Alfa-MOS Technology

AF1821

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

General Description

The AF1821 is a TRIAC dimmable, primary-side-control offline LED lighting controller which can achieve high power factor and flicker-free TRIAC dimming output LED current for an isolate lighting application in a single stage converter. 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 photo coupler.

AF1821 can realize flicker-free TRIAC dimming. And it integrates power factor correction function and works in boundary conduction mode for reducing the MOSFET switching losses.

The extremely low start up current and the quiescent current can reduce the power consumption thus lead to an excellent efficiency performance.

The multi-protection function of AF1821 can greatly enhance the system reliability and safety.

The AF1821 features over-voltage protection, short-circuit protection, cycle-by-cycle current limit, VCC UVLO and auto-restart over temperature protection.

The AF1821 is available in a small SOP-8 package.

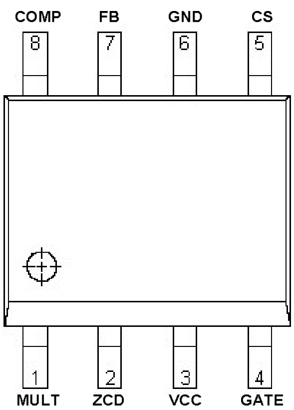
Features

- Real Current Control Without Secondary-feedback Circuit
- Flicker-free Phase-controlled TRIAC Dimming
- Accurate Constant Current Output
- Boundary Conduction Mode Operation
- 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 a 8 Pin SOP-8 Package

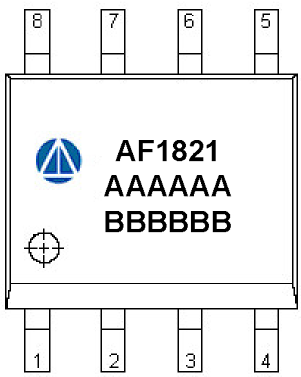
Application

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

Pin Define (SOP-8)



Marking Information



TYPICAL APPLICATION

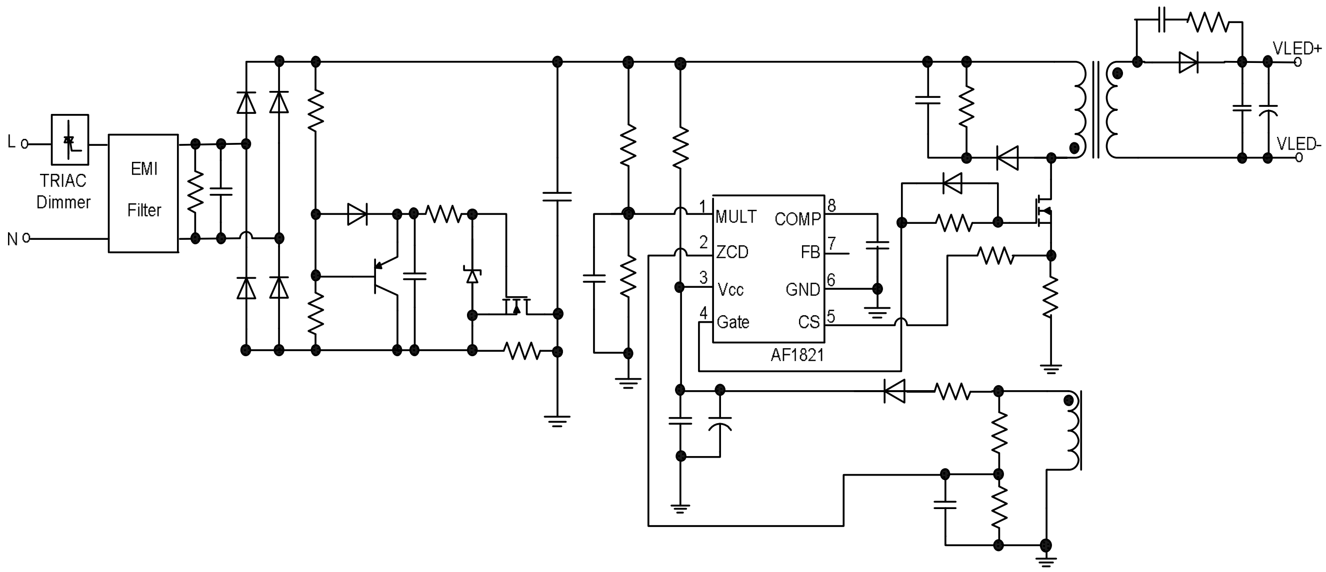


Fig 1. Application Circuit

Block Diagram

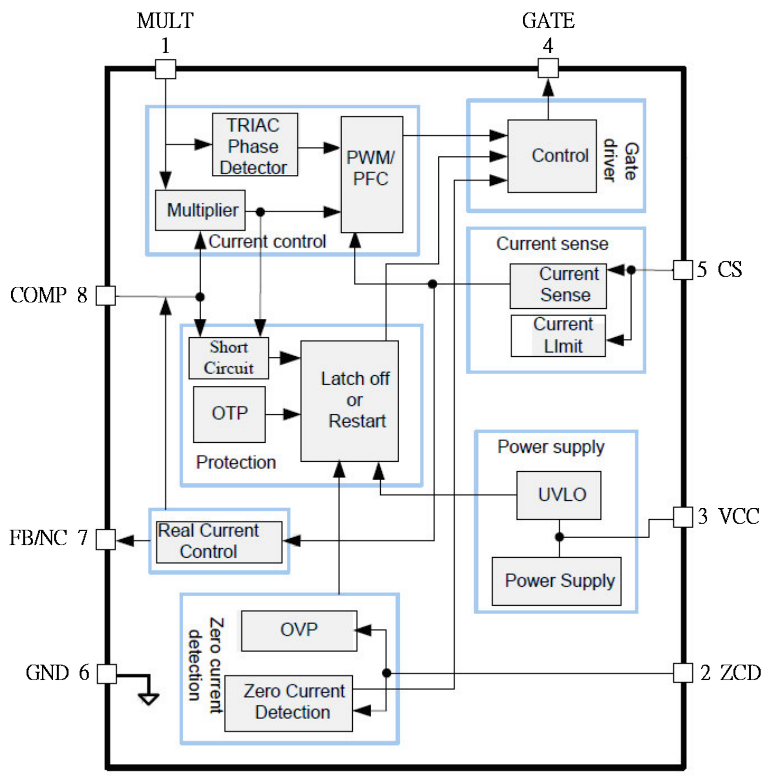


Fig 2. Function Block Diagram

Pin Description

Pin	Symbol	Description
MULT	1	One of the input pin of the internal multiplier. Connects this pin to the tap of resistor divider from the rectified voltage of the AC line. The half-wave sinusoid signal in this pin is provided a reference signal for the internal current control loop. The MULT pin is also used for detecting the TRIAC dimming phase.
ZCD	2	Zero current detection pin. A negative going edge triggers the turn on signal of the external MOSFET, connects 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 overvoltage- protection (OVP) threshold after a blanking time 1us, the over-voltage condition is detected.
VCC	3	Supply voltage pin. This pin supply power both for control signal and the gate drive signal. Connect this pin to an external bulk capacitor of typically 22uF with a 100pF ceramic cap to reduce the noise.
GATE	4	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.
CS	5	Current sense pin. The MOSFET current is sensed via a resistor, the resulting voltage 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 get an excellent line regulation. If the voltage in this pin is higher than the current limit threshold 2.9V after some blanking time in the turning on interval, the gate signal will be turned off.
GND	6	Ground pin. Current return of the control signal and the gate drive signal.
FB/NC	7	Feedback signal Pin. If using primary side control, this pin can be NC.
COMP	8	Loop Compensation pin. Connects a compensation network to stabilize the LED driver and get an accurate LED current of the LED driver.

Ordering Information

Part Ordering No.	Part Marking	Package	Unit	Quantity
AF1821S8RG	AF1821	SOP-8	Tape & Reel	2500 EA

※ A Lot code
※ B Date code
※ AF1821S8RG : 13” Tape & Reel ; Pb- Free ; Halogen- Free

Absolute Maximum Ratings[1]

The following ratings designate persistent limits beyond which damage to the device may occur.

Symbol	Parameter	Value	Unit
V_{CC}[1]	VCC Pin Voltage	GND-0.3 to GND+30	V
V_{analog}	Analog Pins Voltage	GND-0.3 to 8	V
$I_{ZCD(MAX)}$	ZCD Pin Maximum Current	-50mA to10mA	mA
$I_{GATE(MAX)}$	GATE Pin Maximum Current	+/-1.2	A
$T_{J(MAX)}$	Maximum Junction Temperature	150	°C
T_{STG}	Storage Temperature Range	-40 to +150	°C

Recommended Operating Conditions [2]

Symbol	Parameter	Value	Unit
V_{CC}	VCC Pin Voltage	10.3 to 23	V
$T_{J(MAX)}$	Maximum Junction Temp	125	°C

Caution:

(1) Exceeding these ratings may damage the device.
(2) The device is not guaranteed to function outside of its operation conditions.

ELECTRICAL CHARACTERISTICS

VCC = 14V, T_A = +25° C, unless otherwise noted.

Parameter	Symbol	Conditions	Min	Typ	Max	Units
Supply Voltage						
Operating Range	VCC	After turn on	10.3		23	V
Turn On Threshold	VCC_on		11	12	13	V
Turn Off Threshold	VCC_off		7	7.6	8.2	V
Hysteretic Voltage	VCC_hys		3.2		3.8	V
Clamp Voltage	Vz	ICC=20mA		30		V
Supply Current						
Start up Current	Istartup	VCC=11V		20	30	uA
Quiescent Current	Iq	No switch		1	2	mA
Operating Current	Icc	Fs =70kHz		2	5	mA
Multiplier						
Operation Range	VMULT		0		3	V
Gain	K(1)		0.5	0.6	0.8	1/V
TRIAC dimming off detect threshold	VMULT_off		0.04	0.11	0.18	V
TRIAC dimming on detect threshold	VMULT_on		0.42	0.52	0.62	V
Error Amplifier						
Feedback Voltage	VFB		0.386	0.4	0.414	V
Transconductance	GEA			100		uA/V
Voltage Gain	VEA			400		V/V
Upper clamp Voltage	VCOMP_H		5.3	5.65	6	V
Lower clamp Voltage	VCOMP_L		0.7	0.9	1.1	V
Max Source Current	ICOMP			75		uA
Max Sink Current	ICOMP			-200		uA
Current Sense Comparator						
Leading edge blanking time	TLEB			280		ns
Current sense clamp voltage	VCS_clamp		2.4	2.9	3.4	V
Zero Current Detector						
Zero Current Detect threshold	VZCD_T	Falling edge		0.35		V
Zero Current Detect Hystestic	VZCD_Hy			0.9		V
Over-voltage Threshold	VZCD_OVP	1us delay after turn-off	5.2	5.5	5.8	V
Minimum off time	Toff_min		2	3.5	5	us
Starter						
Start timer period	Tstart			130		us
Gate Driver						
Output clamp voltage	Vgate-clamp		11	13	15	V
Max source current	Igate-source			1		A
Max sink current	Igate-sink			-1.2		A

Notes:

(1) The multiplier output is given by: Vcs=K• Vmult• (Vcomp-1).

Function Description

The AF1821 is a TRIAC dimmable primary side control offline LED lighting controller which incorporates all features for high performance LED lighting. LED current can be accurately controlled with the real current control method from the primary side information. High power factor can also be achieved to eliminate the pollution to the AC line.

Start Up

Initially, VCC of the AF1821 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 AF1821 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 reflected on the auxiliary winding (Fig. 3). 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(Fig. 4).

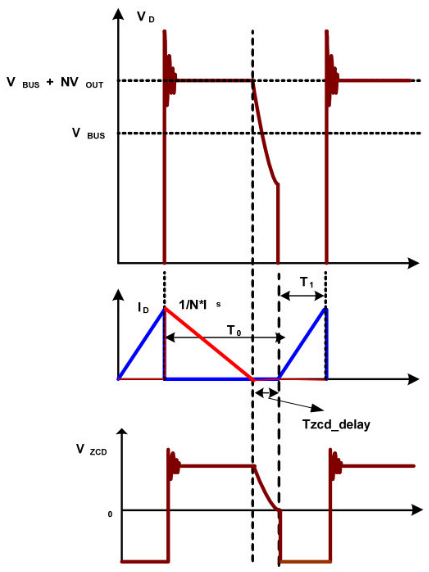


Fig 3. Boundary Conduction Mode Operation

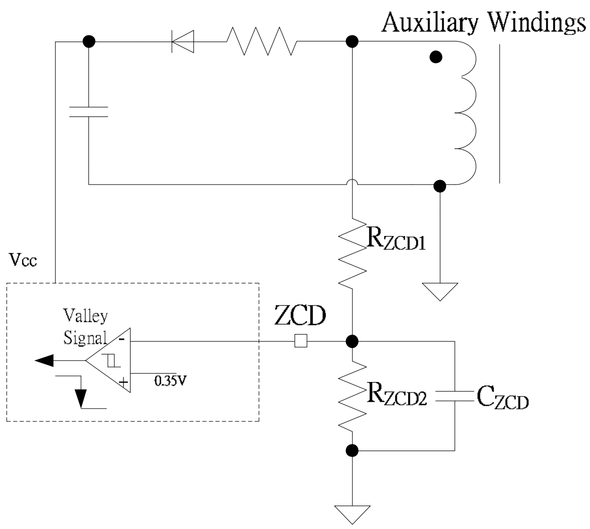


Fig 4. Zero Current Detector

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 AF1821 controlling 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 0.4V)

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 comparing 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.

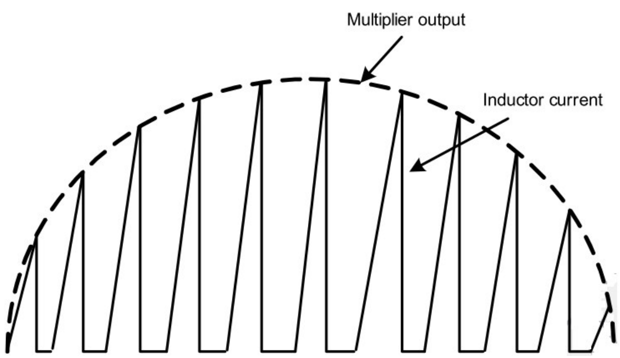


Fig 5. Power Factor Correction Scheme

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 AF1821 stops switching and totally shuts down, the VCC will restart charging by the external start up resistor from AC line. Fig. 6 shows the typical waveform of VCC under-voltage lockout.

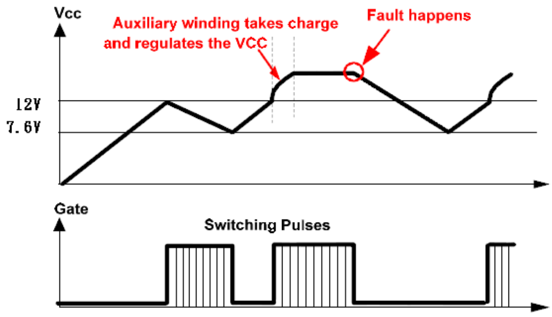


Fig 6. VCC Under-Voltage Lockout

Auto Starter

The AF1821 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 130us, the starter will automatically send out the turn on signal which can avoid the IC unnecessary shutdown by ZCD missing detection.

Minimum Off Time

The AF1821 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, AF1821 employs an internal minimum i=off time limiter-3.5us, show as Fig 7.

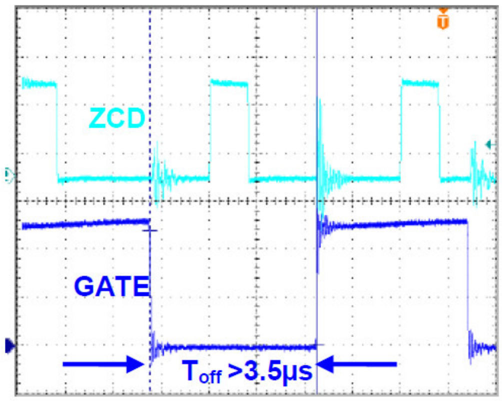


Fig 7. Minimum Off Time

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. Fig 8 shows the leading edge blanking.

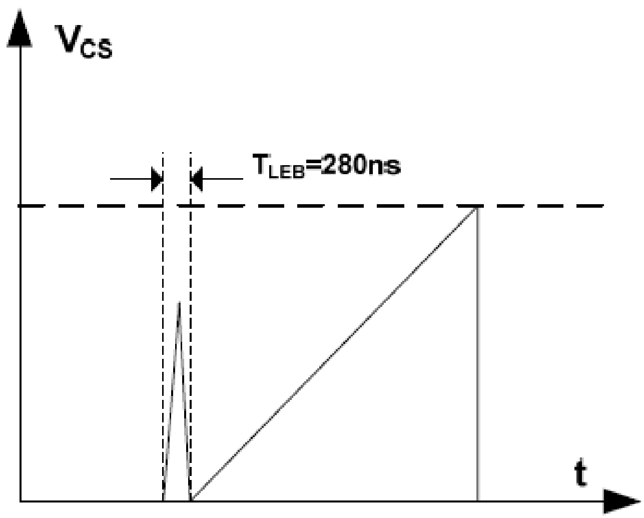


Fig 8. Leading Edge Blanking

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 Fig 9. 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 auxiliary winding turns

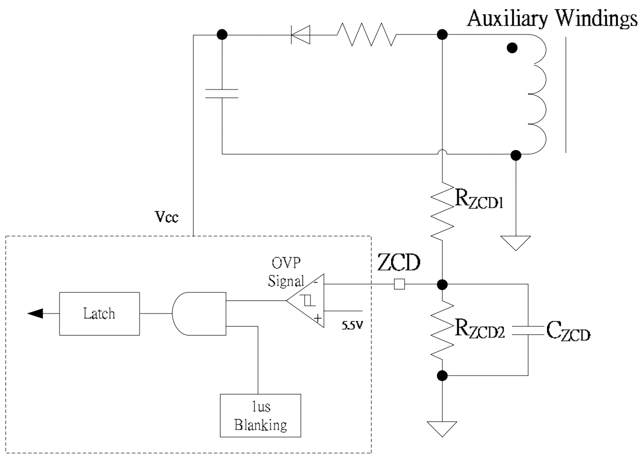


Fig 9. OVP Sample Unit

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 Fig 10.

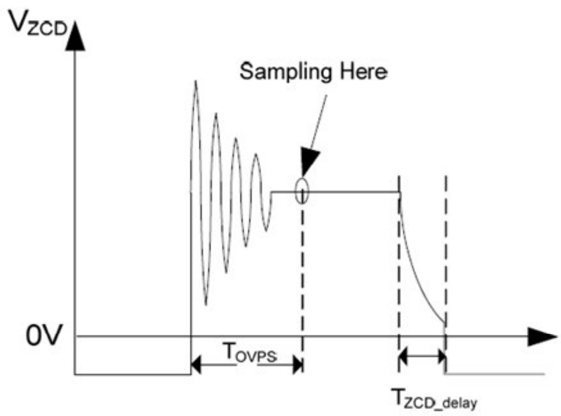


Fig 10. ZCD Voltage and OVP Sample

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.

TRIAC Phase Dimming Control

The AF1821 can implement TRIAC-based dimming function. As shown in Fig 11, the TRIAC dimmer is a bi-directional SCR with turn on phase adjustable. The AF1821 will detect the dimming phase signal on MULT pin and fed into the control loop for the dimming control.

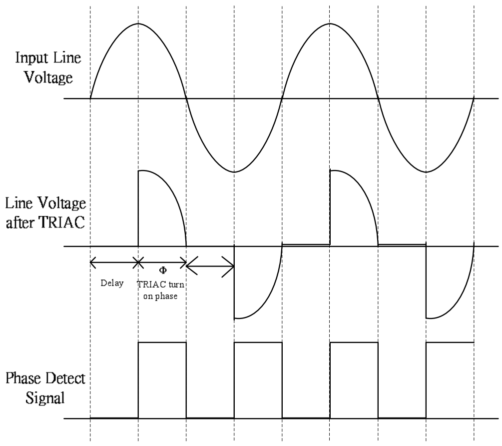


Fig 11. TRIAC Phase Detect Signal for a Leading Edge TRIAC Dimmer

Typical electrical characteristic

Steady State

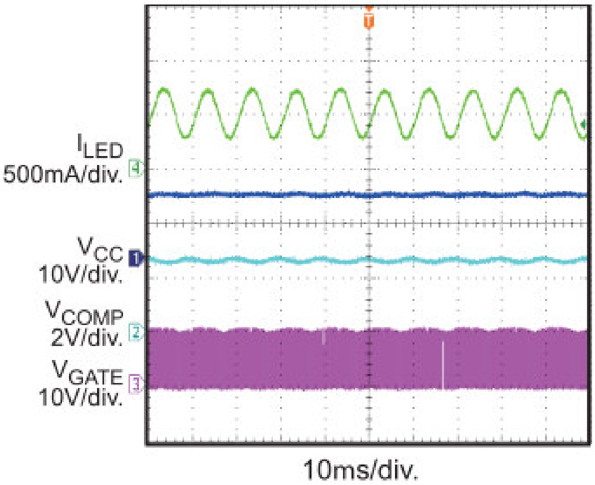


Figure 30— 110 VAC, Full Load

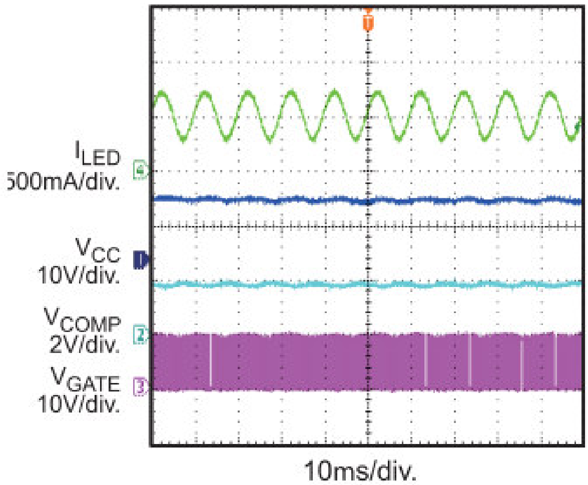


Figure 31— 220 VAC, Full Load

Input Voltage and Current

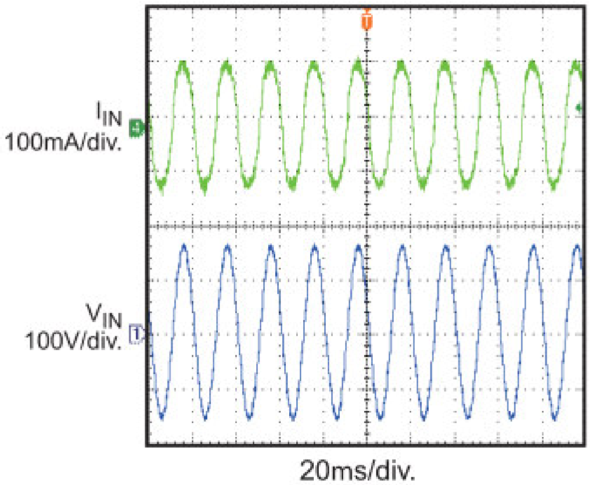


Figure 32— 110 VAC, Full Load

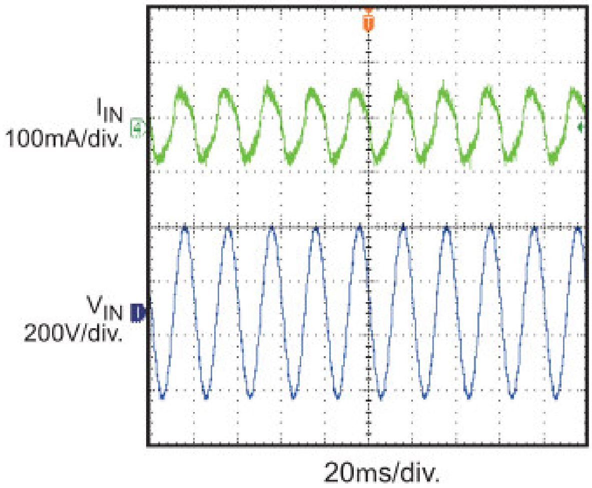


Figure 33— 220 VAC, Full Load

Boundary Conduction Operation

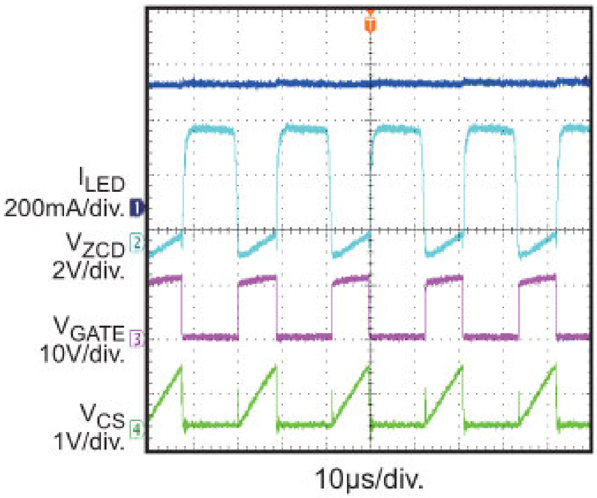


Figure 32— 110 VAC, Full Load

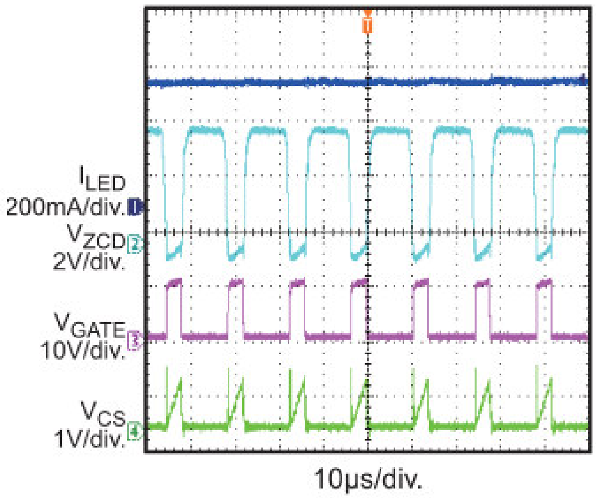


Figure 33— 220 VAC, Full Load

Start Up

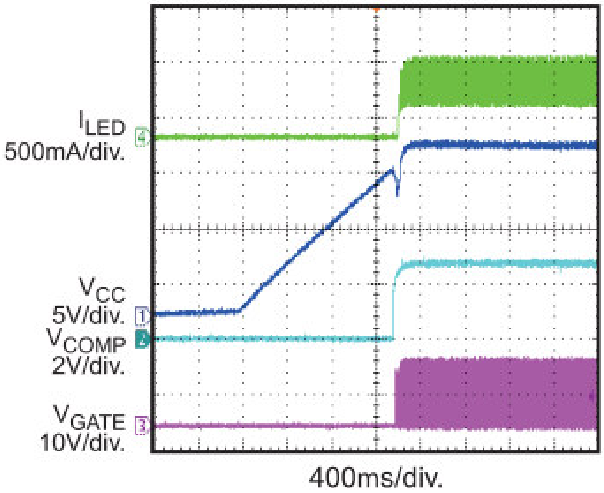


Figure 34— 110 VAC, Full Load

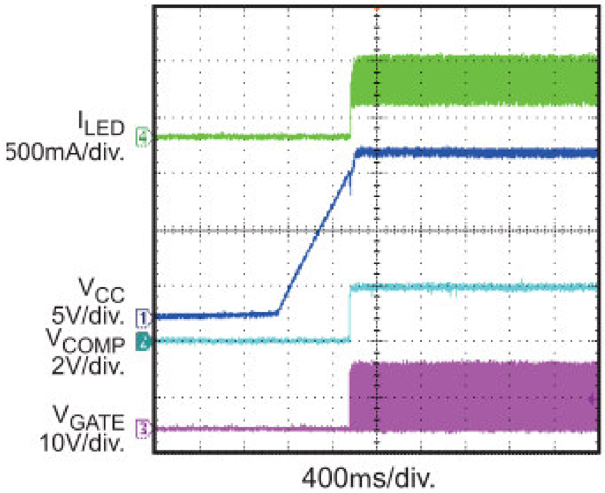


Figure 35— 220 VAC, Full Load

OVP (Open load at normal operation)

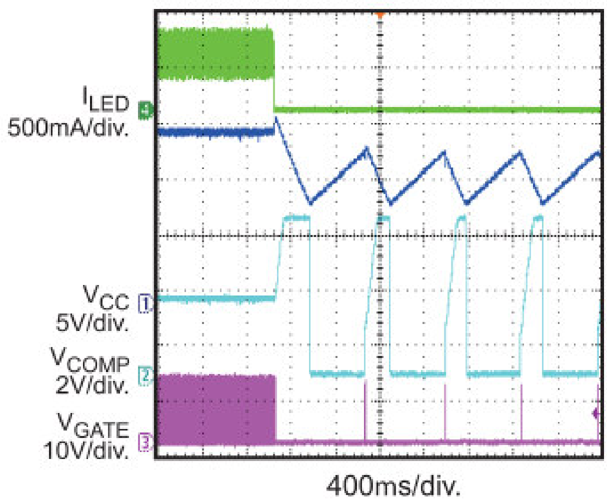


Figure 36— 110 VAC

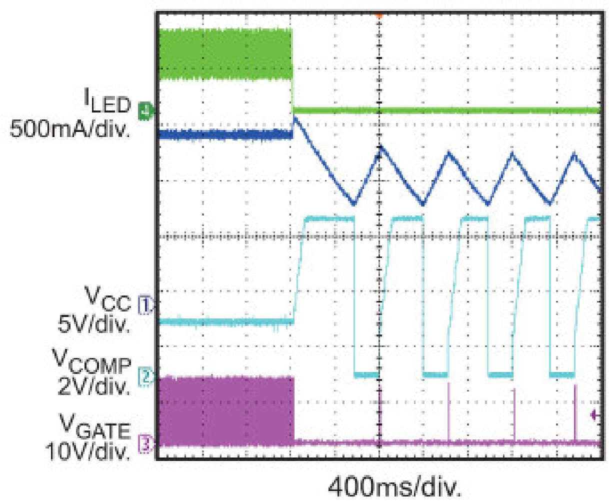


Figure 37— 220 VAC

SCP (Short LED+ to LED- at normal operation)

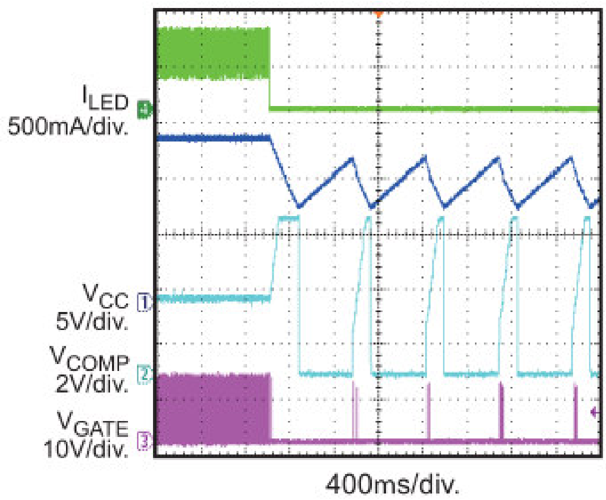


Figure 38— 110 VAC

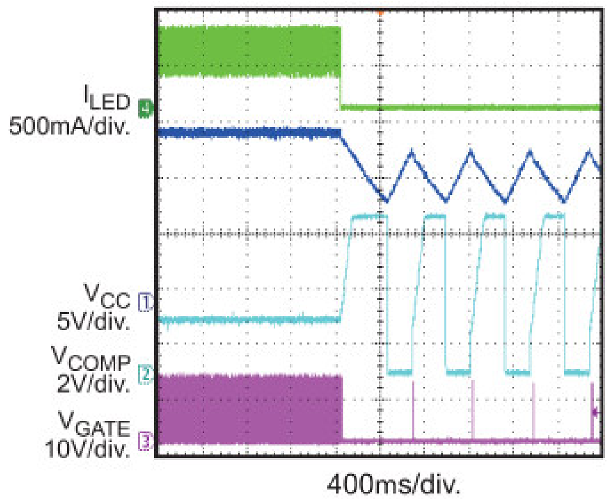
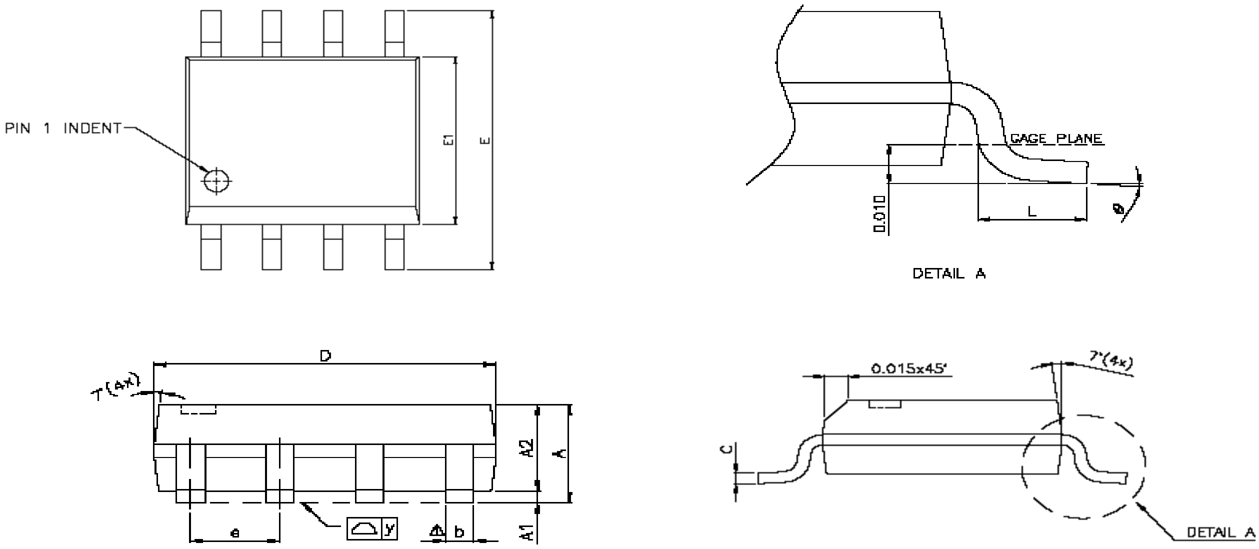


Figure 39— 220 VAC

Package Information (SOP-8)



SYMBOLS	DIMENSIONS IN MILLIMETERS			DIMENSIONS IN INCHES		
	MIN	NOM	MAX	MIN	NOM	MAX
A	1.47	1.60	1.73	0.058	0.063	0.068
A1	0.10	—	0.25	0.004	—	0.010
A2	—	1.45	—	—	0.057	—
b	0.33	0.41	0.51	0.013	0.016	0.020
C	0.19	0.20	0.25	0.0075	0.008	0.0098
D	4.80	4.85	4.95	0.189	0.191	0.195
E	5.80	6.00	6.20	0.228	0.236	0.244
E1	3.80	3.90	4.00	0.150	0.154	0.157
e	—	1.27	—	—	0.050	—
L	0.38	0.71	1.27	0.015	0.028	0.050
△2 y	—	—	0.076	—	—	0.003
θ	0°	—	8°	0°	—	8°

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