Current sensing with INA226-Q1 in HEV and EV BMS subsystems

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Introduction

A typical HEV and EV battery management system (BMS) can have both high-voltage and low-voltage subsystems. The low-voltage subsystem generally refers to the 12-V to 48-V systems that are responsible for managing power train, lighting, air-conditioning, and infotainment systems. The load current can vary widely depending on the operating condition of the vehicle. In order to measure current accurately over a wide dynamic range, precision current sense amplifiers (CSA) that are stable over temperature are highly desirable. The CSA can be configured as either high side or low side in a BMS system.

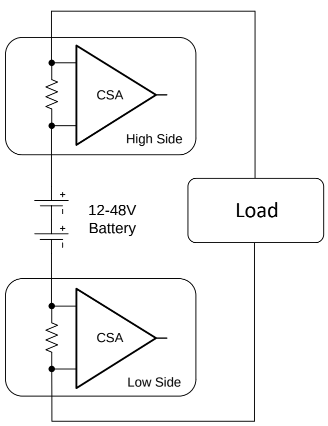

Figure 1. Typical Current-Sensing Configurations in a Low-Voltage BMS Subsystem

INA226-Q1 Features

The INA226-Q1 is a current shunt and power monitor with an I^2C- or SMBUS-compatible interface featuring up to 16 programmable addresses. The INA226-Q1 senses bus voltages that can vary from 0 V to 36 V, and shunt voltage that can vary from –81.9175 mV to +81.9175 mV, independent of the supply voltage. The differential shunt voltage is measured with respect to the IN– pin, whereas the bus voltage is measured with respect to ground. The device operates from a single 2.7-V to 5.5-V supply, drawing a typical quiescent current of 330 µA during active conversion.

With an integrated high-performance analog-to-digital converter (ADC), the INA226-Q1 eliminates many of the error sources otherwise found in a discrete solution consisting of op amp, resistor network, and ADC.

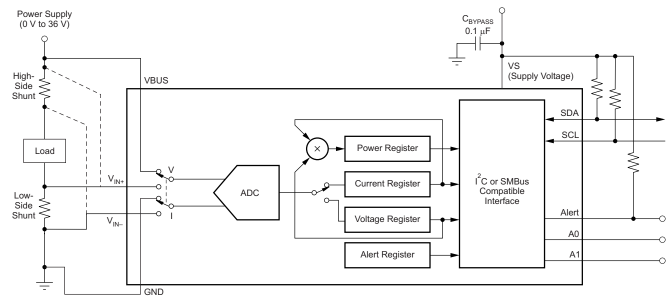

Figure 2. INA226-Q1 Block Diagram

The INA226-Q1 features an ultra-low input shunt offset of 10 µV; and shunt voltage resolution of 2.5 µV. The exceptional accuracy and resolution make the INA226-Q1 an excellent choice for current sensing applications where wide dynamic range is required. Ultra low drift makes one-time calibration a possibility thereby enables accurate measurements at low current levels.

Optimize for Speed and Accuracy of the INA226-Q1

Great flexibility is built into the INA226-Q1 ADC architecture. Conversion time and averaging can be optimized to achieve the best conversion speed and accuracy. Also, the conversion time and averaging can be independently configured for bus voltage and shunt voltage. Therefore, the bus voltage and shunt voltage can be sampled at different speeds. This design further increases the flexibility in designing an optimal sampling scheme for a given application.

For example, suppose the voltage, current, and power information is desired every 5 ms. The device can be configured with the conversion times set to 588 µs for both shunt- and bus-voltage measurements, and the averaging mode set to 4. This configuration results in the data updating approximately every 4.7 ms.

The device could also be configured with a different conversion time setting for the shunt- and bus-voltage measurements. This configuration allows for time to be focused on the more challenging measurement. In the BMS system, it is usually at the lowest current range level, which translates into the lowest shunt voltage. Bus voltage measurement can possibly be obtained with a reduced sampling time relative to the shunt voltage measurement. Using the same example, the shunt voltage conversion time can be set to 4.156 ms, the bus voltage conversion time set to 588 µs, and the averaging mode set to 1. This configuration also results in data updating approximately every 4.7 ms.

Comparative Study of Speed and Accuracy for the INA226-Q1

Increasing the conversion time or averaging effectively filters the input noise. The averaging feature can significantly improve the measurement accuracy. This approach allows the device to reduce noise coupled to the signal during measurements. A greater number of averages enables the device to be more effective in reducing the noise component of the measurement.

The internal ΔΣ ADC of the INA226-Q1 provides inherently good noise rejection. The conversion times selected can have an impact on the measurement accuracy. Longer conversion time allows averaging on a larger data stream, which in turn is a more precise representation of the analog input signal. In order to achieve the highest accuracy measurement possible, use a combination of the longest allowable conversion times and highest number of averages based on the timing requirements of the system.

The following graphs provide a visual contrast of the effects of different choices of conversion times and different number of averaging.

Figure 3 shows the effects of varying conversion time. In this test, both the shunt voltage and bus voltage (V_{CM}) are set to 0 V. Averaging is disabled; that is, the number of averaging is set to 1. The conversion time is set to 140 µs, 1.1 ms, and 8.244 ms, which correspond to each of the first, middle, and last third of the graph relative to the horizontal axis. As expected, the noise floor drops visibly as conversion time increases.

Figure 4 shows the effects of averaging when the conversion time is fixed. In this test, the conversion time is fixed at 140 µs. The number of averaging is set to 1, 28, and 1024, which correspond to the first, middle, and last third of the graph relative to the horizontal axis. Similarly, the noise floor drops dramatically as the number of averaging increases.

Figure 5 is obtained with the same condition as in Figure 4, except that the common-mode voltage is set to 25 V instead of 0 V. The change in common-mode voltage has an effect on the INA226-Q1 output; however, this effect is bound by the CMRR spec, which is typically 140 dB.

Conclusion

Current sensing in HEV and EV BMS subsystems faces the challenge of wide dynamic range. Digital precision current-sense amplifiers with ultra-low drift can greatly improve the overall performance while reducing system complexity.

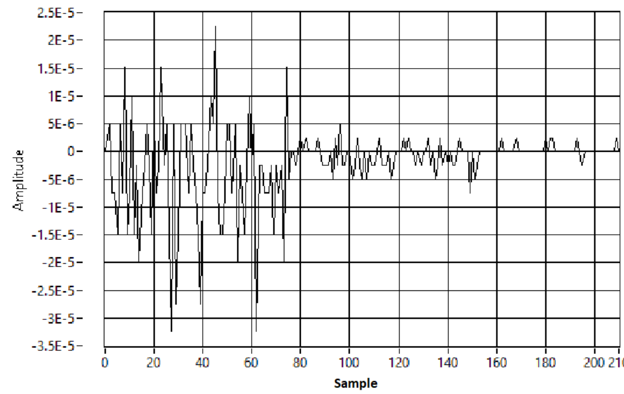

Figure 3. Noise Output (V) at Three Conversion Times – 140 µs, 1.1 ms, and 8.244 ms – With V_{CM} = 0 V

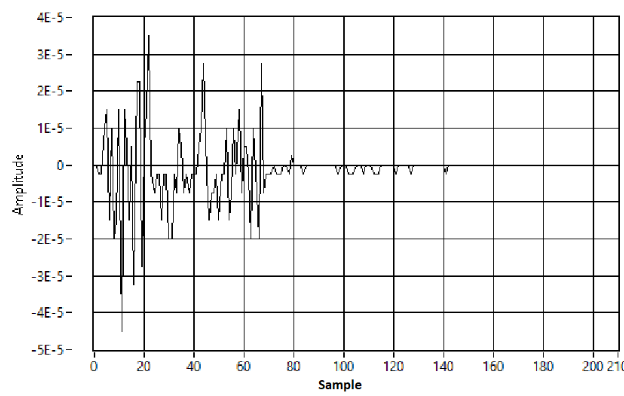

Figure 4. Noise Output (V) at Three Averaging Levels – 1, 128, and 1024 – With V_{CM} = 0 V

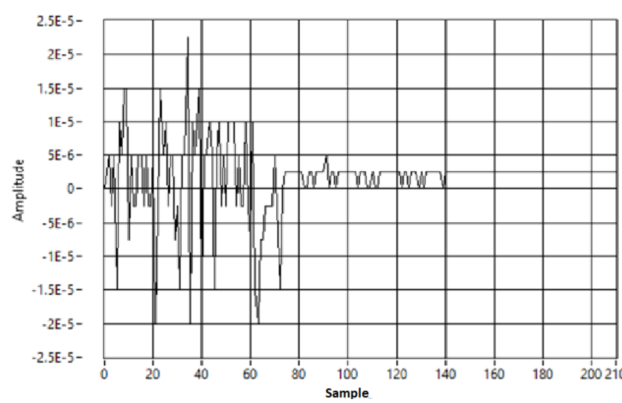

Figure 5. Noise Output (V) at Three Averaging Levels – 1,128, and 1024 – With V_{CM} = 25 V

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