Parameter Sensing in Power Electronic Modules

Modern inverter applications and electrical drive control algorithms depend on accurate measurements regarding key parameters. For the application and the inverter two parameters are of special interest. The line current driving the application and the power module's temperature provide the necessary information on the state of operation. New power modules like Infineon's MIPAQ family integrate proper sensors, as well as adapted electronics, to provide highly accurate readings and ease the design and improvement of compact high performance drives. **Dr. Martin Schulz, Dr. Ulrich Schwarzer, Infineon Technologies, Warstein, Germany**

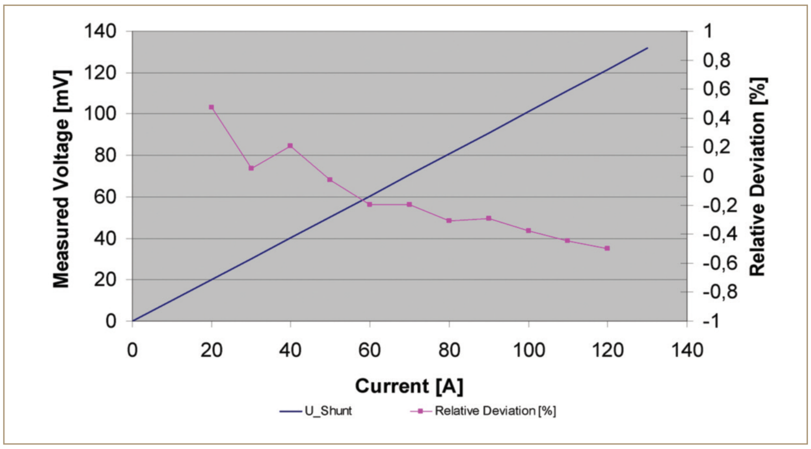

Figure 1: Measured voltage across a 1mΩ Shunt with in the MIPAQ base

As a voltage across a resistor is proportional to the current flowing, utilising resistors as current sensors is among the most basic ideas to measure electric currents. Despite the losses that inherently appear, the method has a certain appeal as shunts as a single part are reliable, stable across a wide temperature range, cost- efficient and robust. Shunts do not suffer from overcurrents and have neither hysteresis nor offset effects. Additionally, shunts can be mounted using well- established processes. Positioning the shunt closer to the heatsink and into the power electronic module provides an excellent thermal interface, and even allows for large currents to be handled. Infineon's MIPAQ base series features specially designed shunts to precisely measure the application current. Figure 1 displays the outstanding linearity of these sensors on the example of module IFS150B12N3T4_B31.

Though other methods of capturing the current exist, dimensions, EMI and temperature development inside the demanding environment of a power module make shunts the predestined solution for the integration. It was shown that other methods like on-chip current sensing using specially designed IGBT chips cannot provide an equally sophisticated measurement [1].

Current measurement

It seems to be a small step from current sensing to current measurement. In detail however, current and temperature range as

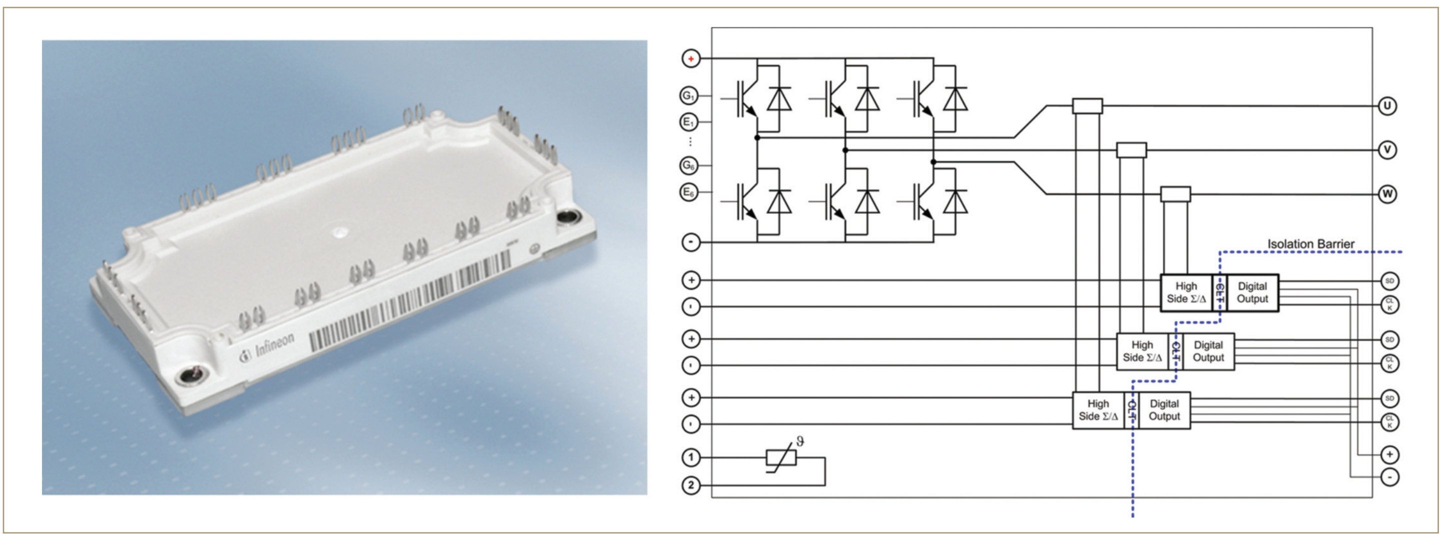

Figure 2: MIPAQ sense featuring a 100A sixpack, shunts and integrated Σ/Δ-Converter

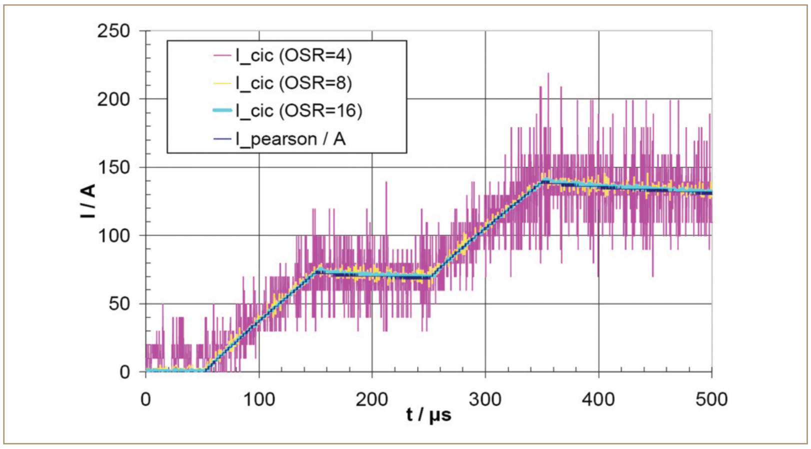

Figure 3: **Current measured with Pearson probe and Σ/Δ-Converter**

well as accuracy demands and the need for galvanic isolation are challenging targets. To minimise part numbers and space requirements, Infineon has expanded the coreless transformer technology (CLT) to form an analog to digital converter based on the well established Sigma/Delta (Σ/Δ) method. This converter achieves an accurate reading and, at the same time, provides galvanic isolation. Built into the MIPAQ sense as displayed in Figure 2, this device in conjunction with the also integrated shunts can be used to form a highly accurate measurement system.

As the Σ/Δ-converter forms an integrating method, a decimator is needed to get the information on the instantaneous current. If a common sinc^3-decimator with varying oversampling rate (OSR) is programmed into a FPGA, the trade-off between speed and accuracy can be demonstrated [2]. Comparing this cost efficient solution with a Pearson current probe reveals the potential of this set-up as depicted in Figure 3.

With an oversampling rate of OSR = 16, a result with 14bit of resolution is achieved, showing only marginal differences compared to the Pearson probe. As the result of the decimator already is digital information, no further conversion is necessary to apply it to a microcontroller for control purpose.

Temperature measurement

The baseplate's temperature as a further parameter is sensed in a variety of power electronic modules. Materials with well defined thermal dependencies are widely used as a temperature sensor. Modern power modules contain a resistor with negative temperature coefficient (NTC) to capture the baseplate's temperature.

As the NTC is a passive component, additional electronics is needed to transform the NTC's temperature depending resistance into a signal that can be used by a microcontroller. One method to do so would be to apply a constant current to the NTC and capture the voltage across the device. As the resistance is a function of temperature, the voltage at constant current resembles the same characteristics. As for the current measurement, digital information would be the preferred solution. The implementation within the MIPAQ serve modules therefore transforms the temperature dependency $R_{NTC}(T)$ into a temperature dependent frequency f(T). Here too, the isolation barrier formed by CLT is used to provide a signal that is galvanically separated from the power electronic section. Simply counting pulses for a predetermined time is sufficient to get an accurate reading of the baseplate's temperature. Due to the large thermal capacitances involved, the time taken for the conversion is of secondary importance. Counting pulses for 50ms or even 100ms leads to proper information, as displayed in Figure 4.

As a consequence of the NTC's characteristics, the relationship between pulses and temperature is not perfectly linear. Nevertheless, an approximation either piecewise linear polygonal or of higher order will provide a temperature information with an accuracy of ±1K.

The trend in development

Today, power electronics modules already contain basic sensors like shunts or NTC-resistors. New developments support designers in coping with the ongoing demands of higher power densities by adding necessary functionalities into the power electronics section, saving space, time and development effort. This integration is considered to be an ongoing trend, so future products are expected to combine even more powerful sensors or measurement technology.

Literature

[1] Domes, Daniel; Schwarzer Ulrich: IGBT-Module integrated Current and Temperature Sense Features based on Sigma-Delta Converter, PCIM 2009, Nürnberg, Germany

[2] Hogenauer, E. B.: An Economial Class of Digital Filters for Decimation and Interpolation, IEEE Transactions on Acoustics, Speech and Signal Processing, Volume 29, Issue 2, Apr 1981 pp. 155 – 162

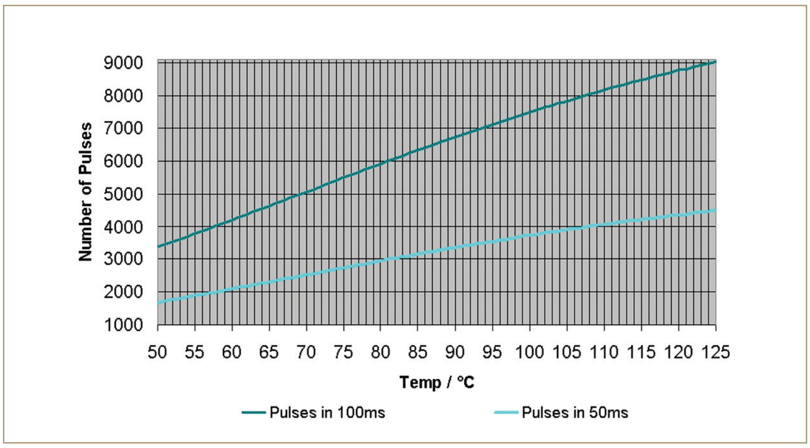

Figure 4: **Relationship of temperature and pulses counted**