Temperature Monitoring in HEV and EV Traction Inverter Systems Using ADS795x-Q1

Description

In electric vehicles (EV) and hybrid electric vehicles (HEV), traction inverters convert high-voltage (HV) DC power from a 400–800 V battery stack to alternating power that drives multi-phase motors. Typically, these motors are driven by insulated gate bipolar transistors (IGBTs) that are capable of handling high currents of up to 800 A. Due to the high voltages and high currents involved, maintaining system performance and reliability is essential. Therefore, it is very important to monitor battery voltage and temperature and feed this information back to the main controller. Texas Instruments offers the ADS795x-Q1 family of multi-channel, 8-, 10-, or 12-bit SAR ADCs to enable multi-channel sensor measurement and monitoring.

This document discusses how to monitor multiple temperature sensors in a traction inverter subsystem, as well as how the features of the ADS7953-Q1 make this ADC the default choice for HEV/EV powertrain monitoring applications. However, note that this discussion applies to the entire ADS795x-Q1 family of devices, as well as many other automotive-qualified SAR ADCs (see Table 1).

Typical HV Traction Inverter Block Diagram

Figure 1 shows a typical system block diagram for a HV traction inverter. In most of these HV systems, the main controller and logic block that govern traction inverter functionality are located on the secondary (12 V battery) side.

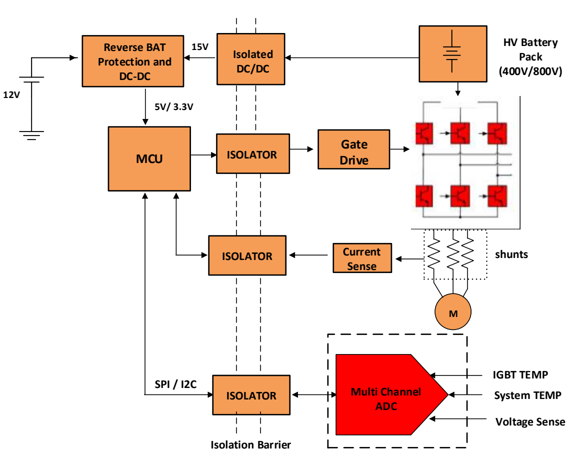

Figure 1. Typical HV Traction Inverter

The HV battery stack voltage and IGBT temperature are monitored by the dedicated supervisor/monitoring device placed on the primary (HV battery pack) side. The main controller communicates with the supervisor/monitoring device over an isolated digital interface to monitor any fault conditions. Shown in red in Figure 1, this monitoring device is typically a multi-channel, high-sample-rate ADC like the ADS7953-Q1 that allows the main control block to access data at the desired read rate.

Monitoring Traction Inverter IGBT Temperature

As mentioned previously, IGBT temperature is one of the critical parameters that need to be monitored in a traction inverter subsystem. IGBT temperature is a key indicator of an IGBT overload condition and must be monitored to detect faults such as IGBT shoot-through effects or phase-to-phase or phase-to-earth short circuits. Generally, analog temperature sensors such as NTCs are used to measure IGBT temperature as these inexpensive devices help reduce system cost. In some cases, these temperature sensors may be integrated into IGBT modules to simplify the overall design. Figure 2 shows a typical block diagram of an NTC inside an IGBT module interfaced with an ADC.

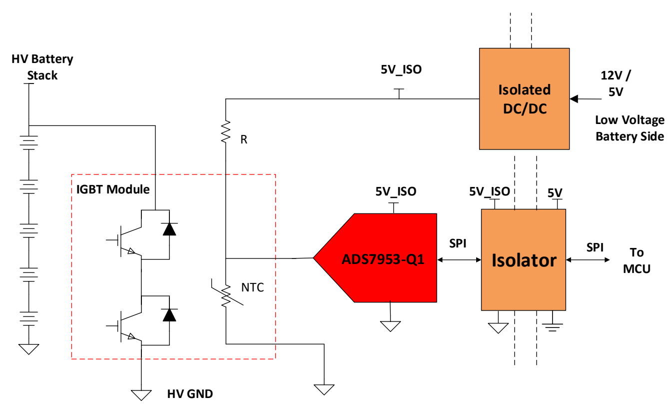

Figure 2. Typical Block Diagram of NTC Interfaced with ADC on HV Battery Pack Side

The typical NTC impedance in one of these integrated IGBT modules is on the order of a few kilo Ohms (kΩ) to keep overall system current consumption low. The NTC's high impedance must be taken into account when interfacing a sensor directly with a SAR ADC. To

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address settling issues due to the high impedance of the ADC input source, a signal conditioning block is generally used to drive the SAR ADC. For more information on how to drive a SAR ADC, refer to TI ADC Precision Labs.

Using the ADS7953-Q1 Multiplexer Output Feature to Reduce System Cost

Apart from IGBT temperature sensing, traction inverters employ multiple other temperature sensors (NTCs) to measure the system's ambient temperature and the battery stack temperature. All of these sensors exhibit similar output impedances and signal levels assuming they are biased from the same voltage source. Since all of these sensors need some sort of conditioning block when interfacing to an ADC, every additional sensor increases system cost and size due to the required external circuitry. However, each sensor could potentially use the same conditioning block due to their similar performance characteristics.

The ADS7953-Q1 SAR ADC has a multiplexer output feature that enables a common signal conditioning block between the multiplexer output (MXO) and ADC input (AINP). A common signal conditioning block (buffer or gain stage amplifier) scales the sensor voltage to match the ADC's full-scale range. This reduction in external circuitry not only reduces system cost, size and power, but also eliminates offset, gain and linearity errors that would otherwise be present using individual signal conditioning circuits. Figure 3 shows the typical block diagram for interfacing multiple NTCs with the ADS7953-Q1 using a common signal conditioning block.

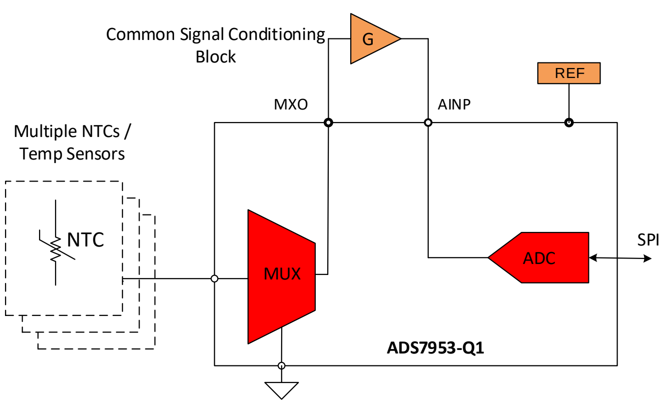

Figure 3. Typical Block Diagram Showing Multiple NTCs Interfaced with ADS7953-Q1

Using the ADS7953-Q1 GPIO and ALARM Feature for System-Level Diagnostics

Many traction inverters require system-level diagnostics that generate an alarm signal when a sensor output deviates outside of an acceptable range. The ADS7953-Q1 offers an ALARM feature that enables the user to independently monitor input signals on each channel against pre-defined thresholds. When an input signal crosses the high or low threshold, the ADC generates an alarm. The ALARM functionality can be configured as an output on any of the ADS7953-Q1's four general-purpose input and output (GPIO) pins. Or, for added diagnostic capability, the ADC's GPIO pins can be used as control signals to turn on relays, switches or LEDs if a fault condition is detected. Figure 4 shows a block-level diagram of the ADS7953-Q1 GPIO and ALARM features.

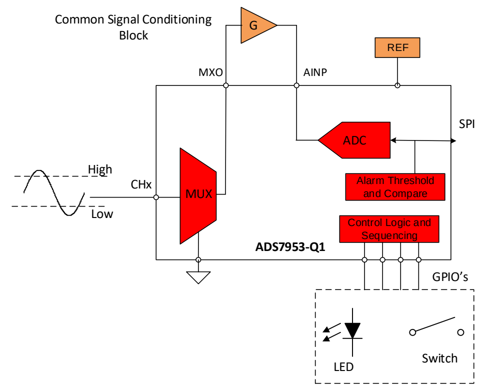

Figure 4. Functional Block Diagram of ADS7953-Q1 Showing GPIO/ALARM Functionality

Alternative System Recommendations

While this document has focused on temperature measurements in traction inverters using the ADS795x-Q1 family of SAR ADCs, these same principles can be applied to monitor voltage rails, temperature sensors and current sensor outputs in other HEV/EV powertrain end equipment such as Onboard Chargers (OBC), DC/DC Converters and Battery Management Systems (BMS).

Moreover, Texas Instruments offers additional ADCs for multi- channel monitoring in these HEV/EV systems. Table 1 summarizes some of these devices.

Table 1. Alternative Device Recommendations

Device	Description
ADC128S052-Q1	12-Bit 500-KSPS 8-Channel ADC With SPI Interface
ADS7828-Q1	12-Bit 50-KSPS 8-Channel ADC With I2C Interface

Conclusion

Monitoring temperature in traction inverter and other powertrain systems is important and helps with system-level diagnostics. The ADS795x-Q1 family of multi-channel, 12-bit SAR ADCs was specifically designed to address the common system requirements of reducing cost, size and power in all automotive powertrain applications.

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