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Hall-effect Sensor/ASIC Integration Shrinks Current Transducers

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The trend in power electronics is no different than that in other electronics fields: a greater degree of integration coupled with a lower component count. Power electronics systems, however, include components such as heatsinks, magnetics, and coils, which can make high levels of integration difficult. Micro-electromechanical systems (MEMS) have already found applications in sensing systems and have the potential to offer advances in other parts of the system.

Traditional current transducers are unsuitable for markets such as domestic electrical products and air-conditioning systems because they are too big and too expensive. Smaller and lower-cost transducers, however, are now making current measurement a reality in these systems. The only limitations are from external factors, such as creepage, clearance, and isolation levels.

One of the first steps towards miniaturization was the development of an application-specific integrated circuit (ASIC) which allowed a Hall-effect closed-loop transducer to be offered in a PCB-mounted package measuring only 22.2 L × 10 W × 24 H (mm). Using an ASIC with Hall-effect open-loop technology results in transducers measuring as small as 18.7 L × 16.7 W × 10.7 H (mm), see Figure 1.

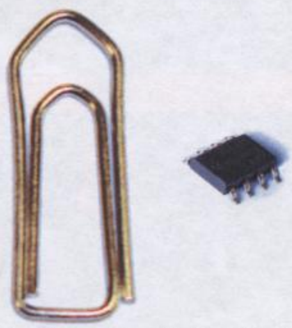
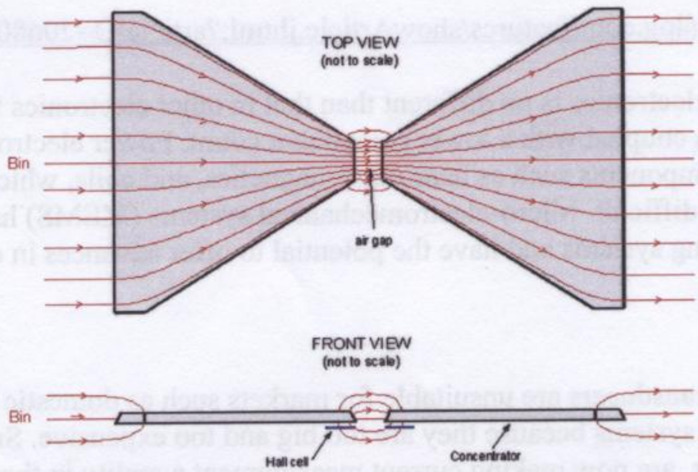
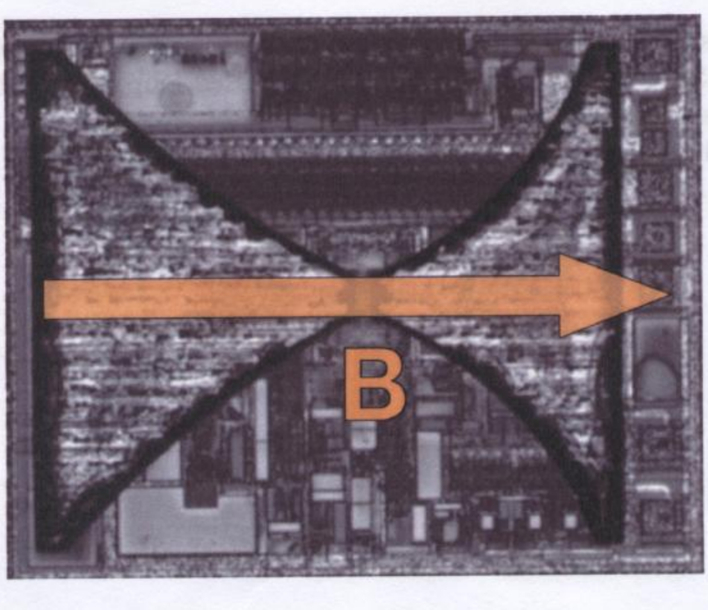


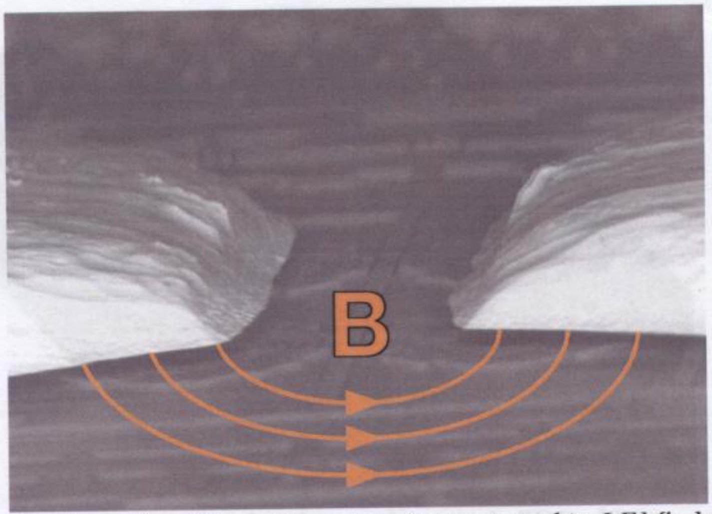
Figure 1: Size of a Hall-effect ASIC

These ASICs integrated the electronics needed for use with current transducers, including field-sensing elements, all active electronic components such as amplifier, transistors, diodes, Zener diodes, and voltage references, as examples. Dedicated silicon technology has produced improved performance in areas such as offset and gain drift. Elements such as the magnetic circuit and the case, however, were still separate from the ASIC at this point.

The next step towards miniaturization was to integrate these remaining core elements into the ASIC package. In order to do this, a transducer converts the magnetic field of a sensed current into a voltage output. This 'primary' current flows in a cable or PCB track near the IC and is electrically isolated from it. Hall-effect devices integrated in the IC are used to measure the magnetic field, with this field being focused in the region of the Hall cells by magnetic concentrators placed on top of the IC (see Figures 2a, b, and c).







Figures 2a, b, and c: Magnetic concentrators used in LEM's Minisens
(Click on images to enlarge)

The shape of the concentrators must be optimized in terms of sensitivity (gain) and linearity for the magnetic fields that will be encountered with the current levels to be measured in typical PCBs. The concentrators produce a noise-free gain of about 8×.

The output of the Hall cells is upconverted in frequency by spinning techniques, so that low magnetic fields can be detected without problems of offsets or 1/f noise. [Note: Spinning techniques are both an upconversion in frequency, and cancellation of offsets, that are intrinsic in Hall cells.] The IC sensitivity to the magnetic field of the primary current is 600 mV/mT maximum. This is the basic working principle of the Hall-effect open-loop technology, but all incorporated into a single, small IC package.

The current sensed can be either positive or negative. The polarity of the magnetic field is detected to generate either a positive or negative voltage output around a voltage reference, defined as the initial offset at no field. The standard initial offset is 2.5 V (internal reference). The user can specify an external reference between +2 and +2.8 V.

The most common way to use these transducers is to place them over a PCB track that is carrying the current to be measured. To optimize the function of the transducer, some simple rules need to be applied to the track dimensions. By varying the PCB and track configuration, it is possible to measure currents ranging from 2 to 100 Amps. One possible configuration places the IC directly over a single PCB track. We will call this "Design 1" (Figure 3).

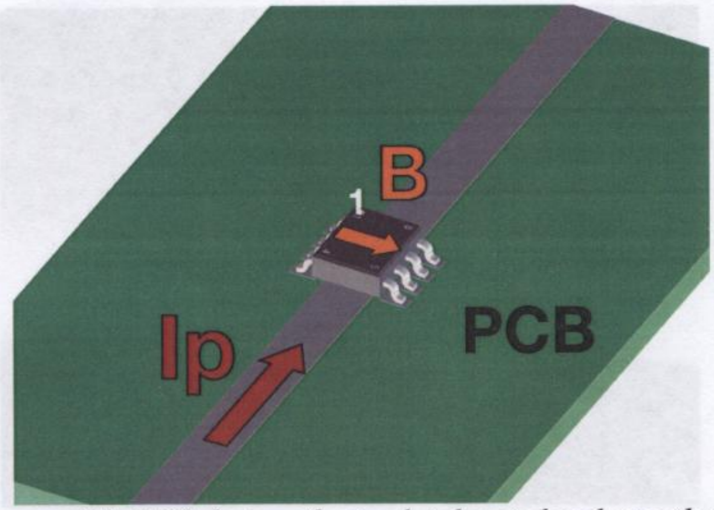


Figure 3: One possible PCB design: the track is located underneath the transducer
(Click on image to enlarge)

In this configuration isolation is provided by the PCB, enabling measurement of currents in the range from 2 to 20 A.

Insulation can be improved by placing the transducer on the opposite side of the board, but still directly over the line of the track. The thickness of the board and the track itself will both affect the sensitivity, as they directly influence the distance between the sensing elements (located into the IC) and the position of the primary conductor. Sensitivity is also affected by the width of the track (Figure 4).

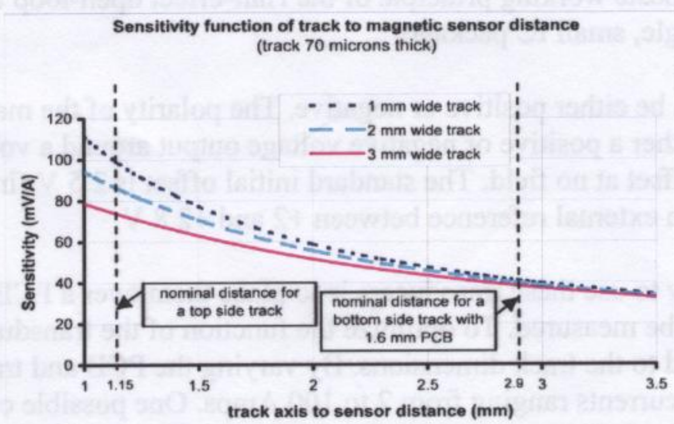


Figure 4: Sensitivity (mV/A) versus track width and distance between the track and the sensing elements.
(Click on image to enlarge)

It is important to note that sensitivity is greater for thinner tracks. However, the thinner the track, the quicker the temperature rises.

(*Part 2* will look at multiturn designs and IC placement on the PC board, You can read it by clicking here.)

About the authors (all are with **LEM** SA, Geneva, Switzerland, 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 Manager and was also in the position of Senior Engineer based in Japan before accepting the responsibility as Application Manager based in Geneva in 2004.

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This article was a particularly nice hit because it ran both online and in print, with several weeks in between.