INSTRUCTION MANUAL

247 Conductivity and Temperature Probes

Revision: 3/96

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247 CONDUCTIVITY AND TEMPERATURE PROBES

1. OVERVIEW

247 Probes (247-L and 247W-L) are designed for measuring the electrical conductivity, dissolved solids, and temperature of fresh water with Campbell Scientific dataloggers. They require the use of negative excitation, so they can be used with the CR10(X), 21X, and CR7 dataloggers but not with the BDR301 or BDR320.

Electrical conductivity (EC) of a solution is a simple physical property, but measurements can be difficult to interpret. This manual instructs the user how to make EC measurements with the 247. Accuracy specifications apply to measurements of EC in water containing KCl, Na_2SO_4, $NaHCO_3$, and/or NaCl, which are typical calibration compounds, and to EC not yet compensated for temperature effects.

Statements made on methods of temperature compensation or estimating dissolved solids are included to introduce common ways of refining and interpreting data, but are not definitive. Authoritative sources to consult include the USGS Water-Supply Paper 1473, The pH and Conductivity Handbook published by OMEGA Engineering, physical chemistry texts, and other sources.

1.1 EC SENSOR

The EC sensor consists of three stainless steel rings mounted in an epoxy tube as shown in Figure 4-1. Resistance of water passing through the tube is measured by excitation of the center electrode with positive and negative voltage. The two outer electrodes return the signal to the datalogger.

This electrode configuration eliminates the ground looping problems associated with sensors in electrical contact with earth ground.

1.2 TEMPERATURE SENSOR

Temperature is measured with a thermistor in a three wire half bridge configuration.

2. SPECIFICATIONS

2.1 PROBE

Construction: The probe housing is epoxy with rounded ends to facilitate installation and removal.

Size: Length 3.125". Diameter 0.75". The diameter of the weighted 247W-L version with the stainless steel sleeve is 1.05".

Maximum Cable Length: 1000 ft. The sensor must be ordered with desired length as cable cannot be added to existing probes.

Depth Rating: Maximum 1000 ft. In applications that require probe placement in well casings, the weighted 247W-L is strongly recommended.

pH Range: Solution pH of less than 3.0 or greater than 9.0 may damage the epoxy housing.

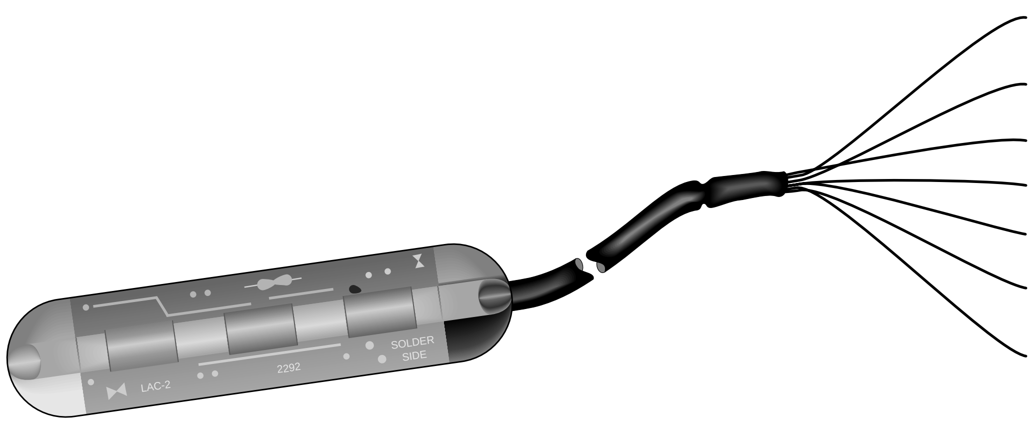

FIGURE 1-1. 247 Conductivity and Temperature Probe

2.2 EC SENSOR

Electrodes: Passivated 316 SS with DC isolation capacitors.

Cell constant: Individually calibrated. The cell constant (K_c) is found on a label near the termination of the cable.

Temp. Range of Use: Above freezing to 50°C.

EC Range: Approx. 0.005 to 7.5 mS cm^{-1}.

Accuracy: in KCl and Na_2SO_4, $NaHCO_3$, and NaCl standards at 25°C:

±5% of reading 0.44 to 7.0 mS cm^{-1}.
±10% of reading 0.005 to 0.44 mS cm^{-1}.

2.3 TEMPERATURE SENSOR

Thermistor: Betatherm 100K6A1.

Range: 0°C to 50°C.

Accuracy: Error ±0.4°C (See Section 8.2).

3. INSTALLATION

CAUTION: Rapid heating and cooling of the probe, such as leaving it in the sun and then submersing it in a cold stream, may cause irreparable damage.

3.1 SITE SELECTION

The EC sensor measures the EC of water inside the epoxy tube, so detection of rapid changes in EC requires that the probe be flushed continuously. This is easy to accommodate in a flowing stream by simply orienting the sensor parallel to the direction of flow. In stilling wells and ground wells, however, diffusion rate of ions limits the response time.

3.2 MOUNTING

The epoxy housing and sensor cable are made of water impervious, durable materials. Care should be taken, however, to mount the probe where contact with abrasives and moving objects will be avoided. Weighting to facilitate installation in wells is provided by the stainless steel sleeve on the 247W-L. Strain on cables can be minimized by using a split mesh strain relief sleeve on the cable, which is recommended for cables over 100 ft. The strain relief sleeve is available from Campbell Scientific as part number 7421.

4. WIRING

The 247s manufactured after January 1, 1994 are connected to a Campbell Scientific datalogger as illustrated in Figure 4-1.

NOTE: The excitation channel used for EC must be separate from the one used for temperature or measurement errors will result.

To make previous versions of the 247 (those without an orange lead) compatible with the information in this manual, connect existing wires as shown in Figure 4-1. Attach one end of a short piece of insulated wire to the excitation channel servicing the black lead and the other end to the H side of the selected differential channel (this wire acts as the absent orange lead). If your probe has a blue lead, it is no longer needed. Tape the exposed portion to avoid shorting the sensor.

5. PROGRAMMING

5.1 PROGRAMMING OVERVIEW

Typical datalogger programs to measure the 247 consist of four parts:

1. Measurement of EC and temperature
2. Correction of ionization errors in EC measurements
3. Correction of temperature errors in EC measurements
4. Output processing

All example programs may require modification by the user to fit the specific application's wiring and programming needs. Example programs in this manual assume that the orange lead is connected to 1H, the white to 1L, the red to 2H, the green to E2, and the black to E1.

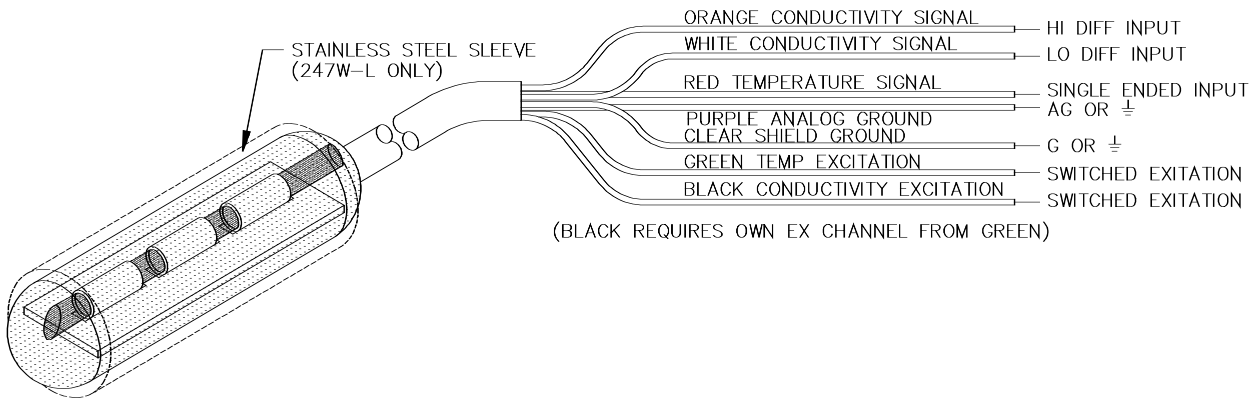

FIGURE 4-1. 247 Wiring Diagram

5.2 MEASUREMENT PROGRAMMING.

EC Results from Instructions 5 or 6 (chosen automatically as part of the autoranging feature of the following program segment) are processed with Instruction 59 to produce the resistance across the electrodes:

Make a preliminary measurement of resistance for autoranging.

01:	P6	Full Bridge
01:	1	Rep
02:	15	2500 mV fast Range (Use 5000 mV fast for 21X)
03:	1	IN Chan
04:	1	Excite all reps w/EXchan 1
05:	2500	mV Excitation (5000 mV for 21X)
06:	1	Loc [:Rs]
07:	-.001	Mult
08:	1	Offset
02:	P59	BR Transform Rf[X/(1-X)]
01:	1	Rep
02:	1	Loc [:Rs]
03:	1	Multiplier (Rf)

Test the preliminary measurement against each case and make a refined measurement.

03:	P93	Case
01:	1	Case Loc Rs
04:	P	83 If Case Location < F
01:	1.8	F
02:	30	Then Do
05:	P5	AC Half Bridge
01:	1	Rep
02:	15	2500 mV fast Range (Use 5000 mV fast for 21X)
03:	2	IN Chan
04:	1	Excite all reps w/EXchan 1
05:	2500	mV Excitation (Use 5000 mV for 21X)
06:	1	Loc [:Rs]
07:	1	Mult
08:	0	Offset
06:	P95	End
07:	P83	If Case Location < F
01:	9.25	F
02:	30	Then Do
08:	P6	Full Bridge
01:	1	Rep
02:	15	2500 mV fast Range (Use 5000 mV fast for 21X)
03:	1	IN Chan
04:	1	Excite all reps w/EXchan 1
05:	2500	mV Excitation (5000 mV for 21X)
06:	1	Loc [:Rs]
07:	-.001	Mult
08:	1	Offset
09:	P95	End
10:	P83	If Case Location < F
01:	280	F
02:	30	Then Do

```
11:      P6         Full Bridge
  01:       1       Rep
  02:      14       250 mV fast Range
                    (Use 500 mV fast for 21X)
  03:       1       IN Chan
  04:       1       Excite all reps w/EXchan 1
  05:    2500       mV Excitation
                        (Use 5000 mV for 21X)
  06:       1       Loc [:Rs      ]
  07:        -.001  Mult
  08:       1       Offset

12:      P95        End

13:      P95        End

14:      P59        BR Transform Rf[X/(1-X)]
  01:       1       Rep
  02:       1       Loc [:Rs      ]
  03:       1       Multiplier (Rf)
```

Subtract resistance errors (Rp) caused by the blocking capacitors (0.005 kΩ) and the cable length (0.000032 kΩ ft^{-1}). Enter cable lead length in nnn below.

```
15:      P30        Z=F
  01:     nnn       F   Enter Lead Length
                        in Feet
  02:      00       Exponent of 10
  03:       5       Loc [:Rp      ]

16:      P37        Z=X*F
  01:       5       Loc Rp
  02:         .00032 F
  03:       5       Loc [:Rp      ]

17:      P37        Z=X*F
  01:       5       Loc Rp
  02:        -.1    F
  03:       5       Loc [:Rp      ]

18:      P34        Z=X+F
  01:       5       Loc [Rp ]
  02:        -.005
  03:       5       Loc [:Rp      ]

19:      P33        Z=X+Y
  01:       1       X Loc Rs
  02:       5       Y Loc Rp
  03:       1       Z Loc [:Rs      ]
```

EC is then calculated by multiplying the reciprocal of resistance, which is conductance, by the cell constant to arrive at EC.

NOTE: The cell constant (K_c) is printed on the label of each sensor. It is entered in place of nnn in this segment.

```
20:      P42        Z=1/X
  01:       1       X Loc Rs
  02:       2       Z Loc [:1/Rs     ]

21:      P37        Z=X*F
  01:       2       X Loc 1/Rs
  02:     nnn       F ENTER CELL
                    CONSTANT
  03:       3       Z Loc [:Ct      ]
```

Temperature Temperature is measured with a single instruction, P11, that measures the thermistor resistance and calculates temperature. Output is °C when a multiplier of 1 and an offset of 0 is used. See Section 10 for detailed information on the function of Instruction P11.

```
22:      P11        Temp 107 Probe
  01:       1       Rep
  02:       3       IN Chan
  03:       2       Excite all reps w/EXchan 2
  04:       4       Loc [:Temp °C   ]
  05:       1       Mult
  06:       0       Offset
```

5.3 CORRECTION OF IONIZATION ERRORS IN EC MEASUREMENT

Ionization caused by the excitation of the EC sensor can cause large errors. Campbell Scientific has developed a linear correction for measurements between 0.005 and 0.44 mS cm^{-1}, and a quadratic correction for measurements between 0.44 and 7.0 mS cm^{-1}. Corrections were determined in standard salt solutions containing KCl, Na_2SO_4, $NaHCO_3$, and NaCl.

The following program segment automatically chooses which correction to apply to the measurement.

```
23:      P89        If X<=>F

  01:       3       X Loc Ct
  02:       4       <
  03:         .474  F
  04:      30       Then Do

24:      P37        Z=X*F
  01:       3       X Loc Ct
  02:         .95031 F
  03:       3       Z Loc [:Ct      ]
```

```
25:     P34         Z=X+F
  01:      3        X Loc Ct
  02:      -.00378  F
  03:      3        Z Loc [:Ct      ]

26:     P94         Else

27:     P55         Polynomial
  01:      1        Rep
  02:      3        X Loc Ct
  03:      3        F(X) Loc [:Ct      ]
  04:      -.02889  C0
  05:      .98614   C1
  06:      .02846   C2
  07:      0.0000   C3
  08:      0.0000   C4
  09:      0.0000   C5

28:     P95         End
```

5.4 CORRECTION OF TEMPERATURE ERRORS

The effect of temperature on the sample solution can cause large errors in the EC measurement. A simple method of correcting for this effect is to assume a linear relationship between temperature and EC. This method generally produces values to within 2% to 3% of a measurement made at 25°C.

The best corrections are made when the temperature coefficient is determined at a temperature near field conditions. See Section 9 for details on how to determine the temperature coefficient. If determining the temperature coefficient is not possible, use a value of 2% $°C^{-1}$ as a rough estimate.

The following program segment implements a previously determined temperature coefficient (TC) and calculates the corrected conductivity.

```
29:     P34         Z=X+F
  01:      4        X Loc Temp °C
  02:    -25        F
  03:      6        Z Loc [:A       ]

30:     P37         Z=X*F
  01:      3        X Loc Ct
  02:    100        F
  03:      8        Z Loc [:100*Ct   ]

31:     P37         Z=X*F
  01:      6        X Loc A
  02:    nnn        F    Enter TC (%°C-1)
  03:      9        Z Loc [:TC PROCES]

32:     P34         Z=X+F
  01:      9        X Loc TC PROCES
  02:    100        F
  03:      9        Z Loc [:TC PROCES]

33:     P38         Z=X/F
  01:      8        X Loc 100*Ct
  02:      9        Y Loc TC PROCES
  03:     10        Z Loc [:C25mScm-1]
```

5.5 OUTPUT PROCESSING

Over large ranges, EC is not linear and is best reported as samples (70). In limited ranges, averaging (71) measurements over time may be acceptable. Convention requires that the temperature at the time of the measurement be reported.

6. CALIBRATION

6.1 CONVERSION FACTORS

1 S (Siemens) = 1 mho = 1/ohm

Although $mS·cm^{-1}$ and $\mu S·cm^{-1}$ are the commonly used units of EC, the SI base unit is $S·m^{-1}$. The result of the example programs is $mS·cm^{-1}$

EC measurements can be used to estimate dissolved solids. For high accuracy, calibration to the specific stream is required. However, for rough estimates, values between 550 and 750 $mg·l^{-1}$ / $mS·cm^{-1}$ are typical with the higher values generally being associated with waters high in sulfate concentration (USGS Water-Supply Paper #1473, p. 99). A common practice is to multiply the EC in $mS·cm^{-1}$ by 500 to produce ppm or $mg·l^{-1}$.

6.2 TYPICAL RANGES

Single distilled water will have an EC of at least 0.001 $mS·cm^{-1}$. ECs of melted snow usually range from 0.002 to 0.042 $mS·cm^{-1}$. ECs of stream water usually range from 0.05 to 50.0 $mS·cm^{-1}$, the higher value being close to the EC of sea water (USGS Water-Supply Paper 1473, p. 102).

6.3 FACTORY CALIBRATION

The 247 is shipped with a cell constant calibrated in a 0.01 molal KCl solution at 25.0°C ±0.05°C. The solution has a EC of 1.408 mS cm^{-1}.

6.4 FIELD CALIBRATION

The cell constant is a dimensional number expressed in units of cm^{-1}. The unit cm^{-1} is slightly easier to understand when expressed as $cm \cdot cm^{-2}$. Because it is dimensional, the cell constant as determined at any one standard, will change only if the physical dimensions inside the 247 probe change. Error due to thermal expansion and contraction is negligible. Corrosion and abrasion, however, have the potential of causing significant errors.

A field calibration of the 247 cell constant can be accomplished as follows:

1. Make a 0.01 molal KCL solution by dissolving 0.7456 g of reagent grade KCl in 1000 g of distilled water.
2. Clean the probe thoroughly with the black nylon brush shipped with the 247 and a small amount of soapy water. Rinse thoroughly with distilled water, dry thoroughly, and place in the KCl solution.
3. Connect the 247 to the datalogger using the wiring described in Section 4. Enter the following program into the datalogger.

The calibration solution temperature must be between 1°C and 35°C; the polynomial in step 11 (58) corrects for temperature errors within this range. The solution constant of 1.408 mS cm^{-1}, entered in step 13 (37), is valid only for a 0.01 molal KCl solution. Location 8, generated by step 14, will contain the resultant cell constant.

```
01:      P5       AC Half Bridge
  01:      1      Rep
  02:     15      2500 mV fast Range
                  (5000 mV fast for 21X)
  03:      2      IN Chan
  04:      1      Excite all reps w/EXchan 1
  05:   2500      mV Excitation
                  (5000 mV for 21X)
  06:      1      Loc [:Rs      ]
  07:      1      Mult
  08:      0      Offset

02:      P59      BR Transform Rf[X/(1-X)]
  01:      1      Rep
  02:      1      Loc [:Rs      ]
  03:      1      Multiplier (Rf)

03:      P30      Z=F
  01:    nnn      F   Enter Lead Length
                      in Feet
  02:     00      Exponent of 10
  03:      5      Loc [:Rp      ]
```

Enter Lead Length in Feet

```
04:      P37      Z=X*F
  01:      5      Loc Rp
  02:      .00032 F
  03:      5      Loc [:Rp      ]

05:      P37      Z=X*F
  01:      5      Loc Rp
  02:     -.1     F
  03:      5      Loc [:Rp      ]

06:      P34      Z=X+F
  01:      5      Loc [Rp ]
  02:     -.005
  03:      5      Loc [:Rp      ]

07:      P33      Z=X+Y
  01:      1      X Loc Rs
  02:      5      Y Loc Rp
  03:      1      Z Loc [:Rs      ]

08:      P11      Temp 107 Probe
  01:      1      Rep
  02:      3      IN Chan
  03:      2      Excite all reps w/EXchan 2
  04:      2      Loc [:t]
  05:      1      Mult
  06:      0      Offset

09:      P34      Z=X+F
  01:      2      X Loc t
  02:    -25      F
  03:      3      Z Loc [:(t-25).01]

10:      P37      Z=X*F
  01:      3      X Loc (t-25).01
  02:      .01    F
  03:      3      Z Loc [:(t-25).01]

11:      P55      Polynomial
  01:      1      Rep
  02:      3      X Loc (t-25).01
  03:      4      F(X) Loc [:f(t)      ]
  04:      .99124 C0
  05:    -1.8817  C1
  06:     3.4789  C2
  07:    -3.51    C3
  08:    -1.2     C4
  09:    -43      C5

12:      P42      Z=1/X
  01:      4      X Loc f(t)
  02:      6      Z Loc [:1/f(t)     ]

13:      P37      Z=X*F
  01:      6      X Loc 1/f(t)
  02:     1.408   F
  03:      7      Z Loc [:Act'l Con]

14:      P36      Z=X*Y
  01:      7      X Loc Act'l Con
  02:      1      Y Loc Rs
  03:      8      Z Loc [:Kc (cm-1)]
```

7. MAINTENANCE

Routine maintenance includes thoroughly cleaning the orifice of the 247 probe with the black nylon brush provided and a little soapy water. Rinse thoroughly.

8. ANALYSIS OF ERRORS

8.1 EC MEASUREMENT ERROR

1. Bridge Measurement Error: < 1.0%
2. Calibration Error:
   bridge measurement: < 0.5%
   calibration solution: < 1.0%
3. Ionization Error of KCl and Na+ Solutions After Correction:
   < 2.0%, 0.45 to 7.0 mS cm^{-1}
   < 8.0%, 0.005 to 0.45 mS cm^{-1}

Correction of Ionization Errors. Figures 8.1-1 and 8.1-2 show the amount of correction applied by the example program to compensate for ionization effects on the measurements. Also shown is an ideal correction. Factors were derived by measuring the standard solutions described in Section 2.2 with values of 0.0234, 0.07, 0.4471, 07, 1.413, 2.070, 3.920, and 7.0 mS cm^{-1}.

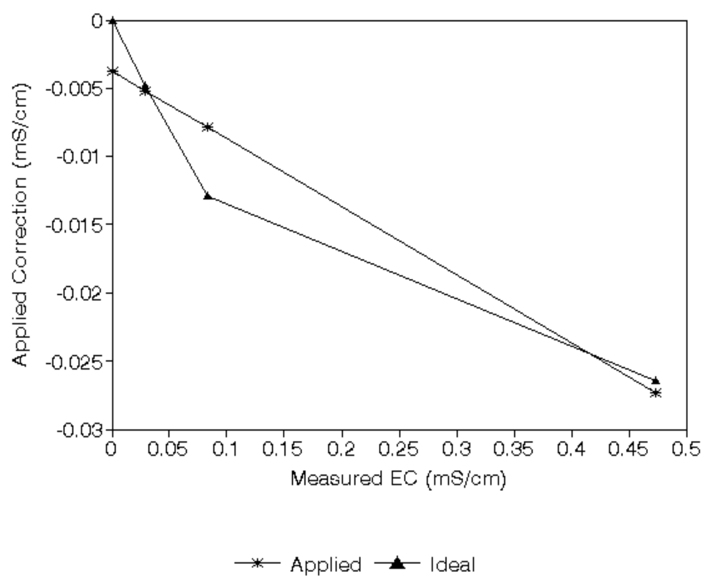

FIGURE 8.1-1. Plot of Ideal and Actual Correction between 0 and 0.44 mS cm^{-1}

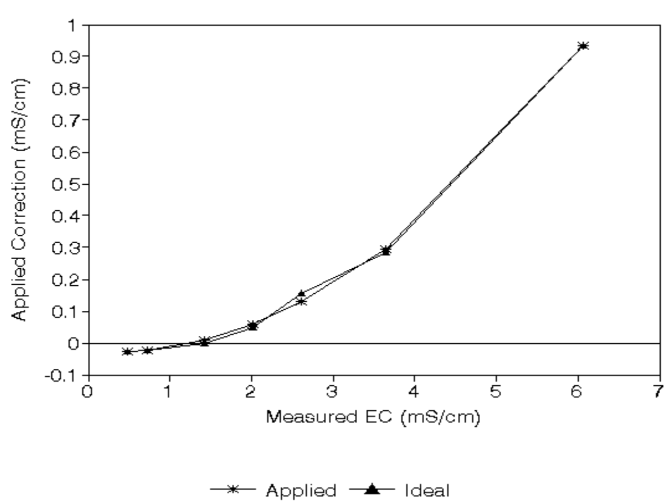

FIGURE 8.1-2. Plot of Ideal and Actual Correction between 0.44 and 7.0 mS cm^{-1}

8.2 TEMPERATURE MEASUREMENT ERROR

The overall probe accuracy is a combination of the thermistor's interchangeability specification, the precision of the bridge resistors, and the polynomial error. In a "worst case" all errors add to an accuracy of ±0.4°C over the range of -24° to 48°C and ±0.9°C over the range of -38°C to 53°C. The major error component is the interchangeability specification of the thermistor, tabulated in Table 8.2-1. For the range of 0° to 50°C the interchangeability error is predominantly offset and can be determined with a single point calibration. Compensation can then be done with an offset entered in the measurement instruction. The bridge resistors are 0.1% tolerance with a 10 ppm temperature coefficient. Polynomial errors are tabulated in Table 8.2-2 and plotted in Figure 8.2-1.

TABLE 8.2-1. Thermistor Interchangeability Specification

Temperature (°C)	Temperature Tolerance (±°C)
–40	0.40
–30	0.40
–20	0.32
–10	0.25
0 to +50	0.20

TABLE 8.2-2. Polynomial Error

-40 to +56	<±1.0°C
-38 to +53	<±0.5°C
-24 to +48	<±0.1°C

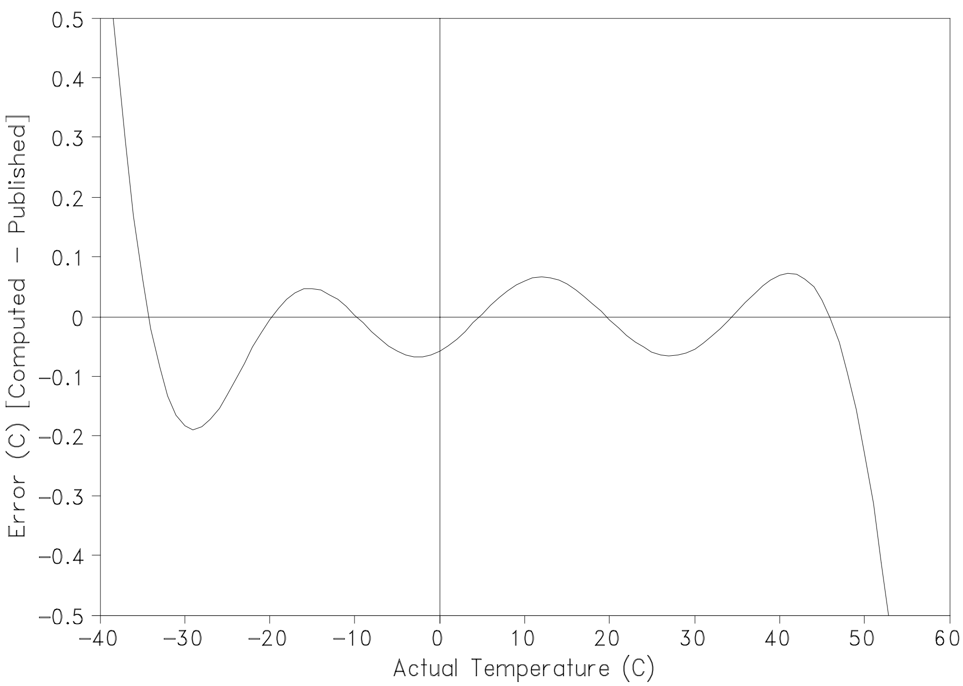

FIGURE 8.2-1. Error Produced by Polynomial Fit to Published Values

9. DERIVING A TEMPERATURE COMPENSATION COEFFICIENT

1. Place the 247 in a sample of the solution to be measured. Bring the sample and the probe to 25°C.

2. Enter the example program from Section 5.2 in the datalogger and record C_t at 25°C from Location 3. This number will be C_{25} in the formula in Step 4.

3. Bring the solution and the probe to a temperature (t) near the temperature at which field measurements will be made. This temperature will be t (in °C) in the formula. Record C_t at the new temperature from Location 3. This number will be C in the formula in Step 4.

4. Calculate the temperature coefficient (TC) using the following formula.

$$TC = 100 * \frac{(C - C_{25})}{(t - 25) * C_{25}} = \% / °C$$

   Enter TC in the appropriate location (nnn) as shown in the program segment in Section 5.4.

10. INSTRUCTION 11 DETAILS

Understanding the details in this section are not necessary for general operation of the 247 probe with CSI's dataloggers.

Instruction 11 outputs a precise 2 VAC excitation (4 V with the 21X) and measures the voltage drop due to the sensor resistance. The thermistor resistance changes with temperature. Instruction 11 calculates the ratio of voltage measured to excitation voltage (Vs/Vx) which is related to resistance, as shown below:

Vs/Vx = 1000/(Rs+249000+1000)

where Rs is the resistance of the thermistor.

See the measurement section of the datalogger manual for more information on bridge measurements.

Instruction 11 then calculates temperature using a fifth order polynomial equation correlating Vs/Vx with temperature. The polynomial coefficients are given in Table 10-2. The polynomial input is (Vs/Vx)*800. Resistance and datalogger output at several temperatures are shown in Table 10-1.

TABLE 10-1. Temperature , Resistance, and Datalogger Output

0.00	351017	-0.06
2.00	315288	1.96
4.00	283558	3.99
6.00	255337	6.02
8.00	230210	8.04
10.00	207807	10.06
12.00	187803	12.07
14.00	169924	14.06
16.00	153923	16.05
18.00	139588	18.02
20.00	126729	19.99
22.00	115179	21.97
24.00	104796	23.95
26.00	95449	25.94
28.00	87026	27.93
30.00	79428	29.95
32.00	72567	31.97
34.00	66365	33.99
36.00	60752	36.02
38.00	55668	38.05
40.00	51058	40.07
42.00	46873	42.07
44.00	43071	44.05
46.00	39613	46.00
48.00	36465	47.91
50.00	33598	49.77
52.00	30983	51.59
54.00	28595	53.35
56.00	26413	55.05
58.00	24419	56.70
60.00	22593	58.28

TABLE 10-2. Polynomial Coefficients

COEFFICIENT	VALUE
C0	-53.4601
C1	9.08067
C2	-8.32569×10^{-01}
C3	5.22829×10^{-02}
C4	-1.67234×10^{-03}
C5	2.21098×10^{-05}

11. ELECTRICALLY NOISY ENVIRONMENTS

AC power lines can be the source of electrical noise. If the datalogger is in an electronically noisy environment, the 107/107B temperature measurement should be measured with the AC half bridge (Instruction 5) with the 60 Hz rejection integration option on the CR10(X) and slow integration on the 21X and CR7 (see Section 13 of the datalogger manual for more information on noise). Instruction 11's fast integration will not reject 60 Hz noise.

Example 2. Sample CR10(X) Instructions Using AC Half Bridge

```
01:        P5          AC Half Bridge
  01:        1         Rep
  02:       22**       7.5 mV 60 Hz rejection Range
  03:        9*        IN Chan
  04:        3*        Excite all reps w/EXchan 3
  05:     2000**       mV Excitation
  06:       11*        Loc [:Air_Temp ]
  07:      800         Mult
  08:        0         Offset

02:       P55          Polynomial
  01:        1         Rep
  02:       11*        X Loc Air_Temp
  03:       11*        F(X) Loc [:Air_Temp ]
  04:      -53.46      C0
  05:       90.807     C1
  06:      -83.257     C2
  07:       52.283     C3
  08:      -16.723     C4
  09:        2.211     C5
```

* Proper entries will vary with program and datalogger channel and input location assignments.

** On the 21X and CR7 use the 15 mV input range and 4000 mV excitation.

12. LONG LEAD LENGTHS TEMPERATURE

If the 247-L/247W-L has lead lengths of more than 300 feet, use the DC Half Bridge instruction (Instruction 4) with a 2 millisecond delay to measure temperature. The delay provides a longer settling time before the measurement is made. Do not use the 247-L/247W-L with long lead lengths in an electrically noisy environment.

Example 3. Sample Program CR10 Using DC Half Bridge with Delay

```
01:        P4          Excite, Delay,Volt(SE)
  01:        1         Rep
  02:        2**       7.5 mV slow range
  03:        9*        IN Chan
  04:        3*        Excite all reps w/EXchan 3
  05:        2         Delay (units .01sec)
  06:     2000**       mV Excitation
  07:       11*        Loc [:Temp_C   ]
  08:         .4***    Mult
  09:        0         Offset

02:       P55          Polynomial
  01:        1         Rep
  02:       11*        X Loc Temp_C
  03:       11*        F(X) Loc [:Temp_C   ]
  04:      -53.46      C0
  05:       90.807     C1
  06:      -83.257     C2
  07:       52.283     C3
  08:      -16.723     C4
  09:        2.211     C5
```

* Proper entries will vary with program and datalogger channel and input location assignments.

** On the 21X and CR7 use the 15 mV input range and 4000 mV excitation.

*** Use a multiplier of 0.2 with a 21X and CR7.

13. 247 SCHEMATIC

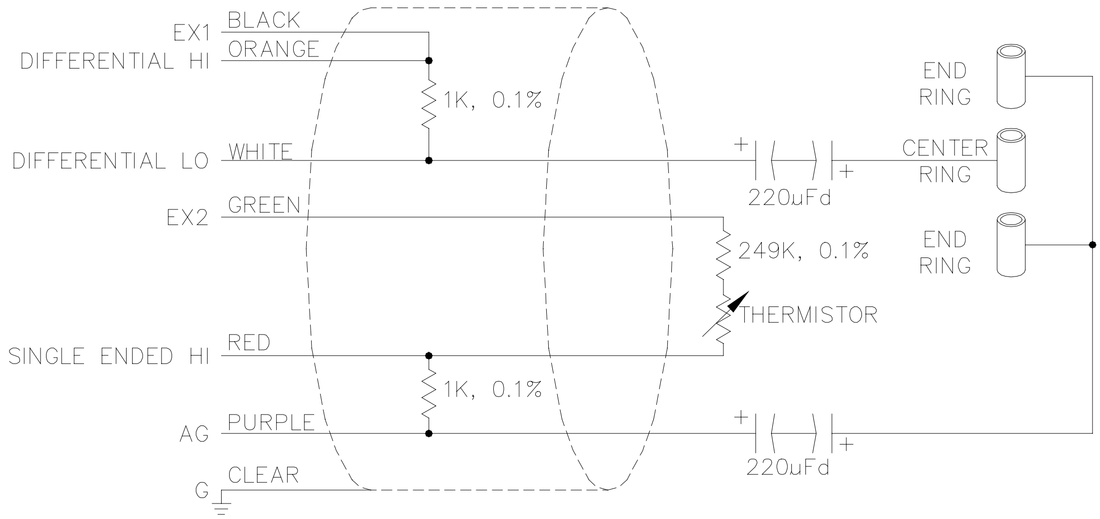

FIGURE 11-1. 247 Conductivity and Temperature Circuit Diagram

Campbell Scientific Companies

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

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

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

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

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

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

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

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

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