MP4020

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

DESCRIPTION

The MP4020 is a TRIAC dimmable, single-power stage, isolated, primary-side-control offline LED lighting controller that acheives high power factor and flicker-free triac dimming in a single SOIC8 package. The proprietary real-current control method can control the LED current accurately from the primary side information. It can significantly simplify the LED lighting system design by eliminating the secondary side feedback components and the optocoupler.

The MP4020 integrates active power factor correction and works in boundary conduction mode in order to reduce the MOSFET switching losses.

The extremely low start-up current and quiescent current reduces the total power consumption to provide a high efficiency solution for lighting applications.

The multi-protection features of MP4020 greatly enhance the system reliability and safety. The MP4020 features over-voltage protection, short-circuit protection, cycle-by-cycle current limit, VCC UVLO and auto-restart over-temperature protection.

FEATURES

- Real-Current Control Without Secondary-Feedback
- Flicker-free Phase-controlled TRIAC Dimming
- Accurate Constant Current Output
- Boundary Conduction Mode for High Efficiency
- Ultra-low (10μA) Start Up Current
- Low (1mA) Quiescent Current
- Input UVLO
- Cycle-by-cycle Current Limit
- Over-voltage Protection
- Short-circuit Protection
- Over-temperature Protection
- Available in an SOIC8 Package

APPLICATIONS

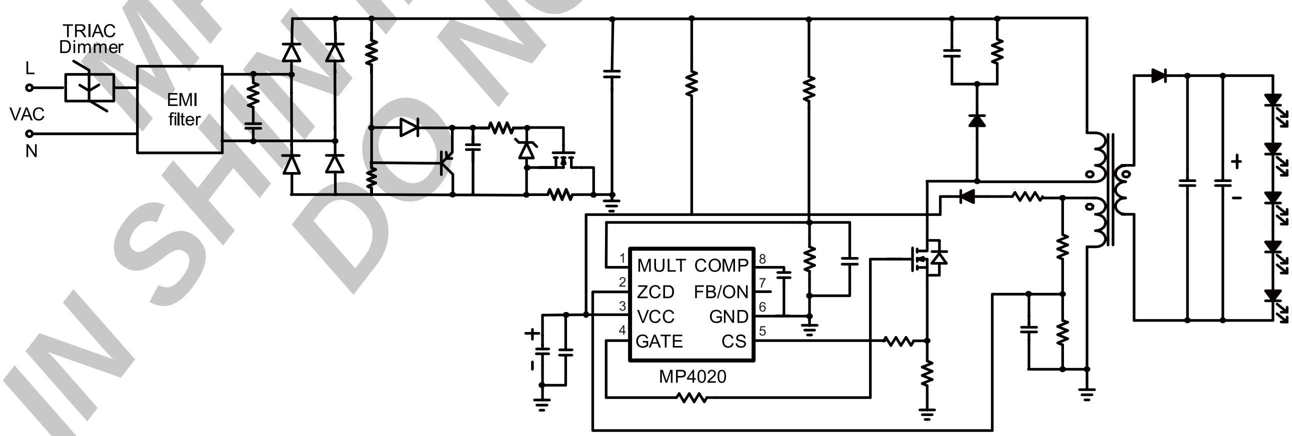
- Solid State Lighting
- Industrial and Commercial Lighting
- Residential Lighting

The MP4020 is under patent pending.

High Voltage

Warning: Although this board is designed to satisfy safety requirements, the engineering prototype has not been agency approved. Therefore, all testing should be performed using an isolation transformer to provide the AC input to the prototype board.

TYPICAL APPLICATION

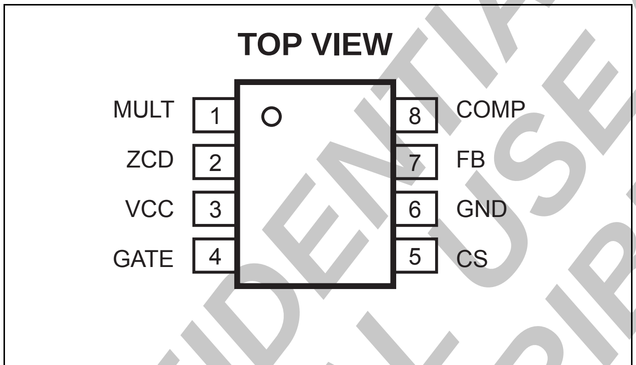


ORDERING INFORMATION

Part Number*	Package	Top Marking	Free Air Temperature (T_A)
MP4020GS	SOIC8	MP4020	-40°C to +105°C

* For Tape & Reel, add suffix –Z (e.g. MP4020GS–Z);
For RoHS Compliant Packaging, add suffix –LF (e.g. MP4020GS–LF–Z)

PACKAGE REFERENCE



SOIC8

ABSOLUTE MAXIMUM RATINGS (1)

Input Voltage V_{CC} ....-0.3V to +30V
Analog Inputs and Outputs ....-0.3V to 8V
ZCD Pin Maximum Current...........-50mA~10mA
Max. Gate Current .... ±1.2A
Continuous Power Dissipation (T_A = +25°C) (2)
SOIC8 .... 1.3W
Junction Temperature ....150°C
Lead Temperature ....260°C
Storage Temperature............... -65°C to +150°C

Recommended Operating Conditions (3)

Supply Voltage V_{CC} ....10.3V to 23V
Maximum Junction Temp. (T_J) .... +125°C

Thermal Resistance (4)

	θ_{JA}	θ_{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_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 board.

ELECTRICAL CHARACTERISTICS

V_{CC} = 14V, T_A = +25°C, unless otherwise noted.

Parameter	Symbol	Condition	Min	Typ	Max	Units
Supply Voltage						
Operating Range	V_{CC}	After turn on	10.3		23	V
Turn On Threshold	$V_{CC\ on}$		11	12	13	V
Turn Off Threshold	$V_{CC\ off}$		7	7.6	8.2	V
Hysteretic Voltage	$V_{CC\ hys}$			4.5		V
Clamp Voltage	V_z	I_{CC}=20mA		32.5		V
Supply Current						
Start up Current	$I_{startup}$	V_{CC}=11V		20	30	μA
Quiescent Current	I_q	No switch		1	2	mA
Operating Current	I_{cc}	F_s =70kHz		2	5	mA
Multiplier						
Operation Range	V_{MULT}		0		3	V
Gain	K(5)		0.5	0.6	0.8	1/V
Triac Dimming Off Detect Threshold	V_{MULT_off}		0.08	0.097	0.12	V
Triac dimming On Detect Tthreshold	V_{MULT_on}		0.26	0.307	0.39	V
Error Amplifier						
Feedback Voltage	V_{FB}		0.386	0.4	0.414	V
Transconductance	G_{EA}			100		μA/V
Voltage Gain	V_{EA}			400		V/V
Upper Clamp Voltage	V_{COMP_H}		5.3	5.65	6	V
Lower Clamp Voltage	V_{COMP_L}		0.7	0.9	1.1	V
Max Source Current	I_{COMP}			75		μA
Max Sink Current	I_{COMP}			-200		μA
Current Sense Comparator						
Leading Edge Blanking Time	T_{LEB}			280		ns
Current Sense Clamp Voltage	V_{CS_clamp}		2.4	2.9	3.4	V
Zero Current Detector						
Zero Current Detect threshold	V_{ZCD_T}	Falling edge		0.35		V
Zero Current Detect Hystestic	V_{ZCD_Hy}			0.9		V
Over-voltage Threshold	$V_{ZCD\ OVP}$	1us delay after turn-off	5.2	5.5	5.8	V
Minimum Off Time	T_{off_min}		2	3.5	5	μs
Starter						
Start Timer Period	T_{start}			130		μs
Gate Driver						
Output Clamp Voltage	$V_{gate\text{-}clamp}$		11	13	15	V
Max Source Current	$I_{gate\text{-}source}$			1		A
Max Sink Current	$I_{gate\text{-}sink}$			-1.2		A

Notes:

5) The multiplier output is given by: Vcs=K•Vmult• (Vcomp-0.9).

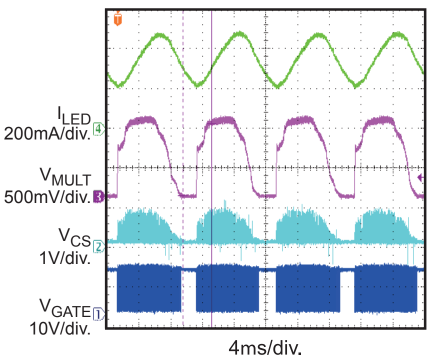
PIN FUNCTIONS

Pin #	Name	Pin Function
1	MULT	This is the input pin of the internal multiplier. Connect this pin to the tap of resistor divider from the rectified voltage of the AC line. The half-wave sinusoid signal in this pin provides a a reference signal for the internal current control loop. The MULT pin is also used for detecting theTRIAC dimming phase.
2	ZCD	Zero current detection pin. A negative going edge triggers the turn on signal of the external MOSFET. Connect this pin through a resistor divider from the auxiliary winding to GND. Over-voltage condition is detected through ZCD. If ZCD voltage is higher than the over-voltage-protection (OVP) threshold after a blanking time 1us, the over-voltage condition is detected.
3	VCC	Supply voltage pin. This pin supplies the power for the control signal and the gate drive signal. Connect this pin to an external bulk capacitor of typically 22µF in parallel with a 100pF ceramic cap to reduce the noise.
4	GATE	Gate drive output pin. The totem pole output stage is able to drive high power MOSFET with a peak current of 1A source capability and 1.2A sink capability. The high level voltage of this pin is clamped to 13V to avoid excessive gate drive voltage.
5	CS	Current sense pin. The MOSFET current is sensed via a resistor, and the resulting voltage is compared to the internal sinusoid shaped current reference signal to determine when the MOSFET turns off. A feed-forward from the rectified voltage of the AC line is recommended to add to maximize the excellent line regulation. If the voltage in this pin is higher than the current limit threshold 2.9V after some blanking time in the turn-on interval, the gate signal will be turned off.
6	GND	Ground pin. Current return of the control signal and the gate drive signal.
7	FB/NC	Feedback signal Pin. For primary side control, leave this pin floating (NC).
8	COMP	Loop Compensation pin. Connect a compensation network to stabilize the LED driver and achieve an accurate LED driver current.

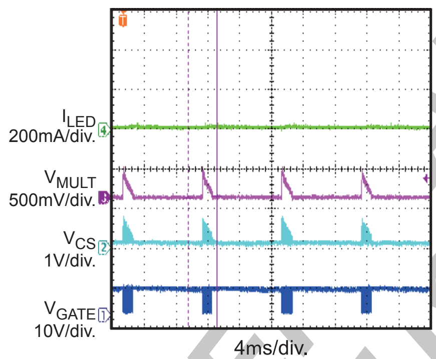
TYPICAL PERFORMANCE CHARACTERISTICS

V_{IN} =110VAC, 5 LEDs in series, I_{OUT}=500mA, V_{OUT}=16V

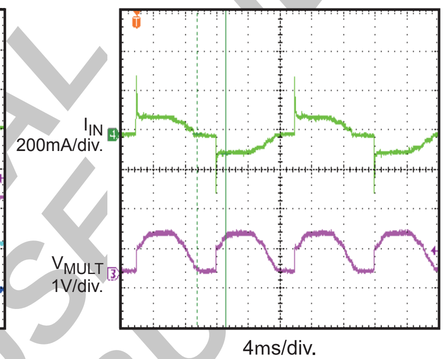
Steady State, Max Dimming Phase



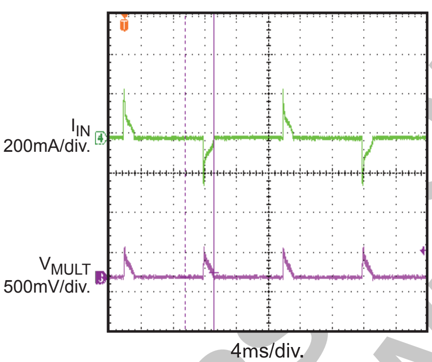
Steady State, Min Dimming Phase



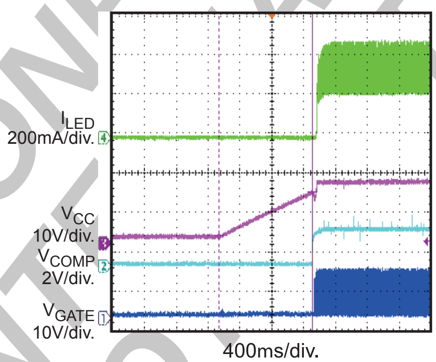
Input Voltage and Current, Max Dimming Phase



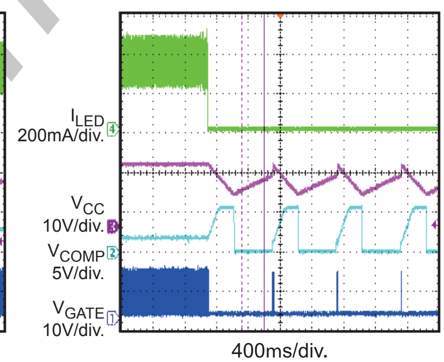
Input Voltage and Current, Min Dimming Phase



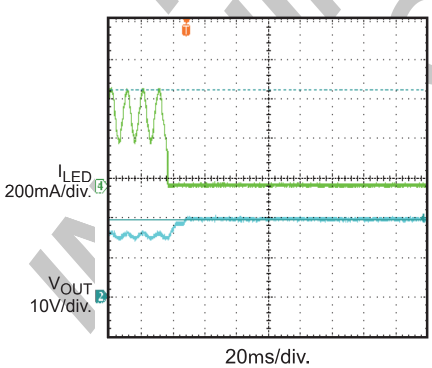
Vin Start Up



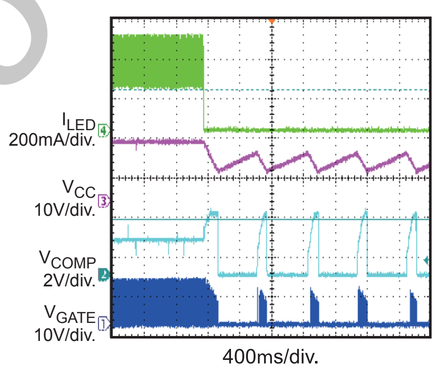
OVP, LED Load Open when working



OVP, LED Load Open when working



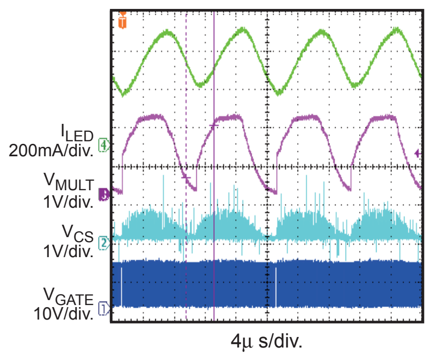
OCP, LED+ Short to LED - when working



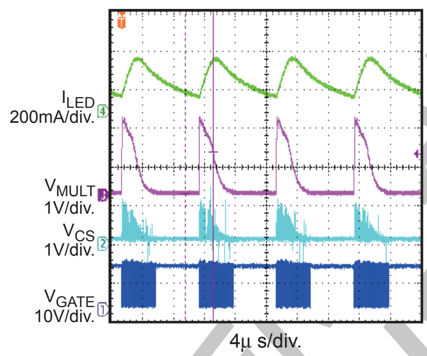
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} =220VAC, 5 LEDs in series, I_{OUT}=500mA, V_{OUT}=16V

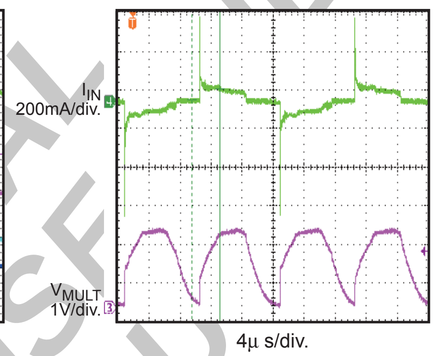
Steady State, Max Dimming Phase



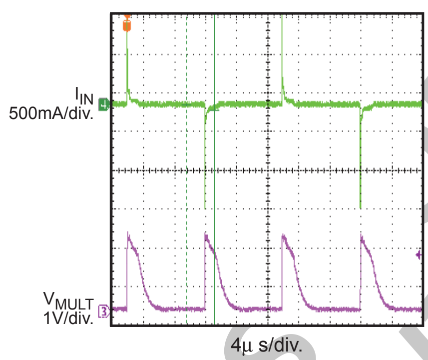
Steady State, Min Dimming Phase



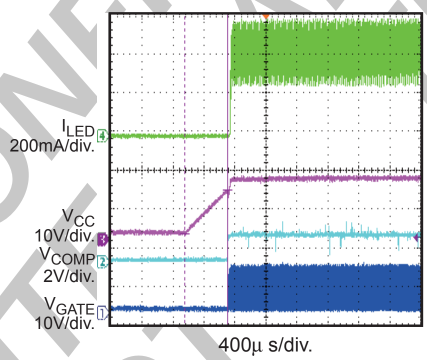
Input Voltage and Current, Max Dimming Phase



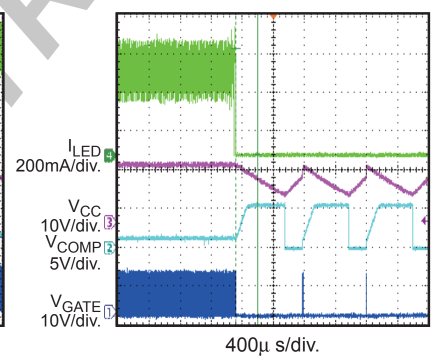
Input Voltage and Current, Min Dimming Phase



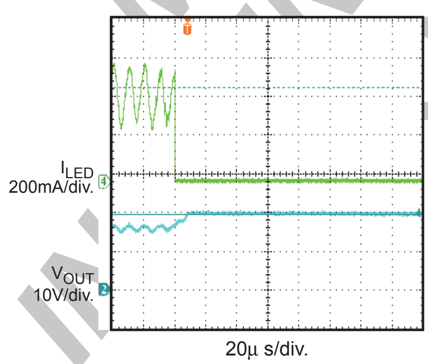
Vin Start Up



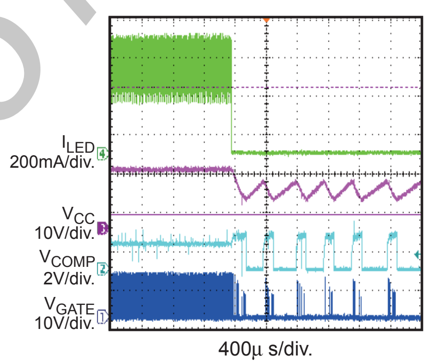
OVP, LED Load Open when Working



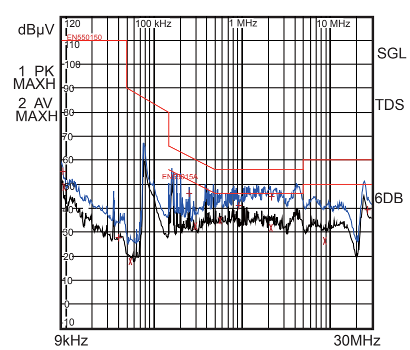
OVP, LED Load Open when Working



OCP, LED+ Short to LED -when Working



Conducted EMI



FUNCTION DIAGRAM

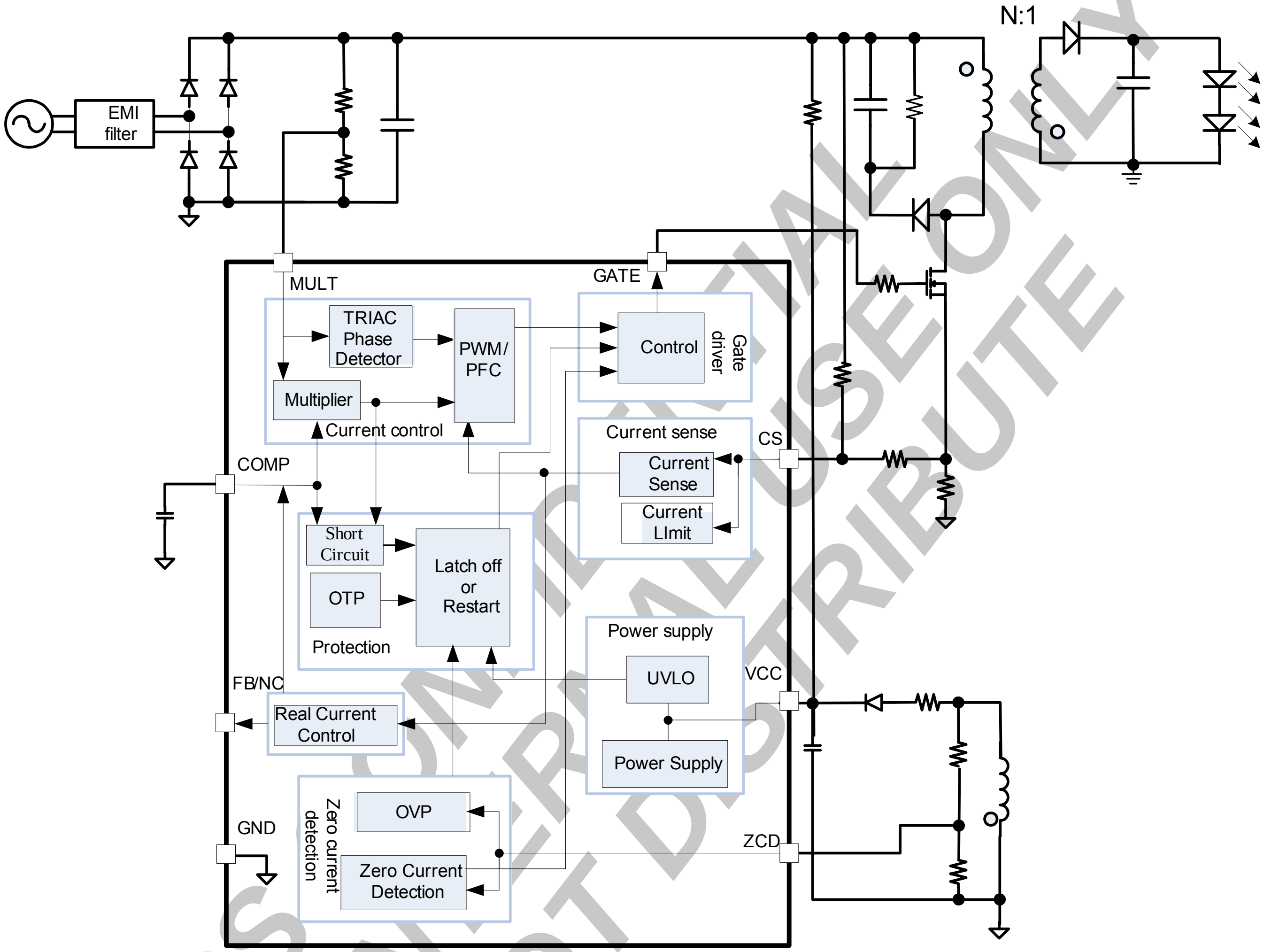


Figure 1—MP4020 Function Block Diagram

OPERATION

The MP4020 is a TRIAC dimmable primary side control offline LED controller that incorporates all the features for high performance LED lighting. LED current can be accurately controlled with the real current control method form the primary side information. Active Power Factor Correction (PFC) is included to eliminate the unwanted harmonic noise injected onto the AC line.

Start Up

Initially, VCC is charged through the start up resistor from the AC line. When VCC reaches 12V, the control logic works and the gate drive signal begins to switch. Then the power supply is taken over by the auxiliary winding.

The MP4020 will shutdown as soon as VCC pin is lower than 7.6V.

Boundary Conduction Mode Operation

During the external MOSFET on time (t_{ON}), the rectified input voltage is applied across the primary side inductor (Lm) and 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 be turn-on, and the current of the inductor begins to decrease linearly from the peak value to zero. When the current decreases to zero, the parasitic resonant of inductor and all the parasitic capacitance makes the MOSFET drain-source voltage decrease, this decreasing is also reflected on the auxiliary winding (see Figure 2). The zero-current detector in ZCD pin generates the turn on signal of the external MOSFET when the ZCD voltage is lower than 0.35V and ensures the MOSFET turn on at a valley voltage (see Figure 3).

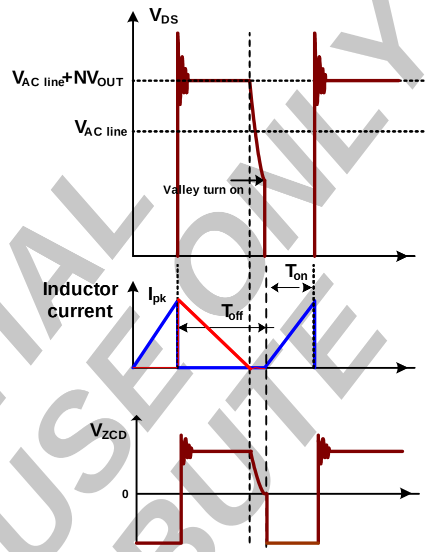


Figure 2—Boundary Conduction Mode

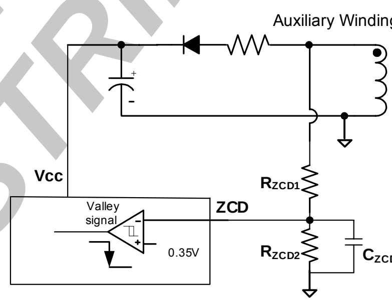


Figure 3—Zero Current Detector

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

Real Current Control

The proprietary real current control method allows the MP4020 to accurately control the secondary side LED current from the primary side information. The output LED mean current can be calculated approximately as:

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

N—Turn ratio of primary side to secondary side

V_{FB}—The feedback reference voltage (typical 0.4)

R_s—The sensing resistor connected between the MOSFET source and GND.

Power Factor Correction

The MULT pin is connected to the tap of the resistor divider from the rectified instantaneous line voltage and fed as one input of the Multiplier. The output of the multiplier will be shaped as sinusoid too. This signal provides the reference for the current comparator and compares with the primary side inductor current which sets the primary peak current shaped as sinusoid with the input line voltage. High power factor can be achieved.

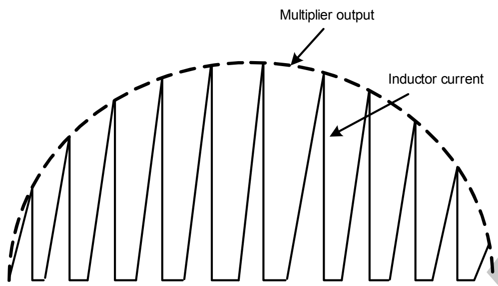


Figure 4—Power Factor Correction Scheme

The maximum voltage of the multiplier output to the current comparator is clamped to 2.9V to get a cycle-by-cycle current limitation.

VCC Under-voltage Lockout

When the VCC voltage drops below UVLO threshold 7.6V, the MP4020 stops switching and totally shuts down. The VCC will restart charging by the external start up resistor from AC line. Figure 5 shows the typical waveform of VCC under-voltage lockout

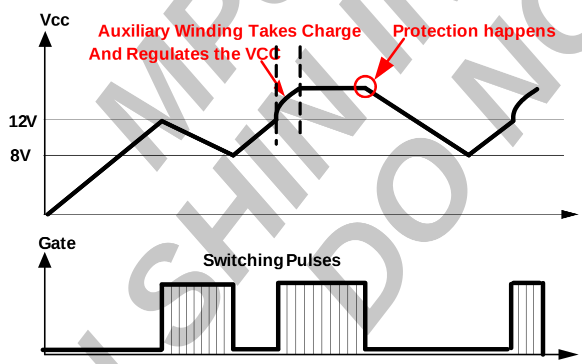


Figure 5—VCC Under-Voltage Lockout

Auto Starter

The MP4020 integrates an auto starter, the starter starts timing when the MOSFET is turned on, if ZCD fails to send out another turn on signal after 130μs, the starter will automatically send out the turn on signal which can avoid the IC unnecessary shut down by ZCD missing detection.

Minimum Off Time

The MP4020 operates with variable switching frequency, the frequency is changing with the input instantaneous line voltage. To limit the maximum frequency and get a good EMI performance, MP4020 employs an internal minimum off time limiter—3.5μs, show as figure 6.

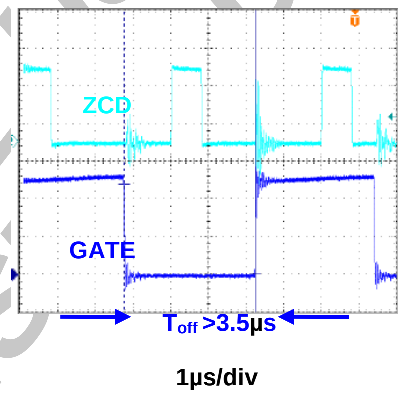


Figure 6—Minimum Off Time

Leading Edge Blanking

In order to avoid the premature termination of the switching pulse due to the parasitic capacitance discharging at MOSFET turning on, an internal leading edge blanking (LEB) unit is employed between the CS Pin and the current comparator input. During the blanking time, the path, CS Pin to the current comparator input, is blocked. Figure 7 shows the leading edge blanking.

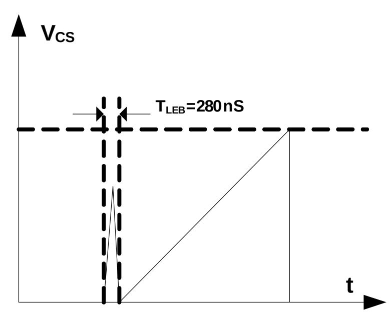


Figure 7—Leading Edge Blanking

Output Over-Voltage Protection (OVP)

Output over voltage protection can prevent the components from damage in the over voltage condition. The positive plateau of auxiliary winding voltage is proportional to the output voltage. The OVP uses the auxiliary winding voltage instead of directly monitoring the output voltage. The OVP sample is shown in figure 8. Once the ZCD pin voltage is higher than 5.5V, the OVP signal will be triggered and latched, the gate driver will be turned off and the IC work at quiescent mode, the VCC voltage dropped below the UVLO which will make the IC shut down and the system restarts again. The output OVP setting point can be calculated as:

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

$V_{out-ovp}$—Output over voltage protection point

N_{aux}—The auxiliary winding turns

N_{sec}—The secondary winding turns

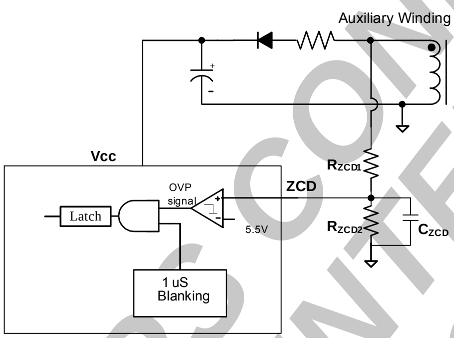


Figure 8—OVP Sample Unit

To avoid the mis-trigger OVP by the oscillation spike after the switch turns off, the OVP sampling has a TOVPS blanking period, typical 1us, shown in figure 9.

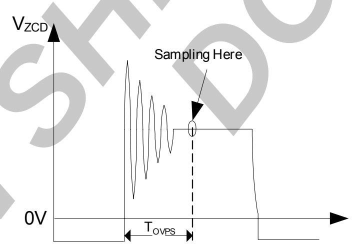


Figure 9—ZCD Voltage and OVP Sample

Output Short Circuit Protection

When the output short circuit happens, the positive plateau of auxiliary winding voltage is also near zero, the VCC can not be held on and it will drop below VCC UVLO. The IC will shut down and restart again.

Thermal Shut Down

To prevent from any thermal damage, when the inner temperature exceeds 150°C, the MP4020 shuts down switching cycle and remains latched until VCC drops below the UVLO, and then restarts again.

TRIAC Phase Dimming Control

The MP4020 can implement TRIAC-based dimming function. As shown in figure 10, the TRIAC dimmer is a bi-directional SCR with turn on phase adjustable. The MP4020 will detect the dimming phase signal on MULT pin and fed into the control loop for the dimming control.

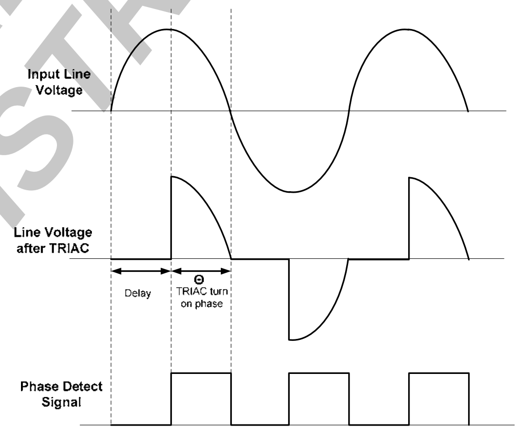


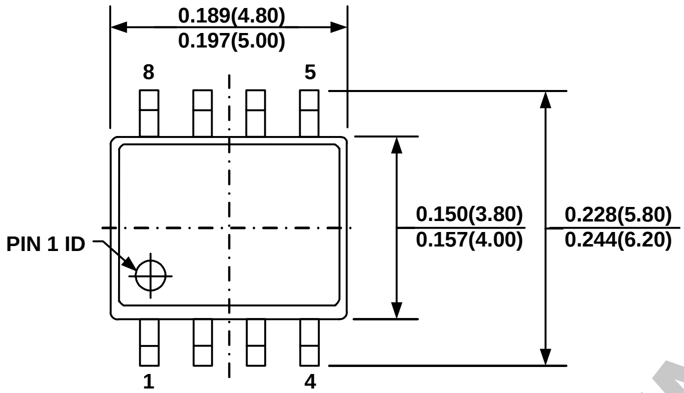
Figure 10—TRIAC Phase Detect Signal for a Leading Edge TRIAC Dimmer

Design Example

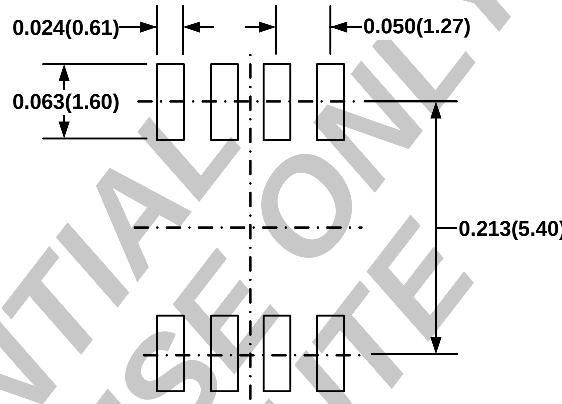
For the design example, please refer to MPS application note AN039 for the detailed design procedure and information.

PACKAGE INFORMATION

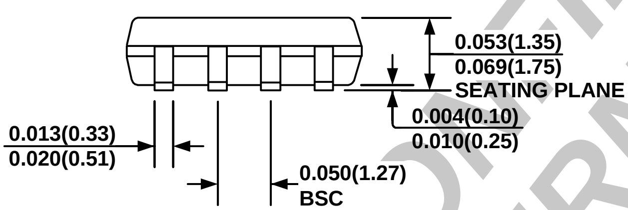
SOIC8



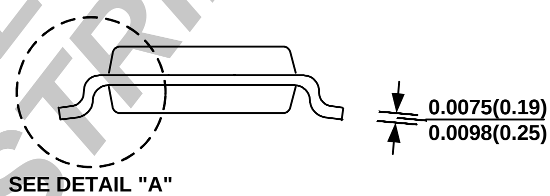
TOP VIEW



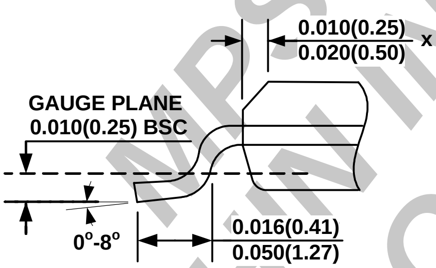
RECOMMENDED LAND PATTERN



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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