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

Neel Seshan, Product Marketing Engineer, Isolation, Interface Group

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

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.

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.
The data is bi-directional but the clock can be either unidirectional 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.

**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.

**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**

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

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES “AS IS” AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, or other requirements. These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI’s products are provided subject to TI’s Terms of Sale (www.ti.com/legal/termsofsale.html) or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI’s provision of these resources does not expand or otherwise alter TI’s applicable warranties or warranty disclaimers for TI products.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2018, Texas Instruments Incorporated