Dimming LEDs – a simple, low-cost solution for color stability

By Steve Sheard, ON Semiconductor

LEDs can be dimmed by reducing the current but this results in a color shift of the light. A better method is to reduce the time they are on by using a PWM signal. This article demonstrates the technique by introducing a simple circuit configured to operate as the backlight of an instrument panel on a vehicle.

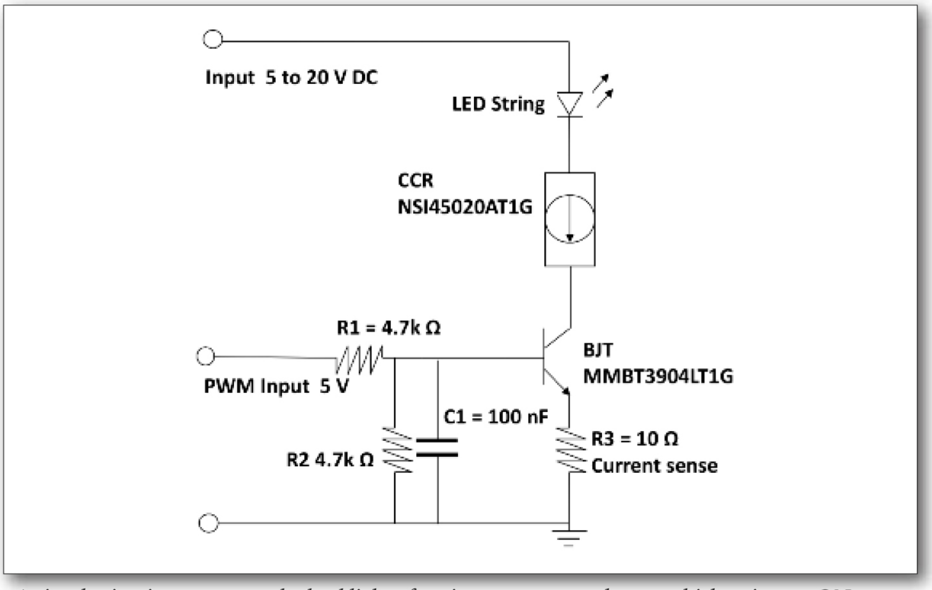
Light – how much is enough? The amount of light required is often determined by who will be in what environment, and what the task might be. The lighting in a conference room may be quite bright for general meetings around a table, but significantly less if a projection system is used to view material. The lighting in a living room will often be adjusted to create the right ambience. The back lighting for a vehicle instrument panel is often adjusted automatically for day or night driving.

Lighting sources have moved from incandescent, very easy to adjust, to fluorescent, requiring special circuits to obtain a varying light level. The introduction of LEDs as the latest generation light source is requiring new electronic circuits to change the light level. There are two methods to change the light output from an LED. The first is to reduce the current through the LEDs; the amount of light emitted from an LED is proportional to the current flowing through it. The second method is to pulse a current through the LED; the light emitted is proportional to the duty cycle.

The dimming of LEDs using a reduction of current is similar to that used for many incandescent lamps. This method of current reduction may be acceptable for a few applications, but as the light level is reduced, the color of the light emitted by LEDs also changes depending on the current. The chromaticity shifts toward yellow at lower currents. The Incandescent lamp can be dimmed with a reduction of current to below 1% because it is just a heated filament. But it is extremely difficult to dim LEDs below 5% using the reduction in current method, because of the voltage potential needed to cause the silicon junction to be breached and begin to conduct. The LED is a diode and as the junction breaches, it is like an avalanche with its resistance dropping rapidly. It is very difficult to have sufficient voltage to make the LED conduct with very small currents.

The method of pulsing the current through the LEDs is known as pulse width modulation (PWM), and has become the preferred method of changing the light level. LEDs being silicon devices, they turn on and off rapidly in response to the current through them being turned on and off. The switching time is in the order of 100 nanoseconds, equating to a maximum frequency of 10 MHz. Applications will typically operate from 100Hz to 100kHz. Below 100Hz the human eye will detect a flicker on the light from LEDs. Between 500Hz and 20kHz the circuit may generate audible sound. Dimming is achieved by turning the LEDs on and off for a portion of a single cycle. This on/off cycle is called the duty cycle (D) and is expressed by the amount of time the LEDs are on (Ton) divided by the total time of one on/off cycle (Ts). The current through the LEDs is constant during the period they are turned on resulting in the light being consistent with no shift in chromaticity (color). The brightness is in proportion to the percentage that the LEDs are turned on.

A simple circuit can be configured to operate as the backlight of an instrument panel on a vehicle using an ON Semiconductor two-terminal constant current regulator (CCR), such as the NSI45020AZT1G, and a bipolar junction transistor (BJT) such as an MMBT3904LT1G in series with the LED string (see figure). A simple bias circuit of two 4.7 kohm resistors (R1, R2) is placed on the base of the BJT. A 10 ohm 1% resistor (R3) is placed into the emitter leg of the BJT to be used as a current sense. Measuring the voltage across it provides a simple current equivalent (200 mV = 20 mA). R3 is only used to measure the current in the circuit, it is not needed once the design is completed. The circuit has a supply voltage range of 5.0V to 20VDC. A 5.0V control voltage from a micro-controller is applied through R1 to the base of the BJT, turning the BJT on. The CCR will automatically hold the current through the LED at 20mA. The values of R1 and R2 can be selected to match the driving circuit. A BJT will typically begin to turn on at 0.5V. If R1 = R2, then this divider circuit will require >1.0V to turn on the BJT. If R1 = 10



A simple circuit operates as the backlight of an instrument panel on a vehicle using an ON Semiconductor two-terminal constant current regulator (NSI45020AZT1G) and a bipolar junction transistor (MMBT3904LT1G) in series with the LED string.

kohm and R2 = 47 kohm the circuit will only need a voltage >0.6V to turn on. The control signal is set to operate at a frequency of 300Hz and the pulse width is 30 microseconds.

As the pulse width is increased the total time the LEDs are on will increase, increasing the light output. As the pulse width approaches zero the light output will also approach zero. Electromagnetic Interference (EMI) may be of concern as with any circuit switching currents. The LEDs and the CCR switch extremely fast, less than 100 nanoseconds. To help eliminate EMI, a capacitor can be added to the circuit. In the basic circuit a 100nF capacitor was added between the base and the emitter of the BJT and caused the slope on the rising and falling edges on the current through the circuit to be extended by 1.5 microseconds. The selected delay / slope will impact the frequency that is selected to operate the dimming circuit. The longer the delay, the lower the frequency will be. The delay time should not be less than a 10:1 ratio of the minimum on-time. The frequency is also impacted by the resolution, i.e. dimming steps, that is required. With a delay of 1.5 microseconds on the rising and falling edges, the minimum on-time would be 30 microseconds. If the design called for a resolution of 100 dimming steps then a total duty cycle time (Ts) of 3 milliseconds or a frequency of 333Hz will be required.

In summary: LEDs can be dimmed either by reducing the current or by reducing the time the LEDs are on. The reduction of current mode results in a color shift of the light being output from the LEDs. The preferred method to dim LEDs is to reduce the time they are on by using a PWM signal. LEDs controlled with simple CCRs in conjunction with a BJT and a PWM signal can be easily dimmed to the required resolution for both automotive and architectural lighting. The use of a BJT allows the LEDs to be driven at a constant current resulting in no shift in the chromaticity; the color of the light remains the same, with only the amount of light emitted being reduced. ■