Enabling Precision Current Sensing Designs with Non-Ratiometric Magnetic Current Sensors

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Electronically controlled systems use local or remote sensor elements to monitor operating parameters for loop control, diagnostics, and system feedback. The quality and accuracy of this information is a key limit to system performance and control capability. In the past, where many electronics had poor control of sensor voltage supplies and references, ratiometry was used to reduce the errors due to parameter fluctuations. In modern systems, with tight control of references to signal chain elements such as analog to digital converters (ADCs), non-ratiometric sensors like the TMCS1100 magnetic current sensor enable improved noise immunity, precision, and design flexibility.

The linear transfer function of a current sensor is shown in Equation 1 with sensitivity (S) and zero current output voltage as gain and offset.

$$V_{OUT} = I_{IN} \times S + V_{OUT,0A} \quad (1)$$

In a fully ratiometric device, both sensitivity and offset vary with the supply, so that full-scale input current always results in an output at either ground or supply, as illustrated by Figure 1.

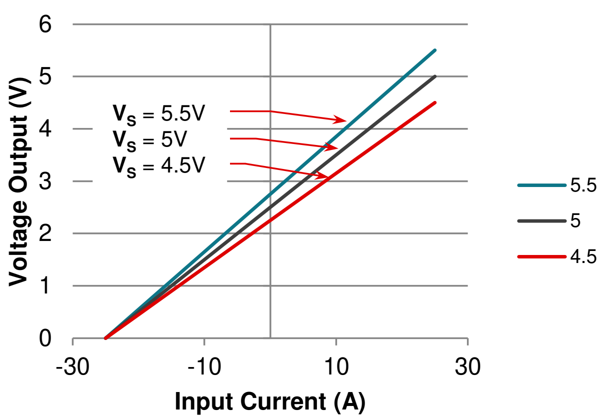

Figure 1. Fully Ratiometric Current Sensor Response

For a non-ratiometric current sensor, the change in voltage output for a given input current change has no dependence upon the supply, and the zero current output voltage is always a fixed voltage, as shown in Figure 2.

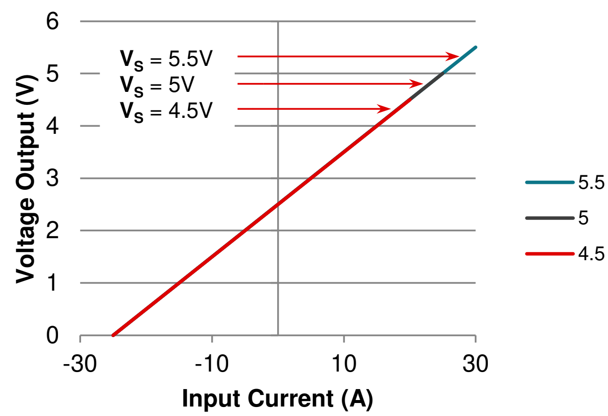

Figure 2. Non-Ratiometric Current Sensor Response

Ratiometry is effective in systems where a common sensor supply and ADC reference is expected to vary widely in operation, as shown in Figure 3. Ratiometry mitigates some of the error caused by a varying, ADC, full-scale reference by also scaling the sensor output range. However, ratiometry scaling is never perfect, and introduces some additional error to the system. It must be fine-tuned over a limited supply range for high accuracy, which reduces design flexibility, as sensor output range must identically match ADC input range. In addition, supply noise is directly injected into the output signal, which causes poor power supply rejection (PSR).

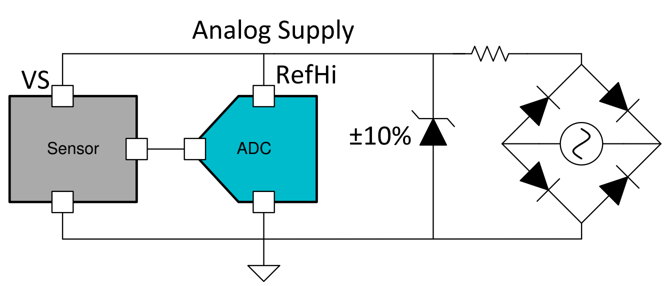

Figure 3. Ratiometric Sensor Architecture for Poorly Regulated Supplies

For systems where a stable ADC reference is available, either with a dedicated internal supply or an external reference, ratiometry only introduces additional error and noise. In these cases, such as in architectures shown in Figure 4, a current sensor with fixed sensitivity provides a superior solution. With a fixed sensitivity, the device has significant PSR, and can even have a different supply voltage than the ADC full scale. This is commonly the case with integrated microcontroller ADCs. This also allows for optimization of fixed-sensitivity internal circuits, which provide higher total accuracy and lower drift.

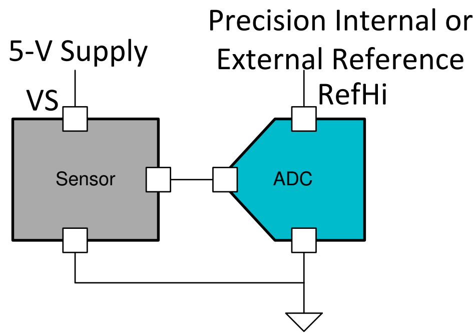

Figure 4. Non-Ratiometric Architecture for Precision Signal Chains

The TMCS1100 and TMCS1101 are precision, isolated magnetic current sensors with fixed sensitivity. The TMCS1100 has an externally supplied reference pin that sets the zero current output voltage, which allows for both custom dynamic measurable ranges and a fully differential signal chain all the way to the ADC, as shown in Figure 5. This architecture, coupled with a precision, fixed-sensitivity signal chain, enables an industry-leading temperature stability with better than 1% accuracy from –40°C to 125°C.

Current sensors are often utilized in power systems where the sensor is often located near the power switching elements, far from the ADC and controller. This results in switching noise and transient events coupling directly into analog supplies and signals. A fixed-sensitivity sensor with an external reference allows the system to reject both of these noise paths. The improved PSR rejects noise injection through the analog supply and the external reference allows for pseudo- or fully-differential sensing, rejecting noise coupling into output signals. This results in lower system-level noise and improved dynamic range, as the differential measurement cancels any drift in the zero current output voltage.

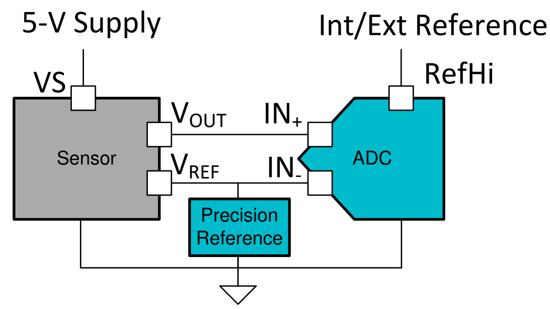

Figure 5. TMCS1100 Optimized Signal Chain

Design flexibility is greatly enhanced by this architecture, as the zero current output can be tailored to any use case condition. Bi-directional, uni-directional, and custom dynamic sensing ranges are achieved by appropriately selecting the reference voltage. Because there is no constraint between the sensor supply, reference, and ADC reference, the sensor output can cross voltage supply domains with no scaling required.

The TMCS1101 has an internal resistor divider providing the reference, with variants of either 50% or 10%, of the supply for bi-directional and uni-directional current sensing respectively. It features a fixed sensitivity as well, and provides better than 1.5% accuracy across the full temperature range.

Table 1. Adjacent Tech Notes

Document Type	Title
Application Note	*Low-Drift, Precision, In-Line Isolated Magnetic Motor Current Measurements* (SBOA351)
Application Note	*Integrating the Current Sensing Path* (SBOA167)