Integrated Control of LEDs in Display and Indication Applications

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LEDs are increasingly being specified as replacements for traditional incandescent light bulbs in a variety of general illumination, display and indication applications. As solid state devices, LEDs exhibit much higher reliability, longer life and significant energy efficiency. Integrated control of LEDs is crucial to the design of new solid state arrays for illumination and specialized lighting applications employing multiple LEDs. While it is possible to use passive (i.e., resistive) current-biasing schemes to maintain a constant current supply to the LEDs, an active current-source-biasing controller provides significantly better control in limited voltage applications, with improved efficiency, lower component count and increased functionality when compared to existing options. This article will contrast the single resistive-biased approach with advanced integrated LED controls that drive as many as eight or 16 current sources with additional diagnostic and control functions.

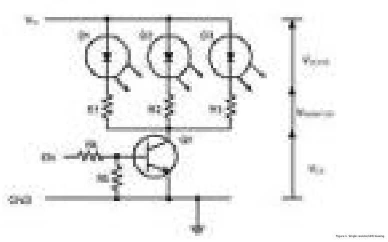
Biasing the Diodes

LEDs are current driven devices, in that the light output (luminous intensity <md> millicandela) is directly related to the forward current passing through them. The purpose of the biasing circuit is to maintain the current through the diode at a more or less constant value.

Passive, or resistive biasing control method. A single current limiting resistor is connected in series with the LED to match the intended power supply (Figure 1.). This method is very low cost, but suffers from current variations due to the spread of diode forward voltage V_{DIODE}. Maximum values of V_{DIODE} rise to 2.7V (+40 percent) for GaAsP diodes and 4.2V(+20 percent) for InGaN diodes at specified current. When multiple diodes are required, as in a cellphone display backlight (total: eight), the extra resistors begin to take up a significant amount of PCB area.

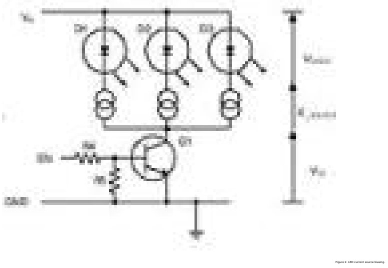
$$I_{DIODE\ 1,2,3} = \frac{V_{IN} - (V_{DIODE} + V_{CE})}{R_{1,2,3}}$$

Fig 7: Single Resistor / LED Biasing



The effect of V_{DIODE} variation may be reduced by increasing the value of V_{IN} to >5 V_{DIODE}; however, this is wasteful in terms of power dissipation, and it is incompatible with low voltage battery supplies such as single Li Ion cells. A Li Ion cell’s voltage range is 3.4V (fully charged) to 3V (discharged) and will exhibit noticeable light output variation when only simple resistor biasing is employed. A better approach for stabilizing intensity variations with supply voltage and improving dropout is to employ active current source biasing.
Current biasing. As its name suggests, the diodes are connected to individual active current sources. Provided that the current source has adequate dynamic range, this method of biasing eliminates the effects of V_{DIODE}; variation. A current source biasing method replaces the individual diode resistors shown in Figure 1 with individual current sources (Figure 2). Provided that there is enough supply voltage to bias the current sources and LEDs, the light output is independent of supply and forward voltages. Q1 is the enable switch in both examples.

Fig 8: LED Current Source Biasing



A new generation of highly integrated LED driver ICs has been developed that incorporates either eight or 16 well-matched current sources, the output current of which is set by a single resistor R_{EXT} in the manner outlined in Figure 3. These integrated LED drivers are designed to drive either eight or 16 LEDs through a fast serial interface with an output constant current driver for each LED, as well as an on-chip diagnostic read-back function. Their high clock-frequency (up to 50 MHz), adjustable output current and flexible serial interface makes these devices appropriate for multiple pattern, multiple color LED applications.
The output current is adjustable (up to 100 mA/channel) using an external resistor (R_{EXT}), and the serial interface with Schmitt trigger inputs includes an integrated shift register. Additionally, an internal data register stores the currently displayed data. The device features integrated diagnostics for over temperature, open-LED, and shorted-LED conditions. Integrated registers store global fault status information during load as well as the detailed temperature/open-LED/shorted-LED

diagnostics results. In addition, these devices also feature a low-current diagnostic mode to minimize display flicker during fault testing. With an operating temperature range from -40°C to +125°C, the LED drivers can also be used for industrial applications.

Fault Detection

The open LED detection is based on the comparison between VDS and VTHL. The open LED status is acquired at the rising edge of Output Enable (OEN) and stored internally. While detecting open LEDs, the output port must be turned on. Open LED detection can be started with one clock pulse during error detection mode while the output port is turned on. (Note: LEDs which are turned off at test time cannot be tested.)

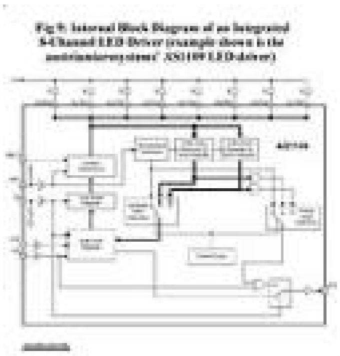


Figure 3. Internal block diagram of an integrated eight-channel LED driver (example shown is the austriamicrosystems' AS1109 LED driver)

The shorted LED detection is based on the comparison between VDS and VTHH. The shorted LED status is acquired at the rising edge of OEN and stored internally. While detecting shorted LEDs, the output port must be turned on. Shorted LED detection can be started with two clock pulses during error detection mode while the output port is turned on. For valid results, the voltage at OUTN0:OUTN7 must be lower then VTHH under low-current diagnostic mode operating conditions. This can be achieved by reducing the VLED voltage or by adding additional diodes, resistors or LEDs. (Note: LEDs which are turned off at test time cannot be tested.)
Acquisition of the error status occurs at the rising edge of OEN. Error-detection mode is started on the rising edge of LD when OEN is high. The CLK signal must be low when entering error detection mode. Error detection for open-LED and shorted-LED can only be performed for LEDs that are switched on during test time. To switch between error-detection modes, clock pulses are needed. (Note: To test all LEDs, a test pattern that turns on all LEDs must be input to the driver.)

Global error mode is entered when error-detection mode is started. Clock pulses during this period are used to select between temperature, open-LED, and shorted-LED tests, as well as low-current diagnostic mode and shutdown mode. In global error mode, an error flag is delivered to pin SDO if any errors are encountered.

Brightness Control and High Voltage Series String Operation

When a number of LEDs must co-exist, intensity matching between groups is required. The LED driver may be controlled individually by manually adjusting R_{EXT} by width modulating the OEN pin, or by replacing R_{SET} with a digital potentiometer wired as a variable resistor. With the digital resistor method, care needs to be exercised to prevent overcurrent in the LEDs during start-up and adjustment. As an example, there is a thermal measurement that monitors the core temperature of the LED driver (typically 150°C) and provides protection against excessive power dissipation caused by system cooling failure. Where a large number of LEDs are required to operate simultaneously, consider connecting a number of LEDs in series at each current source output. Because most driver ICs are limited to 5V (+15V max at OUT_0-7) operation, additional measures are required to provide <gt>5V support. Figure 4 shows one possible solution. Transistors Q0-7 are general purpose “high” voltage NPN transistors connected as “cascode shields” for the LED driver (austriamicrosystems’ AS1109 in this example). The cascode connection is such that the emitter current is nearly identical to the collector current for Q0-7, when the current gain (b) is >100. Thus, the LED control provided by the driver in this example is maintained at the collectors of Q0-7. The collector voltage of Q0-7 sets the maximum voltage at V_{IN} that can be safely supported. In this way, the 5V V_{DD} supply of the driver may control series LEDs connected to +24V and higher input voltage supplies. Note that when the LED controller IC is driving multiple series strings, diagnostics will operate on each series string, not each individual LED.

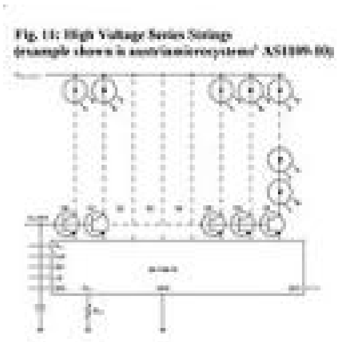


Figure 4. High Voltage Series strings.

Conclusion

Integrated control systems for LEDs are an important part of the design consideration for new applications employing solid state lighting arrays for illumination and indication. Advanced LED controllers are capable of providing eight or 16 current sources (as many as 64 LEDs) as well as provide diagnostic capabilities.

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