Technical Article

Always Make the Right Turn: How to Design Fault Circuits in Automotive Lighting Systems

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It's incredibly important to indicate a system failure to users, especially when it comes to automotive lighting.

Consider the turn indicator in an automotive rear light, for example, which signals that a driver wants to change lanes or make a turn. A common and growing light source for turn indicators is LEDs, driven by a dual-stage LED driver circuit topology that includes a first-stage buck voltage regulator and a second-stage constant-current linear LED driver. Dual-stage topologies offer the advantage of thermal efficiency.

The LED-based turn indicator module shown in Figure 1 comprises a typical automotive battery, switch, input filter, buck regulator and some LED drivers. So what happens if the light stops working? How will you know? Which part of the system failed?

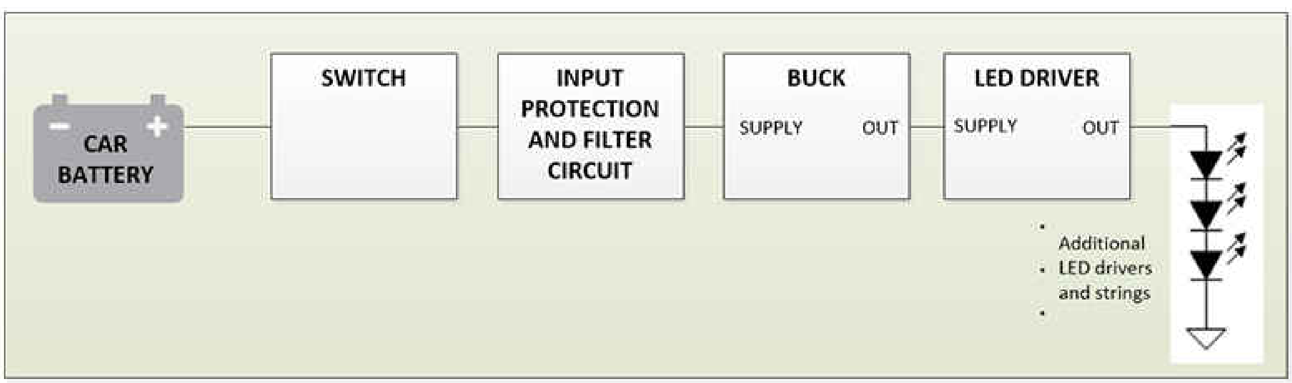

Figure 1. Turn indicator module

Buck regulator and LED driver integrated circuits implement diagnostic features in order to detect an event against faults. For example, the POWER GOOD signal is a diagnostic feature used to indicate whether or not the output of a buck is in regulation. Similarly, constant-current LED drivers output a FAULT signal to indicate LED short and open circuits.

In this article, I will focus on rear lighting fault circuits and how to combine PWRGD signals from a buck regulator and the FAULT signal from a LED driver to design a fault circuit.

The Buck Converter PWRGD Signal

The POWER GOOD pin is typically an open-drain output with an external pullup resistor. The output asserts high in normal operation and low if the output voltage is low because of an incorrect output voltage, thermal shutdown or enable shutdown. For TI devices, check out buck regulators with POWER GOOD pin functionality.

According to data sheets, the POWER GOOD pin must be pulled high using recommended values. Given system requirements, it is possible to pull the POWERGOOD pin high to the output of a buck regulator using a pullup resistor. However, if the buck regulator output voltage is greater than the recommended pullup voltage, it's best to use a Zener diode to clamp to a lower voltage.

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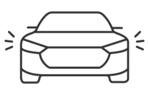

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LED Driver FAULT Signal

In TI linear LED drivers, the FAULT pin is an open-drain transistor with a weak internal pullup and must be pulled high in order to release the fault signal. In normal operation, the FAULT pin asserts high. If an LED short or open fault occurs, the device has an internal pulldown current and the FAULT pin asserts low.

TI's automotive-grade LED drivers have two FAULT pin design options:

- **One-fail-all-fail (OFAF):** Shuts down all devices and reports a fault if there is a fault in one of the devices.
- **Disabled OFAF:** When one device has a fault, the remaining devices continue operating and a fault is reported.

When connecting the FAULT pins of up to 15 devices together, the system uses OFAF. Figure 2 shows the fault connector circuit connected to the FAULT pins of LED drivers. The fault connector circuit is used to improve FAULT signal robustness. The open drain with pullup is used for easy interface with external circuitry.

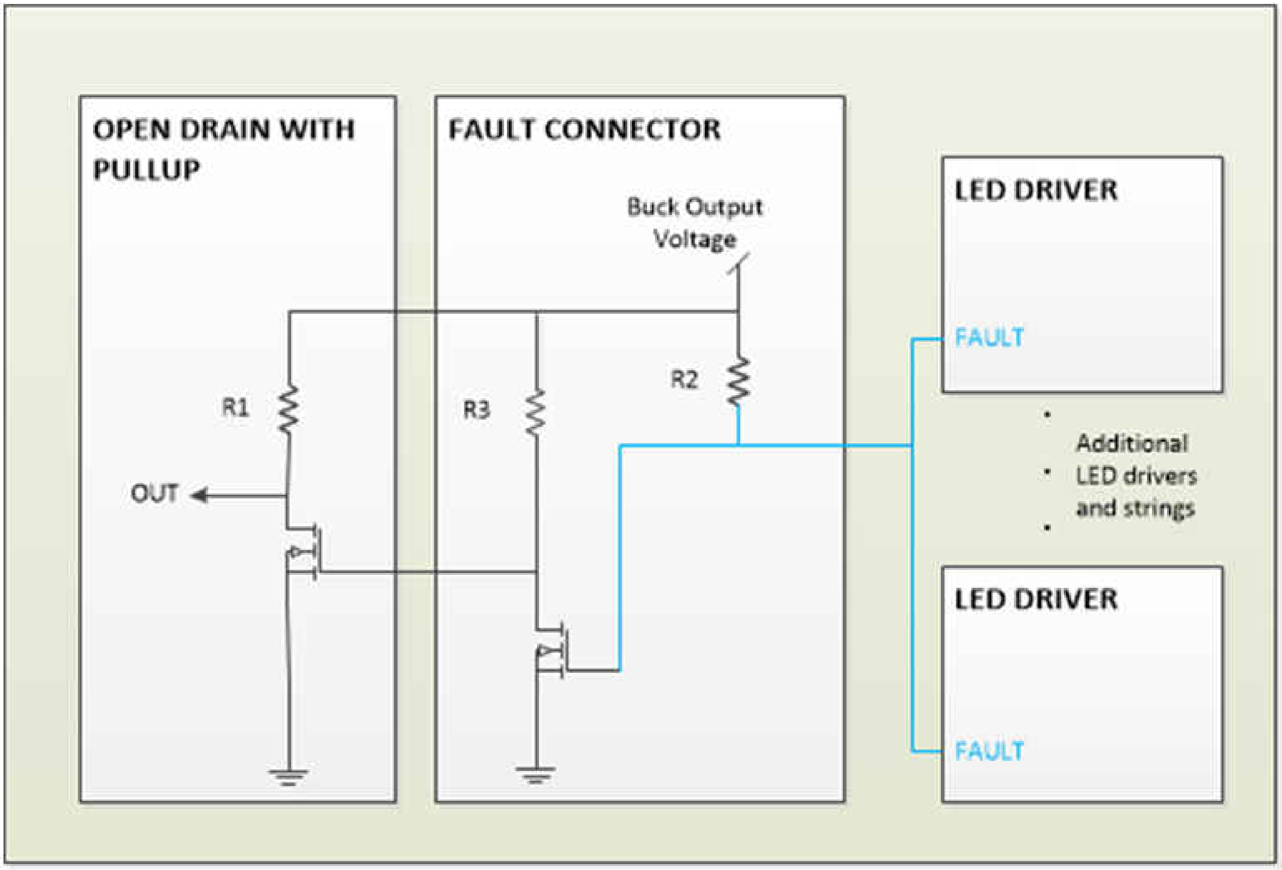

Figure 2. Fault Connector

Disabled OFAF requires a fault aggregator circuit. Figure 3 shows the fault aggregator circuit connected to the FAULT pins of LED drivers. The open-drain output with pullup is used to assert OUT low in the event of a fault and high if there is no fault.

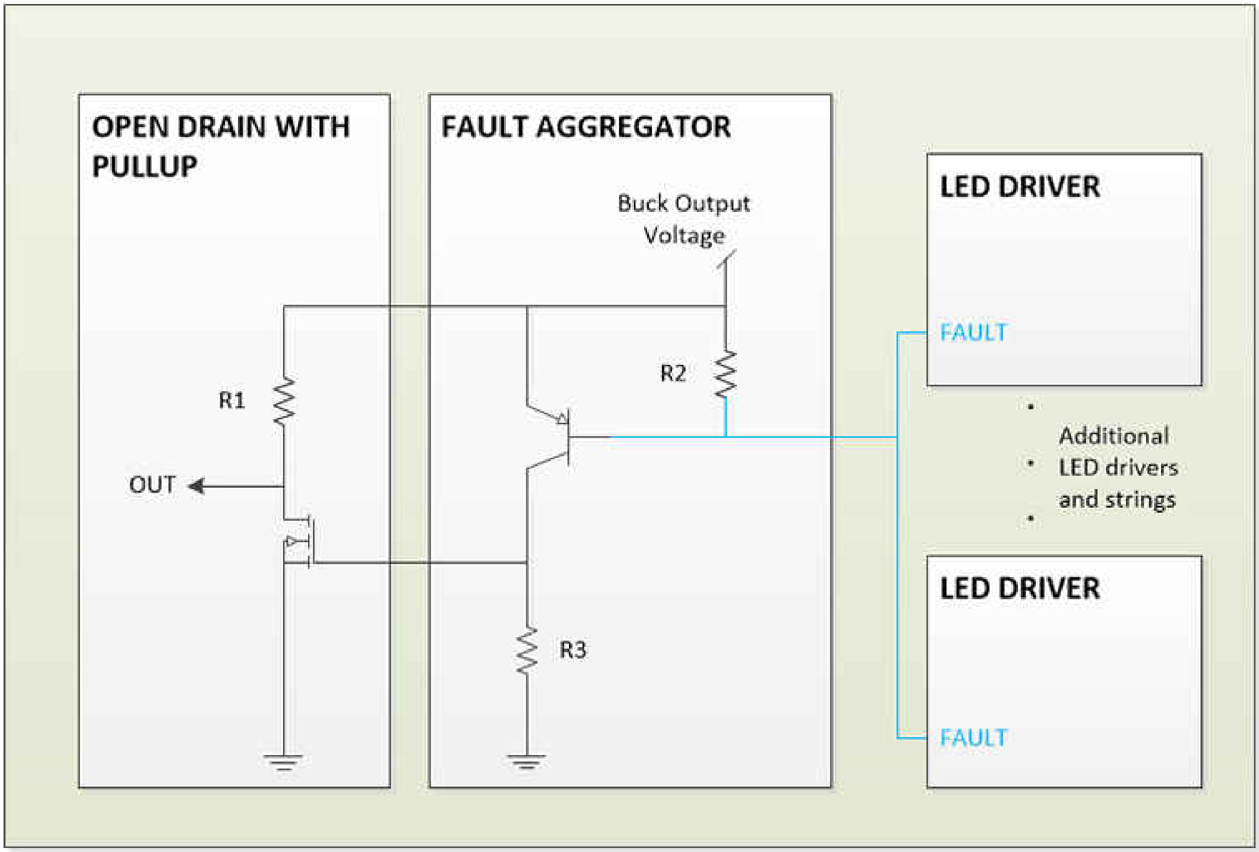

Figure 3. Fault Aggregator

The fault aggregator circuit is defined as a fault pin pullup circuit. In order to disable OFAF, the FAULT pin must be pulled up to maintain a voltage greater than 2 V at all times. The P-channel transistor (PNP) is used to convert the FAULT pin from a current-controlled pin to a voltage. Pullup resistor R2 keeps FAULT greater than 2 V. Typically, a fault signal asserts low in the event of a fault and asserts high if there is no fault. Thus, the open-drain output with pullup inverts the logic of the fault aggregator circuit to assert OUT low in the event of a fault and high if there is no fault. You can omit the open-drain output with pullup from the design if the system requires OUT high in the event of a fault and low if there is no fault.

When a fault is triggered, the LED driver internally pulls down current, and the pulldown current flows through pullup resistor R2. The PNP turns on, the output of PNP goes high and OUT becomes low. When no fault is triggered, the LED driver internally pulls up and PNP acts as an open switch. The output of PNP goes low and OUT becomes high. In both cases, FAULT remains greater than 2 V.

Considering the turn indicator module, the buck regulator output voltage should power the fault aggregator circuit; a Zener diode can clamp the buck regulator output to a lower voltage. In case of a buck regulator failure, there is no power to the fault aggregator, and a fault is indicated.

The “Automotive high side dimming rear light reference design” shows how to design a fault aggregator circuit using TI’s TPS92630-Q1 and TPS92638-Q1.

Using POWER GOOD Signal to Enable an LED Driver

One approach to combine the buck regulator POWER GOOD signal and LED driver FAULT signal is to take advantage of the enable (EN) pin of the LED driver. When the EN pin is high, the LED driver operates normally. When the EN pin is low, the LED driver is in sleep mode, with ultra-low quiescent current.

Figure 4 shows how to connect the POWER GOOD pin to the EN pin using pullup resistor R4 and a Zener diode. The Zener diode provides a lower pullup voltage for the POWER GOOD pin. The POWER GOOD pin is pulled high by R4 to the clamping voltage from the Zener diode.

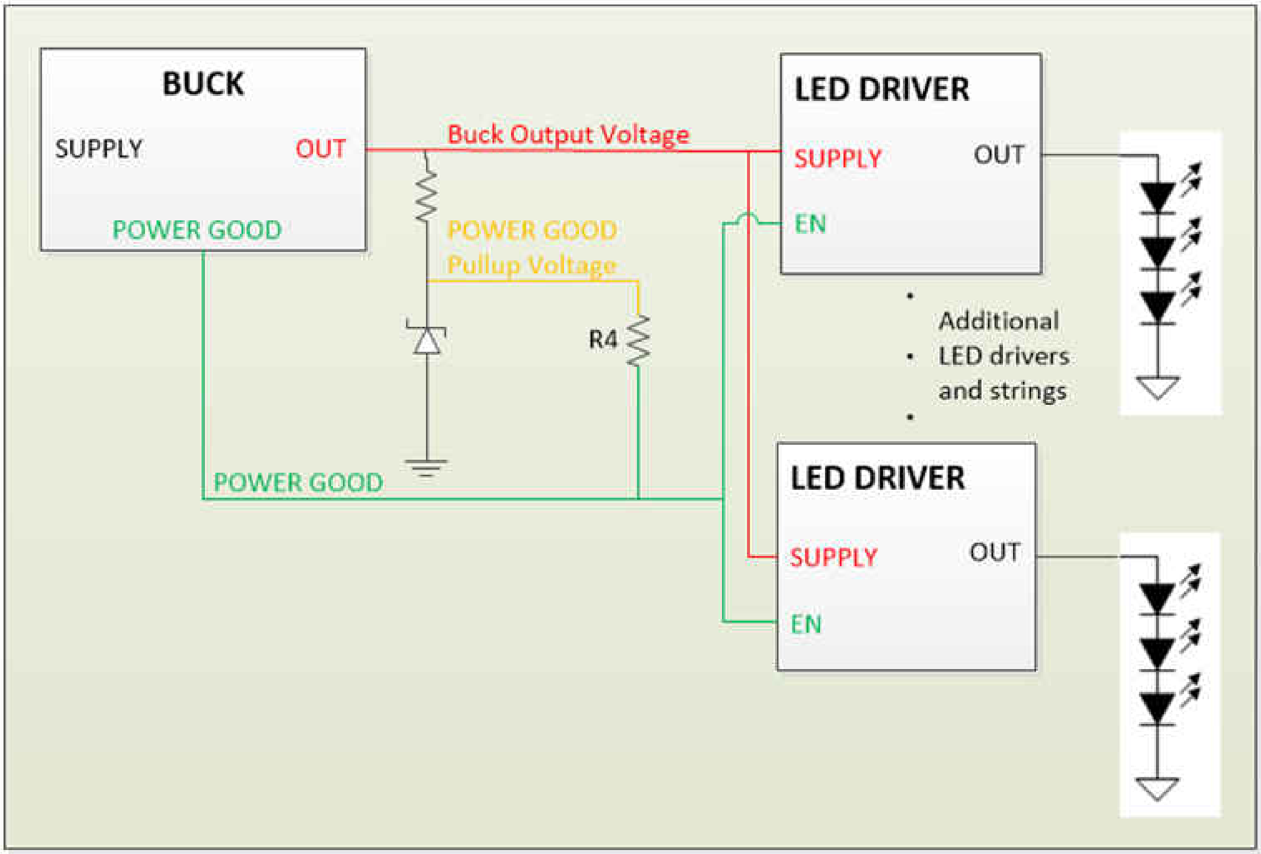

Figure 4. Connecting POWER GOOD and EN

By connecting the output of the POWER GOOD pin to the EN pin of the LED drivers, the POWER GOOD signal now controls the LED drivers. In normal operation, the POWER GOOD pin asserts high and the LED drivers are enabled. In the case of a buck regulator failure, the POWER GOOD pin I asserts low, the LED drivers are not enabled, the fault aggregator circuit has no power, and OUT becomes low – indicating a fault.

System Fault Analysis

The goal for a fault circuit is to indicate any fault in the turn indicator module that prevents the LEDs from turning on. The sources of a fault could be an incorrect voltage output from the buck regulator, incorrect current output from LED drivers or faulty LEDs.

Figure 5 shows the complete turn indicator module block diagram, where the POWER GOOD pin connects to the EN pin of the LED drivers using pullup resistor R4 and a Zener diode. The fault aggregator circuit disables OFAF.

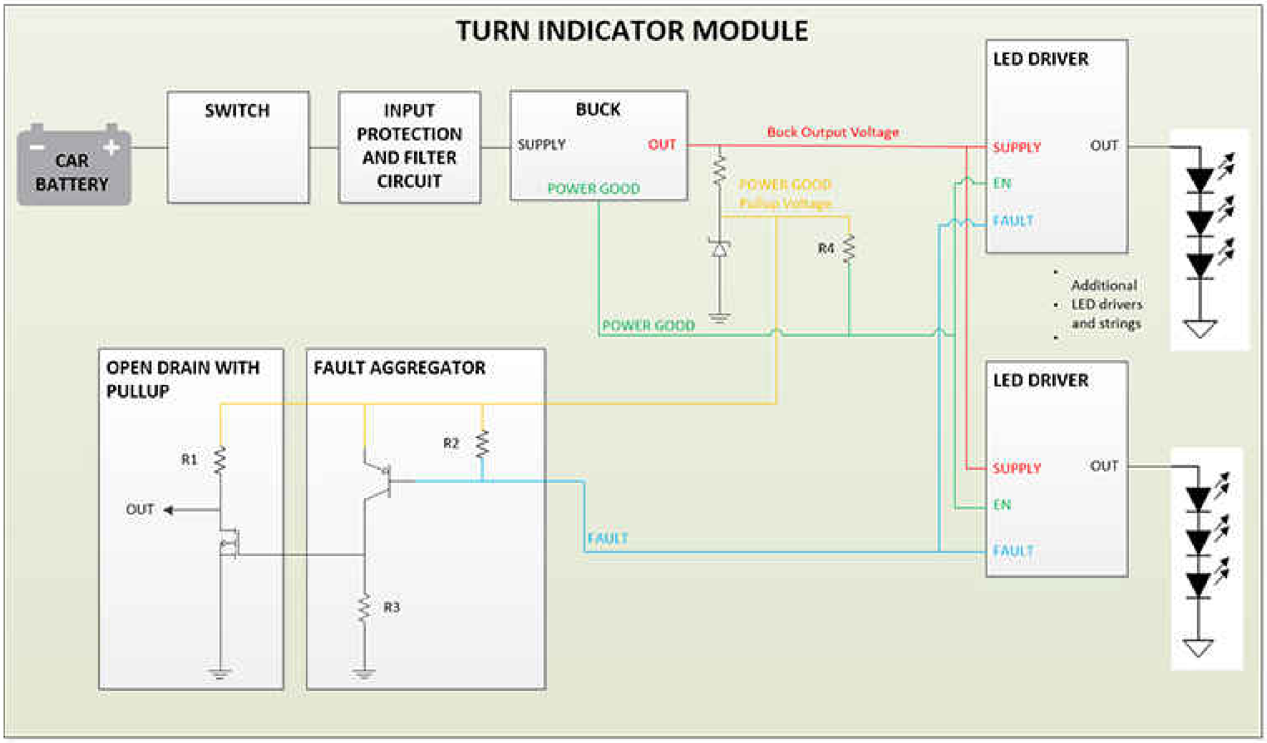

Figure 5. Disabling OFAF with a Zener Diode and Fault Aggregator

When the system operates normally, the battery voltage is filtered and bucked down to power the LED drivers. The POWER GOOD pin is pulled up to the Zener diode clamping voltage, asserts high and enables the LED drivers. The LEDs then power on, with no short or open LED fault detected. Thus, FAULT asserts low, the fault aggregator asserts low, and no fault is indicated to the output.

Now consider a buck regulator output voltage fault. The buck output voltage is out of nominal range, and the POWER GOOD pin asserts low. The LED drivers are disabled and the LEDs are powered off. FAULT asserts low when the LED drivers are disabled. The fault aggregator has no power from the Zener diode clamp voltage, and the output goes low, indicating a fault.

The turn indicator module can fail in other ways. Some examples include an LED short or open circuit or LED driver thermal shutdown. The circuit shown in Figure 4 enables detection of these different fault types in the turn indicator module.

Conclusion

Automotive lighting systems are implementing more fault circuits. To save space and reduce cost for fault circuits, try connecting the POWER GOOD pin to the EN pin of the LED driver. For LED faults, consider using or disabling OFAF. Choose the design option that meets the requirements for your specific application.

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