design ideas

Edited by Bill Travis

LED driver doubles as fault monitor

Anthony Smith, Scitech, Biddenham, Berdfordshire, England

LEDs find wide use as indicators and as light emitters in devices such as optocouplers. In some applications, the LED or the emitter may be located remotely at some distance from the main unit. Typical examples are dashboard-mounted automotive indicators and industrial optosensors. In critical applications, you may require some means of monitoring the integrity of the LED. Using just four transistors and six resistors, this circuit provides switchable, constant-current drive for an LED and indicates both open- and short-circuit fault conditions (**Figure 1**). And there's a bonus, too. Control signal V_{CONT} switches the LED on and off. When V_{CONT} is high, Q_1 and the LED are off. When V_{CONT} is as low as 0V, Q_1 turns on and sources a constant current to the LED. Because most LEDs have a forward-voltage drop of at least 1.2V, adequate base-bias voltage exists for Q_3, which turns on, thereby providing a conduction path for Q_2. This conduction, in turn, provides bias for Q_4, which turns on and pulls high, thus indicating a healthy LED.

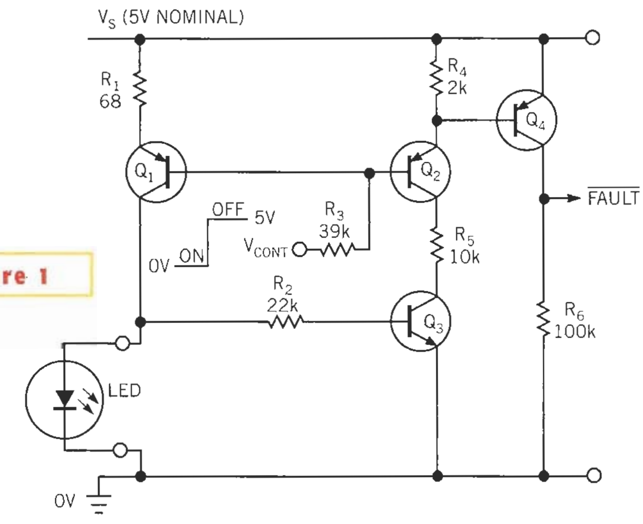
Because Q_2 and Q_4 are both now on, the base potential of Q_1 sits at roughly two V_{BE} drops below the positive-supply rail, V_S, thereby placing one V_{BE} drop across R_1. Consequently, with $R_1=68\Omega$, Q_1 sources a steady current of approximately 10 mA to the LED. Provided that the value of R_2 is large enough, little of the LED's forward current diverts into Q_3's base. As long as the LED remains undamaged, $\overline{FAULT}$ stays high, signaling normal drive conditions. Should the LED go open-circuit, Q_1's collector load becomes just R_2 in series with Q_3's base. Because R_2 is much larger than R_1, Q_1 saturates, the voltage across R_1 falls to around 20 mV or so, and the emitter potentials of Q_1 and Q_2 rise toward V_S. With insufficient base drive, Q_4 now turns off, and the output falls to 0V to signal the fault condition.

On the other hand, if a fault puts a short circuit across the LED, Q_3 immediately turns off and deprives Q_2 of collector current. Q_2's base-emitter junction now behaves like a diode, clamping Q_1's base to a potential dictated mainly by Q_2's V_{BE} drop and by the ratio of R_3 to R_4. Because R_4's value is smaller than that of R_3, Q_2's emitter potential now rises toward V_S. Once again, Q_4 turns off and goes low to indicate the fault condition. With the resistor values shown in **Figure 1**, Q_1's base now sits at approximately 4V, leaving only 200 to 300 mV across R_1. Therefore, the short-circuit current is effectively "choked back" to less than a third of the normal value, thereby saving power—the bonus. Under normal conditions, with the LED on, Q_1 conducts more current than Q_2, causing its V_{BE} drop to be slightly larger than that of Q_2. Consequently, the potential across R_1 is slightly less than a diode drop, and you may need to experiment with the value of R_1 to set the desired LED current.

You must select R_3 to satisfy the base-current requirements of Q_1 and Q_2 when V_{CONT} is low. Tests on the prototype circuit produced good results with $R_3=39$ kΩ, although a smaller value may be required, depending on the LED current and the current gain of Q_1 and Q_2. When the LED is on, both Q_2 and Q_3 are fully on, so a reasonably large value of R_5 is required to limit their joint collector current to an acceptable level. However, R_5 must not be too large, or Q_2 will be unable to furnish the current that R_4 and Q_4's base require. Making R_5 approximately four or five times larger than R_4 is a good starting point.

Although the circuit in **Figure 1** has a

Figure 1



This LED driver doubles as a fault monitor and limits short-circuit current to boot.

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5V supply, you could use other voltages, provided that you scale the resistor values accordingly. Operation at lower voltages is possible as long as Q_1 has adequate "headroom" to stay out of saturation, but beware of problems if you use a blue or a white LED, because these devices tend to have relatively high forward-voltage drops. The transistor types are not critical; most small-signal devices with high current gain should be adequate, although Q_1 may need to be a power device if your design requires a high LED current, a high supply voltage, or both.□