



The Future of Analog IC Technology®

# MPQ3386-AEC1

## 50V, 6 String White LED Driver

### AEC-Q100 Qualified

### DESCRIPTION

The MPQ3386 is a step-up converter with 6-channel current sources designed for driving the white LED arrays for large size LCD panel backlighting applications.

The MPQ3386 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 MPQ3386 regulates the current in each LED string to the user programmed value set by an external current setting resistor.

The MPQ3386 applies 6 internal current sources in each LED string terminal to get current balance. And the current matching achieves 3% regulation accuracy between strings. Its low 600mV regulation voltage on LED current sources reduces power loss and improves efficiency.

The MPQ3386 features external PWM dimming or DC input PWM dimming, which allows the flexible control of the backlighting luminance under wide range of the ambient brightness, and also avoids the possibility of PWM dimming audible noise. The dimming PWM signal can be generated internally, and the dimming frequency is programmed by an external setting capacitor.

### FEATURES

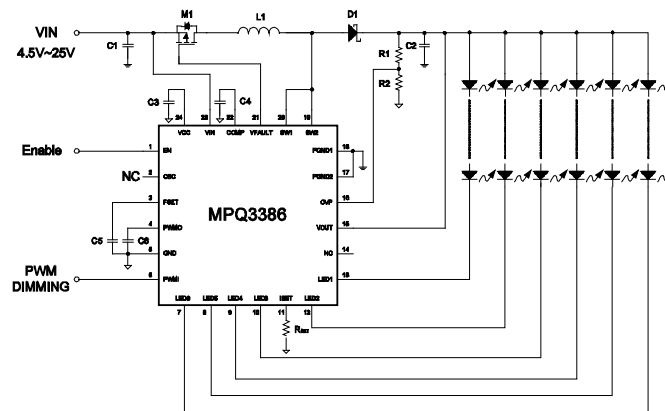
- Guaranteed Industrial/Automotive Temp Range Limits
- 4.5V to 25V Input Voltage Range
- 50V Maximum Step-up Voltage
- Balanced Driver for 6 Strings of WLED
- 3% Current Matching Accuracy Between Strings
- Selectable Switching Frequency: 1.25MHz or 625kHz
- PWM or DC Input Burst PWM Dimming
- Programmable Over-voltage Protection Threshold
- Under Voltage Lockout
- Open and Short LED Protection
- Thermal Shutdown
- Small QFN24 (4x4mm) Package
- Available in AEC-Q100 Qualified Grade 1

### APPLICATIONS

- Notebook & Netbook PC
- Small LCD TV
- Portable Terminals Display
- Automotive System and Tablet Computer

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### TYPICAL APPLICATION



## ORDERING INFORMATION

Part Number	Package	Top Marking
MPQ3386DR*	QFN-24 (4mmx4mm)	3386DR
MPQ3386DR-AEC1**	QFN-24 (4mmx4mm)	3386DR

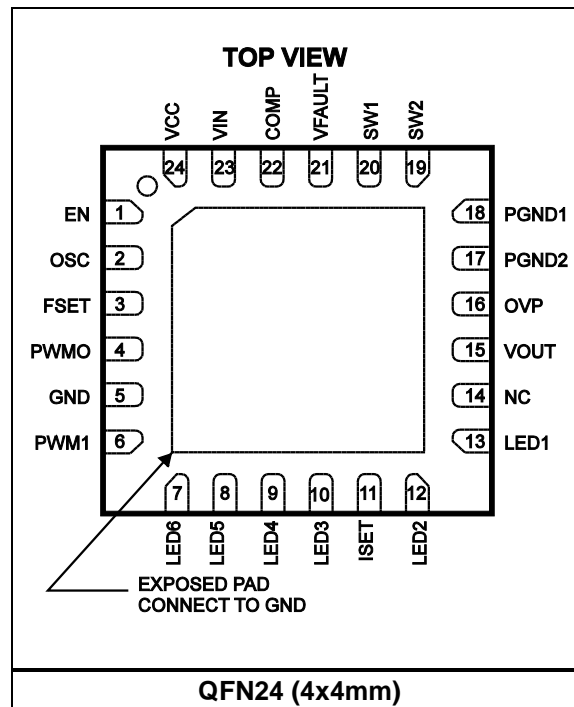
\* For Tape & Reel, add suffix -Z (e.g. MPQ3386DR-Z).

For RoHS Compliant Packaging, add suffix -LF (e.g. MPQ3386DR-LF-Z)

\*\* For Tape & Reel, add suffix -Z (e.g. MPQ3386DR-AEC1-Z).

For RoHS Compliant Packaging, add suffix -LF (e.g. MPQ3386DR-AEC1-LF-Z)

## PACKAGE REFERENCE



### ABSOLUTE MAXIMUM RATINGS <sup>(1)</sup>

V <sub>IN</sub> .....	-0.3V to +30V
V <sub>VFAULT</sub> .....	V <sub>IN</sub> - 6V to V <sub>IN</sub>
V <sub>SW</sub> , V <sub>OUT</sub> , V <sub>LED1</sub> to V <sub>LED6</sub> .....	-1V to +50V
All Other Pins.....	-0.3V to +6V
Continuous Power Dissipation (T <sub>A</sub> = +25°C) <sup>(2)</sup>	.....2.9W
Junction Temperature	150°C
Lead Temperature .....	260°C
Storage Temperature.....	-65°C to +150°C

### Recommended Operating Conditions <sup>(3)</sup>

Supply Voltage V <sub>IN</sub> .....	4.5V to 25V
Operating Junction Temp. (T <sub>J</sub> ).	-40°C to +125°C

### Thermal Resistance <sup>(4)</sup>

	θ <sub>JA</sub>	θ <sub>JC</sub>
QFN-24 (4mmx4mm) .....	42	9

#### Notes:

- 1) Exceeding these ratings may damage the device.
- 2) The maximum allowable power dissipation is a function of the maximum junction temperature T<sub>J</sub> (MAX), the junction-to-ambient thermal resistance θ<sub>JA</sub>, and the ambient temperature T<sub>A</sub>. The maximum allowable continuous power dissipation at any ambient temperature is calculated by P<sub>D</sub> (MAX) = (T<sub>J</sub> (MAX)-T<sub>A</sub>)/θ<sub>JA</sub>. 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 operating conditions.
- 4) Measured on JESD51-7, 4-layer PCB.

## ELECTRICAL CHARACTERISTICS

$V_{IN} = 12V$ ,  $V_{EN} = 5V$ ,  $T_J = -40^{\circ}C$  to  $+125^{\circ}C$ , unless otherwise noted. Typical values are at  $T_J = 25^{\circ}C$

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.	1.1	1.8	2.5	mA	
Supply Current (Shutdown)	$I_{ST}$	$V_{EN}=0V$ , $V_{IN}=12V$		0.05	1	$\mu A$	
LDO Output Voltage	$V_{CC}$	$V_{EN}=5V$ , $0 < I_{VCC} < 10mA$ $6V < V_{IN} < 25V$ ,	4.5	5	5.5	V	
Input UVLO Threshold	$V_{IN\_UVLO}$	Rising Edge	3.4	3.9	4.3	V	
Input UVLO Hysteresis				165		mV	
EN ON Threshold	$V_{EN\_ON}$	$V_{EN}$ Rising	2.0			V	
EN OFF Threshold	$V_{EN\_OFF}$	$V_{EN}$ Falling			0.4	V	
<b>STEP-UP CONVERTER</b>							
SW On-Resistance	$R_{DS\_ON}$	$I_{DS}=20mA$	$T_J=25^{\circ}C$		0.21	0.3	$\Omega$
			$-40^{\circ}C$ to $+125^{\circ}C$		0.21	0.45	
SW Leakage Current	$I_{SW\_LK}$	$V_{SW}=45V$			1	$\mu A$	
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	$V_{OSC\_L}$				1.2	V	
Minimum On Time <sup>(6)</sup>	$T_{ON\_MIN}$	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%	$T_J=25^{\circ}C$	2.0	2.5	A	
			$-40^{\circ}C$ to $+125^{\circ}C$	1.5	2.5		
COMP Transconductance	$G_{COMP}$	$\Delta I_{COMP} = \pm 10\mu A$	70	100	130	$\mu A/V$	
COMP Output Current	$I_{COMP}$		30	60	90	$\mu A$	
<b>PWM DIMMING</b>							
PWMI High-Level Threshold	$V_{PWMI\_H}$		1.5			V	
PWMI Low-Level Threshold	$V_{PWMI\_L}$				0.4	V	
PWMO Output Impedance	$R_{PWMO}$		300	400	500	k $\Omega$	
PWMI Leakage Current	$I_{PWMI\_LK}$		-1		+1	$\mu A$	
DPWM Frequency	$f_{DPWM}$	$C_{FSET}=2.2nF$	1.2	1.6	2	kHz	

**ELECTRICAL CHARACTERISTICS (continued)**
 $V_{IN} = 12V$ ,  $V_{EN} = 5V$ ,  $T_J = -40^{\circ}C$  to  $+ 125^{\circ}C$ , unless otherwise noted. Typical values are at  $T_J = 25^{\circ}C$ .

Parameters	Symbol	Condition	Min	Typ	Max	Units	
<b>LED CURRENT REGULATION</b>							
LEDX Average Current	$I_{LED}$	$R_{ISET} = 60.4k\Omega$	$T_J = 25^{\circ}C$	19	20	21	mA
			$-40^{\circ}C$ to $+ 125^{\circ}C$	18.6		21.4	
Current Matching		$I_{LED} = 20mA$		1	3	%	
Maximum LED Current per String	$I_{LEDmax}$	$R_{ISET} = 40.2 k\Omega$	$T_J = 25^{\circ}C$	27	30	33	mA
			$-40^{\circ}C$ to $+ 125^{\circ}C$	24		33	
LEDX Regulation Voltage <sup>(5)</sup>	$V_{LEDX}$	$I_{LED} = 20mA$	520	600	680	mV	
<b>PROTECTION</b>							
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	$V_{LEDX\_UV}$		130	175	230	mV	
Thermal Shutdown Threshold <sup>(6)</sup>	$T_{ST}$			150		$^{\circ}C$	
LEDX Over Voltage Fault Timer			1.3	1.6	1.9	ms	
VFAULT Pull Down Current	$I_{FAULT}$		40	55	80	$\mu A$	
VFAULT Blocking-Off Voltage (with Respect to $V_{IN}$ )	$V_{FAULT}$	$V_{IN} = 12V$ , $V_{IN} - V_{FAULT}$	4.7	6	6.7	V	

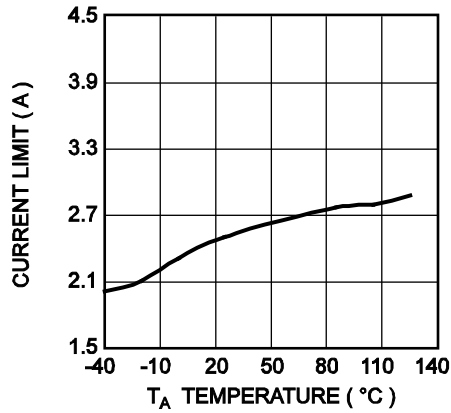
**Notes:**

- 5) Matching is defined as the difference of the maximum to minimum current divided by the sum of the maximum and minimum currents.  
6) Design guarantee, no production test.

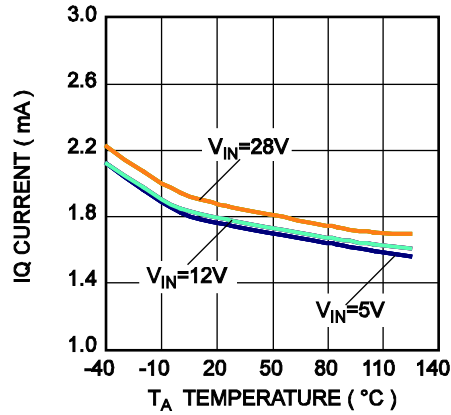
## TYPICAL PERFORMANCE CHARACTERISTICS

$V_{IN} = 12V$ , 10 LEDs in series, 6 strings parallel, 20mA/string, unless otherwise noted.

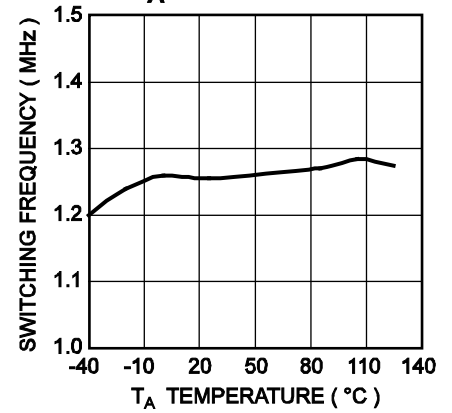
**Current Limit vs.  $T_A$**



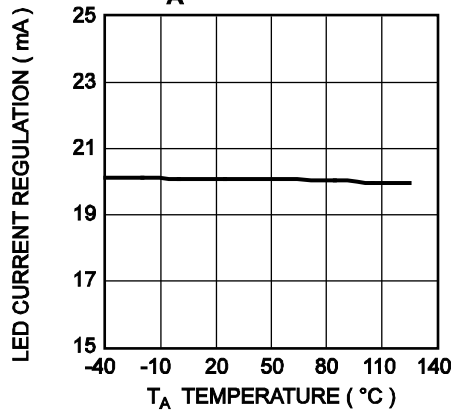
**$I_Q$  Current vs.  $T_A$**



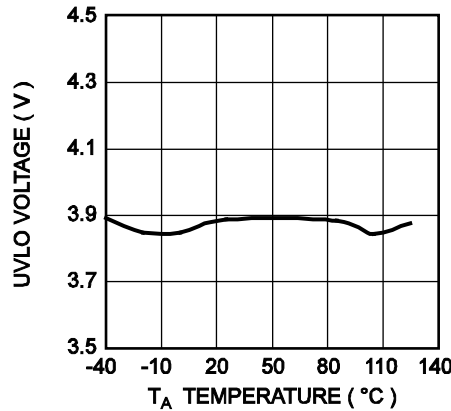
**Switching Frequency vs.  $T_A$**



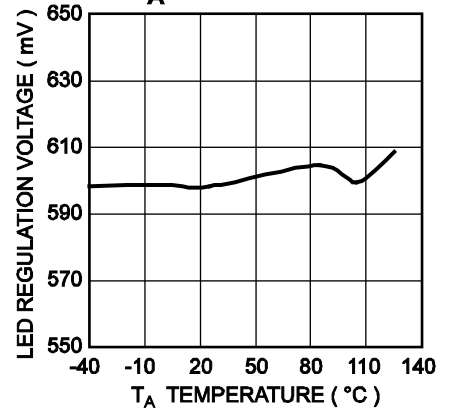
**LED Current Regulation vs.  $T_A$**



**UVLO vs.  $T_A$**



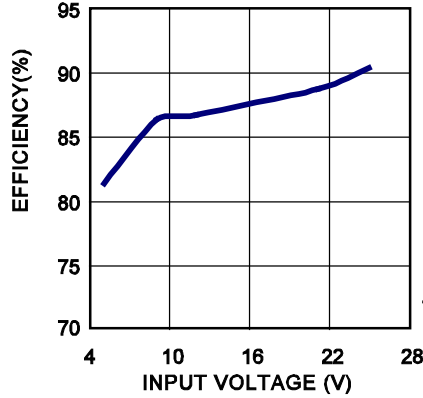
**LED Regulation Voltage vs.  $T_A$**



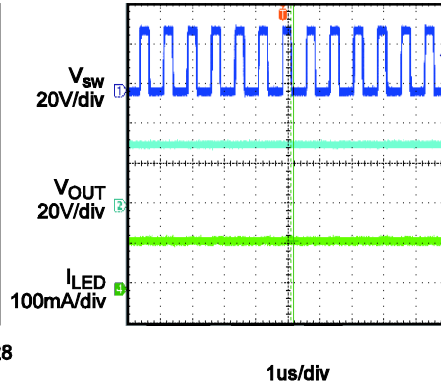
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$V_{IN} = 12V$ , 10 LEDs in series, 6 strings parallel, 20mA/string, unless otherwise noted.

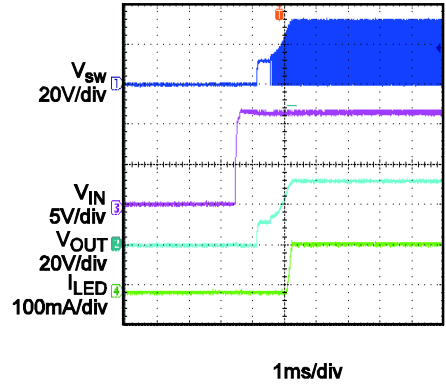
**Efficiency vs. Input Voltage**



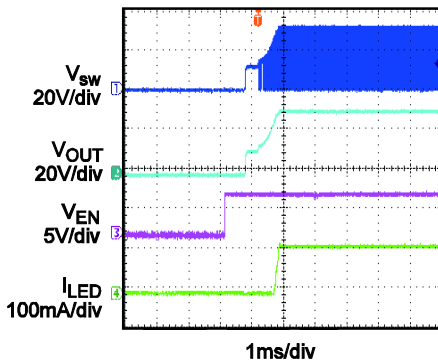
**Steady State**



**Vin Startup**

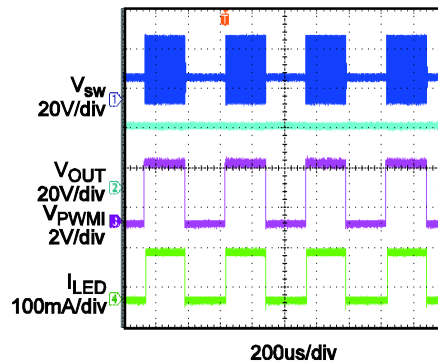


**Ven Startup**



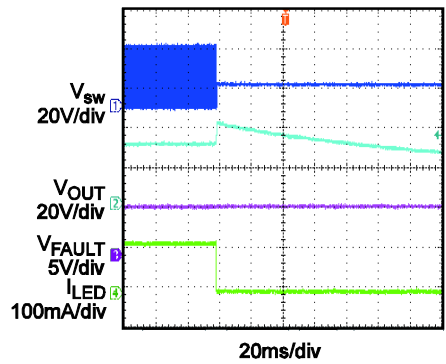
**PWM Dimming**

$f_{PWM} = 2kHz$ ,  $D_{PWM} = 50\%$



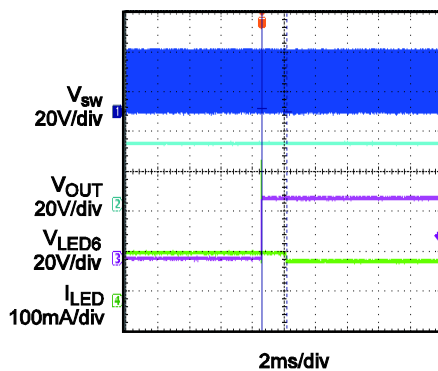
**Open LED Protection**

open all LED strings at working



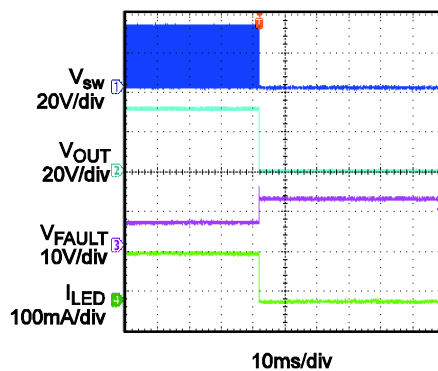
**Short LED Protecton**

short Vout to LEDx at working



**Short LED Protection**

short Vout to GND at working



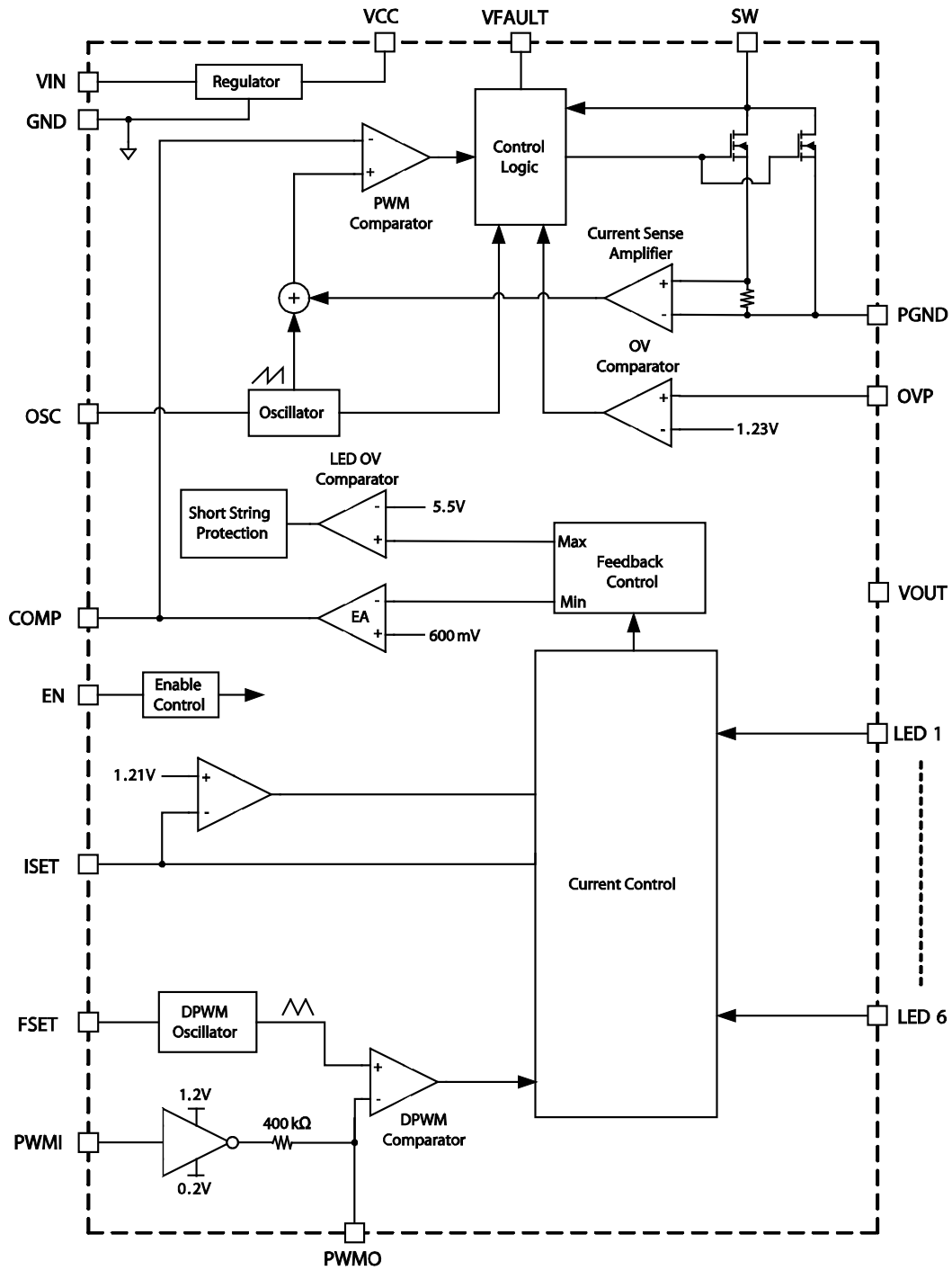
## PIN FUNCTIONS

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	FSET	Dimming PWM Frequency Set. Connect a capacitor between FSET and GND to set the DPWM frequency by the equation: $f_{DPWM} = 3.5\mu F / C_{FSET}$ . The frequency of DPWM is recommended to be set from 100Hz to 2kHz.
4	PWMO	PWM Filter Output. To use external PWM dimming mode, connect a capacitor between PWMO and GND to form a low-pass filter with an internal 400k $\Omega$ resistor. It filters the external PWM logic signal on PWMI pin into a DC signal whose level is inversely proportional to the duty-cycle of the input PWM signal and then the DC signal is translated into a duty-cycle of the dimming PWM. To use DC input PWM dimming mode, directly apply a DC voltage from 0.2V to 1.2V on PWMO pin for dimming PWM duty cycle control. The DC input PWM dimming polarity is negative.
5	GND	Analog Ground.
6	PWMI	PWM Signal Input. To use external PWM dimming mode, apply a PWM signal on this pin for brightness control. This signal is filtered and its duty cycle is converted into a DC signal to calculate the DPWM duty cycle. And the DPWM duty cycle equals to the input PWM duty cycle. To use DC input PWM dimming mode, float this pin.
7	LED6	LED String 6 Current Input. This pin is the open-drain output of an internal dimming control switch. Connect the LED String 6 cathode to this pin. If this string is not used, connect Vout to this pin.
8	LED5	LED String 5 Current Input. This pin is the open-drain output of an internal dimming control switch. Connect the LED String 5 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	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.
11	ISET	LED Current Set. Tie a current setting resistor from this pin to ground to program the current in each LED string. $I_{LED} = 1.21V / R_{SET}$
12	LED2	LED String 2 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.
13	LED1	LED String 1 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.
14	NC	No Connection.
15	Vout	Voltage Output. Connect this pin to output.

**PIN FUNCTIONS** *(continued)*

Pin #	Name	Description
16	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 MPQ3386 triggers OV Protection mode.
17	PGND2	Step-up Converter Power Ground.
18	PGND1	Step-up Converter Power Ground. PGND1 and PGND2 should be shorted externally.
19	SW1	Step-up Converter Power Switch Output. SW1 is the drain of the internal MOSFET switch. Connect the power inductor and output rectifier to SW1. SW1 can swing between GND and 50V. SW1 and SW2 should be shorted externally.
20	SW2	Step-up Converter Power Switch Output. SW2 is the drain of the internal MOSFET switch. Connect the power inductor and output rectifier to SW2. SW2 can swing between GND and 50V. SW1 and SW2 should be shorted externally.
21	VFAULT	Fault Disconnection Switch Driver Output. When the system starts up normally, this pin turns on the external PMOS. When the MPQ3386 is disabled, the external PMOS is turned off to disconnect the input and output.
22	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.
23	VIN	Supply Input. VIN supplies the power to the chip, as well as the step-up converter switch. Drive VIN with a 4.5V to 25V power source. Must be locally bypassed.
24	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.



**FUNCTION DIAGRAM**

**Figure 1—MPQ3386 Function Diagram**



When applying a PWM signal to the PWMI pin, the MPQ3386 generates a DC voltage on PWMO pin which is proportional to the duty cycle of the PWMI pin signal. By comparing the PWMO pin signal with the FSET pin triangle waveform, the converter gets a low frequency chopping signal that the duty cycle is same as the input signal. This low frequency chopping signal will modulate the LED current.

A DC analog signal can be directly applied at the PWMO pin to modulate the LED current. And the DC signal is translated into the duty-cycle of the low frequency chopping signal. The polarity is negative.

The brightness of the LED array is proportional to the duty cycle of the DPWM signal. The DPWM signal frequency is set by the cap at the FSET pin.

### **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 is less than 175mV. 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 MPQ3386 always tries to light at least one string and if all strings in use are open, the MPQ3386 shuts down the step-up converter. The part will maintain mark-off information until the part shuts down.

### **Short String Protection**

The MPQ3386 monitors the LEDX pin voltage to judge if the short string 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 when the internal dimming control logic is on, 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 are shut off totally until the part restarts. If all strings in use are short, the MPQ3386 shuts down the step-up converter.

## APPLICATION INFORMATION

### Selecting the Switching Frequency

The switching frequency of the step-up converter is alternative from 1.25MHz and 625kHz. A bi-level Switching Frequency Selection (OSC) input sets the internal oscillator frequency for the step-up converter. Tie OSC pin to GND corresponds to the frequency 625kHz and tie OSC pin to VCC or floating corresponds 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  $R_{SET}=60.4k\Omega$ , 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 ever exceeds the programmed OVP threshold, the protection will be triggered.

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

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

### Selecting Dimming Control Mode

The MPQ3386 provides 4 different dimming methods

1, PWM dimming mode with internal triangle waveform generator

Apply a 100Hz to 50kHz square waveform to the PWMI pin. The internal 400k $\Omega$  and external capacitor on PWMO pin filters the dimming signal to a DC voltage(0.2V~1.2V).Then DC voltage is modulated to a internal PWM dimming signal whose frequency is set via the capacitor on FSET pin according to the equation:

$$f_{DPWM} = 3.5\mu F / C_{FSET}$$

The minimum recommended amplitude of the PWM signal is 2.1V (See Figure 3)

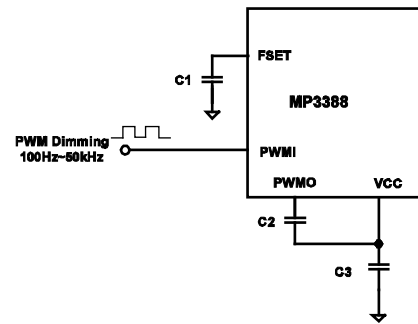


Figure 3—PWM Dimming

### with Internal Triangle Waveform Generator

2, Direct PWM dimming with positive logic

An external PWM dimming signal is directly employed to achieve PWM dimming control. Connect a 100k $\Omega$  resistor from FSET pin to GND and apply the 100Hz to 2kHz PWM dimming signal to PWMI pin. The minimum recommended amplitude of the PWM signal is 1.5V (See Figure 4).

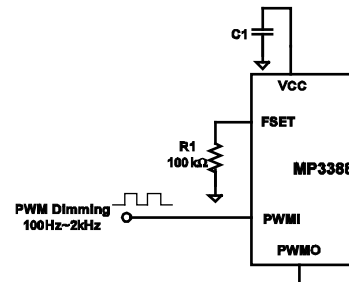
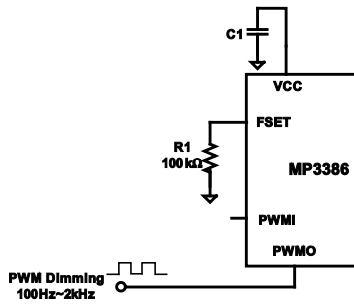


Figure 4—Direct PWM Dimming

### with Positive Logic

3, Direct PWM dimming with negative logic

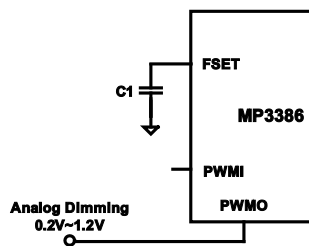
It is similar to method 2. Apply a 100Hz to 2 kHz external square waveform to the PWMO pin for negative logic PWM dimming. The minimum recommended amplitude of the PWM signal is 1.5V (See Figure 5)



**Figure 5— Direct PWM Dimming with Negative Logic**

#### 4, DC input PWM dimming

To apply DC input PWM dimming, apply an analog signal (range from 0.2V to 1.2V) at the PWMO pin to modulate the LED current directly. If the PWMO is applied with a DC voltage <math>0.2V</math>, the PWM duty cycle will be 100%. If the PWMO pin is applied with a DC voltage >math>1.2V</math>, the output will be 0% (See Figure 6). The capacitor on FSET pin set the frequency of internal triangle waveform.



**Figure 6—DC input PWM dimming**

### Selecting the Inductor

A  $10\mu H$  (for 1.25MHz switching frequency) /  $22\mu H$  (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

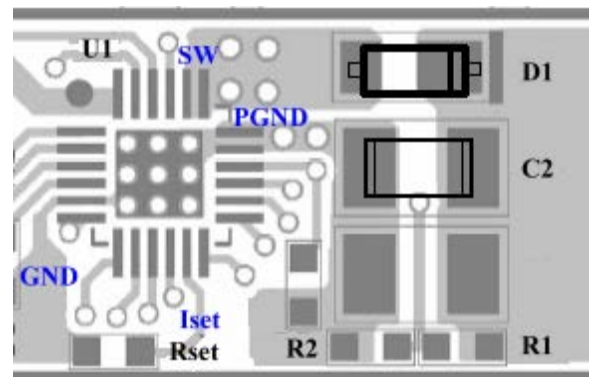
coefficients. For most applications, a  $4.7\mu F$  capacitor is sufficient.

### 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  $2.2\mu F$  ceramic capacitor will be sufficient.

### 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 MPQ3386 SW to PGND pin (U1), output diode (D1), and output capacitor (C2) is flowing with high frequency pulse current. it must be as short as possible (See Figure 7).



**Figure 7—Layout Consideration**

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

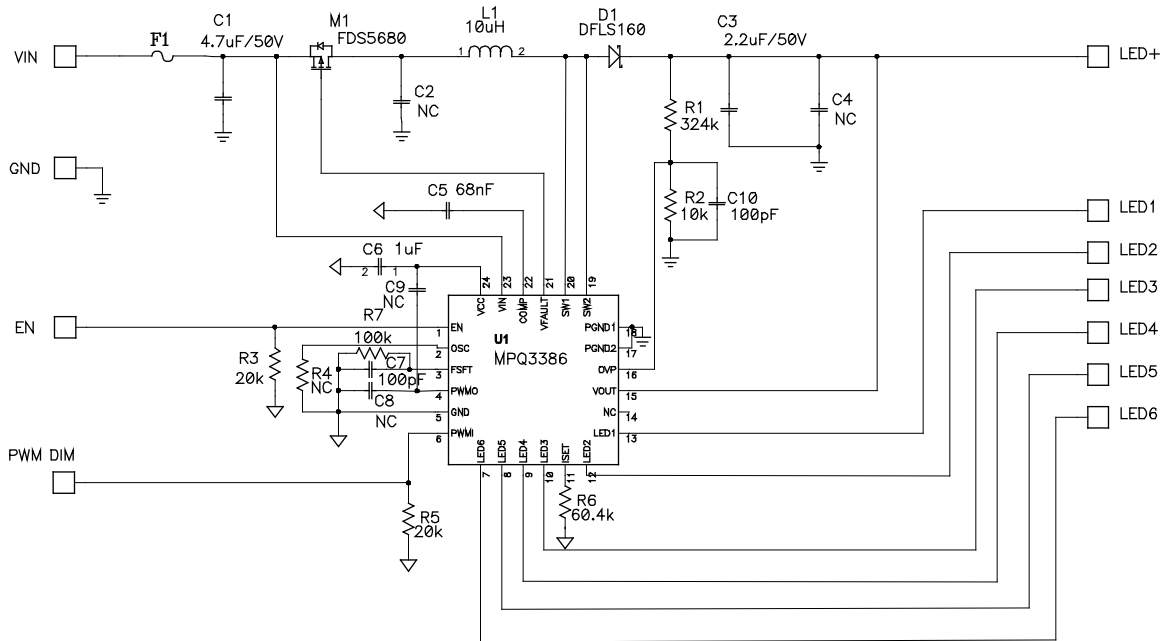
**Design Example**

Below is a design example following the application guidelines for the specifications.

**Table 1: Design Example**

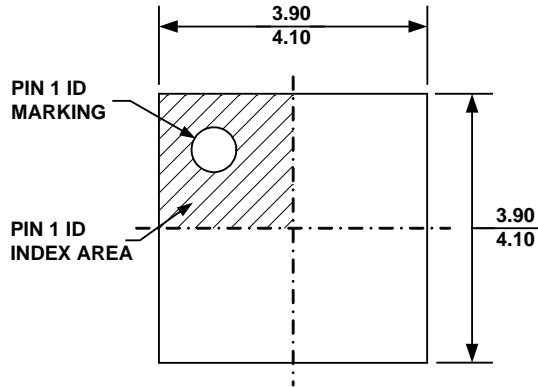
Parameter	Symbol	Value	Units
Input Voltage	$V_{IN}$	4.5 – 25	V
LEDs #		6 string parallel and 10 LEDs each string	
LED Current	$I_{LED}$	20/string	mA

The detailed application schematic is shown in Figure 8. The typical performance and circuit waveforms have been shown in the Typical Performance Characteristics, please refer to the related Evaluation Board Datasheets.

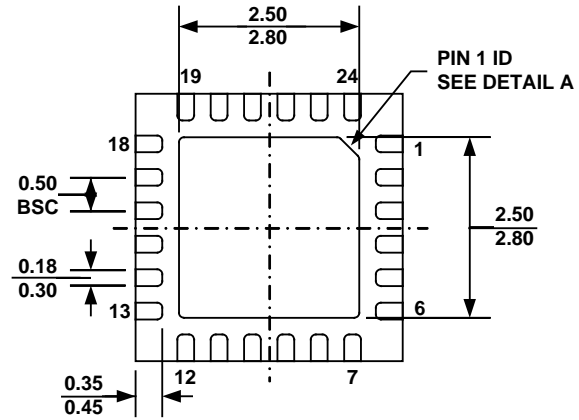

**Figure 8—Detail Application Schematic**

# PACKAGE INFORMATION

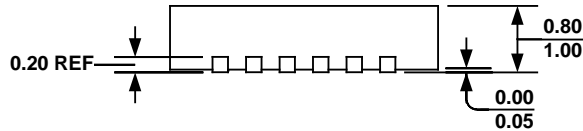
## QFN24 (4mm x 4mm)



**TOP VIEW**

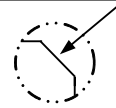


**BOTTOM VIEW**

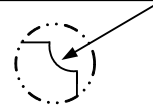


**SIDE VIEW**

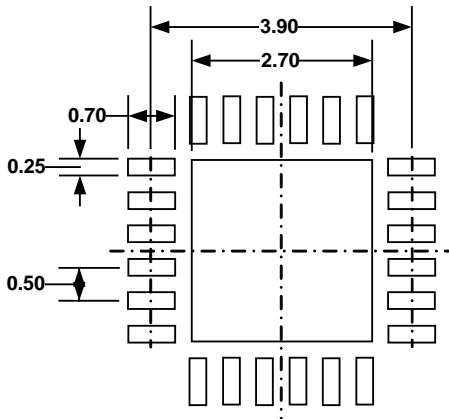
**PIN 1 ID OPTION A**  
0.30x45° TYP.



**PIN 1 ID OPTION B**  
R0.25 TYP.



**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 CONFIRMS TO JEDEC MO-220, VARIATION VGGD.
- 5) DRAWING IS NOT TO SCALE.

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