Automotive Off-Board Sensor Power Considerations

One doesn't need to look long at modern cars to see that sensors are ubiquitous and plentiful throughout the body of a vehicle. And their purposes are diverse, from keeping the cabin climate at a cool, stable temperature to detecting when a door is ajar to determining throttle position. However, depending on what is being sensed, their location may often times be in remote areas that are not near a control module. In such cases, their excitation voltage and signal, whether analog or digital, is transmitted via wire harnessing.

This presents its own set of challenges since wire harnessing introduces another potential point of failure. Wire harnessing, as seen in Figure 1, typically bunches together many wires that route along the vehicle frame. Such proximity to other wires and the chassis can lead to unwanted shorting that must be anticipated and protected against.

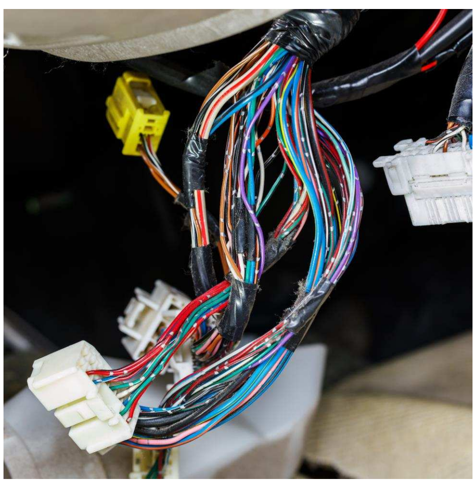

Figure 1. Typical wiring harness found in a vehicle

Failure Modes and Protection

There are four main failure modes as regards wire harnessing: a short to the chassis (or GND), a short to the battery potential, a short to another potential, or an open circuit. Before considering the impacts of each failure, it's helpful to look at a simplified control unit sourcing power to the remote sensor like the configuration shown in Figure 2.

One DC/DC converter or LDO, is used to supply 5V to the MCU and ADC. However, an additional regulator (a tracking LDO in this case) or load switch is required to provide 5V to the off-board sensor. This is because, in the case of a failure event with the wire harnessing, the control unit needs to be protected.

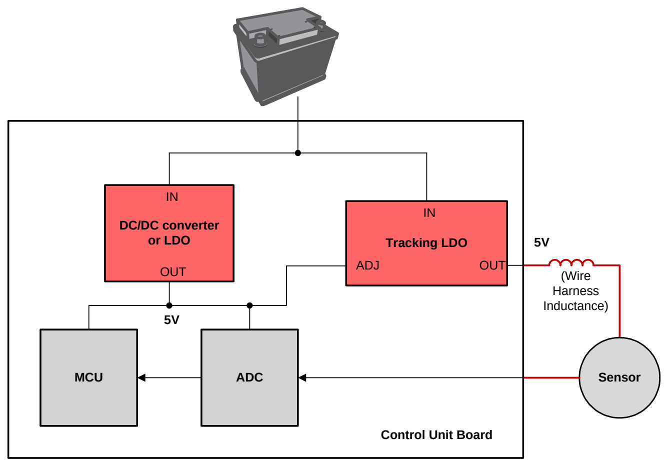

Figure 2. A typical configuration for providing off-board power using a tracking LDO

Consider a short-to-GND failure, as shown in Figure 3. In such an event, the regulator or load switch supplying the sensor must have a current limit that activates quickly. In the case of an LDO, this puts the linear regulator into a constant current mode that can subsequently trigger thermal shutdown due to the increased dissipation across the device. The MCU and ADC, unaffected by the failure event, will be able to detect a failure given the absence of a sensor signal.

A short-to-battery failure is also possible. This could potentially bias the output of the regulator higher than the voltage at the input terminal, as shown in Figure 3. Unimpeded, current will try to flow backward through the regulator. Fortunately, there are robust LDOs that incorporate back-to-back MOSFETs that prevent reverse current flow.

An alternative, common option is to add a diode in series with the input to prevent reverse current and subsequent damage to the regulator. This option, however, adds cost and contributes to the voltage drop across the device in the case of an LDO. Again, with either implementation, the MCU, ADC and rest of the control unit is unaffected by the wire harness failure.

It should be noted that the shorting of the output of the regulator to any voltage higher than the regulated voltage has the potential to damage an IC. This is why, whether the output is shorted to 9V, a 12V battery potential or any other voltage, the chosen regulator must be able to withstand such exposure without blowing the internal ESD cells. This rating is typically included in the Absolute Maximum Ratings section of the device datasheet.

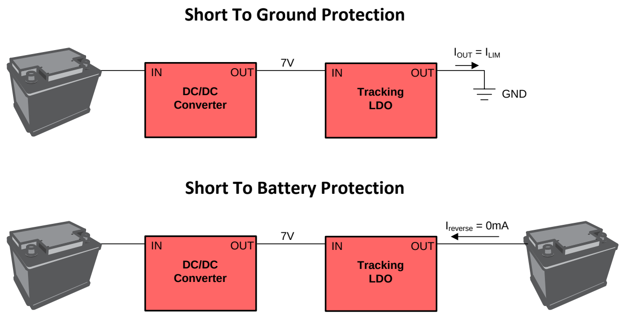

Figure 3. Two failure scenarios for off-board power supplies

Since any of these failures is possible with wire harnessing, the regulator or load switch supplying off-board power must be robust and incorporate various kinds of protection to shield the control unit from damage. This, however, is only the first consideration of a regulator powering an off-board sensor.

Tracking LDOs and Measurement Accuracy

In addition to protecting the control unit from wire harness failures, a special type of regulator is sometimes required to supply off-board sensors. This type of regulator, a tracking LDO, is specially designed to supply power to sensors with ratiometric outputs. These include many temperature sensors (like NTCs) and rotational sensors (like hall-effect sensors).

Since a sensor's ratiometric output is proportional to the excitation voltage, an accurate reading from the ADC requires its reference voltage to be the same as that of the sensor supply voltage. This is problematic with a traditional LDO given that the output voltage of one LDO may not be exactly the same as another due to differences in process, junction temperature, and line and load variations. Such incongruence can lead to inaccurate readings.

To overcome this, a tracking LDO does not have an internal reference voltage like a traditional LDO. Instead, the inverting input of the internal error amplifier is bonded out to an ADJ pin. This pin can then be connected to the voltage rail being supplied to the ADC reference, as shown in Figure 2. The LDO is then put into a unity gain configuration.

This topology allows the tracker LDO output to track the supply voltage of the ADC reference. As such, the excitation voltage of the sensor will be very close to that of the ADC reference voltage. With the TPS7B4253-Q1, the output will track the ADJ pin voltage with a maximum deviation of ±4mV.

To understand the value of a tracker LDO, it helps to look at an example. Consider an HVAC system where the temperature in the cabin is being gauged by a remote NTC and an 8-bit ADC.

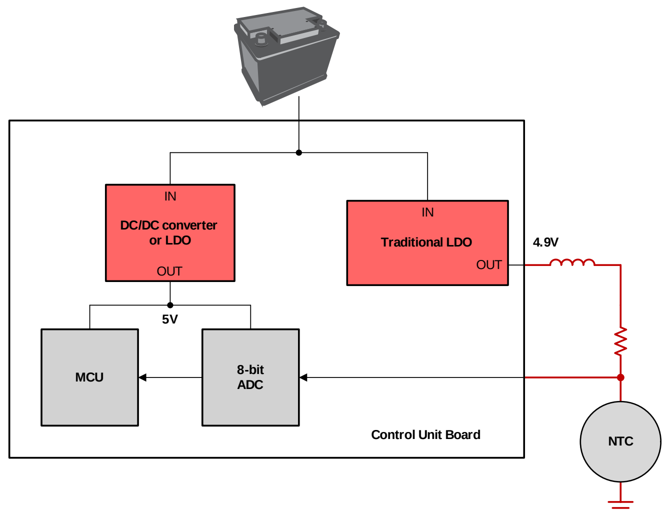

Figure 4. Providing power to a ratiometric sensor with a non-tracking LDO

If the voltage being supplied to the NTC is only 4.9V, then the voltage being read at the sensor will shift versus when it was supplied by 5V. 25°C may have once corresponded with a 2.5V reading. However, since the excitation voltage is now 4.9V, 25°C now corresponds with a 2.45V output resulting in a 50mV delta from the true value. Since the ADC codes in ~19.5mV steps, the temperature will be read out as slightly hotter (by two bits) than it actually is. If each bit corresponds to a 0.5°C difference, then the control module will cool longer, or heat shorter, by 1°C to reach the target temperature in the cabin. This problem is exacerbated when the reference voltage and sensor excitation voltage are even further apart.

This example goes to show that having a tracker LDO will drastically improve sensor readings and lead to more accurate control systems when a sensor is being powered remotely. This is in addition to the value the tracker LDO brings in protecting the control unit from any wire harnessing failures.

Table 1. Device Recommendations

Device	Tracking Accuracy	Output Current	Package
TPS7B4250-Q1	±5 mV	50 mA	SOT23-5
TPS7B4254-Q1	±4 mV	150mA	SO PowerPAD-8
TPS7B4253-Q1	±4 mV	300mA	SO PowerPAD-8 HTSSOP-20

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