# Linear current source applied to LED driver with PWM dimming using TSB582

## Introduction

Linear current sources are not as efficient as DC-DC ones, but they are cost-effective. They also have the advantage of integration at the expense of a limitation due to power dissipation.

Thanks to its output current capabilities, the TSB582 is an excellent auto grade-rated device that can be used as a current source for resolvers, LEDs, and many other applications.

This design note explains how to design a current source based on the TSB582 with a particular example based on LED driving including PWM dimming capability. However, the design is generic and may be used for any other type of sensor/actuator.

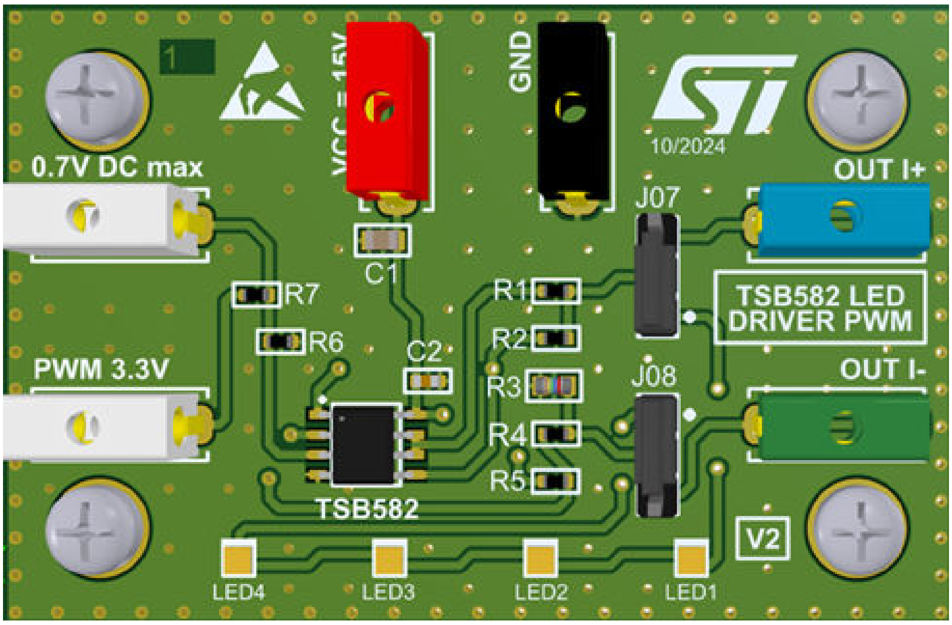
The key element to sizing the application is knowing, for a given current, the min. and max. voltages that the op amp output will have to apply (which is dependent on the element to bias and the sense voltage across the shunt).

The power supply will then have to be higher than this max. voltage plus the saturation voltage of the op amp.

Then, the power dissipation needs to be considered, to ensure that the op amp will not go into thermal shutdown mode.

# 1 LED driver application with the TSB582

Figure 1. TSB582 LED driver PWM



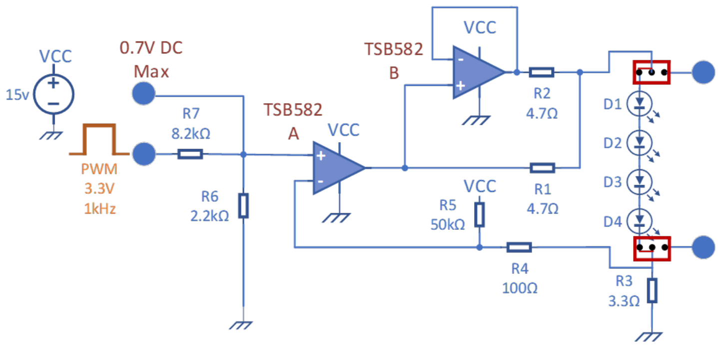

**Features**

- Supply voltage range: 15 V
- $I_{OUT}$ : 200 mA
- Benefits:
  - Uses an operational amplifier as LED driver
  - Automotive grade solution
  - Flexibility

Application

- LED
- Current source
- DRL driving

Figure 2. Schematic of the LED driver application with the TSB582




## 1.1 Description

This application is an LED driver that works with a PWM generated by an STM32 microcontroller. A jumper allows it to be switched in a current source for other applications.

## 1.2 How it works

A microcontroller such as an STM32 is used to deliver a PWM signal with a 3.3 V amplitude between 200 Hz and 1 kHz.

- The signal is converted into a current thanks to the op amp. Both channel outputs are shorted to increase output current capability.

- The R1 and R2 resistors are used to avoid a short-circuit on the op amp outputs related to $V_{IO}$ mismatch between channels. This architecture also allows for better efficiency as the saturation voltage of each channel will be closer to the $V_{CC}$ rail (as they drive only half of the current), allowing less power dissipation in the op amp.

- The R3 shunt resistor sets the current in the LEDs ($V_{IN}$ / R3).

- The R5 and R4 shift the voltage on V- to ensure the saturation of the op amp when V+ = 0 V.

- The R7 and R6 form a voltage divider used to work over the full range of the microcontroller’s PWM (3.3 V) and match the input range of the system.

- There are some jumpers that allow the output to be switched for any other current source application.

**Current in the LEDs:**

LEDs are current-driven. The higher the current, the brighter the LEDs, within the limit of the datasheet. In our application, we choose to drive some DRL (Daytime Running Lights) with a forward current ($I_{LED}$) of 200 mA.

$$I_{LED} = \frac{V_{in}}{R3}$$

**Voltage drop sizing according to $V_{CC}$ and $V_{OUT}$**

$V_{DROP} = V_{CC} - V_{OUT}$

Figure 3. $V_{DROP}$ according to $V_{CC}$ and $V_{OUT}$ explanation schematic

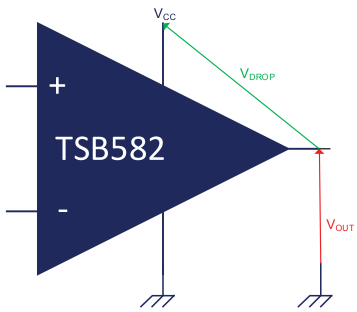
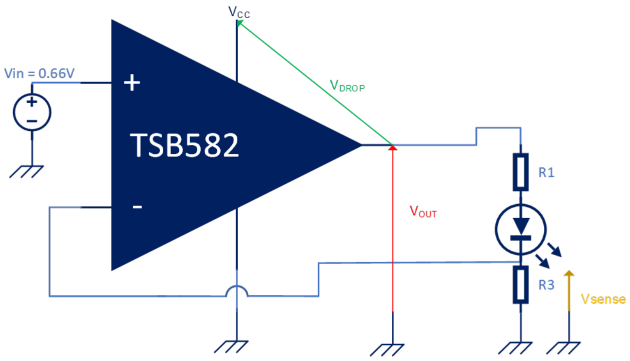



Figure 4. $V_{DROP}$ schematic applied to our application



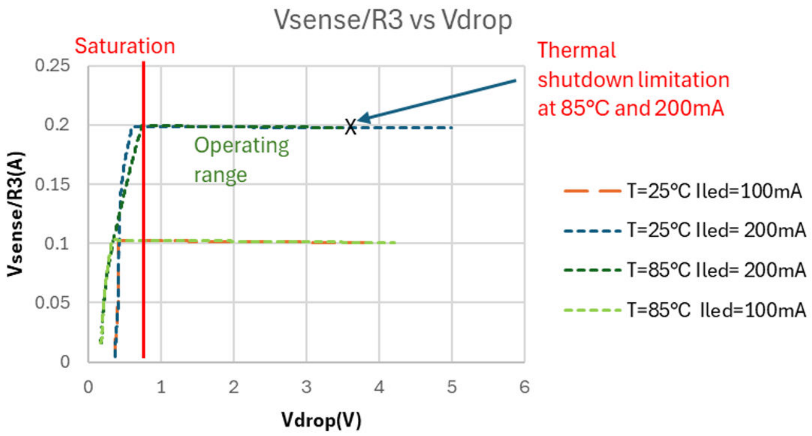

$V_{OUT}$ is calculated according to the number of LEDs.

$V_{OUT}$ = Number of LEDs * $V_F$ + $I_{LED}$ * $R_3$ + ($I_{LED}$ / 2) * $R_1$

In the following test, we set the current of our application to two values: 100 mA and 200 mA. The TSB582 is designed to operate at 36 V, but in this type of application, the power supply is limited due to the power dissipated in the package. To measure the $I_{LED}$ of the op amp, we measure the voltage across R3.

**Result:**

**Figure 5. Vsense/R3 vs. $V_{DROP}$**




We can see on the curve that the minimum voltage drop required to operate correctly is around 0.5 V for 100 mA and around 1 V for 200 mA. It causes a temperature increase in the op amp.

The thermal range of use can be improved by selecting an appropriate $V_{DROP}$values; the closer $V_{CC}$ is to $V_{OUT}$, the higher $T_{AMBIENT}$ can be. It can also be improved if the user reduces $I_{OUT}$ to limit the power.

In the worst-case scenario ($I_{LED}$ = 200 mA and T = 85 °C), if $V_{DROP}$ is close to 3 V, it activates the thermal shutdown due to the temperature increase. Note that the board is not optimized to achieve an $R_{THJA}$ of 45 °C/W. Here, it is rather 95 °C/W. If $V_{DROP}$ is less than 1.7 V, $I_{LED}$ cannot reach 200 mA; the op amp is saturated ($V_{CC}$ should be increased).

A good use case is $V_{DROP}$ = 2 V.

**Impact of the number of LEDs on the application:**

Each LED has a voltage drop between the anode and the cathode (forward voltage). In our case, the LED LM301B has a 3 V forward voltage. The voltage drop of each LED has a real impact on the function of the op amp because the more LEDs there are, the higher $V_{OUT}$ is, and therefore $V_{CC}$.

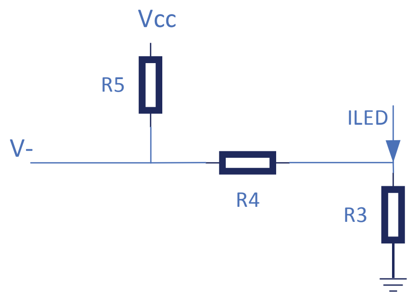
**Switching the LEDs off:**

To switch the LEDs off, the input signal is set to 0 V, but due to the input offset voltage and the 0 V setting error, there might still be a small current driven into the LEDs. To solve this issue, we have added a voltage divider (R4 and R5), which adds an offset of 30 mV to $V_-$ to saturate the 000 op amp in every case.

When $V_+$ = 0, $V_-$ = 30 mV for $V_{CC}$ = 15 V. The differential input is significantly higher than the worst-case input-offset voltage ($V_{IO(max)}$ = 3 mV)

The output is controlled in all use cases.

**Figure 6.** **Output control**




$$I_{LED} = (V-)\left(\frac{1}{R3} + \frac{R4}{R5*R3} + \frac{1}{R5}\right) - \frac{Vcc}{R5}\left(1 + \frac{R4}{R3}\right)$$

For a given targeted $I_{LED}$, $V_{IN}$ should be set to:

$$V_{IN} = \frac{I_{LED} + Vcc\left(\frac{1}{R5} + \frac{R4}{R3R5}\right)}{\left(\frac{1}{R3} + \frac{R4}{R5*R3} + \frac{1}{R5}\right)}$$

$$V_{IN} = R3*Iled + Vcc\left(\frac{R3}{R5} + \frac{R4}{R5}\right)$$

So, $V_{IN} = R3*\left[Iled + \frac{Vcc}{R5}*\left(1 + \frac{R4}{R3}\right)\right]$

It creates an offset of 9.4 mA in our example.

$$V_{IN} = R3*[Iled + 9.4mA]$$

Ensuring the LEDs are properly switched off thanks to this offset causes a permanent leakage current ($V_{CC}$/R5 = 0.3 mA) when the system is on but it is insignificant compared to the typical $I_{CC}$ of the TSB582: 2.3 mA per channel. Note that the op amp cannot generate a negative voltage, so when $V_{IN}$ = 0 V, there is no current in the LED and only thee 0.3 mA in R3.

**Performance of the application as a function of the number of LEDs:**

$$V_{OUT}(typ) = VIN + VF.LED\ x\ Nb.LEDs + R1*\frac{ILED}{2}$$

| |
|---|
| $V_{CC}(min) = V_{OUT}(max) + V_{DROP}(min)$ |
| $V_{F(max)} = V_{FORWARD} + V_{TOLERANCE} = 2.8 + 0.1$ |
| $V_{DROP} = V_{CC} - V_{OUT}$<br>$\text{Power Dissipated} = V_{DROP}*I_{LED} + V_{CC}*I_{CC}$<br>$\text{Temperature elevation} = P_{DISSIPATED} * R_{THJA}$ |

To consider the actual performance of the PCB, an $R_{THJA}$ of 100 °C/W is considered instead of 45 °C/W:

Considering we would like to source 200 mA DC in the LEDs, here are different use cases.

Op amp $T_J$ (°C) = $I_{CC}$ * $V_{CC}$ + $I_{LED}$ * $V_{DROP}$ * $R_{THJA}$ + $T_{AMBIENT}$

Figure 7. **Application setup vs. number of LEDs**

| Number of LED | Vout typ (V) | Vcc min (V) | Vcc rounded up (V) | WC voltage drop in the opamp (V) | Maximum Power Dissipated (mW) | Maximum Temperature Elevation (°C) | Maximum operating temperature (°C) |
|---|---|---|---|---|---|---|---|
| 1 | 3.9 | 6.0 | 7 | 3.2 | 664 | 66 | 84 |
| 2 | 6.7 | 8.9 | 9 | 2.5 | 533 | 53 | 97 |
| 3 | 9.5 | 11.8 | 12 | 2.8 | 607 | 61 | 89 |
| 4 | 12.3 | 14.7 | 15 | 3.1 | 681 | 68 | 82 |

We considered $V_{DROP}$ = 200 mV.

Note that if the PWM is not set to 100%, the power dissipation would be decreased and the maximum operating temperature increased.

In our application, we consider driving four LEDs with a 15 V power supply. This leads to an efficiency of 73%, which is good for a linear current source.

This schematic can be fine-tuned for your DRL (Daytime Running Lights) application (considering the TSB582 is automotive grade).

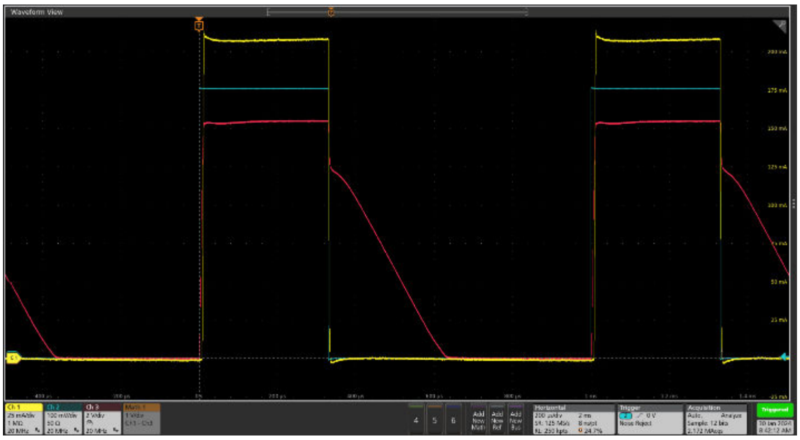
## 1.3 Performance of the application

We are using a PWM of 1 kHz.

Application without the offset block implemented ($V_{CC}$ = 15 V, 4 LEDs, PWM duty cycle = 33%)

Yellow = $I_{LED}$, Red = $V_{OUT}$, Blue = $V_{IN}$

Figure 8. **Performance of the application without the offset block implemented**

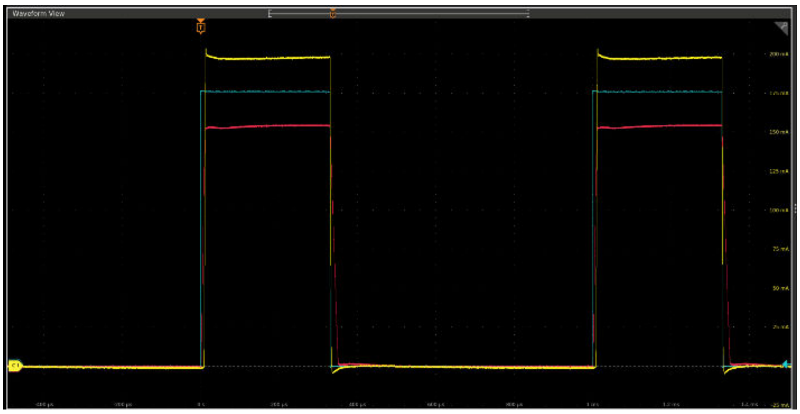


We see the output voltage (red) takes time to get down to saturation as the differential input voltage is not high enough to cause saturation when $V_{IN}$ = 0 V.

With the correction ($V_{CC}$ = 15 V, 4 LEDs, PWM duty cycle = 33%):

Yellow = $I_{LED}$, Red = $V_{OUT}$, Blue = $V_{IN}$

Figure 9. **Performance of the application with the offset block implemented**



The offset implementation clearly allows the LEDs to be completely switched off. To get the proper amount of current one should apply 3.3 x 209.4 mA instead of 3.3 x 200 mA at op amp input.

Figure 10. Application performance ($I_{LEDs}$ vs. $V_{IN\_DC}$)

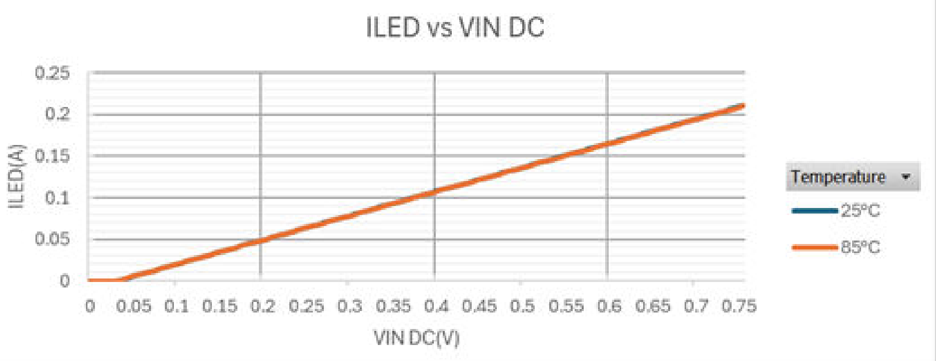
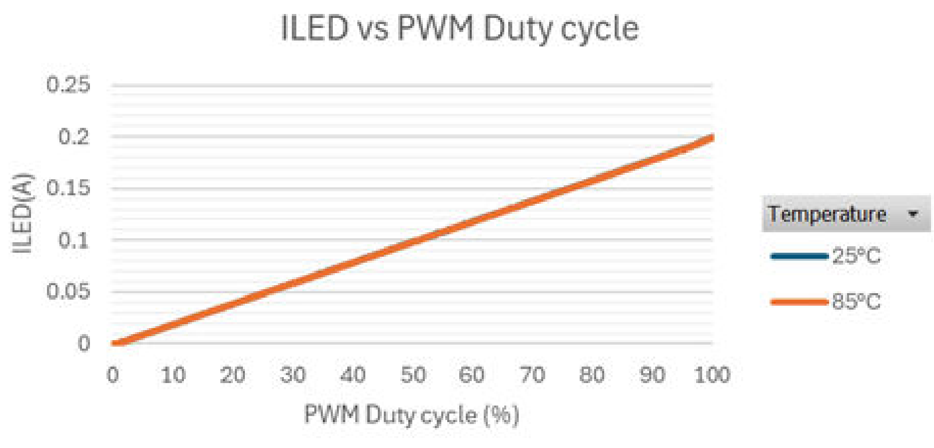



Figure 11. Application performance ($I_{OUT}$ vs. PWM input)




**Performance of the application:**

This note shows a simple way to use the TSB582 op amp as a current source. This can be convenient for many applications that do not require the use of a DC-DC to reduce the cost of the BOM.

You can easily control it with the duty cycle of the PWM or with the DC input voltage.

The board is designed to be adapted to any other application using the jumpers. Make sure to adapt the $V_{CC}$ to the $V_{DROP}$ voltage required by your application.

## Revision history

Table 1. **Document revision history**

| Date | Version | Changes |
|---|---|---|
| 07-Jan-2026 | 1 | Initial release. |

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