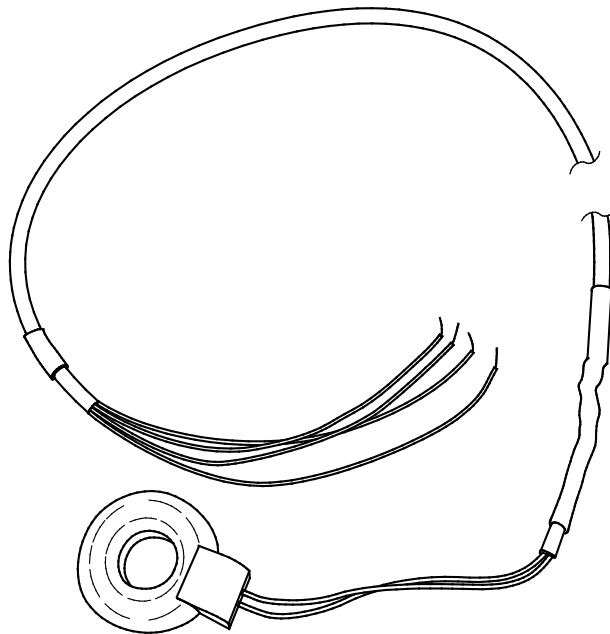


CS11

Current Transformer



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DANGER — MANY HAZARDS ARE ASSOCIATED WITH INSTALLING, USING, MAINTAINING, AND WORKING ON OR AROUND TRIPODS, TOWERS, AND ANY ATTACHMENTS TO TRIPODS AND TOWERS SUCH AS SENSORS, CROSSARMS, ENCLOSURES, ANTENNAS, ETC. FAILURE TO PROPERLY AND COMPLETELY ASSEMBLE, INSTALL, OPERATE, USE, AND MAINTAIN TRIPODS, TOWERS, AND ATTACHMENTS, AND FAILURE TO HEED WARNINGS, INCREASES THE RISK OF DEATH, ACCIDENT, SERIOUS INJURY, PROPERTY DAMAGE, AND PRODUCT FAILURE. TAKE ALL REASONABLE PRECAUTIONS TO AVOID THESE HAZARDS. CHECK WITH YOUR ORGANIZATION'S SAFETY COORDINATOR (OR POLICY) FOR PROCEDURES AND REQUIRED PROTECTIVE EQUIPMENT PRIOR TO PERFORMING ANY WORK.

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- Use only qualified personnel for installation, use, and maintenance of tripods and towers, and any attachments to tripods and towers. The use of licensed and qualified contractors is highly recommended.
- Read all applicable instructions carefully and understand procedures thoroughly before beginning work.
- Wear a **hardhat** and **eye protection**, and take **other appropriate safety precautions** while working on or around tripods and towers.
- **Do not climb** tripods or towers at any time, and prohibit climbing by other persons. Take reasonable precautions to secure tripod and tower sites from trespassers.
- Use only manufacturer recommended parts, materials, and tools.

Utility and Electrical

- **You can be killed** or sustain serious bodily injury if the tripod, tower, or attachments you are installing, constructing, using, or maintaining, or a tool, stake, or anchor, come in **contact with overhead or underground utility lines**.
- Maintain a distance of at least one-and-one-half times structure height, 20 feet, or the distance required by applicable law, **whichever is greater**, between overhead utility lines and the structure (tripod, tower, attachments, or tools).
- Prior to performing site or installation work, inform all utility companies and have all underground utilities marked.
- Comply with all electrical codes. Electrical equipment and related grounding devices should be installed by a licensed and qualified electrician.

Elevated Work and Weather

- Exercise extreme caution when performing elevated work.
- Use appropriate equipment and safety practices.
- During installation and maintenance, keep tower and tripod sites clear of un-trained or non-essential personnel. Take precautions to prevent elevated tools and objects from dropping.
- Do not perform any work in inclement weather, including wind, rain, snow, lightning, etc.

Maintenance

- Periodically (at least yearly) check for wear and damage, including corrosion, stress cracks, frayed cables, loose cable clamps, cable tightness, etc. and take necessary corrective actions.
- Periodically (at least yearly) check electrical ground connections.

WHILE EVERY ATTEMPT IS MADE TO EMBODY THE HIGHEST DEGREE OF SAFETY IN ALL CAMPBELL SCIENTIFIC PRODUCTS, THE CUSTOMER ASSUMES ALL RISK FROM ANY INJURY RESULTING FROM IMPROPER INSTALLATION, USE, OR MAINTENANCE OF TRIPODS, TOWERS, OR ATTACHMENTS TO TRIPODS AND TOWERS SUCH AS SENSORS, CROSSARMS, ENCLOSURES, ANTENNAS, ETC.

Table of Contents

PDF viewers: These page numbers refer to the printed version of this document. Use the PDF reader bookmarks tab for links to specific sections.

1. Introduction.....	1
2. Precautions	1
3. Initial Inspection	1
4. QuickStart	1
5. Overview	3
6. Specifications	4
7. Installation	5
7.1 Data Logger Connections.....	5
7.2 Programming.....	6
7.2.1 ACPower() Instruction.....	7
7.2.2 Millivolt Burst Measurements.....	8
7.2.3 CR300 Series	9
7.2.4 CR200X Series.....	9
7.3 Multiplier	10

Appendices

A. Importing Short Cut Code Into CRBasic Editor... A-1	A-1
B. Example Programs	B-1
B.1 ACPower() Example	B-1
B.2 Millivolt Burst Measurement and Multiplexer Sample Program	B-2
B.3 CR300-Series Example	B-3
B.4 CR200(X)-Series Example.....	B-4
C. Theory of Operation	C-1
C.1 Typical Electrical Circuit	C-1
C.2 Current Transformer Description	C-2
C.3 Converting a Milliamp Signal to a Millivolt Signal	C-3
C.4 Using a CR300-Series or CR200(X)-Series Datalogger	C-4
C.5 Multiple AC-Wire Passes Through the CS11	C-5

Figures

5-1.	Top (right) and bottom views of the CS11 Current Transformer.....	4
7-1.	AC load wire installed in CS11.....	5
7-2.	CS11 schematic.....	6
7-3.	Graph of a CS11 waveform.....	10
C-1.	Generator schematic.....	C-1
C-2.	Schematic of generator with current transformer.....	C-1
C-3.	Schematic of current transformer with the AC wire.....	C-2
C-4.	CS11 with the AC wire.....	C-2
C-5.	Magnetic flux schematic.....	C-2
C-6.	Windings schematic.....	C-3
C-7.	Adding 1250 mV creates positive output.....	C-4
C-8.	CS11 measurement range.....	C-4
C-9.	CS11 with the AC wire making two passes through the CS11.....	C-5

Tables

7-1.	CS11 Wire Color, Function, and Data Logger Connection.....	6
7-2.	Measurement Range, Maximum Amperage, and Amperage Resolution (one pass only).....	8
B-1.	Wiring for AC Power Example.....	B-1
B-2.	Wiring for Multiplexer Example.....	B-2
B-3.	Wiring for CR300-Series Program.....	B-3
B-4.	Wiring for CR300-Series Program.....	B-4
C-1.	Passes, Multiplier, and Voltage Range.....	C-5

CRBasic Examples

B-1.	CR1000X Program Using AC Power Instruction.....	B-1
B-2.	CR1000X Program Reading 32 CS11 Current Transformers.....	B-2
B-3.	CR300 Program Measuring the CS11.....	B-3
B-4.	CR200(X) Program to Measure the CS11.....	B-4

CS11 Current Transformer

1. Introduction

The CS11 detects and measures the current along an AC wire using the magnetic field that is generated by that current. The sensor outputs a millivolt signal allowing it to be directly connected to our data loggers. The CS11 is recommended for measurements that do not require high accuracy, such as motor or generator load condition monitoring, efficiency studies, intermittent fault detection, and rough submetering.

NOTE

This manual provides information only for CRBasic data loggers. For retired Edlog data logger support, see an older manual at www.campbellsci.com/old-manuals.

2. Precautions

- READ AND UNDERSTAND the *Safety* section at the front of this manual.
- Care should be taken when opening the shipping package to not damage or cut the CS11 cable jacket. If damage to the cable is suspected, consult with a Campbell Scientific support and implementation engineer.
- 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.

3. Initial Inspection

Upon receipt of the CS11, inspect the packaging and contents for damage. File any damage claims with the shipping company. Immediately check package contents against the shipping documentation. Contact Campbell Scientific about any discrepancies.

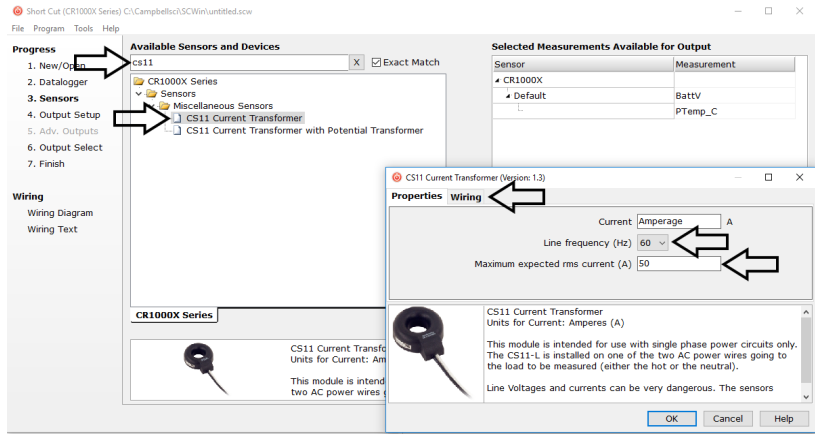
4. QuickStart

A video that describes data logger programming using Short Cut is available at: www.campbellsci.com/videos/cr1000x-datalogger-getting-started-program-part-3. *Short Cut* is an easy way to program your data logger to measure the sensor and assign data logger wiring terminals. *Short Cut* is available as a download on www.campbellsci.com. It is included in installations of *LoggerNet*, *PC200W*, *PC400*, or *RTDAQ*.

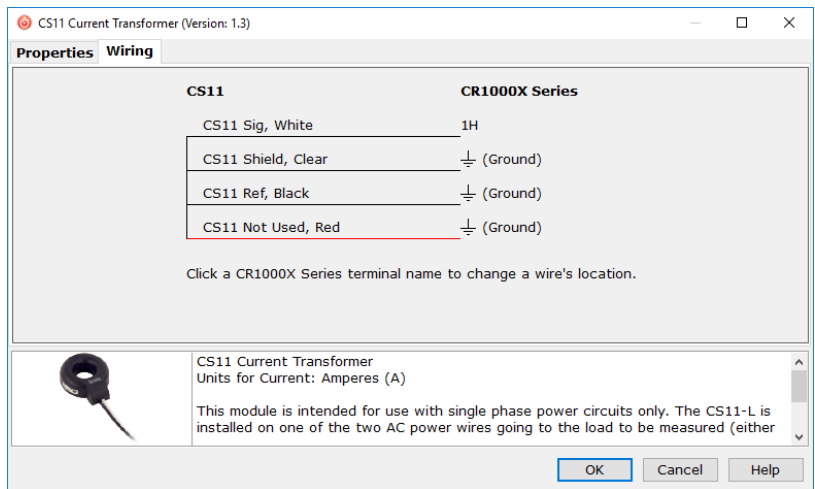
The following procedure also shows using *Short Cut* to program the sensor.

1. Open *Short Cut* and click **Create New Program**.
2. Double-click the data logger model.

3. In the **Available Sensors and Devices** box, type CS11 or locate the sensor in the select **Sensors | Miscellaneous Sensors** folder. Double-click **CS11 Current Transformer**. The default line frequency is 60 Hz. This can be changed by clicking the **Line frequency (Hz)** box and selecting 50 Hz. Type the **Maximum expected rms current (A)**.

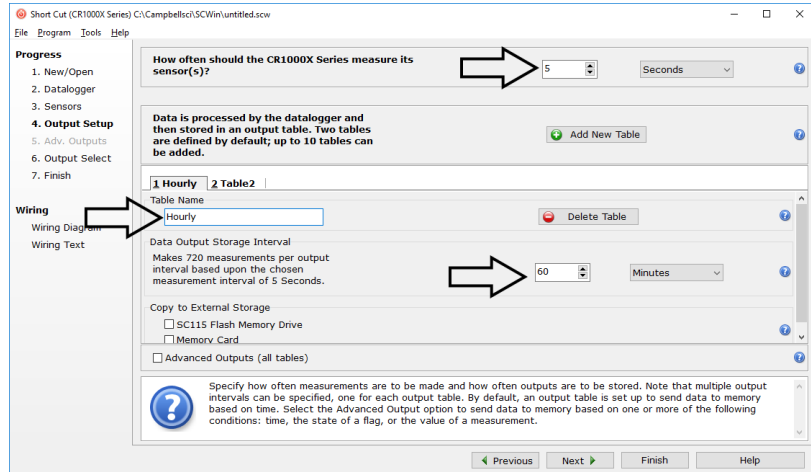


4. Click the **Wiring** tab to see how the sensor is to be wired to the data logger. Click **OK** after wiring the sensor.

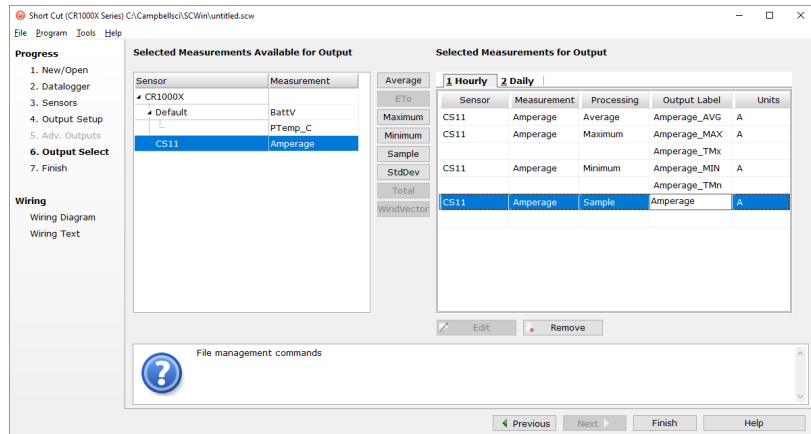


5. Repeat steps three and four for other sensors.

- In **Output Setup**, type the scan rate, meaningful table names, and **Data Output Storage Interval**.



- Select the output options.



- Click **Finish** and save the program. Send the program to the data logger if the data logger is connected to the computer.
- If the sensor is connected to the data logger, check the output of the sensor in data display in *LoggerNet*, *PC400*, *RTDAQ*, or *PC200W* to make sure it is making reasonable measurements.

5. Overview

The CS11 (FIGURE 5-1) uses CR Magnetic’s CR8459 Current Transformer to detect the current along an AC wire using the magnetic field that is generated by that current. The CS11 is external to the AC-wire jacket and has no direct electrical connection to the system.



FIGURE 5-1. Top (right) and bottom views of the CS11 Current Transformer

The CS11 was designed to be compatible with most of the data loggers.

6. Specifications

Features:

- Ideal applications include motor or generator load conditions, efficiency studies, intermittent fault detection, and rough submetering
- Sensor is external to the wire jacket and has no direct electrical connection to the system
- Compatible with Campbell Scientific CRBasic data loggers: CR200(X) series, CR300 series, CR6 series, CR800 series, CR1000, CR1000X series, and CR3000

Measurement Ranges: 0.15 to 200 A (0.15 to 125 A for CR200X)

Frequency: 50 and 60 Hz

Insulation Resistance: 100 MΩ @ 500 Vdc

High Potential: 2000 V

Rated Current: 200 A, 125 A (CR200X series, CR300 series)

Storage Temperature: -25 to 70 °C

Operating Temperature: -25 to 55 °C

Case Material: Polypropylene Resin

Construction: Epoxy Encapsulated

Accuracy with 10 Ω	
Burden Max. (resistive):	Typically $\pm 1\%$ 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:	$i^{\text{Mult}} = 200 \text{ A}/1000\text{mV} = 0.2$

7. Installation

If you are programming your data logger with *Short Cut*, skip Section 7.1, *Data Logger Connections* (p. 5), and Section 7.2, *Programming* (p. 6). *Short Cut* does this work for you. See Section 4, *QuickStart* (p. 1), for a *Short Cut* tutorial.

Place one AC wire through the hole of the CS11 (see FIGURE 7-1). The sensor may be placed on either the hot or neutral AC wire.

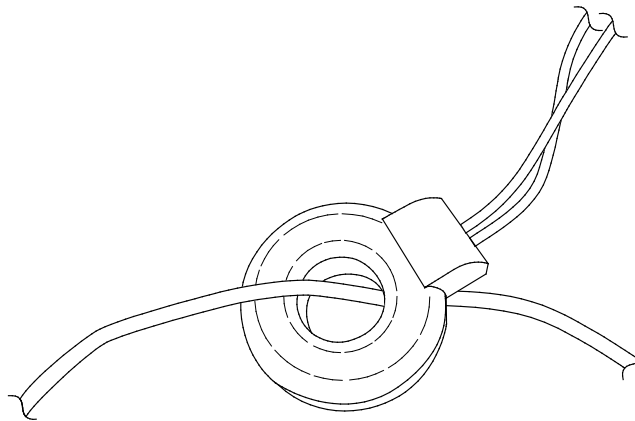


FIGURE 7-1. AC load wire installed in CS11

Multiple AC-wire passes are possible and described in Appendix C.5, *Multiple Passes Through the Sensor* (p. C-5).

7.1 Data Logger Connections

FIGURE 7-2 provides the schematic of the CS11.

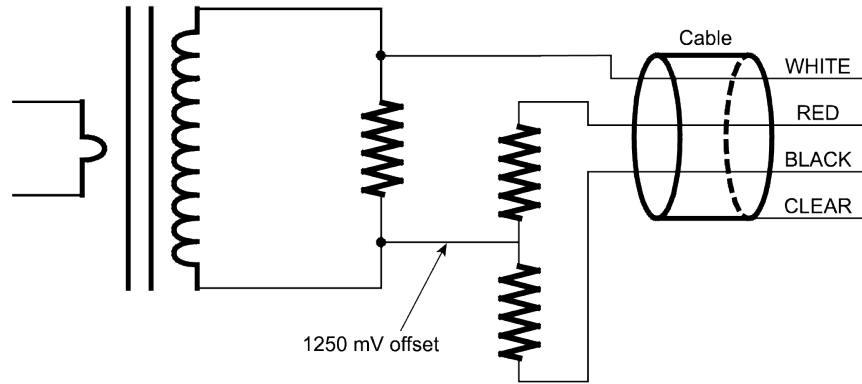


FIGURE 7-2. CS11 schematic

TABLE 7-1 provides CS11 connections to the data logger. When using the **ACPower()** CRBasic instruction, another sensor, a potential transformer, is required in addition to the CS11 sensor to obtain all of these measurements and values. If the potential transformer is used, its signal wire needs to be connected to a data logger single-ended terminal and its reference wire needs to be connected a data logger analog ground terminal. Refer to Section 7.2.1, *ACPower() Instruction* (p. 7), for more information.

TABLE 7-1. CS11 Wire Color, Function, and Data Logger Connection			
CS11 Wire Color	Function	CR300-Series or CR200(X)-Series Connection Terminals	All Other Data Logger Connection Terminals
White	Signal	SE (single-ended, analog input)	U configured for single-ended analog input ¹ , SE (single-ended, analog input)
Black	Signal Reference	⏏ (analog ground)	⏏ (analog ground)
Red	Voltage Excitation or Ground	VX or EX	⏏ (analog ground)
Clear	Shield	⏏ (analog ground)	⏏ (analog ground)

¹ U terminals are automatically configured by the measurement instruction.

7.2 Programming

Short Cut is the best source for up-to-date data logger programming code. If your data acquisition requirements are simple, you can probably create and maintain a data logger program exclusively with *Short Cut*. If your data acquisition needs are more complex, the files that *Short Cut* creates are a great source for programming code to start a new program or add to an existing custom program.

NOTE *Short Cut* cannot edit programs after they are imported and edited in *CRBasic Editor*.

A *Short Cut* tutorial is available in Section 4, *QuickStart* (p. 1). If you wish to import *Short Cut* code into *CRBasic Editor* to create or add to a customized program, follow the procedure in Appendix A, *Importing Short Cut Code Into CRBasic Editor* (p. A-1). Programming basics for most CRBasic data loggers are provided in the following sections. Complete program examples for select CRBasic data loggers can be found in Appendix B, *Example Programs* (p. B-1).

To monitor the amperage of an alternating current circuit, the program must take many samples from the CS11 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 data logger, the untapped programming capacity, and other factors. Typically the **ACPower()** or **VoltSE()** CRBasic instructions are used.

7.2.1 ACPower() Instruction

Most CRBasic data loggers can use the **ACPower()** instruction to measure the CS11. This instruction is not available for the CR300-series or CR200(X)-series dataloggers.

The **ACPower()** instruction measures the voltage, frequency and amperage of an AC load, then calculates the phase angle, harmonic distortion of both the voltage and the current, as well as the real power of the load. To obtain all of these measurements and values, a potential transformer is required in addition to the CS11 sensor. The data logger measures the current of the CS11 and measures voltage signal and frequency of the potential transformer.

If a potential transformer is not used, the **ACPower()** instruction will provide amperage, but the other values returned will show up as NAN (not a number) or another inaccurate value.

Syntax

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

The **DestAC** parameter is variable array with a length of 7. Use option 1 for the **ConfigAC**. **LineFrq** is typically 50 or 60 Hz. **ChanV** is the single-ended terminal in which the potential transformer is connected. 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). The **MaxVrms** parameter is the expected maximum rms (root mean square) voltage to measure. The data logger uses **VMult** and **MaxVrms** to calculate which input range to use for the voltage measurement. **ChanI** is the single-ended terminal in which the potential transformer is connected. The calculation for the **IMult** parameter is in Section 7.3, *Multiplier* (p. 10). Refer to TABLE 7-2 for the **MaxIrms**. The data logger uses **IMult** and **MaxIrms** to calculate which input range to use for the current measurement.

7.2.2 Millivolt Burst Measurements

Refer to Section 7.2.1, *ACPower() Instruction (p. 7)*, if using a potential transformer. Refer to Section 7.2.3, *CR300 Series (p. 9)*, or Section 7.2.4, *CR200X Series (p. 9)*, if using these data loggers.

For most CRBasic data loggers, amperage can be monitored by making millivolt burst measurements then calculating rms. The millivolt burst measurements are made by using the **VoltSE()** instruction with multiple reps on the same channel (negative value for terminal number). The **StdDevSpa()** instruction calculates rms. Section 7.3, *Multiplier (p. 10)*, provides information about calculating the multiplier that is applied to the rms value. TABLE 7-2 shows the maximum amperage for each data logger, depending on the range code in the **VoltSE()** instruction.

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

When using these instructions, 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 **VoltSE()** instructions in the program. Doing so would result in an incorrect zero amperage reading.

TABLE 7-2. Measurement Range, Maximum Amperage, and Amperage Resolution (one pass only)

VoltSE Voltage Range (mV)	Maximum Amps (MaxIrms)	Amperage Resolution
2.5	0.5	0.000133
5	1	0.000067
7.5	1.5	0.000400
10	2	0.000133
15	3	0.000200
20	4	0.000134
25	5	0.001334
50	10	0.000666
200	40	0.002660
250	50	0.013340
500	100	0.006660
1000	200	0.013320

TABLE 7-2. Measurement Range, Maximum Amperage, and Amperage Resolution (one pass only)

VoltSE Voltage Range (mV)	Maximum Amps (MaxIrms)	Amperage Resolution
2500	200 ¹	0.133400 ¹
5000	200	0.066600

¹ The maximum amperage for the CR200(X)-series and CR300-series datalogger is 125.

7.2.3 CR300 Series

With the CR300X-series dataloggers, the CRBasic program uses the **ExciteV()** instruction to create a positive reference output that the CR300-series dataloggers can measure. The CS11 is measured with the **VoltSE()** instruction with a range of mV2500, an integration of 4000, and an offset of -1250.

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.

7.2.4 CR200X Series

The CR200X-series datalogger program uses an **ExciteV()** instruction to create 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. 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 (FIGURE 7-3). The average energy under the curve is calculated using the **RMSSpa()** instruction. Section 7.3, *Multiplier (p. 10)*, provides information about calculating the multiplier that is applied to the rms value.

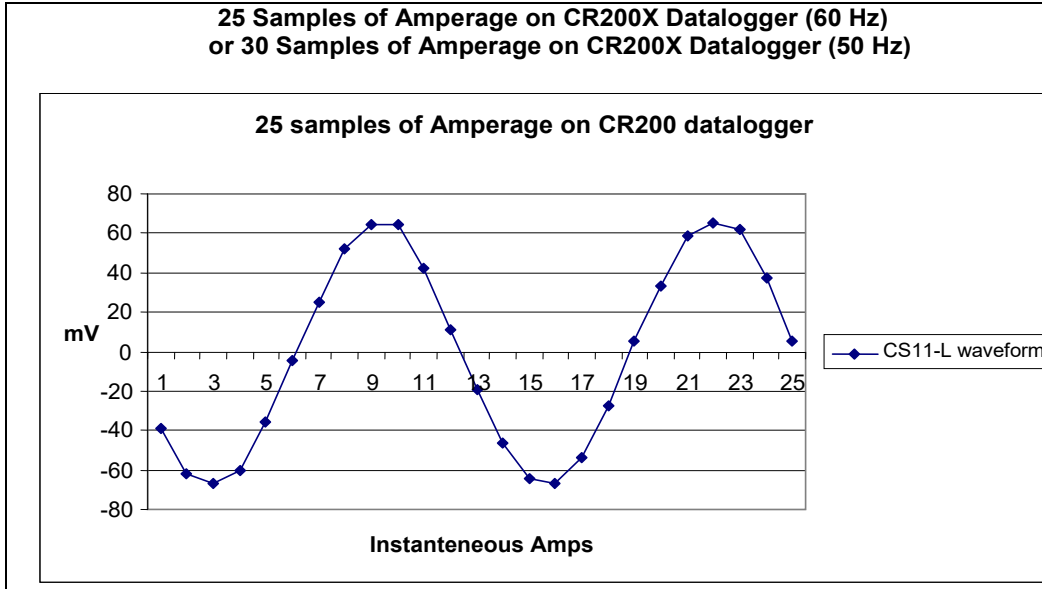


FIGURE 7-3. Graph of a CS11 waveform

7.3 Multiplier

Use Equation 1 to calculate the multiplier that is applied to the RMS value.

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

Where, C = a correction constant

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

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

Appendix A. Importing Short Cut Code Into CRBasic Editor

This tutorial shows:

- Importing a *Short Cut* program into a program editor for additional refinement
- Importing a wiring diagram from *Short Cut* into the comments of a custom program

Short Cut creates files, which can be imported into *CRBasic Editor*. Assuming defaults were used when *Short Cut* was installed, these files reside in the C:\campbellsci\SCWin folder:

- .DEF (wiring and memory usage information)
- .CR2 (CR200(X)-series datalogger code)
- .CR300 (CR300-series datalogger code)
- .CR6 (CR6-series datalogger code)
- .CR8 (CR800-series datalogger code)
- .CR1 (CR1000 datalogger code)
- .CR1X (CR1000X-series datalogger code)
- .CR3 (CR3000 datalogger code)
- .CR5 (CR5000 datalogger code)

Import *Short Cut* code and wiring diagram into *CRBasic Editor*:

1. Create the *Short Cut* program following the procedure in Section 4, *QuickStart* (p. 1). Finish the program. On the **Advanced** tab, click the **CRBasic Editor** button. The program opens in CRBasic with the name **noname.CR_**. Provide a name and save the program.

NOTE

Once the file is edited with *CRBasic Editor*, *Short Cut* can no longer be used to edit the program it created.

2. The program can now be edited, saved, and sent to the data logger.
3. Import wiring information to the program by opening the associated .DEF file. By default, it is saved in the c:\campbellsci\SCWin folder. Copy and paste the section beginning with heading “–Wiring for CRXXX–” into the CRBasic program, usually at the head of the file. After pasting, edit the information such that an apostrophe (') begins each line. This character instructs the data logger compiler to ignore the line when compiling. You can highlight several lines of CRBasic code then right-click and select **Comment Block**. (This feature is demonstrated at about 5:10 in the [CRBasic | Features](#) video.)

Appendix B. Example Programs

B.1 ACPower() Example

This program uses a potential transformer and the **ACPower()** instruction. Although this is a CR1000X program, other data loggers are programmed similarly. TABLE B-1 provides wiring for the program.

TABLE B-1. Wiring for ACPower Example		
CS11 Wire Color	Function	CR1000X
	Potential Transformer Signal	SE1
	Potential Transformer Reference	⏏ (analog ground)
White	CS11 Signal	SE2
Black	CS11 Signal Reference	⏏ (analog ground)
Red	CS11 Ground	⏏ (analog ground)
Clear	CS11 Shield	⏏ (analog ground)

CRBasic Example B-1. CR1000X Program Using ACPower Instruction

```
'CR1000X Series DataLogger
'CS11_with_ACPower_Instruction.CR1

PipeLineMode 'must be pipeline mode
Public Batt_volt
Public Array1(7)
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
  Scan (500,mSec,0,0)
  Battery (Batt_volt)
  '0.2 multiplier for the CS11 (200Amps/1000mV=0.2)
  ACPower (Array1(),1,60,1,0.345345,120,2,.2,200,1)
  CallTable (AmpTable)
  NextScan
EndProg
```

B.2 Millivolt Burst Measurement and Multiplexer Sample Program

This program uses the CR1000X and an AM16/32-series multiplexer to read 32 CS11 Current Transformers. Although this program is for the CR1000X, other data loggers are programmed similarly. TABLE B-2 provides wiring for the program.

CR1000X	AM16/32B (2x32 mode)	CS11
12V	12V	
G	G	
C4	RES	
C5	CLK	
⏏ (signal ground)	COM ODD H	
SE2	COM ODD L	
⏏	COM ⏚	
	High Channels 1H – 24H	White
	Low Channels 1L – 24L	Black
	⏚	Red, Clear

CRBasic Example B-2. CR1000X Program Reading 32 CS11 Current Transformers

```
'CR1000X 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 data logger
Public Amps(NumSensors) 'the line current
Public i, Batt_Volt
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 (NumSensors,Amps,IEEE4,False,False)
  Average (NumSensors,Amps,FP2,False)
EndTable

BeginProg
  Amp_mult = 0.2      '0.2 multiplier for the CS11
  Scan (10,Sec,0,0)
  Battery (Batt_volt)
  'Turn AM16/32 Multiplexer On
  PortSet(C4,1)
  i=0
  SubScan(0,uSec,NumSensors)
  'Switch to next AM16/32 Multiplexer Channel
  PulsePort(C5,10000)
  i=i+1
  VoltSe (i_sig (1), num_samples,mV5000,-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(C4,0)
CallTable (AmpTable)
NextScan
EndProg

```

B.3 CR300-Series Example

The following is a CR300-series program for measuring the CS11. TABLE B-3 provides wiring for the program.

CS11 Wire Color	Function	CR300
White	Signal	SE1
Black	Signal Reference	⏏ (analog ground)
Red	Voltage Excitation	VX1
Clear	Shield	⏏ (analog ground)

CRBasic Example B-3. CR300 Program Measuring the CS11

```

'CR300

'Declare Variables and Units
Dim Sum
Dim SumSqr
Dim mV
Public Crnt_A
Units Crnt_A=A

DataTable (Amp,1,-1)
  DataInterval (0,1,min,10)
  Average (1,Crnt_A,FP2,False)
  Maximum (1,Crnt_A,FP2,False,0)
EndTable

'Main Program
BeginProg
  'Main Scan
  Scan(1,Sec,0,0)

  'This example is using Vx1 and SE1
  'CS11 Current Transformer measurement 'Crnt_A'
  ExciteV(Vx1,2500,0)
  SumSqr=0
  Sum=0

  SubScan (2,mSec,50)
  VoltSe(mV,1,mv2500,1,False,0,4000,1,-1250)
  'Calculate sum of squares of mV
  SumSqr=SumSqr+mV^2
  'Calculate sum of mV
  Sum=Sum+mV
NextSubScan

```

```

ExciteV(Vx1,0,0)
'Calculate standard deviation and scale measurement
Crnt_A=SQR((SumSqr-(Sum^2/50))/50)*0.2
'Filter out low end noise when amperage is near zero
If Crnt_A<0.2 Then Crnt_A=0
CallTable (Amp)
NextScan
EndProg

```

B.4 CR200(X)-Series Example

The following is a CR200(X)-series program for measuring the CS11. TABLE B-4 provides wiring for the program.

CS11 Wire Color	Function	CR300
White	Signal	SE1
Black	Signal Reference	⏏ (analog ground)
Red	Voltage Excitation	VX1
Clear	Shield	⏏ (analog ground)

CRBasic Example B-4. CR200(X) Program to Measure the CS11

```

'CR200 Series Datalogger
'Program name: CS11Manual60Hz.cr2

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

```

Appendix C. Theory of Operation

C.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 C-1).

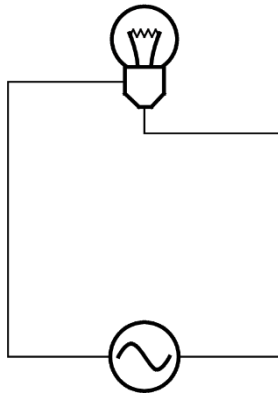


FIGURE C-1. Generator schematic

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 C-2 through FIGURE C-4). This sensor is called a CT or Current Transformer. The CS11 is a current transformer.

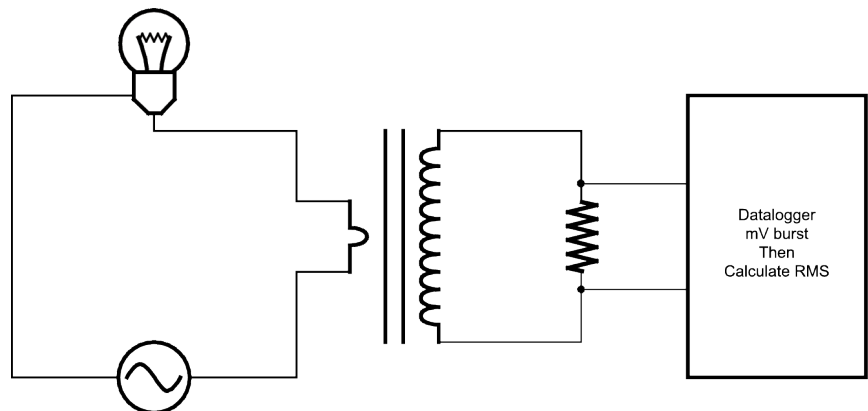


FIGURE C-2. Schematic of generator with current transformer

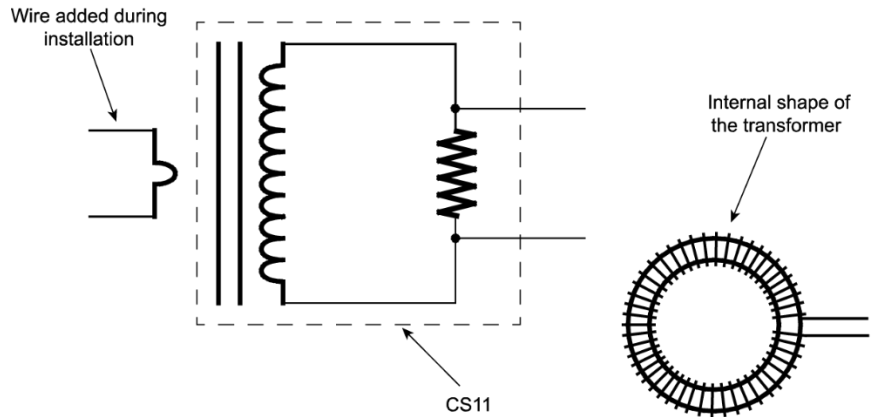


FIGURE C-3. Schematic of current transformer with the AC wire

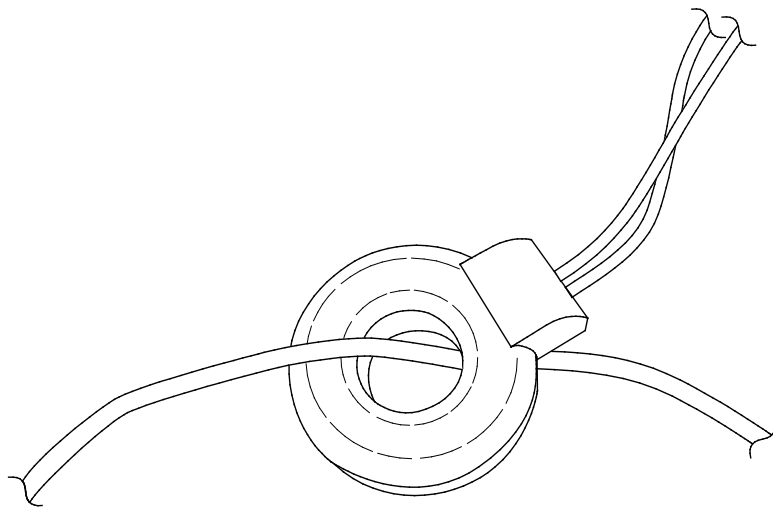


FIGURE C-4. CS11 with the AC wire

C.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 C-5).

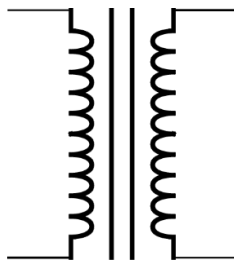


FIGURE C-5. Magnetic flux schematic

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

$$i_1 \cdot n_1 = i_2 \cdot n_2 \quad \text{Equation A}$$

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 C-6).

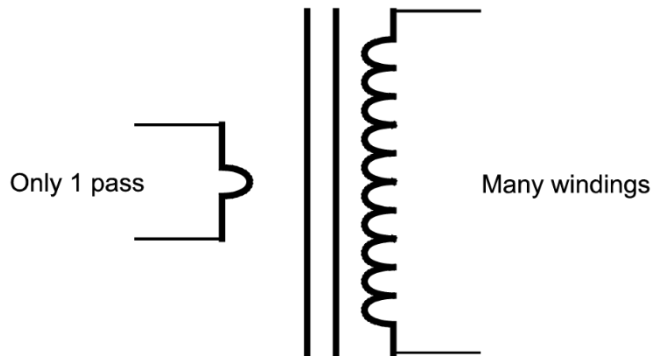


FIGURE C-6. Windings schematic

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

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

$$i_2 = i_1 \cdot n_1/n_2 \quad \text{Equation B}$$

For example: The CS11 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:

$$i_2 = 20 \cdot (1/2000) = 0.01 \text{ amp on secondary winding}$$

C.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 data logger can measure it.

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

$$E = I \cdot R \quad (E = \text{Volts}, I = \text{Amps}, R = \text{Ohms}) \quad \text{Equation C}$$

For example: Using the previous example:

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

The CS11 contains a 10-ohm burden (shunt) resistor ($R=10\text{ ohm}$). Therefore, E is:

$$E = 0.01\text{ amps} \cdot 10\text{ ohms} = 0.1\text{ volts (or 100 mV)}$$

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 data loggers.

C.4 Using a CR300-Series or CR200(X)-Series Datalogger

The CS11 consists of a CR Magnetic's CR8459 Current Transducer with a 10-ohm burden resistor incorporated into its cable. The resistor allows most of our data loggers to measure it.

The voltage range of the CR300-series and CR200X-series dataloggers require a voltage excitation to shift the measurement range (see FIGURE C-7 and FIGURE C-8).

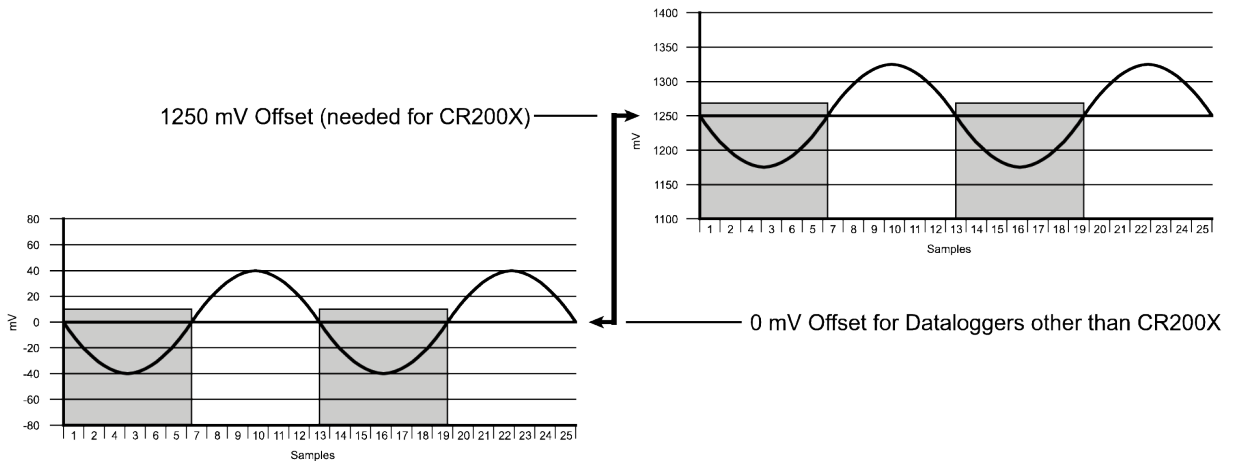


FIGURE C-7. Adding 1250 mV creates positive output

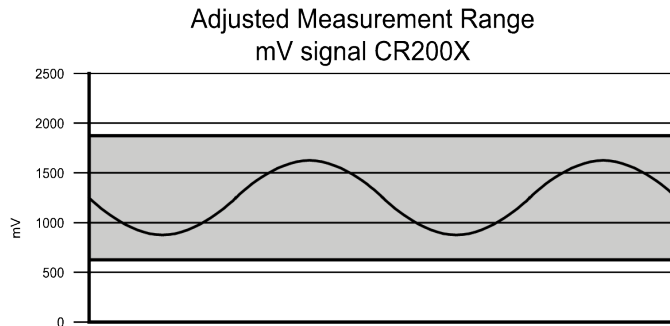


FIGURE C-8. CS11 measurement range

C.5 Multiple AC-Wire Passes Through the CS11

You can pass the AC wire multiple times through the CS11 to amplify the amperage signal of the AC wire (FIGURE C-9). However, the data logger program needs a different multiplier and the **VoltSE()** instruction needs a different measurement range (TABLE C-1).

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

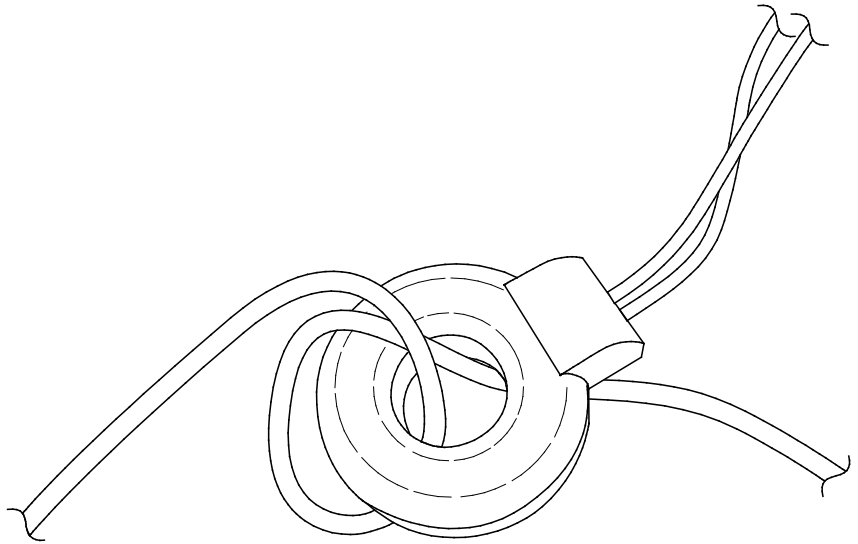


FIGURE C-9. CS11 with the AC wire making two passes through the CS11

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