Protect power-LED strings from overcurrent

Luca Bruno, ITIS Hensemberger Monza, Lissone, Italy; Edited by Martin Rowe and Fran Granville - June 23, 2011

A common method for driving multiple power LEDs is through two parallel strings. This inexpensive and less critical driver circuit can provide a lower voltage. However, the driver circuit must deliver twice the current of other methods and needs a circuit that halves the current in the two strings, regardless of the LEDs’ forward voltages. The LEDs’ forward-voltage tolerance is as high as 20%, and the voltages change with LED temperature and aging.

A current mirror performs this task well. If an LED breaks, it can cause destructive overcurrent. The current mirror, however, can safely partially protect two parallel, connected strings of any number of 350-mA power LEDs from these overcurrents (Figure 1).

The circuit can balance the currents between strings with a matching error of approximately 2% because of the equal voltages of 0.5V developed on 1.5Ω emitter resistors R₁ and R₂ with 1% tolerance. The voltage drop across resistor R₃ compensates for the mismatching of LED voltage drops and holds both Q₁ and Q₂ in the linear region. The voltage drop depends on how many LEDs make up the two strings.
If an LED of String 2 fails, however, no base current flows to transistors $Q_1$ and $Q_2$, and they turn off. All LEDs in String 1 have automatic overcurrent protection. The circuit doesn’t perform the same function if an LED in String 1 fails because all of the 700-mA driver current flows into String 2, which needs some form of protection. You can solve this problem by adding only three components (Figure 2).

In normal operation, transistor $Q_3$ operates in its linear region with an emitter-collector voltage of 0.7V because both diodes $D_1$ and $D_2$ are forward-biased. The power dissipation of $Q_3$ is only about 0.5W, and it thus needs no heat sink. The 700-mA driver current coming from the collector of $Q_3$ divides equally between the strings through steering diode $D_2$, as the current mirror dictates. If an LED in String 1 fails, diode $D_2$ blocks the base current of $Q_3$, turning it off. The driver current can no longer flow through String 2, safeguarding the LEDs.

You must compensate for diode $D_2$’s 0.7V voltage drop, which slightly increases the value of resistor $R_3$. You can adapt the current mirror for driving any type of LED without exceeding the absolute maximum rating of the transistors’ collector current, which is 1.5A. You can test the current mirror with any 700-mA constant-current LED driver, or even a voltage regulator configured as a current source, such as National Semiconductor’s LM317 regulator. The circuit underwent testing, with the LM317 acting as a 700-mA current source with five LEDs per string.