



# MP4030

## TRIAC-Dimmable, Primary-Side-Control Offline LED Controller with Active PFC

The Future of Analog IC Technology®

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### DESCRIPTION

The MP4030 is a TRIAC-dimmable, primary-side-control, offline LED lighting controller with active PFC. It can output an accurate LED current for an isolated lighting application with a single-stage converter. The proprietary real-current-control method can accurately control the LED current using primary-side information. It can significantly simplify LED lighting system design by eliminating secondary-side feedback components and the optocoupler.

The MP4030 implements power-factor correction and works in boundary-conduction mode to reduce MOSFET switching losses.

The MP4030 has an integrated charging circuit at the supply pin for fast start-up without a perceptible delay.

The proprietary dimming control expands the TRIAC-based dimming range.

The MP4030 has multiple protections that greatly enhance system reliability and safety, and include over-voltage protection, short-circuit protection, programmable primary-side over-current protection, supply-pin under-voltage lockout, and over-temperature protection.

All fault protections feature auto-restart.

The MP4030 is available in an 8-pin SOIC package.

### FEATURES

- Primary-Side-Control without Requiring a Secondary-Side Feedback Circuit
- Internal Charging Circuit at the Supply Pin for Fast Start-Up
- Accurate Line Regulation
- High Power Factor
- Flicker-Free, Phase-Controlled TRIAC Dimming with Expanded Dimming Range.
- Operates in Boundary Conduction Mode
- Cycle-by-Cycle Current Limit
- Programmable Primary-Side Over-Current Protection
- Over-Voltage Protection
- Short-Circuit Protection
- Over-Temperature Protection
- Available in an 8-Pin SOIC Package

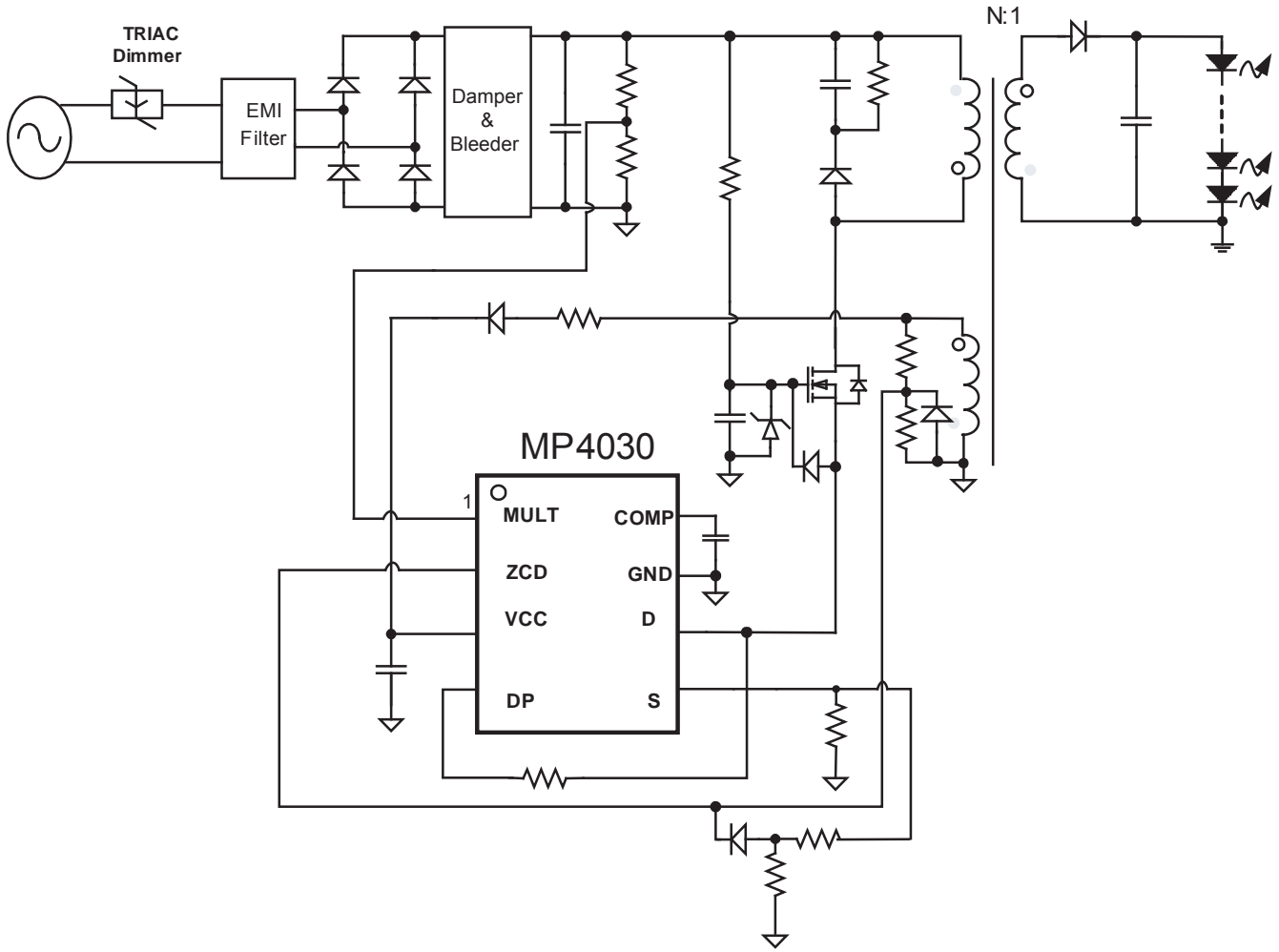
### APPLICATIONS

- Solid-State Lighting, including:
- Industrial and Commercial Lighting
- Residential Lighting

All MPS parts are lead-free and adhere to the RoHS directive. For MPS green status, please visit MPS website under Products, Quality Assurance page.

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**TYPICAL APPLICATION**

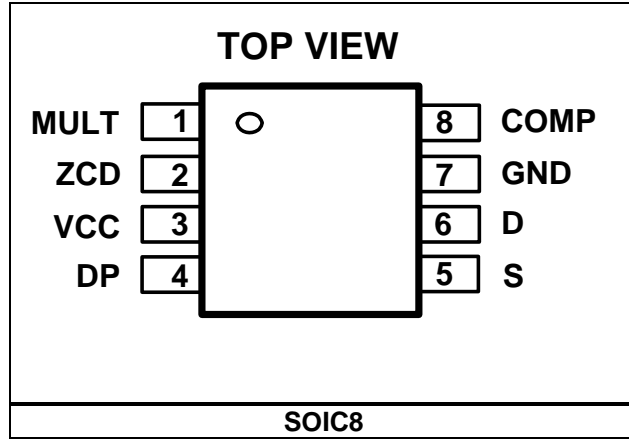


**ORDERING INFORMATION**

Part Number*	Package	Top Marking
MP4030GS	SOIC8	MP4030

\* For Tape & Reel, add suffix -Z (e.g. MP4030GS-Z);

**PACKAGE REFERENCE**



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

Input Voltage VCC .....	-0.3V to +30V
Low-Side MOSFET Drain Voltage .....	-0.7V to +30V
ZCD Pin Voltage .....	-8V to +7V
Other Analog Inputs and Outputs .....	-0.3V to 7V
ZCD Pin Current .....	-5mA to +5mA
Continuous Power Dissipation (T <sub>A</sub> = +25°C) <sup>(2)</sup>	
SOIC8 .....	1.3W
Junction Temperature .....	150°C
Lead Temperature .....	260°C
Storage Temperature.....	-65°C to +150°C

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

Supply Voltage VCC .....	11V to 27V
Operating Junction Temp (T <sub>J</sub> )..	-40°C to +125°C

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

	$\theta_{JA}$	$\theta_{JC}$
SOIC8 .....	96	45 ... °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<sub>J</sub>(MAX), the junction-to-ambient thermal resistance  $\theta_{JA}$ , 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>)/  $\theta_{JA}$ . 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 board.

## ELECTRICAL CHARACTERISTICS

$T_A = +25^\circ\text{C}$ , unless otherwise noted.

Parameter	Symbol	Condition	Min	Typ	Max	Units
<b>Supply Voltage</b>						
Operating Range	$V_{CC}$	After turn on	10		27	V
VCC Upper Level: Internal Charging Circuit Stops and IC Turns On	$V_{CCH}$		9.5	10	10.5	V
VCC Lower Level: Internal Charging Circuit Triggers	$V_{CCL}$		8.55	9	9.45	V
Vcc Re-charge and IC turns off Level in Fault Condition	$V_{CCEN}$	Fault condition	6.55	7	7.45	V
<b>Supply Current</b>						
VCC Charging Current from D	$I_{D\ charge}$	$V_D=16V, V_{CC}=5V$	12.5	15	17.5	mA
Quiescent Current	$I_q$	No switching, $V_{CC}=15V$		800	1000	$\mu\text{A}$
Quiescent Current at Fault	$I_{q\_fault}$	Fault condition, IC latch, $V_{CC}=15V$	180	220	300	$\mu\text{A}$
Operating Current	$I_{cc}$	$f_s = 70\text{kHz}, V_{CC}=15V$		1	2	mA
<b>Multiplier</b>						
Linear Operation Range	$V_{MULT}$	$V_{COMP}$ from 1.9V to 4.9V	0		3	V
Gain	$K^{(5)}$	$V_{COMP}=2V, V_{MULT}=0.5V$	0.84	1.06	1.26	1/V
		$V_{COMP}=2V, V_{MULT}=1.5V$	0.9	1.08	1.23	1/V
		$V_{COMP}=2V, V_{MULT}=3V$	0.93	1.1	1.25	1/V
TRIAC Dimming Off Detection Threshold	$V_{MUL\_off}$		0.13	0.15	0.17	V
TRIAC Dimming On Detection Threshold	$V_{MUL\_on}$		0.32	0.35	0.38	V
TRIAC Dimming Off Line-Cycle Blanking Ratio	$D_{off\_LEB}$			25%		
Dimming Pull-Down MOSFET Turn on Threshold	$V_{MULT\_DP\_on}$		0.22	0.25	0.28	V
Dimming Pull down MOSFET Turn off Delay Time	$T_{DP\_off\ delay}$	starts at the rising edge of $V_{MULT}=V_{MULT\ on}$	150	200	250	$\mu\text{s}$
<b>Error Amplifier</b>						
Reference Voltage	$V_{REF}$		0.386	0.4	0.414	V
Transconductance	$G_{EA}$	Guaranteed by design		250		$\mu\text{A/V}$
COMP Lower Clamp Voltage	$V_{COMPL}$		1.85	1.9	1.95	V
Max. Source Current	$I_{COMP+}$			57		$\mu\text{A}$
Max. Sink Current without Dimmer	$I_{COMP-}$			-300		$\mu\text{A}$
Sink Current at TRIAC Dimming Off	$I_{sink\_dim}$		63	70	77	$\mu\text{A}$
Short-Circuit Detect Threshold	$V_{COMP\_SCP}$		4.85	5	5.15	V

**ELECTRICAL CHARACTERISTICS (continued)**
**T<sub>A</sub> = +25°C, unless otherwise noted.**

Parameter	Symbol	Condition	Min	Typ	Max	Units
<b>Current Sense Comparator</b>						
Leading Edge Blanking Time	T <sub>LEB</sub>		575	685	795	ns
Current Sense Upper Clamp Voltage	V <sub>S clamp H</sub>		2.2	2.3	2.4	V
Current Sense Lower Clamp Voltage	V <sub>S clamp L</sub>		0.08	0.1	0.12	V
<b>Zero-Current Detector</b>						
Zero-Current-Detect Threshold	V <sub>ZCD T</sub>	Falling Edge	0.32	0.35	0.37	V
Zero-Current-Detect Hystestic	V <sub>ZCD HY</sub>		520	550	580	mV
Zero-Current-Detect LEB	V <sub>ZCD LEB</sub>	Starts at Gate Turn Off	1.8	2.5	3.1	µs
Over-Voltage Threshold	V <sub>ZCD OVP</sub>		5.2	5.5	5.8	V
OVP Detect LEB	T <sub>OVP LEB</sub>	Starts at Gate Turn Off	1.5	2	2.5	µs
Over-Current Threshold	V <sub>ZCD OCP</sub>		0.81	0.9	0.99	V
OCP Blanking Time	T <sub>LEB OCP</sub>	Starts at Gate Turn On	575	685	795	ns
Minimum Off Time	T <sub>off min</sub>		4.2	5.6	7	µs
<b>Starter</b>						
Start Timer Period	T <sub>start</sub>		90	115	140	µs
<b>Internal Main MOSFET</b>						
Breakdown Voltage	BV <sub>DSS main</sub>	V <sub>GS=0</sub>	30			V
Drain-Source On-Resistor	R <sub>DS(on)_main</sub>	I <sub>D</sub> =100mA	200	250	300	mΩ
<b>Internal Dimming Pull Down MOSFET</b>						
Breakdown Voltage	BV <sub>DSS DP</sub>	V <sub>GS=0</sub>	30			V
Drain-Source On-Resistor	R <sub>DS(on)_DP</sub>	I <sub>D</sub> =50mA	22	26	30	Ω

**Notes:**

 5) The multiplier output is given by:  $V_s = K \cdot V_{MULT} \cdot (V_{COMP} - 1.5)$

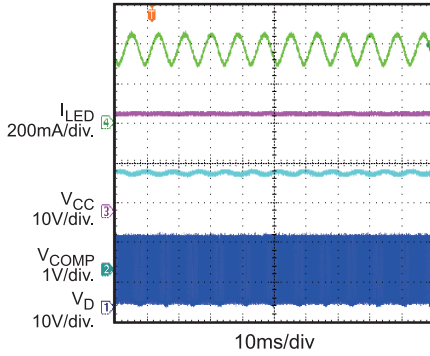
## PIN FUNCTIONS

Pin #	Name	Pin Function
1	MULT	One of the Internal Multiplier Input. Connect to the tap of resistor divider from the rectified voltage of the AC line. The half-wave sinusoid signal to this pin provides a reference signal for the internal current control loop. The MULT pin also detects the TRIAC dimming phase.
2	ZCD	Zero-Current Detection. A negative going edge triggers the internal MOSFET's turn-on signal. Connect to the tap of a resistor divider from the auxiliary winding to GND. The ZCD pin can also detect over-voltage and over-current conditions. Over-voltage occurs if $V_{ZCD}$ exceeds the over-voltage-protection (OVP) threshold after a 2 $\mu$ s blanking time when the internal MOSFET turns off. Over-current occurs if $V_{ZCD}$ exceeds 0.9V during the gate-on interval after the leading edge blanking time
3	VCC	Supply Voltage. Supplies power for both the control signal and the internal MOSFET's gate driver. Connect to an external bulk capacitor—typically 22 $\mu$ F with a 100pF ceramic capacitor to reduce noise.
4	DP	Dimming Pull-Down. Drain of the internal dimming pull-down MOSFET. Connect a resistor from this pin to the D pin to pull down the rectified input voltage during the TRIAC dimming OFF interval.
5	S	Internal Low-Side main MOSFET Source. Connect a resistor from this pin to GND to sense the internal MOSFET current. An internal comparator compares the resulting voltage to the internal sinusoid shaped current reference signal to determine when the MOSFET turns off. If the voltage exceeds the current-limit threshold of 2.3V after the leading edge blanking time during the turn-on interval, the gate signal turns off.
6	D	Internal Low-Side main MOSFET Drain. This pin also internally connects to VCC via a diode and a JFET to form an internal charging circuit for VCC. Connect to the source of the high-side MOSFET.
7	GND	Ground. Current return of the control signal and the gate drive signal.
8	COMP	Loop Compensation. Connects to a compensation network to stabilize the LED driver and accurately control the LED driver current. The COMP pin can also monitor for short-circuit conditions: if the COMP voltage rises above 5V, the short-circuit protection triggers.

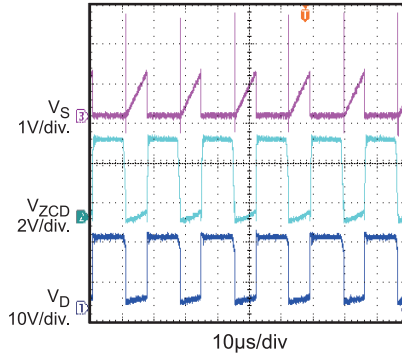
## TYPICAL PERFORMANCE CHARACTERISTICS

$V_{IN} = 120VAC$ , 7 LEDs in series,  $I_O = 350mA$ ,  $V_O = 22V$ ,  $L_m = 1.6mH$ ,  $N_p:N_s:N_{AUX} = 82:16:19$ , Triac dimmable.

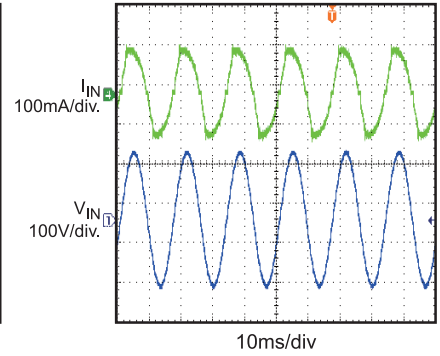
Steady State



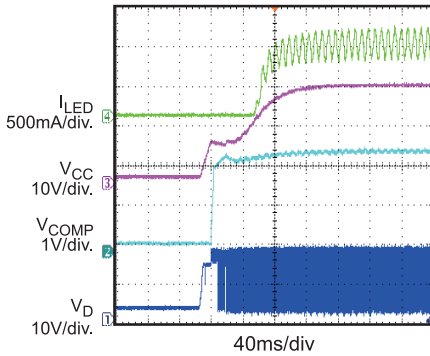
Steady State



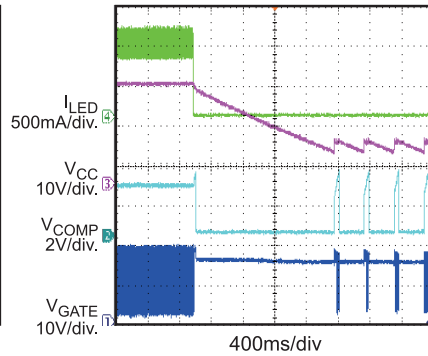
Steady State



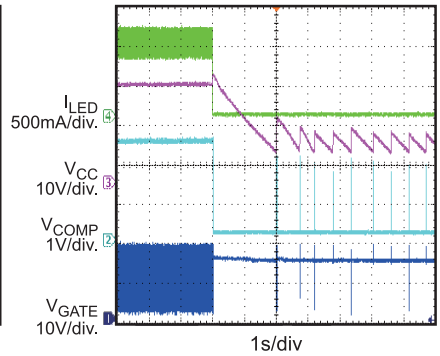
$V_{IN}$  Start Up



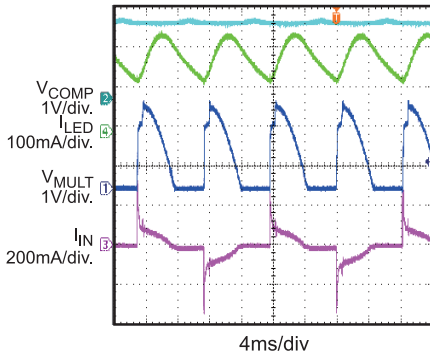
Short Circuit Protection  
LED + Short to LED When Working



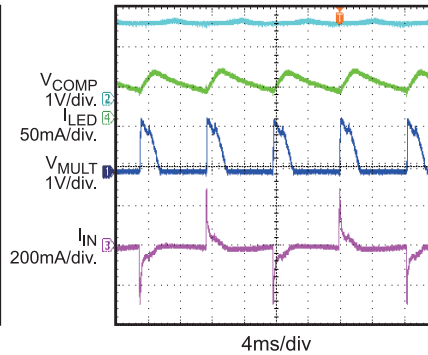
Over Voltage Protection  
LED Load Open When Working



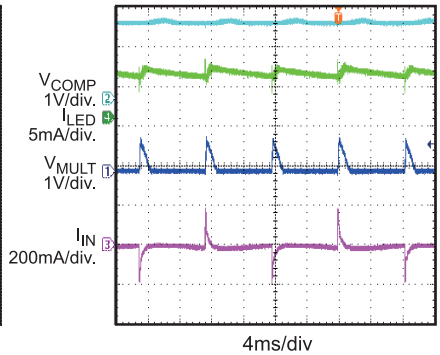
Triac Dimming  
D=60%



Triac Dimming  
D=40%

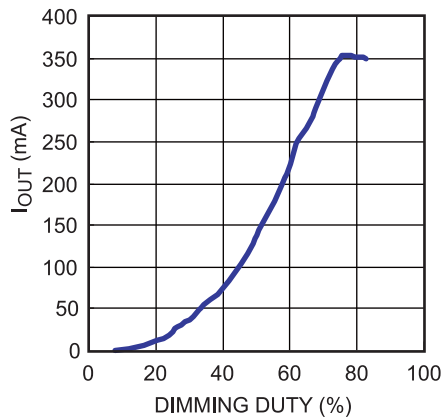
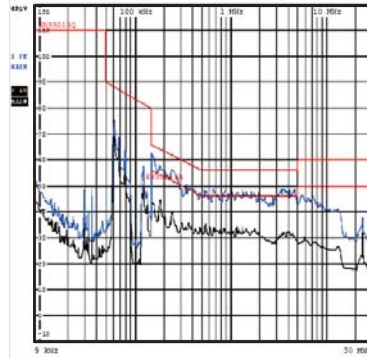


Triac Dimming  
D=20%



## TYPICAL PERFORMANCE CHARACTERISTICS

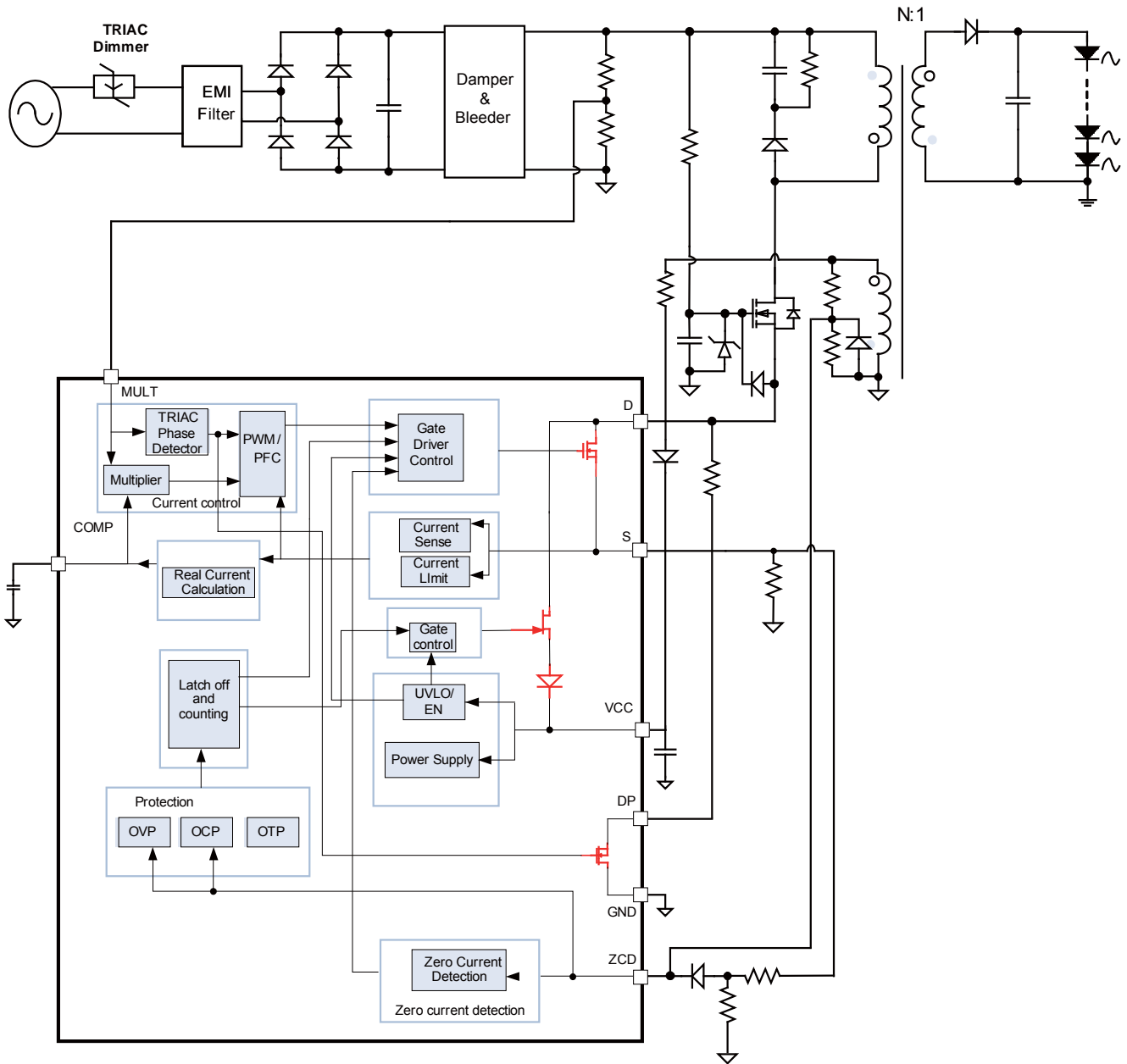
$V_{IN}$  =120VAC, 7 LEDs in series,  $I_O$ =350mA,  $V_O$ =22V,  $L_m$ =1.6mH,  $N_P:N_S:N_{AUX}$  =82:16:19, Triac dimmable.

**Dimming Curve**

**Conducted EMI**

**Performance Data**

<b><math>V_{in}</math> (VAC)</b>	108V	120V	132V
<b><math>P_{in}</math> (W)</b>	9.58W	9.54W	9.47W
<b>PF</b>	0.993	0.99	0.982
<b>THD</b>	7.00%	9.50%	11.60%
<b><math>I_o</math> (A)</b>	0.36A	0.364A	0.364A
<b><math>V_o</math> (V)</b>	21.62V	21.65V	21.64V
<b>Efficiency</b>	81.20%	82.60%	83.10%



**FUNCTION DIAGRAM**



**Figure 1: Functional Block Diagram**

## OPERATION

The MP4030 is a TRIAC-dimmable, primary-side-control, offline LED controller designed for high-performance LED lighting. The MP4030 can accurately control the LED current using the real-current-control method based on primary-side information. It can also achieve a high power factor to eliminate noise pollution on the AC line. The integrated VCC charging circuit can achieve fast start-up without any perceptible delay. The MP4030 is suitable for TRIAC-based dimming with an extended dimming range.

### Boundary-Conduction Mode

During the external MOSFET ON time ( $T_{ON}$ ), the rectified input voltage applied across the primary-side inductor ( $L_m$ ) increases the primary current increases linearly from zero to the peak value ( $I_{pk}$ ). When the external MOSFET turns off, the energy stored in the inductor forces the secondary side diode to turn on, and the inductor current decreases linearly from the peak value to zero. When the current decreases to zero, the parasitic resonance caused by the inductor and the combined parasitic capacitances decreases the MOSFET drain-source voltage that is also reflected on the auxiliary winding (see Figure 2). The zero-current detector generates the external MOSFET turn-on signal when the ZCD voltage falls below 0.35V after a blanking time and ensures the MOSFET turns on at a relatively low voltage (see Figure 3).

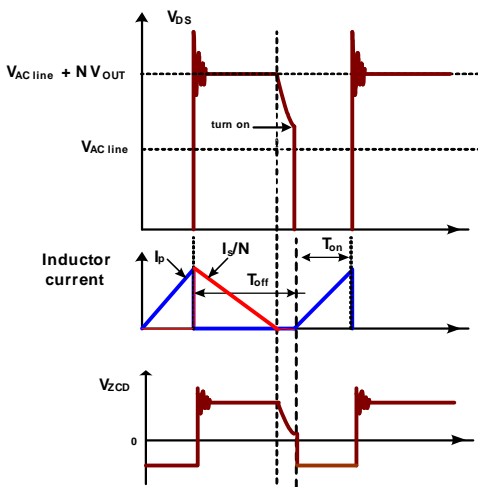


Figure 2: Boundary-Conduction Mode

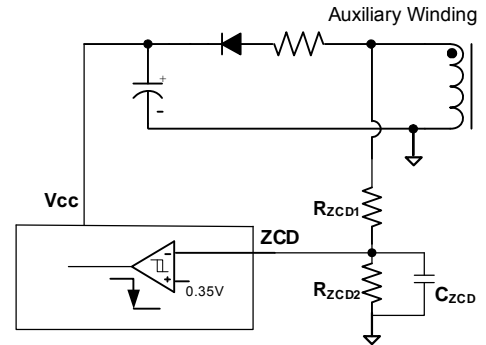


Figure 3: Zero-Current Detector

As a result, there are virtually no primary switch turn-on losses and no secondary-diode reverse-recovery losses. This ensures high efficiency and low EMI noise.

### Real-Current Control

The proprietary real-current-control method allows the MP4030 to control the secondary-side LED current based on primary-side information. The output LED mean current can be calculated approximately as:

$$I_o \approx \frac{N \cdot V_{FB}}{2 \cdot R_s}$$

Where:

- N is the turn ratio of the primary side to the secondary side,
- $V_{FB}$  is the feedback reference voltage (typically 0.4), and
- $R_s$  is the sense resistor between the MOSFET source and GND.

### Power-Factor Correction

The MULT pin connects to the tap of a resistor divider from the rectified instantaneous line voltage. The multiplier output also has a sinusoidal shape. This signal provides the reference for the current comparator against the primary-side-inductor current, which shapes the primary-peak current into a sinusoid with the same phase as the input line voltage. This achieves a high power factor.

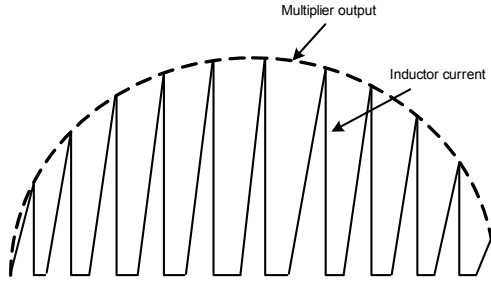


Figure 4: Power-Factor Correction

The multiplier's maximum output voltage to the current comparator is clamped to 2.3V to limit the cycle-by-cycle current. The multiplier's minimum output voltage is clamped to 0.1 to ensure a turn-on signal during the TRIAC dimming OFF interval, which pulls down the rectifier input voltage and accurately detects the dimming phase.

**VCC Timing Sequence**

Initially, VCC charges through the internal charging circuit from the AC line. When VCC reaches 10V, the internal charging circuit stops charging, the control logic initializes and the internal main MOSFET begins to switch. Then the auxiliary winding takes over the power supply. However, the initial auxiliary-winding positive voltage may not be large enough to charge VCC, causing VCC to drop. Instead, if the VCC voltage drops below the 9V threshold, the internal charging circuit triggers and charges VCC to 10V again. This cycle repeats until the auxiliary winding voltage is high enough to power VCC.

If any fault occurs during this time, the switching and the internal charging circuit will stop and latch, and VCC drops. When VCC decreases to 7V, the internal charging circuit re-charges for auto-restart.

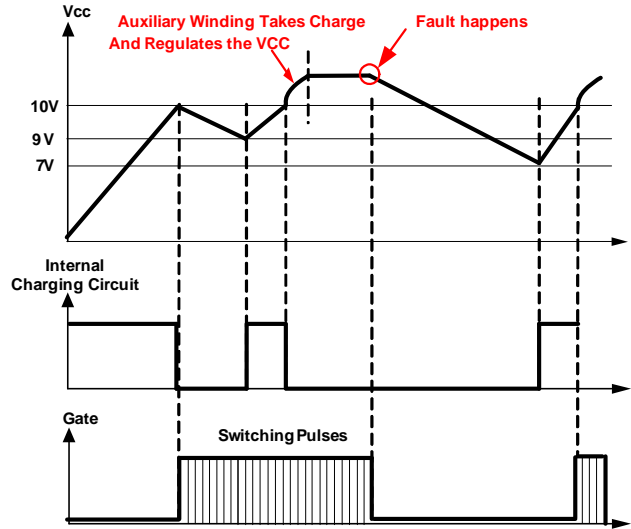


Figure 5: VCC Timing Sequence

**Auto Start**

The MP4030 includes an auto starter that starts timing when the MOSFET turns off. If ZCD fails to send a turn-on signal after 122µs, the starter will automatically send a turn-on signal to avoid unnecessary I<sub>c</sub> shutdowns if ZCD fails.

**Minimum OFF Time**

The MP4030 operates with a variable switching frequency; the frequency changes with the instantaneous input-line voltage. To limit the maximum frequency and get good EMI performance, the MP4030 employs an internal minimum OFF-time limiter of 5µs, as shown in Figure 6.

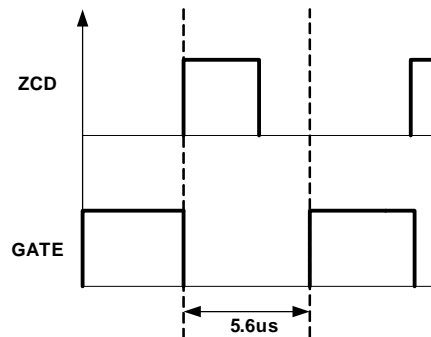
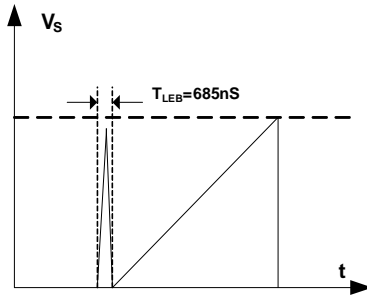


Figure 6: Minimum OFF time

**Leading-Edge Blanking**

In order to avoid premature switching-pulse termination due to the parasitic capacitances discharging when the MOSFET turns on, an internal leading-edge blanking (LEB) unit between the S pin and the current-comparator input blocks the path from the S pin to the current comparator input during the blanking time. Figure 7 shows the leading-edge blanking.



**Figure 7: Leading-Edge Blanking Output Over-Voltage Protection (OVP)**

Output over-voltage protection (OVP) prevents component damage from over-voltage conditions. The auxiliary winding voltage’s positive plateau is proportional to the output voltage, and the OVP monitors this auxiliary winding voltage instead of directly monitoring the output voltage as shown in Figure 8. Once the ZCD pin voltage exceeds 5.5V, the OVP signal triggers and latches, the gate driver turns off, and the IC functions in quiescent mode. When the VCC voltage drops below the UVLO threshold, the IC shuts down and the system restarts. The output OVP set point can be calculated as:

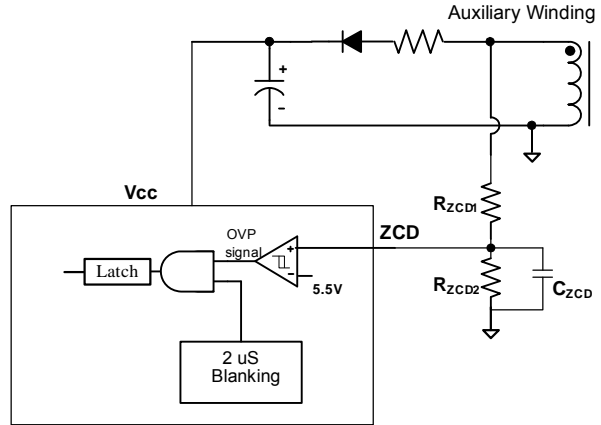
$$V_{out\_ovp} \cdot \frac{N_{aux}}{N_{sec}} \cdot \frac{R_{ZCD2}}{R_{ZCD1} + R_{ZCD2}} = 5.5$$

Where:

\$V\_{out\\_ovp}\$ is the output OVP threshold,

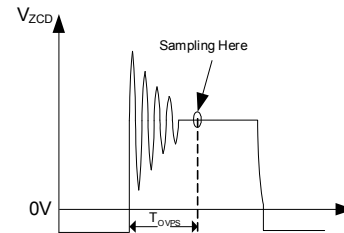
\$N\_{aux}\$ is the number of auxiliary winding turns, and

\$N\_{sec}\$ is the number of secondary winding turns



**Figure 8: OVP Sampling Circuit**

To avoid switch-on spikes mis-triggering OVP, OVP sampling has a \$T\_{OVPS}\$ blanking period of around 2µs, as shown in Figure 9.

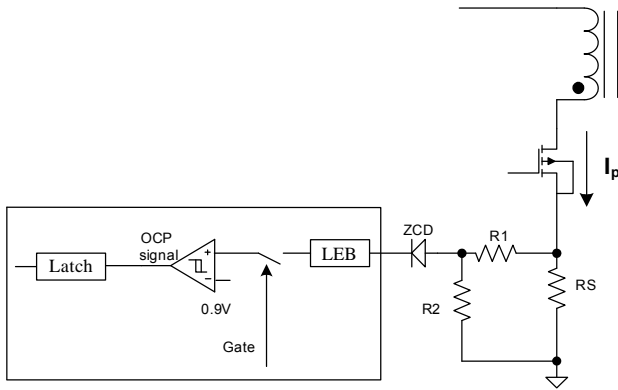


**Figure 9: ZCD Voltage and OVP Sampling Output Short-Circuit Protection (SCP)**

In the event of an output short-circuit, the COMP voltage rises. When the voltage reaches 5V, the IC will shut down and restart until VCC drops below UVLO.

**Primary Over-Current Protection (OCP)**

The ZCD pin has an internally-integrated comparator for primary OCP. When the gate is on, the comparator is enabled. Over-current occurs when \$V\_{ZCD}\$ exceeds 0.9V after a blanking time. Then the IC shuts down and restarts until VCC dropping below UVLO. Figure 10 shows ZCD OCP.

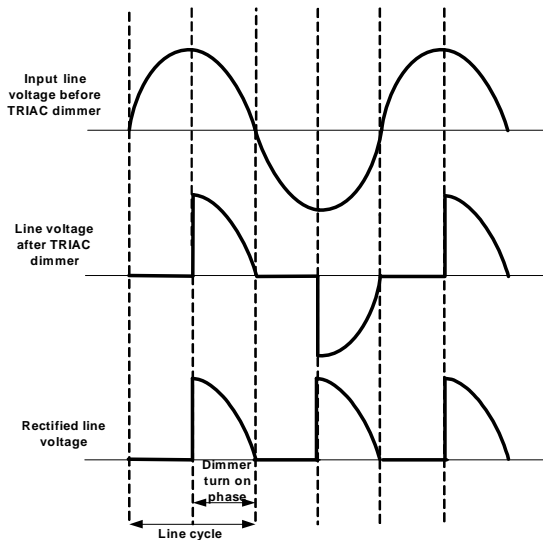


**Figure 10: ZCD Over-Current Protection Circuit Thermal Shutdown**

To prevent internal temperatures from exceeding 150°C and causing lethal thermal damage, the MP4030 shuts down the switching cycle and latched until VCC dropping below UVLO and restarts again.

**TRIAC-Based Dimming Control**

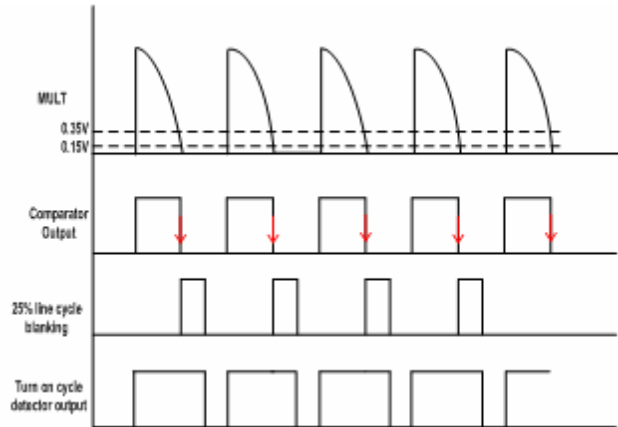
The MP4030 can implement TRIAC-based dimming. The TRIAC dimmer usually consists of a bi-directional SCR with an adjustable turn-on phase. Figure 11 shows the leading-edge TRIAC dimmer waveforms.



**Figure 11: TRIAC Dimmer Waveforms**

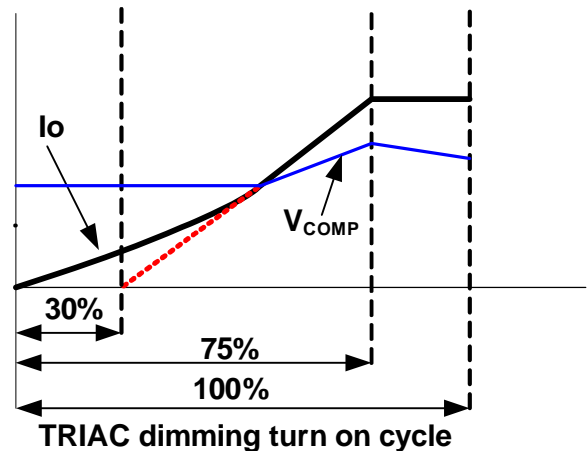
The MP4030 detects the dimming turn-on cycle through the MULT pin, which is fed into the control loop to adjust the internal reference voltage. When the MULT voltage exceeds 0.35V, the device treats this signal as a dimmer turn-on signal. When the MULT voltage falls below 0.15V, the system treats this as a dimmer turn-off signal. The MP4030 has a 25% line-cycle-detection

blanking time with each line cycle, The real phase detector output adds this time, as shown in Figure 12. That means if the turn-on cycle exceeds 75% of the line cycle, the output remains at the same maximum current. It improves the line regulation during the maximum TRIAC turn-on cycle or without a dimmer.



**Figure 12: Dimming Turn-On Cycle Detector**

If the turn-on cycle decreases to less than 75% of the line cycle, the internal reference voltage decreases as the dimming turn-on phase decreasing, and the output current decreases accordingly to implement dimming. As the dimming turn-on cycle decreases, the COMP voltage also decreases. Once the COMP voltage reaches to 1.9V, it is clamped so that the output current decreases slowly to maintain the TRIAC holding current and avoid random flicker. Figure 13 shows the relationship between the dimming turn-on phase and output current.



**Figure 13: Dimming Curve**

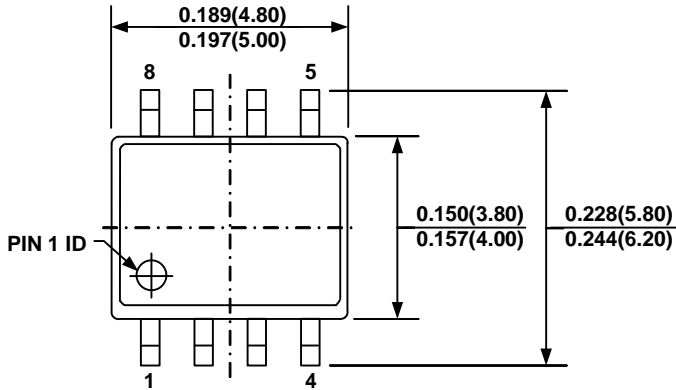
**Dimming Pull-Down MOSFET**

The DP MOSFET turns on when the MULT decreases to 0.25V. Connect a resistor to the D pin to provide the pull-up current during the dimming turn-off interval, and pull down the

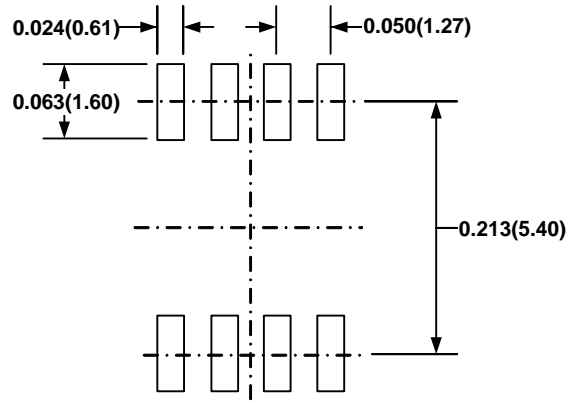
rectified line voltage to zero quickly to avoid any mis-detection on the MULT pin.

PACKAGE INFORMATION

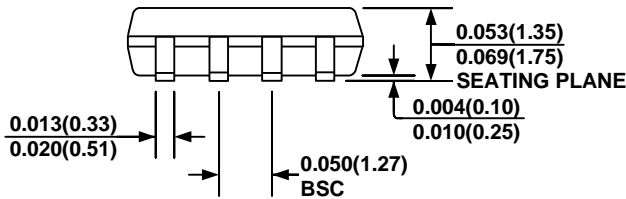
SOIC8



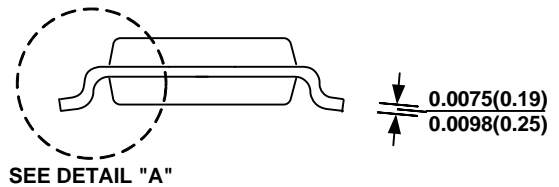
TOP VIEW



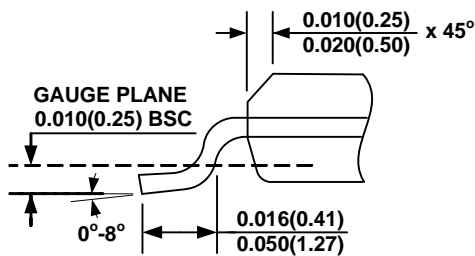
RECOMMENDED LAND PATTERN



FRONT VIEW



SIDE VIEW



DETAIL "A"

NOTE:

- 1) CONTROL DIMENSION IS IN INCHES. DIMENSION IN BRACKET IS IN MILLIMETERS.
- 2) PACKAGE LENGTH DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS.
- 3) PACKAGE WIDTH DOES NOT INCLUDE INTERLEAD FLASH OR PROTRUSIONS.
- 4) LEAD COPLANARITY (BOTTOM OF LEADS AFTER FORMING) SHALL BE 0.004" INCHES MAX.
- 5) DRAWING CONFORMS TO JEDEC MS-012, VARIATION AA.
- 6) DRAWING IS NOT TO SCALE.

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