LM3590 Series White LED Driver

Check for Samples: LM3590

FEATURES

- **Drives up to 3 Stacked White LEDs**
- **6.0V-12.6V Input Voltage Range**
- **Up to 20mA LED Output Current**
- **Excellent LED Current Matching Specified by Series Configuration**
- **Single Connection to the White LEDs in the Display Module**
- **Tightly Controlled Programmable Current Source**
- **Low Shutdown Current (0.1µA typ.)**
- **PWM Brightness Control**
- **Very Small Solution Size**
- **SOT-23-5 Package: 3mm × 3mm × 1.0mm (L×W×H)**

APPLICATIONS

- **White LED Display Backlights**
- **Keypad Backlights**
- **General Purpose Constant Current Driver for High Forward-voltage LEDs**

DESCRIPTION

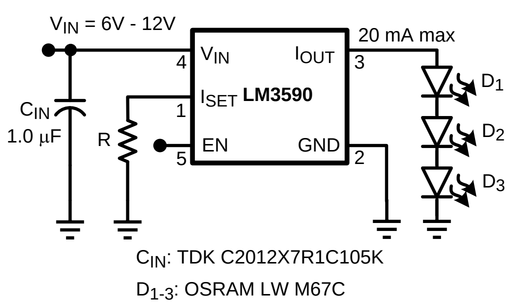
The LM3590 is a White LED constant current driver capable of supplying up to 3 White LEDs connected in series with 20mA. This device operates over a wide 6V-12.6V input voltage range. The output can accomodate LEDs with a combined forward voltage of up to 11.5V, from a 12V input supply. The LED drive current is programmed by using an external resistor on the I_{SET} pin.

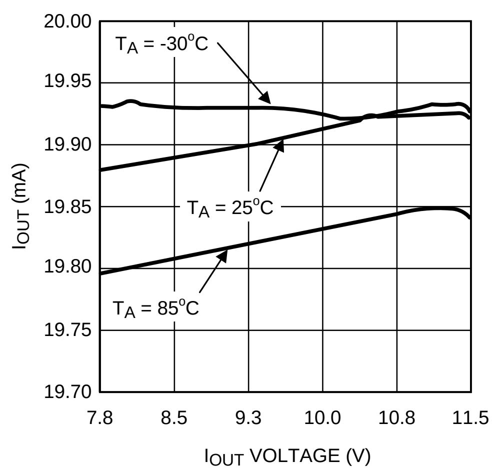
LED brightness can be linearly varied up to the programmed LED current by applying a Pulse Width Modulated (PWM) signal to the EN pin of the device. The LED output current of the LM3590 is tightly controlled over temperature and voltage. LED Current matching is ensured due to the series configuration of the LEDs. The series topology also simplifies the connection between the White LEDs in the display module and the LM3590 since only one connection is required.

The LM3590 typically draws only 50µA when operating in the no-load condition and draws less than 0.1µA when the device is shut down.

The LM3590 is available in a small 5-pin SOT-23 package.

Typical Application Circuit





Connection Diagram

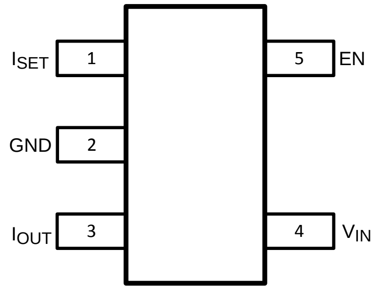


Figure 1. Top View

PIN DESCRIPTIONS

Pin #	Name	Function
1	I_{SET}	Programmable LED current Input. The LED current has the following relationship with the resistor used: $R_{SET} = 100 \times (125 \div I_{OUT})$
2	GND	Ground Connection
3	I_{OUT}	Constant Current LED Output
4	V_{IN}	Power Supply Voltage Input. Input voltage range: 6V-12.6V
5	EN	Device Enable

These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

ABSOLUTE MAXIMUM RATINGS(1)(2)(3)

V_{IN}		−0.3 to 13.0V Max
EN		−0.3 to (V_{IN}+0.3V) w/ 13.0V max
Maximum Junction Temperature, T_{JMAX}		150°C
Storge Temperature		−65°C to +150°C
Maximum Lead Temperature (Soldering, 5 sec.)		260°C
ESD Rating (4)	Human Body Model	1.5kV
	Machine Model	200V

(1) Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings are conditions under which operation of the device is specified. Operating Ratings do not imply ensured performance limits. For ensured performance limits and associated test conditions, see the Electrical Characteristics table.
(2) All voltages are with respect to the potential at the GND pin.
(3) If Military/Aerospace specified devices are required, please contact the Texas Instruments Sales Office/Distributors for availability and specifications.
(4) The human-body model is a 100pF capacitor discharged through a 1.5kΩ resistor into each pin. The machine model is a 220pF capacitor discharged directly into each pin.

OPERATING CONDITIONS

Input Voltage Range	6.0V to 12.6V
EN Voltage Range	0V to V_{IN}
Ambient Temperature (T_A) Range (1)	−40°C to +85°C
Junction Temperature (T_J) Range	−40°C to +110°C

(1) Maximum ambient temperature (T_{A-MAX}) is dependent on the maximum operating junction temperature ($T_{J-MAX-OP}$ = 110ºC), the maximum power dissipation of the device in the application (P_{D-MAX}), and the junction-to-ambient thermal resistance of the part/package in the application (θ_{JA}), as given by the following equation: $T_{A-MAX} = T_{J-MAX-OP} - (\theta_{JA} \times P_{D-MAX})$. The ambient temperature operating rating is provided merely for convenience. This part may be operated outside the listed T_A rating, so long as the junction temperature of the device does not exceed the maximum operating rating of 110ºC.

THERMAL INFORMATION

Junction-to-Ambient Thermal Resistance, SOT-23-5 Package (θ_{JA}) (1)	220°C/W

(1) Junction-to-ambient thermal resistance is highly application and board-layout dependent. In applications where high maximum power dissipation exists, special care must be paid to thermal dissipation issues. For more information on these topics, please refer to the Power Dissipation section of this datasheet.

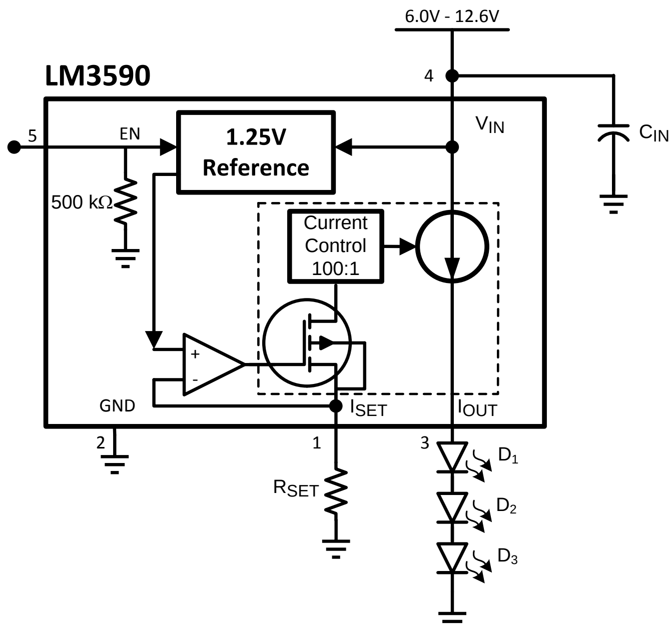
ELECTRICAL CHARACTERISTICS[1][2]

Limits in standard typeface are for T_J = 25°C and limits in **boldface** type apply over the full Operating Junction Temperature Range (−40°C ≤ T_J ≤ +110°C). Unless otherwise specified, C_{IN} = 1 µF, V_{IN} = 12.0V, V_{EN} = 3.0V, R_{SET} = 6.19kΩ, V_{IOUT} = 10.8V.

Symbol	Parameter	Conditions	Min	Typ	Max	Units
I_{OUT}	Output Current Capability	V_{IN} = 12V 7.5V ≤ V_{IOUT} ≤ 11.5V	**19** (−5%)	20	**21** (+5%)	mA
		V_{IOUT} = 10.8V 11.3V ≤ V_{IN} ≤ 12.6V	**19** (−5%)	20	**21** (+5%)	mA
		R_{SET} = 8.35kΩ		15		mA
		R_{SET} = 12.5kΩ		10		mA
	Output Current Programming			125 ÷ R_{SET}		A
	I_{OUT} ratio to I_{SET}			100:1		
I_Q	Quiescent Supply Current	11.3V ≤ V_{IN} ≤ 12.6V R_{SET} = OPEN I_{OUT} = OPEN		50	**75**	µA
I_{SD}	Shutdown Supply Current	V_{IN} = 12.6V V_{EN} = 0V		0.1	**1**	µA
V_{ISET}	I_{SET} Reference Voltage			1.25		V
V_{HR}	Minimum Current Source Voltage Headroom (V_{IN} − V_{IOUT})[3]	I_{OUT} = 95% nominal		300		mV
V_{IH}	Logic Input EN: High level		**1.1**		**V_{IN}**	V
V_{IL}	Logic Input EN: Low level		**0**		**0.3**	V
I_{EN}	Enable Pin Input Current[4]			6		µA
t_{ON}	Turn-On Time	I_{OUT} = 90% of steady state		50		µs

(1) All voltages are with respect to the potential at the GND pin.
(2) All room temperature limits are 100% tested or specified through statistical analysis. All limits at temperature extremes are specified by correlation using standard Statistical Quality Control methods (SQC). All limits are used to calculate Average Outgoing Quality Level (AOQL). Typical numbers are not ensured, but do represent the most likely norm.
(3) The current source is connected internally between V_{IN} and V_{IOUT}. The voltage across the current source, [V_{IN} − V_{IOUT}], is referred to as headroom voltage. For the current source to regulate properly, a minimum headroom voltage must be present across it. Minimum required headroom voltage is proportional to the current flowing through the current source, as dictated by this equation: $V_{HR\text{-}MIN}$ = 300mV × (I_{OUT} ÷ 20mA).
(4) An internal 500kΩ pull-down resistor is connected between the EN and GND pins.

FUNCTIONAL BLOCK DIAGRAM



TYPICAL PERFORMANCE CHARACTERISTICS

Unless otherwise specified, C_{IN} = 1µF, V_{IN} = 12.0V, V_{EN} = 3.0V, V_{IOUT} = 10.8V, R_{SET} = 6.19kΩ, T_A = 25°C. C_{IN} is a low ESR multi-layer ceramic capacitor (MLCC).

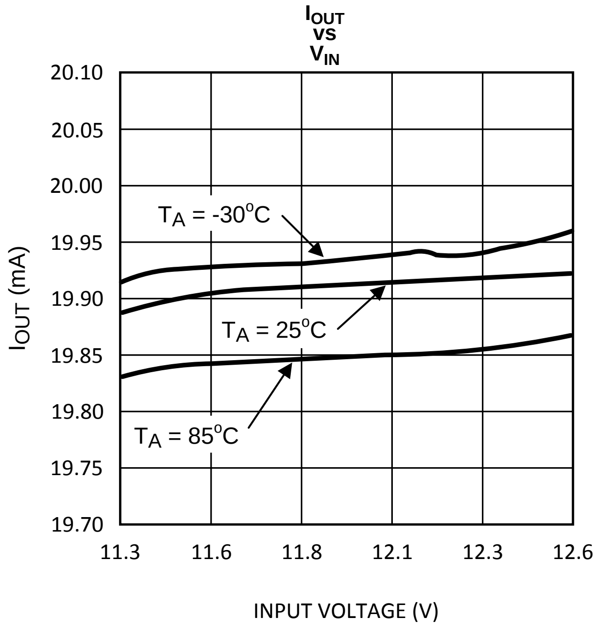


Figure 2.

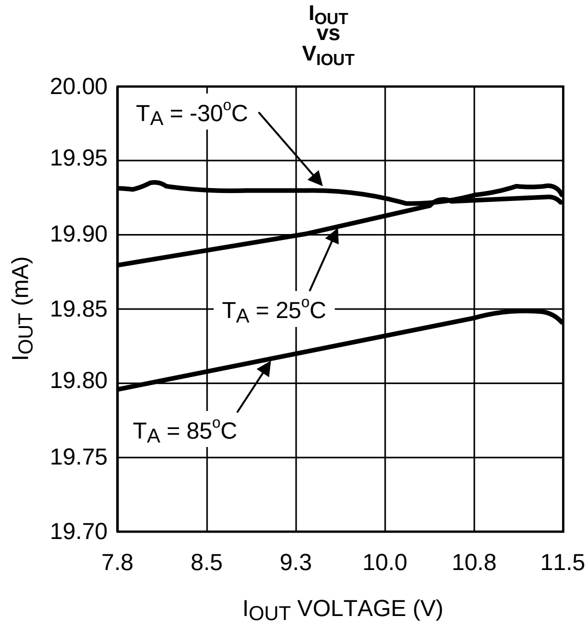


Figure 3.

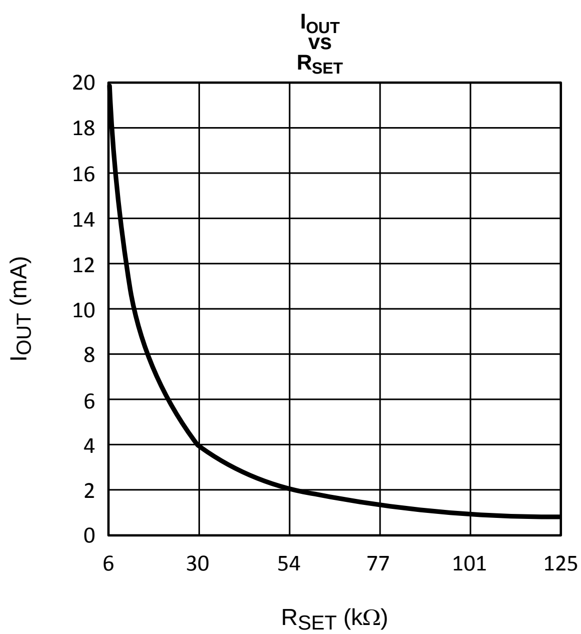


Figure 4.

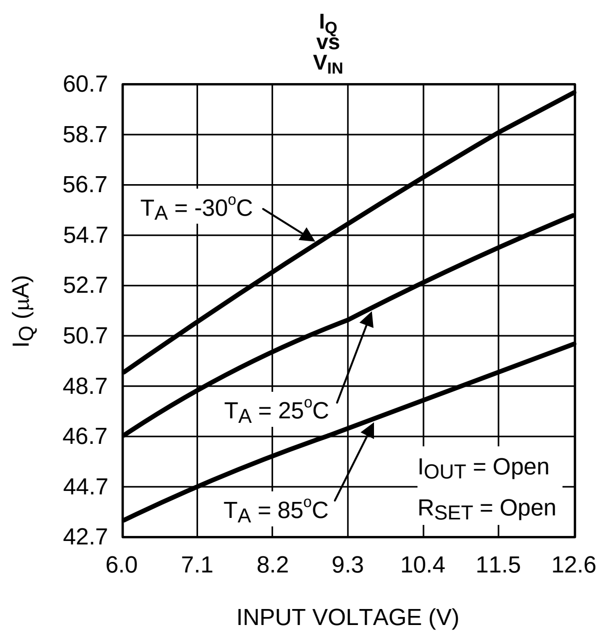


Figure 5.

TYPICAL PERFORMANCE CHARACTERISTICS (continued)

Unless otherwise specified, C_{IN} = 1µF, V_{IN} = 12.0V, V_{EN} = 3.0V, V_{IOUT} = 10.8V, R_{SET} = 6.19kΩ, T_A = 25°C. C_{IN} is a low ESR multi-layer ceramic capacitor (MLCC).

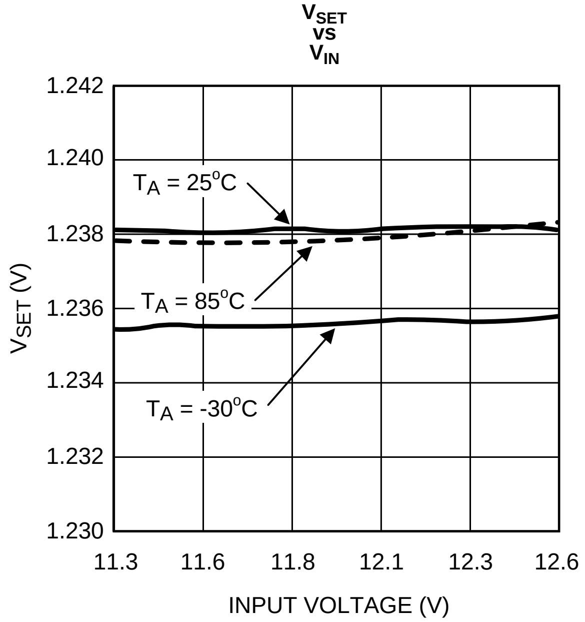


Figure 6.

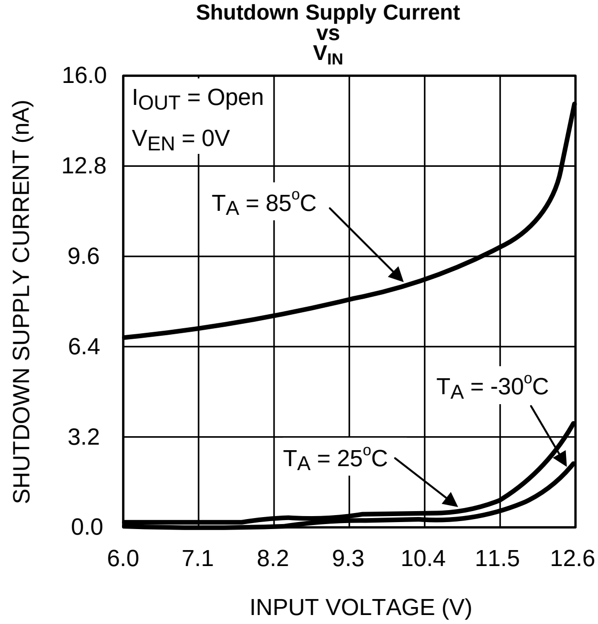


Figure 7.

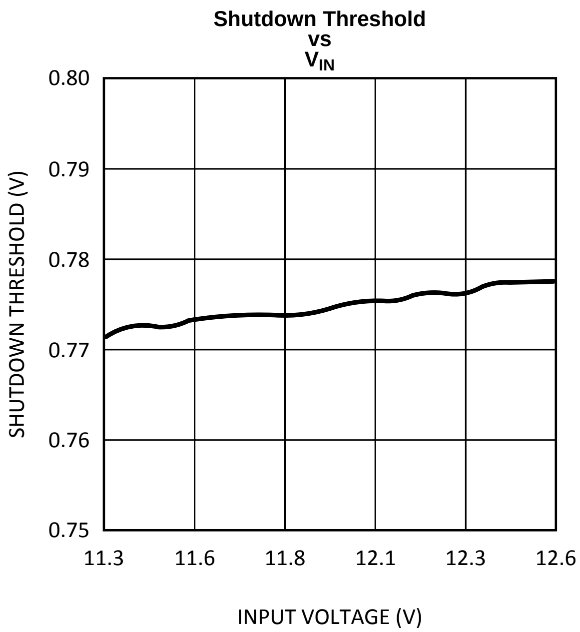


Figure 8.

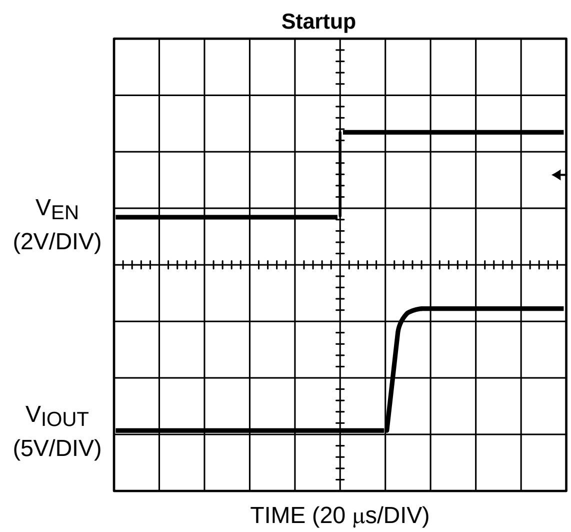


Figure 9.

APPLICATION INFORMATION

CIRCUIT DESCRIPTION

The LM3590 is a constant current series White-LED Driver, providing up to 20mA from an input voltage between 7.5V to 12.6V. To set the LED drive current, the LM3590 uses a resistor connected to the I_{SET} pin to set a reference current. This reference current is then multiplied and mirrored to the constant current output, I_{OUT}. The LED brightness can be controlled by applying a PWM (Pulse Width Modulation) signal to the Enable pin (EN). (see PWM BRIGHTNESS CONTROL PROCEDURES section).

ENABLE MODE

The Enable pin (EN) disables the part and reduces the quiescent current to 0.1µA (typ.). The LM3590 has an active-high enable pin (LOW = shut down, HIGH = operating). The LM3590 EN pin can be driven with a low-voltage CMOS logic signal (1.5V logic, 1.8V logic, etc). There is an internal 500kΩ pull-down between the EN and GND pins of the LM3590.

CAPACITOR SELECTION

Although not required for normal operation, a capacitor can be added to the voltage input of the LM3590 to reduce line noise. A surface-mount multi-layer ceramic capacitor (MLCC) is recommended. MLCCs are small, inexpensive and have very low equivalent series resistance (ESR, ≤15mΩ typ.). MLCCs with a X5R or X7R temperature characteristic are preferred for use with the LM3590. Table 1 lists suggested capacitor suppliers for the typical application circuit.

Table 1. Ceramic Capacitor Manufacturers

Manufacturer	Contact
TDK	www.component.tdk.com
Murata	www.murata.com
Taiyo Yuden	www.t-yuden.com

LED SELECTION

The LM3590 is designed to drive up to 3 LEDs with the combined forward voltages of the LEDs being no greater than 11.5V, when using a 12V input supply. The typical and maximum diode forward voltage depends highly on the manufacturer and their technology. Table 2 lists two suggested manufacturers. LED Forward current matching is specified by design, due to the series LED configuration of the LM3590.

Table 2. White LED Selection

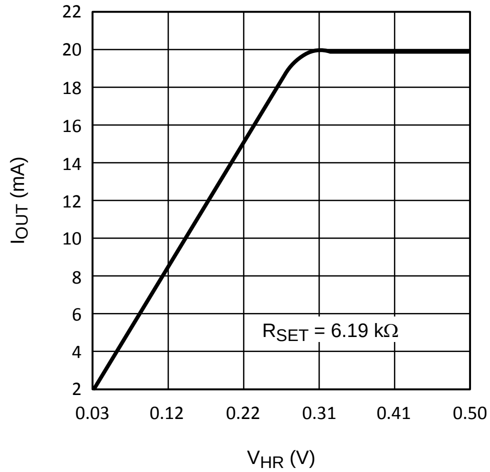
Manufacturer	Contact
Osram	www.osram-os.com
Nichia	www.nichia.com

LED HEADROOM VOLTAGE (V_{HR})

A single current source is connected internally between V_{IN} and I_{OUT}. The voltage across the current source, ($V_{IN} - V_{IOUT}$), is referred to as headroom voltage (V_{HR}). The current source requires a sufficient amount of headroom voltage to be present across it in order to regulate properly. Minimum required headroom voltage is proportional to the current flowing through the current source, as dictated by the equation:

$$V_{HR\text{-}MIN} = k_{HR} \times I_{OUT}$$

The parameter k_{HR}, typically 15mV/mA in the LM3590, is a proportionality constant that represents the ON-resistance of the internal current mirror transistors. For worst-case design calculations, using a k_{HR} of 20mV/mA is recommended. (Worst-case recommendation accounts for parameter shifts from part-to-part variation and applies over the full operating temperature range). Figure 10 shows how output current of the LM3590 varies with respect to headroom voltage.



$V_{HR} = V_{IN} - V_{IOUT}$
$V_{IN} = 12.0V$

Figure 10. I_{OUT} vs V_{HR}

On the flat part of the graph, the current is regulated properly as there is sufficient headroom voltage for regulation. On the sloping part of the graph the headroom voltage is too small, the current source is squeezed, and the current drive capability is limited. Thus, operating the LM3590 with insufficient headroom voltage across the current source should be avoided.

I_{SET} PIN

An external resistor, R_{SET}, connected to the I_{SET} pin sets the output current. The internal current mirror sets the series LED output current with a 100:1 ratio to the current through R_{SET}. The current matching through each LED is ensured by the series LED drive topology. The following equation approximates the LED current:

$I_{OUT} = 100 \times (1.25V \div R_{SET})$ (Amps)

PWM BRIGHTNESS CONTROL PROCEDURES

The brightness of the LEDs can be linearly varied from zero up to the maximum programmed current level by applying a Pulse-Width-Modulated signal to the EN pin of the LM3590. The following procedures illustrate how to program the LED drive current and adjust the output current level using a PWM signal.

1. Determine the maximum desired I_{OUT} current. Use the I_{OUT} equation to calculate R_{SET}
2. Brightness control can be implemented by pulsing a signal at the EN pin. LED brightness is proportional to the duty cycle (D) of the PWM signal. For linear brightness control over the full duty cycle adjustment range, the PWM frequency (f) should be limited to accommodate the turn-on time (T_{ON} = 50µs) of the device.

   $D \times (1/f) > T_{ON}$

   $f_{MAX} = D_{MIN} \div T_{ON}$

   If the PWM frequency is much less than 100Hz, flicker may be seen in the LEDs. For the LM3590, zero duty cycle will turn off the LEDs and a 50% duty cycle will result in an average I_{OUT} being half of the programmed LED current. For example, if R_{SET} is set to program 15mA, a 50% duty cycle will result in an average I_{LED} of 7.5mA.

POWER DISSIPATION

The power dissipation ($P_{DISSIPATION}$) and junction temperature (T_J) can be approximated with the equations below. P_{IN} is the product of the input current and input voltage, P_{IOUT} is the power consumed by the LEDs, T_A is the ambient temperature, and θ_{JA} is the junction-to-ambient thermal resistance for the SOT23-5 package. V_{IN} is the input voltage to the LM3590, V_{IOUT} is the sum of the forward voltages of LEDs connected to the I_{OUT} pin, and I_{OUT} is the programmed LED current.

$$P_{DISSIPATION} = P_{IN} - P_{IOUT}$$
$$= (V_{IN} \times I_{OUT}) - (V_{IOUT} \times I_{OUT})$$
$$T_J = T_A + (P_{DISSIPATION} \times \theta_{JA})$$

The junction temperature rating takes precedence over the ambient temperature rating. The LM3590 may be operated outside the ambient temperature rating, so long as the junction temperature of the device does not exceed the maximum operating rating of 110°C. The maximum ambient temperature rating must be derated in applications where high power dissipation and/or poor thermal resistance causes the junction temperature to exceed 110°C.

Application Circuits

Figure 11 shows how to program the LED current to four different DC levels using two digital logic signals. The programmed LED current is a function of the equivalent resistance on the I_{SET} pin (R_{ISET}), resulting from the logic signals on SET1 and SET2. Example values for R1, R2, and RSET an the resulting 4 current levels are shown below.

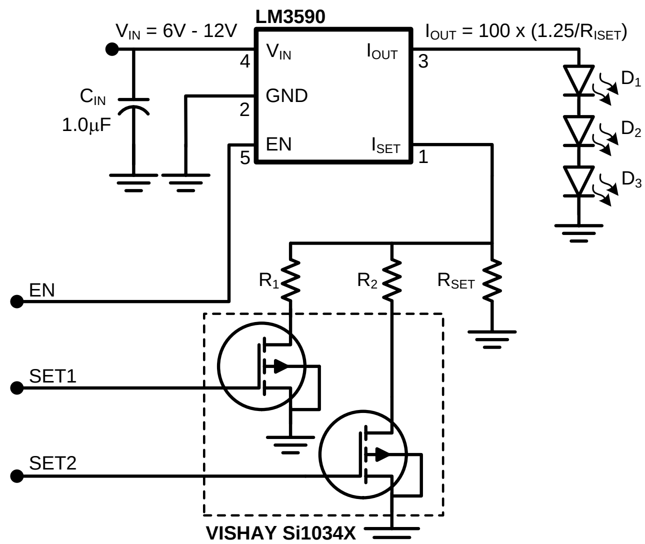


Figure 11. Example: R_1 = 15.8kΩ, R_2 = 31.6kΩ, R_{SET} = 31.6kΩ

Table 3. Digital LED Current Programming

EN	SET1	SET2	R_{ISET}	Example R_{ISET}	Example I_{OUT}
0	X	X	Shutdown	Shutdown	Shutdown
1	1	1	$R_{SET} \| R_1 \| R_2$	31.6kΩ‖15.kΩ‖31.6kΩ	16mA
1	1	0	$R_{SET} \| R_1$	31.6kΩ‖15.kΩ	12mA
1	0	1	$R_{SET} \| R_2$	31.6kΩ‖31.6kΩ	8mA
1	0	0	R_{SET}	31.6kΩ	4mA

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