MP3384

50V, 4-String White LED Driver

The Future of Analog IC Technology

DESCRIPTION

The MP3384 is a step-up converter with 4-channel current sources designed for driving the white LED arrays for large size LCD panel backlighting applications.

The MP3384 uses current mode, fixed frequency architecture. The switching frequency can be selected at 1.25MHz or 625kHz. It generates an output voltage up to 50V from a 4.5V to 25V input supply. The MP3384 independently regulates the current in each LED string to the user programmed value set by an external current setting resistor.

The MP3384 applies 4 internal current sources to achieve a current balance of 2.5% regulation accuracy between strings. Its low 600mV regulation voltage on LED current sources reduces power loss and improves efficiency.

The MP3384 includes under voltage lockout, current limiting, over voltage, short LED, open LED and thermal shut-down protection.

The MP3384 is available in small QFN16 (3mmx 3mm) package.

FEATURES

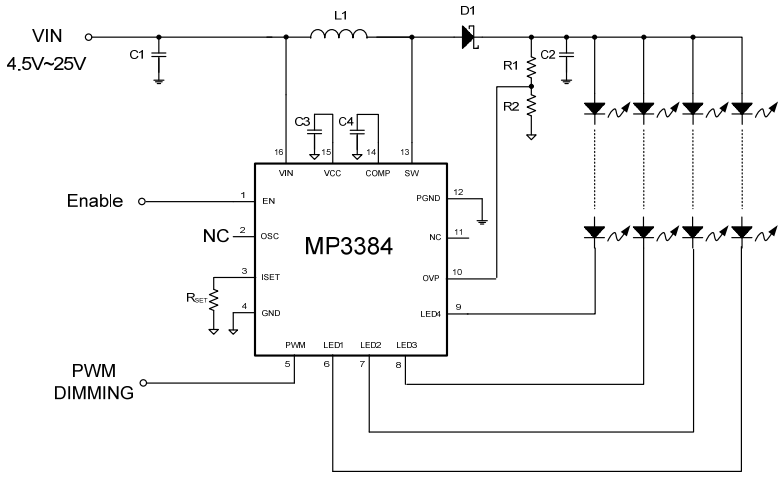
- High Efficiency and Small Size
- 4.5V to 25V Input Voltage Range
- 50V Maximum Step-up Voltage
- Balanced Driver for 4 Strings of WLED
- 2.5% Current Matching Accuracy Between Strings
- Selectable Switching Frequency: 1.25MHz or 625kHz
- PWM Dimming
- Programmable Over-voltage Protection
- Under Voltage Lockout
- Open and Short LED Protection
- Thermal Shutdown
- Small 16-pin QFN (3mm x 3mm)

APPLICATIONS

- Notebook PC
- Netbook PC
- Digital Picture Frames
- Handy Terminals Display
- Automotive System and Tablet Computer

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TYPICAL APPLICATION



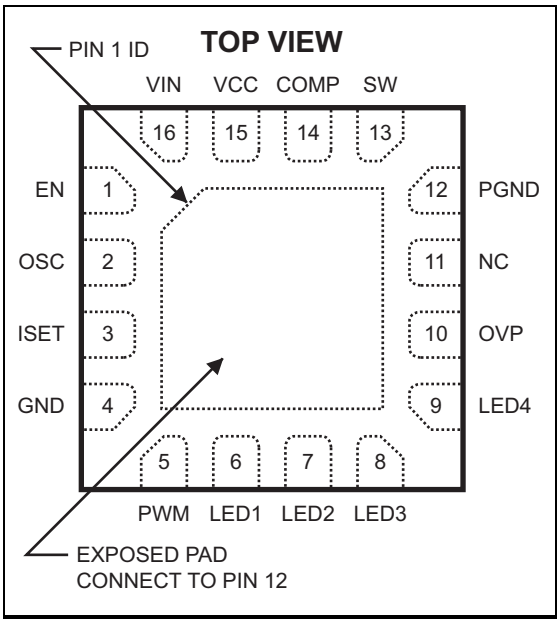
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ORDERING INFORMATION

Part Number*	Package	Top Marking
MP3384EQ	QFN16 (3mm X 3mm)	5S

* For Tape & Reel, add suffix –Z (e.g. MP3384EQ–Z).
For RoHS compliant packaging, add suffix –LF (e.g. MP3384EQ–LF–Z)

PACKAGE REFERENCE



ABSOLUTE MAXIMUM RATINGS (1)

V_{IN} .....-0.3V to +30V
V_{SW}, V_{LED1} to V_{LED4}.....-1V to +50V
All Other Pins.....-0.3V to +6V
Continuous Power Dissipation (T_A = +25°C) (2)
.....2.1W
Junction Temperature.....150°C
Lead Temperature .....260°C
Storage Temperature..... -65°C to +150°C

Recommended Operating Conditions (3)

Supply Voltage V_{IN} .....4.5V to 25V
Max LED Current/String..... 40mA
Operating Junction Temp. (T_J). -40°C to +125°C

Thermal Resistance (4)

	θ_{JA}	θ_{JC}	
QFN16 (3mm x 3mm)	60	12	°C/W

Notes:
1) Exceeding these ratings may damage the device.
2) The maximum allowable power dissipation is a function of the maximum junction temperature $T_{J(MAX)}$, the junction-to-ambient thermal resistance θ_{JA}, and the ambient temperature T_A. The maximum allowable continuous power dissipation at any ambient temperature is calculated by $P_{D(MAX)} = (T_{J(MAX)}-T_A)/\theta_{JA}$. Exceeding the maximum allowable power dissipation will cause excessive die temperature, and the regulator will go into thermal shutdown. Internal thermal shutdown circuitry protects the device from permanent damage.
3) The device is not guaranteed to function outside of its operation conditions.
4) Measured on JESD51-7, 4-layer PCB.

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ELECTRICAL CHARACTERISTICS

V_{IN} =12V, V_{EN} = 5V, T_A = +25°C, unless otherwise noted.

Parameters	Symbol	Condition	Min	Typ	Max	Units
Operating Input Voltage	V_{IN}		4.5		25	V
Supply Current (Quiescent)	I_Q	V_{IN}=12V, V_{EN}=5V, no load.		1.8		mA
Supply Current (Shutdown)	I_{ST}	V_{EN}=0V, V_{IN}=12V			2	μA
LDO Output Voltage	V_{CC}	V_{EN}=5V, 6V<V_{IN}<25V, 0<I_{VCC}<10mA	4.5	5	5.5	V
Input UVLO Threshold	V_{IN_UVLO}	Rising Edge	3.6	4.1	4.45	V
Input UVLO Hysteresis				200		mV
EN ON Threshold	V_{EN_ON}	V_{EN} Rising	1.8			V
EN OFF Threshold	V_{EN_OFF}	V_{EN} Falling			0.6	V
STEP-UP CONVERTER						
SW On-Resistance	R_{DS_ON}	I_{DS}=20mA		0.5		Ω
SW Leakage Current	I_{SW_LK}	V_{SW}=45V			1	μA
Switching Frequency	f_{SW}	V_{OSC}=V_{CC} or Floating	1.0	1.25	1.5	MHz
		V_{OSC}=0V	500	625	750	kHz
OSC High-Level Threshold	V_{OSC_H}		2.1			V
OSC Low-Level Threshold	V_{OSC_L}				0.8	V
Minimum On Time	T_{ON_MIN}	PWM Mode, when no pulse skipping happens		100		ns
Maximum Duty Cycle	D_{MAX}		90	93	96	%
SW Current Limit	I_{SW_LIMIT}	Duty=90%	1.2			A
COMP Transconductance	G_{COMP}	ΔI_{COMP}=±10uA		100		μA/V
COMP Output Current	I_{COMP}			60		μA
PWM DIMMING						
PWM High-Level Threshold	V_{PWMI_H}		1.5			V
PWM Low-Level Threshold	V_{PWMI_L}				0.6	V

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ELECTRICAL CHARACTERISTICS *(continued)*

V_{IN} =12V, V_{EN} = 5V, T_A = +25°C, unless otherwise noted.

Parameters	Symbol	Condition	Min	Typ	Max	Units
LED CURRENT REGULATION						
LEDX Average Current	I_{LED}	R_{ISET}=60.4kΩ	19.4	20	20.6	mA
Current Matching (5)		I_{LED}=20mA			2.5	%
LEDX Regulation Voltage	V_{LEDX}	I_{LED}=20mA		600		mV
PROTECTION						
OVP Over Voltage Threshold	V_{OVP_OV}	Rising Edge	1.17	1.23	1.3	V
OVP UVLO Threshold	V_{OVP_UV}	Step-up Converter Fails	48	70	102	mV
LEDX Over Voltage Threshold	V_{LEDX_OV}	V_{IN}>5.5V	5.1	5.5	5.9	V
LEDX UVLO Threshold	V_{LEDX_UV}		135	180	235	mV
Thermal Shutdown Threshold	T_{ST}			150		℃
LEDX Over Voltage Fault Timer			1.3	1.6	1.9	ms

Notes:

5) Matching is defined as the difference of the maximum to minimum current divided by 2 times average currents.

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PIN FUNCTIONS

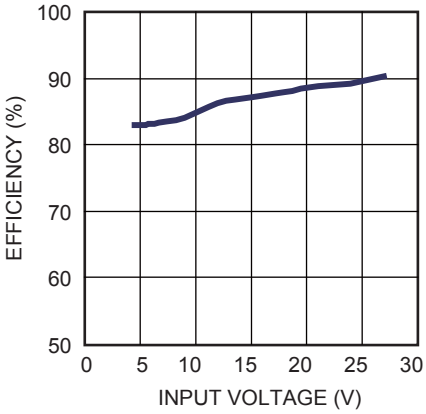
Pin #	Name	Description
1	EN	Enable Control Input. Do not let this pin floating.
2	OSC	Switching Frequency Selection Input. When float this pin or connect this pin to VCC, the step-up converter switching frequency is 1.25MHz. When connect this pin to GND, the step-up converter switching frequency is 625kHz.
3	ISET	LED Current Setting. Tie a current setting resistor from this pin to ground to program the current in each LED string. I_{LED} = 1000 x 1.21V / R_{SET}
4	GND	Analog Ground.
5	PWM	PWM Signal Input. The logic signal on this pin controls the PWM burst mode dimming frequency and duty cycle.
6	LED1	LED String 1 Current Input. This pin is the open-drain output of an internal dimming control switch. Connect the LED String 1 cathode to this pin. If this string is not used, connect Vout to this pin.
7	LED2	LED String 2 Current Input. This pin is the open-drain output of an internal dimming control switch. Connect the LED String 2 cathode to this pin. If this string is not used, connect Vout to this pin.
8	LED3	LED String 3 Current Input. This pin is the open-drain output of an internal dimming control switch. Connect the LED String 3 cathode to this pin. If this string is not used, connect Vout to this pin.
9	LED4	LED String 4 Current Input. This pin is the open-drain output of an internal dimming control switch. Connect the LED String 4 cathode to this pin. If this string is not used, connect Vout to this pin.
10	OVP	Over-voltage Protection Input. Connect a resistor divider from output to this pin to program the OVP threshold. When this pin voltage reaches 1.23V, the MP3384 triggers OV Protection mode.
11	NC	No Connect.
12	PGND	Step-up Converter Power Ground. Connect exposed pad to PGND.
13	SW	Step-up Converter Power Switch Output. SW is the drain of the internal MOSFET switch. Connect the power inductor and output rectifier to SW. SW can swing between GND and 50V.
14	COMP	Step-up Converter Compensation Pin. This pin is used to compensate the regulation control loop. Connect a capacitor or a series RC network from COMP to GND.
15	VCC	The Internal 5V Linear Regulator Output. VCC provides power supply for the internal MOSFET switch gate driver and the internal control circuitry. Bypass VCC to GND with a ceramic capacitor. If VIN is less than 5.5V, apply an external 5V supply directly on VCC.
16	VIN	Supply Input. VIN supplies the power to the MP3384 chip. Drive VIN with a 4.5V to 25V power source. Must be locally bypassed.

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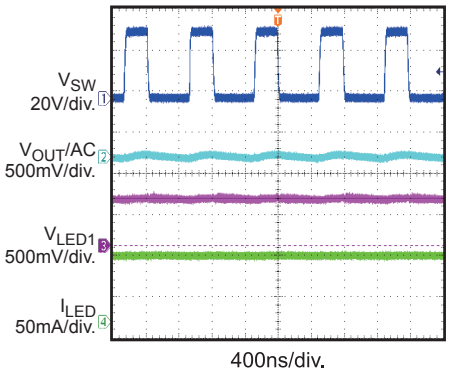
TYPICAL PERFORMANCE CHARACTERISTICS

V_{IN} =12V, 10 LEDs in series, 4 strings parallel, 20mA/string, unless otherwise noted.

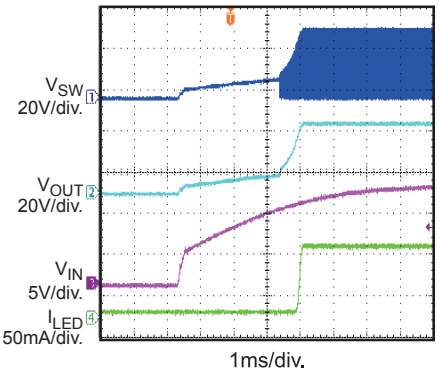
Efficiency vs. Input Voltage



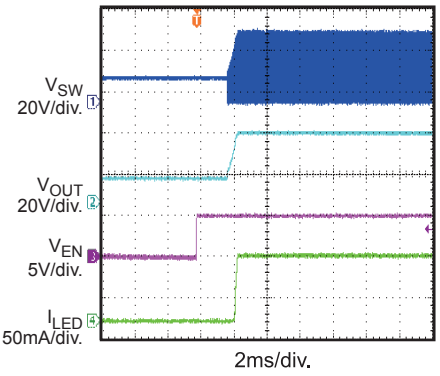
Steady State



V_{IN} Startup

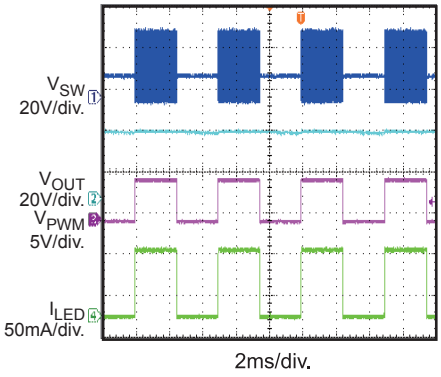


V_{EN} Startup



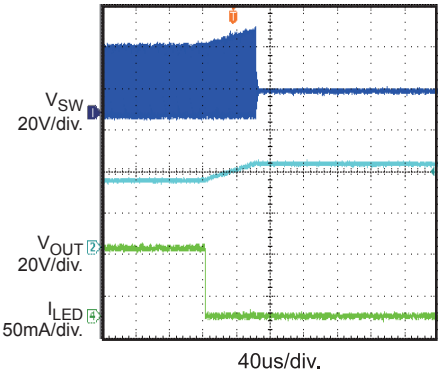
PWM Dimming

f_{PWM}=200Hz, D_{PWM}=50%



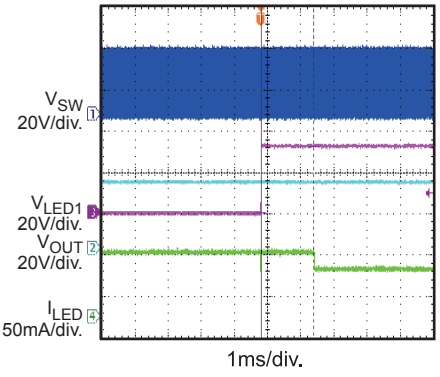
Open LED Protection

Open all LED strings at working



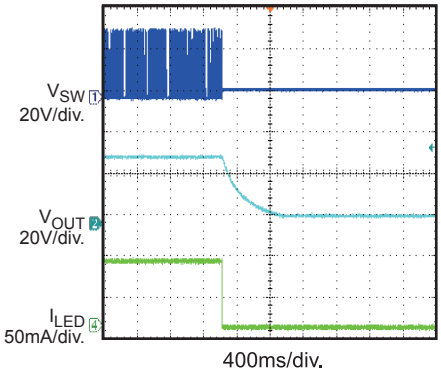
Short LED Protecton

Short V_{OUT} to LED1 at working



Thermal Protection

T_{case}=140˚C



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FUNCTION DIAGRAM

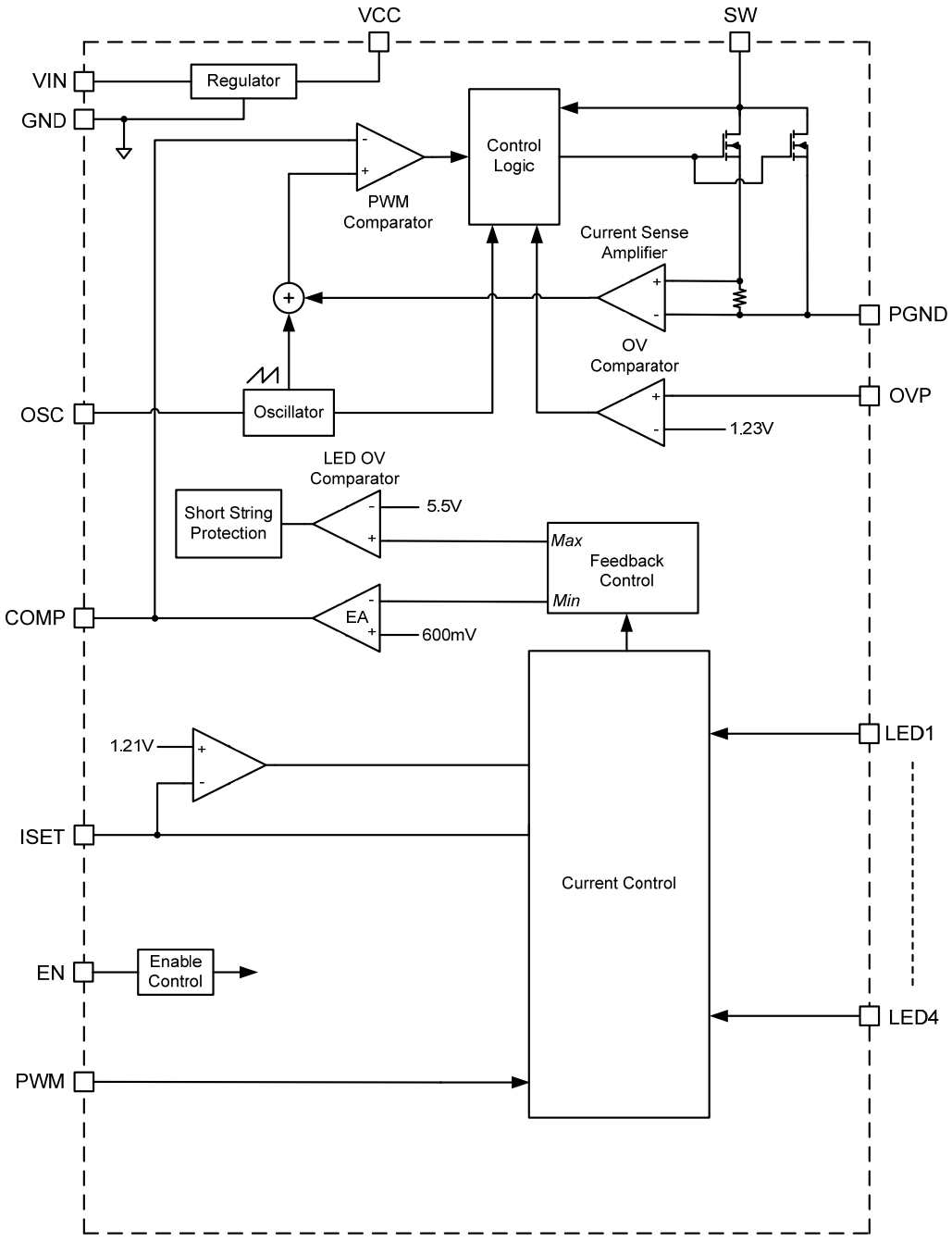


Figure 1—MP3384 Function Diagram

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OPERATION

The MP3384 employs a constant frequency, peak current mode step-up converter and 4-channels regulated current sources to regulate the array of 4 strings white LEDs. The operation of the MP3384 can be understood by referring to the block diagram of Figure 1.

Internal 5V Regulator

The MP3384 includes an internal linear regulator (VCC). When VIN is greater than 5.5V, this regulator offers a 5V power supply for the internal MOSFET switch gate driver and the internal control circuitry. The VCC voltage drops to 0V when the chip shuts down. In the application of VIN lower than 5.5V, tie VCC and VIN together. The MP3384 features Under Voltage Lockout. The chip is disabled until VCC exceeds the UVLO threshold. And the hysteresis of UVLO is approximately 200mV.

System Startup

When the MP3384 is enabled, the chip checks the topology connection first. the chip monitors the OVP pin to see if the Schottky diode is not connected. If the OVP voltage is lower than 70mV, the chip will be disabled. The MP3384 will also check other safety limits, including UVLO and OTP after the OVP test is passed. If they are all in function, it then starts boosting the step-up converter with an internal soft-start.

It is recommended on the start up sequence that the enable signal comes after input voltage and PWM dimming signal established.

Step-up Converter

The converter operation frequency is selectable (1.25MHz or 625kHz), which is helpful for optimizing the external components sizes and improving the efficiency.

At the beginning of each cycle, the power FET is turned on with the internal clock. 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 PWM comparator. When this result voltage reaches the output voltage of the error amplifier (V_{COMP}) the power FET is turned off.

The voltage at the output of the internal error amplifier is an amplified signal of the difference between the 600mV reference voltage and the feedback voltage. The converter automatically chooses the lowest active LEDX pin voltage for providing enough bus voltage to power all the LED arrays.

If the feedback voltage drops below the 600mV reference, the output of the error amplifier increases. It results in more current flowing through the power FET, thus increasing the power delivered to the output. In this way it forms a close loop to make the output voltage in regulation.

At light-load or Vout near to Vin operation, the converter runs into the pulse-skipping mode, the FET is turned on for a minimum on-time of approximately 100ns, and then the converter discharges the power to the output in the remnant period. The FET will keep off until the output voltage needs to be boosted again.

Dimming Control

The MP3384 provides PWM Dimming mode with external PWM signal on PWM pin. The method results in PWM chopping of the current in the LEDs for all 4 channels to provide LED control. The brightness of the LED array is proportional to the duty cycle of the PWM signal.

Open String Protection

The open string protection is achieved through the over voltage protection. If one or more strings are open, the respective LEDX pins are pulled to ground and the IC keeps charging the output voltage until it reach OVP threshold. Then the part will mark off the open strings whose LEDX pin voltage are less than 180mV. Once the mark-off operation completes, the remaining LED strings will force the output voltage back into tight regulation. The string with the highest voltage drop is the ruling string during output regulation.

The MP3384 always tries to light at least one string and if all strings in use are open, the MP3384 shuts down the step-up converter. The

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part will maintain mark-off information until the part shuts down.

Short String Protection

The MP3384 monitors the LEDX pin voltage to judge if the short string condition occurs. If one or more strings are short, the respective LEDX pins will be pulled up to the boost output and tolerate high voltage stress. If the LEDX pin voltage is higher than 5.5V, the short string condition is detected on the respective string. When the short string fault (LEDX over-voltage fault) continues for greater than 1.6ms, the string is marked off and disabled. Once a string is marked off, its current regulation is forced to disconnect from the output voltage loop regulation. The marked-off LED strings will be shut off totally until the part restarts. If all strings in use are short, the MP3384 will shut down the step-up converter.

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APPLICATION INFORMATION

Selecting the Switching Frequency

The switching frequency of the step-up converter can be selected to 1.25MHz or 625kHz. A bi-level Switching Frequency Selection (OSC) input sets the internal oscillator frequency for the step-up converter. When connects OSC pin to GND, the switching frequency is set to 625kHz, when floats the OSC pin or connects it to VCC, the frequency is set to 1.25MHz.

Setting the LED Current

The LED string currents are identical and set through the current setting resistor on the ISET pin.

$$I_{LED} = 1000 \times 1.21V / R_{SET}$$

For R_{SET}=60.4kΩ, the LED current is set to 20mA. The ISET pin can not be open.

Setting the Over Voltage Protection

The open string protection is achieved through the over voltage protection (OVP). In some cases, an LED string failure results in the feedback voltage always zero. The part then keeps boosting the output voltage higher and higher. If the output voltage reaches the programmed OVP threshold, the protection will be triggered.

To make sure the chip functions properly, the OVP setting resistor divider must be set to a proper value. The recommended OVP point is about 1.3 times of the output voltage for normal operation.

$$V_{OVP}=1.23V*(R_1+R_2)/R_2$$

PWM Dimming Mode

The MP3384 provides PWM dimming mode with external PWM signal on PWM pin.

An external PWM dimming signal is directly employed to achieve PWM dimming control. Apply the 100Hz to 2kHz PWM dimming signal to PWM pin. The minimum recommended amplitude of the PWM signal is 1.5V (See Figure 2).

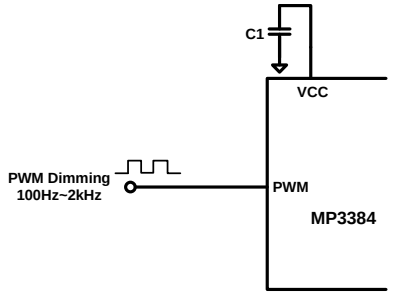


Figure 2— PWM Dimming

Selecting the Inductor

A 22μH (for 1.25MHz switching frequency) /47uH (for 625kHz switching frequency) inductor with a DC current rating of at least 40% higher than the maximum input current is recommended for most applications. For highest efficiency, the inductor's DC resistance should be as small as possible.

Selecting the Input Capacitor

The input capacitor reduces the surge current drawn from the input supply and the switching noise from the device. The input capacitor impedance at the switching frequency should be less than the input source impedance to prevent high frequency switching current from passing through the input. Ceramic capacitors with X5R or X7R dielectrics are highly recommended because of their low ESR and small temperature coefficients. For most applications, a 4.7μF capacitor is sufficient.

Selecting the Output Capacitor

The output capacitor keeps the output voltage ripple small and ensures feedback loop stability. The output capacitor impedance should be low at the switching frequency. Ceramic capacitors with X7R dielectrics are recommended for their low ESR characteristics. For most applications, a 2.2μF ceramic capacitor is sufficient.

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Layout Considerations

Careful attention must be paid to the PCB board layout and components placement. Proper layout of the high frequency switching path is critical to prevent noise and electromagnetic interference problems. The loop of MP3384 SW to PGND pin (U1), output diode (D1), and output capacitor (C3) is flowing with high frequency pulse current, therefore, it must be as short as possible (See Figure 3).

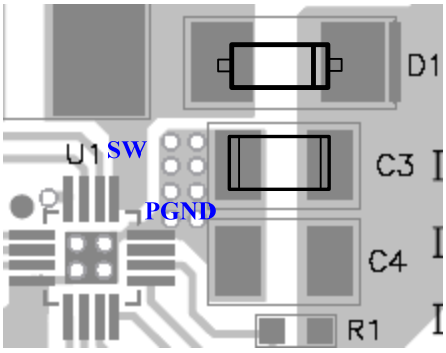


Figure 3—Layout Consideration

The IC exposed pad is internally connected to GND pin, and all logic signals are referred to GND. The PGND should be externally connected to GND and is recommended to keep away from the logic signals.

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TYPICAL APPLICATION CIRCUIT

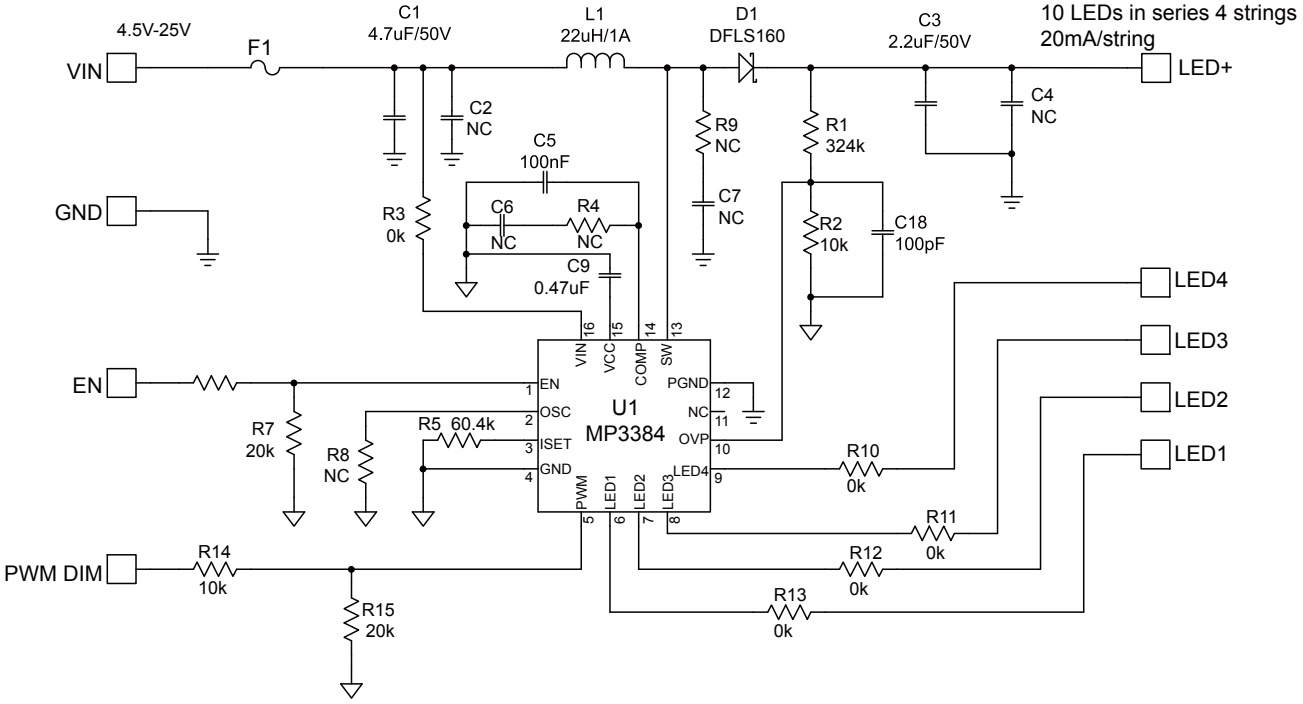
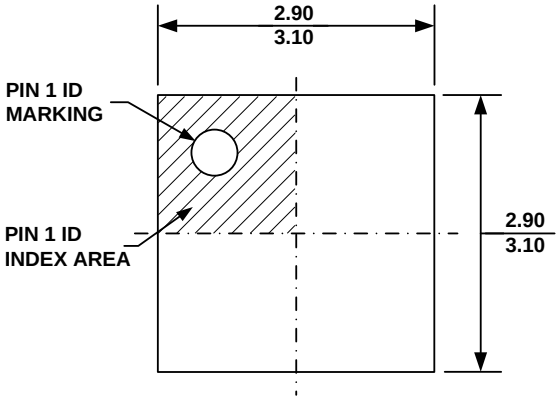


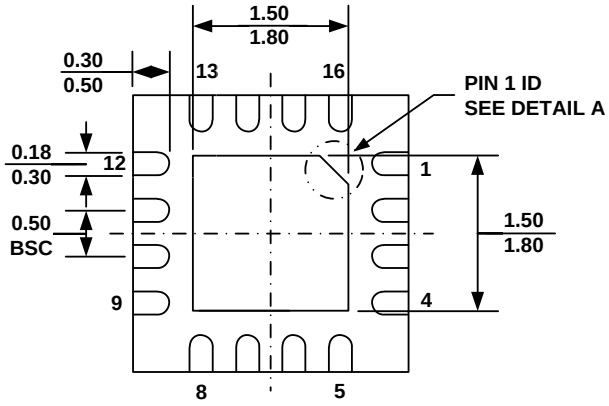
Figure 4—Driving 10 LED in Series and 4 String LED Application Circuit

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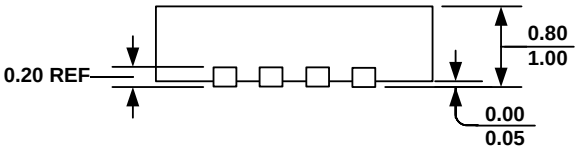
PACKAGE INFORMATION



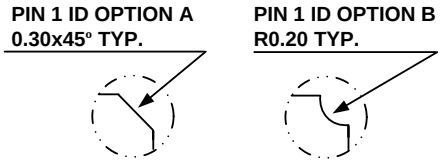
TOP VIEW



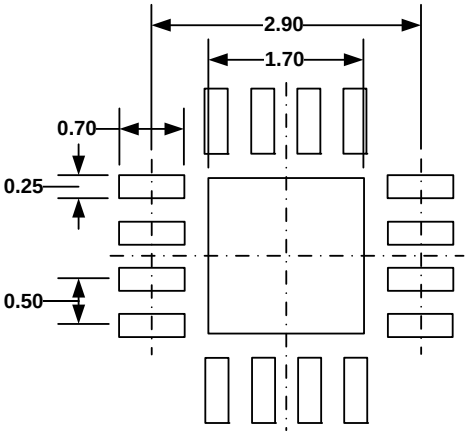
BOTTOM VIEW



SIDE VIEW



DETAIL A



RECOMMENDED LAND PATTERN

NOTE:

1) ALL DIMENSIONS ARE IN MILLIMETERS.
2) EXPOSED PADDLE SIZE DOES NOT INCLUDE MOLD FLASH.
3) LEAD COPLANARITY SHALL BE 0.10 MILLIMETER MAX.
4) DRAWING CONFORMS TO JEDEC MO-220, VARIATION VEED-4.
5) DRAWING IS NOT TO SCALE.

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