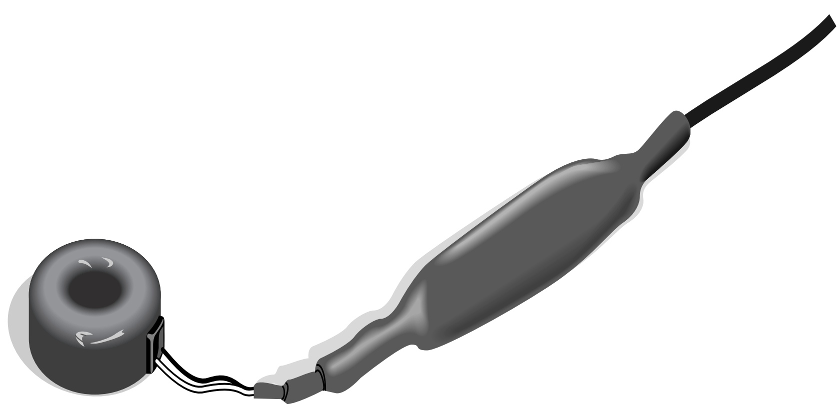
INSTRUCTION MANUAL

CS10-L and CS15-L Current Transformers

Revision: 3/12



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Figures

CS10-L and CS15-L Current Transformers

1. General Description

Campbell Scientific's CS10 and CS15 detect and measure the ac current along an electrical wire using the magnetic field that is generated by that current. The CS10 or the CS15 do not have direct electrical connection to the system. These sensors output a millivolt signal allowing them to be directly connected to our dataloggers.

The CS10 is compatible with our CR800, CR850, CR1000, CR3000, CR510, CR10(X), and CR23X dataloggers. It uses CR Magnetic's CR8459 Current Transducer to measure the approximate current over a range of 0 to 200 A. The CS15 was developed specifically for our CR200(X)-series dataloggers. It is a modified version of the CS10 that measures the approximate current over the range of 0 to 125 A. Both sensors are recommended for measurements that do not require high accuracy.

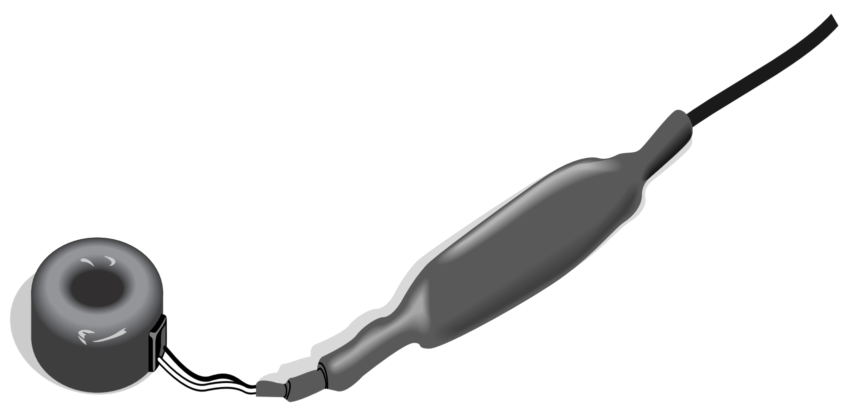

FIGURE 1. CS10-L Current Transformer

2. Specifications

Example Applications:

- Motor or generator load conditions
- Efficiency studies
- Intermittent fault detection
- Rough submetering

Specifications

Measurement Ranges:	0.15 to 200 A (CS10) 0.15 to 125 A (CS15)
Frequency:	50 and 60 Hz
Insulation Resistance:	100 M ohm @ 500 VDC
High Potential:	2000 volts
Rated Current:	200 A (CS10), 125 A (CS15)
Storage Temperature:	-25ºC to 70ºC
Operating Temperature:	-25ºC to 55ºC
Case Material:	Polypropylene Resin
Construction:	Epoxy Encapsulated
Accuracy with 10 ohm burden max. (resistive):	typically ±5 percent of actual value with provided multiplier
Dimensions:	Outer diameter: 1.89” (4.8 cm) Inner diameter: 0.75” (1.9 cm) Height: 0.67” (1.7 cm)

3. Installation

Place one AC load wire through the hole of the CS10-L or CS15-L (see Figure 2).

FIGURE 2. AC load wire installed in CS10 (color of ac load wire can vary)

4. Wiring

The CS10-L and CS15-L use a single-ended analog channel as follows.

CS10-L	
White	Single-Ended Channel
Black	AG or ⏚
Shield	AG or ⏚

CS15-L	
Red	EX
White	SE
Black	⏚
Shield	⏚

5. Programming

NOTE SCWIN users: This manual was written primarily for those whose needs are not met by SCWin. Your procedure is much simpler: just add the CS10-L or CS15 (in the Miscellaneous Sensors folder), save your program, and follow the wiring shown in Step 2 of SCWin.

The datalogger is programmed using either CRBasic or Edlog. Dataloggers that use CRBasic include our CR200(X)-series, CR800, CR850, CR1000, and CR3000. Dataloggers that use Edlog include our CR510, CR10(X), and CR23X. In CRBasic, the VoltSE instruction is used to measure the sensor. In Edlog, a P1 instruction is used.

In order to monitor the amperage of an alternating current circuit, the program must take many samples from the CS10-L or CS15-L sensor to capture the waveform over a specified time, and then calculate the average energy under the curve. There are many methods to do this, depending on the datalogger, the untapped programming capacity, and other factors.

5.1 CR800, CR850, CR1000, or CR3000 Programming

With these dataloggers, the best method for monitoring amperage is to make millivolt burst measurements, and then calculate RMS. The millivolt burst measurements are made by using the VoltSE instruction with multiple reps on the same channel (i.e., negative value for channel number). The SpaDevSpa instruction calculates RMS.

NOTE Program must be run in the pipeline mode.

It is important to get complete cycles. If you make 100 measurements during a 0.1 second time period, you'll get five complete cycles for a 50 Hz waveform or six complete cycles for a 60 Hz waveform.

CAUTION Do not average the waveform or use 60 Hz (or 50 Hz) rejection. Under these circumstances, the amperage value will always be zero.

Below is an example CR1000 program. In the program, a multiplier of 0.2 is applied to the RMS value; see Section A.4 for more information.

```
'CR1000 program to measure rms current
PipeLineMode                'must be pipeline mode

Const num_samples = 100     '100 Samples @ 1000 micro sec = 0.1 second (5 @ 50Hz or 6 @ 60 Hz).
Public Amps                 'the line current
Public Amp_mult
Dim i_sig (num_samples)     'to hold the burst measurements, each 100 samples long
PreserveVariables           'to store values between power cycles

DataTable (AmpTable,True,-1)
    DataInterval (0,1,Min,10)
    Maximum (1,Amps,IEEE4,False,False)
    Average (1,Amps,FP2,False)
EndTable

BeginProg
    Amp_mult = 0.2          '0.2 multiplier for the CS10-L
    Scan (250, mSec, 10, 0)
        VoltSe (i_sig (1), num_samples, mV2500,-1, True, 1000, 0, 1.0, 0)
        StdDevSpa (Amps, num_samples, i_sig (1))
        Amps = Amps * Amp_mult   'put in amps
        CallTable (AmpTable)
    NextScan
EndProg
```

5.2 CR200(X)-series Dataloggers

The CS15 is manufactured specifically for the CR200(X)-series dataloggers. It has an extra wire and requires an ExciteV instruction in the program. The voltage excitation creates a positive reference output that the CR200(X)-series can measure.

The recommended programming method for CR200(X)-series dataloggers (where the scan interval is limited to once per second) is to place the VoltSE instruction within a loop. The first CR200(X) example program has a loop that samples 25 times, and the second CR200(X) example program has a loop that samples 30 times. A 25-sample loop produces almost two cycles of a 60 Hz wave form, and a 30-sample loop produces almost two cycles of a 50 Hz wave form (see Figure 3). The average energy under the curve is calculated using the RMSSpa instruction. A multiplier of 0.2 is applied to the RMS value; see Section A.4 for more information.

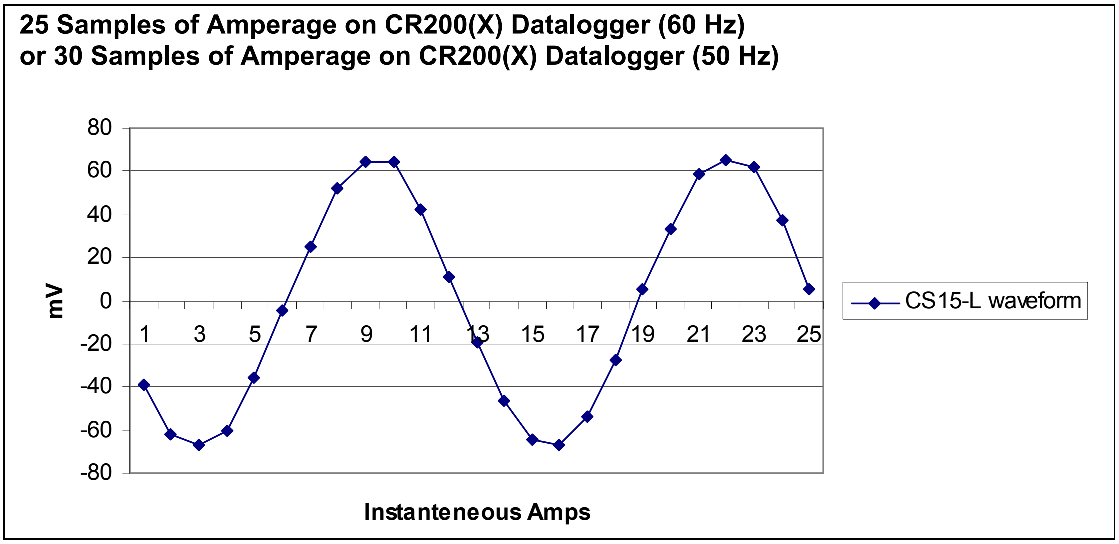

FIGURE 3. Graph of a CS15 waveform

CR200(X) Program for 60 Hz

```
'CR200(X) Series Datalogger
' Program name: CS15-LManual.cr2
'date: 4 Mar 2009
'program author: Brad Maxfield

Const Samples = 25                    ' 25 samples for 2 waves of 60 Hz.
'Const Samples = 30                   ' 30 samples for 2 waves of 50 Hz.
Public Crnt_A
Public mV(Samples)
Dim Counter

'Define Data Tables
DataTable (Test,1,-1)
        DataInterval (0,1,min)
    Average (1,Crnt_A,False)
    Maximum (1,Crnt_A,False,0)
EndTable

'Main Program
BeginProg
        Scan (1,Sec)
    ExciteV (Ex1,mV2500)
    For Counter = 1 To Samples
        VoltSe (mV(Counter),1,1,1.0,-1250)
    Next
        ExciteV (Ex1,mV0)
        RMSSpa (Crnt_A,(Samples-0),mV(1))
        Crnt_A=Crnt_A*0.2             ' Multiplier for sensor
        If Crnt_A<0.15 Then           ' Eliminate noise below 0.15 amps.
            Crnt_A = 0
        EndIf
```

```
        CallTable Test
    NextScan
EndProg
```

CR200(X) Program for 50 Hz

```
' CR200(X) Series Datalogger
' Program name: CS15-LManual.cr2
' date: 4 Mar 2009
' program author: Brad Maxfield

Const Samples = 30                    ' 30 samples for 2 waves of 50 Hz.
'Const Samples = 25                   ' 25 samples for 2 waves of 60 Hz.
Public Crnt_A
Public mV(Samples)
Dim Counter

'Define Data Tables
DataTable (Test,1,-1)
        DataInterval (0,1,min)
    Average (1,Crnt_A,False)
    Maximum (1,Crnt_A,False,0)
EndTable

'Main Program
BeginProg
        Scan (1,Sec)
    ExciteV (Ex1,mV2500)
    For Counter = 1 To Samples
        VoltSe (mV(Counter),1,1,1.0,-1250)
    Next
        ExciteV (Ex1,mV0)
        RMSSpa (Crnt_A,(Samples-0),mV(1))
        Crnt_A=Crnt_A*0.2             ' Multiplier for sensor
        If Crnt_A<0.15 Then           ' Eliminate noise below 0.15 amps.
            Crnt_A = 0
        EndIf
        CallTable Test
    NextScan
EndProg
```

5.3 CR510, CR10X, CR23X Dataloggers

With these dataloggers, the best method for monitoring amperage is to make millivolt burst measurements using Instruction 23 and then calculate RMS using Instruction 82. For Instruction 23, the entry for parameter 4 needs to be 0001. This triggers on the first channel, triggers immediately, stores data in input locations, and makes single-ended measurements.

Remember that it is important to get complete cycles. For Instruction 23, if parameters 5 and 6 are 2.0 and 0.05, respectively, then you get five complete cycles for a 50-Hz waveform, and six complete cycles for a 60-Hz waveform (see Figure 4). The multiplier for the CS10 is 0.2; see Section A.4 for more information.

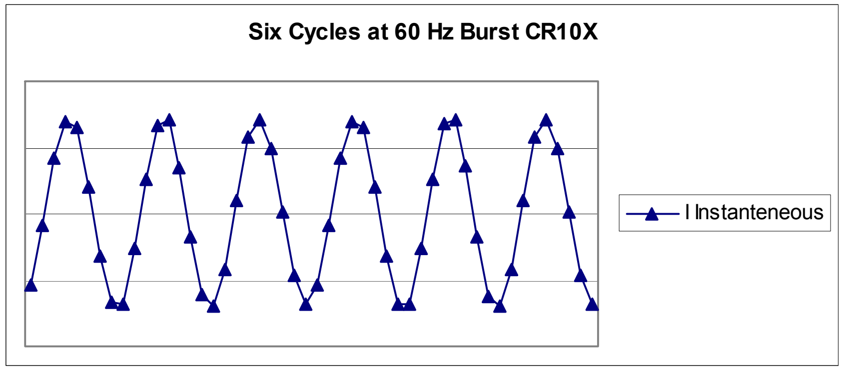

FIGURE 4. Graph of CS10 waveform using burst mode

The following CR10X program generates the waveforms shown in Figure 4.

NOTE The instructions listed below do not store data in final storage. P92, P77, and output processing instructions such as P70 are required to store the data permanently.

```
; Parameter 2 should be 2500 mV for 50-200 amps
; should be 250 mV for 5-49 amps
; should be 25 mV for 0-4.9 amps
; Parameter 5 should be 2.0 msec for 50 Hz or 60 Hz
; Parameter 6 should be 0.05 thousand scans for 50 Hz or 60 Hz
; if parameter 5 & 6 are 2.0 and 0.05, then you have 5 complete cycles at 50 Hz
; or 6 complete cycles at 60 Hz.
;
1:  Burst Measurement (P23)
   1:   1        Input Channels per Scan       ; Should always be 1
   2:   15       2500 mV Fast Range            ; Change according to expected Amperage
   3:   1        In Chan                       ; Change according to Wiring
   4:   0001     Trig/Trig/Dest/Meas Options   ; Should always be 0001
   5:   2.0      Time per Scan (msec)          ; Must be 2.0
   6:   .05      Scans (in thousands)          ; Must be 0.05 (for 50 measurements * 2.0 msec = 100 mS)
   7:   0        Samples before Trigger        ; Should always be 0
   8:   0.0      mV Limit                      ; Should always be 0
   9:   0000     mV Excitation                 ; Should always be 0
   10:  4        Loc [ Amps_1    ]             ; First location of Block (array)
   11:  .2       Multiplier                    ; Match Multiplier of CT:0.2 for CS10-L with 10 ohm shunt
   12:  0.0      Offset

2:  Z=F x 10^n (P30)
   1:   0.0      F
   2:   00       n, Exponent of 10
   3:   1        Z Loc [ Counter   ]
```

```
; This part of the program will calculate the RMS Amperage
; Standard Deviation in this part of the code works mathematically the same
; as RMS calculation, and it is easier to program this way.  The RMS
; value is calculated and stored back into an input location for further
; processing if needed.

3:  Beginning of Loop (P87)
  1:  0          Delay
  2: 50          Loop Count

    4:  Z=Z+1 (P32)
      1:  1          Z Loc [ Counter   ]

    5:  If (X<=>F) (P89)
      1:  1          X Loc [ Counter   ]
      2:  1          =
      3:  50         F
      4:  10         Set Output Flag High (Flag 0)

    6:  Set Active Storage Area (P80)
      1:  3          Input Storage Area
      2:  2          Loc [ BurstAmps ]

    7:  Standard Deviation (P82)^3012
      1:  1          Reps
      2:  4       -- Sample Loc [ Amps_1    ]

8:  End (P95)
```

5.4 21X, CR7 Dataloggers

Some Edlog dataloggers such as the 21X and CR7 do not have a burst mode. For those dataloggers, you can use a "Loop Measurement Method" similar to the method used with the CR200(X). This method is also an option for our CR510, CR10X, and CR23X, but only three measurements per period will be made. Figure 5 shows a graph produced by a CR10X program with a loop that samples 90 times. A portion of this program is shown below.

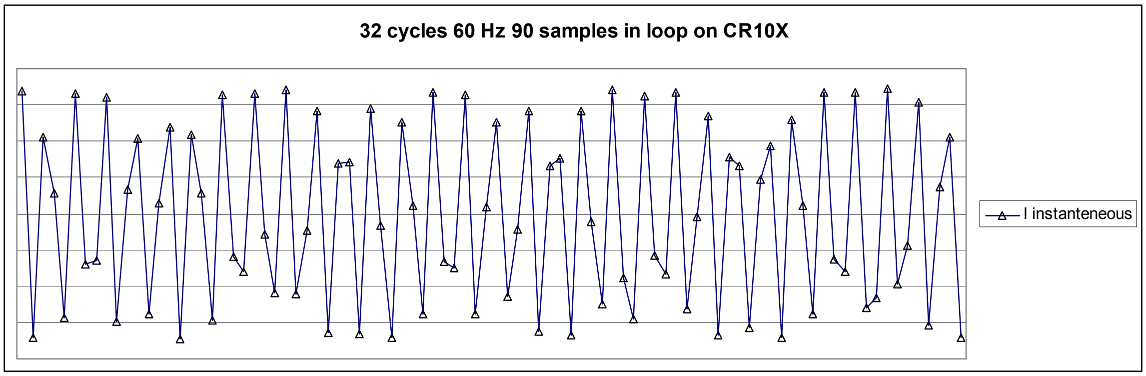

FIGURE 5. Graph of a CS10 waveform using 90 samples of amperage

NOTE The instructions listed below do not store data in final storage. P92, P77, and output processing instructions such as P70 are required to store the data permanently.

```
3:  Beginning of Loop (P87)
  1:   0               Delay
  2:   90              Loop Count

     4:  Z=Z+1 (P32)
       1:   4               Z Loc [ Counter   ]

     5:  Volt (SE) (P1)
       1:   1               Reps
       2:   14              250 mV Fast Range
       3:   1               SE Channel
       4:   57         --   Loc [ LoopAmp_1 ]
       5:   .2              Multiplier
       6:   0.0             Offset

     6:  If (X<=>F) (P89)
       1:   4               X Loc [ Counter   ]
       2:   1               =
       3:   90              F
       4:   10              Set Output Flag High (Flag 0)

     7:  Z=X (P31)
       1:   57         --   X Loc [ LoopAmp_1 ]
       2:   3               Z Loc [ Sensor    ]

     8:  Set Active Storage Area (P80)
       1:   3               Input Storage Area
       2:   2               Loc [ Amp       ]

     9:  Standard Deviation (P82)^12989
       1:   1               Reps
       2:   3               Sample Loc [ Sensor    ]

10:  End (P95)
```

The above CR10X program may provide an adequate waveform because the program makes more than two measurements per period and samples many periods. However, if the datalogger's Burst Measurement Instruction is used with specific settings, the program will make more measurements per cycle assuring that complete periods for both 50 and 60 Hz (5 at 50 Hz and 6 at 60 Hz) will be monitored (see Figure 4).

5.5 CR1000 with Multiplexer Sample Program

This program uses the CR1000 and an AM16/32-series multiplexer to read 32 CS10-L current transformers.

```
'CR1000 program to measure rms current
PipeLineMode                              'must be pipeline mode
Const num_samples = 100                   '6 waveforms for 60 Hz, 5 waveforms for 50 Hz
Const   NumSensors=32                     'Number of Sensors on the Mux   MUX in 2X32 Mode *****
                                          'Sensor wired to Low on each of the 32 channels.
                                          'Odd Low on Mux wired to SE2 on Datalogger
Public Amps(NumSensors), i,  Batt_Volt    'the line current
Public Amp_mult, TempAmps
Dim i_sig (num_samples)                   'to hold the burst measurements, each 100 samples long
PreserveVariables                         'to store values between power cycles

DataTable (AmpTable,True,-1)
    DataInterval (0,1,Min,10)
    Maximum (NumSensors,Amps,IEEE4,False,False)
    Average (NumSensors,Amps,FP2,False)
EndTable

BeginProg
    Amp_mult = 0.2                        '0.2 multiplier for the CS10-L/CS15-L
    Scan (10,Sec,0,0)
        Battery (Batt_volt)
        'Turn AM16/32 Multiplexor On
        PortSet(4,1)
        i=0
        SubScan(0,uSec,NumSensors)
            'Switch to next AM16/32 Multiplexer Channel
            PulsePort(5,10000)
            i=i+1
            VoltSe (i_sig (1), num_samples, mV2500,-2, True, 1000, 0, 1.0, 0)
            StdDevSpa (Amps(i), num_samples, i_sig (1))
            Amps(i) = Amps(i) * Amp_mult     'put in amps
            If Amps(i) <= 0.15 Then Amps(i) = 0
        NextSubScan
        'Turn AM16/32 Multiplexer Off
        PortSet(4,0)
        CallTable (AmpTable)
    NextScan
EndProg
```

5.6 CR10X with Multiplexer Sample Program

This program uses the CR10X and an AM16/32-series multiplexer to read 32 CS10-L current transformers.

```
;{CR10X}
; Example program for CS10-L
;
; Program to test the CS10-L or CS15-L sensor on a CR10X datalogger
; and AM1632 Multiplexer.
;
*Table 1 Program
  01: 30          Execution Interval (seconds)

; Turn on the multiplexer

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

2:  Excitation with Delay (P22)
  1:  1           Ex Channel
  2:  0           Delay W/Ex (0.01 sec units)
  3:  15          Delay After Ex (0.01 sec units)
  4:  0           mV Excitation

3:  Beginning of Loop (P87)
  1:  0000        Delay
  2:  32          Loop Count

; Clock multiplexer to next channel

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

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

    6:  Do (P86)
      1:  1           Call Subroutine 1

; This part of the program will calculate the RMS Amperage
; Standard Deviation in this part of the code works mathematically the same
; as RMS calculation, and it is easier to program this way.  The RMS
; value is calculated and stored back into an input location for further
; processing if needed.

    7:  Do (P86)
      1:  2           Call Subroutine 2
```

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

      9:  Z=X (P31)
        1:   2                  X Loc [ BurstAmps ]
        2:   4           --     Z Loc [ CS10_1    ]

      10:  Do (P86)
        1:   3                  Call Subroutine 3

      11:  Z=X (P31)
        1:   3                  X Loc [ Burst_A2  ]
        2:   5           --     Z Loc [ CS10_2    ]

12:  End (P95)

13:  Do (P86)
  1:   51              Set Port 1 Low

; This part of the program will store a one minute average of the amperage.

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

15:  Set Active Storage Area (P80)^17815
  1:   1               Final Storage Area 1
  2:   60              Array ID

16:  Real Time (P77)^10331
  1:   1220            Year,Day,Hour/Minute (midnight = 2400)

17:  Average (P71)^5143
  1:   64              Reps
  2:   4               Loc [ CS10_1    ]

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

*Table 3 Subroutines
;
; Parameter 2 should be 2500 mV for 50-200 amps
;            should be 250 mV for 5-49 amps
;            should be 25 mV for 0-4.9 amps
; Parameter 5 should be 2.0 msec for 50 Hz or 60 Hz
; Parameter 6 should be 0.05 thousand scans for 50 Hz or 60 Hz
;  if parameter 5 & 6 are 2.0 and 0.05, then you have 5 complete cycles at 50 Hz
;  or 6 complete cycles at 60 Hz.

1:  Beginning of Subroutine (P85)
  1:   1               Subroutine 1
```

```
    2:  Burst Measurement (P23)
     1:   1              Input Channels per Scan
     2:   15             2500 mV Fast Range
     3:   1              In Chan
     4:   0001           Trig/Trig/Dest/Meas Options
     5:   2.0            Time per Scan (msec)
     6:   .05            Scans (in thousands)
     7:   0              Samples before Trigger
     8:   0.0            mV Limit
     9:   0000           mV Excitation
     10:  71             Loc [ Amps_1    ]
     11:  .2             Multiplier
     12:  0.0            Offset

    3:  Burst Measurement (P23)
     1:   1              Input Channels per Scan
     2:   15             2500 mV Fast Range
     3:   2              In Chan
     4:   0001           Trig/Trig/Dest/Meas Options
     5:   2.0            Time per Scan (msec)
     6:   .05            Scans (in thousands)
     7:   0              Samples before Trigger
     8:   0.0            mV Limit
     9:   0000           mV Excitation
     10:  123            Loc [ AmpsII_1  ]
     11:  .2             Multiplier
     12:  0.0            Offset

4:  End (P95)

5:  Beginning of Subroutine (P85)
  1:   2             Subroutine 2

    6:  Z=F x 10^n (P30)
     1:   0.0            F
     2:   00             n, Exponent of 10
     3:   1              Z Loc [ Counter   ]

    7:  Beginning of Loop (P87)
     1:   0              Delay
     2:   50             Loop Count

        8:  Z=Z+1 (P32)
         1:   1              Z Loc [ Counter   ]

        9:  If (X<=>F) (P89)
         1:   1              X Loc [ Counter   ]
         2:   1              =
         3:   50             F
         4:   10             Set Output Flag High (Flag 0)

        10:  Set Active Storage Area (P80)
         1:   3              Input Storage Area
         2:   2              Loc [ BurstAmps ]
```

```
        11:  Standard Deviation (P82)^13110
          1:    1                  Reps
          2:    71          --     Sample Loc [ Amps_1    ]

    12:  End (P95)

13:  End (P95)

14:  Beginning of Subroutine (P85)
  1:    3                  Subroutine 3

    15:  Z=F x 10^n (P30)
      1:    0.0            F
      2:    00             n, Exponent of 10
      3:    1              Z Loc [ Counter   ]

    16:  Beginning of Loop (P87)
      1:    0              Delay
      2:    50             Loop Count

        17:  Z=Z+1 (P32)
          1:    1                  Z Loc [ Counter   ]

        18:  If (X<=>F) (P89)
          1:    1                  X Loc [ Counter   ]
          2:    1                  =
          3:    50                 F
          4:    10                 Set Output Flag High (Flag 0)

        19:  Set Active Storage Area (P80)
          1:    3                  Input Storage Area
          2:    3                  Loc [ Burst_A2  ]

        20:  Standard Deviation (P82)^6732
          1:    1                  Reps
          2:    123         --     Sample Loc [ AmpsII_1  ]

    21:  End (P95)

22:  End (P95)

End Program
```

Appendix A. Theory of Operation

A.1 Typical Electrical Circuit

An example of a typical electrical circuit is a generator that provides energy in the form of a 60-Hz sine wave. The energy is carried from the point of generation to the point of consumption via two wires. The generator creates an electrical load that lights up the light bulb (see Figure A-1).

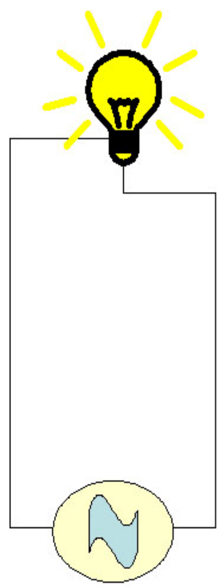

FIGURE A-1. Generator schematic

If we want to know the consumption (amps) of the load, we need a way to measure what is passing through the wires.

We can add a sensor into the circuit to measure the amperage going through the circuit (see Figures A-2 through Figure A-4). This sensor is called a CT or Current Transformer. Our CS10 and CS15 are current transformers.

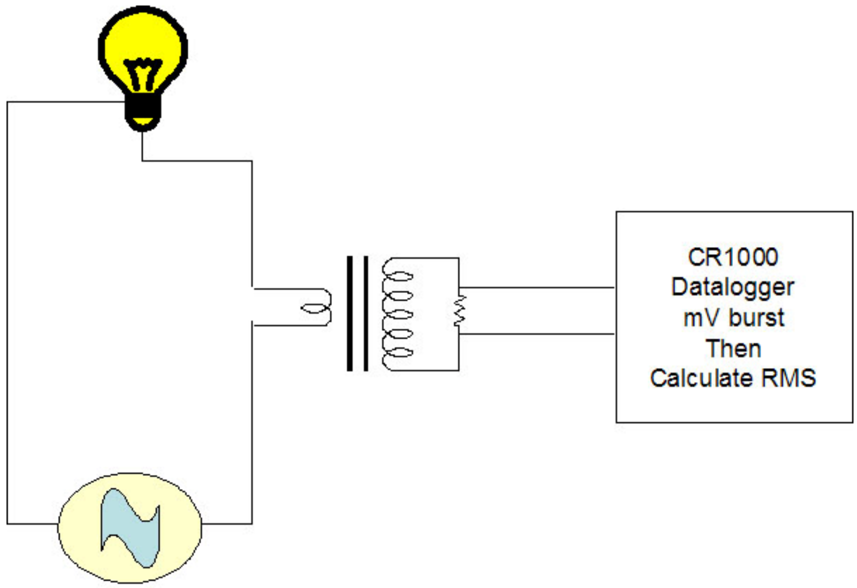

FIGURE A-2. Schematic of generator with current transformer

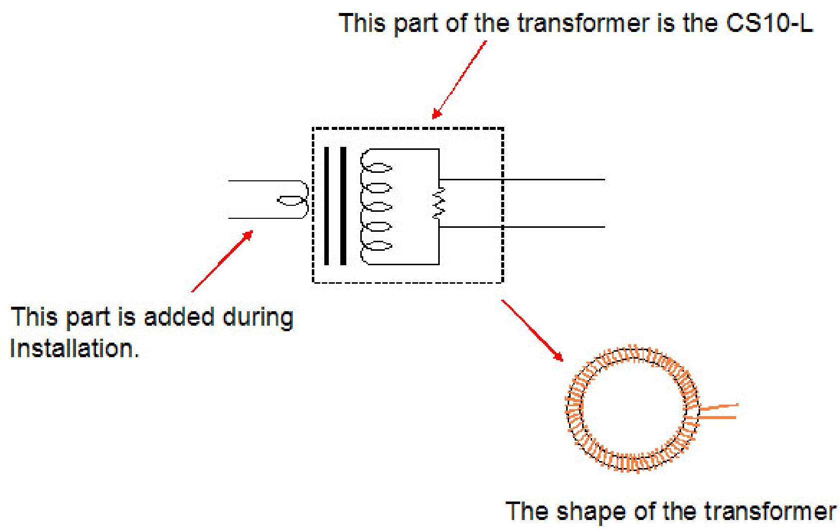

FIGURE A-3. Schematic of current transformer with the wire

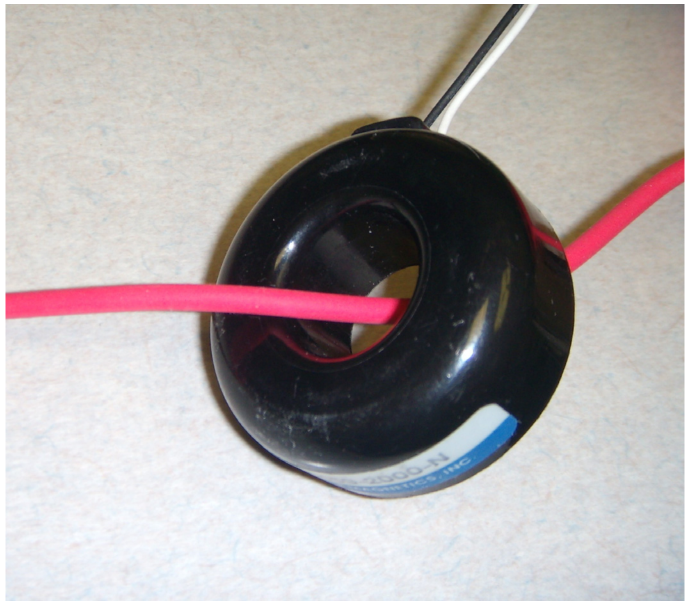

FIGURE A-4. CS10 with the wire

A.2 Current Transformer Description

A current transformer is a special kind of transformer that transfers energy from one side to another through magnetic fluxes (see Figure A-5).

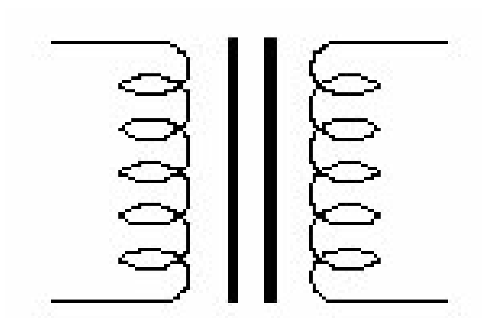

FIGURE A-5. Magnetic flux schematic

The formula for a transformer is as follows (Equation A):

$$i_1 * n_1 = i_2 * n_2 \qquad \text{Equation A}$$

Where i = amps and n = number of turns or windings

And where n_1 is the primary winding and n_2 is the secondary

With the current transformer, the primary coils or windings are minimized to avoid removing power out of the circuit, but still have a signal large enough to measure (see Figure A-6).

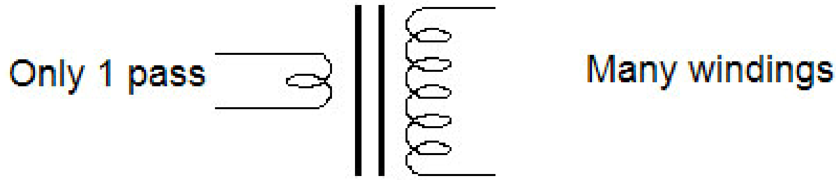

FIGURE A-6. Windings schematic

A tiny bit of the current is transferred to the secondary coil.

We can find the current induced on the secondary windings by solving for i_2:

$i_2 = i_1 * n_1/n_2$ Equation B

For Example: The CS10 current transducer has an n_2 value of 2000 windings. If 20 amps pass through the primary winding, the following amperage is produced on the secondary winding:

$i_2 =$ 20 * (1/2000) = 0.01 amp on secondary winding

A.3 Converting a Milliamp Signal to a Millivolt Signal

After the current is transformed from one level to another level, we need to convert the amperage signal into a voltage signal so that the datalogger can measure it.

Use Ohm's Law (Equation C) to convert amperage to voltage:

E = I * R   (E=Volts, I = Amps, R = Ohms)   Equation C

For Example: Using our previous example:

E = 0.01 amps * R

The CS10-L contains a 10-ohm burden (shunt) resistor. Therefore E is:

E = 0.01 amps * 10 ohms = 0.1 volts (or 100 mV)

From these calculations, we can determine if we want slightly better resolution on the measurement. We can lower the Range Code to 250 mV for some dataloggers.

A.4 Multiplier

Use Equation D to calculate the multiplier.

$$m=C*n_2/n_1*(1/R)*(1\ V/1000\ mV) \quad \text{Equation D}$$

Where, C = a correction constant

If we assume a correction constant of 1, then we can solve for the equation from the above information.

$$m = 1 * 2000/1 * (1/10) * (1/1000) = 0.2 \text{ multiplier}$$

A.5 CS10/CS15 Comparison

The CS10 consists of a CR Magnectic's CR8459 Current Transducer with a 10-ohm burden resistor incorporated into its cable (see Figure A-7). The resistor allows most of our dataloggers to measure it.

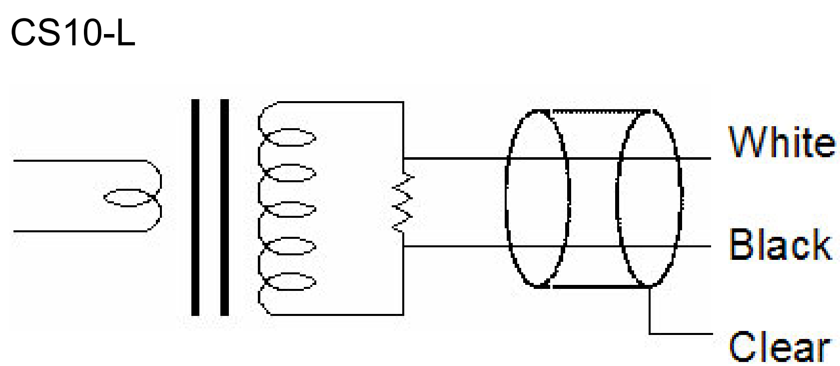

FIGURE A-7. CS10 schematic

The CS15, a modified version of the CS10, was developed specifically for the CR200(X)-series dataloggers. CR200(X)-series dataloggers require special treatment because they cannot measure negative values; range is only 0 to 2500 mV (see Figure A-9).   To create positive reference, the CS15-L uses Voltage Excitation to shift the measurement range (see Figures A-8 through A-10).

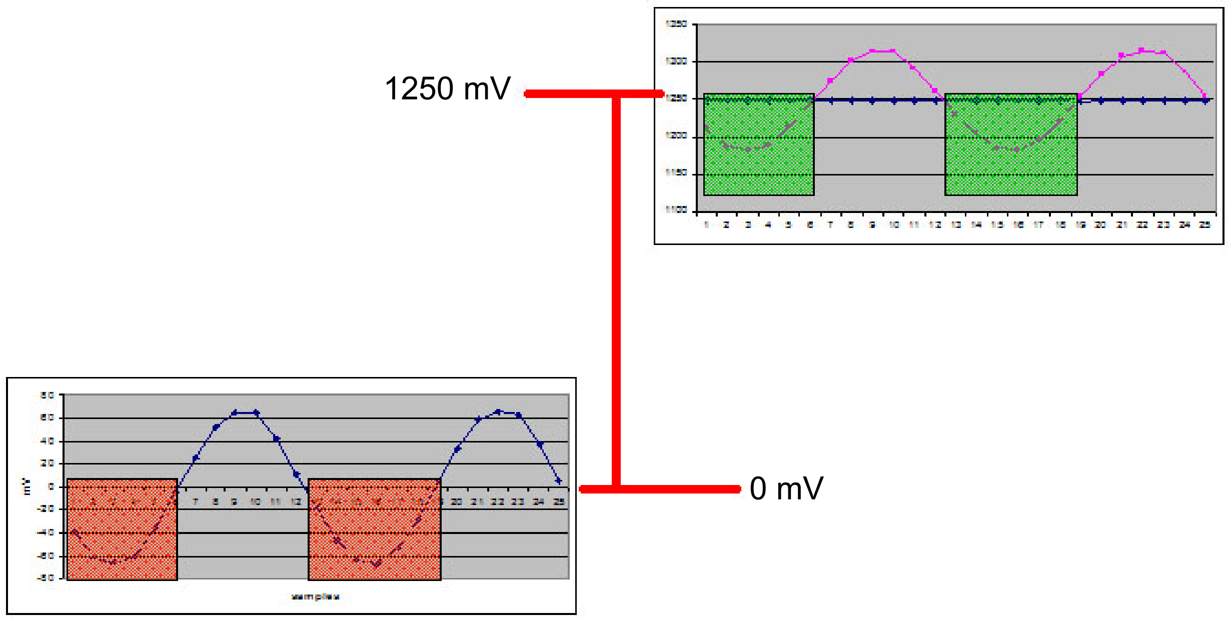

FIGURE A-8. Adding 1250 mV creates positive output

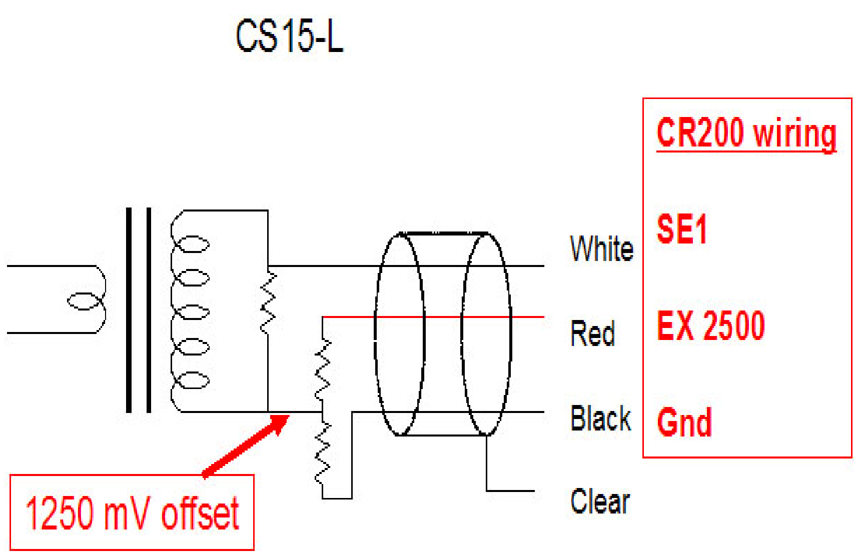

FIGURE A-9. CS15 schematic

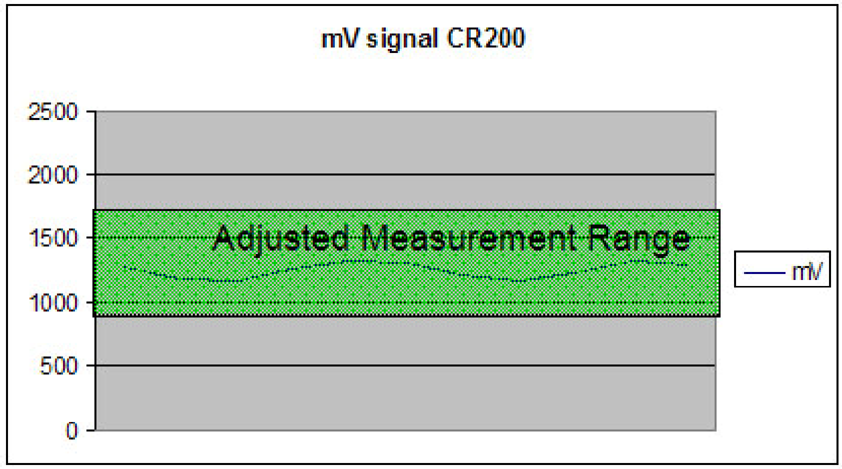

FIGURE A-10. CS15 measurement range

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