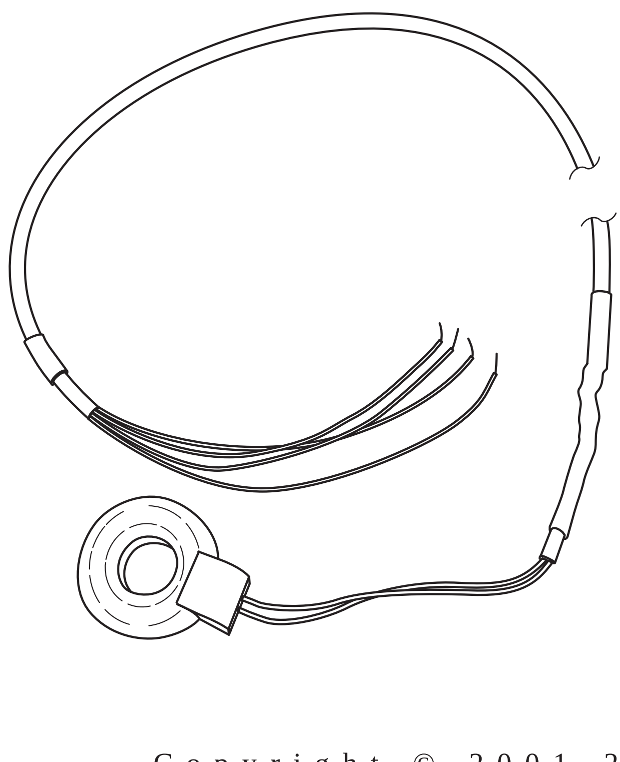
INSTRUCTION MANUAL

CS11-L Current Transformer

12/13



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PLEASE READ FIRST

About this manual

Please note that this manual was originally produced by Campbell Scientific Inc. (CSI) primarily for the US 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/in2) = 68.95 mb
Volume:	1 US gallon = 3.785 litres

In addition, part ordering numbers may vary. For example, the CABLE5CBL is a CSI part number and known as a FIN5COND at Campbell Scientific Canada (CSC). CSC Technical Support will be pleased to assist with any questions.

About sensor wiring

Please note that certain sensor configurations may require a user supplied jumper wire. It is recommended to review the sensor configuration requirements for your application and supply the jumper wire is necessary.

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CS11-L Current Transformer

1. General Description

Campbell Scientific's CS11-L (FIGURE 1-1) detects and measures the AC current along an electrical wire using the magnetic field that is generated by that current. The CS11-L does not have direct electrical connection to the system. The sensor outputs a millivolt signal allowing it to be directly connected to our dataloggers.

The CS11-L is compatible with our CR200X, CR800, CR850, CR1000, CR3000, CR500, CR510, CR10(X),CR21X, 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 CS11-L has been developed in such a way that it can be used on most of the datalogger models past and present, including the CR200(X). However, the CR200(X) datalogger requires slightly different wiring than the other dataloggers and requires derating of the maximum amperage to 125 amps.

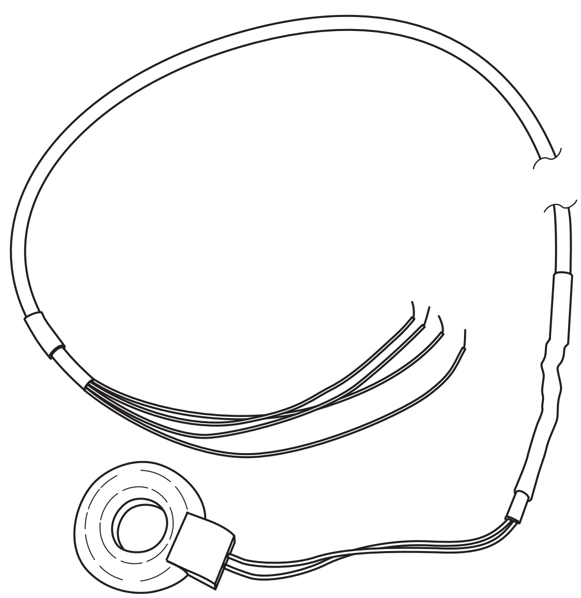


FIGURE 1-1. CS11-L Current Transformer

2. Specifications

Example Applications:

- Motor or generator load conditions
- Efficiency studies
- Intermittent fault detection
- Submetering

Measurement Ranges:	0.15 to 200 A (0.15 to 125 A for CR200X)
Frequency:	50 and 60 Hz
Insulation Resistance:	100 M ohm @ 500 Vdc
High Potential:	2000 volts
Rated Current:	200 A, 125 A (CR200X)
Storage Temperature:	–25º to 70ºC
Operating Temperature:	–25º to 55ºC
Case Material:	Polypropylene Resin
Construction:	Epoxy Encapsulated
Accuracy with 10 ohm Burden Max. (resistive):	Typically ±1 percent of actual value with provided multiplier
Dimensions	
Outer Diameter:	4.8 cm (1.89 in)
Inner Diameter:	1.9 cm (0.75 in)
Height:	1.7 cm (0.67 in)
Multiplier:	i^{Mult}=200 A/1000mV=0.2

3. Installation

Place one AC wire through the hole of the CS11-L (see FIGURE 3-1). The sensor may be placed on either the hot or neutral AC wire.

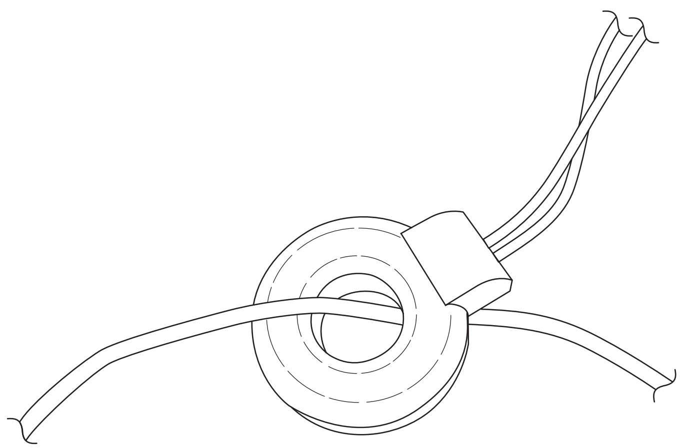


FIGURE 3-1. AC load wire installed in CS11-L (color of ac load wire can vary)

4. Wiring

The CS11-L uses a single-ended analog channel as follows:

Wire Color	Terminal
RED	⏚ or AG (VX on CR200X)
WHITE	SE
BLACK	⏚ or AG
Shield	⏚ or AG

CS11-L

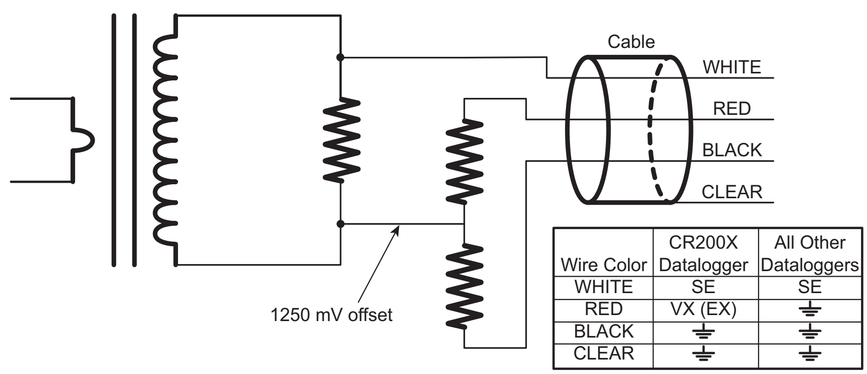


FIGURE 4-1. CS11-L schematic

If multiple wire passes are needed, see the end of the first paragraph in Appendix A.6, *Multiple Passes Through the Sensor*.

5. ACPower Instruction

5.1 Using the ACPower Instruction with the CS11-L

The CS11-L can be measured by programming the datalogger using the **ACPower** Instruction (found in the CR8X0, CR1000, CR3000 dataloggers). The **ACPower** instruction is designed to measure the voltage, frequency and amperage of an AC load, then calculate the phase angle, harmonic distortion of both the voltage and the current, as well as the real power of the load. In order to obtain all of these measurements and values, another sensor, a potential transformer, is required in addition to the CS11-L sensor. The datalogger will measure voltage signal and frequency of the potential transformer. It will also measure the current of the CS11-L.

```
'CR1000 Series Datalogger
' CS11-L_with_ACPower_AmpsOnly.CR1
'date: June 24, 2013
'
' Wiring:
'  SE2      White CS11-L
'  AG       Black CS11-L
'  AG       Clear CS11-L
'  AG       Red   CS11-L

PipeLineMode                 ' must be pipeline mode
Public Batt_volt
Public Amp_Mult
Public Amperage
Dim Array1(10)


PreserveVariables            ' to store values between power cycles

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

BeginProg
  Amp_Mult = 200/1000         ' 0.2 multiplier for the CS11-L (200Amps/1000mV=0.2)
  Scan (500,mSec,0,0)
    Battery (Batt_volt)
    ACPower (Array1(),1,60,1,0.345345,120,2,.2,200,1)
    Amperage=Array1(4)
'    If Amperage <= 0.15 Then Amperage = 0
    CallTable (AmpTable)
  NextScan
EndProg
```

If no potential transformer will be used, the CS11-L and the **ACPower** instruction will give you amperage, but not the other values, so you should ignore all of the other values returned from the **ACPower** instruction. Most of these other values will show up as NAN (not a number) when no potential transformer is used.

5.2 ACPower (from CRBasic Help)

The **ACPower** instruction measures real AC power and a number of power quality parameters for single-phase, split-phase, and three-phase ‘Y’ configurations.

Syntax

ACPower (*DestAC, ConfigAC, LineFrq, ChanV, VMult, MaxVrms, ChanI, IMult, MaxIrms, RepsI*)

The **ACPower** instruction is suitable for net-metering applications, as well as variable-frequency (wild AC) applications. Potential and current transformers must be used to measure the voltage and current using the datalogger.

WARNING **Working with live electrical equipment is dangerous! The user is responsible for ensuring all wiring conforms to local safety regulations and that the enclosure is labeled accordingly.**

DestAC The *DestAC* parameter is a variable or variable array in which to store the measurement results. The number of values returned depends upon the option chosen for the configuration parameter. If *DestAC* is not dimensioned large enough to hold all values, only those values that will fit into the array will be stored.

ConfigAC The *ConfigAC* parameter is used to determine the type of measurement that will be made.

Option	Description
1	Single-phase with one voltage measurement and the number of current measurements specified by the *RepsI* parameter. This configuration monitors a single load with one voltage and one current measurement, or multiple loads in sub-panel applications with one voltage and multiple current measurements. See FIGURE 5-1.

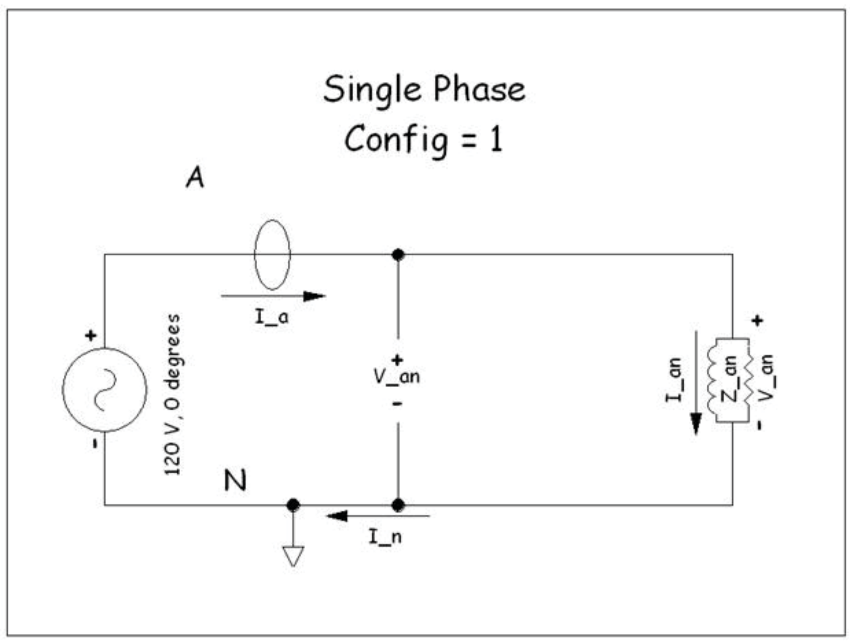


FIGURE 5-1. ACPower Configuration 1

Option	Description
2	Split-phase with one voltage measurement and two current measurements. This configuration is typical of residential service-entry panels, as well as residential and commercial distribution panels. Split-phase configurations have two line (or "hot") conductors plus a neutral conductor. See FIGURE 5-2.

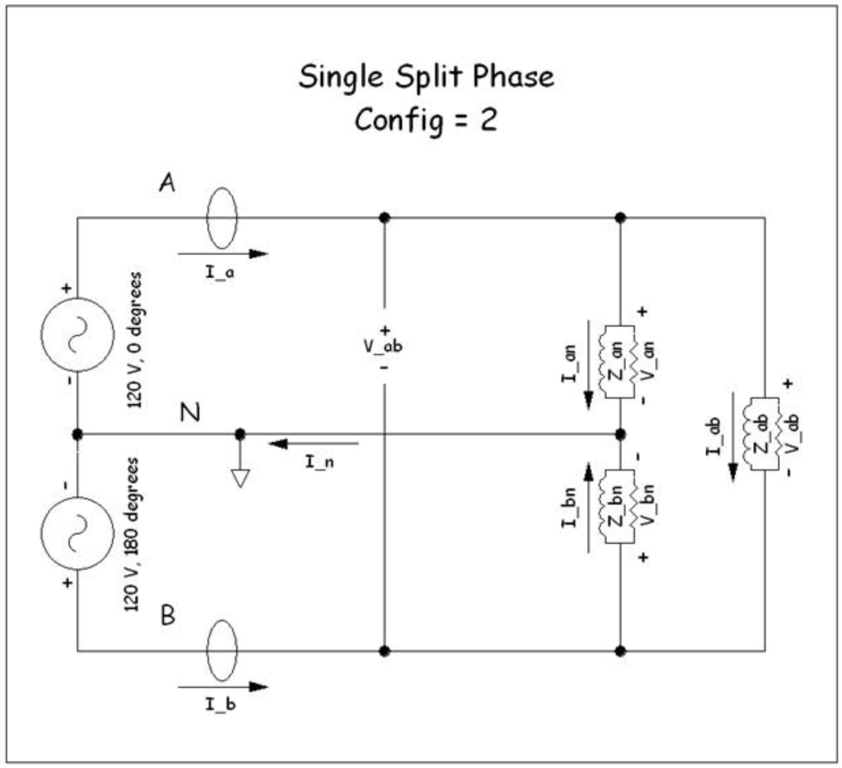


FIGURE 5-2. ACPower Configuration 2

Option	Description
3	Three-phase 'Y', four-conductor, configurations with three voltage measurements and three current measurements. This configuration is typical of commercial entry panels and commercial distribution panels. The four conductors are three line (or "hot") conductors plus a neutral conductor. See FIGURE 5-3.

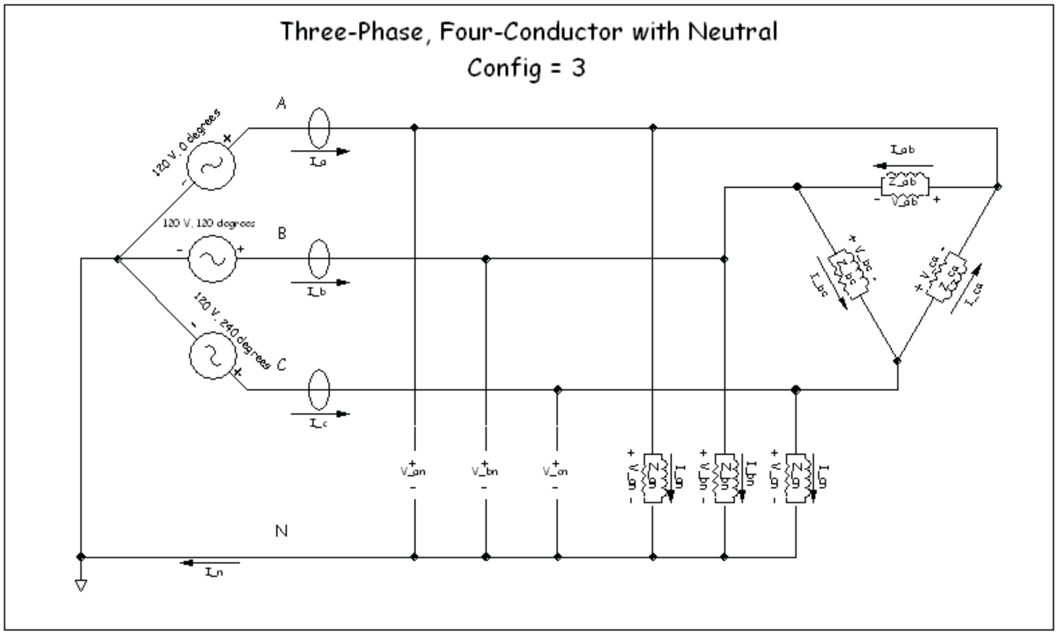


FIGURE 5-3. ACPower Configuration 3

LineFrq The *LineFrq* parameter is the expected line frequency in hertz. Valid entries are 60, 50, or a value between 2 and 20. A value between 2 and 20 indicates measurements from variable-frequency power, where *LineFrq* is the minimum frequency to be measured. Note that smaller values for *LineFrq* increase the measurement and processing time for this instruction.

ChanV The *ChanV* parameter is the single-ended channel for the voltage measurement. For single- and split-phase configurations (ConfigAC = 1 or 2), the datalogger makes a voltage measurement at *ChanV*. For three-phase configurations (ConfigAC = 3), the datalogger makes three voltage measurements on increasing consecutive channels starting at *ChanV*.

VMult The *VMult* parameter is the potential transformer multiplier represented as input volts per output mV. A typical value is 115 V/333 mV (or 0.345345).

MaxVrms	The *MaxVrms* parameter is the expected maximum rms (root mean square) voltage to measure. *MaxVrms* is specified at the primary of the potential transformer, or equivalently, the non-datalogger side of the potential transformer. Typical values are 120 or 240. The datalogger uses *VMult* and *MaxVrms* to calculate which input range to use for the voltage measurement.
ChanI	The *ChanI* parameter is the single-ended channel for the current measurement. For single-phase configurations (ConfigAC = 1) with *RepsI* greater than 1, the datalogger makes multiple current measurements on increasing consecutive channels starting at *ChanI*. For split-phase configurations (ConfigAC = 2), the datalogger makes two current measurements on increasing consecutive channels starting at *ChanI*. For three-phase configurations (ConfigAC = 3), the datalogger makes three current measurements on increasing consecutive channels starting at *ChanV*.
IMult	The *IMult* parameter is the current transformer multiplier as input amps per output mV. A typical value is 15 amps/333 mV (or 0.045045).
MaxIrms	The *MaxIrms* parameter is the expected maximum rms current to measure. *MaxIrms* is specified at the primary of the current transformer, or equivalently, the non-datalogger side of the current transformer. The datalogger uses *Imult* and *MaxIrms* to calculate which input range to use for the current measurement(s).
RepsI	The *RepsI* parameter is the number of current measurements to make on consecutive single-ended input channels. This parameter is used only in configuration 1 and is ignored by the datalogger for configurations 2 and 3.

Results Returned

In each of the three configurations, *DestAC* may be a single-element variable or a dimensioned variable array. The **ACPower** instruction will store as many results as will fit in *DestAC*.

If the *LineFrq* value is between 2 and 20, inclusive, (for example, the expected frequency is not known or “wild”), the phase (*VPhaseI*) and harmonic ratio (*VHarmRatio*) will not be included in the results.

ConfigAC = 1 — Returns a maximum of 3 + 4•RepsI values in the following order:

Power(RepsI). The real power in Watts measured by the voltage and each current measurement, repeated to give RepsI values.

MeasFrq. The measured voltage frequency in Hz.

Voltage. The measured voltage in Volts rms.

Current(RepsI). The measured current in amps rms, repeated to give *RepsI* values.

VPhaseI(RepsI). The measured phase angle in radians that the voltage leads the current, repeated to give *RepsI* values. The cosine of *VPhaseI* is the power factor.

VHarmRatio. The measured voltage harmonic distortion ratio given as the total harmonic content divided by the fundamental content at *LineFrq* Hz. *VHarmRatio* is unitless.

IHarmRatio(RepsI). The measured current harmonic distortion ratio given as the total harmonic content divided by the fundamental content at *LineFrq* Hz, repeated to give *RepsI* values. *IHarmRatio* is unitless.

ConfigAC = 2 Returns a maximum of 12 values in the following order:

TotPower. The total real power in watts.

Power(2). The real power in watts measured by the voltage and each of two current measurements.

MeasFrq. The measured voltage frequency in Hz.

Voltage. The measured voltage in volts rms.

Current(2). The measured current in amps rms, repeated to give two values.

VPhaseI(2). The measured phase angle in radians that the voltage leads the current, repeated to give two values. The cosine of *VPhaseI* is the power factor.

VHarmRatio. The measured voltage harmonic distortion ratio given as the total harmonic content divided by the fundamental content at *LineFrq* Hz. *VHarmRatio* is unitless.

HarmRatio(2). The measured current harmonic distortion ratio given as the total harmonic content divided by the fundamental content at *LineFrq* Hz, repeated to give two values. *IHarmRatio* is unitless.

ConfigAC = 3 Returns a maximum of 20 values in the following order:

TotPower. The total real power in watts.

Power(3). The real power in watts measured for each of the three line conductors.

MeasFrq. The measured voltage frequency in Hz.

Voltage(3). The measured voltage in volts rms for each of the three line conductors.

Current(3). The measured current in Amps rms for each of the three line conductors.

VphaseI(3). The measured phase angle in radians that the voltage leads the current for each of the three line conductors. The cosine of *VphaseI* is the power factor.

VHarmRatio(3). The measured voltage harmonic distortion ratio given as the total harmonic content divided by the fundamental content at *LineFrq* Hz for each of the three line conductors. *VHarmRatio* is unitless.

IHarmRatio(3). The measured current harmonic distortion ratio given as the total harmonic content divided by the fundamental content at *LineFrq* Hz for each of the three line conductors. *IHarmRatio* is unitless.

6. 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 CS11-L (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 CR500, CR510, CR10(X), CR21X 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 CS11-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.

TABLE 6-1 shows the maximum amperage for each datalogger, depending on the range code.

TABLE 6-1. Max Amps on Each of the Range Codes in the Datalogger (one pass only).

Datalogger >>> Range Codes (mV)	CR200(X) Series	CR10X CR500 CR510	CR1000 CR800 CR850	CR21X	CR23X	CR3000	Amperage Resolution
2.5		0.5	0.5				0.000133
5				1			0.000067
7.5		1.5	1.5				0.000400
10					2		0.000133
15				3			0.000200
20						4	0.000134
25		5	5				0.001334
50				10	10	10	0.000666
200					40	40	0.002660
250		50	50				0.013340
500				100			0.006660
1000					200	200	0.013320
2500	125	200	200				0.133400
5000			200	200	200	200	0.066600

6.1 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 (for example, negative value for channel number). The **SpaDevSpa** instruction calculates rms.

NOTE Program must be run in the pipeline mode on CRBasic dataloggers.

It is important to measure complete cycles. If 100 measurements are taken during a 0.1 second time period, the result will be five complete cycles for a 50 Hz waveform or six complete cycles for a 60 Hz waveform.

CAUTION Do not average the waveform reading in the data table nor use the 60 Hz or 50 Hz noise rejection in the measurement instructions in the program. Doing so would result in an incorrect zero amperage reading.

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

6.1.1 Example CR1000 Program

```
'CR1000 Series Datalogger
' CS11-L_with_ACPower_Instruction.CR1
'date: June 12, 2013
'
' Wiring:
'  SE1      PT Potential Transformer Signal
'  AG       PT reference
'  SE2      White CS11-L
'  AG       Black CS11-L
'  AG       Clear CS11-L
'  AG       Red   CS11-L

PipeLineMode                  ' must be pipeline mode
Public Batt_volt
Public Amp_Mult
Public Array1(10)
Alias Array1(1) = Real_Power
Alias Array1(2) = Frequency
Alias Array1(3) = Voltage
Alias Array1(4) = Amperage
Alias Array1(5) = Phase_Angle
Alias Array1(6) = V_Harm_Ratio
Alias Array1(7) = I_Harm_Ratio

PreserveVariables             ' to store values between power cycles

DataTable (AmpTable,True,-1)
  DataInterval (0,1,Min,10)
    Totalize (1,Real_Power,IEEE4,False)
    Average (1,Frequency,FP2,False)
    Average (1,Voltage,FP2,False)
    Average (1,Amperage,FP2,False)
    Maximum (1,Phase_Angle,FP2,False,False)
    Maximum (1,V_Harm_Ratio,FP2,False,False)
    Maximum (1,I_Harm_Ratio,FP2,False,False)
EndTable


BeginProg
  Amp_mult = 0.2              ' 0.2 multiplier for the CS11-L (200Amps/1000mV=0.2)
  Scan (500,mSec,0,0)
    Battery (Batt_volt)
    ACPower (Array1(),1,60,1,0.345345,120,2,.2,200,1)
    CallTable (AmpTable)
  NextScan
EndProg
```

6.2 CR200X-series Dataloggers

The CS11-L is compatible with the CR200X-series dataloggers, with slightly different wiring. The RED wire is connected to a VX terminal and requires an **ExciteV** instruction in the program. The voltage excitation creates a positive reference output that the CR200X-series can measure.

The recommended programming method for CR200X-series dataloggers (where the scan interval is limited to once per second) is to place the **VoltSE** instruction within a loop. The first CR200X example program has a loop that samples 25 times, and the second CR200X example program has a loop that samples 30 times. A 25-sample loop produces almost two cycles of a 60 Hz waveform, and a 30-sample loop produces almost two cycles of a 50 Hz waveform (see FIGURE 6-1). The average energy under the curve is calculated using the **RMSSpa** instruction. A multiplier of 0.2 is applied to the rms value; see Appendix A.4, *Multiplier*, for more information.

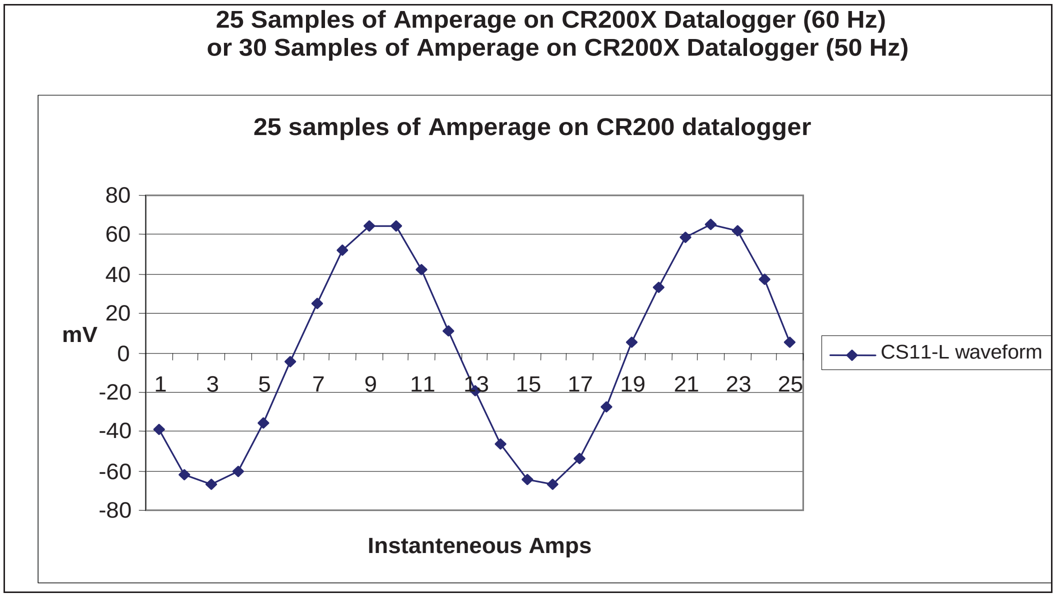


FIGURE 6-1. Graph of a CS11-L waveform

6.2.1 CR200(X) Program for 60 Hz

```
'CR200 Series Datalogger
' Program name: CS11-LManual60Hz.cr2
'date: Jun 2013

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

DataTable (Amp,1,-1)
  DataInterval (0,1,min)
  Average (1,Crnt_A,False)
  Maximum (1,Crnt_A,False,0)
EndTable

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 Amp
  NextScan
EndProg
```

6.2.2 CR200(X) Program for 50 Hz

```
'CR200 Series Datalogger
' Program name: CS11-LManual50Hz.cr2
'date: Jun 2013

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

DataTable (Amps,1,-1)
  DataInterval (0,1,min)
  Average (1,Crnt_A,False)
  Maximum (1,Crnt_A,False,0)
EndTable

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
    CallTable Amps
  NextScan
EndProg
```

6.3 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 measure complete cycles. For **Instruction 23**, if parameters 5 and 6 are 2.0 and 0.05, respectively, you get five complete cycles for a 50 Hz waveform, and six complete cycles for a 60-Hz waveform (see FIGURE 6-2). The multiplier for the CS11-L is 0.2; see Appendix A.4, *Multiplier*, for more information.

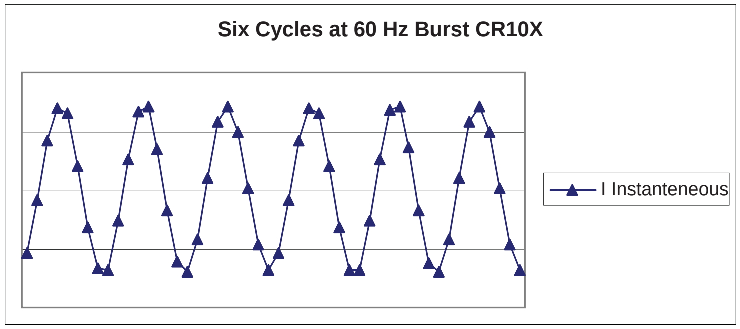


FIGURE 6-2. Graph of CS11-L waveform using burst mode

The following CR10X program generates the waveforms shown in FIGURE 6-2.

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.

6.3.1 Example CR10X Program

```
; 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 CS11-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 rmscalculation, 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)
```

6.4 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 CR200X. This method is also an option for our CR510, CR10X, and CR23X, but only three measurements per period will be made. FIGURE 6-3 shows a graph produced by a CR10X program with a loop that samples 90 times. A portion of this program is shown below.

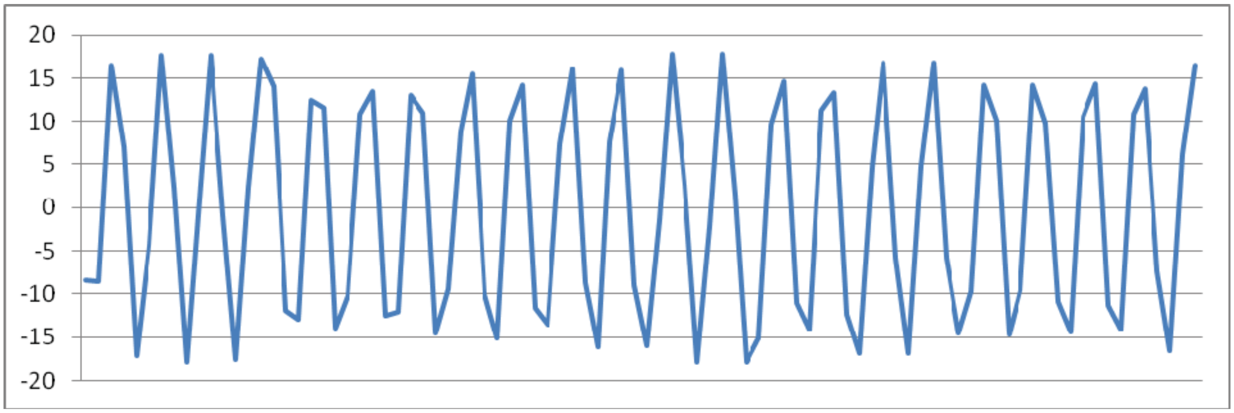


FIGURE 6-3. Graph of a CS11-L waveform using 90 samples of amperage

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.

6.4.1 Example CR21X Program

```
3:  Z=F (P30)
  1:   0.0             F
  2:   4               Z Loc [ Counter   ]

4:  Beginning of Loop (P87)
  1:   0000            Delay
  2:   90              Loop Count

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

    6:  Volt (SE) (P1)
      1:    1              Reps
      2:   14              500 mV Fast Range
      3:   1               SE Channel
      4:   57          --  Loc [ LoopAmp_1 ] ; Use F4 to get indexing --
      5:   .2              Multiplier
      6:   0.0             Offset

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

    8:  Z=X (P31)
      1:   57          --  X Loc [ LoopAmp_1 ] ; Use F4 to get indexing --
      2:   3               Z Loc [ Sensor    ]

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

    10:  Standard Deviation (P82)^15810
      1:   1               Reps
      2:   3               Sample Loc [ Sensor    ]

11:  End (P95)
```

The above CR21X program may provide an adequate waveform because the program makes more than two measurements per period (Nyquist Frequency) 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 6-2).

6.5 CR1000 with Multiplexer Sample Program

This program uses the CR1000 and an AM16/32-series multiplexer to read 32 CS11-L Current Transformers.

6.5.1 Example CR1000 program reading 32 CS11-L Current Tranformers

```
'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 CS11-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
```

6.6 CR10X with Multiplexer Sample Program

This program uses the CR10X and an AM16/32-series multiplexer to read 32 CS11-L current transformers.

6.6.1 Example CR10X program reading 32 CS11-L Current Transformers

```
;{CR10X}
; Example program for CS11-L
;
; Program to test the CS11-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 [ CS11_1    ]
```

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

    11:  Z=X (P31)
     1:  3              X Loc [ Burst_A2  ]
     2:  5          --  Z Loc [ CS11_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 [ CS11_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).

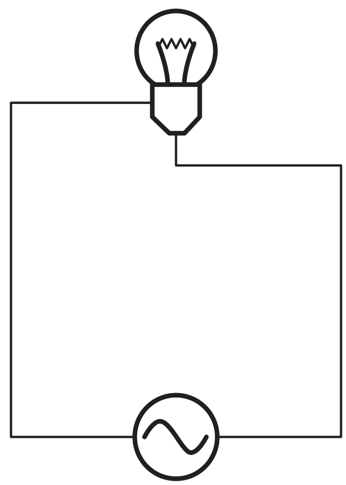


FIGURE A-1. Generator schematic

To determine the consumption (amps) of the load, a way is needed to measure what is passing through the wires.

A sensor is added to the circuit to measure the amperage going through the circuit (see FIGURE A-2 through FIGURE A-4). This sensor is called a CT or Current Transformer. The CS11-L is a current transformer.

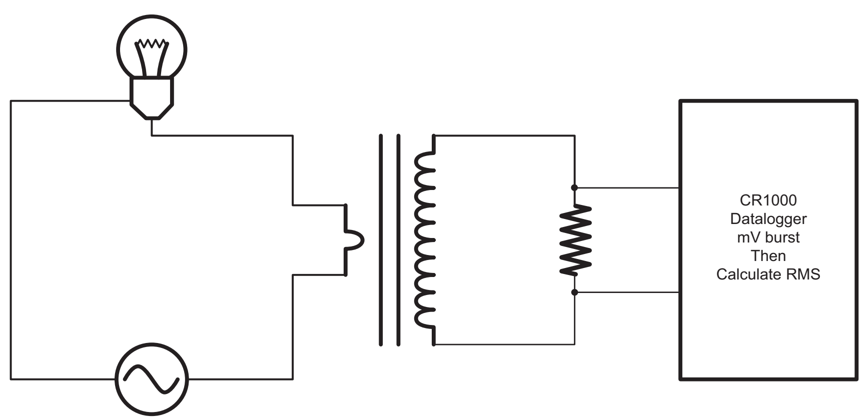


FIGURE A-2. Schematic of generator with current transformer

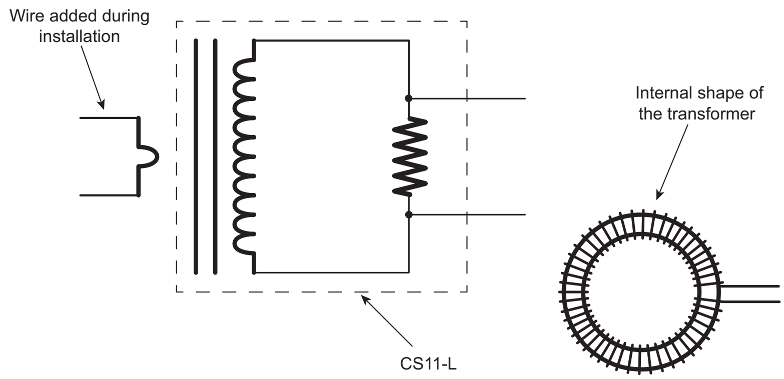


FIGURE A-3. Schematic of current transformer with the wire

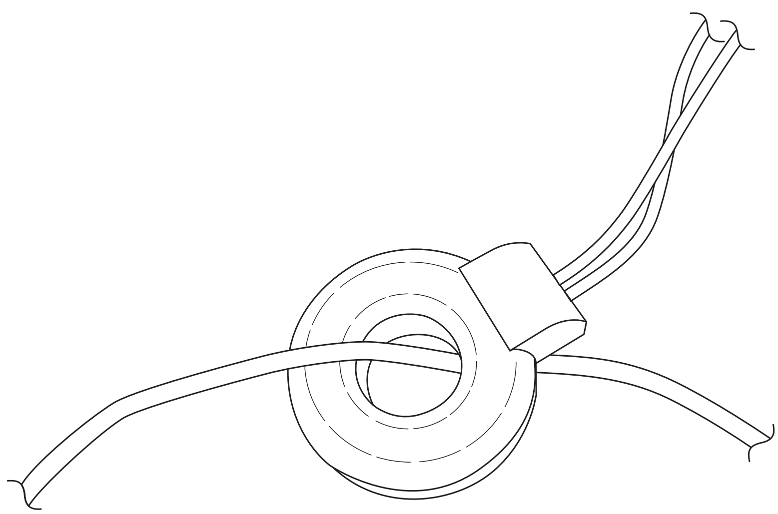


FIGURE A-4. CS11-L with the wire

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).

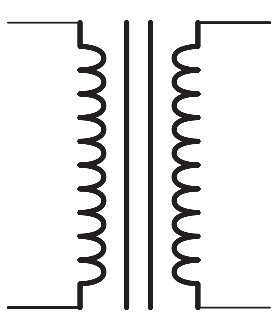


FIGURE A-5. Magnetic flux schematic

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

$i_1 \bullet n_1 = i_2 \bullet n_2$ 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).

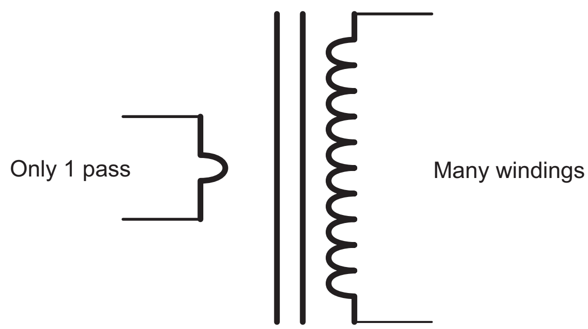


FIGURE A-6. Windings schematic

A small amount of current is transferred to the secondary coil.

Find the current induced on the secondary windings by solving for i_2:

$i_2 = i_1 \bullet n_1/n_2$ Equation B

For example: The CS11-L 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:

$i_2 = 20 \bullet (1/2000) = 0.01$ 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, the amperage signal must be converted to a voltage signal so that the datalogger can measure it.

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

$E = I \bullet R$ (E=Volts, I = Amps, R = Ohms) Equation C

For example: Using the previous example:

$E = 0.01 \text{ amps} \bullet R$

The CS11-L contains a 10-ohm burden (shunt) resistor (R=10 ohm). Therefore, E is:

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

From these calculations, it can be determined if a better resolution on the measurement is needed. The Range Code can be lowered to 250 mV for some dataloggers.

A.4 Multiplier

Use Equation D to calculate the multiplier.

$m=C \bullet n_2/n_1 \bullet (1/R) \bullet (1\ V/1000\ mV)$ Equation D

Where, C = a correction constant

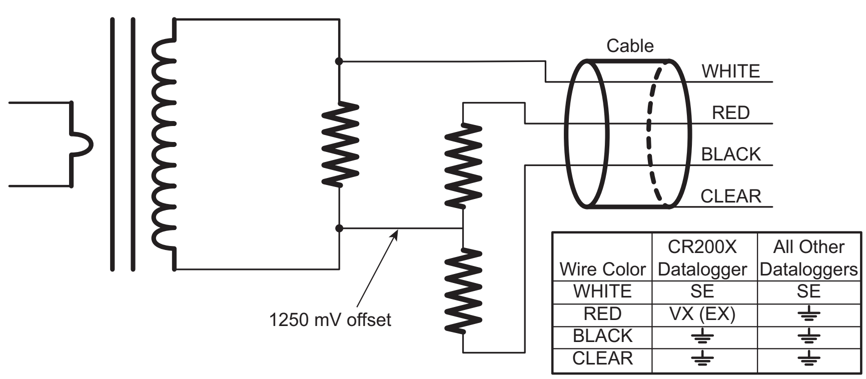
If a correction constant of 1 is assumed, then the equation can be solved from the above information.

m = 1 • 2000/1 • (1/10) • (1/1000) = 0.2 multiplier

A.5 CS11-L Details

The CS11-L 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.

CS11-L



Wire Color	CR200X Datalogger	All Other Dataloggers
WHITE	SE	SE
RED	VX (EX)	⏚
BLACK	⏚	⏚
CLEAR	⏚	⏚

FIGURE A-7. CS11-L schematic

CR200X-series dataloggers require special treatment because they cannot measure negative values; range is only 0 to 2500 mV (see FIGURE A-8). To create positive reference, the CS11-L uses Voltage Excitation to shift the measurement range (see FIGURE A-8 and FIGURE A-9).

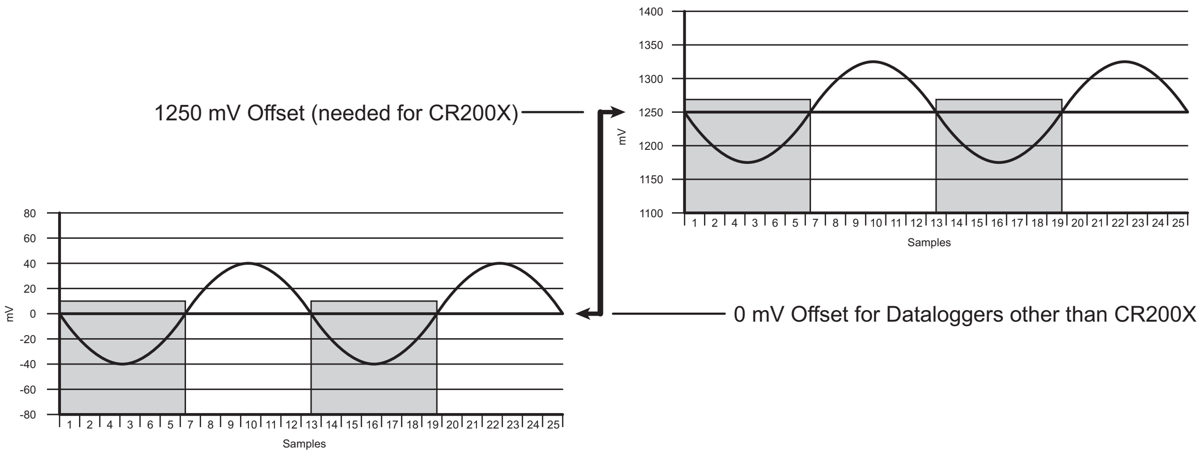


FIGURE A-8. Adding 1250 mV creates positive output

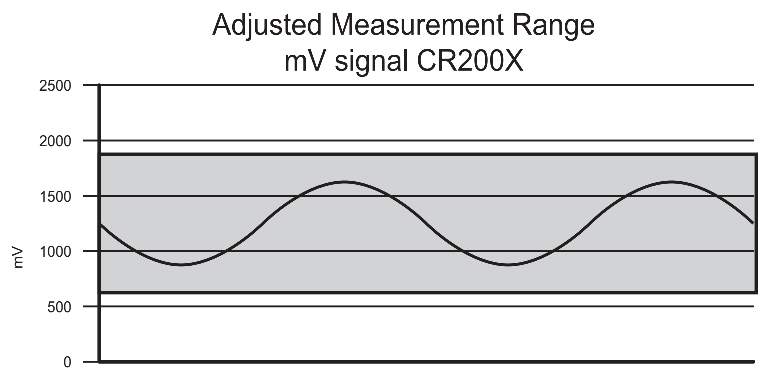


FIGURE A-9. CS11-L measurement range

A.6 Multiple Passes Through the Sensor

Multiple passes can pass through the sensor to amplify the signal of the amperage being measured (FIGURE A-10). However, the multiplier will need to be changed, depending on how many passes through the sensor.

NOTE The range code needs to be changed to match the number of wire passes through the sensor.

Passes	New Multiplier	Range Code
2	0.1	x2
4	0.05	x4
5	0.04	x5
8	0.025	x8
10	0.02	x10
20	0.01	x20

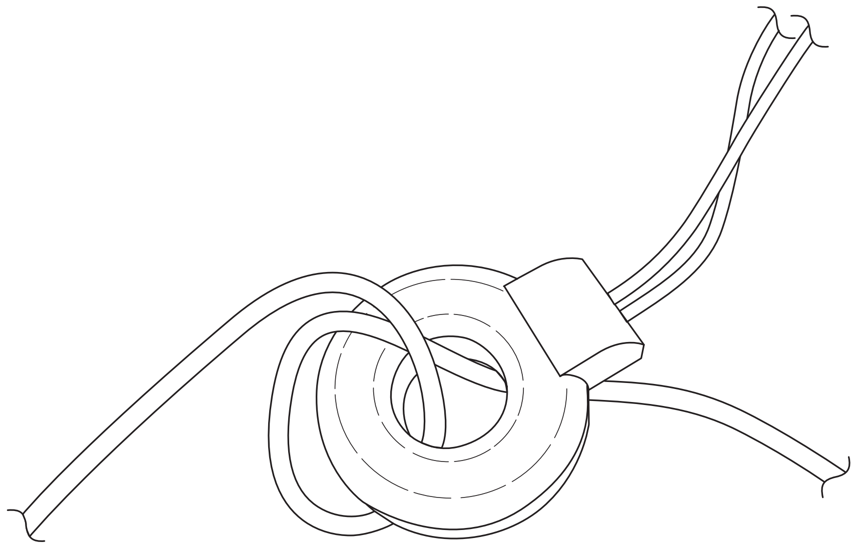


FIGURE A-10. CS11-L with a wire making two passes through the sensor

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