CS547A Conductivity and Temperature Probe and A547 Interface

User Manual

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PLEASE READ FIRST

About this manual

Please note that this manual was originally produced by Campbell Scientific Inc. primarily for the North American market. Some spellings, weights and measures may reflect this origin.

Some useful conversion factors:

Area: 1 in^2 (square inch) = 645 mm^2

Length: 1 in. (inch) = 25.4 mm
1 ft (foot) = 304.8 mm
1 yard = 0.914 m
1 mile = 1.609 km

Mass: 1 oz. (ounce) = 28.35 g
1 lb (pound weight) = 0.454 kg

Pressure: 1 psi (lb/in^2) = 68.95 mb

Volume: 1 UK pint = 568.3 ml
1 UK gallon = 4.546 litres
1 US gallon = 3.785 litres

In addition, while most of the information in the manual is correct for all countries, certain information is specific to the North American market and so may not be applicable to European users.

Differences include the U.S standard external power supply details where some information (for example the AC transformer input voltage) will not be applicable for British/European use. *Please note, however, that when a power supply adapter is ordered it will be suitable for use in your country.*

Reference to some radio transmitters, digital cell phones and aerials may also not be applicable according to your locality.

Some brackets, shields and enclosure options, including wiring, are not sold as standard items in the European market; in some cases alternatives are offered. Details of the alternatives will be covered in separate manuals.

Part numbers prefixed with a "#" symbol are special order parts for use with non-EU variants or for special installations. Please quote the full part number with the # when ordering.

Recycling information

At the end of this product's life it should not be put in commercial or domestic refuse but sent for recycling. Any batteries contained within the product or used during the products life should be removed from the product and also be sent to an appropriate recycling facility.

Campbell Scientific Ltd can advise on the recycling of the equipment and in some cases arrange collection and the correct disposal of it, although charges may apply for some items or territories.

For further advice or support, please contact Campbell Scientific Ltd, or your local agent.

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CS547A Conductivity and Temperature Probe and A547 Interface

1. Overview

The CS547A conductivity and temperature probe, and A547 interface are designed for measuring the electrical conductivity, dissolved solids, and temperature of fresh water with Campbell Scientific dataloggers. This sensor can be used with any CSI logger that can issue an AC excitation. This includes most new CRBasic dataloggers as well as older, Edlog loggers. Exceptions include the CR200-series, the BDR301 and BDR320 loggers which did not have this feature. Use with our AM16/32(B) multiplexer is possible when needing to measure several of these probes on one datalogger.

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 CS547A. 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 in the tube is measured by excitation of the centre electrode with positive and negative voltage.

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

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

1.2 A547 Interface

The interface contains the completion resistors and blocking capacitors. The interface should be kept in a non-condensing environment that is maintained within the temperature range of the unit.

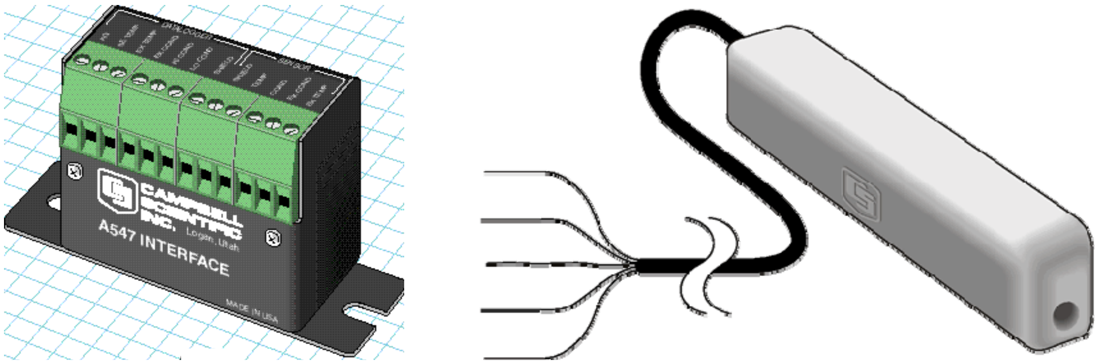

Figure 1-1. A547 Interface and CS547A Conductivity and Temperature Probe

2. Specifications

2.1 CS547A Probe

Construction	The probe housing is epoxy
Size — L x W x H	89 mm (3.5 inches) x 25.4 mm (1 inch) x 19 mm (0.75 inch)
Maximum Cable Length	305 m (1000 ft). The sensor must be ordered with desired length as cable cannot be added to existing probes.
Depth Rating	Maximum 305 m (1000 ft)
pH Range	Solution pH of less than 3.0 or greater than 9.0 may damage the stainless steel housing.
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	0° to 50°C.
EC Range	Approx. 0.005 to 7.0 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}.

2.2 A547 Interface

Size	Dimensions: 64 mm (2.5”) x 46 mm (1.8”) x 23 mm (0.9”) Weight: 45 g (2 oz)
Temperature Rating	-15°C to +50°C

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 hole running through the sensor, 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 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. 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.

Because the CS547A has a slightly positive buoyancy, we recommend securing the sensor to a fixed or retractable object or selecting the cable weight option.

The A547 is usually mounted in the datalogger enclosure.

4. Wiring

WARNING **The excitation channel used for each EC measurement must be separate from the one used for temperature or measurement errors will result. If multiple CS547A/A547s are to be wired to a single logger, each conductivity excitation must be kept on a separate, dedicated EX channel, but you can combine several temperature excitations lines onto a single EX port. (On newer loggers, these are labelled as Vx.)**

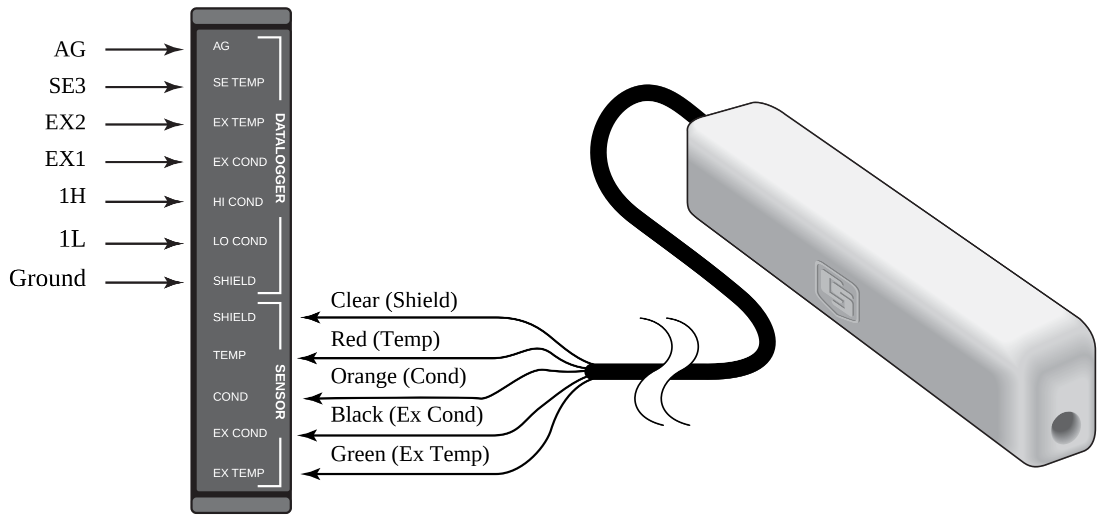

Figure 4-1. CS547A Wiring Diagram for Example Below

5. Programming

All example programs may require modification by the user to fit the specific application's wiring and programming needs. All program examples in this manual are for the CR10(X) or CR1000 and assume that datalogger is wired to the A547 interface are as follows: the LO COND lead is connected to 1L, the HI COND to 1H, the EX COND to EX1, the EX TEMP to EX2, and the SE TEMP to SE3.

Public Variable Declarations / Input Location Labels

Definitions for the following program:

Rs	Solution resistance
Rp	Resistance of leads/cable and blocking caps
Ct	Solution EC with no temp. correction
Temp_degC	Solution temperature in °C
C25mScm_1	EC corrected for temperature

5.1 Programming Overview

Typical datalogger programs to measure the CS547A consist of four parts:

1. Measurement of EC and temperature

   EC: Resistance across the electrodes is computed from the results of the **BrFull** (P6) or **BrHalf** (P5) instructions (chosen automatically as part of the autoranging feature) followed by the Bridge Transformation algorithm (P59).

2. Correction of ionization errors in EC measurements

   Ionization caused by the excitation of the EC sensor can cause large errors. Campbell Scientific has developed a linear correction for conductivity between 0.005 and 0.44 mS cm^{-1}, and a quadratic correction for conductivity 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.

3. Correction of temperature errors in EC measurements

   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 as a rough estimate.

4. Output processing

   Over large ranges, EC is not linear and is best reported as samples using instruction P70. In limited ranges, averaging (P71) measurements over time may be acceptable. Convention requires that the temperature at the time of the measurement be reported.

5.1.1 Measurement Programming - CRBasic Example Code

```
'Program name: CS547A.CR1

'\\\\\\\\\\\\\\\\\\\\\\\\\ DECLARATIONS /////////////////////////
Public Rp, CellConstant, TempCoef
Public Rs, Ct
Public TempDeg_C
Public C25mScm_1
Dim OneOvrRs, Ct100, A, TC_Proces

'\\\\\\\\\\\\\\\\\\\\\\\\ OUTPUT SECTION ////////////////////////
DataTable (ECSample,True,-1)
    DataInterval (0,60,Min,10)
    Sample (1,Ct,FP2)
    Sample (1,TempDeg_C,FP2)
    Sample (1,C25mScm_1,FP2)
EndTable

'\\\\\\\\\\\\\\\\\\\\\\\\\\\\ PROGRAM ////////////////////////////
BeginProg
    'evaluate and edit each of these 3 user specific values
    Rp=25                       'edit this value to the actual footage of cable on your sensor
    CellConstant=1.50           'edit this value with the Cell Constant (Kc) printed
                                'on the label of each sensor
    TempCoef=2                  'see section 9 of the manual for an explanation of how
                                'to more precisely determine the value of this coefficient

    Scan(5,Sec, 3, 0)
        'make a preliminary measurement of resistance to determine best range code
        BrFull(Rs, 1, mV2500, 1, VX1, 1, 2500, True, True, 0, 250, -0.001, 1)
        Rs = 1*(Rs/(1.0-Rs))
        'test the initial measurement to then make a more accurate measurement
        Select Case Rs
            Case Is < 1.8
            BRHalf(Rs, 1, mV2500, 2, VX1, 1, 2500, True, 0, 250, 1, 0)
            Rs =(Rs/(1-Rs))
```

```
            Case Is < 9.25
            BRFull(Rs, 1, mV2500, 1, VX1, 1, 2500, True, True, 0, 250, -0.001, 1)
            Rs =(Rs/(1-Rs))

            Case Is < 280
            BRFull(Rs, 1, mV250, 1, VX1, 1, 2500, True, True, 0, 250, -0.001, 1)
            Rs = (Rs/(1-Rs))

        EndSelect

'Subtract resistance errors (Rp) caused by the blocking capacitors
'(0.005Kohm and the cable length(0.000032Kohm/ft)

        Rp = (Rp* -0.000032)-0.005
        Rs = Rs + Rp

'EC is then calculated by multiplying the reciprocal of the resistance,
'which is conductance, by the cell constant

        OneOvrRs = 1 / Rs
        Ct = OneOvrRs * CellConstant

'the following corrects for errors of ionization in the EC measurement

        If (Ct < 0.474) Then
            Ct = (Ct * 0.9503) - 0.0038
        Else
            Ct=-0.0289+0.9861*Ct+0.0285*Ct^2
        EndIf

'correct errors in the EC measurement due to temperature

        Therm107(TempDeg_C,1,3,Vx2,0,_50Hz,1,0)
        A = TempDeg_C + -25
        Ct100 = Ct * 100
        TC_Proces = A * TempCoef
        TC_Proces = TC_Proces + 100
        C25mScm_1 = Ct100 / TC_Proces

        'end scan loop by calling output table
        CallTable ECSample
    NextScan
EndProg
```

5.1.2 Measurement Programming - Edlog Dataloggers

```
*Table 1 Program
  01:  5              Execution Interval (seconds)

;Make a preliminary measurement of resistance for autoranging.

1:  Full Bridge (P6)
  1:   1              Reps
  2:   15             ±2500 mV Fast Range
  3:   1              DIFF Channel
  4:   1              Excite all reps w/Exchan 1
  5:   2500           mV Excitation
  6:   1              Loc [ Rs      ]
  7:   -.001          Mult
  8:   1              Offset

2:  BR Transform Rf [X/(1-X)] (P59)
  1:   1              Reps
  2:   1              Loc [ Rs      ]
  3:   1              Multiplier (Rf)
;
;Test the initial measurement to make a more accurate measurement.
;

3:  CASE (P93)
  1:   1              Case Loc [ Rs      ]

    4:  If Case Location < F (P83)
      1:   1.8            F
      2:   30             Then Do

        5:  AC Half Bridge (P5)
          1:   1              Reps
          2:   15             ±2500 mV Fast Range
          3:   2              SE Channel
          4:   1              Excite all reps w/Exchan 1
          5:   2500           mV Excitation
          6:   1              Loc [ Rs      ]
          7:   1.0            Mult
          8:   0.0            Offset

        6:  BR Transform Rf[X/(1-X)] (P59)
          1:   1              Reps
          2:   1              Loc [ Rs      ]
          3:   1              Multiplier (Rf)

    7:  End (P95)

    8:  If Case Location < F (P83)
      1:   9.25           F
      2:   30             Then Do

       9:  Full Bridge (P6)
          1:   1              Reps
          2:   15             ±2500 mV Fast Range
          3:   1              DIFF Channel
          4:   1              Excite all reps w/Exchan 1
          5:   2500           mV Excitation
```

```
            6:  1           Loc [ Rs      ]
            7:  -.001       Mult
            8:  1           Offset

        10:  BR Transform Rf[X/(1-X)] (P59)
            1:  1           Reps
            2:  1           Loc [ Rs      ]
            3:  1           Multiplier (Rf)

    11:  End (P95)

        12:  If Case Location < F (P83)
         1:280      F
         2:30    Then Do

        13:  Full Bridge (P6)
            1:  1           Reps
            2:  14          ±250 mV Fast Range
            3:  1           DIFF Channel
            4:  1           Excite all reps w/Exchan 1
            5:  2500        mV Excitation
            6:  1           Loc [ Rs      ]
            7:  -.001       Mult
            8:  1           Offset

        14:  BR Transform Rf[X/(1-X)] (P59)
            1:  1           Reps
            2:  1           Loc [ Rs      ]
            3:  1           Multiplier (Rf)

    15:  End (P95)

16:  End (P95)

;
;Subtract resistance errors (Rp) caused by the blocking capacitors
;(0.005Kohm) and the cable length (0.000032kohm/ft).  Enter cable lead
;length in nnn below.
;

17:  Z=F (P30)
  1:  nnn          F                          Enter cable length in feet.
  2:  00           Exponent of 10
  3:  5            Z Loc [ Rp      ]

18:  Z=X*F (P37)
  1:  5            X Loc [ Rp      ]
  2:  .00032       F
  3:  5            Z Loc [ Rp      ]

19:  Z=X*F (P37)
  1:  5            X Loc [ Rp      ]
  2:  -.1          F
  3:  5            Z Loc [ Rp      ]

20:  Z=X+F (P34)
  1:  5            X Loc [ Rp      ]
  2:  -.005        F
  3:  5            Z Loc [ Rp      ]
```

```
21:  Z=X+Y (P33)
   1:   1              X Loc [ Rs       ]
   2:   5              Y Loc [ Rp       ]
   3:   1              Z Loc [ Rs       ]

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

NOTE:  The cell constant (Kc) is printed on the label of each sensor or it can be calculated (see
Section 6.4).  It is entered in place of nnn below.

22:  Z=1/X (P42)
   1:   1              X Loc [ Rs       ]
   2:   2              Z Loc [ one_ovrRs ]

23:  Z=X*F (P37)
   1:   2              X Loc [ one_ovrRs ]
   2:   nnn            F                        Enter cell constant.
   3:   3              Z Loc [ Ct       ]

24:  Temp (107) (P11)
   1:   1              Reps
   2:   3              SE Channel
   3:   2              Excite all reps w/E2
   4:   4              Loc [ Temp_degC ]
   5:   1.0            Mult
   6:   0.0            Offset

;
;The following program set corrects for errors of ionization in the EC
;measurement.
;

25:  IF (X<=>F) (P89)
   1:   3              X Loc [ Ct       ]
   2:   4              <
   3:   .474           F
   4:   30             Then Do

     26:  Z=X*F (P37)
      1:3     X Loc [ Ct       ]
      2:.95031           F
      3:3     Z Loc [ Ct       ]

     27:  Z=X+F (P34)
      1:3     X Loc [ Ct       ]
      2:-.00378          F
      3:3     Z Loc [ Ct       ]

28:  Else (P94)

     29:  Polynomial (P55)
        1:   1              Reps
        2:   3              X Loc [ Ct       ]
        3:   3              F(X) Loc [ Ct       ]
        4:   -.02889        C0
        5:   .98614         C1
        6:   .02846         C2
```

```
        7:   .000000      C3
        8:   .000000      C4
        9:   .000000      C5

30:  End (P95)

;This next program set will correct errors in the EC measurement resulting
;from temperature differences.
;

31:  Z=X+F (P34)
  1:   4                X Loc [ Temp_degC ]
  2:   -25              F
  3:   6                Z Loc [ A        ]

32:  Z=X*F (P37)
  1:   3                X Loc [ Ct       ]
  2:   100              F
  3:   7                Z Loc [ Ct100   ]

33:  Z=X*F (P37)
  1:   6                X Loc [ A        ]
  2:   nnn              F                              Enter TC (%/°C) to correct cond.  reading.
  3:   8Z Loc [ TC_Proces ]

34:  Z=X+F (P34)
  1:   8                X Loc [ TC_Proces ]
  2:   100              F
  3:   8                Z Loc [ TC_Proces ]

35:  Z=X/Y (P38)
  1:   7                X Loc [ Ct100   ]
  2:   8                Y Loc [ TC_Proces ]
  3:   9                Z Loc [ C25mScm_l ]            EC corrected for temperature.

;Output processing, convention states that the temperature be reported
;with the EC measurement.
;

36:  Do (P86)
  1:   10               Set Output Flag High (Flag 0)

37:  Sample (P70)
  1:   1                Reps
  2:   3                Loc [ Ct       ]

38:  Sample (P70)
  1:   1                Reps
  2:   4                Loc [ Temp_degC ]

39:  Sample (P70)
  1:   1                Reps
  2:   9                Loc [ C25mScm_l ]

*Table 2 Program
  02:  0.0              Execution Interval (seconds)

*Table 3 Subroutines
End Program
```

6. Calibration

6.1 Conversion Factors

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

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

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 $mg \cdot l^{-1}$ / $mS \cdot cm^{-1}$ are typical with the higher values generally being associated with waters high in sulphate concentration (USGS Water-Supply Paper #1473, p. 99). A common practice is to multiply the EC in $mS \cdot cm^{-1}$ by 500 to produce ppm or $mg \cdot l^{-1}$.

6.2 Typical Ranges

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

6.3 Factory Calibration

The CS547A is shipped with a cell constant calibrated in a 0.01 molal KCl solution at 25.0°C ±0.05°C. The solution has an 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 CS547A 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 CS547A 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, or purchase a calibration solution.

2. Clean the probe thoroughly with the black nylon brush shipped with the CS547A and a small amount of soapy water. Rinse thoroughly with distilled water, dry thoroughly, and place in the KCl solution.

3. Connect the CS547A and A547 or probe and interface 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 (P58) corrects for temperature errors within this range. The solution constant of 1.408 mS cm^{-1} (for prepared solution mentioned above), entered in step 13 (P37), is valid only for a 0.01 molal KCl solution. Location 8 [Kc (cm-1)], generated by step 14, will contain the resultant cell constant.

6.4.1 CRBasic Program Example

```
'CR1000 Datalogger
'Field Calibration program to determine new Cell Constant (Kc) for CS547A conductivity probe
Public Rs, Rp, T
Dim T_25, f_of_T
Public  Conductivity, Kc
Const  CalSolution = 1.408                    'for 0.01 molal KCL solution
'Data Table not required for Field Calibration – monitor "Kc" in Public table
'Main Program
BeginProg
'edit cable length (Rp) to reflect footage of actual lead length
        Rp = 25 'feet
    Scan (10,Sec,0,0)
        BrHalf(Rs, 1, mV2500, 2, VX1, 1, 2500, True, 0, 250, 1, 0)
        Rs =(Rs/(1-Rs))
        'correct for resistance of cabling
        Rs = Rs + (((Rp*.00032)* -0.1) - 0.005)
        'compensate for temperature effects
        Therm107 (T,1,3,Vx2,0,_50Hz,1.0,0)
        T_25 = (T-25) * 0.01
        f_of_T = 0.99124 - (1.8817*T_25) + (3.4789*T_25^2) - (3.51*T_25^3) - (1.2*T_25^4)
                 - (43*T_25^5)
        Conductivity = (1/f_of_T)*CalSolution
        Kc = Conductivity * Rs
        NextScan
EndProg
```

6.4.2 Edlog Program Example

```
1:  AC Half Bridge (P5)
  1:   1              Rep
  2:   15             2500 mV fast Range (5000 mV fast for 21X)
  3:   2              IN Chan
  4:   1              Excite all reps w/EXchan 1
  5:   2500           mV Excitation (5000 mV for 21X)
  6:   1              Loc [Rs      ]
  7:   1              Mult
  8:   0              Offset

2:  BR Transform Rf[X/(1-X)] (P59)
  1:   1              Rep
  2:   1              Loc [Rs      ]
  3:   1              Multiplier (Rf)

3:  Z=F (P30)
  1:   nnn            F                           Enter Cable Length in Feet
  2:   00             Exponent of 10
  3:   5              Loc [Rp      ]

4:  Z=X*F (P37)
  1:   5              Loc [Rp      ]
  2:   .00032         F
  3:   5              Loc [Rp      ]

5:  Z=X*F (P37)
  1:   5              Loc [Rp      ]
  2:   -.1            F
  3:   5              Loc [Rp      ]
```

```
6:  Z=X+F (P34)
   1:    5                Loc [Rp      ]
   2:    -.005
   3:    5                Loc [Rp      ]

7:  Z=X+Y (P33)
   1:    1                X Loc [Rs      ]
   2:    5                Y Loc [Rp      ]
   3:    1                Z Loc [Rs      ]

8:  Temp 107 Probe (P11)
   1:    1                Rep
   2:    3                IN Chan
   3:    2                Excite all reps w/EXchan 2
   4:    2                Loc [t      ]
   5:    1                Mult
   6:    0                Offset

9:  Z=X+F (P34)
   1:    2                X Loc [t      ]
   2:    -25              F
   3:    3                Z Loc [T25_01]

10:  Z=X*F (P37)
   1:    3                X Loc [T25_01]
   2:    .01              F
   3:    3                Z Loc [T25_01]

11:  Polynomial (P55)
   1:    1                Rep
   2:    3                X Loc [T25_01]
   3:    4                F(X) Loc [f_of_T      ]
   4:    .99124           C0
   5:    -1.8817          C1
   6:    3.4789           C2
   7:    -3.51            C3
   8:    -1.2             C4
   9:    -43              C5

12:  Z=1/X (P42)
   1:    4                X Loc [f_of_T      ]
   2:    6                Z Loc [one_ovrfT    ]

13:  Z=X*F (P37)
   1:    6                X Loc [one_ovrfT    ]
   2:    1.408            F                              EC of calibration solution
   3:    7                Z Loc [Conductiv]

14:  Z=X*Y (P36)
   1:    7                X Loc [Conductiv]
   2:    1                Y Loc [Rs      ]
   3:    8                Z Loc [Kc      ]

End
```

7. Maintenance

Routine maintenance includes thoroughly cleaning the orifice of the CS547A 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}.

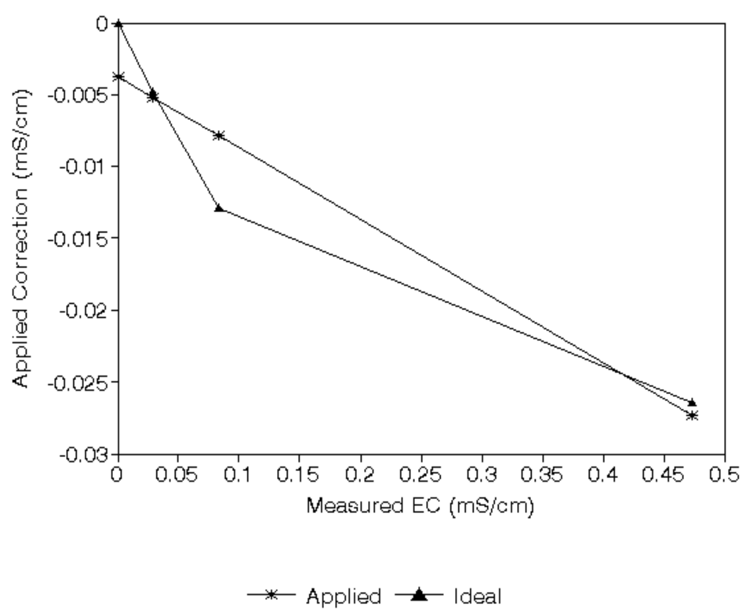

Figure 8.1-1. Plot of Ideal and Actual Correction between 0 and 0.44 mS cm^{-1}

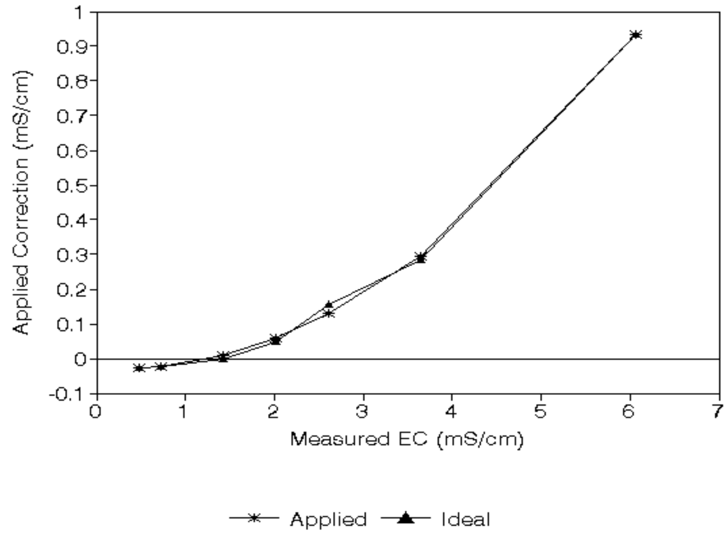

Figure 8.1-2. Plot of Ideal and Actual Correction between 0.44 and 7.0 mS cm^{-1}

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

Temperature (°C)	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

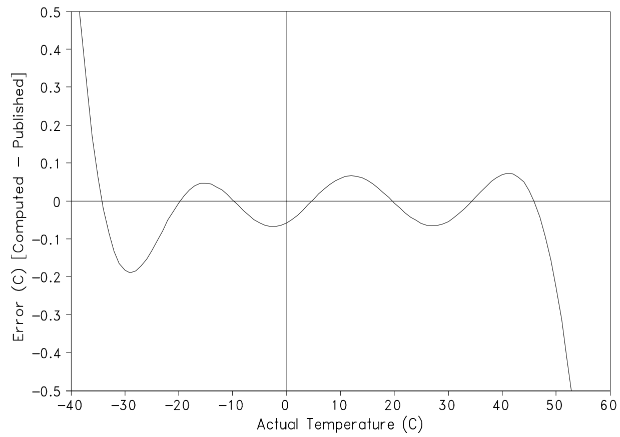

Figure 8.2-1. Error Produced by Polynomial Fit to Published Values

9. Deriving a Temperature Compensation Coefficient

1. Place the CS547A 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 5.2 .

10. Therm107 / P11 Instruction Details

Understanding the details in this section is not necessary for general operation of the CS547A probe with CSI's dataloggers.

The **Therm107** instruction (or P11 in Edlog) 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. The instruction 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.

Temperature is calculated 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 temperature measurement should be measured with longer integration periods than 250µSec. For CRBasic loggers, the **Therm107** Integration parameter has options for 60 Hz rejection that impose a long 3mSec integration. Sixty and 50 Hz rejection is also available as an option in the Excitation Channel parameter of Instruction 11 for the CR10X, CR510, and CR23X dataloggers. For the CR10, CR21X and CR7, the 107 should be measured with the AC half bridge (Instruction 5).

Example 11-1, CR1000 measurement instruction with 60 Hz rejection:

```
Therm107(TempDeg_C,1,3,2,0,_60Hz,1.0,0.0)
```

Example 11-2. Sample CR10(X) Instructions Using AC Half Bridge

```
1:  AC Half Bridge (P5)
  1:  1          Rep
  2:  22**       7.5 mV 60 Hz rejection Range
  3:  3*         IN Chan
  4:  2*         Excite all reps w/EXchan 2
  5:  2000**     mV Excitation
  6:  11*        Loc [ Air_Temp ]
  7:  800        Mult
  8:  0          Offset

2:  Polynomial (P55)
  1:  1          Rep
  2:  11*        X Loc [ Air_Temp ]
  3:  11*        F(X) Loc [ Air_Temp ]
  4:  -53.46     C0
  5:  90.807     C1
  6:  -83.257    C2
  7:  52.283     C3
  8:  -16.723    C4
  9:  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 CS547A 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 CS547A with long lead lengths in an electrically noisy environment.

For all CRBasic loggers, as well as CR10X, CR510 and CR23X that have 60 and 50 Hz integration options, this forces a 3 mSec settling time, which accommodates long lead lengths. Longer settling times can be entered into the Settling Time parameter

Example 12-1. CR1000 measurement instruction with 20 mSec (20000 uSec) delay:

```
Therm107(TempDeg_C,1,3,2,20000,_60Hz,1.0,0.0)
```

Example 12-2. Sample Program CR10 Using DC Half Bridge with Delay

```
1:  Excite, Delay,Volt(SE) (P4)
   1:  1          Rep
   2:  2**        7.5 mV slow range
   3:  3*         IN Chan
   4:  2*         Excite all reps w/EXchan 2
   5:  2          Delay (units .01sec)
   6:  2000**     mV Excitation
   7:  11*        Loc [ Temp_C   ]
   8:  .4***      Mult
   9:  0          Offset

2:  Polynomial (P55)
   1:  1          Rep
   2:  11*        X Loc Temp_C
   3:  11*        F(X) Loc [ Temp_C   ]
   4:  -53.46     C0
   5:  90.807     C1
   6:  -83.257    C2
   7:  52.283     C3
   8:  -16.723    C4
   9:  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. CS547A Schematic

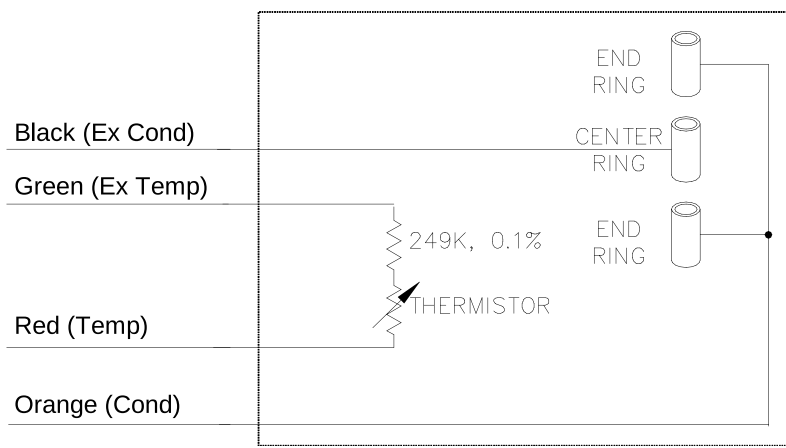

Figure 13-1. CS547A Conductivity and Temperature Circuit Diagram

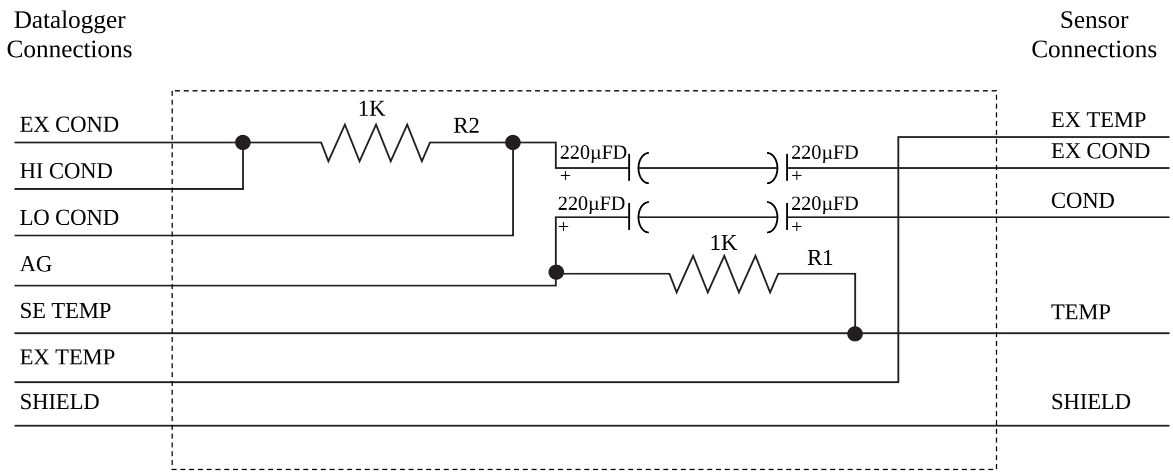

Figure 13-2. A547 Interface Circuit Diagram

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