

## DESCRIPTION

The MP24894 is a high-efficiency step-down controller. It is designed to operate in continuous current mode (CCM) to power LEDs of high-brightness with a wide input voltage range of 6V to 60V.

The MP24894 employs a hysteretic control architecture that accurately regulates LED current with a feedback coming from an external high-side current-sense resistor. This control scheme optimizes circuit stabilization and fast response time without loop compensation. Its low 200mV average feedback voltage reduces power loss and improves the converter's efficiency.

The MP24894 implements PWM and analog dimming together through the EN/DIM pin.

The MP24894 includes thermal overload protection in case of output overload.

The MP24894 is available in TSOT6 package.

## FEATURES

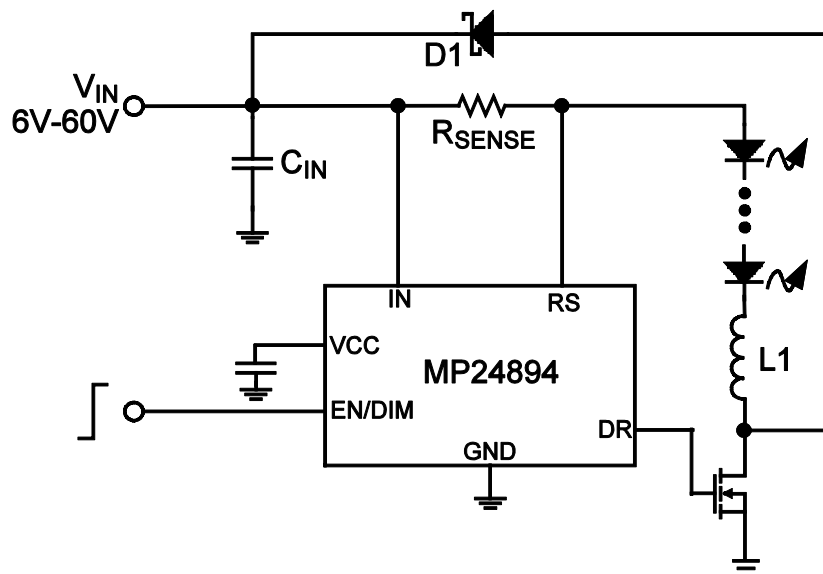
- Wide 6V to 60V Input Range
- Able to Drive >1A LED Load
- Hysteresis Control
- High Efficiency (>95%)
- 2500:1 PWM Dimming Ratio
- Open LED Protection
- Short LED Protection
- Thermal Shutdown

## APPLICATIONS

- Low Voltage Halogen Replacement
- Low Voltage General Illumination
- Automotive/Decorative LED Lighting
- Signs/Emergency Lighting
- LED Backlighting

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## TYPICAL APPLICATION

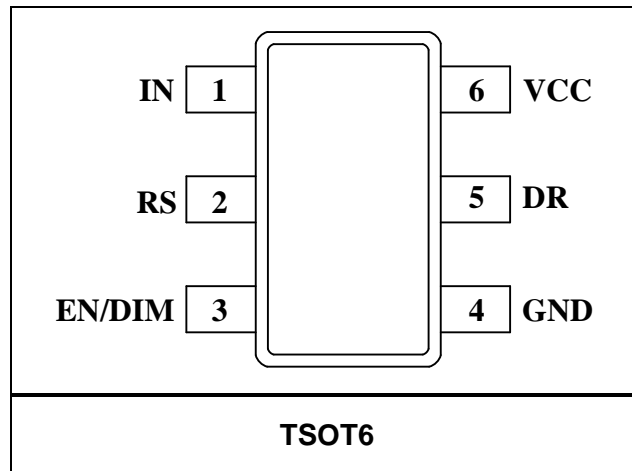


### ORDERING INFORMATION

Part Number*	Package	Top Marking
MP24894GJ	TSOT6	ACG

\* For Tape & Reel, add suffix -Z (e.g. MP24894GJ-Z);

### PACKAGE REFERENCE



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

$V_{IN}$ .....	-0.3V to +65V
$V_{RS}$ .....	$(V_{IN} - 5V)$ to $V_{IN}$
All Other Pins .....	-0.3V to +6.5V
Continuous Power Dissipation ( $T_A = 25^\circ\text{C}$ ) <sup>(2)</sup>	
TSOT6 .....	1.25W
Junction Temperature .....	150°C
Lead Temperature .....	260°C
Storage Temperature .....	-65°C to +150°C

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

Supply Voltage $V_{IN}$ .....	6V to 60V
Operating Junction Temp. ( $T_J$ ) .....	-40°C to +125°C

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

	$\theta_{JA}$	$\theta_{JC}$
TSOT6 .....	100	55... °C/W

#### Notes:

- Exceeding these ratings may damage the device.
- The maximum allowable power dissipation is a function of the maximum junction temperature  $T_J(\text{MAX})$ , the junction-to-ambient thermal resistance  $\theta_{JA}$ , and the ambient temperature  $T_A$ . The maximum allowable continuous power dissipation at any ambient temperature is calculated by  $P_D(\text{MAX}) = (T_J(\text{MAX}) - T_A) / \theta_{JA}$ . 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.
- The device is not guaranteed to function outside of its operation conditions.
- Measured on JESD51-7, 4-layer PCB.

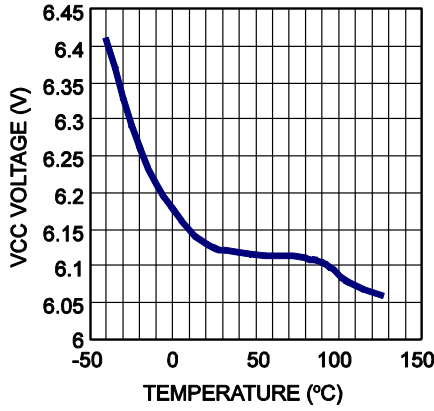
## ELECTRICAL CHARACTERISTICS

$V_{IN} = 24V$ ,  $T_A = 25^{\circ}C$ , unless otherwise noted.

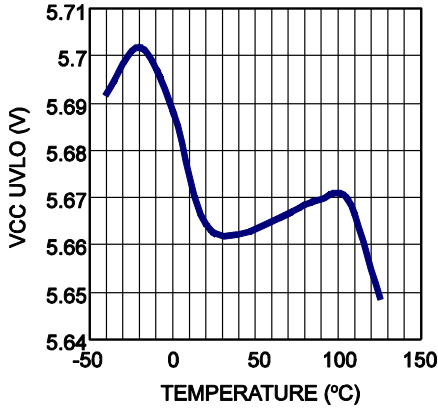
Parameter	Symbol	Condition	Min	Typ	Max	Units
Input voltage	$V_{IN}$		6		60	V
Shutdown supply current	$I_{SD}$			80	108	$\mu A$
Quiescent supply current	$I_Q$	No Switching		0.3	0.5	mA
VCC voltage	$V_{CC}$	$V_{EN/DIM} = 3.5V$	5.5	6		V
Feedback average voltage (with respect to $V_{IN}$ )	$V_{IN-V_{RS}}$	$V_{EN/DIM} = 3.5V$	194	200	206	mV
Feedback reference voltage hysteresis	$V_{FB\_HYS}$			$\pm 30$		mV
EN/DIM enable high voltage	$V_{EN\_HIGH}$	$V_{EN}$ Rising		0.29	0.34	V
EN/DIM enable hysteresis	$V_{EN\_HYS}$		20	50	80	mV
EN/DIM pull-up current		Pull up to 5V		2.8		$\mu A$
EN/DIM pull-down current		Pull down to GND		25		$\mu A$
Min recommended pwm dimming frequency	$F_{PWMmin}$			0.1		kHz
Max recommended pwm dimming frequency	$F_{PWMmax}$			20		kHz
Gate driver source resistor	$R_{source}$	$V_{GS} = 5.5V$		6		$\Omega$
Gate driver sink resistor	$R_{sink}$			2		$\Omega$
Gate driver output-voltage high	$V_{OH}$	$I_{DRV} = 10mA$	5.5			V
Gate driver output-voltage low	$V_{OL}$	$I_{DRV} = 10mA$			0.5	V
Minimum on time	$T_{ON\_MIN}$	Guarantee by Designer		100		ns
Minimum off time	$T_{OFF\_MIN}$	Guarantee by Designer		100		ns
Recommended maximum operating frequency	$F_{MAX}$			1		MHz
UVLO threshold voltage(VCC)	$V_{UVLOTH}$	VCC Rising		5.6		V
UVLO hysteresis	$V_{UVLOHYS}$			0.4		V
Thermal shutdown threshold		Temp Rising		150		$^{\circ}C$
Thermal shutdown hysteresis		Guarantee by Designer		20		$^{\circ}C$

## TYPICAL CHARACTERISTICS

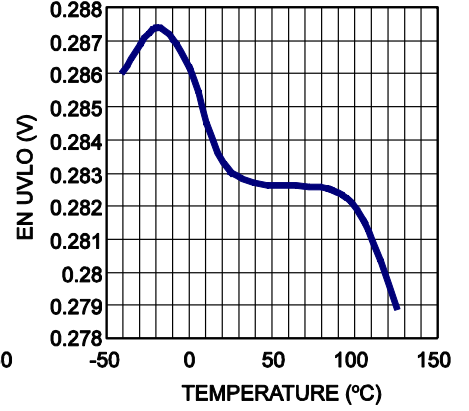
**VCC Voltage vs. Temperature**



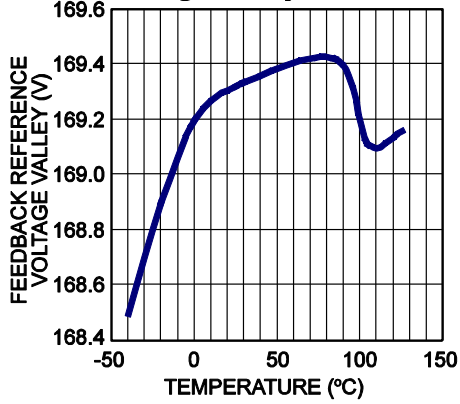
**VCC UVLO vs. Temperature**



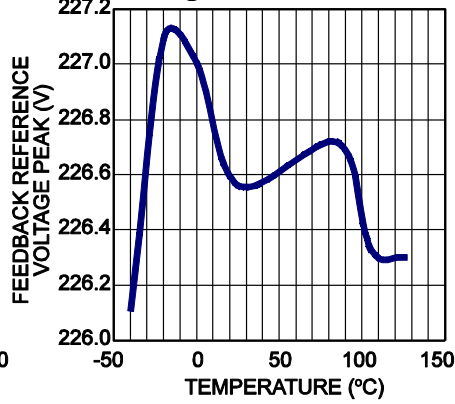
**EN UVLO vs. Temperature**



**Feedback Reference Voltage Valley**



**Feedback Reference Voltage Peak**

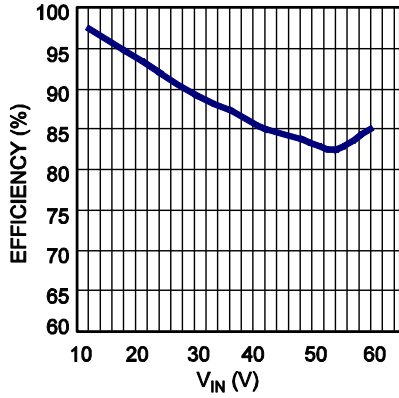


## TYPICAL PERFORMANCE CHARACTERISTICS

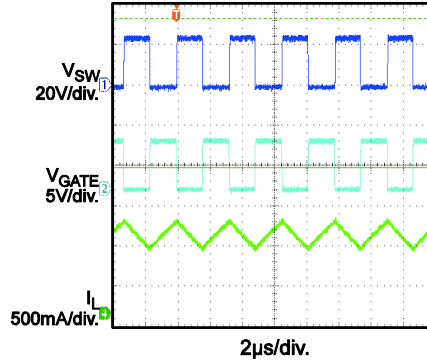
Performance waveforms are tested on the evaluation board of the Design Example section.

$V_{IN} = 24V$ , 3LEDs,  $I_{OUT} = 1A$ ,  $T_A = 25^\circ C$ , unless otherwise noted.

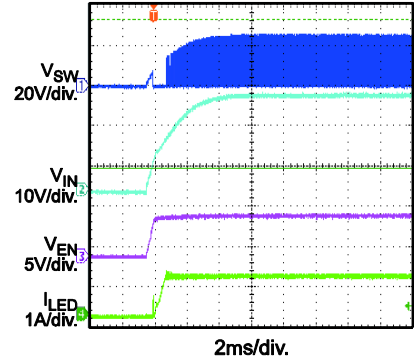
**Efficiency**



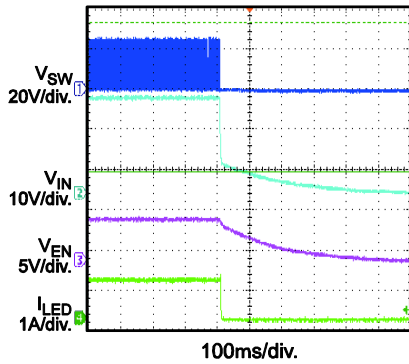
**Steady State**



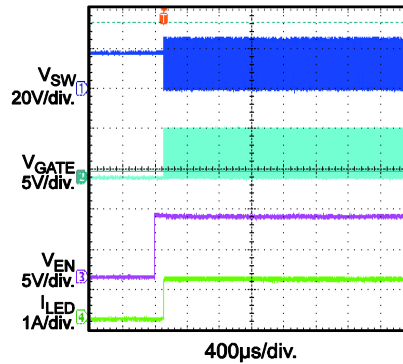
**Input Power On**



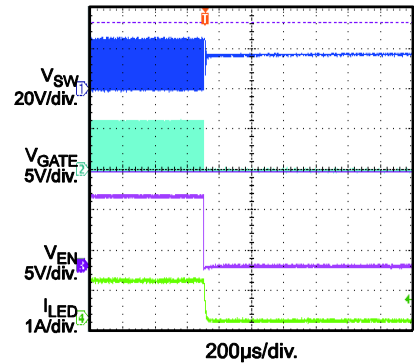
**Input Power Off**



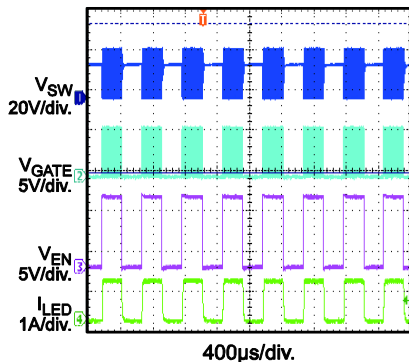
**EN Power On**



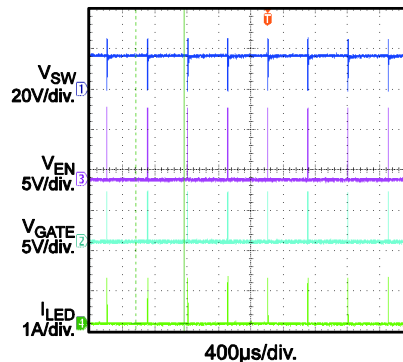
**EN Power Off**



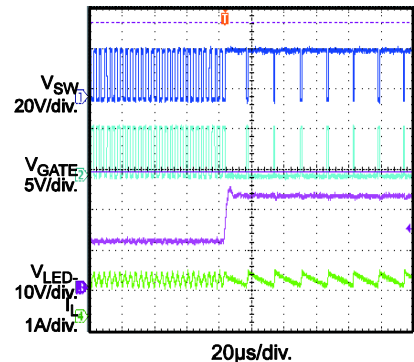
**PWM Dimming (2kHz, 50%)**



**PWM Dimming (2kHz, 1%)**



**Short LED+ to LED- Protection**

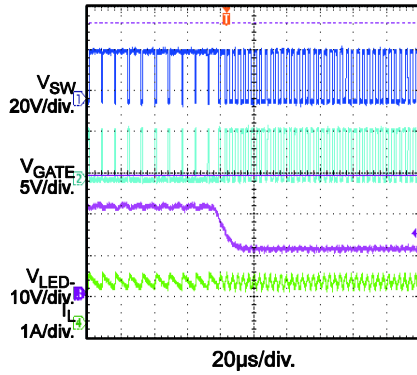


## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

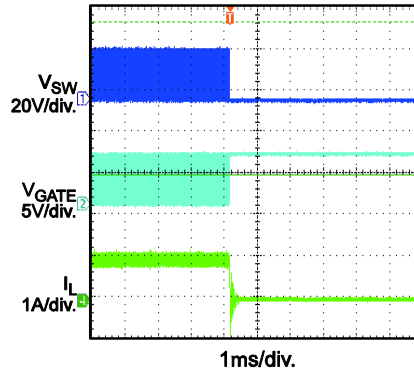
Performance waveforms are tested on the evaluation board of the Design Example section.

$V_{IN} = 24V$ , 3LEDs,  $I_{OUT} = 1A$ ,  $T_A = 25^\circ C$ , unless otherwise noted.

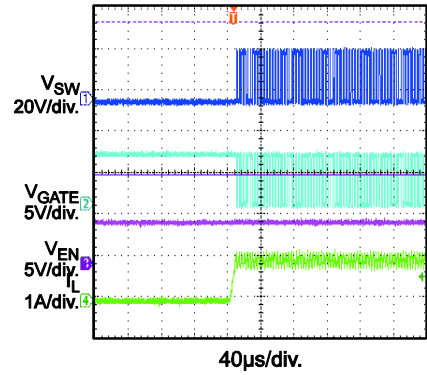
**Short LED+ to LED- Recovery**



**Open LED Load Protection**



**Open LED Load Recovery**



## PIN FUNCTIONS

TSOT6 Pin#	Name	Description
1	IN	Input Supply Pin. Connect a decoupling capacitor from IN pin to GND.
2	RS	LED Current Sense Input. Connect a current-sense resistor that programs LED average current to the IN pin.
3	EN/DIM	Enable/Dimming Command Input. A voltage greater than 0.3V turns on the chip. To use PWM dimming, apply a square wave signal to this pin. If dimming-off time is larger than 20ms, the IC shuts down. For analog dimming, the EN/DIM pin voltage rises from 0.3V to 2.7V and LED current will change from 20% to 100% of the maximum LED current.
4	GND	Ground.
5	DR	Gate-Driver Output. Connect this pin to the gate of the external MOSFET.
6	VCC	Internal Regulator Output. Connect a 1 $\mu$ F decoupling cap from this pin to ground.

## FUNCTIONAL BLOCK DIAGRAM

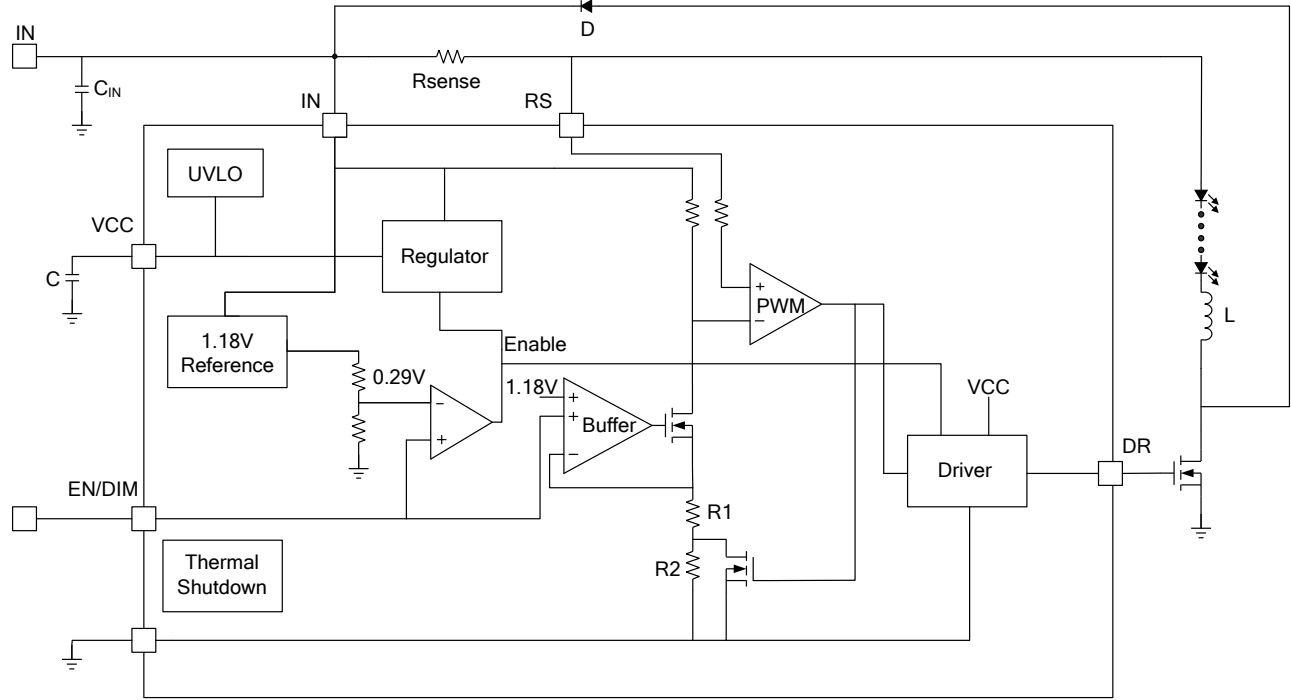


Figure 1—MP24894 Functional Block Diagram



## OPERATION

### Steady State

The MP24894 is a step-down LED-current controller with hysteresis control that is easily configured for a wide input that ranges from 6V to 60V input. The MP24894 uses a high-side current-sense resistor to detect and regulate LED current. The voltage across the current-sense resistor is measured and regulated in the  $200\text{mV}\pm 30\text{mV}$  range.

The internal 1.18V reference voltage provides a 0.3V reference to enable the part. When  $V_{\text{EN}} > 0.3\text{V}$ , the output of the comparator goes high and enables the other blocks. The MP24894 also provides a 5V pull-up voltage as current reference voltage when EN/DIM pin is float.

The inductor current is sensed through the high-side resistor,  $R_{\text{sense}}$ . When the switch is on, R2 (see Figure 1) is shorted and inductor current upper-threshold is fixed by R1. When the switch is off, inductor current lower-threshold is fixed by R1 and R2. The ratio of R1 and R2 determines the current hysteresis.

### System Soft Start

The voltage on the EN/DIM pin provides the inductor current reference. An external capacitor from the EN/DIM pin to ground provides a soft-start delay. When  $V_{\text{IN}}$  starts, internal voltage source charges the capacitor from 0V to 5V to fulfill soft-start function.

### Dimming Control

The MP24894 allows the EN/DIM pin to control both Analog and PWM dimming. Whenever the voltage on DIM is less than 0.25V, the chip turns off. For analog dimming, when the voltage on DIM is from 0.3V to 2.7V, the LED current will change from 20% to 100% of the maximum LED current. If the voltage on EN pin is higher than 2.9V, output LED current will equal the maximum LED current. For PWM dimming, the signal amplitude must exceed 3V. Choose a PWM frequency in range of 100Hz to 20kHz for good dimming linearity.

## APPLICATION INFORMATION

### Setting the LED Current

The LED current is identical and set by the current sense resistor between the IN pin and RS pin.

$$R_{SENSE} = 200\text{mV}/I_{LED}$$

For  $R_{SENSE} = 0.2\Omega$ , the LED current is set to 1A

### Selecting the Inductor

Lower value of inductance can result in a higher switching frequency, which causes a larger switching loss. Choose a switch frequency between 100kHz to 600kHz for most application. According to switching frequency, inductor value can be estimated as:

$$L = \frac{(1 - \frac{V_{OUT}}{V_{IN}}) \times V_{OUT}}{0.3 \times I_{LED} \times f_{SW}}$$

For higher efficiency, choose an inductor with a DC resistance 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. Choose a capacitor value between 10 $\mu$ F and 22 $\mu$ F for most applications. The voltage rating should be greater than the input voltage. Use a low ESR capacitor for input decoupling.

### Selecting the Output Capacitor

For most applications, the output capacitor is not necessary. For applications that require that the peak-to-peak LED ripple current falls below 30% of the average current, add a capacitor across the LEDs. Higher capacitor values will result in proportionally lower ripple. A value of 2.2 $\mu$ F will meet most requirements.

### Selecting Soft-Start Capacitor

When selecting a soft-start capacitor, the delay time can be estimated as 0.2ms/nF. For PWM dimming, select  $C < 2.2\text{nF}$  to eliminate its effect on the average LED current.

### Dimming Control

The MP24894 provides 1:2500 high-ratio PWM dimming. Apply a 100Hz to 20kHz square waveform to the EN/DIM pin. The average LED current is proportional to PWM duty cycle. Add a 100pF to 2nF capacitor between the EN/DIM pin and GND pin to reduce the impact of EN/DIM pin noise.

### Layout Consideration

Pay careful attention to the PCB layout and component placement.  $R_{SENSE}$  should be placed close to the IN pin and RS pin to minimize the current-sense error. The input loop — including input capacitor, Schottky diode, and MOSFET — should be as short as possible. The VCC capacitor and EN capacitor should be placed as close to the chip as possible.

### Design Example

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

**Table 1: Design Example**

$V_{IN}$	24V
$V_{OUT}$	10V
I <sub>out</sub>	1A

The detailed application schematic is shown in Figure 2. The typical performance and circuit waveforms have been shown in the Typical Performance Characteristics section. For more device applications, please refer to the related Evaluation Board Datasheets.

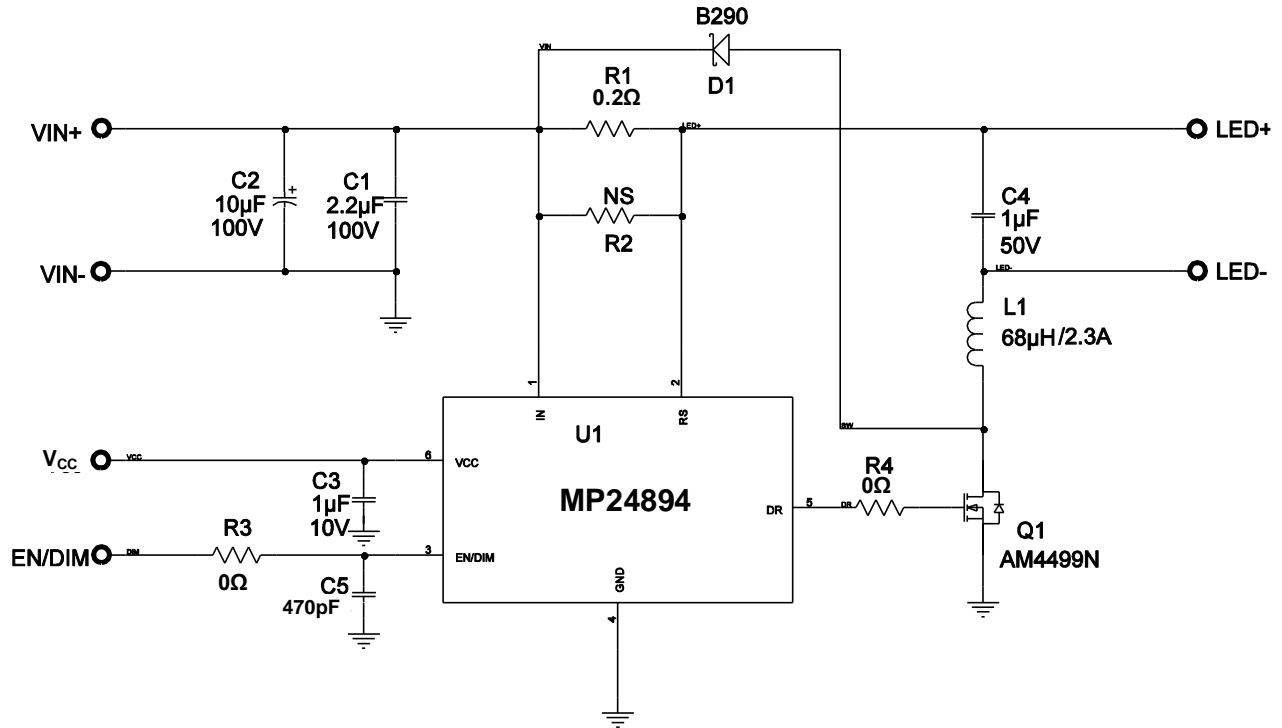
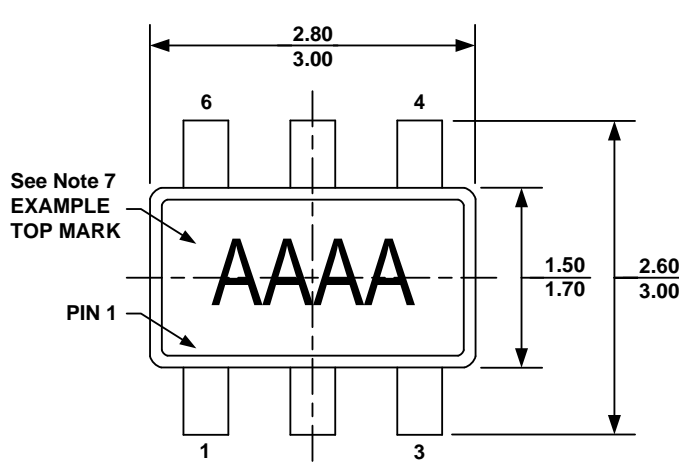


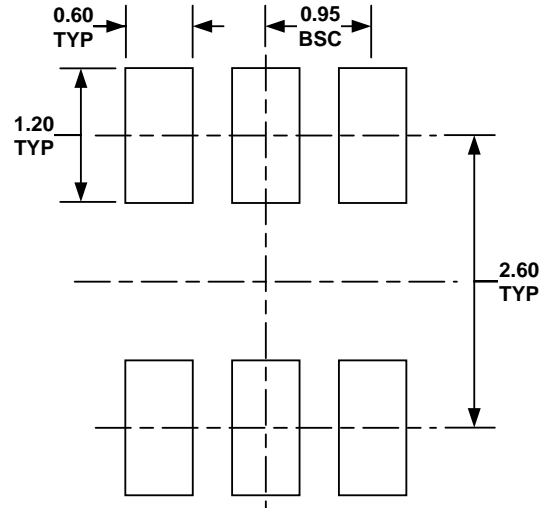
Figure 2: Typical Application Circuit

**PACKAGE INFORMATION**

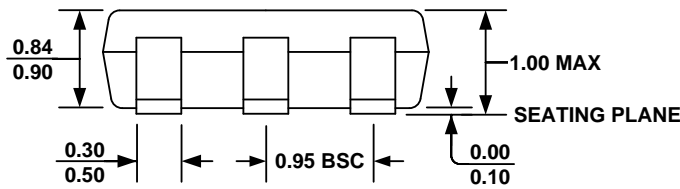
**TSOT6**



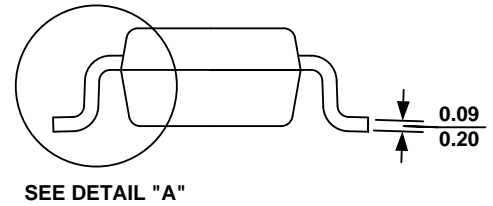
**TOP VIEW**



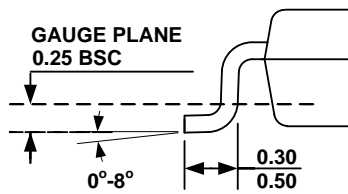
**RECOMMENDED LAND PATTERN**



**FRONT VIEW**



**SIDE VIEW**



**DETAIL "A"**

**NOTE:**

- 1) ALL DIMENSIONS ARE IN MILLIMETERS.
- 2) PACKAGE LENGTH DOES NOT INCLUDE MOLD FLASH, PROTRUSION OR GATE BURR.
- 3) PACKAGE WIDTH DOES NOT INCLUDE INTERLEAD FLASH OR PROTRUSION.
- 4) LEAD COPLANARITY (BOTTOM OF LEADS AFTER FORMING) SHALL BE 0.10 MILLIMETERS MAX.
- 5) DRAWING CONFORMS TO JEDEC MO-193, VARIATION AB.
- 6) DRAWING IS NOT TO SCALE.
- 7) PIN 1 IS LOWER LEFT PIN WHEN READING TOP MARK FROM LEFT TO RIGHT, (SEE EXAMPLE TOP MARK)

## REVISION HISTORY

Revision #	Revision Date	Description	Pages Updated
1.0	6/21/2012	Initial Release	-
1.01	11/4/2013	<ul style="list-style-type: none"><li>Removed feedback “reference voltage peak” and “feedback reference voltage valley” parameters</li><li>Added “feedback average voltage” and “feedback reference voltage hysteresis” parameters</li></ul>	3
1.1	10/9/2023	<ul style="list-style-type: none"><li>Updated the Dimming Control section</li><li>Updated the Layout Consideration section</li></ul>	10
		<ul style="list-style-type: none"><li>Updated Figure 2 (Typical Application Circuit)</li><li>Changed the EN capacitor from NS to 470pF</li></ul>	11

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