2
 5: 1         Delay (units 0.01 sec)
 6: 5000      mV Excitation
 7: 11     -- Loc [ Pot______]
 8: 1         Mult
 9: 0         Offset
```

End of Potentiometer Measurement Loop

```
10:  End (P95)
```

Disables Multiplexer

```
11:  Set Port (P20)
 1: 0        Set Low
 2: 1        Port Number

*Table 2 Program
  02: 0.0000    Execution Interval (seconds)

*Table 3 Subroutines

End Program
```

Input Location Labels:

```
-Input Locations-
1 strain_1  6 0 0
2 strain_2  10 0 0
3 strain_3  10 0 0
4 strain_4  10 0 0
5 strain_5  10 0 0
6 strain_6  10 0 0
7 strain_7  10 0 0
8 strain_8  10 0 0
9 strain_9  10 0 0
10 strain_10 18 0 0
11 probe_1   6 0 0
12 probe_2   10 0 0
13 probe_3   10 0 0
14 probe_4   10 0 0
15 probe_5   10 0 0
16 probe_6   10 0 0
17 probe_7   10 0 0
18 probe_8   10 0 0
19 probe_9   10 0 0
20 probe_10  10 0 0
21 probe_11  10 0 0
22 probe_12  10 0 0
```

5.4 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 by changing 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 Connection 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 viewed as the only way to make a particular measurement. Refer to the datalogger manual for more information on basic bridge measurements. Most of the following examples do not depict datalogger/AM416 control connections (see Section 4), but their presence is implied and required. Campbell Scientific recommends that only sensor shield (drain) wires be connected to AM416 shield terminals.

6.1 Single-Ended Analogue Measurement Without Sensor Excitation

Sensor to multiplexer wiring: Up to two single-ended sensors not requiring excitation may be connected to one AM416 input SET.

Multiplexer to datalogger wiring: Signal lines from COM terminals are connected to two consecutive single-ended analogue input channels. Signal ground lines are tied to analogue ground (AG) in the CR10/10X and datalogger ground (⏚) in the CR23X, 21X and CR7. The COM shield line is tied to datalogger earth ground (see Figure 7). Up to 32 single-ended sensors may be measured by two single-ended datalogger channels in this manner.

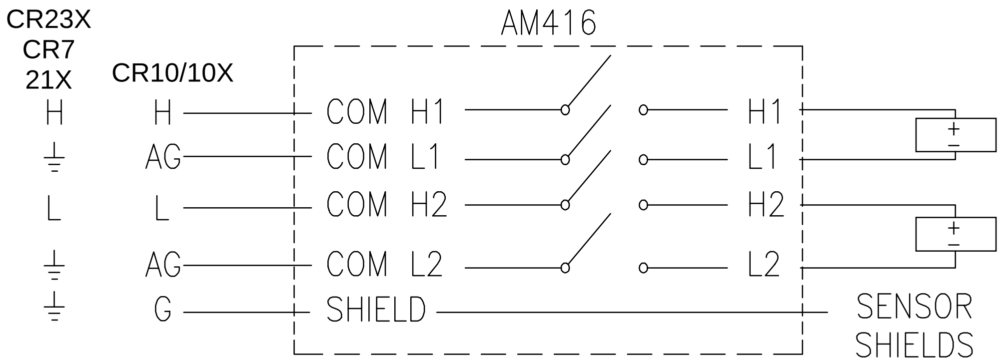


Figure 7 Single-ended Measurement Without Excitation

CAUTION Low level single-ended measurements are not recommended in a 21X application in which the 21X's internal 12V DC supply is being used to power the multiplexer or other peripherals (see Section 4.1.4)

6.2 Differential Analogue Measurement Without Sensor Excitation

Sensor to multiplexer wiring: Up to two differential sensors not requiring 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 analogue input at the datalogger (see Figure 8). Up to 32 differential sensors may be measured by two differential datalogger channels in this way.

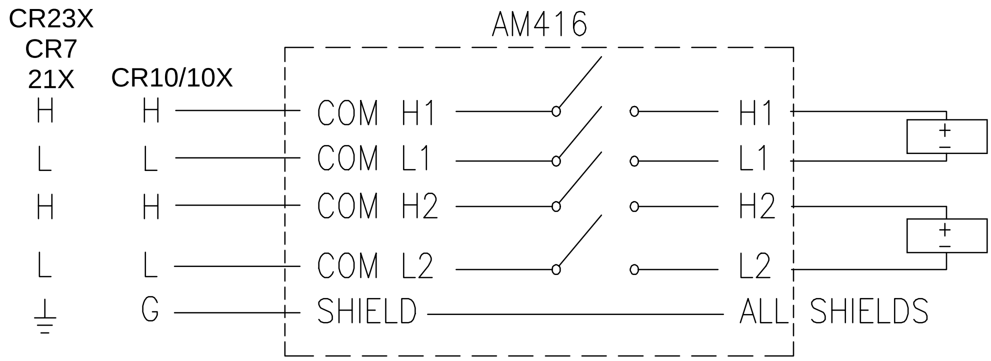


Figure 8 Differential Measurement Without Excitation

6.3 Half Bridge Measurements

Measurements of this type can be subdivided into three categories based on the nature of the completion resistance and the presence or absence of measured excitation. If the sensor's completion resistor(s) are installed at the datalogger (e.g. a Campbell Scientific 107 probe modified for multiplexer use), then three probes per SET may be excited and measured (see Figure 9). 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 can be multiplexed in common, up to two sensors per SET can be measured (see Figure 10). If measured excitation is required (i.e. 4-wire half bridge), then only one sensor per SET can be measured (see Figure 11) .

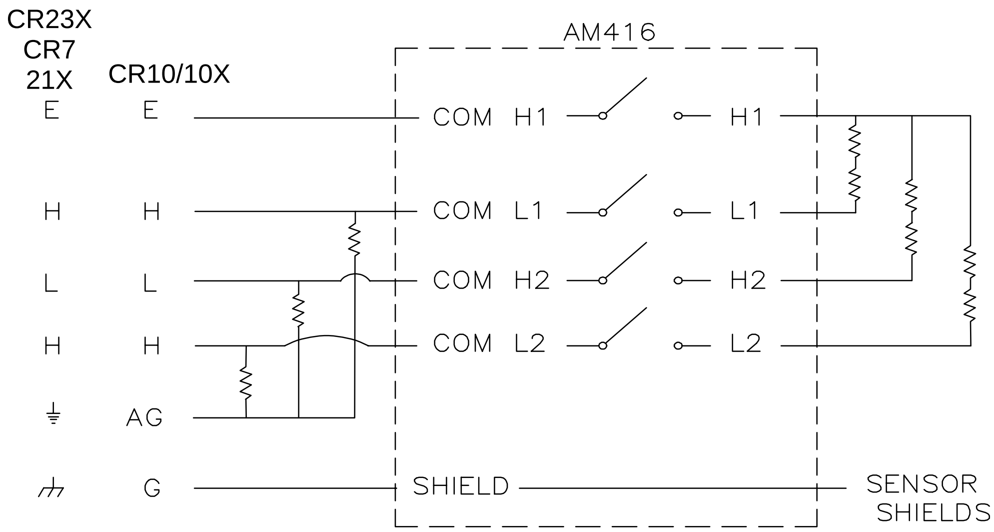


Figure 9 Half Bridge (Modified 107 Temperature Probe) Connection and Measurement

---

NOTE When completion resistors for resistive bridge measurements are required at the datalogger, the use of Campbell Scientific Terminal Input Modules (TIMs), which plug directly into the datalogger's wiring panel, is recommended. Please contact Campbell Scientific for details.

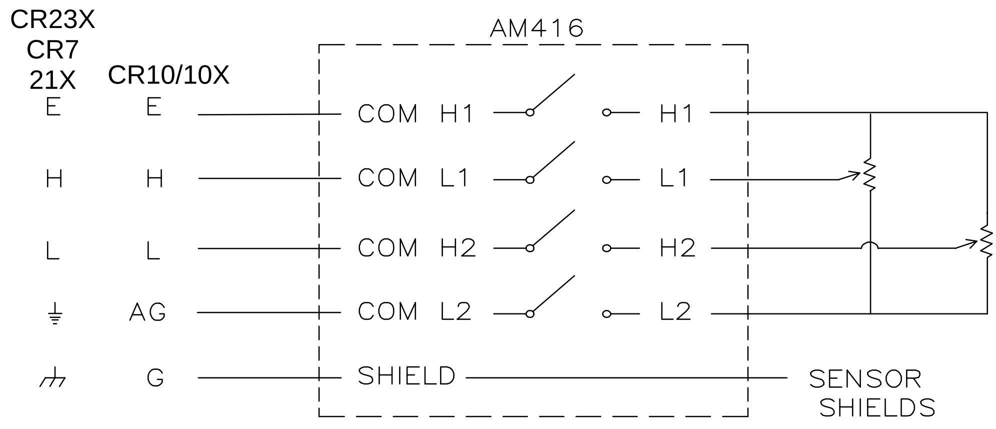


Figure 10 Potentiometer Connection and Measurement

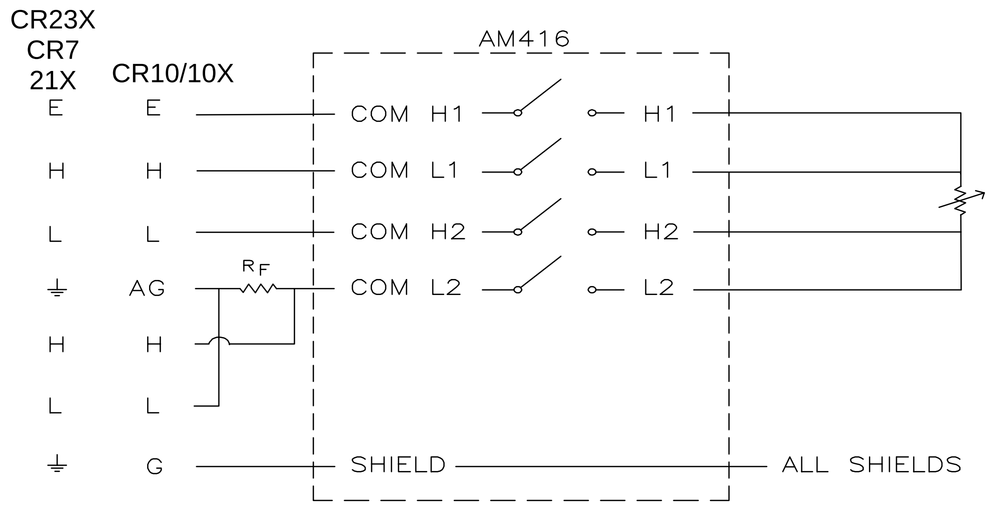


Figure 11 Four-Wire Half Bridge Connection and Measurement

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 (see Figure 9).

Multiplexer to datalogger wiring: Signal lines from the multiplexer COM terminals are input into three consecutive single-ended analogue input channels. A precision completion resistor ties the analogue input channel to analogue ground in the CR10/10X or to datalogger ground in the CR23X, CR7 or 21X .

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 (see Figure 10).

Multiplexer to datalogger wiring: Signal lines from two COM terminals are connected to two consecutive single-ended analogue 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 analogue 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 (see Figure 11). Up to 16 4-wire half bridges can be measured by two differential datalogger channels in this manner

6.4 Full Bridge Measurements

Sensor to multiplexer wiring: Excitation, ground, and the two signal leads may be connected to one input SET (see Figure 12).

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

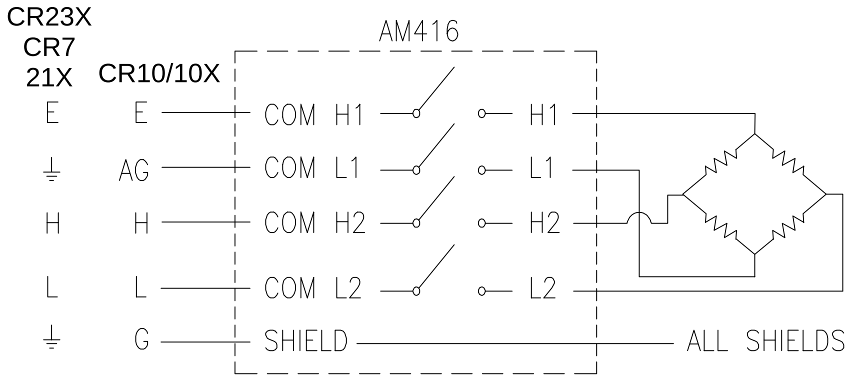


Figure 12 Differential Measurement with Sensor Excitation

6.5 Full Bridges with Excitation Compensation

Sensor to multiplexer wiring: In a 6-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 (see Figure 13).

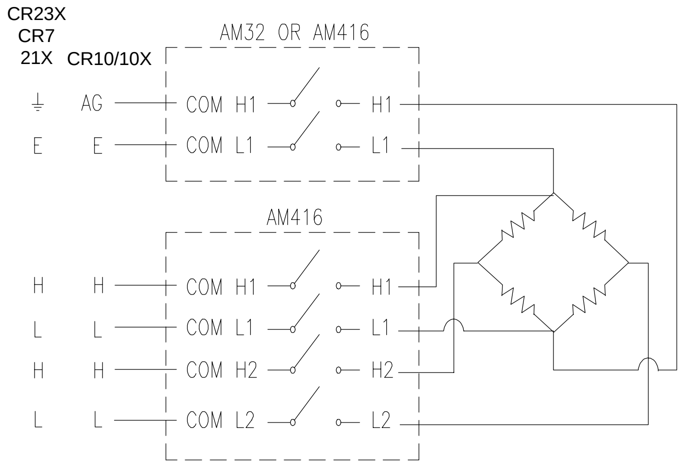


Figure 13 Full Bridge Measurement with Excitation Compensation

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

6.6 Thermocouple Measurements

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

6.6.1 Measurement Considerations

Reference junction: As shown in Figures 14 and 15, two reference junction configurations are possible: reference at the datalogger or reference at the AM416.

Datalogger reference: The CR23X, 21X and the CR7 723-T Analogue Input card with RTD have built-in temperature references. For the CR10/10X, the 10TCRT Thermocouple Reference (not included as standard with the CR10/10X) is installed on the wiring panel between the two analogue 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 (see Figure 14). The ‘polarity’ of the thermocouple wire must be maintained on either side of the multiplexer (e.g. if constantan wire is input to the L1 terminal, then a constantan wire should run between the multiplexer’s COM L1 terminal and the datalogger measurement terminal). Figures 14 and 15 depict type T thermocouple applications, but the output of other thermocouple types (e.g. E, J and K) may also be measured and linearised by the dataloggers.

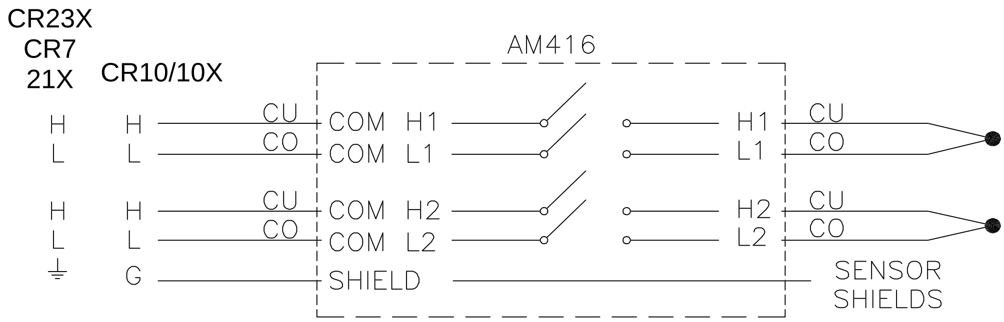


Figure 14 Differential Thermocouple Measurement with the Reference Junction at the Datalogger

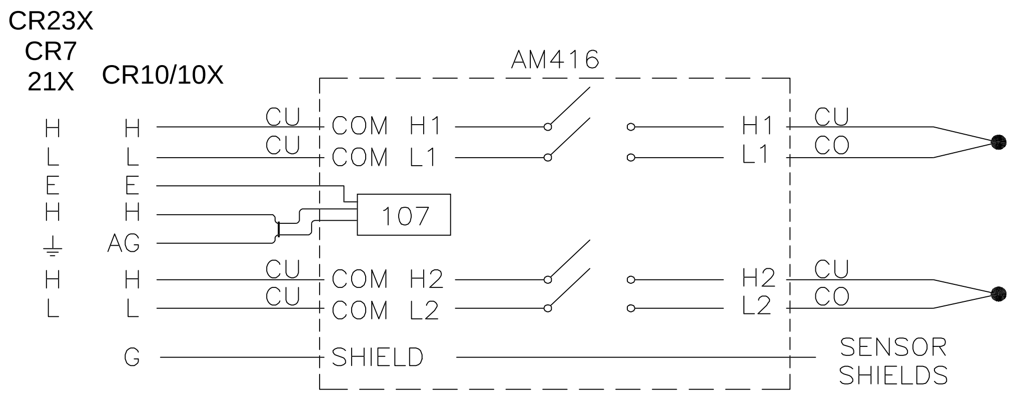


Figure 15 Differential Thermocouple Measurement with the Reference Junction at the AM416

CAUTION

If thermocouple temperatures 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. If a mix of TCs and other sensor types are multiplexed through the AM416, it is generally best to locate the reference junction on the AM416, as shown in Figure 15.

AM416 Reference: An external reference, usually a thermistor, may be located at the AM416, as shown in Figure 15. This approach requires an additional single-ended datalogger input to measure the reference temperature. Locate the reference between the COM terminals and, when practical, measure the thermocouples on SETs that are in close proximity to the COM terminals in order to minimise thermal gradients.

Thermal Gradients: Thermal gradients between the AM416's sensor input terminals and COM terminals can cause errors in thermocouple readings. For example, with type T thermocouples, a one degree gradient between the input terminals and the COM terminals will result in a one degree measurement error (approximately). The aluminium cover plate helps to minimise gradients, but for best results, the AM416 should be shielded and insulated from thermal sources.

When an enclosure is used, gradients induced from heat conducted along the thermocouple wire can be minimised by coiling some wire inside the enclosure. This procedure allows the heat to dissipate before it reaches the terminal. If the AM416 is housed in a field enclosure, the enclosure should be shielded from solar radiation.

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 sides of the thermocouples are connected to terminals H1, L1, and H2. The low sides of the thermocouples are multiplexed in common through terminal L2.

Multiplexer to datalogger wiring: If the reference junction is at the datalogger, then the wires that connect 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 (e.g. a Campbell Scientific 107 probe) 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 the reference junction is at the AM416, then two pairs 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 configurations and programming sequences are possible. Please consult Campbell Scientific 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 are multiplexed through the AM416. One thermocouple and one soil moisture block are connected to each SET.

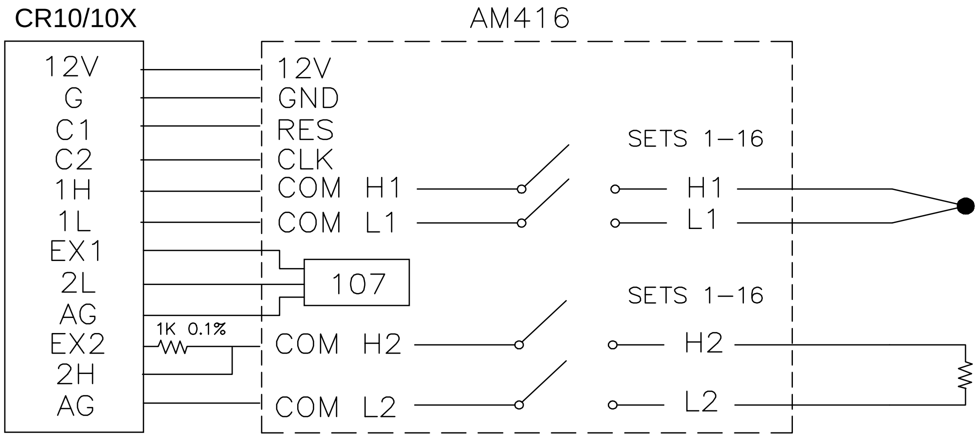


Figure 16 Thermocouple and Soil Moisture Block Measurement

Example Program: Thermocouple and Soil Moisture Block Measurement

(Program is for a CR10X; 33 Locations allocated to Input Storage)

```
;{CR10X}
;
*Table 1 Program
  01: 60        Execution Interval (seconds)
```

Reference temperature for thermocouples

```
1:  Temp (107) (P11)
 1: 1        Reps
 2: 4        SE Channel
 3: 1        Excite all reps w/E1
 4: 1        Loc [ Reftemp   ]
 5: 1        Mult
 6: 0        Offset
```

Enable multiplexer

```
2:  Do (P86)
 1: 41       Set Port 1 High
```

Begin measurement loop

```
3:  Beginning of Loop (P87)
 1: 0        Delay
 2: 16       Loop Count
```

Clock pulse and delay

```
4:  Do (P86)
 1: 72       Pulse Port 2

5:  Excitation with Delay (P22)
 1: 1        Ex Channel
 2: 0        Delay W/Ex (units = 0.01 sec)
 3: 1        Delay After Ex (units = 0.01 sec)
 4: 0        mV Excitation
```

Measure one thermocouple per loop

```
6:  Thermocouple Temp (DIFF) (P14)
 1: 1        Reps
 2: 1        2.5 mV Slow Range
 3: 1        DIFF Channel
 4: 1        Type T (Copper-Constantan)
 5: 1        Ref Temp (Deg. C) Loc [ Reftemp   ]
 6: 2     -- Loc [ TC1_1     ]
 7: 1        Mult
 8: 0        Offset
```

Measure one soil moisture block per loop

```
7:  AC Half Bridge (P5)
 1: 1        Reps
 2: 14       250 mV Fast Range
 3: 3        SE Channel
 4: 2        Excite all reps w/Exchan 2
 5: 250      mV Excitation
 6: 18    -- Loc [ Soilm1    ]
 7: 1        Mult
 8: 0        Offset
```

End measurement loop

```
8:  End (P95)
```

Disable multiplexer

```
9:  Do (P86)
 1: 51       Set Port 1 Low
```

Calculate bridge transform on soil moisture blocks

```
10:  BR Transform Rf[X/(1-X)] (P59)
 1: 16       Reps
 2: 18       Loc [ Soilm1    ]
 3: 1        Multiplier (Rf)

*Table 2 Program
  02: 0.0000    Execution Interval (seconds)

*Table 3 Subroutines

End Program

-Input Locations-
1 Reftemp   1 1 1
2 TC1_1     7 0 1
3 TC1_2     10 0 0
4 TC1_3     10 0 0
5 TC1_4     10 0 0
6 TC1_5     10 0 0
7 TC1_6     10 0 0
8 TC1_7     10 0 0
9 TC1_8     10 0 0
10 TC1_9     10 0 0
11 TC1_10    10 0 0
12 TC1_11    10 0 0
13 TC1_12    10 0 0
14 TC1_13    10 0 0
15 TC1_14    10 0 0
16 TC1_15    10 0 0
17 TC1_16    18 0 0
```

```
18 Soilm1    5 1 2
19 Soilm1_2  9 1 1
20 Soilm1_3  9 1 1
21 Soilm1_4  9 1 1
22 Soilm1_5  9 1 1
23 Soilm1_6  9 1 1
24 Soilm1_7  9 1 1
25 Soilm1_8  9 1 1
26 Soilm1_9  9 1 1
27 Soilm1_10 9 1 1
28 Soilm1_11 9 1 1
29 Soilm1_12 9 1 1
30 Soilm1_13 9 1 1
31 Soilm1_14 9 1 1
32 Soilm1_15 9 1 1
33 Soilm1_16 17 1 1
```

6.8 Multiple Vibrating Wire Sensors connected via two AM416s and a single AVW1 Interface

Multiple vibrating wire sensors can be connected via one or more AM416s and an AVW1 interface to a CR10/10X or CR23X datalogger. A schematic wiring diagram is shown in Figure 17. In this example, the power for the AVW1 is supplied by the datalogger, although an external supply could be used if required. For complete details of the sensors and AVW1 Interface see the *AVW1 and AVW4 Vibrating Wire Interfaces User Guide.* The AVW1 program instructions are added to the overall CR10/10X program as shown in the example below.

Example Program: Measurement of Multiple (16) Vibrating Wire Sensors using one AM416 with an AVW1 Interface and a CR10/10X Datalogger

(Program is for CR10X; 96 Locations allocated to Input Storage)

```
;{CR10X}
;
*Table 1 Program
  01: 60        Execution Interval (seconds)
```

Activate multiplexer

```
1:  Do (P86)
 1: 41       Set Port 1 High
```

Begin measurement loop

```
2:  Beginning of Loop (P87)
 1: 0        Delay
 2: 16       Loop Count
```

Clock pulse

```
3:  Do (P86)
 1: 72       Pulse Port 2
--------------------------------------------------
```

4: *User specified measurement instructions for Vibrating Wire Sensors (see 'AVW1 and AVW4 Vibrating Wire Interfaces User Guide')*

```
--------------------------------------------------
```

End measurement loop

```
5:  End (P95)
```

Deactivate multiplexer

```
6:  Do (P86)
 1: 51       Set Port 1 Low

*Table 2 Program
  02: 0.0000    Execution Interval (seconds)

*Table 3 Subroutines

End Program
```

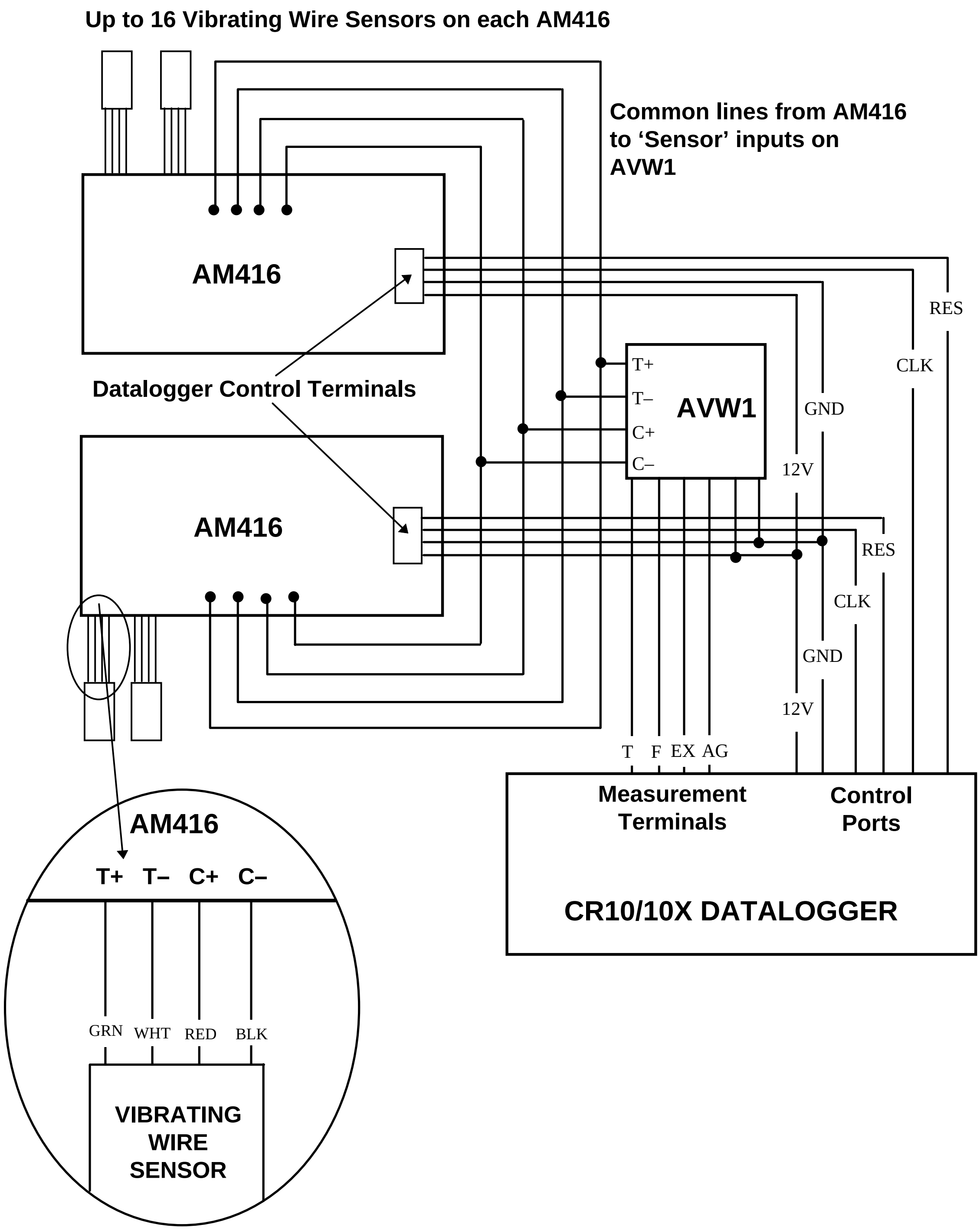


Figure 17 Schematic Wiring Diagram for Multiple Vibrating Wire Sensors and AVW1 Interface

To measure 16 Geokon Vibrating Wire Sensors following the example program in Section 4 of the *AVW1 and AVW4 Vibrating Wire Interfaces User Guide*, a total of 96 input locations would be required. The six values of Temp. (°C), Pressure (psi), Pt (psi), (T-To*C), Pt (feet of water) and Distance (feet) would be stored sequentially for each of the 16 loops of the program.

7. General Measurement Considerations

7.1 Long Lead Lengths

Long lead lengths contribute to the formation of induced and capacitive voltages on the sensor and AM416 lead wires. To minimise this phenomenon, Campbell Scientific recommends the 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 measurements section of your datalogger manual for more information.

7.2 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 information on grounding procedures.

7.3 Completion Resistors

In some applications it is advisable to place completion resistors at the datalogger terminal strips. Special Terminal Input Modules (TIMs) are available for this purpose. Also, in some cases, sensors specific to the use of multiplexers are available from Campbell Scientific. Examples include soil moisture probes and thermistors. Please consult Campbell Scientific for ordering and pricing information.

7.4 Contact Degradation

Once current in excess of 30mA 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. (See also Section 3.)

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.

Enclosures may be purchased through Campbell Scientific which offer a degree of protection against dust, spraying water, oil, falling dirt, or dripping non-corrosive liquids. 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 centre 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. Be careful to clear the terminal strips.

In high humidity environments, user-supplied silicone rubber sealant (or a similar substance) helps to reduce the passage of moisture into the enclosure via the cable conduits.

Using silicone rubber means that the sealant can easily be removed should it be necessary to disconnect a sensor or add a new wire.

CAUTION

Do not use bath or tile sealant, which gives off corrosive fumes that can damage circuit boards. Use proper electronic grade silicone rubber or plumber's putty.

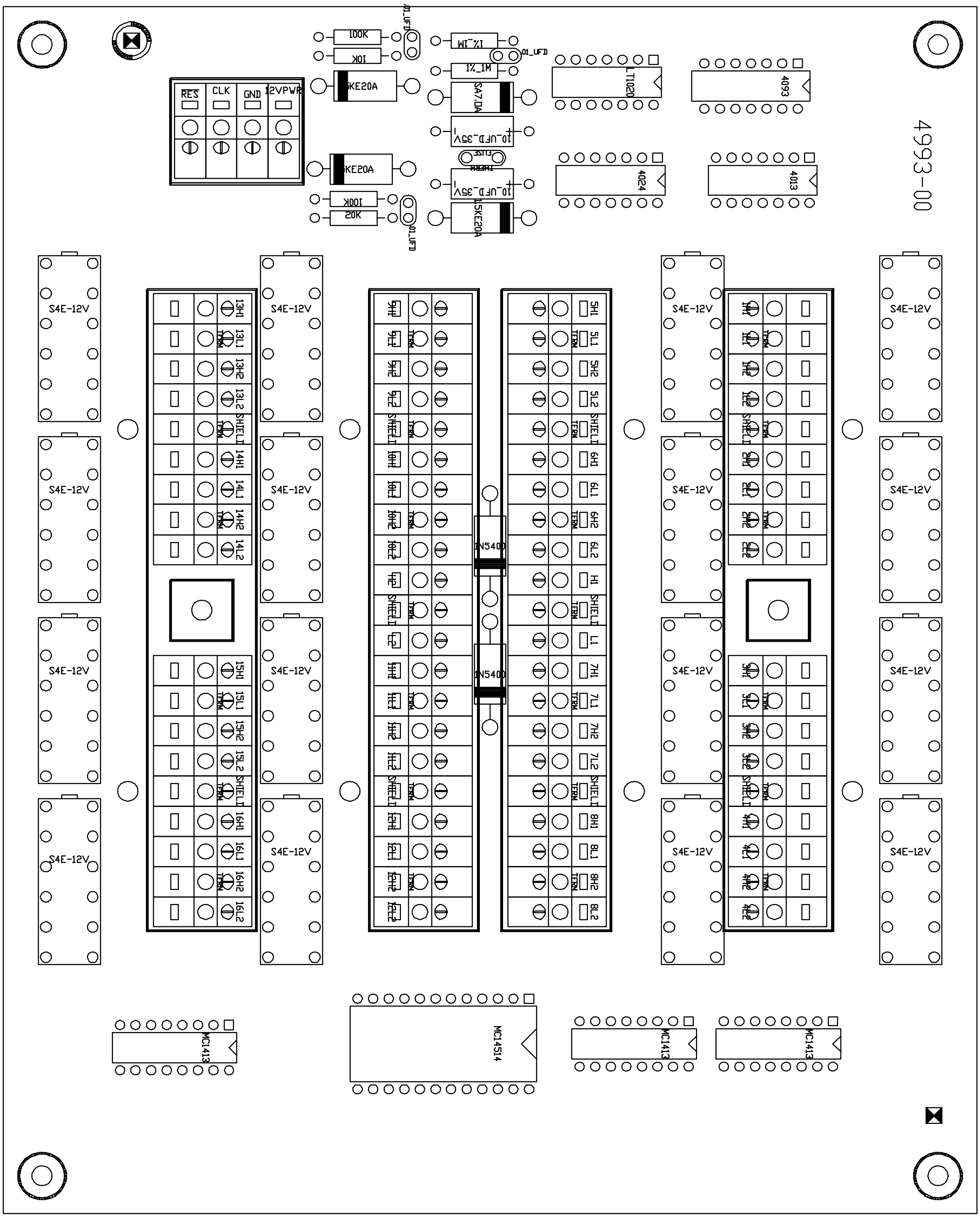
WARNING

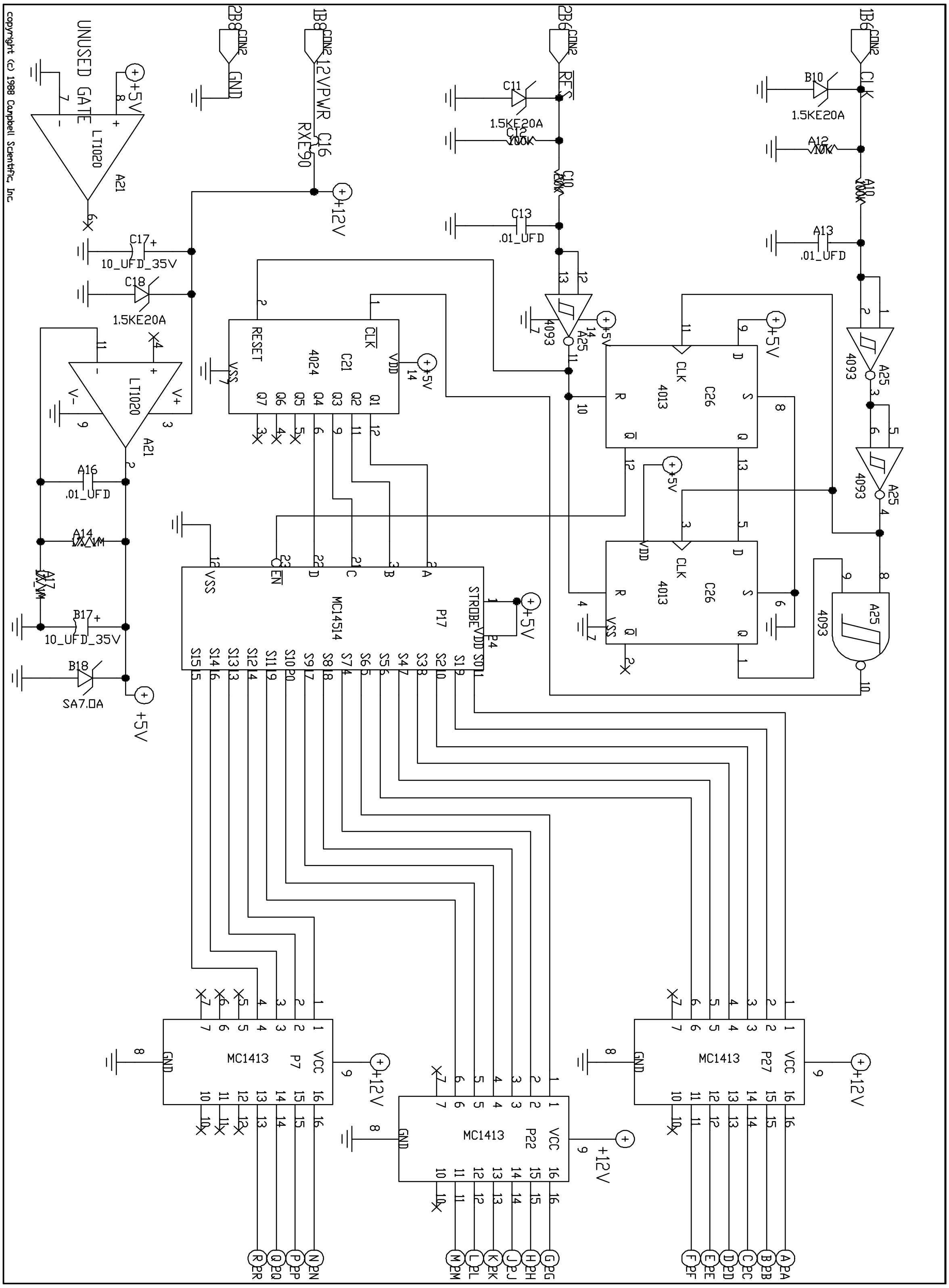
Because lead-acid batteries may emit explosive hydrogen gas, DO NOT seal an enclosure containing lead-acid batteries.

8.1 Environmental Constraints

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

Appendix A. AM416 Circuit Board Layout and Schematics

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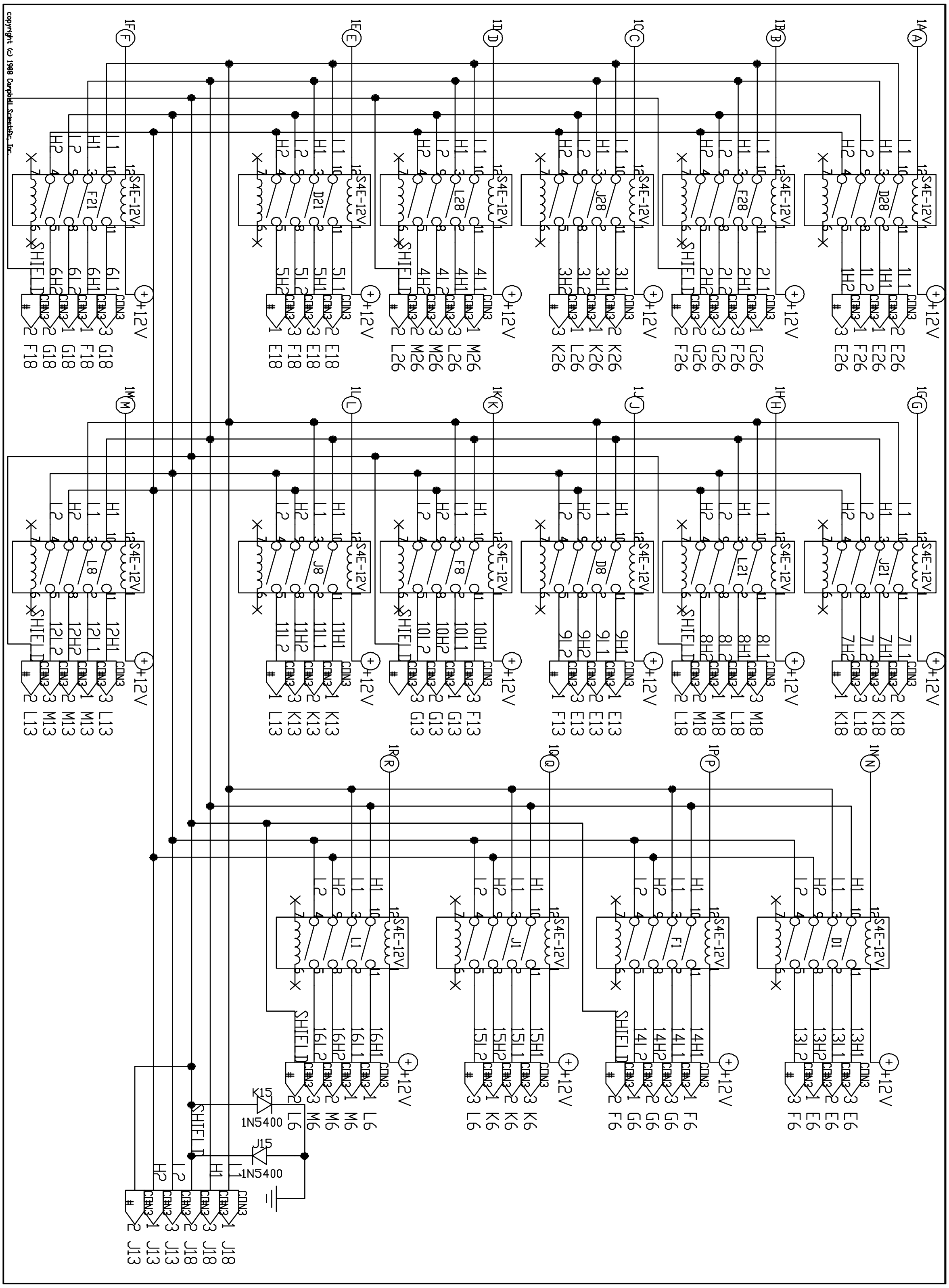
UNUSED GATE
LT1020
4024
4013
4093
MC14514
MC1413
1.5KE20A
+5V
+12V



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 aluminium case designed to 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.