Selecting Current Sensors and Transformers

Choosing the right current sensor does not need to be guesswork

Applications

Current sensors detect the flow of AC or DC current in a wire or circuit trace. They can be used to detect an on/off/ pulse current condition or to measure the magnitude of the current in the wire or trace. This discussion is limited to AC current sensors.

Ideal current sensors would not use any power to detect the current in the wire or trace, but real current sensors require some of the circuit energy to provide the information.

Current sensors are frequently used to measure and control the load current in power supplies, safety circuits and a variety of control circuits. In applications where controlling the current is required, such as in power supplies, accurately sensing the magnitude of the current is a fundamental requirement.

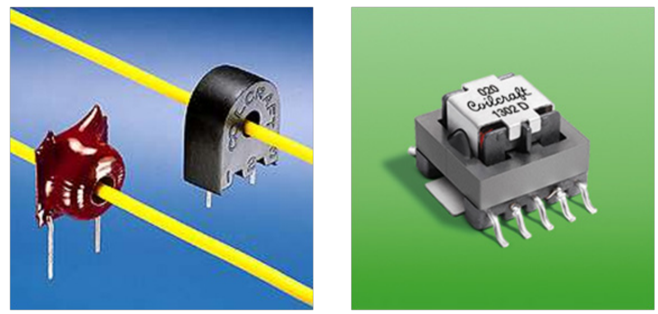
In pulsed-current applications or where it is only required to detect an on condition such as some safety circuits, the precise magnitude of the current may not be required. In other safety circuits, the sensed current can be used to trigger a shut down when the current exceeds a pre-set limit.

Technology

A resistor can be used to sense current by measuring the voltage drop across the resistor. By Ohm's law, the sensed current $I = V/R$. Using a low value resistor in series with the measured current keeps the voltage drop, and loss due to dissipation, to a minimum. This sounds simple, but because the voltage drop is low across such a small resistance, amplification of the voltage may be needed to detect it, creating additional circuit complexity.

Shunt current sensors sample a small proportional fraction of the sensed current. The current is shunted through a parallel resistor and the voltage drop measured. As with the series resistor, the voltage drop is proportional to the current being sensed.

Current sense transformers are typically used for AC current sensing. The circuit can be somewhat simple when using a true RMS-to-DC converter such as the LT1966 from Linear Technology. These current sensing devices may use a single wire from the circuit to act as the primary of the transformer (Figure 1a) or they may have the primary (usually 1-turn) winding provided (Figure 1b).



a. Sensor Only b. Transformer

Figure 1. Types of current sensors

These AC current sense transformers develop a current in the secondary that is proportional to the sensed current in the primary. The secondary current is measured as the voltage drop across the terminating resistor (R_T) as shown in Figure 2. By using a low turns ratio current transformer (pri/sec <<1), the current drawn through the terminating resistor is minimized. This also reduces the voltage produced across the terminating resistor, which may then require amplification if that output voltage is too low. Choice of transformer turns ratio and terminating resistor must balance the desire for low current draw against the need for sufficient output voltage.

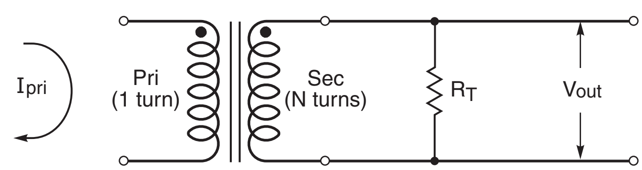


Figure 2. Typical application schematic

Selecting AC Current Sensors / Transformers

Selecting an appropriate current sensor requires the frequency range and current rating of the sensor for your application conditions. The sensor type, mounting (surface mount or through hole), turns ratio and overall dimensions are additional considerations. Sensor type can be either a "sensor only", in which a conductor integral to the application serves as the primary (Figure 1a) or it can be a current transformer in which the primary is included (Figure 1b).

The worst-case current and frequency determine the highest flux density that will be seen by the sensor or transformer. Exceeding 2000 Gauss for most AC current sensors means that the output becomes non-linear vs. the current being sensed and the output voltage is no longer strictly proportional to the input current. Higher secondary turns helps keep the flux density below this limit.

For the wire-through-hole style current sensors the turns ratio can be dramatically reduced by looping additional turns (one pass through the hole is one turn) if the wire size and hole size permit. This allows a higher input current transformer to be used to provide higher output voltage across the terminating resistor (see sidebar eq. 4).

Coilcraft Current Transformer Selector Tool

Coilcraft provides an online tool* to aid in selecting the right current sensor or current transformer for specific application conditions (Figure 3).

The tool requires user input of expected maximum sensed current, input frequency (kHz), duty cycle of the primary current waveform, and the desired output voltage. The output voltage is the desired output voltage for the expected maximum input current.

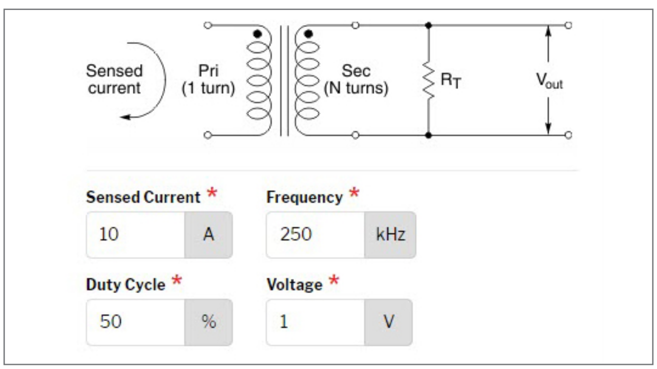


Figure 3. Current sensor selector input screen

The tool calculates the required terminating resistance (R_T) based on the maximum input current (Ipri), the number of secondary turns (Nsec) and the output voltage (Vout) by:

$$R_T = \mathrm{Nsec} \times \mathrm{Vout}/\mathrm{Ipri}$$

(Calculations based on a 1-turn primary.)

The tool also calculates the maximum flux density of the secondary, based on the output voltage (Vout), duty cycle, secondary turns, and frequency to make sure it does not exceed 2000 Gauss.

The results, shown in Figure 4, list all Coilcraft part numbers that meet these input conditions and shows a graph of the output voltage vs. sensed current for the calculated R_T.

Conclusion

Selecting an appropriate current sense transformer requires knowledge of the expected maximum sensed current, frequency and duty cycle of the sensed current, as well as the desired output voltage corresponding to the expected maximum sensed current. With this information, the Coilcraft Current Transformer Selector Tool provides the appropriate terminating resistor value and a list of current sensors that meet the application conditions.

Part Number	Minimum Inductance (mH)	Sensed Current max (A)	Primary DCR typ (mΩ)	Secondary DCR typ (mΩ)	Secondary VT product (V-µs)	Turns ratio (1:N)	Bmax (Gauss)	RT (Ω)	Footprint (mm²)	Length (mm)	Width (mm)	Height (mm)	Mount	AEC grade
CU8965-AL Sample Buy	1.33	20	1.5	10680	1500	1:100	125.00	10.0	35.0	7.0	5.0	3.0	SM	1
CST7030-020L Sample Buy	0.05	20	1.5	420	500	1:20	625.00	2.0	36.4	7.0	5.2	3.0	SM	1
CST7030-050L Sample Buy	0.33	20	1.5	2760	500	1:50	250.00	5.0	36.4	7.0	5.2	3.0	SM	1
CST7030-070L Sample Buy	0.65	20	1.5	5040	500	1:70	178.57	7.0	36.4	7.0	5.2	3.0	SM	1
CST7030-100L Sample Buy	1.33	20	1.5	10680	500	1:100	125.00	10.0	36.4	7.0	5.2	3.0	SM	1
CST7030-150L Sample Buy	2.99	20	1.5	22300	500	1:150	83.33	15.0	36.4	7.0	5.2	3.0	SM	1

Figure 4. Current sensor selector results screen

* https://www.coilcraft.com/CurrentTransformerFinder

How is the primary current measured by a current transformer?

For any transformer, the turns ratio is proportional to the inverse of the current ratio:

$$Npri / Nsec = Isec / Ipri$$

where:
Ipri = primary current, Npri = primary turns,
Isec = secondary current, Nsec = secondary turns

Solving for Isec
$Isec = Ipri \times Npri / Nsec$

If Npri = 1 turn,
$Isec = Ipri / Nsec$

Solving for the current in the primary (sensed current):

$$Ipri = Isec \times Nsec \qquad \text{(eq. 1)}$$

The voltage across the terminating resistor R_T is by Ohm's Law:

$Vout = Isec \times R_T$

Solving for Isec
$Isec = Vout / R_T$

Substituting into eq. 1

$$Ipri = (Vout / R_T) \times Nsec \qquad \text{(eq. 2)}$$

gives the sensed current in the 1-turn primary, by measuring Vout, and knowing the terminating resistance R_T and the number of secondary turns Nsec.

If Npri is not = 1 turn,

$$Ipri = (Vout / R_T) \times (Nsec / Npri) \qquad \text{(eq. 3)}$$

$$Vout = (Ipri \times R_T) \times (Npri / Nsec) \qquad \text{(eq. 4)}$$