

Simplify current and voltage monitoring with isolated SPI and I2C in your battery management systems (BMS)

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Introduction

With the growth of Hybrid Electric vehicles (HEV) and Electric vehicles (EV), the conventional 12 V circuits now need to communicate with higher voltage circuits. For the hybrid vehicles, this would be 48 V batteries whereas for the fully electric vehicles this could be 400 V or even more. These multiple voltage domains in the car make it mandatory to include isolation devices to protect the low voltage side components and circuits from the high voltage battery side. This adds a new challenge to the designers who were not used to isolation in the conventional vehicles. This document provides various options to isolate the ADC's in battery monitoring circuits.

Battery monitoring and over-current detection circuit

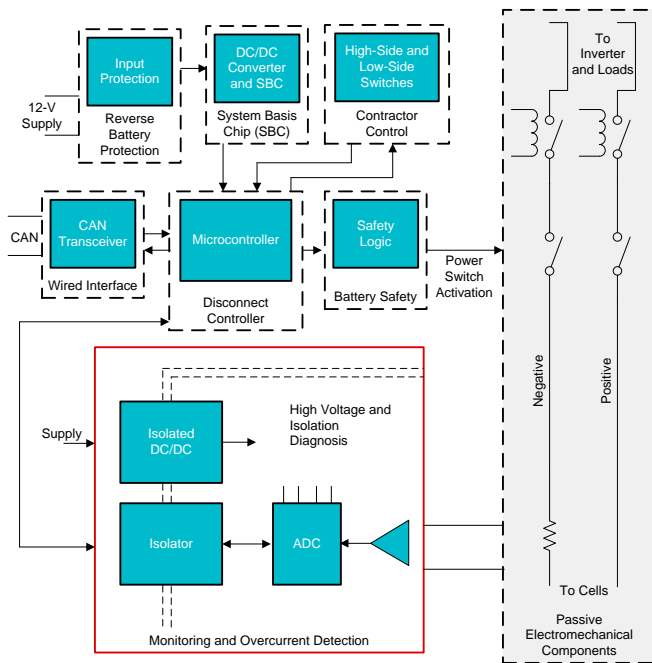


Figure 1. Typical monitoring and Over-current detection circuit in a BMS

Typical monitoring circuits consist of a shunt resistor in series with the system load. The voltage drop across this shunt resistor is indicative of the load current. The signal from the shunt resistor gets amplified and converted to digital signal before being fed to the microcontroller (MCU). Since the MCU is on the low voltage side while the measurement circuitry

comprising of the amplifier and the ADC is on the high voltage side, an isolation devices sits between these two circuits as shown in Figure 1. The type of isolator to be used depends on the interface used to communicate between the ADC and the MCU.

SPI Interface

Most commonly SPI interface is used for communication between the ADC and the MCU. The frequently used configuration for the isolation is 3 channels in one direction (SD, SCLK, CS) and one in the opposite direction (SDO). This leads to a 3/1 digital isolator as shown in Figure 2. The ISO7741-Q1 is a 4 channel (3/1) device that is available in the reinforced rating (5 kVrms) in the wide SOIC-16 (DW) package or in the basic rating (2.5 kVrms) in the QSOP-16 (DBQ) package.

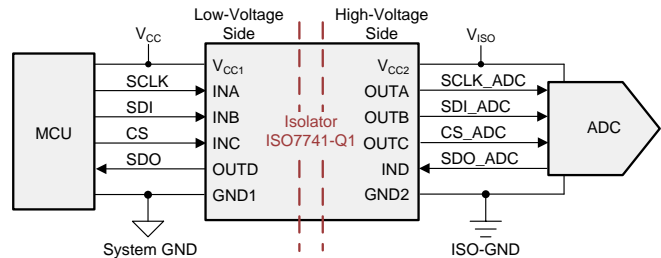


Figure 2. SPI Signals Isolated in Battery Management Systems

I2C Interface

When the ADC is communicating with only I2C signals, then the isolator also needs to change to support the I2C communication. The advantage of the I2C communication is the reduced number for traces on the board. SPI interface needs 3 or 4 wires while I2C communication can be done over two lines (one for data and one for the clock) as shown in Figure 3.

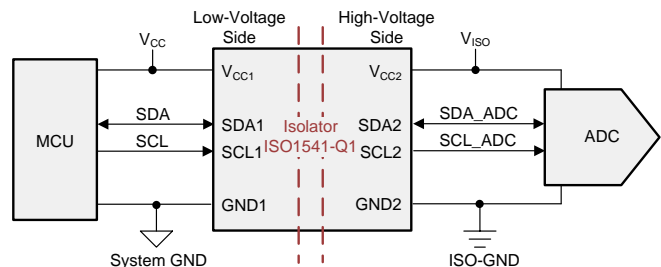


Figure 3. I2C Signals Isolated in Battery Management Systems

The data is bi-directional but the clock can be either uni-direction in the master-slave configuration or could be bi-directional as in the multi-master configuration or in systems that utilize clock stretching. The ISO1540-Q1 has two isolated bidirectional channels for clock and data lines while the ISO1541-Q1 has a bidirectional data and a unidirectional clock channel. Both these devices support 2.5 kVrms basic isolation and are available in the SOIC-8 (D) package.

There are other ways to implement the I2C functionality using a standard isolator. More details on designing a reinforced isolated I2C bus interface by using digital isolators can be found [here](#).

Discrete Isolated Power

In addition to isolating the signals, the power supply between the ADC and the MCU also needs to be isolated. In some systems there are step down regulators to provide the power supply needed by each side and in those cases there is no need to generate the isolated power supply separately. But in case there is a need to provide the isolated power supply from the MCU side to power up the ADC and the amplifier, then SN6501-Q1 provides a push pull driver to drive the primary of the isolation transformer that provides the required load current and voltage on the secondary side. Simple rectifying passives and an LDO (optional) complete the isolated power circuitry as depicted in [Figure 4](#) and [Figure 5](#).

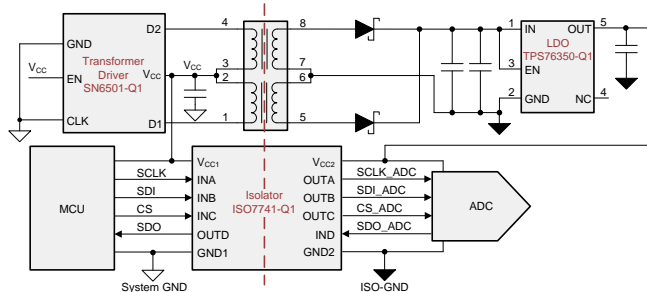


Figure 4. Discrete isolated Power Supply for Isolated SPI

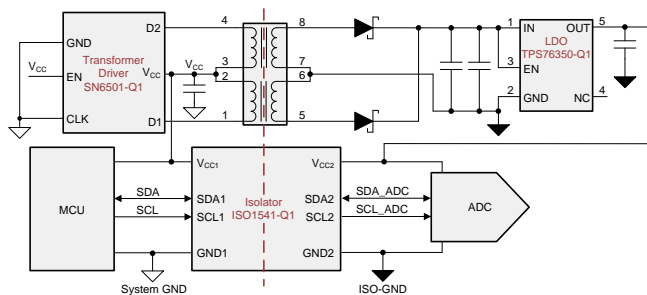


Figure 5. Discrete isolated Power Supply for Isolated I2C

Integrated Isolated Power

Discrete isolated power solution consumes larger board space due to the external transformer size, not just in the X and Y dimension but also in the height (Z) dimension. [Figure 6](#) shows an alternate solution that uses a digital isolator with integrated power. In this solution, the isolated power circuitry is included inside the isolator device thereby making this solution compact and system certifications easier with only a single device to certify. With discrete isolated power solution, the external transformer can be larger so the switching frequency is lower and so are the emissions. With integrated power solution, since the transformers are smaller in size, the switching frequencies are higher leading to higher emissions as compared to the discrete solution. But these emissions can be reduced by using stitching capacitors as demonstrated in this [application note](#).

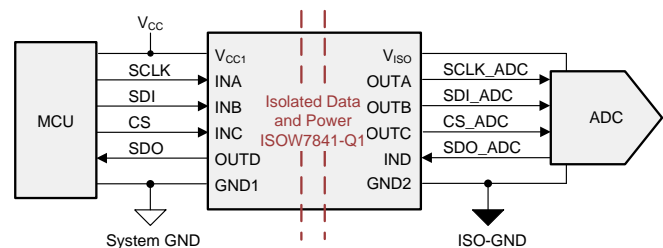


Figure 6. Integrated Isolated Power Supply for Isolated SPI

Conclusions

Digital isolators or isolated I2C devices can be used for protection of the low voltage side from the high voltage side in battery monitoring sub-circuit of a BMS. The selection of the appropriate isolation depends on the interface (SPI or I2C) used. Discrete or integrated isolated power supplies can be selected depending on the trade-offs of emissions, board space and design simplicity.

Table 1. Device Features

Device	Description	Performance parameters	Package
ISO1540-Q1	Low power Isolated Bidirectional Clock, Bidirectional I2C Isolators	2.5kVrms, 1MHz	SOIC-8
ISO1541-Q1	Low Power Isolated Unidirectional Clock, Bidirectional I2C Isolators	2.5kVrms, 1MHz	SOIC-8
ISO7741-Q1	High-Speed, Low-Power, Robust EMC Quad-Channel (3/1) Digital Isolator	5kVrms, 100Mbps	SSOP-16, SOIC-16
ISO7742-Q1	High-Speed, Low-Power, Robust EMC Quad-Channel (2/2) Digital Isolator	5kVrms, 100Mbps	SSOP-16, SOIC-16
SN6501-Q1	Low-Noise 350 mA, 410 kHz Transformer Driver	High Primary-side Current Drive: 350 mA (5V) / 150 mA (3.3V)	SOT23-5
ISOW7841	High-Efficiency, Low-Emissions, Reinforced Digital Isolator With Integrated Power	0.65W Output Power, 5kVrms, 100Mbps	SOIC-16

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