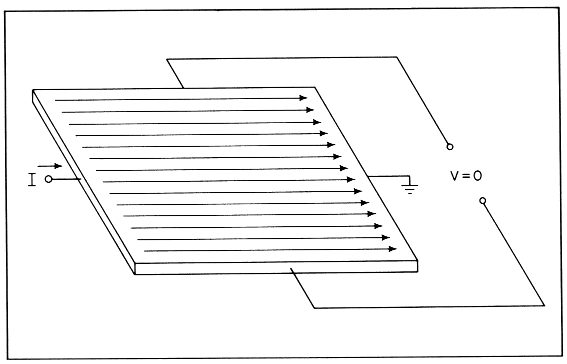
amploc
current sensors

Engineers’ Reference Handbook

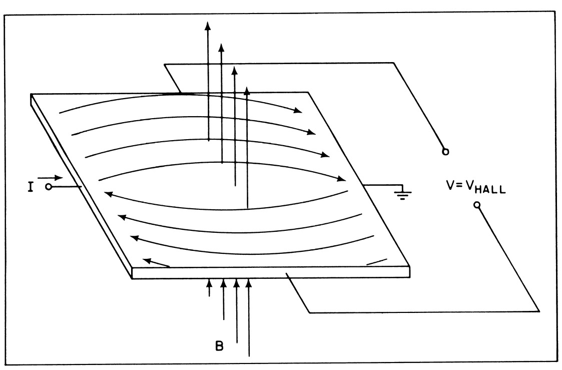
CURRENT SENSING HANDBOOK

The Hall Effect Theory

The Hall Effect principal states that when a current carrying conductor is placed in a magnetic field, a voltage will be generated perpendicular to the direction of the field and the flow of current. Consider Figure 1 in which a constant current is passed through a thin sheet of semiconducting material to which are attached output connections at right angles to the current flow. With zero magnetic field current distribution is uniform and there is no potential difference at the output contacts.



When a perpendicular magnetic field is present, as illustrated in Figure 2, the current flow is distorted. The uneven distribution of electron density creates a potential difference across the output terminals. This voltage is called the Hall voltage.



A practical equation that describes the interaction of the magnetic field, current and Hall voltage is:

$$V_H = k \cdot I \cdot B \sin \Theta$$

Where:

• constant k is a function of the geometry of the Hall element, the ambient temperature and the strain placed on the Hall element.
• B sin Θ is the component of magnetic field perpendicular to the sheet.

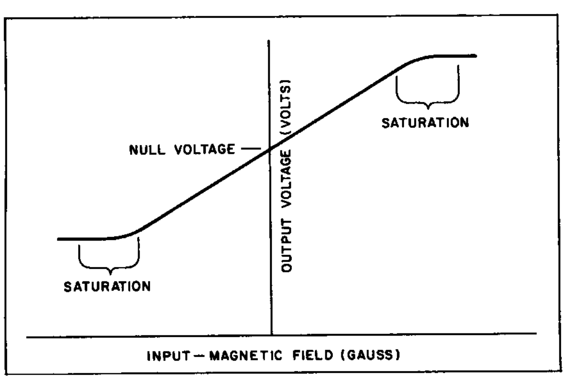
If the input current is held constant the Hall voltage will be directly proportional to the strength of the magnetic field.

The Hall voltage is a low level signal of the order of 20 to 30 microvolts in a magnetic field of one gauss. A signal of this magnitude requires a low noise, high impedance, moderate gain amplifier. Figure 3 shows a block diagram of a typical Hall current sensor.

The magnetic field sensed by the Hall plate can be either positive or negative. As a result, the output of the amplifier will be driven either positive or negative, thus requiring both plus and minus power supplies.

To avoid the requirement for two supplies, a fixed offset or bias is introduced into the differential amplifier. The bias value appears on the output when no magnetic field is present and is referred to as a null voltage. When a positive magnetic field is sensed, the output will increase above the null voltage. Conversely, when a negative magnetic field is sensed, the output will decrease below the null voltage, but remain positive.

This concept is illustrated in Figure 4.

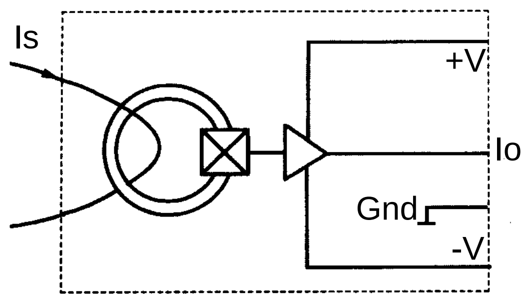


Sensed currents that exceed the rating of the sensor and drive it out of the linear operating range cause saturation as shown in Figure 4. Saturation takes place in the amplifier and in the magnetic circuit. Excessive currents will not damage the Hall sensing element.

OPEN LOOP SENSORS

Open loop transducers are capable of measuring dc, ac and complex waveform currents with galvanic isolation. Advantages are low power consumption, small size and low weight. Insertion losses are virtually zero and current overloads cause no damage. The PRO and X series sensors in this catalog are open loop sensors and can be operated from single voltage or dual voltage power supplies. Ratings range from 5A to 450A.

An open loop sensor is illustrated schematically in Figure 5. It shows a Hall generator mounted in the air gap of a magnetic core. A current carrying conductor placed through the aperture of the core produces a magnetic field proportional to the current magnitude. The core concentrates the magnetic field around the Hall generator, the output of which is fed into an amplifier.



The linearity of the open-loop sensor is determined by the characteristics of the magnetic core and the Hall generator. Offset drift over temperature is determined primarily by the temperature sensitivity of the Hall generator .

The frequency bandwidth of closed loop sensors is limited by Eddy current and hysterisis losses in the magnetic core. Eddy current losses depend upon the thickness of the laminations, the peak magnetic induction and frequency. Hysterisis losses are proportional to frequency and peak magnetic induction. Bandwidth is also determined by the characteristics of the amplifier and compensation circuits.

CLOSED LOOP SENSORS

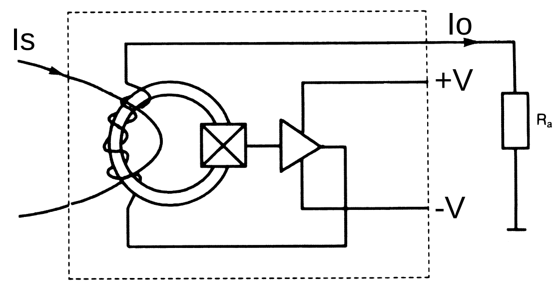


Figure 6 is a block diagram of a closed loop sensor. It shows a Hall generator mounted in the air gap of a magnetic core, a coil wound around the core and a current amplifier. A current carrying conductor placed through the aperture of the core produces a magnetic field that is proportional to current magnitude.

The Hall generator output voltage is boosted by a high gain amplifier, the output of which is fed into a push-pull driver stage that drives the coil wound in series opposition on the magnetic core. Thus creating a magnetic field equal to and opposite to the field of the sensed current: maintaining the core flux level near zero. The output of the closed loop sensor is proportional to the aperture current and the number of turns of the coil. A sensor with a 1000 turn coil will provide an output of 1 mA/A. The output current signal is converted to a voltage by connecting a resistor between output of the sensor and ground. Output voltage can be scaled by selecting various resistor values.

This technique allows significant improvements in sensor performance by eliminating the influence of non-linearities in the magnetic core and by reducing the effects of temperature sensitivity in the Hall element.

Most closed loop sensors require dual power supplies.

The AMP-LOC CS series of closed loop sensors are available in ratings from 25A to 300A.

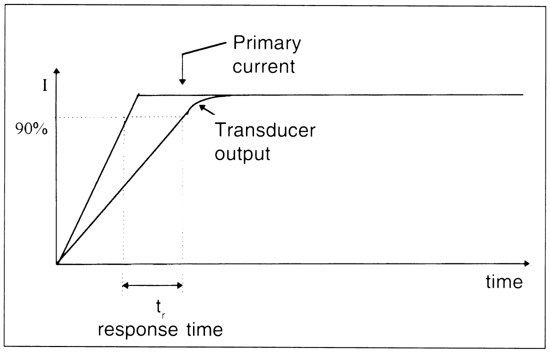
TRUE RMS TO DC CONVERTER

Most current sensors produce outputs that are instantaneous representations of the measured currents. For complex or ac waveshapes there may be a requirement to convert the outputs to true rms values.

RMS converters available from Maxim are designed to accept complex input waveforms containing ac and dc components. They can be operated from either a single or dual supplies. The converters are designated MX536A/ MX636. Both devices draw less than 1 mA of quiescent supply current, making them ideal for battery-powered applications. They exhibit >1MHz bandwidth and <.5% accuracy.

DEFINITIONS

Response Time
Response time is defined as the delay between the instant the sensed current reaches 90% of its final value and the instant the sensor output signal reaches 90% of final value as illustrated in Figure 7. For open loop sensors response time and di/dt ratings depend primarily upon the slew rate of the amplifier.



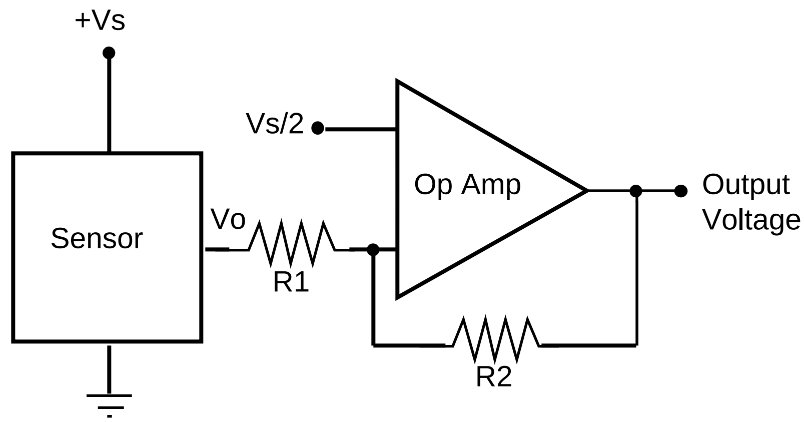
di/dt accurately followed
The linear rate of change in current that the sensor can accurately measure.

Linearity
Output deviation from a straight line response to the current being measured.

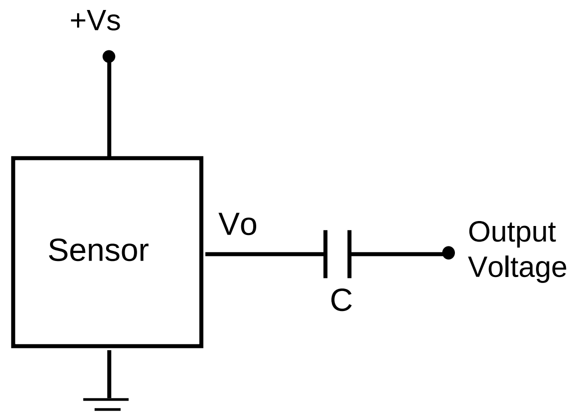
APPLICATION NOTE

Interface circuits commonly used with AMPLOC current sensors

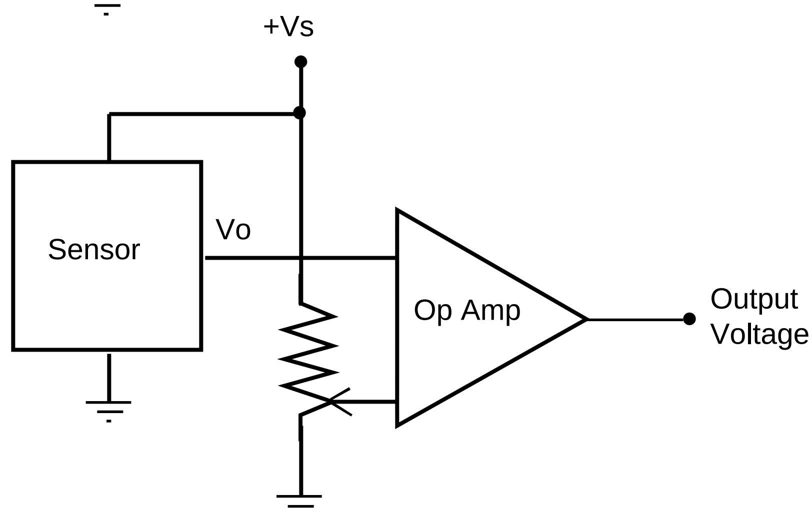
Output proportional to sensed current.



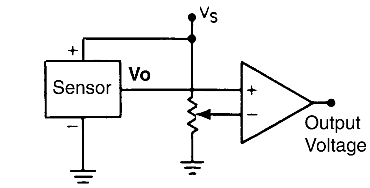
Output proportional to ac current.



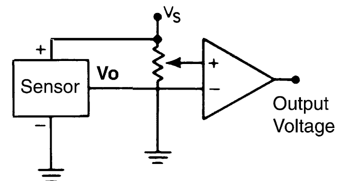
Digital swtch with adjustable operate point.



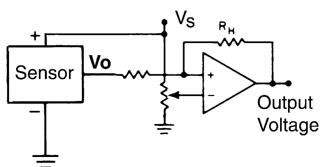
Non-inverting



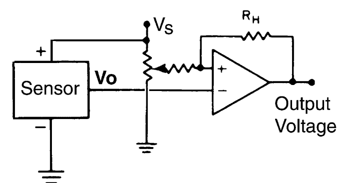
Inverting



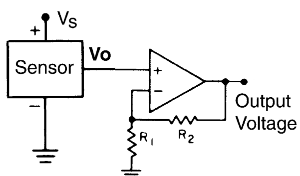
Non-inverting with Hysteresis



Inverting with Hysteresis

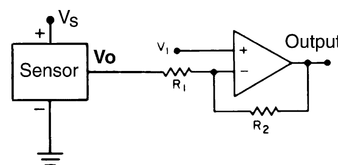


Non-inverting



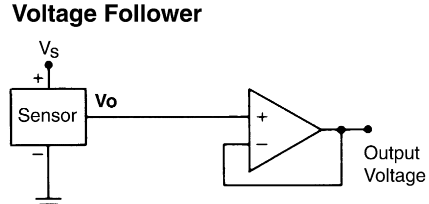
Output = $Vo\left(1 + \frac{R_2}{R_1}\right)$

Inverting



Output = $(V_1 - Vo)\,\frac{R_2}{R_1} + V_1$

Voltage Follower



AMP-LOC SENSORS

AMP-LOC current sensors in this handbook provide galvanic isolation and are capable of measuring dc, ac and complex waveform currents.

• For best overall electrical performance consider the CS closed loop sensor series .

These sensors are characterized by:

√ Accuracy 0.4% -0.8%
√ Linearity 0.1% -0.2%
√ Low temperature drift
√ Response time 0.4 µsec-0.8 µsec
√ Bandwidth dc to 250kHz
√ di/dt to 70A/µsec

• For smallest size and lowest weight consider the XL and XM series. These open loop sensors are encapsulated in tough polypropylene and are practically impervious to chemical attack. They are the smallest linear current sensors on the market. In terms of cost/performance they offer great value.

• For operation in temperatures ranging from -55C to +150C and where size is important consider the PRO series . They are open loop sensors that are utilized in satellites, aircraft and undersea applications. These sensors are light weight and low cost.

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current sensors

805/964-9119 FAX 805/967-8789
Box 152, Goleta, CA 93116
e-mail:escor @west.net
www.west.net/~escor

Closed Loop Sensor

Nominal Rating 50A rms — CS50-P

Electrical Data

- Nominal current(In) ±50A rms
- Current range 0~ ±400A peak*
- Nominal output current 50mA
- Turns Ratio 1000/1
- Measuring Resistance (Rm) ref. figure 1
- Overall accuracy at 25°C 0.5%
- Supply voltage ±12V ~ ±18V
- Current consumption 15mA + output current

* at ±18V power supply, Rm ≤ 1Ω, 25°C

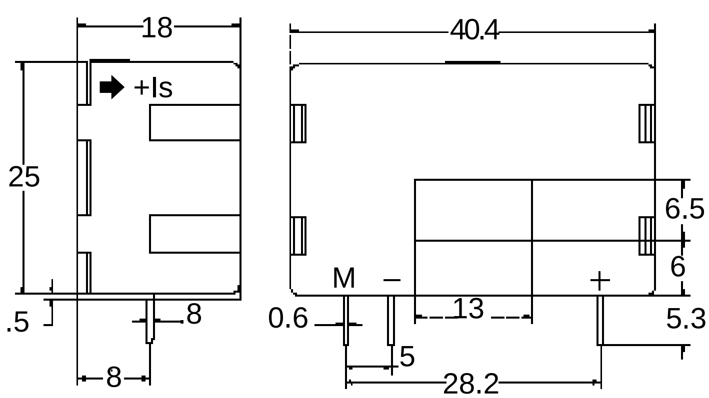
Dynamic Performance

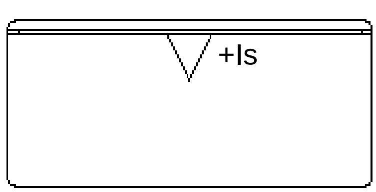
- Null offset current. Max.0.2mA (25°C)
- Thermal drift offset current Max. 0.25mA (0°C to 70°C)
- Linearity: better than 0.1%
- Response time better than 1µS
- di/dt: better than 50A/µS
- Frequency range: DC to 100KHz

Figure1 Maximum value of the measuring resistance

At maximum input amp-turns (peak) / Supply voltage	50 A•T	100 A•T	300# A•T	400# A•T
±12V	70Ω	50Ω	–	–
±15V	200Ω	80Ω	5Ω	–
±18V	250Ω	100Ω	10Ω	1Ω

\# Derate according to duty cycle



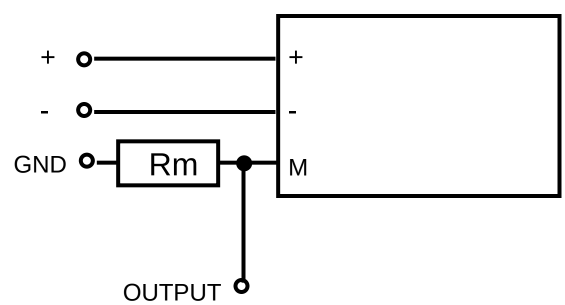


Dimensions: (mm)
Weight: 24 gms.

General Data

- Sensor housing: insulated plastic case
- Fire-retardant feature: UL94V-O
- Isolation voltage: 5kV/50Hz/1min.
- Operating temperature: -25°C to +85°C
- Storage temperature: -40°C to +100°C
- A positive output current is obtained on terminal M when the input current flows in the direction of the arrow.

Electrical Connection



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Box 152, Goleta, CA 93116
e-mail:sales@amploc.com
www.amploc.com

Closed Loop Sensor

Nominal Rating 100A — CS100A-P

Electrical Data

- Nominal current(In) ± 100A
- Current range 0~ ± 200A
- Nominal output current (Im) 50 mA
- Turns Ratio 2000/1
- Measuring Resistance (Rm) 0 ~100 Ω
- Overall accuracy at 25°C 0.5%
- Supply voltage ±15V ~ ±18V
- Current consumption 15mA + output current

Note

- Busbar temperature should not exceed 100°C .
- A positive output voltage is obtained on terminal M when the input current flows in the direction of the arrow.

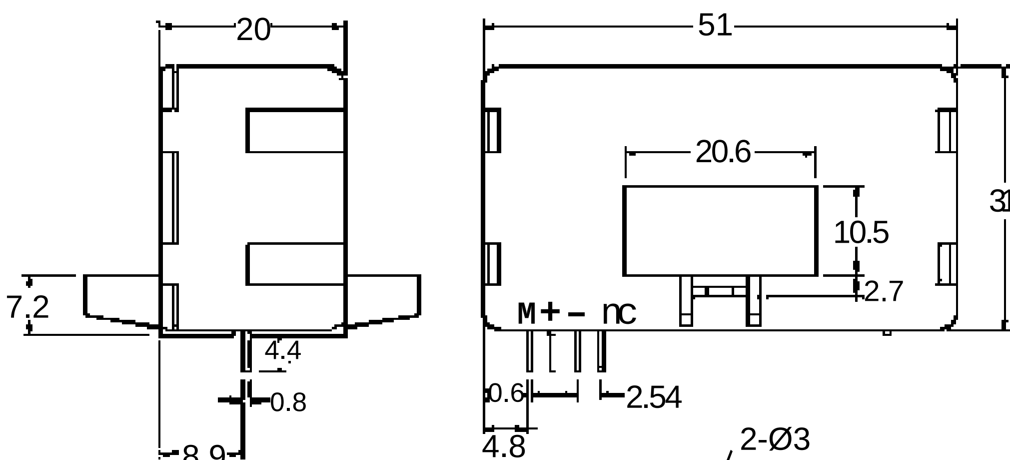
Dynamic Performance

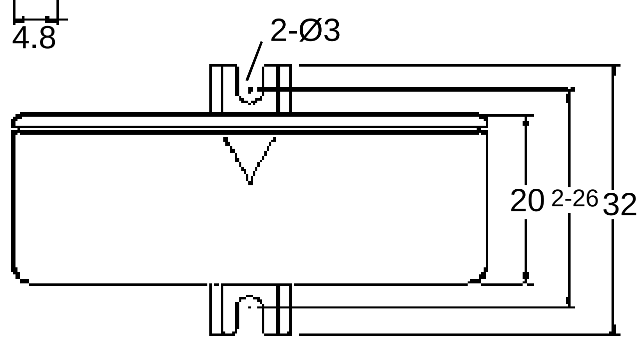
- Null offset current. Max.0.2mA (25°C)
- Thermal drift offset current Max. 0.3mA (-25°C to 85°C)
- Linearity: better than 0.1%
- Response time better than 0.5µS
- di/dt: better than 70A/µS
- Frequency range: DC to 250KHz

General Data

- Sensor housing: Fire retardant UL94V-O
- Isolation voltage: 5kV/50Hz/1min.
- Operating temperature: -25°C to + 85°C
- Storage temperature: -40°C to + 100°C

Connect the Measuring Resistor Rm between terminal M and power supply ground. Output voltage= ImxRm.





Mating connector:
Samtec SSW-1-03-02-T-S-RA

Dimensions:(mm)
Weight: 34 gms.

ampCloc current sensors

805/964-9119 FAX 805/967-8789
Box 152, Goleta, CA 93116
e-mail:sales@ampCloc.com
www.ampCloc.com

Closed Loop Sensor

Nominal Rating 200A rms **CS200A-P**

Electrical Data

- Nominal current(In) ±200A rms
- Current range 0~ ±400A peak*
- Nominal output current 100 mA
- Turns Ratio 2000/1
- Measuring Resistance (Rm) ref. figure 1
- Overall accuracy at 25°C 0.5%
- Supply voltage ±12V ~ ±18V
- Current consumption 15mA + output current

Dynamic Performance

- Null offset current. Max.0.2mA (25°C)
- Thermal drift offset current
  Max. 0.3 mA (-25°C to 85°C)
- Linearity: better than 0.1%
- Response time better than0.6µS
- di/dt: better than 70A/µS
- Frequency range: DC to 250KHz

Electrical Connection

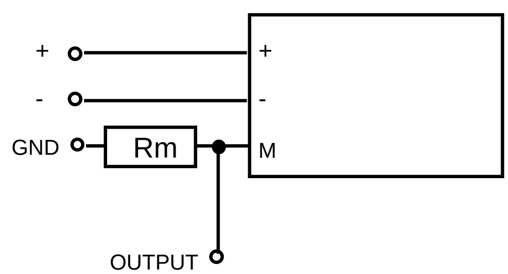
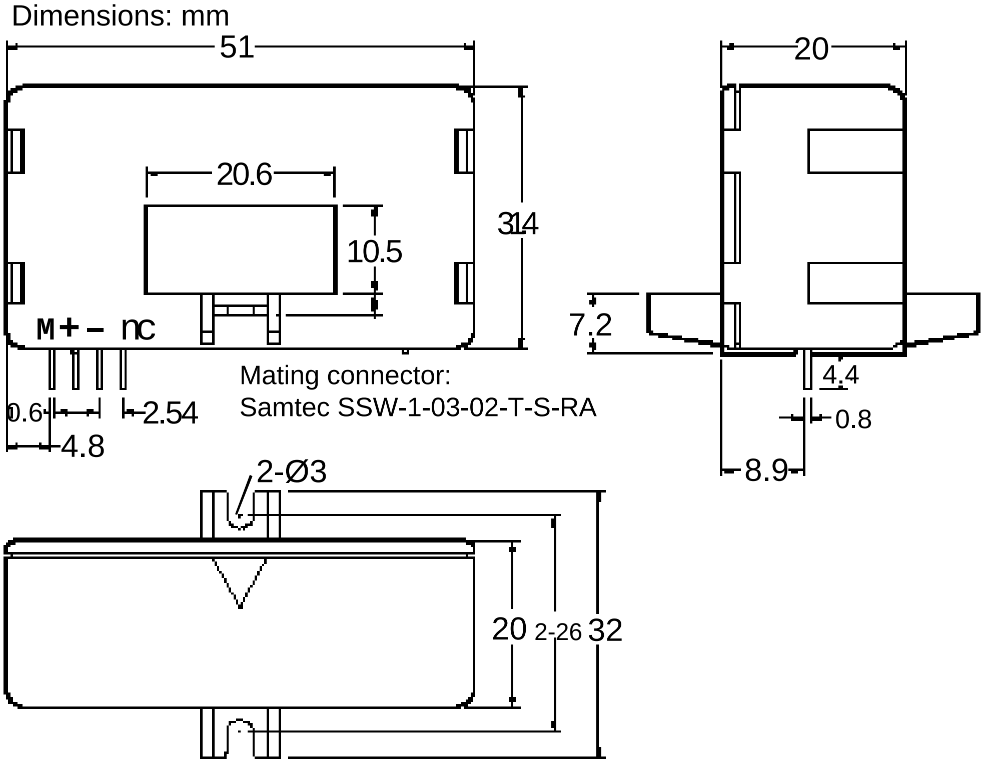


Figure1 Maximum value of the measuring resistance

At maximum input amp-turns (peak) / Supply voltage	200 A•T	300 A•T	A•T	A•T
±12V	15 Ω			
±15V	40 Ω	3Ω		
±18V				

Dimensions: mm



ampl oc current sensors

25,50,100 Ampere Ratings

Hall effect linear sensors. (-40 to +125C)

805/964-9119 FAX 805/967-8789
Box 152, Goleta, CA 93116
e-mail:sales@amploc.com
www.amploc.com

Sensor Style	Fig.	Sensed Current (Amps peak)	Vs= +5V ΔVo at peak rated current *	Vs= +5V Sensitivity mV/A *
XAE25	1	25	.98V	39
XL50	1	50	1.65V	33
XL100b	1	100	2.1V	21
XM100b	2	100	2.1V	21

* proportional to Vs

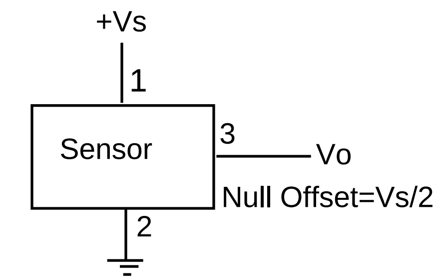
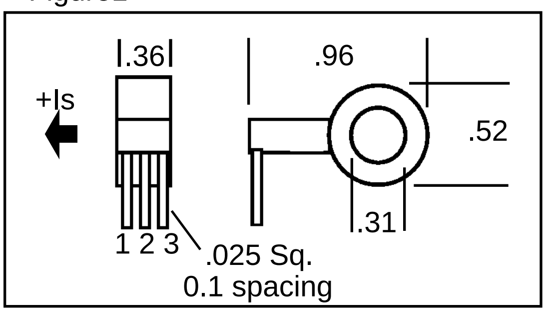
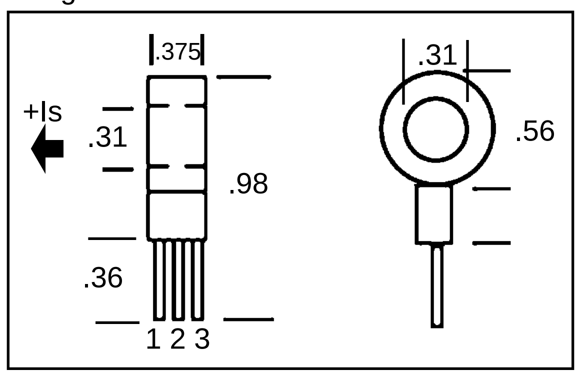


Figure1



Dimensions: Inches
Weight: 4 grams.

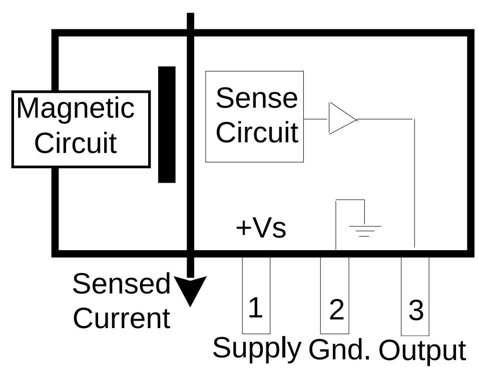
Figure 2

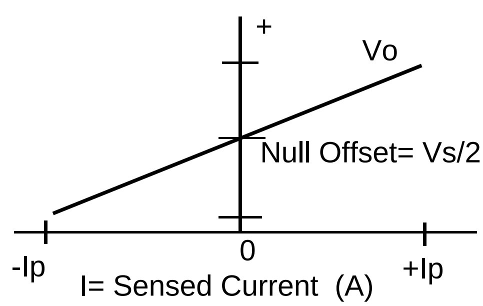


Caution:Do not reverse supply voltage polarity.

ELECTRICAL CHARACTERISTICS

Supply voltage, Vs.....................+4.5 to +8 Vdc
Supply Current......................... 10mA max.
Output Current.............................. 2mA max.
Offset Voltage, Vo (Sensed I = 0A.). Vs/2±1%
Output Voltage, Vo is proportional to Vs.
Temperature Error
Null.................. .... .03%/C
Gain... .03%/C
Temperature Range.................-40C to + 125C
Response Time................................. 7µSec.
Linearity (Full Scale)................................. 1%
Accuracy (Full Scale)............................... ±2%
A.C. Hysterisis Error................................ 0.8%





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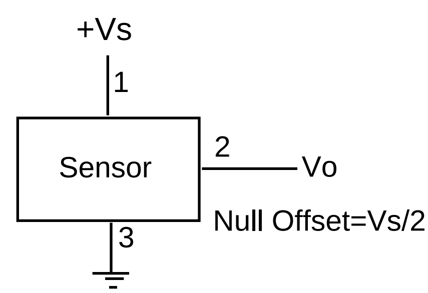
5 to 100 Ampere Ratings

Hall effect linear sensors. (-55 to +125C)

Sensor Style	Fig.	Sensed Current (Amps peak)	Vs= +12V ΔVo at peak rated current *	Vs= +12V Sensitivity mV/A*
PRO5	1	5	1.4V.	280
PRO10	1	10	2.3V.	230
PRO25	1	25	1.4V.	56
PRO50	1	50	2.3V.	46
PRO100	2	100	2.9V.	29
PRO50S	3	50	2.3V.	46



* proportional to Vs

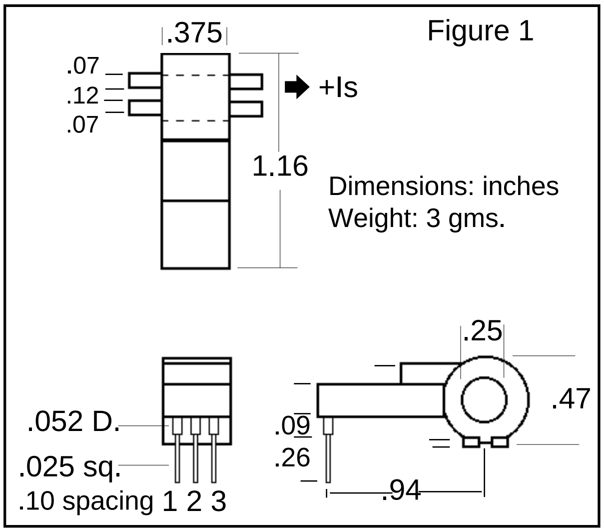


Figure 1

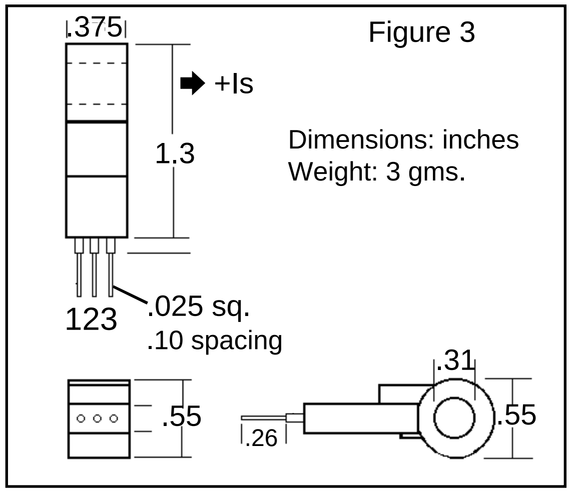


Figure 3

Caution:Do not reverse supply voltage polarity.

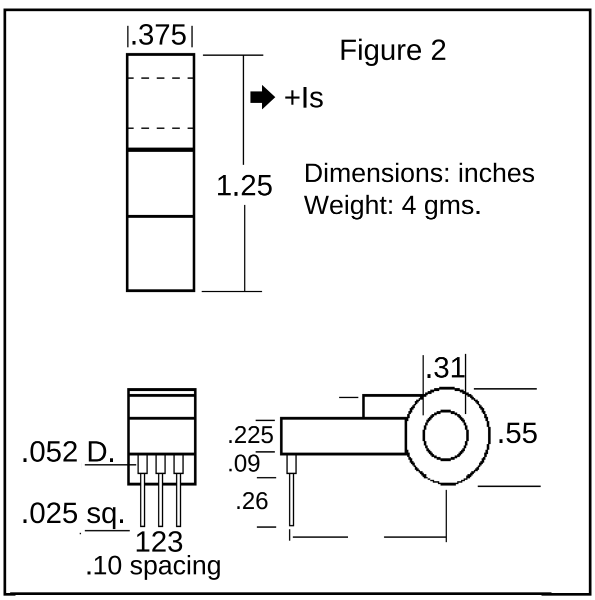


Figure 2

ELECTRICAL CHARACTERISTICS

Supply voltage, Vs.....................+6.6 to +12.6Vdc
Supply Current.............................. 25mA max.
Output Current.................................. 1mA max.
Offset Voltage, Vo(Sensed Current= 0A.).Vs/2±1%
Output Voltage, Vo is proportional to Vs.
Temperature Error
Null... .02%/C
Gain.. .02%/C
Temperature Range........................-50C to + 125C
Response Time....................................... 2μSec.
Linearity (Full Scale)....................................... 1%
Accuracy (Full Scale)..................................... ±3%
A. C. Hysterisis Error.................................... 0.8%