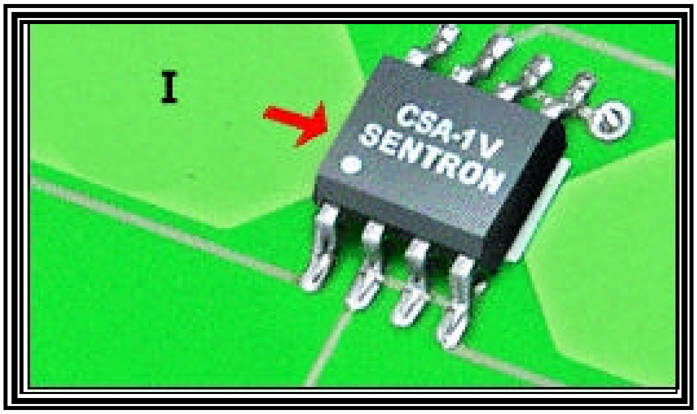
Operation and application of the Sentron CSA-1V-SO surface mount current sensor



Contents

Introduction

The CSA-1V is an integrated circuit combining Hall devices and Sentron's patented **IMC (*IMC = Integrated Magnetic Concentrator)*** Hall technology. The Hall-sensor is fabricated using a conventional CMOS technology with an additional ferromagnetic layer. The ferromagnetic layer is used as a magnetic flux concentrator providing a magnetic gain of about 10, to increase the output signal without increasing the inherent sensor electrical noise. The CSA-1V is a SOIC-8 packaged device suitable for surface mount PCB construction and miniaturization. The CSA-1V is a very simple device to use and provides an analog output voltage proportional to the magnetic field generated by the current flowing through a conductor near the IC. The CSA-1V is bi-directional device therefore it can sense both DC currents as well as AC currents up to 100 kHz.

It is particularly appropriate for on-board DC and/or AC current measurements with ohmic isolation, very low insertion loss, fast response, small package size and low assembly cost requirements. There is no upper limit to the level of current that can be measured because the output level is dependant on the conductor size and distance from the sensor.

Basic operation.

The CSA-1V senses current by converting the magnetic field generated by current flowing through a conductor to a voltage which is proportional to that field.

The magnetic field at distance r from an ideally thin, straight and infinitely long current conductor carrying a current I is given by

$$H(r) = \frac{I}{2pr}$$

In a vacuum (or air) the magnetic induction (or flux density) B can be calculated from H by multiplication with the permeability

$$B = m_0 H \qquad m_0 = 4p \cdot 10^{-7} \frac{Vs}{Am}$$

See section on Current to Voltage transfer functions for direct relationship between current and the CSA-1V

Example: Flux density at a distance r = 2 mm from a current conductor carrying 20 Amperes:

$$B = 4p \cdot 10^{-7} \frac{Vs}{Am} \cdot \frac{20A}{2p \cdot 0.002m} = 2.0\ mT$$

The CSA-1V can be used to measure current in an adjacent wire as shown in Figure 1 or in PCB trace conductors mounted below the IC as shown in Figure 2.

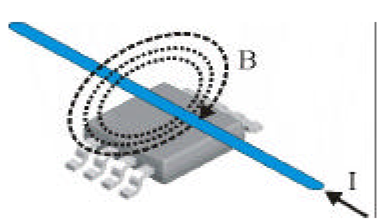


Figure 1 - Sensing current in a conductor

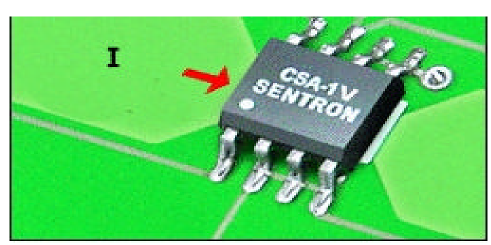


Figure 2 – Sensing current in a PCB

Basic electrical connections

The connection diagram is shown in figure 3. The CSA-1V has two output configurations; Single ended output (V_{out}) which provides a 0 to 5V analog output with respect to ground (Fig 3a) and a differential output ($V_{out\ diff}$) which provides a 0 +/- 2.5 volts with respect to an internal reference voltage (CO_OUT) Fig 3b.

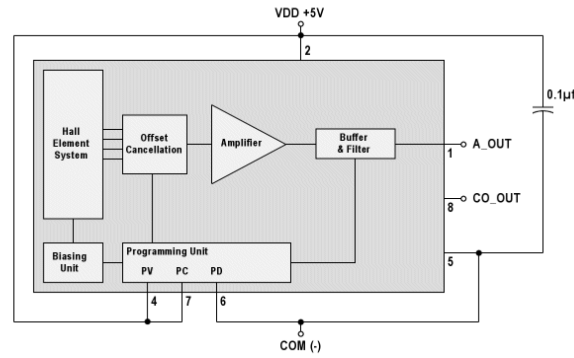


Figure 3 - Basic electrical connection diagram

The single ended output is provided between pins 1 and 5. With zero current, the output is nominally at ½ VDD (approximately 2.5 Volts) and will go toward GND (0 volts) when the current is negative. The output will go toward VDD (+5 Volts) when the current is positive. The actual levels will depend on the mechanical relationship between the sensor and the current carrying conductor.

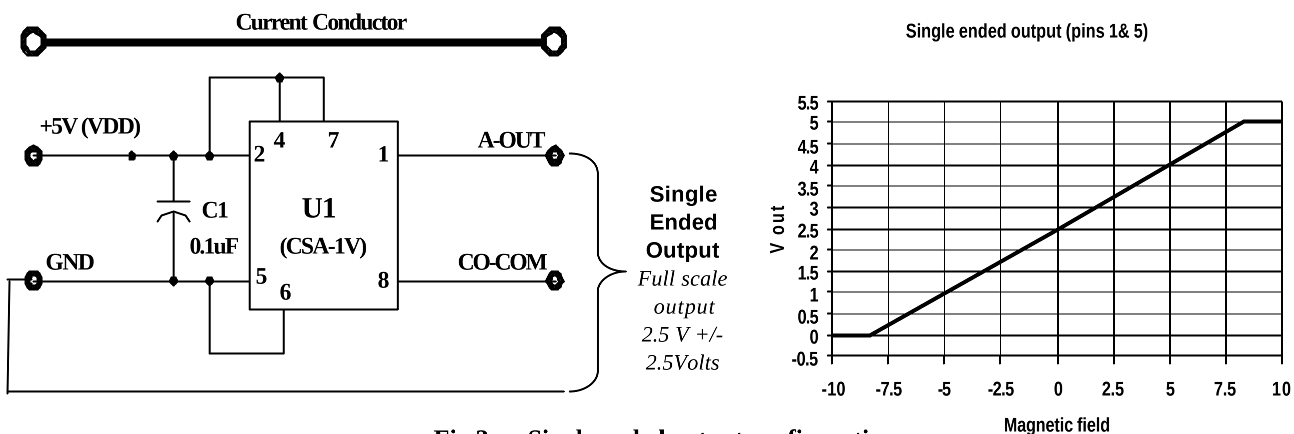


Fig 3a – Single ended output configuration

The differential output voltage ($V_{out\ diff}$) is provided between pins 1 and 8. With zero current, the differential output voltage will be zero and go toward – 2.5 volts with negative current. The output will go toward + 2.5 volts when the current is positive.

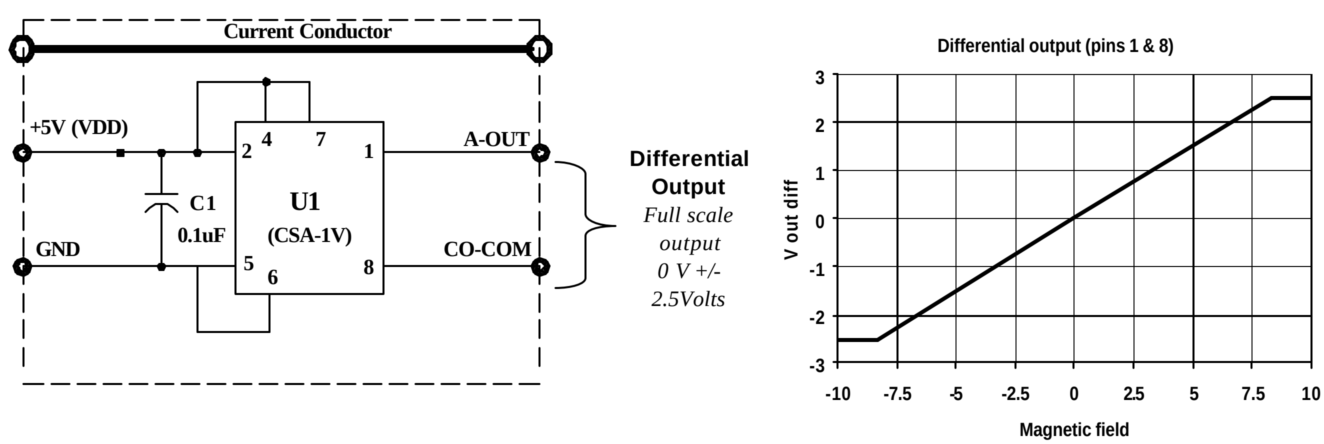


Fig 3b– Differential Output configuration

In both, cases the maximum output should be scaled to +/- 2.0 volts in order to provide a margin of 0.5 volts from the 0 and 5 volt rails and to prevent electrical saturation.

The IC is a 5 V device but will operate within specifications over a +/- 10% variation from the nominal 5 volt supply. The analog output characteristics are ratio-metric to supply voltage which should be considered in the circuit design. There are many cases where ratio-metric outputs are desired, however if the output needs to be absolute, the 5 volt supply voltage should be a regulated and stable source.

IMPORTANT There are three pins (pins 4, 6 & 7) used for factory programming and they should be terminated as shown in the schematic diagram. Pins 4 & 7 should be terminated to VDD (pin 2) and pin 6, should be terminated to GND (pin 5). It is recommended that a 0.01uF to 0.1uF ceramic capacitor be placed across the supply and ground as close as possible to the IC. **CAUTION –** Voltage spikes exceeding 7 Volts on VDD will potential damage the CSA-1V.

Current -Voltage transfer functions

As shown above, the current to voltage transfer function is dependant on the distance between the center of the conductor and the location of the sensing element in the CSA-1V. It is also affected by the shape of the conductor.

The sensing area of the IC is located approximately 0.3 mm below the top surface of the IC package, see figure 4. The output will produce a positive output when the magnetic field vector, B, is in the direction shown.

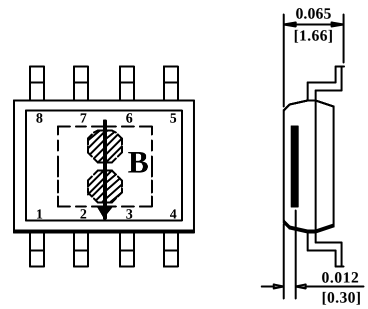
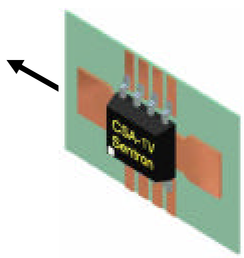
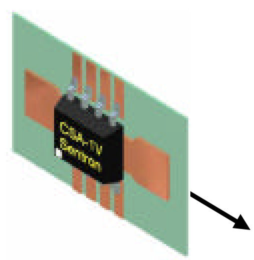


Figure 4- Direction of sensitivity and location of sensing element

Current flow creates negative going output voltage





Current flow Creates positive going output voltage

Figure 5 illustrates the magnetic flux lines from two different examples of conductor shapes. The upper conductor is a circular wire and the lower is a wide trace on a PCB. Notice that the direction of the magnetic flux is reversed for the two conductors assuming the current is flowing out of the page.

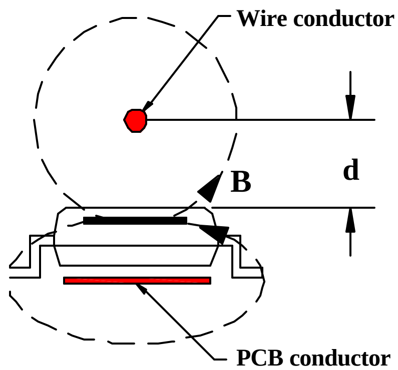


Figure 5 – Shape and direction of magnetic field from two different conductor shapes. Current flowing out of page

Circular conductor on top of IC.

The CSA-1V differential output voltage for a circular conductor (wire) located on top of the IC can be approximated with the following equation:

$$V_{out\ diff} \approx \frac{0.060 * I}{(d + 0.3mm)}$$

d = distance (mm) from chip surface to center of wire as shown in figure 5 in mm

I = Current in conductor

Sample calculation for a wire on top of IC:

If the current in the conductor is 25 amps and the distance from the wire center to the surface of the IC is 1.0 mm, then the differential output voltage will be:

$$V_{out\ diff} \approx \frac{0.060*25}{(1+0.3)} \cong 1.15\ volts$$

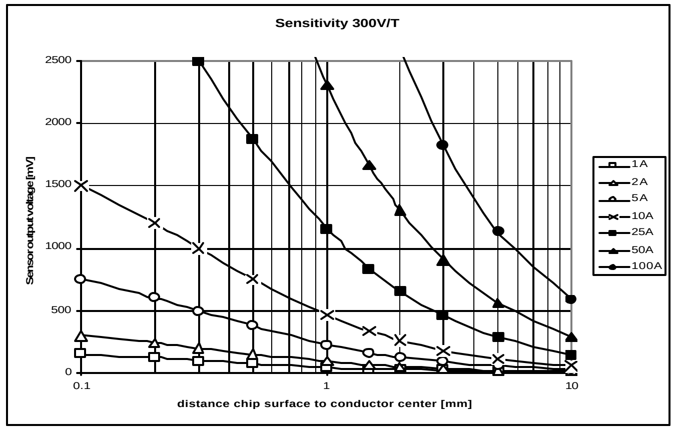


Fig. 6- CSA-1V sensor output voltage is dependent on the applied current in the current conductor (wire on the top of the sensor) and the distance between chip surface and center of the current conductor.

Flat Conductor on PCB under the IC.

The CSA-1V output for the flat conductor directly below the IC can be approximated with the following equation:

$$V_{out\ diff} \approx 40\frac{mV}{amp} * I$$

I = Current in conductor

Conductor width ˜ 0.125" wide

Sample calculations for flat conductor located <u>directly under</u> the CSA-1V:

If the current, ***I,*** is +15 amps (*positive current in this illustration will be current flowing out of the page*), the output will be:

$$V_{out\ diff} \approx 40\frac{mV}{amp} * (+15\ amps) \cong 0.60\ volts$$

If the current, ***I***, is -15 amps the differential output voltage will be:

$$V_{out\ diff} \approx 40\frac{mV}{amp} * (-15\ amps) \cong -0.60\ volts$$

Accuracy considerations

The absolute accuracy of the current measurement is dependant on several factors which are:

- Sensitivity variation
- DC Offset voltage
- Stray fields
- Physical relationship between the conductor and sensor

The variation in magnetic sensitivity of the CSA-1V is +/- 3%. Therefore for a given current, there could be a "+/-"variation in voltage output from device to device. The DC offset voltage is specified to +/-15mV max therefore any output voltage for a given current could vary by +/- 15 mV. The sensor is an open filed magnetic sensor therefore it not only measures the fields from the conductor, it can sense fields from other sources which can be a source for error. Earth's field for example can be +/- 0.6 Gauss, thereby causing an error voltage of +/- 18 mV.

Generally speaking, the higher the current and closeness of the conductor to the IC, the more accurate the reading will be. However the limits of electrical and magnetic saturation need to be respected. At small currents where the output voltage is low, the 15 mV offset could contribute to significant error in the measurement. For example: if the maximum output voltage is 200 mV, the 15 mV DC offset could introduce a 7.5% error in the measurement. With 3% sensitivity variation and 7.5% offset error, the maximum error for a low current measurement could be as high as 10%. If the circuit is configured to provide an output of 2.0 volts full scale, then the maximum error would be +/- 3.0 plus 0.75% for a total of 3.75%. For AC currents, the errors caused by DC offsets and earths' filed can be eliminated by AC coupling the CSA-1V output as shown in Figure 7 below.

Increased accuracy can be acquired by using two ICs as shown in figures 9, 12 & 13 to cancel out the potential affect of stray fields and then adjusting out the net DC offset from the two CSA-1Vs. The total error from this configuration is equal to the error of the CSA-1V's sensitivities which is 2%, even at low current levels.

The position of the wire or conductor over the sensor will have an impact on the accuracy. Any change in distance from the IC face will change the output and any side to side movement will also change the output, thereby contributing to the potential error. A single wire will be more sensitive to side to side movement than the flat bus wire. The installation should assure there is no movement in the physical location of the conductor and that the conductor position is the same for each part in a production run.

Saturation Limits

The CSA-1V has excellent linearity from zero to magnetic fields of 5 mT (50 Gauss) and will reach electrical saturation at 8.3 mT (83 Gauss). The device will not be damaged or upset by magnetic fields up to 1T (10,000 Gauss). Therefore high current surges will not upset or damage the device and recovery from these conditions occurs in microseconds.

Measuring AC Currents (Improved linearity)

Two of the main contributors to non-linearity and reduced accuracy can be eliminated by AC coupling the output of the CSA-1V. Both the DC offset and any influence from earth's magnetic field will be eliminated by AC coupling. The non-linearity of AC signal will be less than 0.2% between 0 and +/-2 Vpp. With sensitivity calibration, the device can easily measure the AC currents with accuracies better than 0.5 % of full scale. See figure 7.

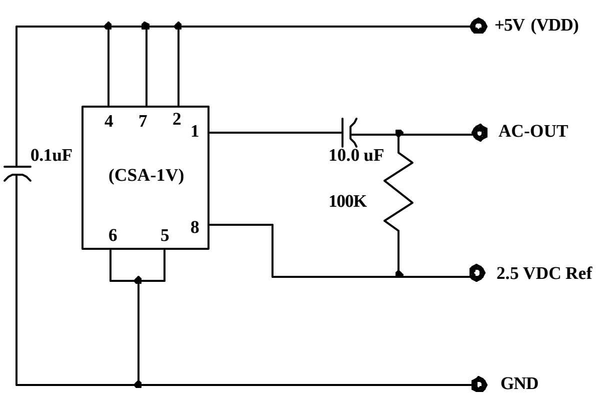


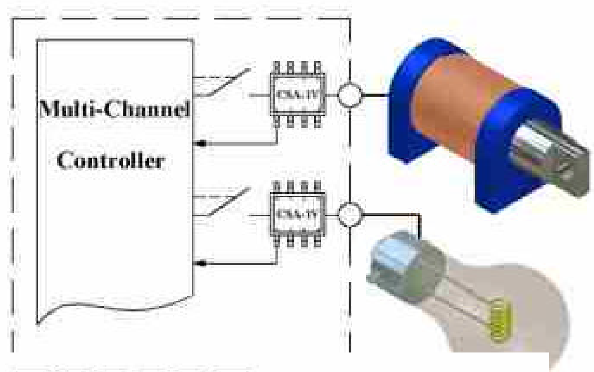
Figure 7. AC coupling of CSA-1V output for AC measurement

Typical Applications - The applications for the CSA-1V are numerous and it can be used over a very large range of currents. The following are some illustrations of some typical applications.

Fault Current Detection

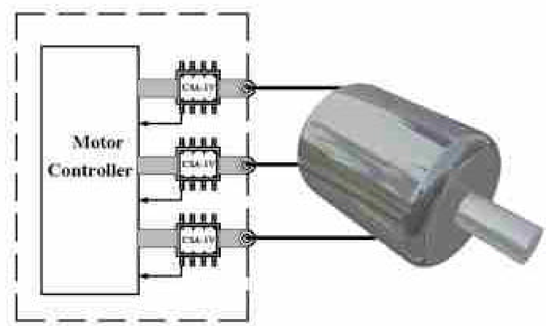
Single or multi-channel circuit monitoring for:

- **Lamps**
- **Solenoids**
- **Heaters**
- **Relays**
- **Motors**



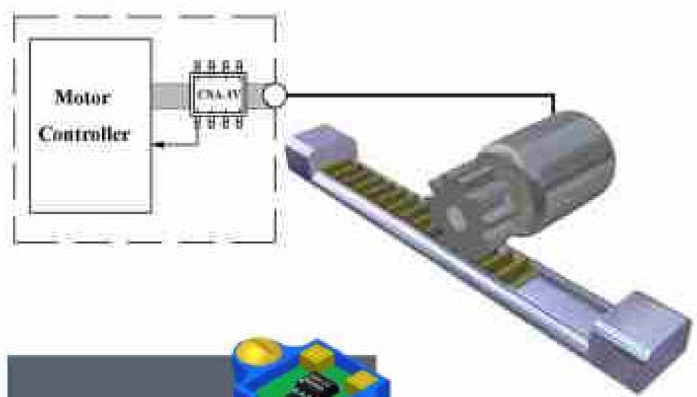
Motor Current Control

- **Brushless or AC motors**



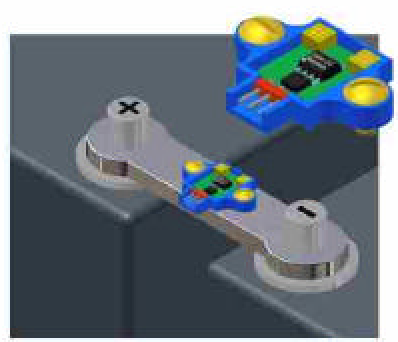
Overload or Stall Currents

- **End of travel detection and motor protection**



Bus Bar Currents

- **Monitoring battery charge and discharge currents**



Accommodating various current ranges.

Very low currents with high isolation voltage requirements

Low currents can be measured with the CSA-1V by increasing the magnetic field via a coil around the sensor. The sensitivity (output voltage vs. current in coil) of the measurement will depend on the size of coil and number of turns. Typical sensitivity is approximately 30mV per ampere-turn. Additional sensitivity and increased immunity to external fields can be gained by adding a shield around the coil. The bobbin provides very high dielectric isolation making this a suitable solution for high voltage power supplies with relative low currents. The output should be scaled to obtain the maximum voltage for the highest current to be measured in order to obtain the best accuracy and resolution.

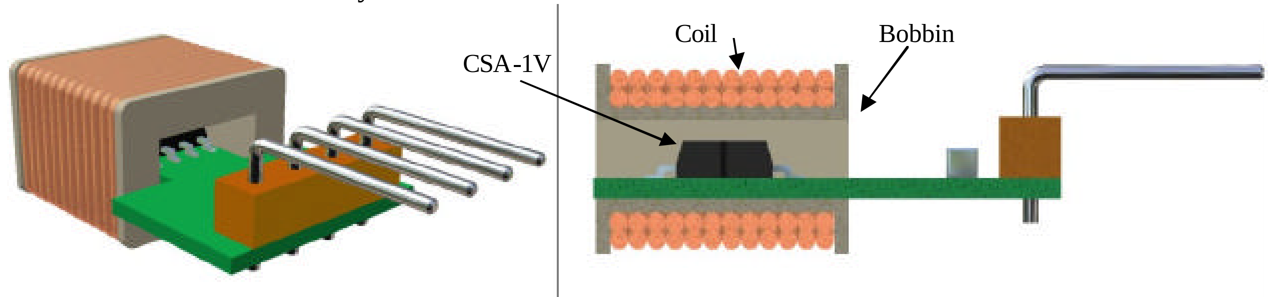


Figure 8 a. CSA-1V sensor with multi-turn coil to increase sensitivity for low current applications

Example of sensitivities: **12 turns of #22 ga magnet wire = 0.32V/amp**
32 turns of #30 ga magnet wire = 1V/amp
600 turns of #30 ga magnet wire = 18V/amp

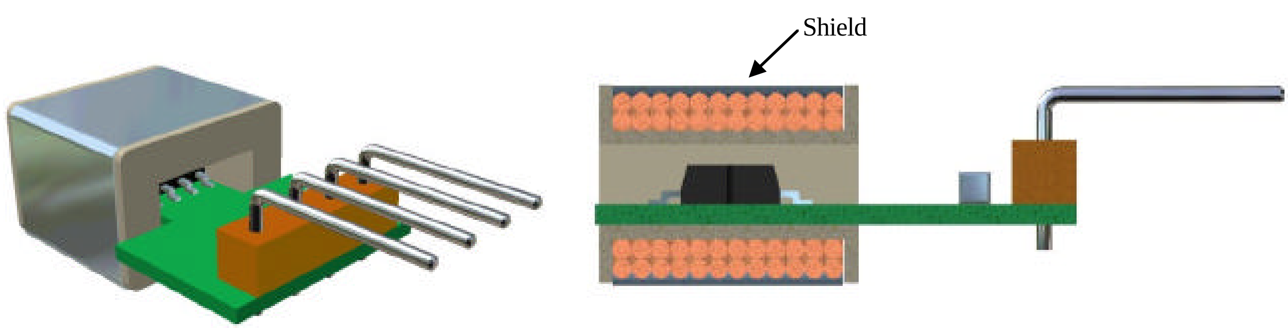


Figure 8 b. CSA-1V sensor with multi-turn coil and shield to increase sensitivity and external field immunity for low current applications

Low current – 1-2 Amps

To increase the signal level for low current sensing circuits, a coil like circuit land pattern can be laid out on the PCB to produce a number of loops as shown in figure 9. With 4 loops, the magnetic field is increased by a factor of approx 3 If two devices are used as shown below, the outputs can be added together with a summing circuit illustrated in Fig 9a, thereby doubling the signal level for a given current. See figure 9a. The CSA-1V's shown in fig 9 are laid out such the outputs both go positive with positive currents and common stray fields create opposite going outputs. Other configurations, such as shown in figure 12, create outputs which are opposite, one CSA goes positive and one goes negative with a positive current flow. In these cases, the interface circuit should be a differential amplifier as shown in figures 27 and 28. The offset voltage and stray field effect can have a major impact on the linearity and or linearity for low current measurements. Therefore it is important to eliminate or minimize both the DC offset voltage and any stray field effect that may be present. The advantage of the two device configuration is common mode stray fields will be cancelled out and any DC offset can be adjusted out with the post circuit shown in figure 9a.

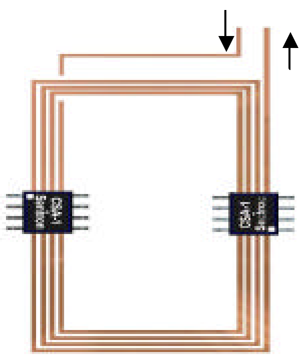


Figure 9–Increasing signal level with multiple loops

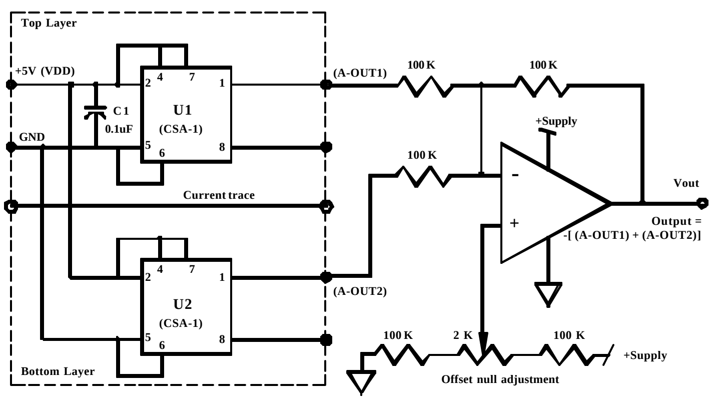


Figure 9a- Summing circuit for dual CSA-1V's in an output voltage doubling and noise cancellation configuration

The differential output voltage for a single 4 loop channel configuration can be approximated with the following equation:

$$V_{out\ diff} \approx 30\frac{mV}{amps} * n_{loops} * I\ amps$$ Where: n = number of loops & ***I*** = current in conductors

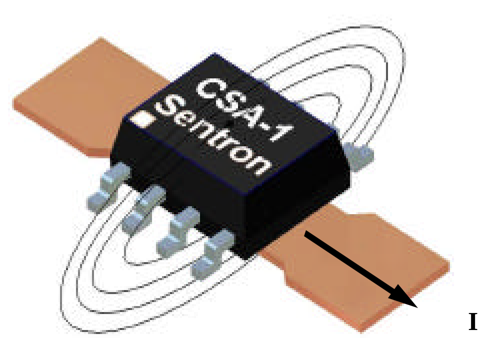
Sample calculation:

If n = 4 and I = +/- 2 amps $$V_{out\ diff} \approx 30\frac{mV}{amps} * 4 * +/- 2\ amps \cong +/- 0.24\ volts$$

<u>Medium Current – Up to 10 Amps</u>

With a single conductor located on the PCB, currents in the range of up to 10 amps can be measured. The sizing of the PCB trace needs to take in account the current handling capability and the total power dissipated. The PCB trace needs to be thick enough and wide enough to handle 10 amps continuously. (See appendix)

The differential output voltage for this configuration can be approximated by the following equation:



$$V_{out\,diff} \approx 40 \frac{mV}{amps} * I\ amps$$

For a current level of 10 amps, the output will be approximately 400 mV

Increased output level for medium current

The sensitivity (mV/Amp) can be increased by a factor of approximately 3 to 100-120mV/Amp by configuring the PCB layout per figure 11a. This configuration increases the magnetic field for a given current by placing the IC within a loop. This loop is created by using traces on both sides of a PCB and a jumper wire mounted over the IC.

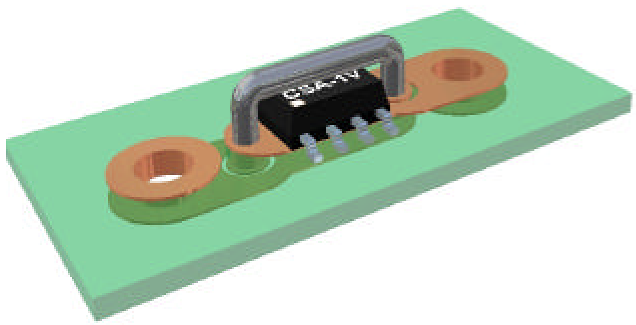


Figure 11a – PCB layout with jumper to increase sensitivity

The current flow through the circuit is shown in figure 11b. The current flows from left wire through a trace on the bottom side of the PCB and directly under the CSA-1V and then up and over the IC through the jumper wire and back under the CSA-1V through the top layer trace and out through the right wire. Each conductor creates a magnetic flux that is sensed by the IC as shown in figure 11c. The three add together and increase the output signal by a factor of approximately three. The actual gain depends on the thickness of the PCB. A 0.03125 thick PCB will create a 110 mV/ Amp sensitivity level. A 0.0625 thick PCB will have a slightly lower level because the bottom conductor will be further away and its contribution to the total flux density at the chip will be less. For 10 amps this configuration will produce an output of approx +/- 1.1 Volts.

$$V_{out\,diff} \approx 110 \frac{mV}{amps} * I\ amps$$

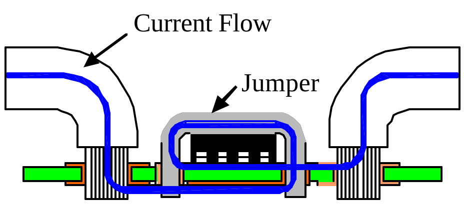


Figure 11b – Current flow under and around the CSA-1V increases magnetic flux density in the chip.

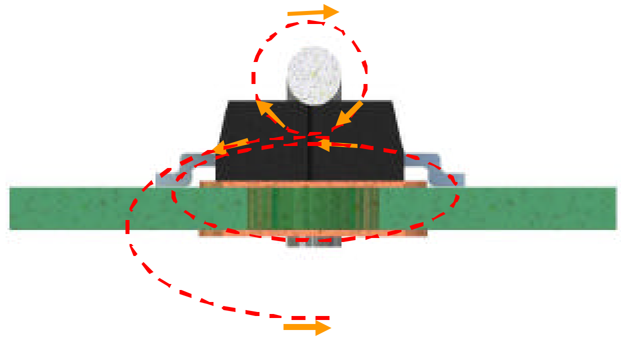


Figure 11c- Magnetic flux generated by the jumper, upper trace and lower trace add together at the sensitive area of the chip

High output, improved accuracy mid-range current measurement.

A technique to increase the output and minimize the stray field effect is shown in figure 12. This technique incorporates two CSA-1Vs using the scheme shown in figure 8a. By placing two of these layouts parallel to each other, but opposite orientation will create equal but opposite outputs for stray fields that can be cancelled out in a post summing circuit. The differential outputs from the two CSA-1V's will produce an output sensitivity level of approximately 0.22 V/Amp. A current of +/- 10 amps will produce a 2.5 V +/- 2.2 V output. Using the circuit shown in figure 27, a very accurate high level current measurement can be made with this configuration.

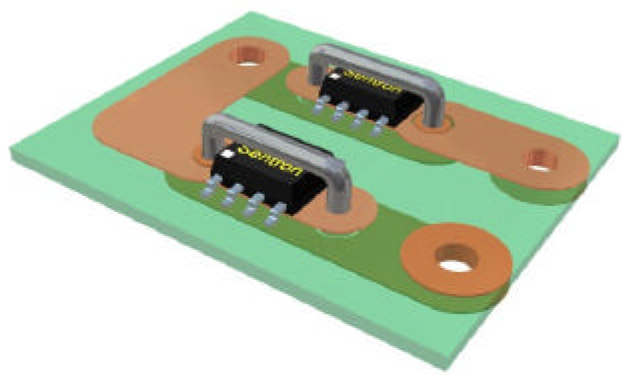


Figure 12 - Dual CSA-1V's with the loop technique to improve the output level and minimize stray field effect.

Increased output level for lower currents in the range of 1-5 amps

This concept can be applied to smaller currents by incorporating a couple of loops into the circuit layout as shown in figure 13. This Dual CSA-1V configuration will provide a full scale output for approximately +/- 5 amps. As with the above layout, using the circuit shown in figure 27, a very accurate, moderate level current measurement can be made with this configuration. Note: Because the wire loops are not located directly over the centerline of the IC, the increased sensitivity is only a 30% improvement over the fig 12 configuration.

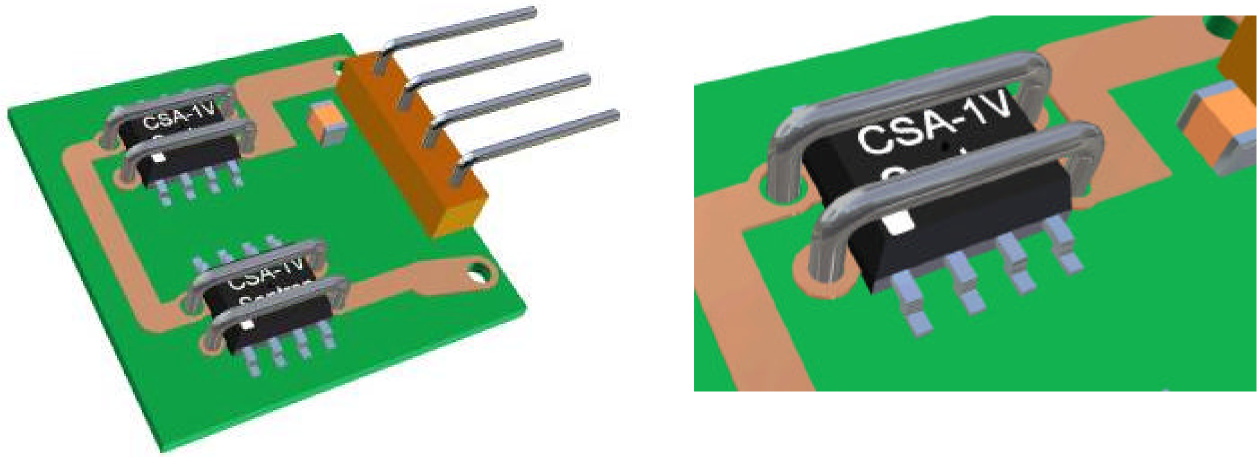
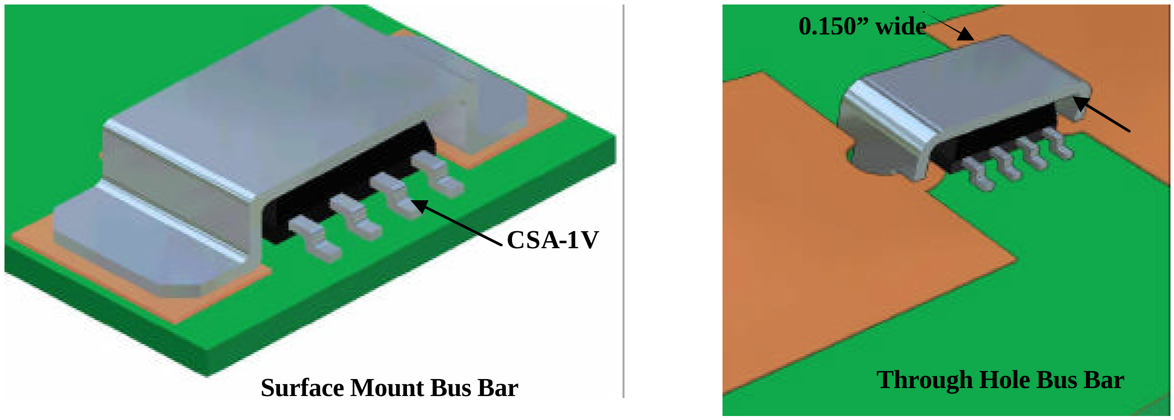


Figure 13 - Dual CSA-1V's with the dual loop technique to improve the output level and minimize stray field effect.

Bus Bar Sensing applications for high current sensing.



Sensitivity ˜40mV/amp

Figure 14a

Up to +/- 30 Amps

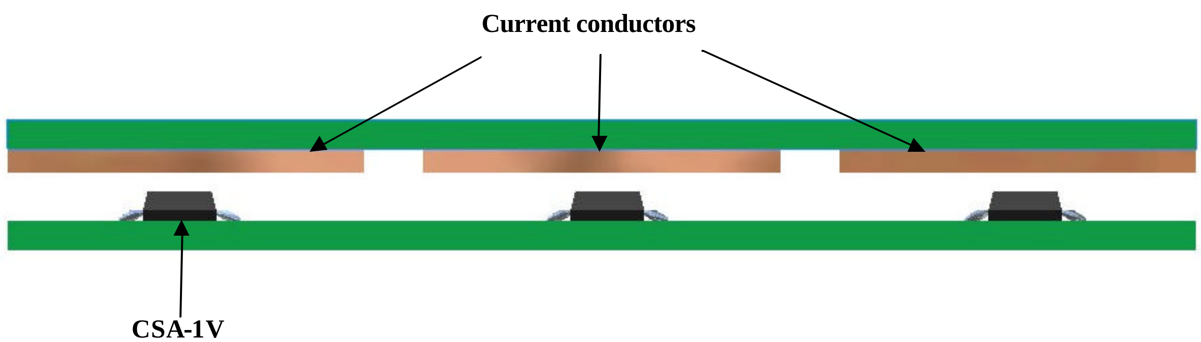


Figure 14b

Up to +/-75 Amps

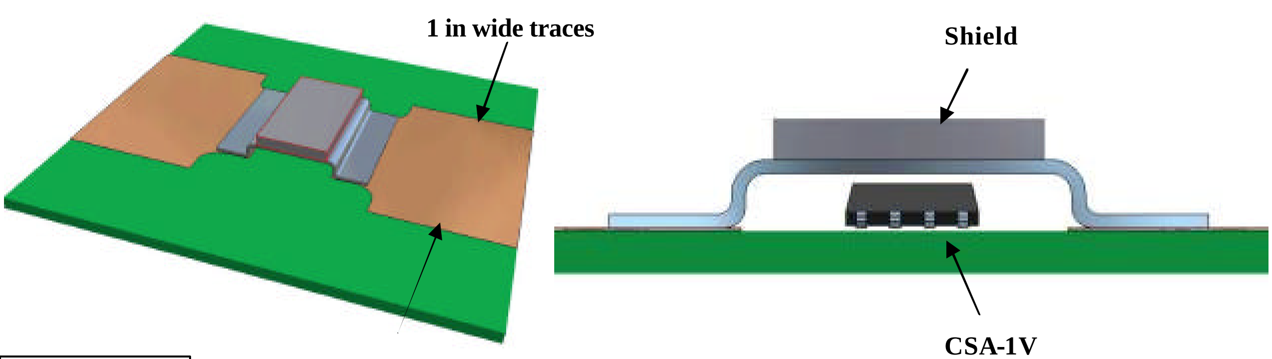


Figure 14c

Up to +/- 100Amps

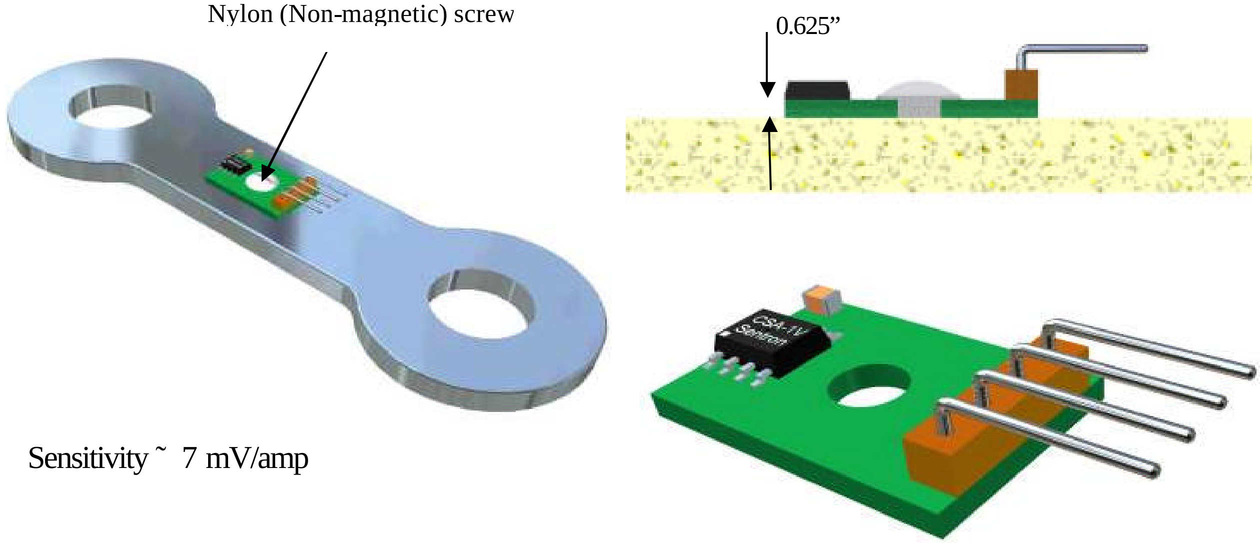


Figure 14d **Battery Bus Bar – Up to +/- 600 Amps**

Another method of measuring high currents on PCB's is to use a large thick gauge copper trace capable of carrying the current on the opposite side of the PCB as shown in figure 15. The CSA-1V should be located near the center of the trace, however because the trace is wide, the output is less sensitive to location on the PCB. See Appendix for link to a web site to calculate the Copper trace width for various currents. This configuration also has less sensitivity due to the distance and width of the conductor.

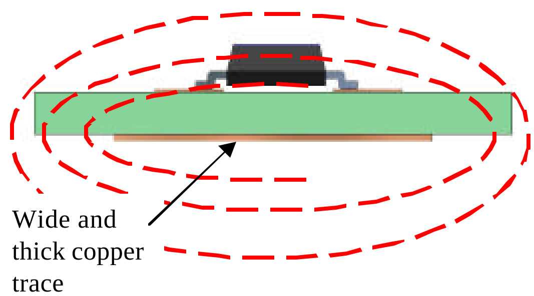
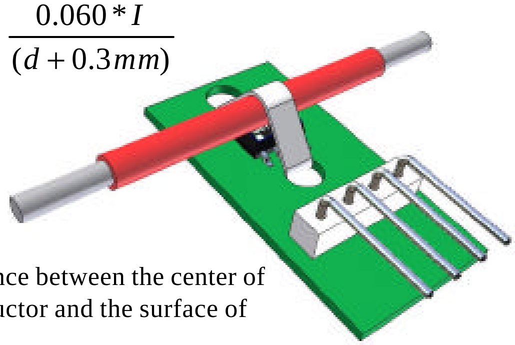


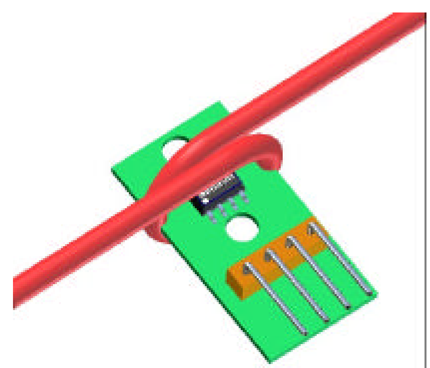
Figure 15- High current application using a wide heavy conductor on the opposite of

Measuring current in external wires

$$V_{out\ diff} \approx \frac{0.060 * I}{(d + 0.3mm)}$$



d = distance between the center of the conductor and the surface of



Looping wire increases sensitivity

Figure 16- Measuring currents in external wires.

Stray magnetic field interference.

The CSA-1V is an open loop magnetic sensor and will respond to any magnetic field that is in the direction of sensitivity (across the chip). Stray fields from other sources, such as transformers, adjacent current carrying conductors and magnetic circuitry can cause noise problems if they are too close to the sensor. There are several things that can be done to minimize the interference. By using two devices as shown in figure 9,11,12,13,17 & 18, common mode magnetic fields are cancelled out with the added advantage of a two fold increase in signal.

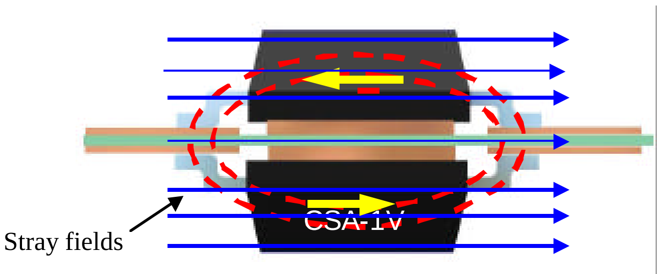


Figure 17- Stray fields generate equal and opposite voltages in the two CSA-1V's and are cancelled out by summing the differential outputs from the two devices.

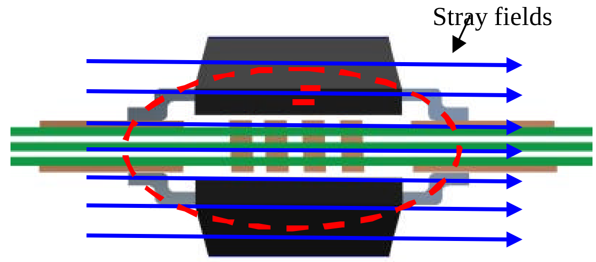


Figure 18 - This configuration provides excellent stray field cancellation and significant improvement in the signal level by making 4 loops per layer for a total of 16 loops.

Placing adjacent wires or PCB traces at right angles to the IC's direction of sensitivity can also minimize the interference, see figure 16. Because the magnetic field drops off dramatically as a function of distance, locating the sensor as far away from the source is also a way of reducing the interference noise. Implementing stray field cancellation techniques and signal amplification via multiple loops should be considered when using the CSA-1V sensor to measure low currents in the range 1-5 amps. Signal to noise ratio will be greatly improved with the incorporation of these techniques.

Shielding

A level of shielding, as shown in figure 19, can be obtained by placing a small (approximately $1cm^2$ x 0.5mm) ferromagnetic metal plate on the opposite side of the conductor from the CSA-1V. Mu-metal is an excellent choice because of its high permeability at low field strengths. The plate will have the affect of concentrating the flux from the field generated by the current in the trace and provide shielding by deflecting stray fields from the sensor. An additional advantage with this shielding technique is an increased level of signal by a factor of 30% to 50% for a given current.

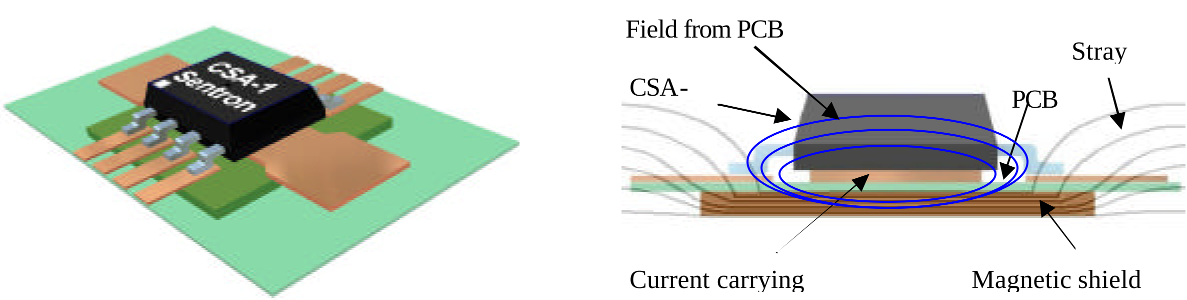


Figure 19 – Shielding the CSA-1V from stray fields. In the configuration using a bus bar, Shielding and increased signal level can be obtained by placing the shield on top of the bus bar as shown in Fig 19a.

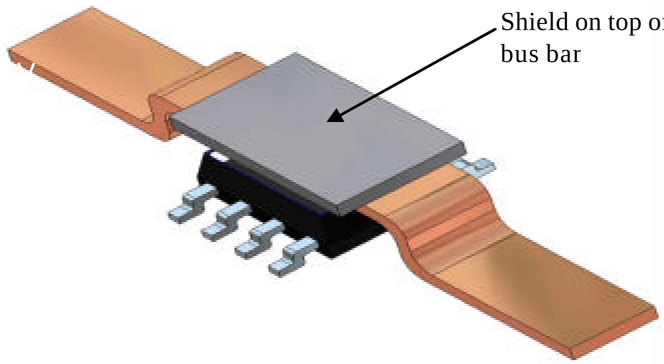


Figure 19a – Adding shielding to the top bus bar configuration increases signal level significantly and minimizes the stray field interference.

Multiple current circuits

Often it will be desirable to monitor several currents on one PCB assembly or there are other current carry traces near by. Because these devices measure the magnetic fields generated by the traces or wires located in close proximity to the sensors, they will also sense magnetic fields from adjacent conductors if the fields generated by these conductors are large enough. It is always good practice to maintain as much spacing as possible between sensors and adjacent wires. Alternatively, running traces at right angles will minimize any pickup from adjacent traces. The amount of potential interference can be estimated from the graphs in the following figures.

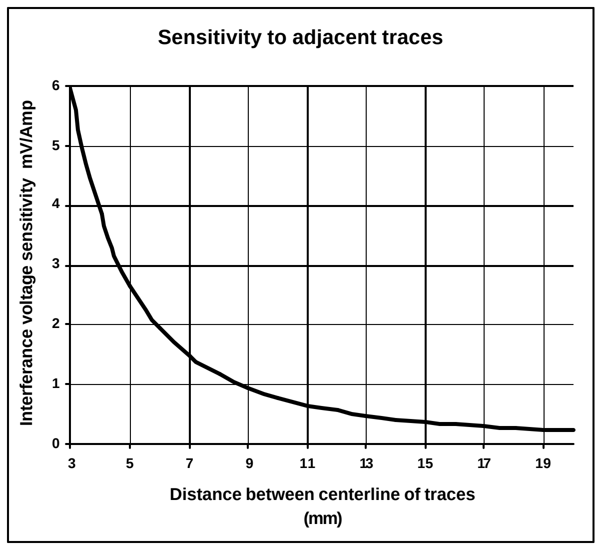


Figure 20 shows the affect of other current conductors which are parallel and placed on the same side of the PCB. The affect is minimal, <5% at distance of 6 mm (˜1/4”).

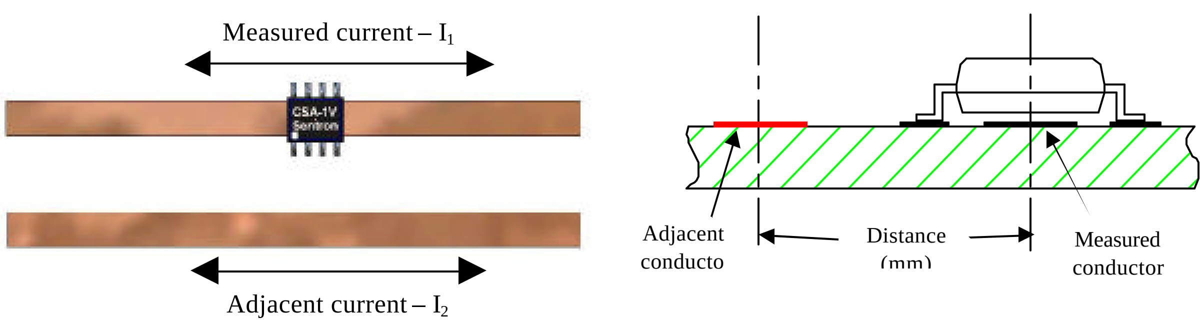
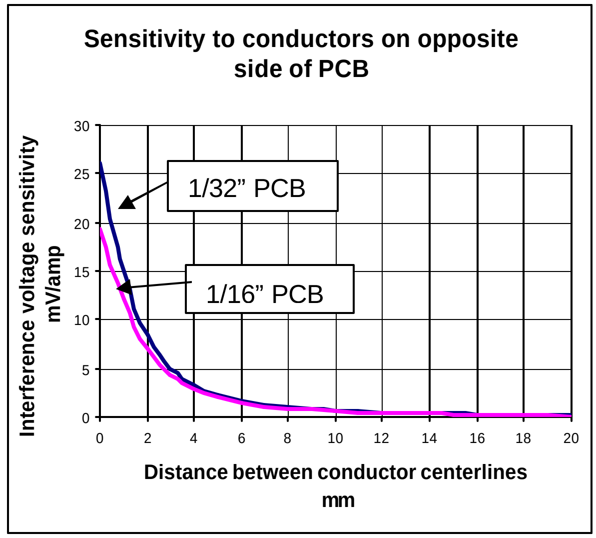
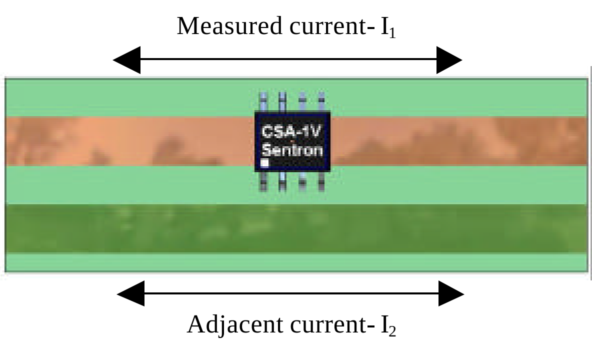


Figure 20 – Affect of placing current carry conductors close to each other.

Figure 21 shows the affect of current conductors which are parallel but on the opposite side of the PCB. The worst condition is when the conductor is placed directly under the IC (d = 0.0).





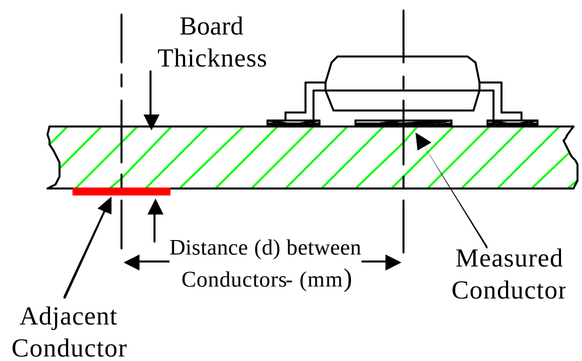


Figure 21– Affect of conductors on opposite side of PCB. Maximum interference occurs at d = 0.0 mm

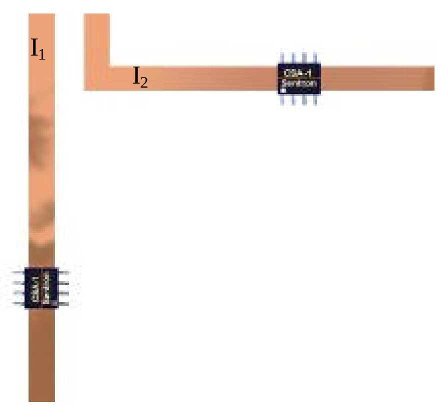


Figure 22 – Placing traces at right angles will significantly reduce any cross talk between sensors.

Bandwidth and response time

The CSA-1V has a wide bandwidth of 100 KHz and a response time of 6 microseconds. The response time of the sensor consists of two components. One is the Hall elements scan rate which takes up to 3 microseconds and the output driver rise time which is 3 microseconds. See figure 23.

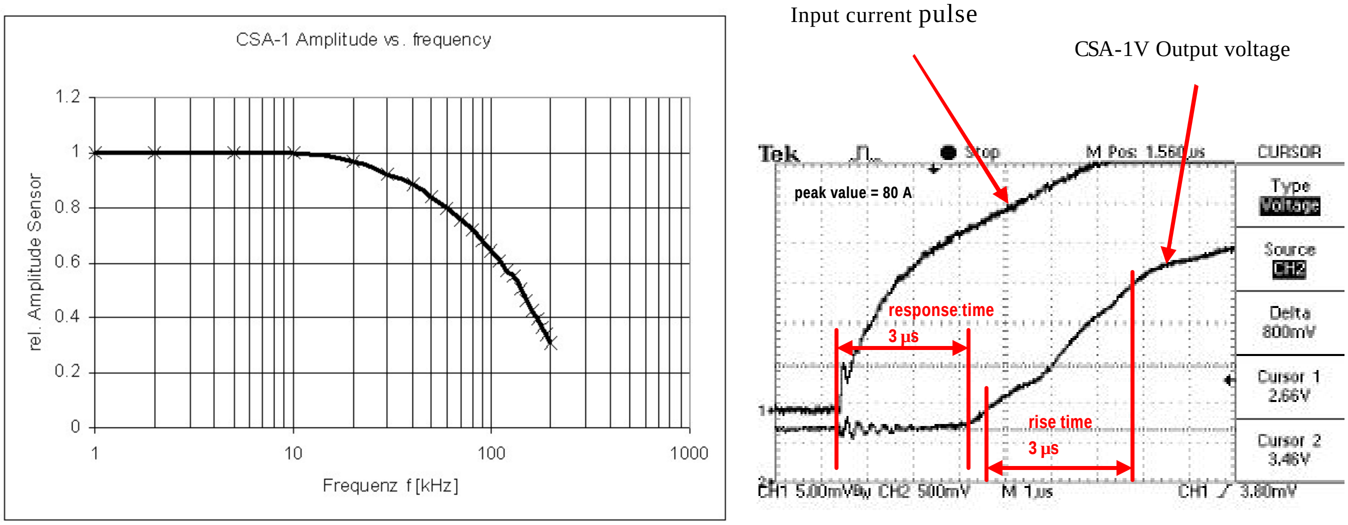


Figure 23 – CSA-1V Frequency plot and response to a current pulse.

Temperature Characteristic

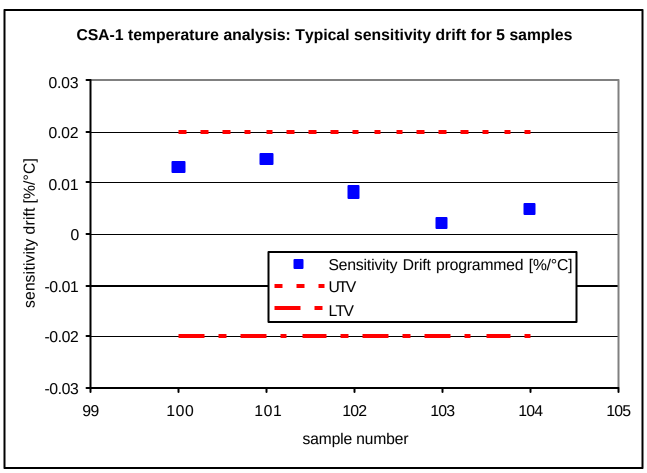


Figure 24 a. Typical temperature characteristics for Output Sensitivity

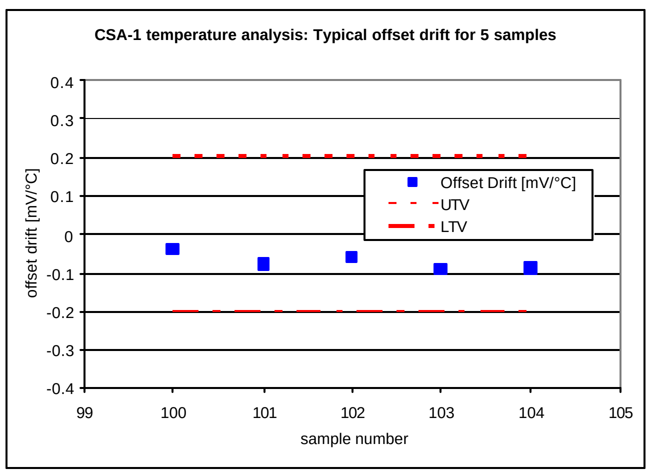


Figure 24 b. Typical temperature characteristics for Offset Voltage

Interface Circuits - The following are some examples of interface circuits that can be used with the CSA-1V's to provide level shifting, differential to single ended and amplification. The output voltage is ratiometric to the supply voltage and with VDD = 5.0VDC, it can swing between 0 and 5 volts (minus 50 mV). It is recommended that the output level be no more than 2.5 +/- 2.0 volts to prevent electrical saturation and non-linearity

Full Scale output =
0 +/- 2.5 Volts

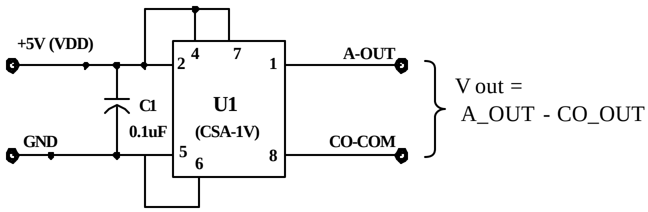


Fig 25 – Direct Differential Output

Full Scale output =
2.5 +/- 2.5 Volts

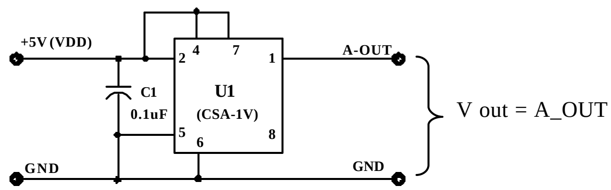


Fig 26 – Direct Single ended Output

Full Scale output =
2.5 +/- 2.5 Volts

.

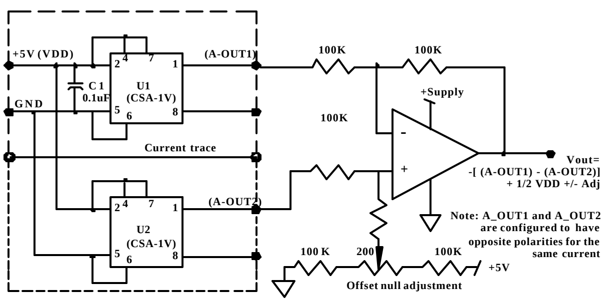


Fig 27 – Differential to single ended, 2-5 V +/- 2.5 swing for bi-directional currents with DC offset adjustment.

Full Scale output =
2.5 +/- 2.5 Volts

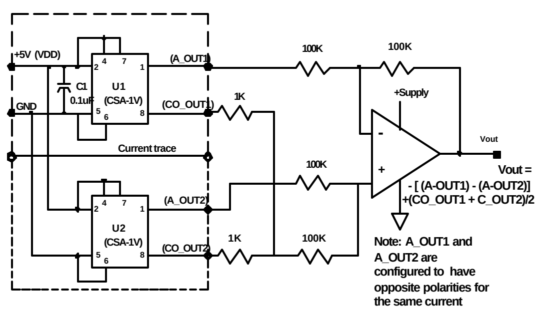
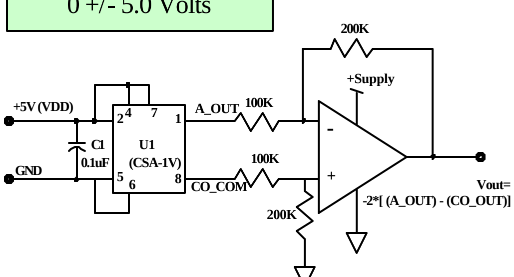


Fig 28 – Differential to single ended, 2-5 V +/- 2.5 swing for bi-directional currents

Full Scale output =
0 +/- 5.0 Volts



Note: DC flow should be configured to create a negative going A_OUT

LED and Digital
Output

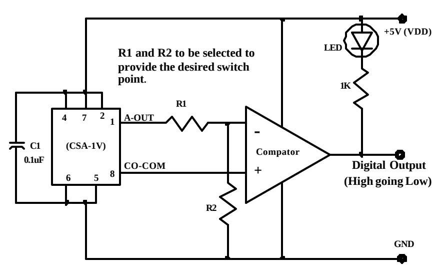


Fig 29 – Differential to single ended, 0-5 V swing for DC currents

Fig 30 – CSA-1V with Comparator to provide a digital output and drive an LED

Appendix

Conversion table for common magnetic units

	mT (Tesla)	G (Gauss)	kA/m	Oe (Oersted)
1 mT	=1.0000	=10.000	=0.7960*	=10.000*
1 G	=0.1000	=1.000	=0.0796*	=1.000*
1 kA/m	=1.2560*	=12.560*	=1.0000	=12.560
1 Oe	=0.1000*	=1.0000*	=0.0796	=1.000

*** in free air**

The following WEB link provides an excellent tool for approximating the trace width of copper traces on PCB's. It can also be used for calculating the approximate size of bus bars.

http://www.desmith.com/NMdS/Electronics/TraceWidth.html

The following is the view of the page you will see at the WEB site

ANSI PCB Trace Width Calculator

This page calculates approximations to the ANSI/IPC-D-275 design standards for PCB trace width.

The trace width formulas are:
$I = 0.0150 \times dT^{0.5453} \times A^{0.7349}$ for internal traces
$I = 0.0647 \times dT^{0.4281} \times A^{0.6732}$ for external traces
where:
I = maximum current in Amps
dT = temperature rise above ambient in °C
A = cross-sectional area in $mils^2$

The values calculated here compare very closely with those derived by the UltraCAD PCBTEMP utility.

I've added a recommended track clearance value based on the UL rule:

clearance in inches = 0.023" x (0.0002" x V)

The formulae as it stands is simplistic, but is reasonable for V > 50. Note that there are many international standard for this sort of thing, e.g. EN60065:1994, which for European mains of 230V, allows for about 120mil for Class I (protected by earthing) and 240mil for Class II (double isolated). Note that if there is no conformal coating and the environment is dirty/humid/condensing then all bets are off. Please read the standards documents yourself.

Ideally, keep "hot" and "cold" areas of your board well apart.

Change a value in an input field, then press TAB to move to the next field. The results tables will be updated automatically.

Input Data		
Field	**Value**	**Units**
Current		Amps
Temperature Rise	10	°C
Cu thickness	2	oz/ft² ☑ mils ☐
Ambient Temperature	25	°C
Conductor Length	1	inches ☑ mm ☐
Peak Voltage	5	Volts

Results Data

Internal Traces	Value	Units	External Traces	Value	Units
Required Trace Width		Mils	Required Trace Width		Mils
Cross-section Area		Mils²	Cross-section Area		Mils²
Resistance		Ohms	Resistance		Ohms
Voltage Drop		Volts	Voltage Drop		Volts
Loss		Watts	Loss		Watts

Required Track Clearance		
Clearance		Mils

Back