4WFB120, 4WFB350, 4WFB1K
4 WIRE FULL BRIDGE TERMINAL INPUT MODULES
INSTRUCTION MANUAL

12/96

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4WFB120, 4WFB350, 4WFB1K
4 WIRE FULL BRIDGE TERMINAL INPUT MODULES
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4WFB120, 4WFB350, 4WFB1K 4 WIRE FULL BRIDGE TERMINAL INPUT MODULES

1. FUNCTION

Terminal input modules connect directly to the datalogger's input terminals to provide completion resistors for resistive bridge measurements, voltage dividers, and precision current shunts. The 4WFB120, 4WFB350, and 4WFB1K complete a full bridge for a strain gage or other sensor that acts as a single variable resistor. The difference between the three models is in the resistor that matches the nominal resistance of a 120 ohm, 350 ohm, or 1000 ohm quarter bridge strain gage.

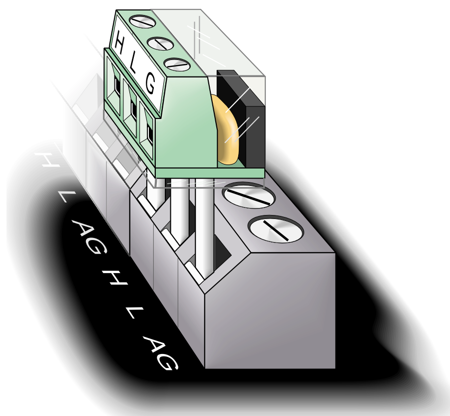

FIGURE 1-1. Terminal Input Module

2. SPECIFICATIONS

2:1 Resistive Divider

Resistors	1 kΩ/1 kΩ
Ratio Tolerance @ 25 °C	±0.02%
Ratio Temperature coefficient	2 ppm/°C
Power rating	0.25 W

Completion Resistor: 120, 360, or 1000 Ω

Tolerance @ 25 °C	±0.01%
Temperature coefficient	
0-60 °C	4 ppm/°C
-55-125 °C	8 ppm/°C
Power rating	0.25 W

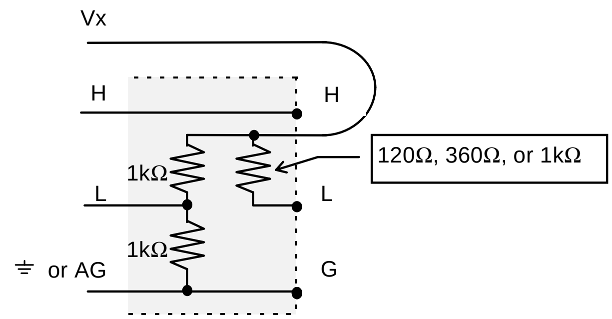

FIGURE 2-1. Schematic

3. MEASUREMENT CONCEPTS

Measuring strain is measuring a change in length. Specifically, the unit *strain* (ε) is the change in length divided by the unstrained length $(\varepsilon = \Delta\, l / l)$. Strain is typically reported in microstrain $(\mu\varepsilon)$; a microstrain is a change in length by one millionth of the length.

A metal foil strain gage is a resistive element that changes resistance as it is stretched or compressed. The strain gage is bonded to the object in which strain is measured. The gage factor, GF, is the ratio of the relative change in resistance for change in strain: $GF = \Delta\, R / R \big/ \Delta\, l / l$. For example, a gage factor of 2 means that if the length changes by one micrometer per meter of length $(1\mu\varepsilon)$, the resistance will change by two micro-ohms per ohm of resistance.

Because the actual change in resistance is so small, a full bridge configuration is used to give the maximum resolution. A "quarter bridge" strain gage is so named because the strain gage becomes one of the four resistors that make up a full bridge. The 4WFBxxx module provides the other three resistors (Figure 4-1). Quarter bridge strain gages are available in nominal unstrained resistances of 120, 350, and 1000 ohms. The 4WFB model must match the resistance of the gage (e.g., the 4WFB120 is used with a 120 ohm strain gage).

The resistance of an installed gage will differ from the nominal value. A zero measurement can be made with the gage installed. This zero measurement can be incorporated into the datalogger program; subsequent measurements can report strain relative to the zero.

Strain is calculated in terms of the result of the full bridge measurement. This result is the measured bridge output voltage divided by the bridge excitation voltage V_{out}/V_{ex}. (The actual result of the full bridge instruction is the millivolts output per volt of excitation, $1000 \cdot V_{out}/V_{ex}$) The result of the zero measurement, $1000 \cdot V_{out0}/V_{ex}$ is stored and used to calculate future strain measurements. Strain is calculated from the change in the bridge measurement,

$$V_r = (V_{out}/V_{ex}) - (V_{out0}/V_{ex}): \qquad 3.1.$$

$$\varepsilon = \frac{4V_r}{GF(1-2V_r)} \qquad 3.2.$$

The calculations are covered in more detail in section 6.

4. WIRING

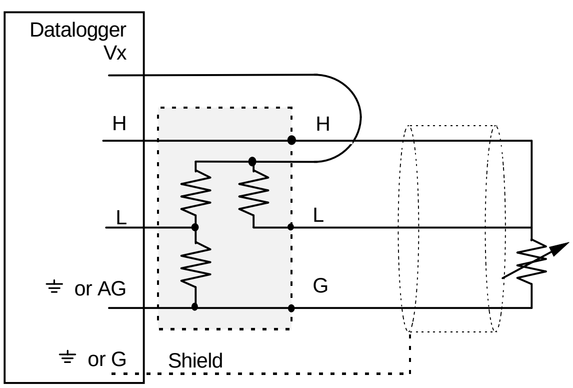

FIGURE 4-1. Wiring for Example Programs

Figure 4-1 illustrates the wiring of the strain gage to the 4WFB module and the wiring of the module to the datalogger. It is important that the gage be wired as shown with the wire from H connected at the gage, and that the leads to the L and G terminals be the same length, diameter, and wire type. With this configuration, changes in wire resistance due to temperature occur equally in both arms of the bridge with negligible effect on the output from the bridge.

5. PROGRAM EXAMPLES

The following examples for the CR10(X), 21X, CR7, and CR9000 all have a subroutine that measures the unstrained "zero" output of the strain gage. The examples calculate strain using equation 3.2 for a strain gage with a GF=2. These are just examples. Besides adding additional measurement instructions, the programs will probably need to have the scan and data storage intervals altered for actual applications. The instructions in the subroutine will also need to be modified for the actual gage factor.

This zeroing subroutine is called automatically when the program is first executed. The user can call the subroutine by setting Flag 1 low using the datalogger support software or the *6 mode with the keyboard display. The "zero" reading is then used during normal measurements for the strain calculations.

The Input Locations assignments used in CR10(X), 21X, and CR7 Examples are listed in Table 5-1.

TABLE 5-1. Input Locations Used in CR10(X), 21X, and CR7 Examples

Addr	Name
1	mVperV
2	mVperV_0
3	Vr
4	uStrain
5	Count
6	GF
7	_4e6
8	Mult
9	1_2Vr
10	Vr_1_2Vr

5.1 CR10(X)

```
;{CR10}
;
*Table 1 Program
  01:          1        Execution Interval (seconds)

; Other measurements could be inserted here of before the Output section

01:  If Flag/Port (P91)                          ; On the first execution (Flag 1 is low)
     1:      21      Do if Flag 1 is Low         ;or when user sets Flag 1 low
     2:       1      Call Subroutine 1            ;call the zeroing subroutine

02:  Full Bridge (P6)                            ; Measure the strain gage
     1:       1      Reps
     2:      22      ± 7.5 mV 60 Hz Rejection Range
     3:       1      DIFF Channel
     4:       1      Excite all reps w/Exchan 1
     5:    2500      mV Excitation
     6:       1      Loc [ mVperV    ]
     7:       1      Mult
     8:       0      Offset

03:  Z=X-Y (P35)                                 ;Subtract zero reading from the
     1:       1      X Loc [ mVperV    ]         ;measurement
     2:       2      Y Loc [ mVperV_0  ]
     3:       3      Z Loc [ Vr        ]

04:  Z=X*F (P37)                                 ;Change Vr from mV/V to V/V
     1:       3      X Loc [ Vr        ]
     2:       0.001  F
     3:       3      Z Loc [ Vr        ]

; The following instructions calculate microstrain

05:  Z=X*F (P37)
     1:       3      X Loc [ Vr        ]
     2:      -2      F
     3:       9      Z Loc [ 1_2Vr     ]

06:  Z=Z+1 (P32)
     1:       9      Z Loc [ 1_2Vr     ]

07:  Z=X/Y (P38)
     1:       3      X Loc [ Vr        ]
     2:       9      Y Loc [ 1_2Vr     ]
     3:      10      Z Loc [ Vr_1_2Vr  ]


08:  Z=X*Y (P36)
     1:      10      X Loc [ Vr_1_2Vr  ]
     2:       8      Y Loc [ Mult      ]
     3:       4      Z Loc [ uStrain   ]
```

```
;Output Section
;This example outputs an average of the 1 second readings
;once per minute.

09:  If time is (P92)
     1:      0      Minutes (Seconds --) into a
     2:      1      Interval (same units as above)
     3:     10      Set Output Flag High

10:  Set Active Storage Area (P80)
     1:      1      Final Storage Area 1
     2:      1      Array ID                    ;Set Array ID = 1 for measurement data

11:  Real Time (P77)
     1:   1110      Year,Day,Hour/Minute

12:  Average (P71)
     1:      1      Reps
     2:      4      Loc [ uStrain   ]


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

*Table 3 Subroutines

01:  Beginning of Subroutine (P85)          ;Subroutine to measure "zero"
     1:      1      Subroutine 1

02:  Do (P86)                               ; This prevents calling subroutine
     1:     11      Set Flag 1 High         ; until user sets flag 1 low again.

03:  Z=F (P30)                              ;Set counter use for average to 0
     1:      0      F
     2:      0      Exponent of 10
     3:      5      Z Loc [ Count     ]

04:  Z=F (P30)                              ;load 4 million (4*uS/S) into input location
     1:      4      F
     2:      6      Exponent of 10
     3:      7      Z Loc [ _4e6      ]

05:  Z=F (P30)                              ;Load Gage Factor into input location
     1:      2      F                       ;Enter the actual Gage Factor here
     2:      0      Exponent of 10
     3:      6      Z Loc [ GF        ]

06:  Z=X/Y (P38)                            ;calculate multiplier to use with strain
     1:      7      X Loc [ _4e6      ]     ;calculation
     2:      6      Y Loc [ GF        ]
     3:      8      Z Loc [ Mult      ]

07:  Beginning of Loop (P87)                ;Loop through 5 times to obtain average
     1:      0      Delay                   ;zero reading
     2:      5      Loop Count
```

```
08:  Z=Z+1 (P32)                                        ;Increment Counter used to determine
     1:      5       Z Loc [ Count    ]                 ;when to output

09:  Full Bridge (P6)                                   ;Measure Strain Gage
     1:      1       Reps
     2:     22       ± 7.5 mV 60 Hz Rejection Range
     3:      1       DIFF Channel
     4:      1       Excite all reps w/Exchan 1
     5:   2500       mV Excitation
     6:      1       Loc [ mVperV   ]
     7:      1       Mult
     8:      0       Offset

10:  IF (X<=>F) (P89)                                   ;Check for last pass through loop
     1:      5       X Loc [ Count    ]                 ;to set output flag
     2:      3       >=
     3:      5       F
     4:     10       Set Output Flag High

11:  Set Active Storage Area (P80)                      ;Direct averaged "zero" reading
     1:      3       Input Storage Area                 ;to input storage
     2:      2       Array ID or Loc [ mVperV_0  ]

12:  Average (P71)
     1:      1       Reps
     2:      1       Loc [ mVperV   ]

13:  If Flag/Port (P91)                                 ;When average is calculated,
     1:     10       Do if Output Flag is High (Flag 0)       ;also send it to Final Storage
     2:     10       Set Output Flag High

14:  Set Active Storage Area (P80)                      ;Direct Output to Final Storage
     1:      1       Final Storage Area 1
     2:     11       Array ID                           ;set Array ID = 11 for zero data

15:  Real Time (P77)
     1:    110       Day,Hour/Minute

16:  Sample (P70)
     1:      1       Reps
     2:      2       Loc [ mVperV_0  ]

17:  End (P95)

18:  End (P95)

End Program
```

5.2 21X

```
;{21X}
*Table 1 Program
  01:        1        Execution Interval (seconds)

; Other measurements could be inserted here or before the Output section

01:  If Flag/Port (P91)                            ; On the first execution (Flag 1 is low)
     1:     21       Do if Flag 1 is Low           ;or when user sets Flag 1 low
     2:      1       Call Subroutine 1              ;call the zeroing subroutine

02:  Full Bridge (P6)                              ; Measure the strain gage
     1:      1       Reps
     2:      2       ± 15 mV Slow Range
     3:      1       DIFF Channel
     4:      1       Excite all reps w/Exchan 1
     5:   5000       mV Excitation
     6:      1       Loc [ mVperV    ]
     7:      1       Mult
     8:      0       Offset

03:  Z=X-Y (P35)                                   ;Subtract zero reading from the
     1:      1       X Loc [ mVperV    ]           ;measurement
     2:      2       Y Loc [ mVperV_0  ]
     3:      3       Z Loc [ Vr        ]

04:  Z=X*F (P37)                                   ;Change Vr from mV/V to V/V
     1:      3       X Loc [ Vr        ]
     2:      0.001   F
     3:      3       Z Loc [ Vr        ]

; The following instructions calculate microstrain

05:  Z=X*F (P37)
     1:      3       X Loc [ Vr        ]
     2:     -2       F
     3:      9       Z Loc [ 1_2Vr     ]

06:  Z=Z+1 (P32)
     1:      9       Z Loc [ 1_2Vr     ]

07:  Z=X/Y (P38)
     1:      3       X Loc [ Vr        ]
     2:      9       Y Loc [ 1_2Vr     ]
     3:     10       Z Loc [ Vr_1_2Vr  ]

08:  Z=X*Y (P36)
     1:     10       X Loc [ Vr_1_2Vr  ]
     2:      8       Y Loc [ Mult      ]
     3:      4       Z Loc [ uStrain   ]

;Output Section
;This example outputs an average of the 1 second readings
;once per minute.
```

```
09:  If time is (P92)
     1:      0       Minutes (Seconds --) into a
     2:      1       Interval (same units as above)
     3:     10       Set Output Flag High

10:  Set Active Storage Area (P80)
     1:      1       Final Storage Area 1
     2:      1       Array ID                          ;Set Array ID = 1 for measurement data

11:  Real Time (P77)
     1:   1110       Year,Day,Hour/Minute

12:  Average (P71)
     1:      1       Reps
     2:      4       Loc [ uStrain   ]


*Table 2 Program
  01:        0.0000  Execution Interval (seconds)

*Table 3 Subroutines

01:  Beginning of Subroutine (P85)                     ;Subroutine to measure "zero"
     1:      1       Subroutine 1

02:  Do (P86)                                          ; This prevents calling subroutine
     1:     11       Set Flag 1 High                   ; until user sets flag 1 low again.

03:  Z=F (P30)                                         ;Set counter use for average to 0
     1:      0       F
     2:      5       Z Loc [ count     ]

04:  Z=F (P30)                                         ;load 4000 into
     1:   4000       F                                 ;input location
     2:      7       Z Loc [ 4e6       ]

05:  Z=X*F (P37)                                       Multiply by 1000 to get (4*uS/S)
     1:      7       X Loc [ 4e6       ]
     2:   1000       F
     3:      7       Z Loc [ 4e6       ]

06:  Z=F (P30)                                         ;Load Gage Factor into input location
     1:      2       F                                 ;Enter the actual Gage Factor here
     2:      6       Z Loc [ GF        ]

07:  Z=X/Y (P38)                                       ;calculate multiplier to use with strain
     1:      7       X Loc [ 4e6       ]               ;calculation
     2:      6       Y Loc [ GF        ]
     3:      8       Z Loc [ Mult      ]

08:  Beginning of Loop (P87)                           ;Loop through 5 times to obtain average
     1:      0       Delay                             ;zero reading
     2:      5       Loop Count

09:  Z=Z+1 (P32)                                       ;Increment Counter used to determine
     1:      5       Z Loc [ count     ]               ;when to output
```

```
10:  Full Bridge (P6)                                 ;Measure Strain Gage
     1:      1        Reps
     2:      2        ± 15 mV Slow Range
     3:      1        DIFF Channel
     4:      1        Excite all reps w/Exchan 1
     5:   5000        mV Excitation
     6:      1        Loc [ mVperV    ]
     7:      1        Mult
     8:      0        Offset

11:  IF (X<=>F) (P89)                                 ;Check for last pass through loop
     1:      5        X Loc [ count     ]             ;to set output flag
     2:      3        >=
     3:      5        F
     4:     10        Set Output Flag High

12:  Set Active Storage Area (P80)                    ;Direct averaged "zero" reading
     1:      3        Input Storage                   ;to input storage
     2:      2        Array ID or Loc [ mVperV_0  ]

13:  Average (P71)
     1:      1        Reps
     2:      1        Loc [ mVperV    ]

14:  If Flag/Port (P91)                               ;When average is calculated,
     1:     10        Do if Output Flag is High (Flag 0)      ;also send it to Final Storage
     2:     10        Set Output Flag High

15:  Set Active Storage Area (P80)                    ;Direct Output to Final Storage
     1:      1        Final Storage
     2:     11        Array ID                        ;set Array ID = 11 for zero data

16:  Real Time (P77)
     1:    110        Day,Hour/Minute

17:  Sample (P70)
     1:      1        Reps
     2:      2        Loc [ mVperV_0  ]

18:  End (P95)

19:  End (P95)

End Program
```

5.3 CR7

```
;{CR7}
*Table 1 Program
  01:          1.0000    Execution Interval (seconds)

; Other measurements could be inserted here or before the Output section

01:   If Flag/Port (P91)                              ; On the first execution (Flag 1 is low)
      1:       21       Do if Flag 1 is Low           ;or when user sets Flag 1 low
      2:        1       Call Subroutine 1             ;call the zeroing subroutine

02:   Full Bridge (P6)                                ; Measure the strain gage
      1:        1       Reps
      2:        3       ±15 mV Slow Range
      3:        1       In Card
      4:        1       DIFF Channel
      5:        1       Ex Card
      6:        1       Ex Channel
      7:        1       Meas/Ex
      8:     5000       mV Excitation
      9:        1       Loc [ mVperV    ]
      10:       1       Mult
      11:       0       Offset

03:   Z=X-Y (P35)                                     ;Subtract zero reading from the
      1:        1       X Loc [ mVperV    ]           ;measurement
      2:        2       Y Loc [ mVperV_0  ]
      3:        3       Z LOC [ Vr        ]

04:   Z=X*F (P37)                                     ;Change Vr from mV/V to V/V
      1:        3       X Loc [ Vr        ]
      2:        0.001   F
      3:        3       Z Loc [ Vr        ]

; The following instructions calculate microstrain

05:   Z=X*F (P37)
      1:        3       X Loc [ Vr        ]
      2:       -2       F
      3:        9       Z LOC [ 1_2Vr     ]

06:   Z=Z+1 (P32)
      1:        9       Z LOC [ 1_2Vr     ]

07:   Z=X/Y (P38)
      1:        3       X Loc [ Vr        ]
      2:        9       Y Loc [ 1_2Vr     ]
      3:       10       Z LOC [ Vr_1_2Vr  ]

08:   Z=X*Y (P36)
      1:       10       X Loc [ Vr_1_2Vr  ]
      2:        8       Y Loc [ Mult      ]
      3:        4       Z LOC [ uStrain   ]
```

```
;Output Section
;This example outputs an average of the 1 second readings
;once per minute.

09:  If time is (P92)
      1:      0      Minutes (Seconds --) into a
      2:      1      Interval (same units as above)
      3:     10      Set Output Flag High

10:  Set Active Storage Area (P80)
      1:      1      Final Storage Area 1
      2:      1      Array ID                        ;Set Array ID = 1 for measurement data

11:  Real Time (P77)
      1:   1110      Year,Day,Hour/Minute

12:  Average (P71)
      1:      1      Reps
      2:      4      Loc [ uStrain   ]


*Table 2 Program
  01:         0.0000 Execution Interval (seconds)

*Table 3 Subroutines

01:  Beginning of Subroutine (P85)                   ;Subroutine to measure "zero"
      1:      1      Subroutine 1

02:  Do (P86)                                        ; This prevents calling subroutine
      1:     11      Set Flag 1 High                 ; until user sets flag 1 low again.

03:  Z=F (P30)                                       ;Set counter use for average to 0
      1:      0      F
      2:      5      Z LOC [ Count     ]

04:  Z=F (P30)                                       ;load 4000 into
      1:   4000      F                               ;input location
      2:      7      Z LOC [ 4e6       ]

05:  Z=X*F (P37)                                     Multiply by 1000 to get (4*uS/S)
      1:      7      X Loc [ 4e6       ]
      2:   1000      F
      3:      7      Z LOC [ 4e6       ]

06:  Z=F (P30)                                       ;Load Gage Factor into input location
      1:      2      F                               ;Enter the actual Gage Factor here
      2:      6      Z LOC [ GF        ]

07:  Z=X/Y (P38)                                     ;calculate multiplier to use with strain
      1:      7      X Loc [ 4e6       ]             ;calculation
      2:      6      Y Loc [ GF        ]
      3:      8      Z LOC [ Mult      ]
```

```
08:  Beginning of Loop (P87)                            ;Loop through 5 times to obtain average
     1:      0      Delay                               ;zero reading
     2:      5      Loop Count

09:  Z=Z+1 (P32)                                        ;Increment Counter used to determine
     1:      5      Z Loc [ Count     ]                 ;when to output

10:  Full Bridge (P6)                                   ;Measure Strain Gage
     1:      1      Reps
     2:      3      ± 15 mV Slow Range
     3:      1      In Card
     4:      1      DIFF Channel
     5:      1      Ex Card
     6:      1      Ex Channel
     7:      1      Meas/Ex
     8:   5000      mV Excitation
     9:      1      Loc [ mVperV    ]
     10:     1      Mult
     11:     0      Offset

11:  IF (X<=>F) (P89)                                   ;Check for last pass through loop
     1:      5      X Loc [ Count     ]                 ;to set output flag
     2:      3      >=
     3:      5      F
     4:     10      Set Output Flag High

12:  Set Active Storage Area (P80)                      ;Direct averaged "zero" reading
     1:      3      Input Storage                       ;to input storage
     2:      2      Array ID or Loc [ mVperV_0  ]

13:  Average (P71)
     1:      1      Reps
     2:      1      Loc [ mVperV    ]

14:  If Flag/Port (P91)                                 ;When average is calculated,
     1:     10      Do if Output Flag is High (Flag 0)       ;also send it to Final Storage
     2:     10      Set Output Flag High

15:  Set Active Storage Area (P80)                      ;Direct Output to Final Storage
     1:      1      Final Storage
     2:     11      Array ID                            ;set Array ID = 11 for zero data

16:  Real Time (P77)
     1:    110      Day,Hour/Minute

17:  Sample (P70)
     1:      1      Reps
     2:      2      Loc [ mVperV_0  ]

18:  End (P95)

19:  End (P95)

End Program
```

5.4 CR9000

The CR9000 has an instruction, StrainCalc that is a generalized instruction for calculating strain from the output of different full bridge configurations:

StrainCalc(Dest,Reps,Source,BrZero,BrConfig,GageFactor,PoissonRatio)

Source is the variable holding the current measurement, BrZero is the zero measurement; this instruction uses the results of the full bridge measurement instruction (multiplier=1, offset=0, mV/V) directly. The code for the Bridge Configuration used with the 4WFB module is -1. Enter the actual gage factor for GageFactor. Enter 0 for the Poisson ratio parameter which is not used with this bridge configuration.

This example program is slightly different in operation than the examples for the other dataloggers. Data are only output to data table STRAINS when the user sets Flag(1). Every measurement is output (rather than averages like in the other examples) while Flag(1) is high.

```
'  Program name: STRAIN.DLD

'  _____________ CR9000 CONFIGURATION _____________
'  Slot 1 = 9011          Slot 5 = 9050        Slot  9 = None
'  Slot 2 = 9031          Slot 6 = 9060        Slot 10 = None
'  Slot 3 = 9041          Slot 7 = 9070        Slot 11 = None
'  Slot 4 = 9080          Slot 8 = None        Slot 12 = None


Public Count, ZStrain, StMeas, Strain, Flag(8)          ' Declare all variables as public

'Data Table STRAINS samples every measurement when user Sets Flag(1) High

DataTable(STRAINS,Flag(1),-1)
  DataInterval(0,0,0,100)                                   'Interval = Scan, 100 lapses
  Sample (1,Strain,Ieee4)
EndTable

'DataTable ZERO_1 stores the "zero" measurements

DataTable(ZERO_1,Count>99,100)                          'Trigger on Count 100
  Average(1,ZStrain,IEEE4,0)
EndTable

'Subroutine to measure Zero, Called when user sets Flag(2)low

Sub Zero
  Count = 0                                             'Reset Count
  Scan(10,mSec,0,100)                                   'Scan 100 times
      BrFull(ZStrain,1,mV50,5,1,6,7,1,5000,1,0,0,100,1,0)
      Count = Count + 1                                 'Increment Counter used By DataTable
      CallTable ZERO_1                                          'Zero_1 outputs on last scan
(Count=100)
  Next Scan
  ZStrain = ZERO_1.ZStrain_Avg(1,1)                     'Set ZStrain = averaged value
  Flag(1) = True
End Sub
```

```
BeginProg
  Scan(10,mSec,0,0)                                   'Scan 10(mSecs)
      If Not Flag(2) Then Zero
      BrFull(StMeas,1,mV50,5,1,6,7,1,5000,1,0,0,100,1,0)
      StrainCalc(Strain,1,StMeas,ZStrain,-1,2,0)
      CallTable STRAINS                               'Strains outputs only when Flag(1)=True
  Next Scan
EndProg
```

6. CALCULATION OF STRAIN

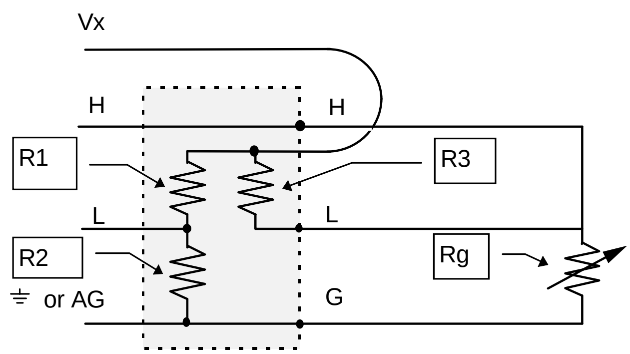

FIGURE 6-1. Strain Gage in Full Bridge

Figure 6-1 is the diagram of the strain gage in the full bridge configuration provided by the terminal input module. The result of the datalogger's full bridge measurement when a multiplier of 1 and an offset of 0 is used is the measured bridge output in millivolts divided by the excitation in volts (1000 mV=1V):

$$1000 \cdot \frac{Vout}{Vin} = 1000 \cdot \left(\frac{R_g}{R_3 + R_g} - \frac{R_2}{R_1 + R_2} \right) \qquad 6.3.$$

The result is output in the units of millivolts output per volt of excitation because the output voltage is small relative to the excitation voltage; these units allow the result to be a larger number easier for the datalogger to display and store (see data format discussion in the datalogger manual). The output is a ratio because: 1) the datalogger's ratiometric measurement technique allows this ratio to be more accurate than the measurement of the output voltage (errors in the excitation and measured output cancel). 2) This ratio can be used directly in the calculation of strain.

When strain is calculated the direct ratio of the voltages (volts per volt not millivolts per volt) will be used:

$$\frac{Vout}{Vin} = \frac{R_g}{R_3 + R_g} - \frac{R_2}{R_1 + R_2} \qquad 6.4.$$

If the previous equation is taken as the result when the gage is unstrained, then when the gage is strained it will change resistance by ΔR_g. The equation for the bridge output is:

$$\frac{Vout}{Vin}_{strained} = \frac{R_g + \Delta R_g}{R_3 + R_g + \Delta R_g} - \frac{R_2}{R_1 + R_2} \qquad 6.5.$$

Subtracting the unstrained (zero) result from the strained result gives V_r:

$$V_r = \left(\frac{Vout}{Vin}\right)_{strained} - \left(\frac{Vout}{Vin}\right)_{unstrained} = \frac{R_g + \Delta R_g}{R_3 + R_g + \Delta R_g} - \frac{R_g}{R_3 + R_g}$$
$$= \frac{R_3 \cdot \Delta R_g}{(R_3 + R_g + \Delta R_g)\cdot(R_3 + R_g)} \qquad 6.6.$$

The terminal input module is selected so that $R_3 = R_g$. Substituting R_g for R_3:

$$V_r = \frac{R_g \cdot \Delta R_g}{(R_g + R_g + \Delta R_g)\cdot(R_g + R_g)} = \frac{R_g \cdot \Delta R_g}{4R_g{}^2 + 2R_g \Delta R_g} = \frac{\Delta R_g}{4R_g + 2\Delta R_g} \qquad 6.7.$$

Solving for strain:

$$\left(4R_g + 2\Delta R_g\right)V_r = \Delta R_g$$

$$4R_g V_r + 2\Delta R_g V_r = \Delta R_g$$

$$4R_g V_r = \Delta R_g - 2\Delta R_g V_r$$

$$4R_g V_r = \Delta R_g \left(1 - 2V_r\right)$$

$$\frac{4V_r}{1-2V_r} = \frac{\Delta R_g}{R_g} \qquad 6.8.$$

Strain is calculated by dividing equation 6.8 by the gage factor. The units are converted to microstrain by multiplying by 10^6 uS/S.

$$\mu\varepsilon = \frac{4 \cdot 10^6 V_r}{GF\left(1 - 2V_r\right)} = \frac{10^6\,\Delta R_g}{GF \cdot R_g} \qquad 6.9.$$