MT7004B

Boost LED Driver

With High Frequency PWM Dimming

DESCRIPTION

The MT7004B is a Boost LED driver for driving up to 39 LEDs (3-series and 13-parallel) from a 5V system rail. The MT7004B uses current mode, fixed frequency architecture to regulate the LED current, which is measured through an external current sense resistor. Its low 110mV feedback voltage reduces power loss and improves efficiency. The OV pin monitors the output voltage and turns off the converter if an over-voltage condition is present due to an open circuit condition.

The MT7004B includes under-voltage lockout, current limiting and thermal overload protection preventing damage in the event of an output overload.

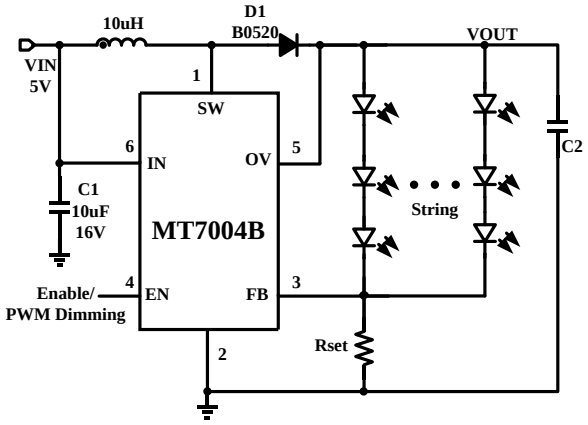
FEATURES

- 2.7V to 6V input voltage range
- Boost PWM with internal power MOSFET
- Drives up to 39 LEDs at 5V input.
- Up 90% Efficiency
- Low feedback voltage: 110mV
- PWM dimming frequency from 100Hz to 200kHz
- Under-Voltage lockout (UVLO) protection
- Internal thermal protection and Open Load Shutdown Threshold(OVP)
- Fixed switching frequency: 1.3MHz
- 1uA shutdown current
- Internal soft-start
- Available in SOT23-6 package

APPLICATION

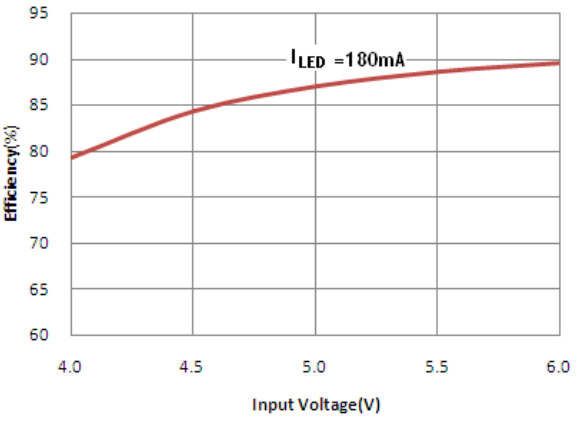
- Small LCD Panels
- Digital Picture Frames
- Handheld Computers and PDAs
- Digital Still Cameras
- Small LCD Displays

Typical Application Circuit

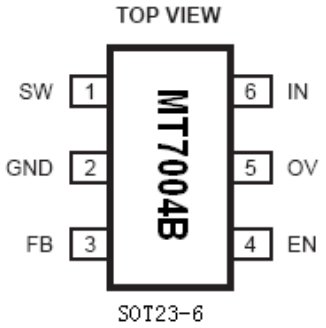


Efficiency vs. Input Voltage

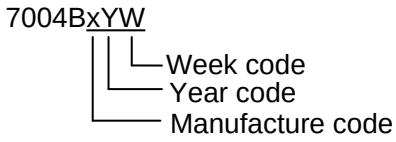
3LED, 9 Strings



Pin configurations



Chip Mark



Pin description

Name	Pin No.	Description
SW	1	SW is the drain of internal power MOSFET. Connect the power inductor and output rectifier to SW. SW can swing between GND and VIN+0.3V.
GND	2	Ground.
FB	3	Feedback input. The MT7004B regulates the voltage across the current sense resistor between GND and FB. Connect a current sense resistor from the bottom of the LED string to GND. Connect the bottom of the LED string to FB. The regulation voltage is 110mV.
EN	4	Chip enable and Dimming Command Input. Holding EN pin low for more than 10ms will turn the part off. To use PWM dimming, add a 100Hz to 200kHz square wave signal to this pin. The EN pin can be left floating.
OV	5	Over Voltage Input. OV measures the output voltage for open circuit protection. Connect OV to the output at the top of the LED string. The default Over-voltage protection threshold is 30.5V. If add external resistor, the OVP threshold can be higher.
IN	6	Power supply. Decouple to ground with 10μF or higher ceramic capacitor close to device

Absolute maximum ratings

SW, OV Pin	-0.3V to +40V
All other pins	+0.3V to 6V
Storage Temperature	-55°C to 150°C

Recommended operating conditions

Supply voltage	2.5V to 6V
Output Voltage	V_{IN} to 36V
Operating Temperature	-40°C to 85°C

Thermal resistance

Junction to ambient ($R_{\theta JA}$)	220°C/W

Electrical characteristics

(V_{IN}=5V, T_A=25°C unless otherwise stated.)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V_{IN}	Input Voltage		2.7		6	V
$I_{shutdown}$	Supply current (Shutdown)	V_{EN}=0V		0.5	1	μA
I_Q	Supply current (Quiescent)	V_{FB}=0.15V		180		μA
f_{SW}	Switching frequency			1.3		MHz
D_{max}	Maximum duty cycle	V_{FB}=0V	85	92		%
Under Voltage lockout						
UVLO	In under voltage lockout	V_{IN} rising.	1.8		2.2	V
	UVLO hysteresis			100		mV
OV	Over voltage protection		28.5	30.5	32.5	V
	OV hysteresis			2		V
Enable						
	EN Threshold	V_{EN} rising, V_{IN}=5V	1.0	1.25	1.6	V
	EN Hysteresis			100		mV
Feedback						
V_{FB}	Feedback voltage		103	110	117	mV
Output switch						
R_{on}	SW On-resistance	*(Note 1)*		0.5		Ω
I_{lim}	Current limit	Duty cycle=60%		1.2		A
OTP	Thermal protection threshold			160		°C
	OTP hysteresis			30		°C

Note 1: *Guaranteed by design*

Block diagram

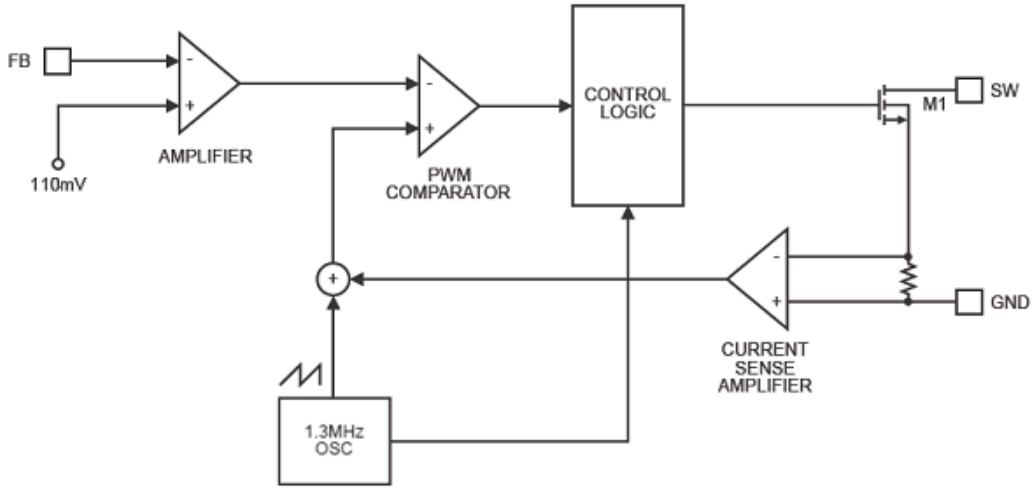


Fig 1—Functional Block Diagram

TYPICAL PERFORMANCE CHARACTERISTICS

(V_{IN} = 5V, 3 LEDs, 9Strings, Iout set as 180mA, unless otherwise noted.)

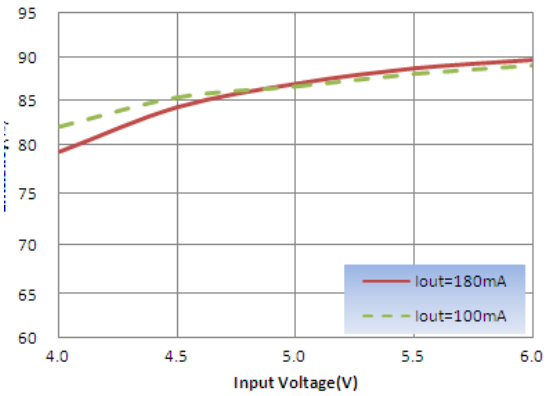


Fig 2. Efficiency vs. Input Voltage

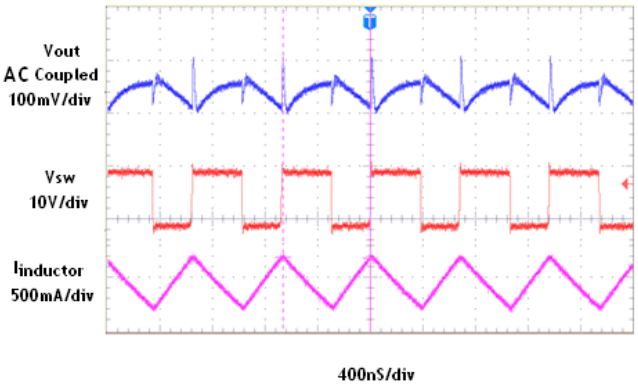


Fig 3. Steady State Operation

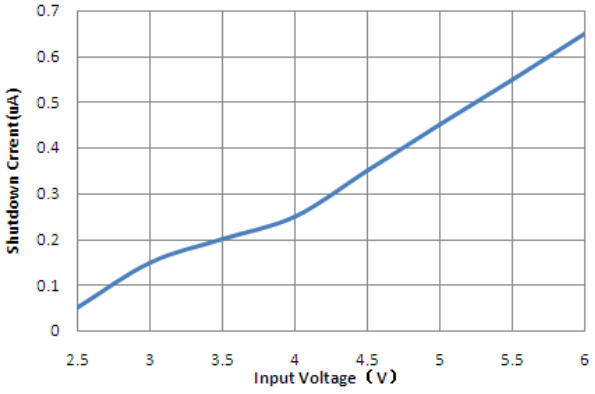


Fig 4. Shutdown Current vs. Input Voltage

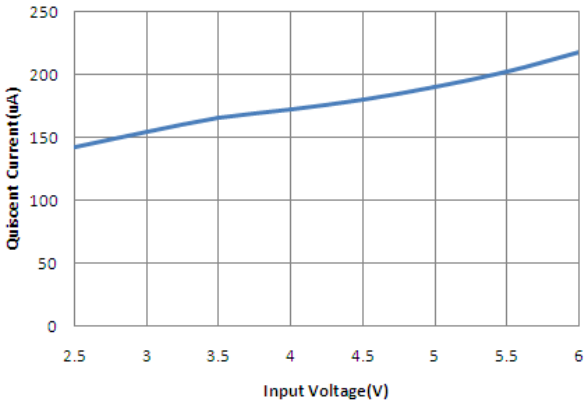


Fig 5. Quiescent Current vs. Input Voltage

TYPICAL PERFORMANCE CHARACTERISTICS (CONTINUED)

(V_{IN} = 5V, 3 LEDs, 9Strings, Iout set as 180mA, unless otherwise noted.)

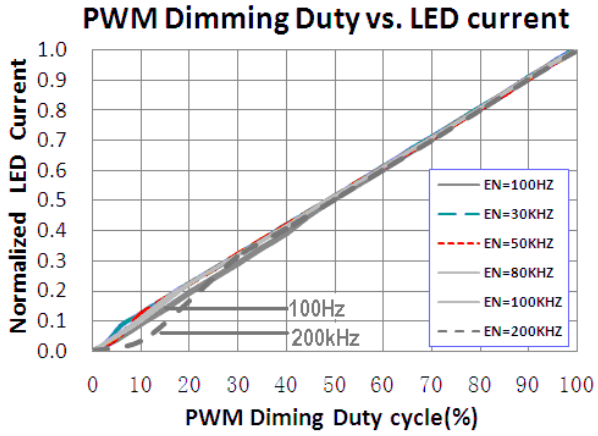


Fig 6. EN PWM dimming vs. LED Current

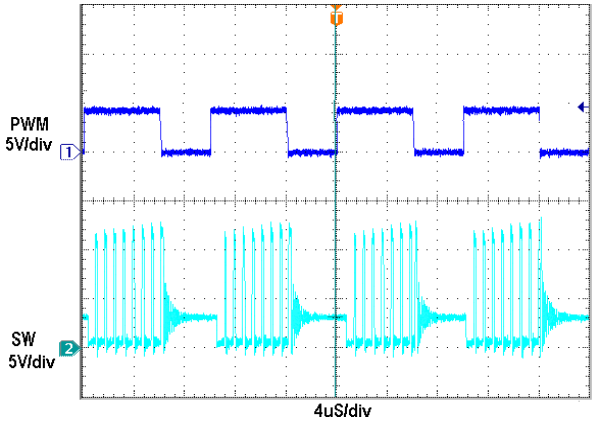


Fig 7. EN PWM dimming vs.SW

F_{PWM}=100kHz, D_{PWM}=0.6

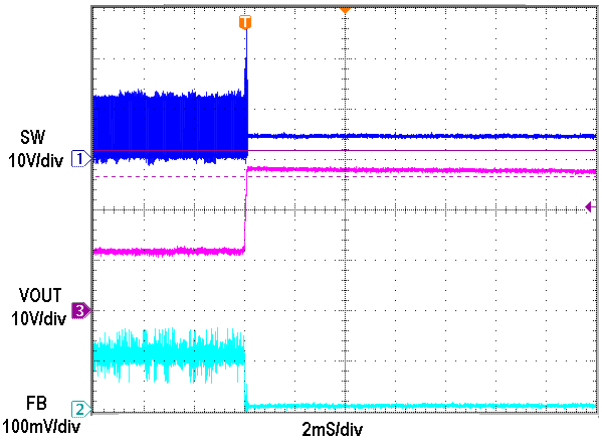


Fig 8. Open Load protection

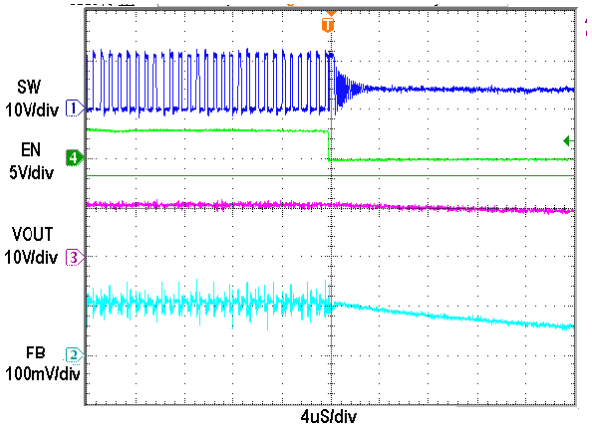


Fig.9 EN Disable

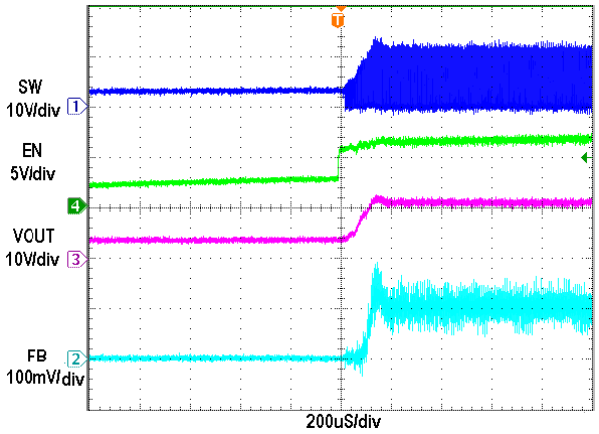


Fig 10. V_{IN} Start Up

OPERATION

The MT7004B is a constant frequency, peak current mode boost regulator architecture to regulate the series string of LEDs. The operation of the MT7004B can be understood by referring to the block diagram.

At the start of each oscillator cycle the FET is turned on through the control circuitry. To prevent sub-harmonic oscillations at duty cycles greater than 50 percent, a stabilizing ramp is added to the output of the current sense amplifier and the result is fed into the positive input of the PWM comparator. When this voltage equals the output voltage of the error amplifier, the power FET is turned off. The voltage at the output of the error amplifier is an amplified version of the difference between the 110mV reference voltage and the feedback voltage. In this way the peak current level keeps the output in regulation. If the feedback voltage starts to drop, the output of the error amplifier increases. This results in more current flowing through the power FET, thus increasing the power delivered to the output.

APPLICATION INFORMATION

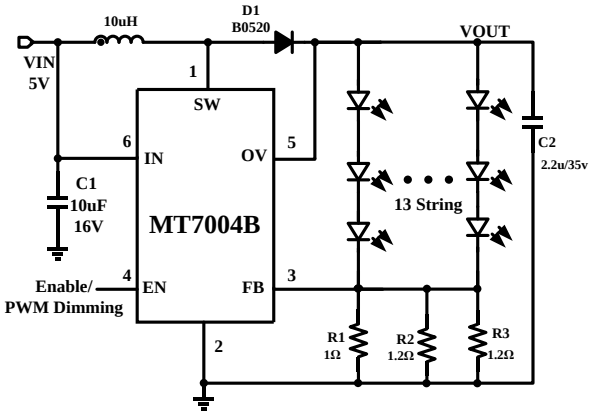


Fig 11. Circuit for Driving 39 WLEDs (3 WLEDs in Series and 13 Strings Paralleled)

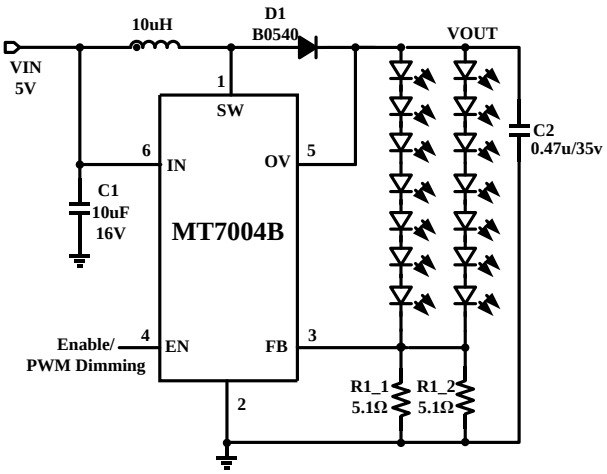


Fig 12. Driving 14 WLEDs (7WLEDs in Series and 2Strings Paralleled) with 5V Input Voltage

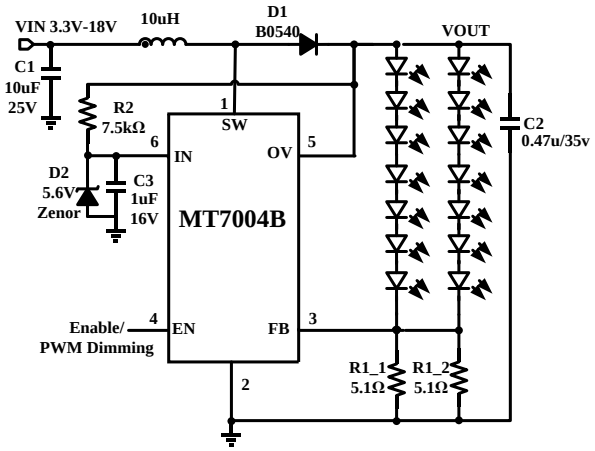


Fig 13. Driving 14 WLEDs (7WLEDs in Series and 2Strings Paralleled) with 3.3V-18V Input Voltage

A typical application circuit can be seen in Figure 11. The 13 strings of 3 LEDs can be driven from a voltage supply range of 5V to 6V at an output current of 260mA. A 2.2μF output capacitor is sufficient for most applications. A 10μH inductor with low DCR (Inductor DC resistance) is recommended to improve efficiency. A 10μF ceramic capacitor is recommended for the input capacitance in the real system. Schottky diodes have fast recovery and a low forward voltage is recommended. Schottky diodes rated with 1000mA are sufficient for the MT7004B. The MT7004B has internal soft-start to limit the amount of current through V_{IN} at startup and also limit the amount of overshoot on the output. The ramped voltage that is added to the current sense amplifier reduces the current output as the duty cycle increases. As more LEDs are added, the output voltage rises but the current that can be delivered to the load is reduced as well.

Setting the LED Current

The LED current is controlled by the feedback resistor, R1, R2 and R3 in Fig.11. The current through the LEDs is given by the equation 110mV/ (R1//R2//R3).

Analog and PWM Dimming

There are three different ways to control dimming for the MT7004B during normal operation.

(a) Adding a PWM Signal to EN Pin

Adding a PWM signal to EN pin directly, the MT7004B is turned on and off by the PWM signal and the LEDs will switch between full loads to completely shut off. The typical frequency of the PWM signal is in the range of 100Hz to 200kHz. Please refer to Fig. 14.

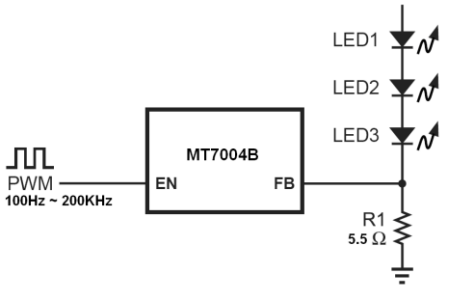


Fig. 14 Dimming Control
Using a PWM signal in EN Pin

The minimum recommended amplitude of the PWM signal is 1.5V. The average current through the LEDs will increase proportionally to the duty cycle of the PWM signal. Reference to Fig.6.

(b) Changing the Effective Feedback Voltage Using a DC Voltage

Applying a constant DC voltage through a resistor divider to FB pin can control the dimming. This can be seen in Fig. 15. As the DC voltage increases, current starts flowing down R1, R2 and R3. The loop will continue to regulate the feedback voltage to 110mV. Thus the current has to decrease through the LEDs by the same amount of current as is being injected from the DC voltage source. With a V_{DC} from 0V to 2V, the resistor values shown for R2 and R3 can control the LED current from 0mA to 20mA.

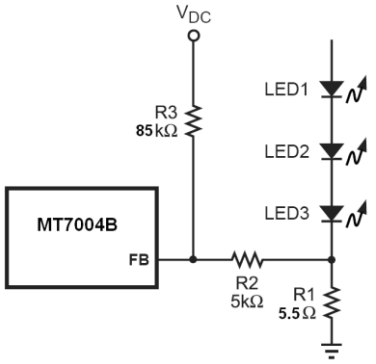


Fig. 15 Dimming Control Using a DC Voltage

(c) Changing the Effective Feedback Voltage Using filtered PWM Signal

If the PWM signal is above 1kHz, the filtered PWM signal can be considered as a varying and adjustable DC voltage. Refer to Fig. 16.

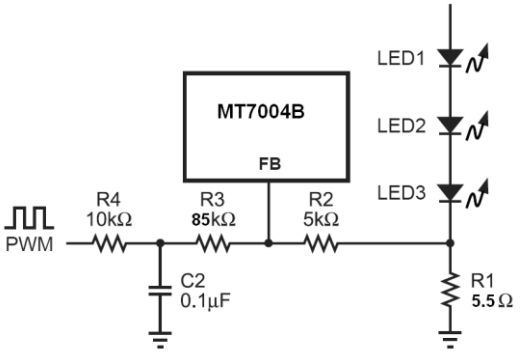


Fig. 16 Dimming Control Using a Filtered PWM Signal

Open Load(LED) Protection

Open Load protection will stop switching if the output voltage goes too high. In some cases an LED may fail, this will result in the feedback voltage always being zero. The part will run at maximum duty cycle boosting the output voltage higher and higher. By tying the OV pin to the top of the LED string, the MT7004B can check for this condition. Refer to Fig.17.

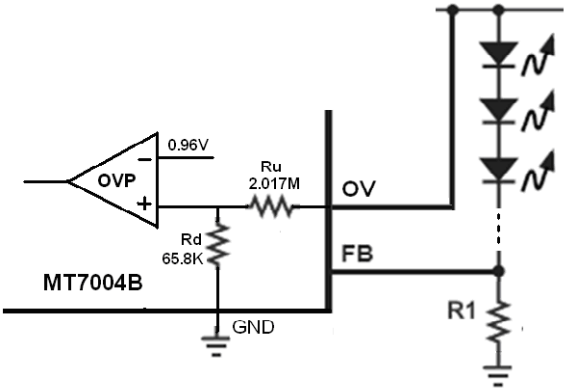


Fig. 17 MT7004B OVP topology

Internally, MT7004B through a resistor divider Rd/(Rd+Ru) to compare the OV pin voltage with 0.96V voltage reference. By default, Ru=2.017Mohm, Rd=65.8kohm. OVP threshold equals 30.4V. If the output exceeds 30.4V, the MT7004B will stop switching. When output voltage drops below a defined voltage (about 28.4V), MT7004B will resume switching operation.

Fig. 8 shows the behavior of the MT7004B into an open load condition.

As MT7004B OVP threshold is about 30.4V (minimum OVP threshold is 28.5V), so the circuit in Fig.17 can't drive more than 9 series LEDs (assume each LED forward voltage is about 3.2V, 9 series LEDs voltage is about 28.8V). By add an external resistor Rx at OV pin, refer to Fig.18, the OVP threshold can be raise higher than 30.4V, so more than 9-series

LED string (such as 12-series LED string) can be driven.

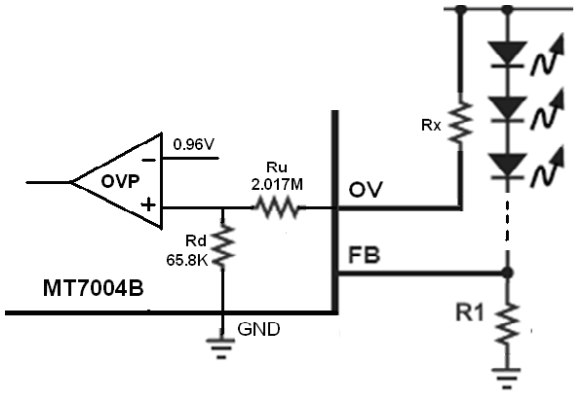


Fig. 18 OVP topology with external resistor

In this case, the OVP threshold will be:

$$OVP = 0.96 \times \frac{Rx + Ru + Rd}{Rd}$$

For example, Rx=660kohm, OVP threshold will be 40V, then 12-series LED string can be driven.

Constant Output Voltage Control

The output voltage of MT7004B can be adjusted by the divider circuit on the FB pin. Fig.19 shows the application circuit for the constant output voltage. The output voltage can be calculated as following:

$$V_{OUT} = V_{FB} \times \frac{R1 + R2}{R2} = 110mV \times \frac{R1 + R2}{R2}$$

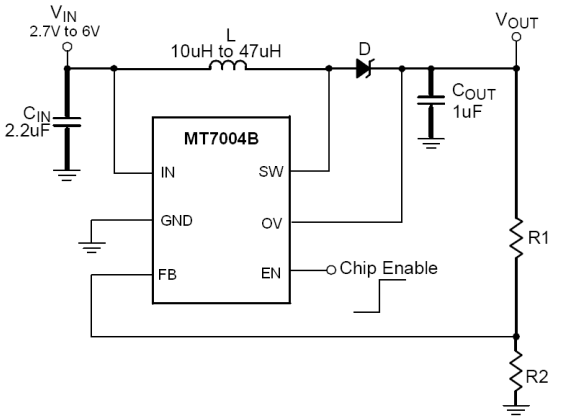


Fig.19 Constant output voltage application

The output voltage must lower than the OV threshold.

Layout Considerations

For best performance of the MT7004B, the following guideline must be strictly followed:

- Input and Output capacitors should be placed close to the IC and connected to ground plane to reduce noise coupling.
- The GND should be connected to a strong ground plane for heat sinking and noise protection.
- Keep the main current traces as possible as short and wide.
- SW node of MT7004B is with high frequency voltage swing. It should be kept at a small area and short trace.
- Place the feedback components as close as possible to the IC and keep away from the noisy devices.

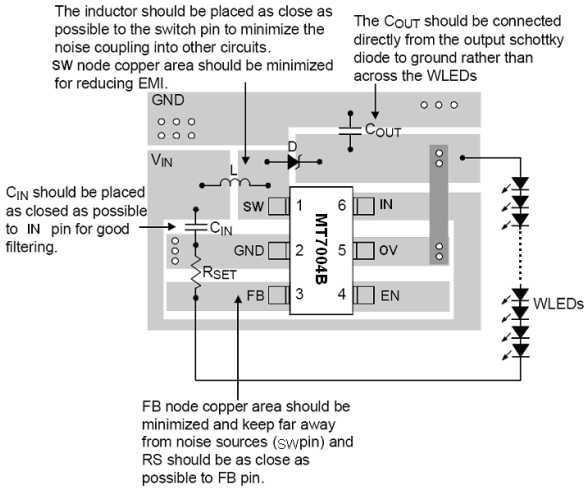
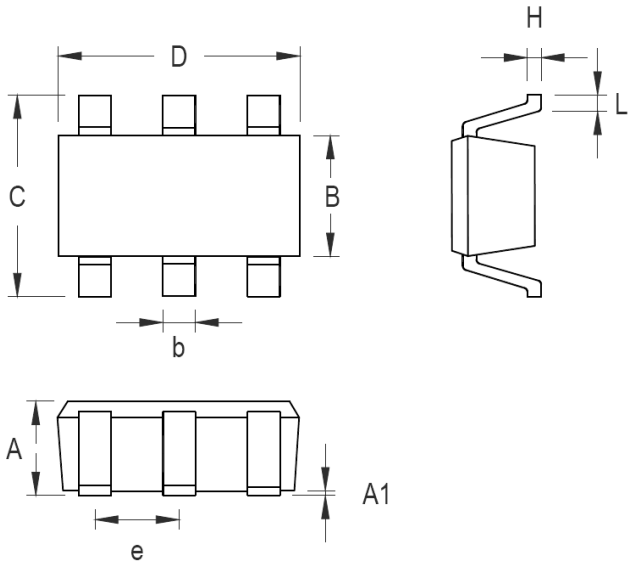


Fig. 20. MT7004B Layout Consideration

PACKAGE INFORMATION

SOT-23-6



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	0.889	1.295	0.035	0.051
A1	0.000	0.152	0.000	0.006
B	1.397	1.803	0.055	0.071
b	0.250	0.559	0.010	0.022
C	2.591	2.997	0.102	0.118
D	2.692	3.099	0.106	0.122
e	0.838	1.041	0.033	0.041
H	0.080	0.254	0.003	0.010
L	0.300	0.610	0.012	0.024

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