



## Hall-effect sensor/ASIC integration shrinks current transducers (Part 2 of 2)

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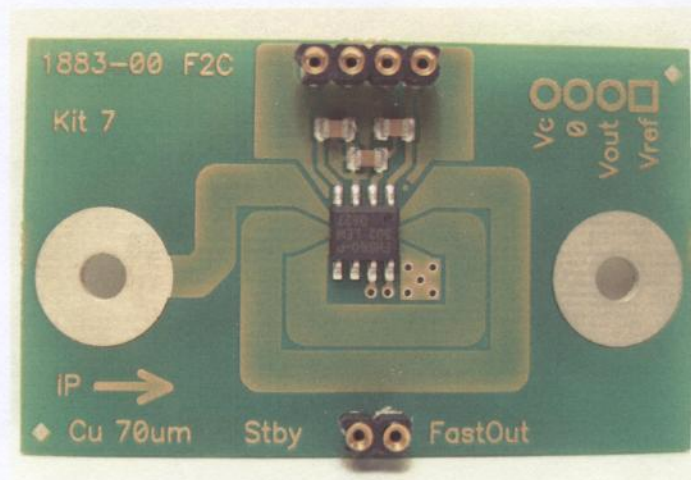
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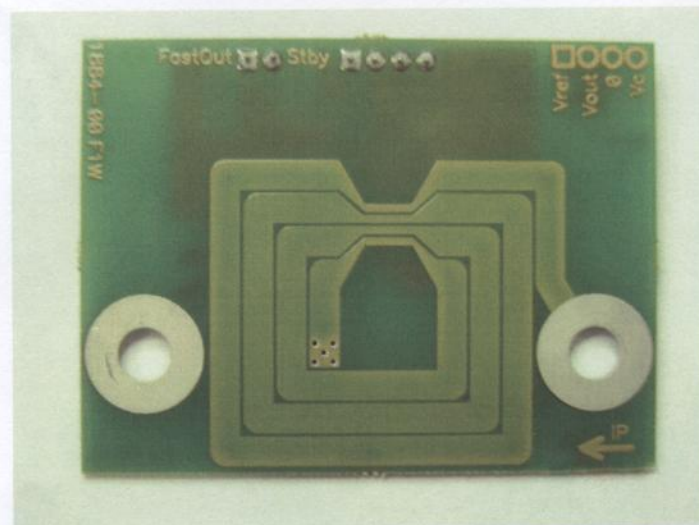
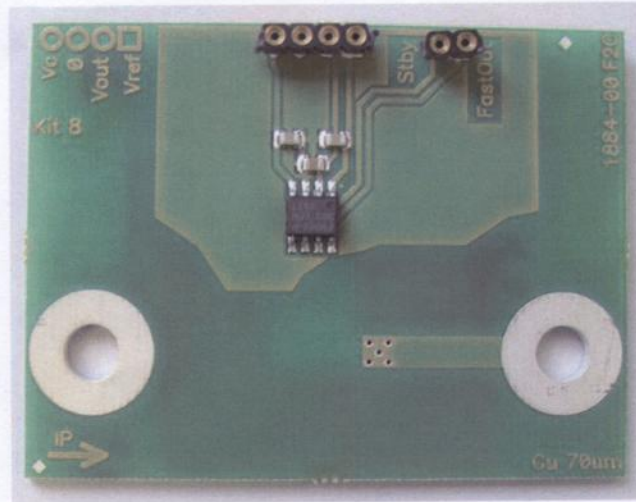
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The maximum current that can be safely and continuously applied is determined by the temperature rise of the track. The use of a track with varying width gives the best combination of sensitivity and track temperature rise. The copper temperature is limited by the PCB material glass transition temperature ( $135^{\circ}\text{C}$ ), while the maximum operating temperature of most [ASIC](#) integrated transducers is  $125^{\circ}\text{C}$ . For safety margin reasons, it is best to work with a maximum allowable temperature at the track level of  $115^{\circ}\text{C}$  (UL advises a limit of  $100^{\circ}\text{C}$ ). To maintain these temperature levels, the width, thickness and shape of the track are very important.

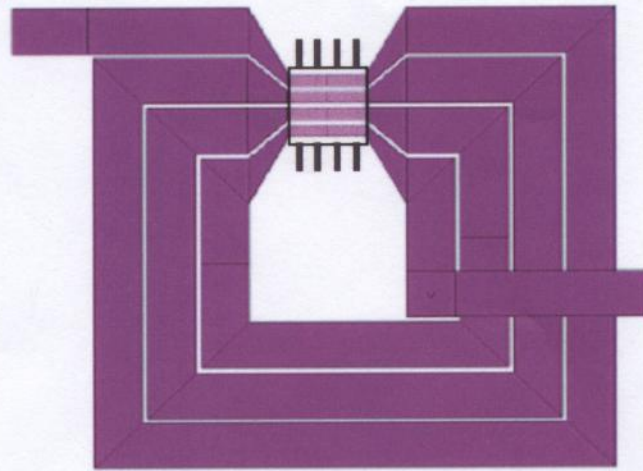
For low currents (under 10 A), it is advisable to make several turns with the primary track to increase the magnetic field generated by the primary current. As with a single track, it is better to have wider tracks around the transducer than under it (to reduce temperature rise). Let us call this design "Multi-turn" (**Figures 5, 6a, and 6b**).





*Figures 5, 6a, and 6b: Possible "multi-turn" designs*

For example, it is possible to have a four-turn design (Figure 6 and **Figure 7**) underneath the transducer on the opposite side of the PCB, providing a high insulation configuration. Another way to increase the sensitivity is to use a narrower track.



*Figure 7: Four-turn track design/high insulation configuration*

High insulation results from the improved creepage and clearance distances, because the primary conductor (four turns of the track) is located on the opposite side of the PCB to the low-voltage parts of the electronics. In this case, both distances are guaranteed to be 8mm (PCB characteristics: 1.6mm/70  $\mu\text{m}$  copper) (Track width: 0.78 mm under the transducer, 3 mm elsewhere).

With this design, 5 A can be measured as nominal primary current with an 85° C ambient temperature, under conditions of natural convection, 30° C track temperature rise. The measuring range is  $\pm 15$  A, with a sensitivity of 130 mV/A as 2 V is produced at the output for a 15 A current. The sensitivity can be increased further by other techniques, like using a "jumper" (wire) over the transducer to create a loop with the PCB track, or implementing multiple turns in different PCB layers. Larger currents can be measured by positioning the transducer farther from the primary conductor.

Many parameters for ASIC integrated transducers can be configured by on-chip non-volatile memory. This can be used to adjust the transducer's gain, offset, polarity, temperature drift and gain algorithm (proportional to, or independent of,  $V_{DD}$ ).

Two outputs are available: one filtered, to limit the noise bandwidth, and one unfiltered which has a response time under 3  $\mu\text{s}$ , for current short-circuit or threshold detection. This is the output from a sample and hold circuit, and the discrete sample values are not filtered.

LEM's Minisens ASIC integrated transducer, for example, operates from a +5 V power supply. To reduce power consumption in sensitive applications it has an optional input from an external signal which places it in a standby mode. It is manufactured in a standard CMOS process and assembled in a SO8-IC package.

The accuracy reached at +25° C by Minisens itself is determined by the following parameters:

- The sensitivity (V/T) error ( $\pm 3\%$ )

- The tolerance on the initial offset at no field ( $\pm 10$  mV)
- The non-linearity error ( $\pm 1.5\%$ )

However, this does not represent the accuracy in the final application.

Overall accuracy has to be seen in the overall conditions, when the transducer is soldered onto PCB. Then, several other parameters that influence the accuracy must be considered as well:

- The distance and shape variations of the primary conductor vs. the IC and the IC placement error on the PCB (let's call them the mechanical design parameters)
- The adjacent perturbing (stray) fields

The final sensitivity (V/A) directly depends on the mechanical design parameters. Each inaccuracy or change will lead to a change in the final sensitivity.

The parameters that are subject to change due to variations in industrial production include:

- the solder-joint thickness
- the copper-track thickness
- the PCB thickness
- the primary-track width
- the positioning of the IC along the Y axis
- the rotation of the IC around the x axis and Z axis

These parameters must be closely controlled in the production process. Alternatively, in-circuit calibration of the transducers can avoid most of these errors. For example, sensitivity and the tolerance on the initial offset can both be easily programmed.

If we look at a defined temperature range, two other parameters must be taken into account: sensitivity temperature drift at  $\pm 300$  ppm/K and offset drift at  $\pm 0.15$  mV/K.

The combination of different transducer configurations and different PCB designs results in a very versatile and inexpensive current transducer, which brings the benefits of isolated current measurements to new applications in that was previously infeasible, such as motor control in household appliances or for current overload detection.

ASIC integrated transducers can be used in low-cost UPSs and battery chargers to provide current control, fault protection and current detection. This fault protection function can also be used in electrical shutters, door openers and similar equipment. These transducers will offer energy savings by enabling current control and providing the precise data that will allow power electronics to drive the motor more efficiently and with lower losses.

**About the authors** (all are with LEM SA, Geneva, Switzerland, [www.lem.com](http://www.lem.com))

**Bernard Richard**, Application Manager, has a Masters degree in Electrical Engineering from the EPFL in Lausanne, Switzerland. Bernard joined LEM in 1998 as Project Development

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