Current measurement

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Precision measurement **with miniature sensor**

Digital current sensor TLI4970 provides engineers with precise results for currents up to 50A

Current sensors are used in numerous applications, ranging from solar inverters and electric drives, server and telecom products, power supplies and home appliances, through to electric and hybrid vehicles. The demand for these sensors is set to increase on account of the growing requirements relating to energy efficiency, more efficient energy conversion, electromobility and smart grids. In all these application areas, sensor requirements include small size, low losses, flexibility and cost-effectiveness, as well as great precision and reliability in operation throughout the entire life of the product. The new TLI4970 Hall-based current sensor satisfies all these requirements with its innovative features.

Detailed information about the currents flowing at a particular moment in time is required for a diverse range of applications, each with different criteria regarding accuracy (absolute and over the product's life), suppression of interference fields, protection against manipulation, measuring range, power loss, bandwidth, dimensions and costs. Against this backdrop, various methods have been devised for current measurement.

In the case of magnetic-field based sensors, it is possible to distinguish between an open-loop and a closed-loop configuration. With open-loop sensors, the primary current generates a magnetic field in a ring core, which in turn is converted by a Hall sensor into a measuring voltage. At the same time, the magnetic flux generated by the primary current is concentrated inside the magnetic circuit. In the case of closed-loop sensors, the magnetic flux generated by the primary current is balanced with the aid of a secondary winding, which involves using a Hall sensor with corresponding electronics. Both approaches have limitations due to core losses, saturation and hysteresis effects, and long-time drift. Compared with the conventional open-loop and closed-loop systems with magnetic cores, the TLI4970 provides greatly improved accuracy, as shown in Figure 1. The error is specified as an initial maximum of 1.0%, with 1.6% over the total life of the product.

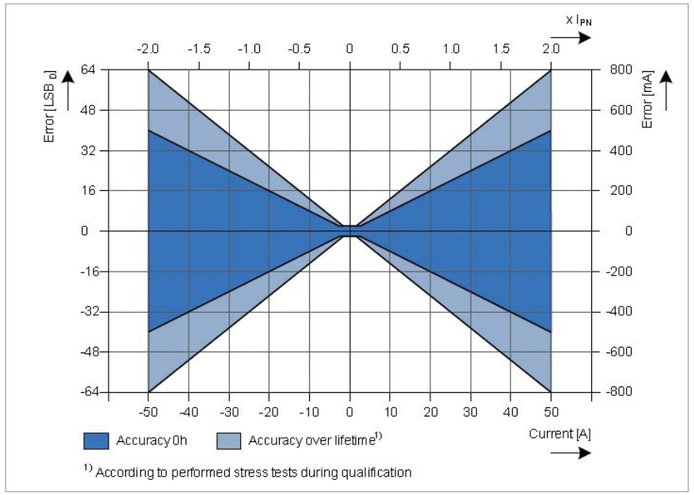
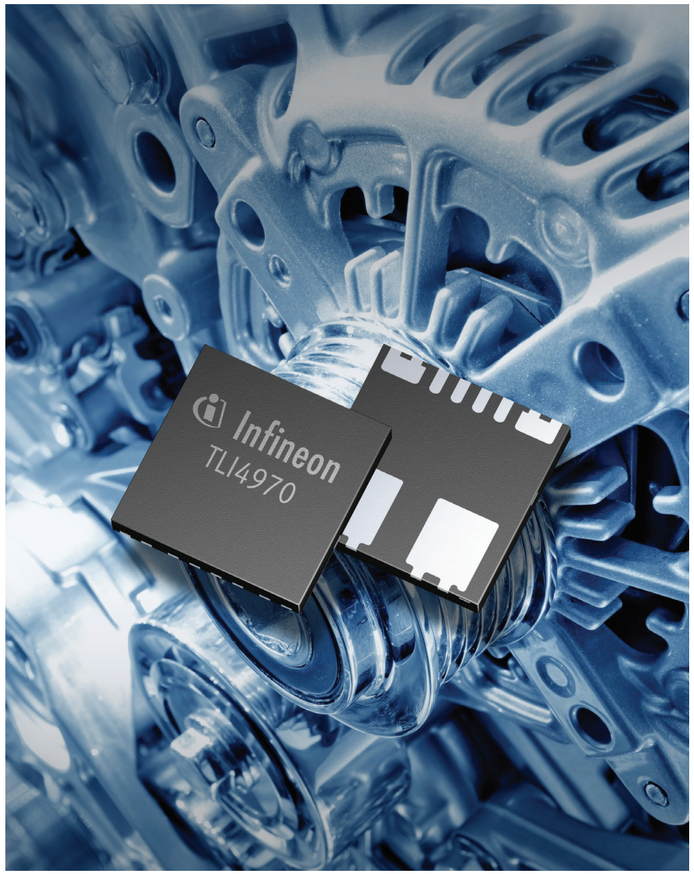


Figure 1: **The TLI4970 is highly accurate over the complete temperature range and product life, realizing an initial maximum error of 1.0%, with 1.6% over the total life of the product**

Miniaturized high-precision

The TLI4970 is a high-precision current sensor from Infineon, based on proven Hall-effect technology, with galvanic isolation between the primary side (conductor rail) and the secondary side (interface to the microcontroller). The core-less concept, without a magnet flux concentrator, as in the case of open-loop configurations, permits substantial miniaturization and does not exhibit any hysteresis effects. The sensor is implemented inside an extremely compact surface-mount (SMD) package and



requires only a quarter of the area of comparable chips, as shown in Figure 2. In addition, the differential measuring method permits excellent suppression of stray fields. The fully digital sensor solution is designed for ease of use, as no external calibration or additional components (such as A/D converters, operational amplifiers or voltage references) are required. As a result, this permits corresponding simplification of the system designs, coupled with a reduced PCB area and lower costs.

The differential measurement principle integrated into the TLI4970 sensor suppresses interference caused by external magnetic fields. Accordingly, the sensor achieves an extremely low offset of just 25mA. With conventional current measurement principles, the measuring accuracy

Figure 2: **The TLI4970 in the industry-wide smallest packaging saves PCB space**

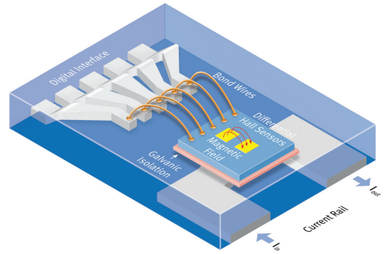


Figure 3: **Schematic design of the TLI4970. The flow of current through the conductor rail on the primary side induces a magnetic field, which is measured by the two differential Hall elements**

is always governed by the ambient conditions (for example, the temperature). In addition, substantial, non-deterministic drifts and aging phenomena are encountered. These can have a negative impact on the accuracy of current measurements, thus necessitating precautions in terms of system design. The TLI4970 precludes such dependencies due to the fact that it incorporates separate structures for measuring the temperature and the mechanical stress. By measuring both variables separately during operation, it is possible to constantly ensure effective compensation – the foundation for long-term measurement stability and, as a result, for highly efficient, reliable and cost-optimized inverters and motors.

Using the TLI4970, it is possible to measure alternating and direct currents up to ±50A in such applications as solar inverters, power supplies with power factor correction (PFC), charging devices and electric drives. The contactless measuring principle does not cause any additional losses, making it ideally suited for current-saving designs (R_p <0.6mΩ). Thanks to its integrated stray field suppression, the sensor is highly robust with regard to external magnetic fields.

In addition to precise current measurement, efficient protection of the power stage is also provided. External short circuits can create critical over-currents. To keep the latency time as short as possible, the TLI4970 provides a separate signal path for the protection. The sensor needs only 1.8µs to detect a related error condition. In order to fine-tune the over-current threshold to the requirements of the application, the system developer can program both the current value and the subsequent filtering in the sensor.

The integration of the current path into the SMD packaging enables the calibration of the sensor before shipment. Therefore complex calibration by the customer after assembly is unnecessary.

The TLI4970 is one of the first current sensors on the market to provide measurement results via the digital 16bit SPI bus (13bit current value). The TLI4970 integrates a differential amplifier, filter and

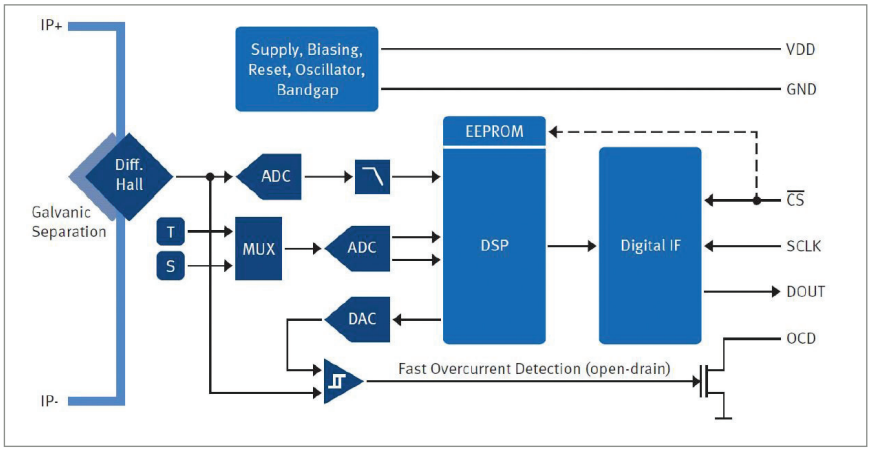


Figure 4: **The block diagram of the TLI4970. The OCD signal path is separate from the current signal path and features a programmable glitch filter**

signal processing. Furthermore, it supports galvanic isolated measurement with up to 600V operation voltage and 3.6kV test voltage.

Design and functional principle

Figure 3 shows the principle design of the TLI4970 and Figure 4 outlines the corresponding block diagram. The flow of current through the conductor rail on the primary side induces a magnetic field, which is measured by the two differential Hall elements. The Hall elements are galvanic isolated from the conductor rail. The signal from the Hall elements is digitized directly by a delta-sigma A/D converter. Downstream from the programmable (0-18kHz) low-pass filter, signals are processed in the DSP.

The temperature (T) and mechanical stress (S) at the chip are measured and digitized independently of the primary current by a second A/D converter. The DSP then uses the temperature and stress information to balance the raw current signal. Finally, the balanced signal is output via the IF and SPI.

Rapid over-current protection

Rapid detection of an over-current in the measuring path is possible via the over-current detection (OCD) pin. The OCD signal path is separate from the current signal path and features a programmable glitch filter. It is also possible to set the symmetrical threshold for the OCD output, from 0 to +/-90A, in increments of 3A. This enables negative and positive over-currents to be detected. The glitch filter time can be programmed from 150ns to 1,550ns in increments of 100ns.

Connected with the logic input of a microcontroller, the pin can, for example, trigger an interrupt in the microcontroller, shut down the system if needed, and/or protect it against damage. The open-drain architecture permits the connection of the OCD pins of several TLI4970 sensors to one single microcontroller input pin.

Robust against interference

When using current sensors based on Hall elements, it is highly important to minimize the influences of external stray magnetic fields. In this respect, the TLI4970 is extremely robust against external magnetic fields. As such, the position of the external magnetic fields in relation to the conductor rail plays an important role. If the corresponding distortion source is vertical to the conductor rail, there are essentially no negative influences due to crosstalk, since the magnetic field is parallel to the Hall elements. If the distortion source is vertical to the conductor rail, this ensures a high level of immunity thanks to the differential measurements. Crosstalk can only occur if the distortion source is parallel to the integrated conductor rail. In this event, the TLI4970 offers efficient crosstalk suppression. For 50A currents, crosstalk effects of just 1mA at a distance of 3mm were measured.

Space and cost saving

The TLI4970 is available in a very small SMD package (PG-TISON-8) with dimensions of just 7mm x 7mm x 1mm for cost-effective assembly. It weighs just 0.2g. In conjunction with integrated functionality in the form of level shifters, filters, galvanic isolation plus secure communication including parity check, it is possible to substantially reduce the overall space requirement as well as material costs.

Extensive design support

The TLI4970 evaluation kit makes evaluation simple. A graphical user interface enables the sensor to be programmed easily and tested quickly for a whole range of system settings. The evaluation kit includes an analog board (Figure 5), which converts the digital SPI output signals into analog signals. This enables developers to test the performance of the TLI4970 directly for their existing system designs that have analog interfaces. Infineon has also ensured that the analog board is pin-compatible with conventional current sensors. ■

Figure 5: **Fast and easy transition to digital current measurement with the TLI4970 analog board**