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LED Biasing in Automotive Applications

Utilising two terminal constant current regulators (CCR)

Often a two terminal constant current source is required to set a regulated current for LED regulation or sensor regulation in automotive applications such as Centre High Mount Stop Lamps (CHMSLs), interior map lights, instrument cluster indicators and switch cluster backlights. Circuit designers may often find themselves reaching for discrete semiconductor components such as zener diodes, NPN and PNP transistors or various diodes and MOSFETs to address this design challenge.

By Brian Blackburn, Senior Field Applications Engineer, ON Semiconductor

In the case of LED biasing however, a two terminal constant current source is an ideal choice for achieving current regulation, especially in the automotive market where battery voltage can continually vary from as low as 7 Volts (V) up to 19V. A designer may use two or three transistors that are matched to provide a current source, or an old standby such as an LM317 voltage regulator connected as a floating current source.

The problem with resistor bias

In their simplest form current sources

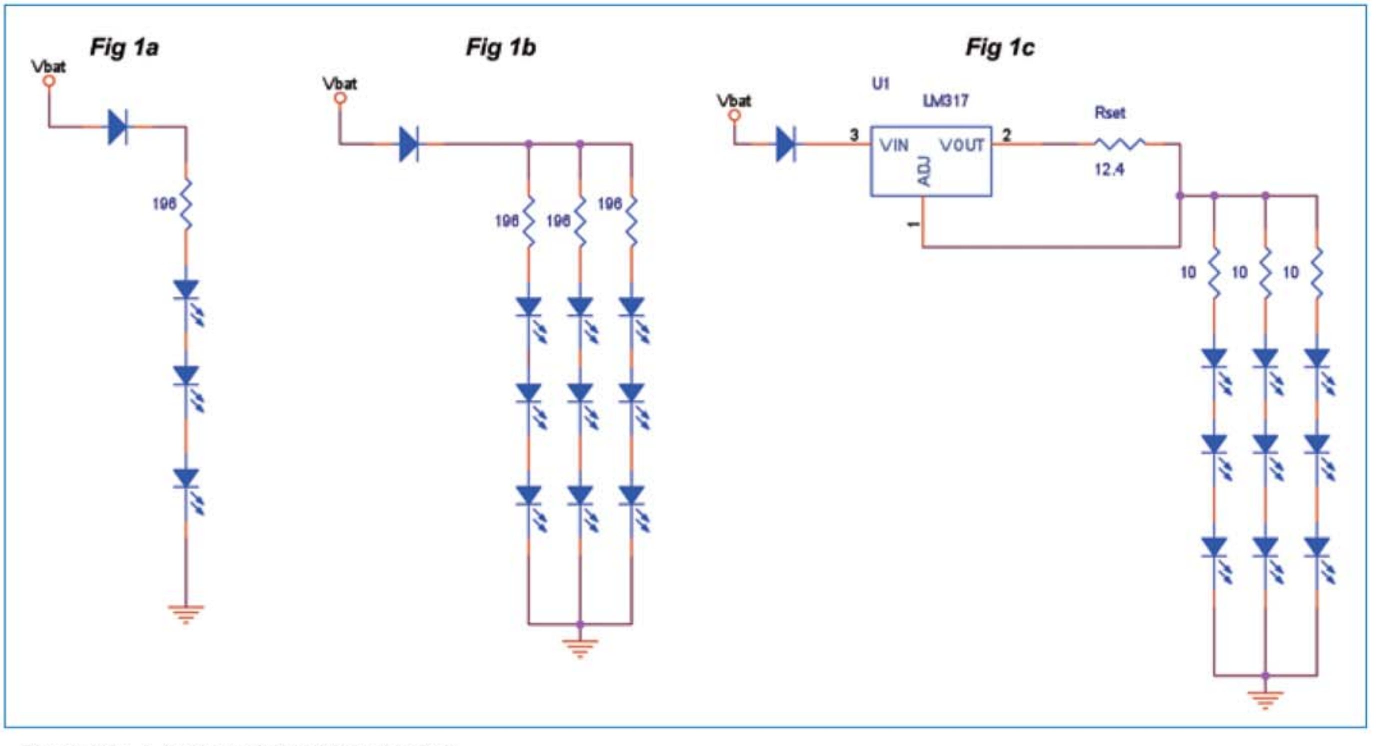

Figure 1a: A basic resistive biased string.
Figure 1b: Multiple LED strings in parallel.
Figure 1c: LM317 arranged as a constant current source.

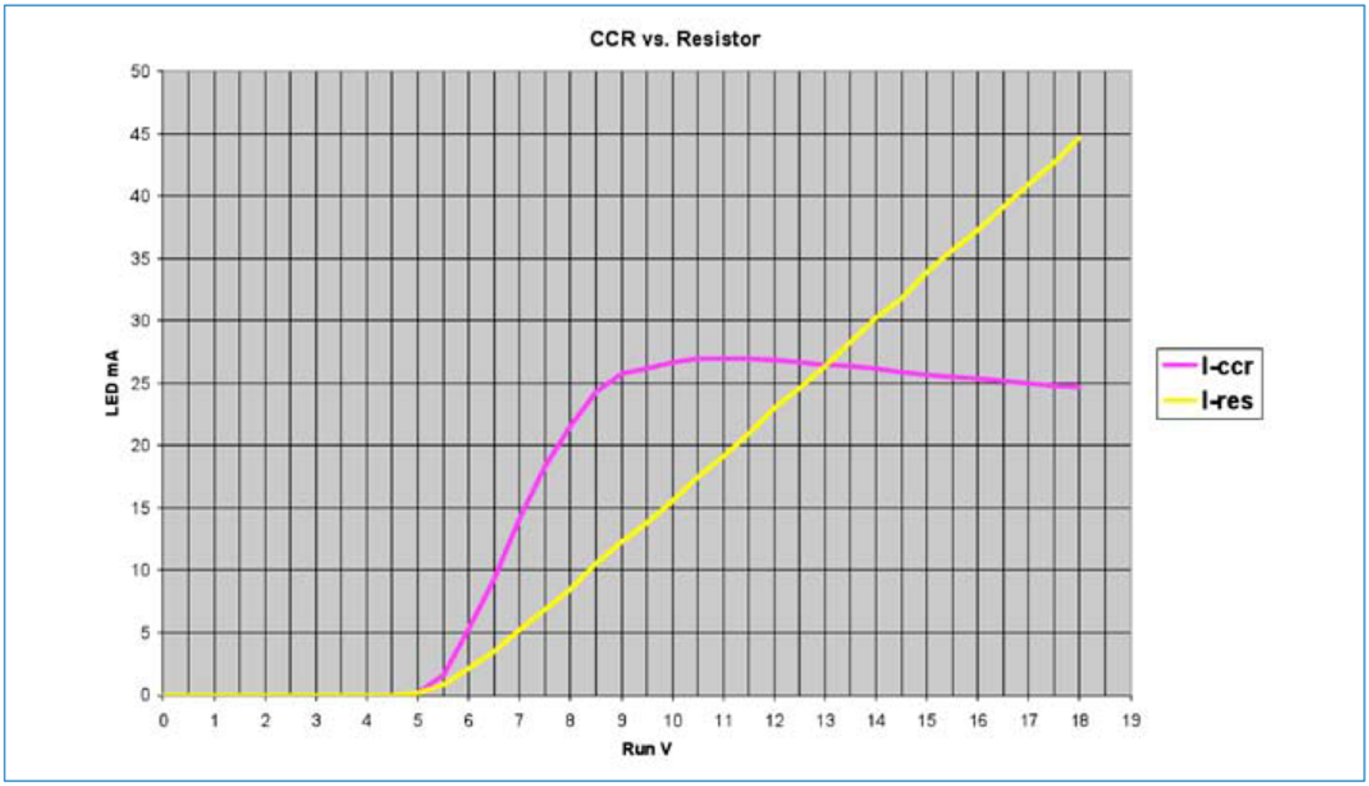

Figure 2: The attributes of utilizing a CCR rather than a resister are highlighted in the IV curve.

are no more than a properly chosen resistor value in which a current is set from a variable battery source such as those seen in automotive applications. For instance, in a CHMSL application, three red LEDs are connected in series, and a properly chosen resistor is added in series to limit the current in the LED string. Figure 1a shows this type of arrangement. This circuit is repeated for as many LEDs as are required to make up the entire CHMSL. Usually the input voltage used for the resistor calculation is 13.5V; the set-up also includes a reverse polarity diode in series to provide added protection. Three LEDs in a string are a typical electrical arrangement since they can be easily biased from a vehicle's battery /charging and cranking system.

If the vehicle's battery voltage increases to 16 V, the LED string current will increase by around 30%. Conversely, when the battery voltage decreases to 9V it only allows 7 milliamps (mA) to flow in the Led string, representing a decrease of 77% in comparison to the 13.5 V case. From these simple calculations, it is easy to see that a resistor is not a very good current source to use for the regulation of LEDs. However, one good aspect of resistor based current regulation is that each string in the CHMSL array can have an individual device to set the current for that string (Figure 1b). Individual string biasing means that if one LED string happens to go open circuit, it does not affect the other adjacent strings.

An alternative current source is based on the old standby LM317 arranged as a floating current source. Examining Figure 1c, the LM317 has an internal bandgap reference of 1.25V. When the adjust pin is fed to the output through a resistor it forces the reference to be applied across the resistor. No ground connection is required for this device and it can float above the LED string voltage providing a highly accurate current source that has outstanding line regulation over the full automotive voltage range.

The problem is that in an application, the designer would only use one LM317 to current-regulate all of the LEDs in the array. Special care should be taken when connecting LEDs in a parallel as in Figure 1c due to the mismatched forward voltage of the LEDs. By feeding the array with a single current source, it forces the current to divide amongst the parallel connected LED strings. Sometimes a resistor is added to each string to take up the slight differences in forward voltage, and force more even current sharing of the LED strings.

If a string goes open circuit, the LM317 cannot distinguish this from a normal operation, and forces the same current to flow among the remaining LEDs. This added power stress will lead to reduction in LED lifetime due to an increase in the LED's junction temperature.

Another often overlooked issue when using the LM317 as a current source is the large drop out voltage that is required. The dropout voltage of Figure 1c consists of the bandgap reference of 1.25 V across the resistor plus the saturation voltage drop across the series pass transistor inside the LM317. This may be as high as 2V or greater depending on the value of the current. Therefore, a low line voltage will cause the LM317 to work in the drop out region, where the regulated current falls rapidly to zero; this may result in little or no light output from the Led array. Ideally, a low cost, two terminal constant current source that can be placed

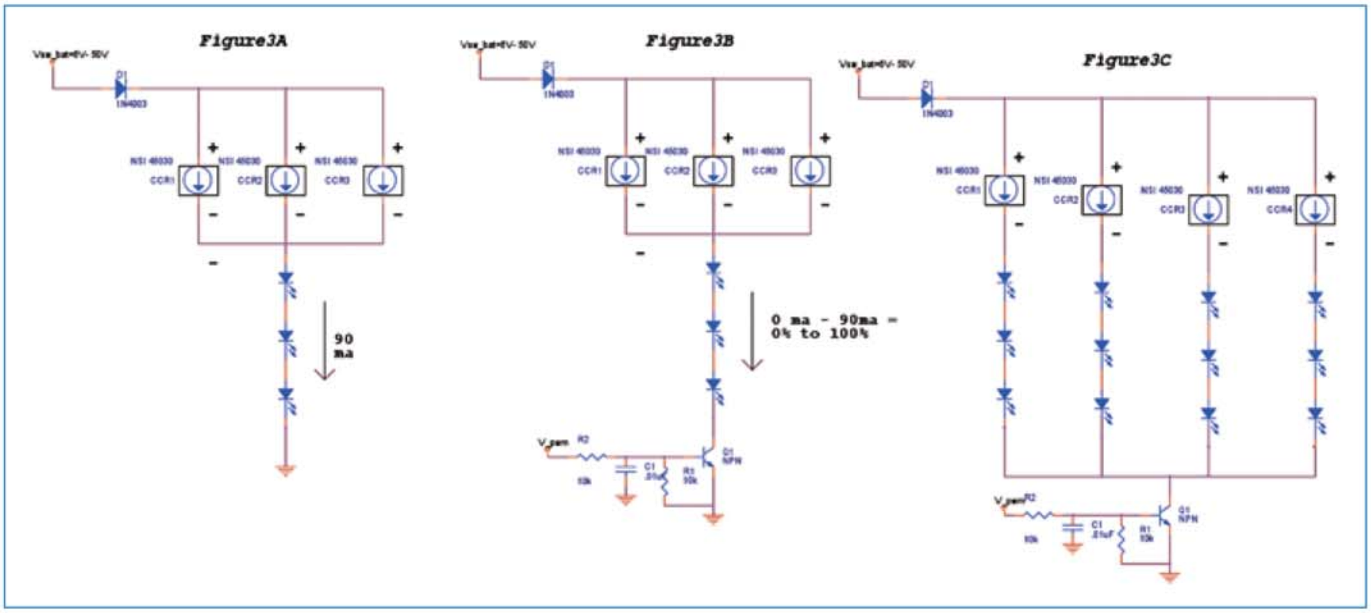

Figure 3a: Due to the constant current nature of the device, CCRs add perfectly in parallel.
Figure 3b: Using a simple NPN Bias Resistor Transistor or BRT allows for the CCR to be PWM controlled for applications that require dimming.
Figure 3c: Several CCR and LED strings could be controlled through a single low side transistor.

in each string like the resistive current source in Figure 1b, combined with solid state current regulation of figure 1c would offer the best circuit approach when LED current regulation is required over the full automotive voltage range.

Constant Current Regulation (CCR) as a design option

A new breed regulation – such as the Constant Current Regulators (CCR) offered by ON Semiconductor – can deliver an easy to implement, economical and robust option for designs requiring a regulated current over a broad voltage range. The added benefit is they are as easy-to-use as a resistor.

In Figure 2, the current / voltage (I/V) characteristic is plotted for both a CCR device and a Resistor in the circuit shown Figure 1a which represents a linear load line with a slope of 1/R or 5.1x10-3 mhos of conduction. If the 196 ohm resistor is replaced with a 30mA CCR, we can see that the slope of the IV line changes as a function of the voltage applied across the device. The initial turn-on shows a conduction of approximately 10 mhos. This higher slope in comparison to the resistor slope shows that at low line voltage, the CCR will allow for greater light output. As the line voltage increases the CCR conduction slope abruptly changes, and the current begins to regulate as the line voltage increases. At a specific line voltage the CCR current will equal the resistor as the two curves cross each other. As the line voltage increases further, the current in the resistor grows at the same linear rate, the CCR however remains constant. It is this high voltage region in which the CCR outshines the resistor bias approach because the regulated current protects the LEDs from the extreme voltage conditions experienced.

Since the Circuit designer needs to provide current regulation for LEDs that have several light intensities across the same LED part number, ON Semiconductor offers CCRs in three current ranges and two packages. 20mA, 25mA and 30mA devices are available in the cost effective SOD 123 package, with 25mA and 30mA parts also offered in a SOT 223 package. If needed, these devices can easily be placed in parallel for higher current requirements.

Due to the constant current nature of the device, CCRs can be added in parallel as shown in figure 3a; this allows the excess power to be amongst several devices thereby limiting the individual junction temperatures. ON Semiconductor will soon be releasing higher current devices suited for applications such as automotive interior map lighting, centre stack lighting, exterior side repeaters, and accent lighting.

Using a simple NPN Bias Resistor Transistor (BRT) as shown in Figure 3 b, allows the CCR to be pulse width modulation (PWM) controlled for applications that require dimming, Several CCR and LED strings could be controlled through a single low side transistor as in figure 3c.

Conclusion

LED current biasing using resistors or expensive current sources like the LM317 can be easily accomplished. However, resistors offer poor regulation and LM317 biasing forces parallel LED configurations that are not desirable from an LED array and current sharing perspective. New solutions such as the CCRs have been shown to provide an optimum way to apply low cost current regulation for individual and series string LEDs for most low current automotive applications. The fact that the CCR devices are available in several current ranges and allow for parallel connections to give increased current ranges, not only facilitates greater design flexibility, but also allows the circuit designer to maintain individual string bias without having to sacrifice outstanding current regulation.

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