

# DACx3401 Delivers Automotive and Commercial LED and Laser Diode Biasing Solution

Uttama Kumar Sahu



Designing a biasing circuit for an LED or a laser diode can be challenging with constraints like density, cost, accuracy, and configurability. The DACx3401 device family presents a solution to address these requirements for both commercial and automotive applications.

## Introduction

LEDs and laser diodes are used in automotive and commercial end equipments such as USB ports, automotive LIDAR, automotive interior lighting, multi-function printers, mobile projectors, and electronic point-of-sale (EPOS). The key requirement of these end equipments is biasing the LEDs at the correct illumination. The set illumination must be constant across temperature, time, and supply variations. Board space and solution cost is also critical for these end equipments. There are multiple approaches to bias LED or laser diodes which include PWM, LED drivers, and so forth. DACs offer an alternative way of biasing the LED or a laser diode with some key benefits. The following is a DAC-based approach to bias LED/laser diodes using the DACx53401 family. The DACx3401 is a family of 10-/8-bit DACs with integrated EEPROM and reference. This cost-optimized DAC is available in tiny 2x2 SON packages, making it an attractive choice for space-constrained applications.

## Biasing Using PWM and Switch-mode Drivers

LEDs and laser diodes can be biased with a PWM signal as shown in Figure 2. The PWM bias signal must be filtered before feeding it to the LED to reduce the light flicker. Typically, this artifact of PWM biasing necessitates choosing higher current rated LEDs. The PWM signals are generated from a digital source. The amplitude of PWM signal can vary up to  $\pm 10\%$  based on power supply design. This causes variation in the current flowing into the LED and thereby impacting the set illumination. The PWM signal also introduces crosstalk to adjacent signals unless the sensitive signal traces are kept spatially away from the PWM traces.

Switch-mode LED drivers provide benefits over PWM-based biasing in that the switching transients are filtered using inductors and capacitors. Many a time, a DAC is used in such systems to set the LED current. Due to the external components, the switch-mode designs become bulky and costly. Hence, they are unsuitable for dense, cost-effective, and precision systems.

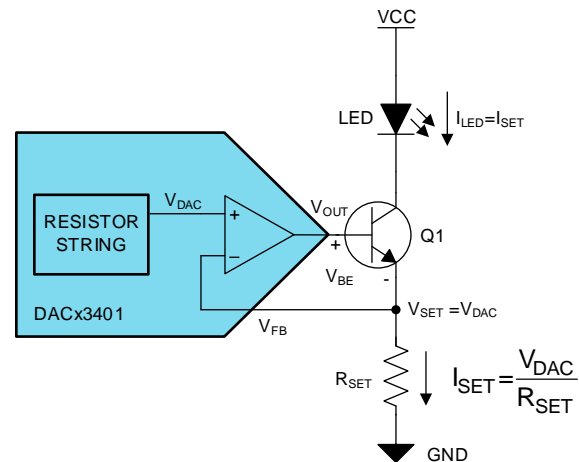


Figure 1. LED Biasing with DACx3401

## LED Biasing Using a DAC

Figure 3 shows a LED biasing design with a DAC. The current flowing through the LED is set by the resistor ( $R_{SET}$ ) and the voltage at the emitter node ( $V_{SET}$ ). The DAC sets the voltage ( $V_{SET}$ ) and the current is regulated by the op amp (OP1) and transistor (Q1). Note that a metal-oxide semiconductor field-effect transistor (MOSFET) or a bipolar junction transistor (BJT) can be used for this approach.

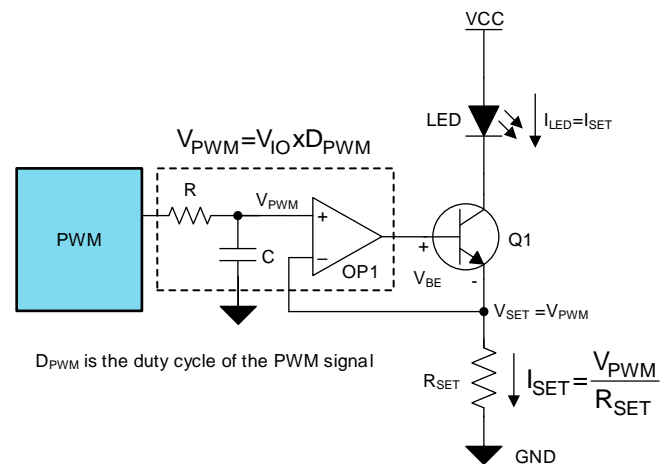
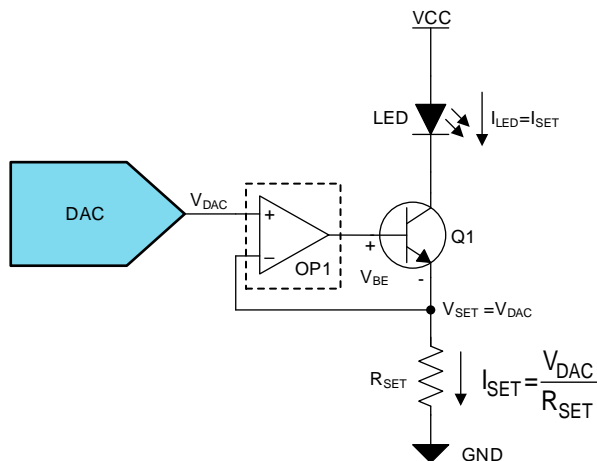


Figure 2. PWM-based LED Biasing

Since the BJT is inside the feedback loop of the op amp, the base-emitter voltage ( $V_{BE}$ ) drop and temperature drift are compensated. To minimize cost and solution size, the op amp can be removed from the design. However, this directly impacts the accuracy of the solution. The  $V_{BE}$  of the BJT can vary up to  $\pm 10\%$  (part to part variation). Additionally, the  $V_{BE}$  drift with temperature can be as high as 500 ppm/ $^{\circ}\text{C}$ . To minimize the impact of these variations, the DAC code needs to be tuned for each BJT and across temperature range.



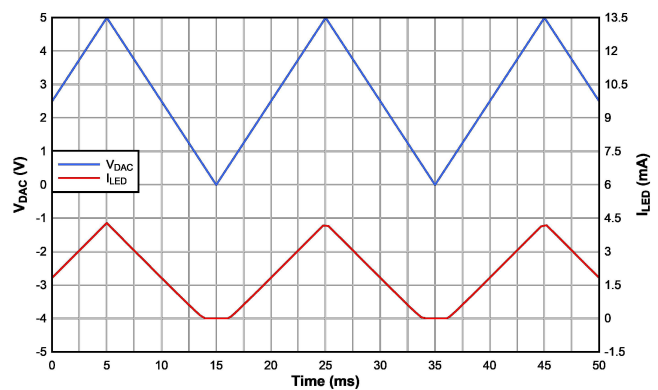
**Figure 3. LED Biasing Using a DAC**

### LED Biasing with DACx3401 or DACx3401-Q1

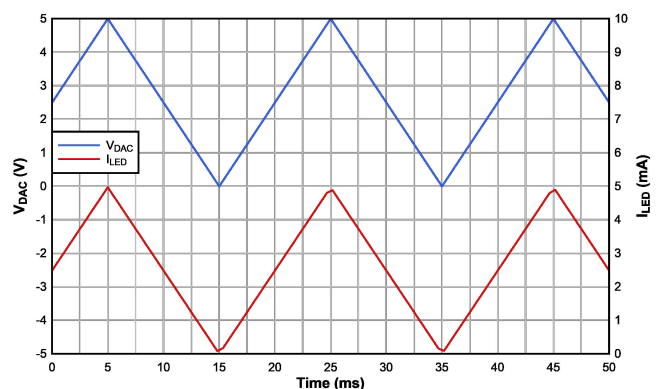
The feedback node of the output op amp in DACx3401 is available as a pin. This helps the designer compensate the base-emitter voltage drop and temperature drift without using any external op amp. Figure 1 shows the circuit diagram of this implementation. Figure 4 and Figure 5 show the waveforms without and with the base-emitter voltage compensation, respectively. You can clearly notice the impact of the  $V_{BE}$  drop in Figure 4.

### Processor-less and 'Set and Forget' Operation

Using the feedback pin of the DACx3401 devices, the  $V_{BE}$  drop and temperature variations are compensated in this approach. For many systems, these are the only source of errors in the signal chain. This means that for a particular luminosity, the DAC can be set to a fixed code. The DACx3401 and DACx3401-Q1 devices include EEPROM that can be used to store the DAC code that is retained even after a power cycle. The DAC code can be set during the production flow and stored on the EEPROM bits. This a key benefit of this DAC family that eliminates the need for a processor in the system saving board space and cost.



**Figure 4. Biasing Without  $V_{BE}$  Compensation**



**Figure 5. Biasing with  $V_{BE}$  Compensation**

### DACx3401 and DACx3401-Q1 Family of DACs

The 10-bit DAC53401 and 8-bit DAC43401 (DACx3401) are a pin-compatible families of buffered voltage-output digital-to-analog converters (DACs). These devices have NVM, internal reference, and PMBus™ compatible I2C interface. The DACx3401 operates with either an internal reference or the power supply as a reference, and provides full-scale output of 1.8 V to 5.5 V. The devices communicate through the I2C interface. These devices support I2C standard mode (100 kbps), fast mode (400 kbps), and fast mode plus (1 Mbps).

### Conclusion

There are multiple ways of designing LED or laser diode biasing circuit. The DAC-based approach offers a compact and low cost solution with good accuracy. The DACx3401 family of devices combine accuracy, feature set, small size, and low cost making them ideal for this application.

## IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, or other requirements. These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to TI's Terms of Sale ([www.ti.com/legal/termsofsale.html](http://www.ti.com/legal/termsofsale.html)) or other applicable terms available either on [ti.com](http://ti.com) or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265  
Copyright © 2019, Texas Instruments Incorporated