Automotive Isolation Amplifier for Voltage Sensing

White Paper

Kenji Yamamoto, Andy Poh

Introduction

The introduction of electric and hybrid electric vehicles have added high voltage electric modules into the car. The battery stack in a hybrid can be in excess of 150V, higher for the inverter driving the motor. Avago Technologies' ACPL-782T automotive isolation amplifier, which is part of the R^{2}Coupler™, integrates many functions such as safe insulation, common mode transient rejection and analog sensing in a compact 300mil dual-in-line package.

Safe Insulation

The high voltages warrant the use of insulation components and optocouplers have been the component of choice here. As part of the R^{2}Coupler, ACPL-782T is targeted for long-life automotive applications. The thick triple insulation layer construction of the R^{2}Coupler forms the basis of the reinforced insulation, and being rated at working voltage of 891Vpeak and transient over-voltage of 6000Vpeak, the ACPL-782T can meet the insulation requirements of most automotive applications.

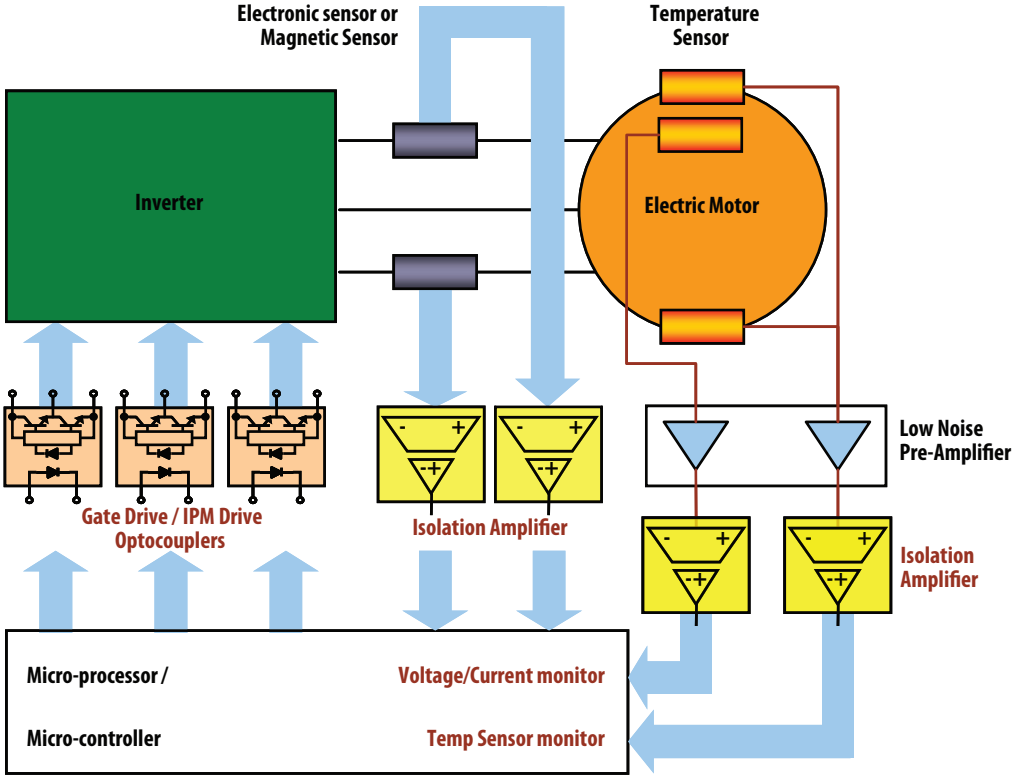

Figure 1. HEV Electric Motor Drive System

Signal Isolation

The switching of the inverter at high current drives the electric motor which generates high speed, high voltage transients in the system. This poses a tough challenge to the processor monitoring the rail voltage and multitude of analog sensors in terms of noise, common mode voltage and ground loop currents.

The ACPL-782T uses Σ–Δ architecture where the differential analog input is converted into digital pulses to be transmitted optically across the insulation barrier. The input-output capacitance, C_{I-O}, of the ACPL-782T is extremely low. This enables the common mode transient rejection performance to ensure all optical digital pulses are transmitted without missing bits. The optical signals are received by the photo-detector, decoded and converted to differential analog output.

System Accuracy Considerations

The input voltage range of the ACPL-782T is +/-200mV. For the full battery stack or the inverter rail voltage, which can be in excess of 200V, the resistor divider network, formed by R_A and R_B as shown in Figure 2, will step down the rail voltage by more than 1000 times to match the input voltage range of the ACPL-782T.

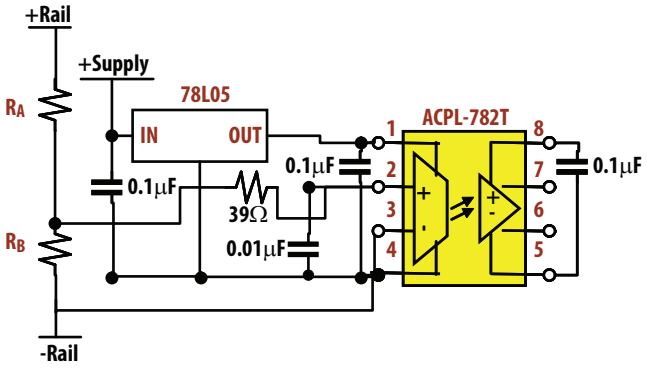

Figure 2. Stepping down the High Rail Voltage to match the Input Voltage Range of ACPL-782T

In this case where the resistor value of R_A is much larger than the resistor value of R_B, the precision of the resistors used and not their values will significantly affect the accuracy. The plot in Figure 3 shows that the divider error is approximately 1% (where $R_A / (R_A+R_B)$ is 0.999) for 0.5% accuracy resistors used.

ACPL-782T features a gain error of 2% and input offset voltage of 1% of full scale input, which can be easily accommodated where high accuracy is required, or calibrated off for high accuracy systems. The low gain drift, offset drift and nonlinearity across the automotive grade 1 temperature range is typically less than 1%, and will be seen in the system as it cannot be removed by calibration.

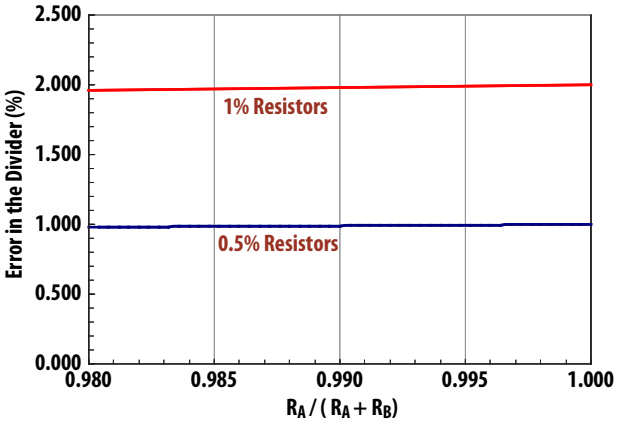

Figure 3. Divider Error for 0.5% and 1% Resistors Used

The ACPL-782T's Σ–Δ architecture shapes the noise profile to higher frequencies far beyond the desired operation bandwidth. This architecture exhibits a trade-off between bandwidth and signal-to-noise ratio (SNR) performance; high frequency noise and transients can then be filtered, yet providing sufficient bandwidth for the lower frequency analog signals. In Figure 4 below, the 10kOhm resistor and 150pF capacitor forms a first order output filter to reduce high frequency noise coming out of the isolation amplifier. This design can be adjusted to suit the desired bandwidth for the application. The table below shows the dynamic performance of the ACPL-782T where filtered bandwidth is narrow to improve the SNR performance.

Bandwidth (1ST Order Analog Filter)	Output Referred Noise	Input Referred Noise	Signal-to-Noise Ratio (Vin=0.2Vp)	Resolution
kHz	mV_{RMS}	mV_{RMS}	dB	Bits
106.1	5.3	0.7	46.5	7.4
63.7	3.9	0.5	49.2	7.9
43.0	3.2	0.4	51.1	8.2
33.2	1.0	0.1	60.8	9.8
13.8	0.7	0.1	64.2	10.4

Other Inverter System Considerations

In practical terms, the processor tends to be in a shielded module away from the motor. The input voltage range of the ACPL-782T is small, and to reduce noise introduced into the input of the amplifier, it would be preferred to locate the automotive isolation amplifier close to the voltage rail to be monitored. The ACPL-782T has a fixed gain of 8. Noise entering the output side will have less effect than noise, of similar amplitude, entering the input side.

The differential output configuration of the amplifier facilitates transmission of the voltage over twisted-pair cables to the processor. The output can then be terminated with high impedance, and through another first order analog filter, to provide accuracy readings all the way to the processor. See Figure 4 for this proposed configuration.

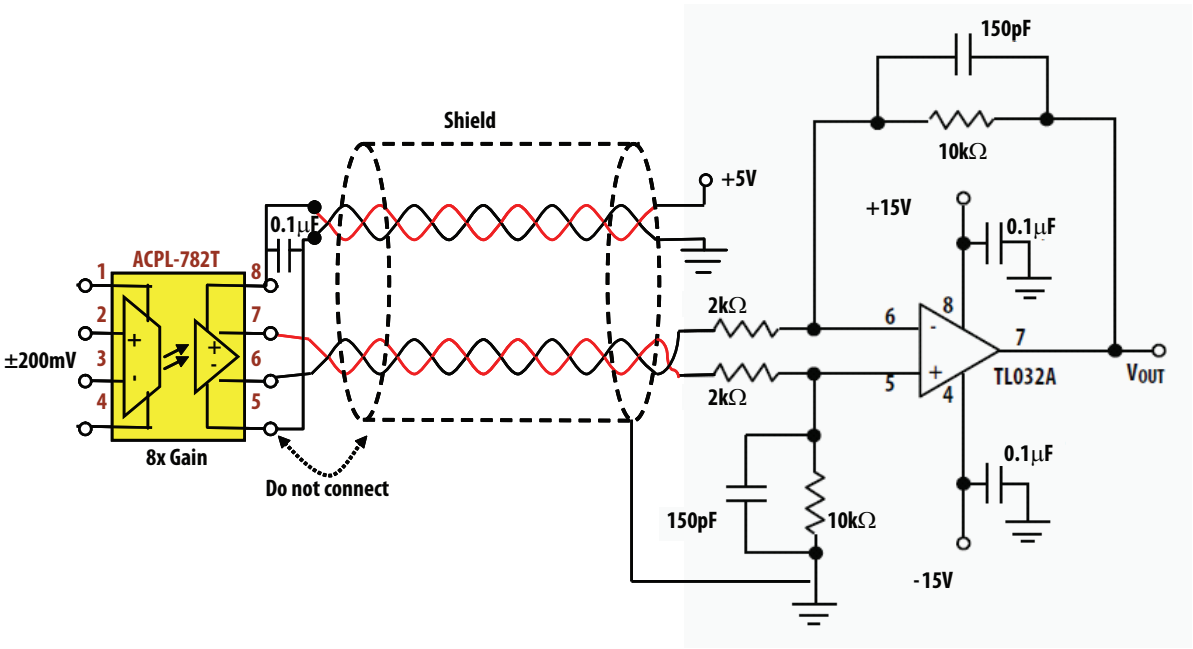

Figure 4. Remote Voltage Sensing Configuration with ACPL-782T

Battery Cell Voltage Sensing

Other than voltage sensing on the inverter module, many voltage sensing nodes can be found in battery cell voltage monitoring. From NiMH battery systems where battery stacks of about 13V to individual cell voltage of Li-Ion battery of about 3.6V can all rely on the ACPL-782T to protect, as well as level-shift, the processor from the high voltage of the full battery stack. The monitoring of the full battery stack voltage and output voltage to the boost converter will see similar step down ranges as the inverter.

Conclusion

As part of R^2Coupler, the ACPL-782T is focused on reinforced insulation and reliability. The low input-output coupling capacitance of the optically-isolated amplifier provides extremely high common mode transient immunity to add robustness to the system. Employing Σ–Δ architecture, the accuracy provided by the amplifier makes it suitable for many voltage-sensing automotive applications and allows for balance between bandwidth and signal-to-noise ratio.

For product information and a complete list of distributors, please go to our web site: **www.avagotech.com**

AV02-1790EN - March 18, 2009