Solutions for Common LED Design Errors in Segmented Display and Multi-indicator Applications

Application Brief D-007

Introduction

LED displays and individual lamps are commonly used as information or status indication devices. These products are typically categorized as intelligent or non-intelligent. An intelligent LED display is one that has an on-board IC integrated with the LEDs, where all the electro-optical biasing of the discrete LEDs has already been provided to the end user. The user varies the brightness of the LEDs by simply changing a combination of "1s" and "0s" in the control register of the IC. The active semiconductor chips have already been matched by the OEM and thus uniformity is provided. However, a non-intelligent display or individual lamp is made up of a semiconductor chip(s), contact wires, and some packaging to provide mechanical stability, environmental protection, and optical lensing. These products are seven and sixteen segment displays, light bars, and discrete lamps. These non-intelligent devices require the designer to determine the electro-optical biasing configuration to achieve a desired brightness and uniformity. The intent of this literature is to address two of the most commonly found biasing errors of non-intelligent LED devices and provide solutions that will allow the designer to avoid these errors in the pursuit of an optimum LED design.

LEDs Electrically Parallel

Whenever there is an application that requires the use of two or more LEDs of the same color and luminous uniformity is desired, it is recommended that the designer not place the LEDs electrically in parallel with each other and in series with the same current limiting resistor (RLIM). Please refer to Fig. 1 for a schematic depiction of the described application.

In this type of application, there is a small possibility that the luminous intensity differences will not be detectable to the end user. This only will occur if the LED's forward voltage (V_F) versus forward current (I_F) characteristics are nearly perfectly matched. Unfortunately, most of the time this is not the case. Usually, the LEDs will have different V_F versus I_F curves as shown in Figure 1. Please note that a magnification of the true difference in the curves has been depicted here for demonstration purposes. For a true V_F versus I_F variation estimation, refer to any manufacturer's LED data sheet and notice the difference

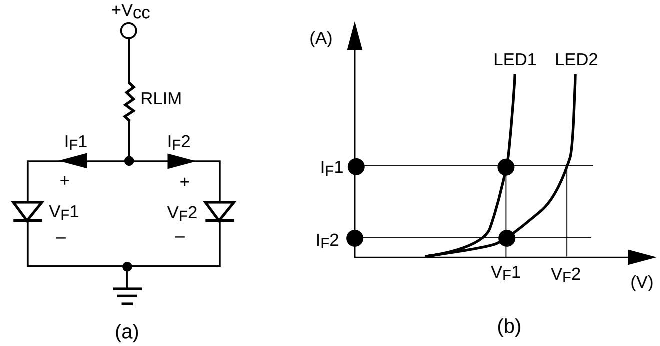

Figure 1. Application Circuit: (a) Two LEDs are configured electrically in parallel while sharing the same current limiting resistor; (b) Forward voltage vs. forward current characteristic curve of LEDs.

between the typical and maximum V_F at a specified test current for any one color LED. There will be even a larger difference among different colored LEDs.

As shown in Figure 1, when LED1 and LED2 are placed in parallel, the forward voltage value of the two will be that of the LED with the lower value. If LED1 with the lower V_F value (V_F1) was forced to take on the value of LED2's higher V_F (V_F2), it would require LED1's forward current to become increased exponentially proportional to the difference between V_F1 and V_F2. This increase in current would cause an increase in voltage drop across RLIM. Thus, the available voltage left to be applied to the LEDs would decrease assuming the voltage supply value remains constant. This is a negative feedback process. This process will force the two LEDs to take on a V_F value much closer to V_F1. From Figure 1, it is observed that if LED2's forward voltage is forced to the V_F1 value, then LED2's forward current will be much less than that of LED1. Therefore, since the light output of an LED is almost linearly proportional to the forward current, LED1 will appear to be brighter than LED2 if the current ratio is greater than 2 to 1, respectively.

If $+V_{CC}$ in the Figure 1 circuit configuration were considered to be a current source, the same kind of problem will occur with or without the current limiting resistor. Due to the fact that the parallel LEDs will have the same forward voltage, they inherently will have a difference in current ratio if they have offset V_F versus I_F characteristics, as shown in Figure 1.

Small Voltage Across Current Limiting Resistor

This problem occurs in a voltage source system with a current limiting resistor (RLIM) in series with an LED as shown in Figure 2. This problem is also due to variations in the LED's V_F versus I_F characteristics. This design error occurs in applications where it is assumed that every LED that is manufactured into a particular circuit configuration will take on its typical V_F versus I_F characteristics. Here, a certain V_F value is subtracted from the voltage value being supplied from the $+V_{CC}$ to ground nodes to determine what RLIM value to use. The $+V_{CC}$ and ground nodes can also be considered as the emitter of a driver and the collecter of a sink, respectively, in some kind of multiplexing scheme.

The problem arises when the voltage drop across the current limiting resistor (VLIM) is small. How small? When the 0.1 to 0.3 V variation among LEDs in the V_F as specified in a data sheet and any voltage variations in any other circuit elements (i.e., power supply, drivers, and sinks) causes a significant percentage change (>50%) in VLIM and thus a significant change in current value. The light output will then change linearly with the current change and thus a loss in uniformity among multiple LEDs on a single product unit, or among LED(s) among multiple units will result.

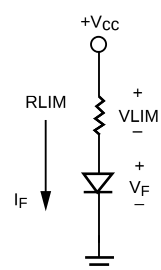

Figure 2. Typical LED application circuit using a current limiting resistor in series with an LED in a voltage source system.

Solutions

1. Do not configure LEDs electrically in parallel.
2. Consider worst case voltage variations that could occur across the current limiting resistor. The forward current should not be allowed to change by more than 40% of its desired value.

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