

Description

The AL1692-30B is a high-performance, high power factor, high-efficiency, and high current precision buck-boost and flyback dimmable LED driver for triac dimmable LED lamp applications. The AL1692-30B topology provides an accurate output current over wide line and load regulation. The wide switching frequency operates at boundary conduction mode (BCM) to ease EMI/EMC design and testing, to meet the latest regulatory standards.

The AL1692-30B LED driver integrates a 500V/3A high-voltage MOSFET. It can cover 120Vac triac dimmable applications by eliminating the external high-voltage MOSFET and varistor, which will reduce the system BOM cost. The AL1692-30B has the built-in thermal fold-back protection trigger point to automatically reduce output current. Other protection features enhance LED lighting system's safety and reliability.

The AL1692-30B dimming curve is compliant with the NEMA SSL6 standard. The AL1692-30B applies to a wide range of dimmers, including leading edge and trailing edge dimmer, to achieve deep dimming down to 1%.

The AL1692-30B is available in SO-7 package.

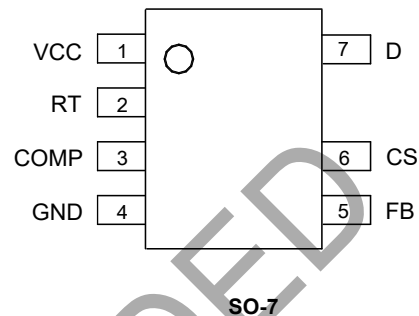
Features

- Tight Current Sense Tolerance: $\pm 3\%$
- Low Startup Current: 100 μ A Typical
- Low Operation Current: 210 μ A (Switching Frequency at 4kHz)
- Single Winding Inductor
- Wide Range of Dimmer Compatibility
- Integration of 500V/3A MOSFET
- NEMA SSL6 Dimming Curve Compliant
- Internal Protections
 - Undervoltage Lockout (UVLO)
 - Leading-Edge Blanking (LEB)
 - Cycle-by-Cycle Overcurrent Protection (OCP)
 - Output Open/Short Protection (OVP/OSP)
 - Thermal Foldback Protection (TFP)
 - Overtemperature Protection (OTP)
- SO-7 Package
- **Totally Lead-Free & Fully RoHS Compliant (Notes 1 & 2)**
- **Halogen and Antimony Free. "Green" Device (Note 3)**
- **For automotive applications requiring specific change control (i.e. parts qualified to AEC-Q100/101/104/200, PPAP capable, and manufactured in IATF 16949 certified facilities), please [contact us](#) or your local Diodes representative.**
<https://www.diodes.com/quality/product-definitions/>

Notes: 1. No purposely added lead. Fully EU Directive 2002/95/EC (RoHS), 2011/65/EU (RoHS 2) & 2015/863/EU (RoHS 3) compliant.
 2. See <https://www.diodes.com/quality/lead-free/> for more information about Diodes Incorporated's definitions of Halogen- and Antimony-free, "Green" and Lead-free.
 3. Halogen- and Antimony-free "Green" products are defined as those which contain <900ppm bromine, <900ppm chlorine (<1500ppm total Br + Cl) and <1000ppm antimony compounds.

Pin Assignments

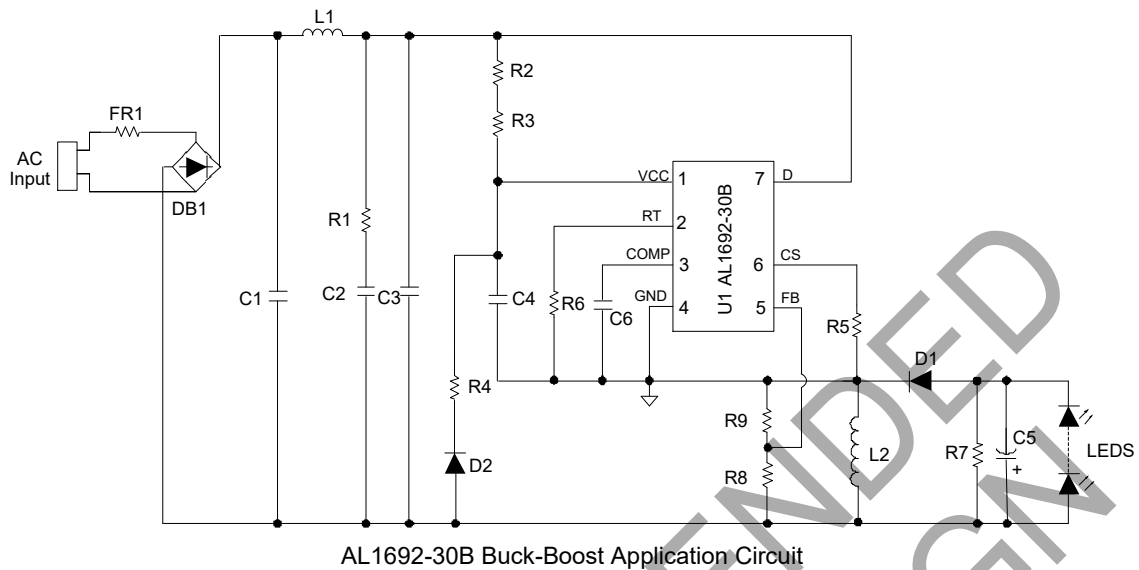
(Top View)



Applications

- Mains dimmable LED lamps
- Offline LED power supply drivers

Typical Application Circuits



Pin Descriptions

Pin Number	Pin Name	Function
1	VCC	Power Supply Voltage
2	RT	Resistor Set the System's Maximum t_{ON}
3	COMP	Compensation for Current Control
4	GND	Ground
5	FB	Feedback for LED Open Protection Voltage
6	CS	Current Sensing
7	D	Drain of the Internal High-Voltage MOSFET

The block diagram illustrates the internal circuitry for VCC clamp and fault management. It includes the following components and connections:

- VCC (Pin 1):** Connected to the VCC clamp and Fault Management blocks.
- RT (Pin 2):** Connected to a **Set t_{ON_MAX}** block, which outputs t_{ON_MAX} to a timer block.
- COMP (Pin 3):** Connected to the timer block and the **Sample and Hold** block.
- GND (Pin 4):** Connected to the timer block and the **OVP** block.
- Fault Management:** Receives **STOP** and **OTP** signals, and outputs **OFF** and **UVLO** signals to the **VCC Management** block.
- VCC Management:** Receives **OFF** and **UVLO** signals, and outputs **VCC Clamp** and **VREF** signals.
- VCC Clamp:** A circuit that clamps the VCC pin to VDD and VREF.
- tons Detection (ZCD):** Receives the **VCC Clamp** signal and outputs a **tons** signal to the **Sample and Hold** block.
- Driver Supply Clamp:** Receives the **VCC Clamp** signal and outputs a **VCC** signal to the **Sample and Hold** block.
- Sample and Hold:** Receives the **tons** and **VCC** signals, and outputs a **Sample and Hold** signal to the **OCP** block.
- OCP:** Receives the **Sample and Hold** signal and outputs a **1.6V** signal to the **OVP** block.
- OVP:** Receives the **1.6V** signal and outputs **VREF_OVP** and **OVP** signals.
- Timer:** Receives t_{ON_MAX} and **STOP** signals, and outputs a **Q** signal to the **Sample and Hold** block.

AL1692-30B Block Diagram

Absolute Maximum Ratings (@T_A = +25°C, unless otherwise specified.) (Note 4)

Symbol	Parameter	Rating	Unit
V _{CC}	Power Supply Voltage	18	V
V _D	Voltage on Drain Pin	500	V
I _{DS}	Continuous Drain Current T _C = +25°C	3	A
V _{CS}	Voltage on CS Pin	-0.3 to 7	V
V _{RT}	Voltage on RT Pin	-0.3 to 7	V
V _{FB}	Voltage on FB Pin	-0.3 to 7	V
T _J	Operating Junction Temperature	-40 to +150	°C
T _{STG}	Storage Temperature	-65 to +150	°C
T _{LEAD}	Lead Temperature (Soldering, 10 seconds)	+260	°C
P _d	Power Dissipation (T _A = +50°C) (Note 5)	0.8	W
θ _{JA}	Thermal Resistance (Junction to Ambient) (Note 5)	123	°C/W
θ _{JC}	Thermal Resistance (Junction to Case) (Note 5)	19	°C/W
—	ESD (Human Body Model)	2,000	V

- Notes:
- Stresses greater than those listed under *Absolute Maximum Ratings* can cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions* is not implied. Exposure to *Absolute Maximum Ratings* for extended periods can affect device reliability. All voltages unless otherwise stated and measured with respect to GND.
 - Device mounted on 1" x 1" FR-4 substrate PCB, 2oz copper, with minimum recommended pad layout.

Recommended Operating Conditions (@T_A = +25°C, unless otherwise specified.)

Symbol	Parameter	Min	Max	Unit
T _A	Ambient Temperature (Note 6)	-40	+105	°C
V _{CC}	Operating V _{CC} Voltage	10	V _{CC_CLAMP} (Min)	V

- Note:
- The device may operate normally at +125°C ambient temperature under the condition not trigger temperature protection.

Electrical Characteristics (@T_A = +25°C, unless otherwise specified.)

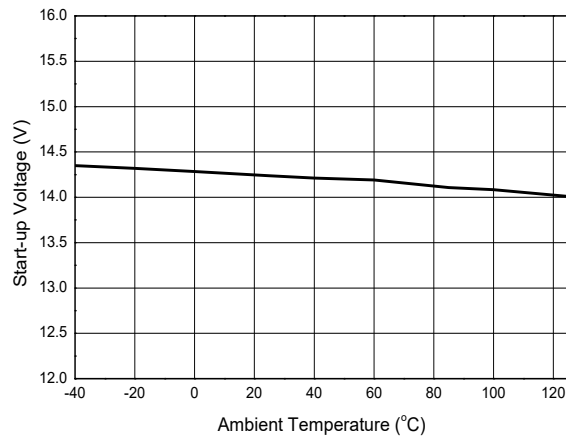
Symbol	Parameter	Condition	Min	Typ	Max	Unit
UVLO						
V _{TH(ST)}	Startup Voltage	—	—	14.5	—	V
V _{OPR(MIN)}	Minimal Operating Voltage	After Turn On	—	8.5	—	V
V _{CC_CLAMP}	V _{CC} Clamp Voltage	I _{CC} = 1mA	14	15.5	—	V
Standby Current						
I _{ST}	Startup Current	V _{CC} = V _{TH(ST)} -0.5V, Before Startup	—	100	—	μA
I _{CC(OPR)}	Operating Current	Switching Frequency at 4kHz	—	210	—	μA
Source Driver						
R _{DS(ON)LV}	Internal Low Voltage MOSFET On-State Resistance (Note 7)	—	—	1	—	Ω
High Voltage and Super-Junction MOSFET						
R _{DS(ON)HV}	Drain-Source On-State Resistance	—	—	3.2	3.6	Ω
V _{DS}	Drain-Source Breakdown Voltage	—	500	—	—	V
I _{DSS}	Drain-Source Leakage Current	—	—	—	1	μA
RT						
V _{RT_REF}	Reference Voltage of RT Pin	—	—	0.5	—	V
Current Sense						
V _{CS_CLAMP}	CS Clamp Voltage	—	—	1.6	—	V
V _{REF}	Internal Current Loop Control Reference	—	0.388	0.4	0.412	V
t _{ON_MIN}	Minimum t _{ON}	—	—	550	—	ns
t _{ON_MAX}	Maximum t _{ON}	R _T = 51kΩ, V _{COMP} = 4V	—	5.4	—	μs
t _{OFF_MIN}	Minimum t _{OFF} (Note 7)	—	—	4	—	μs
t _{OFF_MAX}	Maximum t _{OFF}	—	—	290	—	μs
FB						
V _{FB}	Feedback Voltage	—	3.7	3.95	4.18	V
I _{FB}	Feedback Pin Input Leakage Current	V _{FB} = 2V	—	4	—	μA
Error Amplifier						
G _M	G _M Trans-Conductance	—	—	25	—	μA/V
I _{SOURCE}	Amplifier Source Current	V _{CS} = 0	—	10	—	μA
I _{SINK}	Amplifier Sink Current	V _{CS} = 1.5V	—	28	—	μA
Thermal Foldback and Overtemperature Protection (OTP)						
T _{FOLD}	Thermal Foldback (Note 7)	—	—	+145	—	°C
—	Thermal Shutdown (Notes 7 & 8)	—	—	+160	—	°C

Notes: 7. These parameters, although guaranteed by design, are not tested in production.

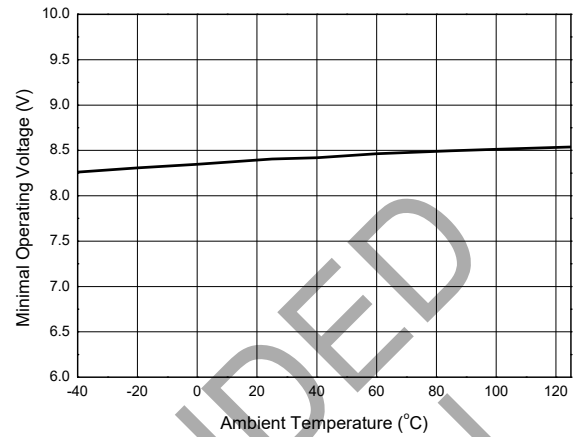
8. The device will latch off when OTP happens, recovered after power cycle and the device won't operate normally at this temperature.

Performance Characteristics (Note 9)

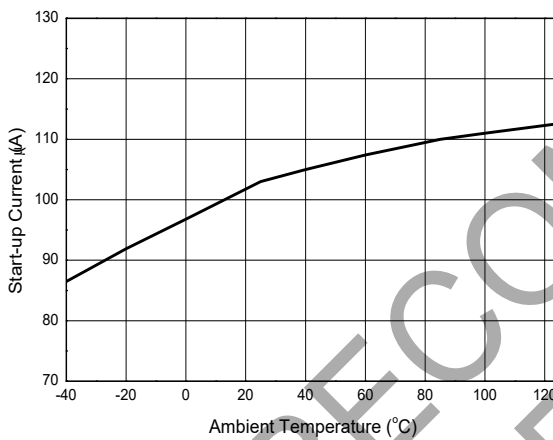
Start-up Voltage vs. Ambient Temperature



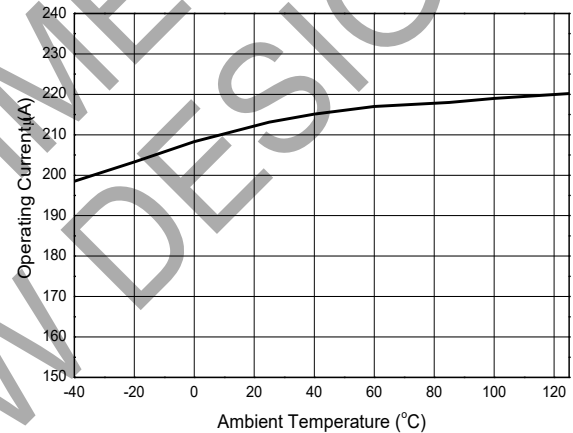
Minimum Operating Voltage vs. Ambient Temperature



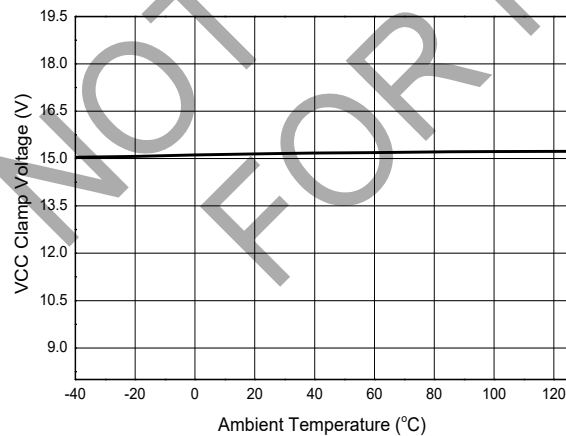
Start-up Current vs. Ambient Temperature



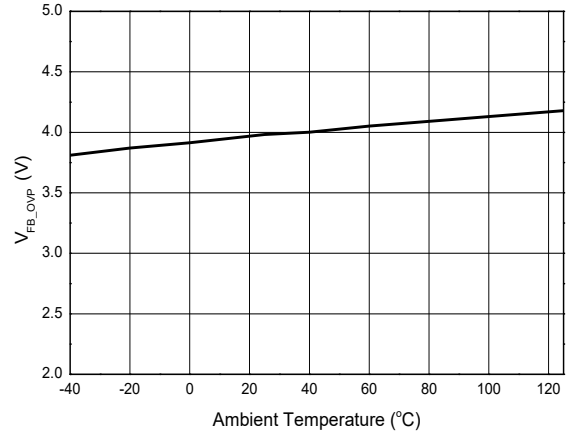
Operating Current vs. Ambient Temperature



VCC Clamp Voltage vs. Ambient Temperature



Feedback voltage vs. Ambient Temperature



Note: 9. These electrical characteristics are tested under DC conditions. The ambient temperature is equal to the junction temperature of the device.

Functional Description and Application Information

Operation

The AL1692-30B is a single stage, single winding, high-efficiency, and high power factor dimmable LED driver for triac dimmable LED lamp applications. The AL1692-30B integrates a 500V/3A high-voltage MOSFET, and it can cover 120Vac triac dimmable applications by eliminating external high-voltage MOSFET and Varistor.

The AL1692-30B adopts source-driver technique to decrease the system operating current. It uses a novel method to detect the t_{OFF} time which results in the removal for the need of an auxiliary winding. The AL1692-30B operates at boundary conduction mode (BCM) which can ease EMI design and achieve high efficiency. High power factor (HPF) is achieved by using constant on-time mode. Coupled with a closed loop of constant current control, the AL1692-30B achieves good line and load regulation.

Startup and Supply Voltage

Before startup, the V_{CC} capacitor C4 is charged by the startup resistors (R2, R3) from the high voltage mains. When the startup voltage is reached, the AL1692-30B starts switching. During normal operation, the V_{CC} supply is provided by startup resistors (R2, R3) and the output voltage (V_{OUT}) rectified by one diode (D2). In this way the system can provide V_{CC} supply at low dimming angle.

The AL1692-30B has an internal V_{CC} clamp voltage (typical 15.5V), which is limited by one internal active zener diode.

When V_{CC} voltage drops to below the $V_{OPR(MIN)}$, switching is stopped. So, the device can operate normally when the voltage on V_{CC} pin is between $V_{OPR(MIN)}$ and V_{CC} clamp voltage.

Protections

Undervoltage Lockout (UVLO)

When the voltage on the V_{CC} pin drops below $V_{OPR(MIN)}$, the IC stops switching. The IC can restart when the voltage on V_{CC} exceeds the startup voltage ($V_{TH(ST)}$).

Leading-Edge Blanking (LEB)

To prevent false detection of the peak current of the inductor, a blanking time following switch-on is designed. When the internal switch turns on, a short current spike can occur because of the capacitive discharge of the voltage over the drain and source. It is disregarded during the LEB time (t_{ON_MIN}).

Cycle-by-cycle Overcurrent Protection (OCP)

The AL1692-30B has a built-in peak current detector. It is triggered when the voltage on CS pin reaches the peak level V_{CS_CLAMP} . The R5 is connected to the CS pin to sense the current of the inductor. The maximum peak current ($I_{PEAK(MAX)}$) of the inductor can be calculated as below:

$$I_{PEAK(MAX)} = \frac{V_{CS_CLAMP}}{R5} \dots\dots\dots(1)$$

The detection circuit is activated after the LEB time. When the detection circuit senses the CS voltage is higher than 1V, the IC will turn off the switching to limit the output current. It automatically provides protection for the maximum LED current during operation. A propagation delay exists between overcurrent detection and actual source-switch off, so the actual peak current is a little higher than the OCP level set by the R5.

Overvoltage Protection and Output-Open Protection (OVP)

The output voltage is sensed by the FB pin, which provides an overvoltage protection (OVP) function. When the output is open or large transient happens, the output voltage will exceed the rated value (R8, R9). When the voltage exceeds V_{FB} , the overvoltage is triggered and the IC will discharge V_{CC} . When the V_{CC} is below the UVLO threshold voltage, IC will restart and the V_{CC} capacitor is charged again by startup resistance. If the overvoltage condition still exists, the system will work in hiccup mode.

Functional Description and Application Information (continued)

Output-Short Protection (OSP)

When LED is shorted, the device cannot detect the t_{OFF} time, and the device controls the system operation at 4kHz low frequency.

Thermal Foldback Protection (TFP)

AL1692-30B has a thermal foldback protection (TFP) function and adopts self-adaptive control method, which can prevent the system from breaking down caused by high temperature. The overheating temperature is set at +145°C typical, when the junction temperature of the IC is higher than +145°C typical, the device will linearly decrease the internal reference voltage to decrease the output current. As a result of this feature, the device can control the system's output power at high ambient temperature, to control the quantity of heat of the system. This enhances the safety of the system at high temperature.

Thermal foldback waveform is shown below:

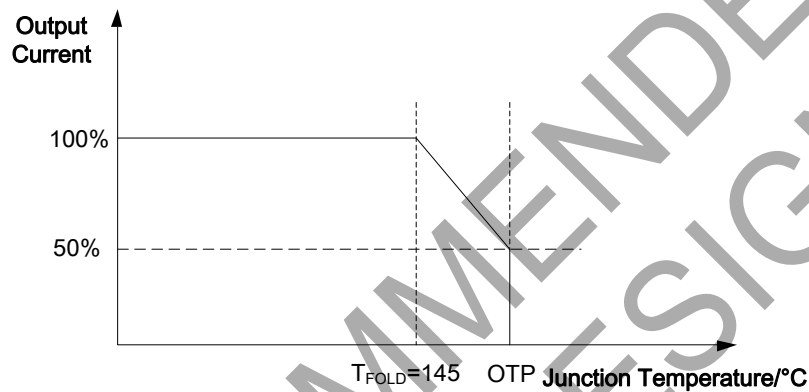


Figure 1. Thermal Foldback Waveform

Overtemperature Protection (OTP)

The AL1692-30B has overtemperature protection (OTP) function. When the junction temperature reaches +160°C typical, the IC will trigger an overtemperature protection, which causes the device to shut down and latched condition. Once OTP is triggered, the system needs to be resumed after the system's AC source supply has been reset and powered up.

Design Parameters

Setting the Current Sense Resistor R5

The AL1692-30B adopts boundary conduction mode, the output current is calculated as below,

$$I_{O_MEAN} = \frac{1}{\pi} \cdot \int_0^{\pi} \frac{1}{2} \cdot I_{PEAK} \cdot \frac{t_{OFF}}{t_{ON} + t_{OFF} + t_{DELAY}} dt \quad \dots\dots\dots (2)$$

Where,

I_{PEAK} is the peak current of the inductance.

t_{ON} is the internal MOSFET on time.

t_{OFF} is the freewheel diode D1 conduction time.

t_{DELAY} is typical 0.4μs.

The AL1692-30B is a closed loop constant current control with the relationship between output current and current sense voltage follows this equation

$$V_{REF} = \frac{1}{\pi} \cdot \int_0^{\pi} I_{PEAK} \cdot R5 \cdot \frac{t_{OFF}}{t_{ON} + t_{OFF} + t_{DELAY}} dt \quad \dots\dots\dots (3)$$

Functional Description and Application Information (continued)

Where,

V_{REF} is the internal reference, typical 0.4V.

$R5$ is the current sense resistor

So we can get the output current equation as below,

$$I_{O_MEAN} = \frac{1}{2} \cdot \frac{V_{REF}}{R5} \quad \dots\dots\dots (4)$$

Inductance Selection (L2)

In buck-boost structure, the peak current of the inductance can be calculated as below

$$I_{PEAK} = \frac{\pi \cdot V_{REF}}{R5 \cdot \int_0^{\pi} \sin(\theta) \cdot \frac{\sqrt{2} \cdot V_{IN_RMS} \cdot \sin(\theta)}{\sqrt{2} \cdot V_{IN_RMS} \cdot \sin(\theta) + V_O} d\theta} \quad \dots\dots\dots (5)$$

Where,

V_{IN_RMS} is the input voltage's RMS value.

V_O is the system output voltage.

The AL1692-30B controls the system operating at boundary conduction mode which results in its operating frequency not being constant. To set the minimum switching frequency f_{MIN} at the crest of the minimum AC input.

$$L2 = \frac{\sqrt{2} V_{IN_RMS} \cdot V_O}{I_{PEAK} \cdot (\sqrt{2} V_{IN_RMS} + V_O) \cdot f_{MIN}} \quad \dots\dots\dots (6)$$

According to Faraday's Law, the winding number of the inductance can be calculated by:

$$N_{L2} = \frac{L2 \cdot I_{PEAK}}{A_e \cdot B_m} \quad \dots\dots\dots (7)$$

Where,

A_e is the core effective area.

B_m is the maximum magnetic flux density.

t_{ON_MAX} Setting

In order to get a good dimmer compatibility and a good dimming depth, the device sets a t_{ON_MAX} by one external resistor R_T ($R6$).

And the t_{ON_MAX} time has the below equation:

$$t_{ON_MAX} = \frac{3.3 \cdot C_{REF}}{\frac{V_{RT_REF}}{10 \cdot R6} + 0.33\mu A} \quad \dots\dots\dots (8)$$

Where

V_{RT_REF} is the internal R_T pin 0.5V's reference.

C_{REF} is the internal 1.5pF capacitor.

Functional Description and Application Information (continued)

Dimming Control

The AL1692-30B is a closed loop control device; the dimming function is realized by t_{ON_MAX} limited when dimmer is connected in. When the dimmer is at the largest conduction angle, the device still has the adjustability to control the output current constant before COMP voltage is adjusted to the maximum 4V, so for most of the dimmer, the output current is almost the same with the no dimmer condition at the largest conduction angle. If the conduction angle is decreased, the COMP pin voltage will continue to increase quickly till to the maximum level (typical 4V), the device will output t_{ON_MAX} to limit system's output current. The t_{ON_MAX} is set by RT pin connected with one resistor, so the dimming depth can be adjusted by RT resistor (R6).

Before the AL1692-30B enters t_{ON_MAX} mode, it keeps the output current constant the same as no dimmer condition. When entering t_{ON_MAX} mode, we can get the following equation:

$$I_{PEAK_DIM} = \frac{V_{IN_RMS} \cdot \sin(\theta) \cdot t_{ON_MAX}}{L2} \quad \dots\dots\dots (9)$$

From the buck-boost output current equation, we can get the output current when dimming:

$$I_o(\theta) = \begin{cases} \frac{1}{2} \cdot \frac{V_{REF}}{R5} & \text{if } t_{ON} < t_{ON_MAX} \\ \frac{1}{\pi} \int_0^\alpha \frac{1}{2} \cdot I_{PEAK_DIM} \cdot \frac{\sqrt{2}V_{IN_RMS} \cdot \sin(\theta)}{\sqrt{2}V_{IN_RMS} \cdot \sin(\theta) + V_o} d\theta & \text{else} \end{cases} \quad \dots\dots\dots (10)$$

Where,

α is the dimmer conduction angle.

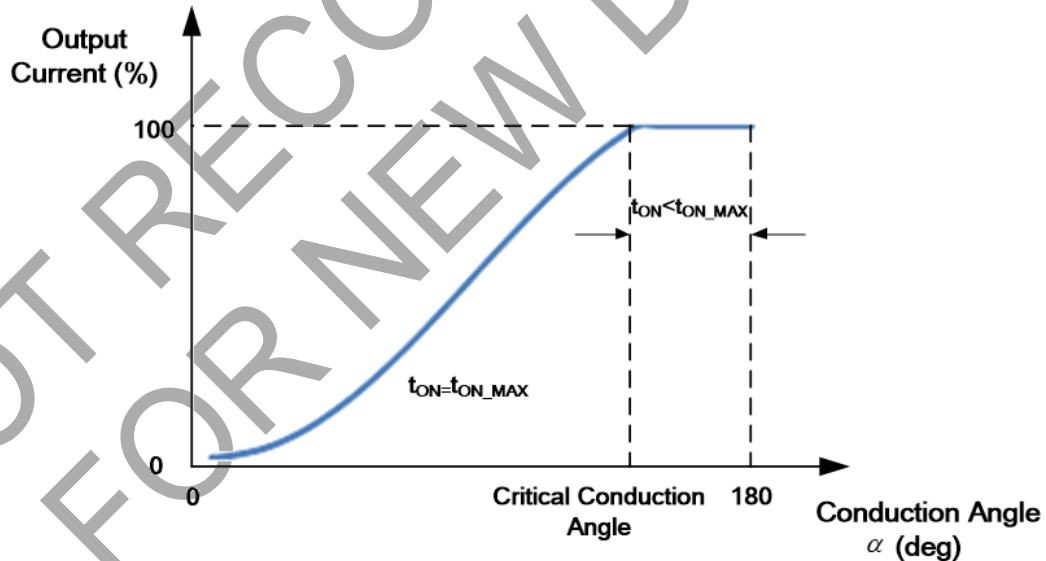


Figure.2 Dimming Curve

Functional Description and Application Information (continued)

Dimmer Compatibility

Passive Bleeder Design

The passive bleeder is designed to supply latching and holding current to eliminate dimmer misfire and flicker.

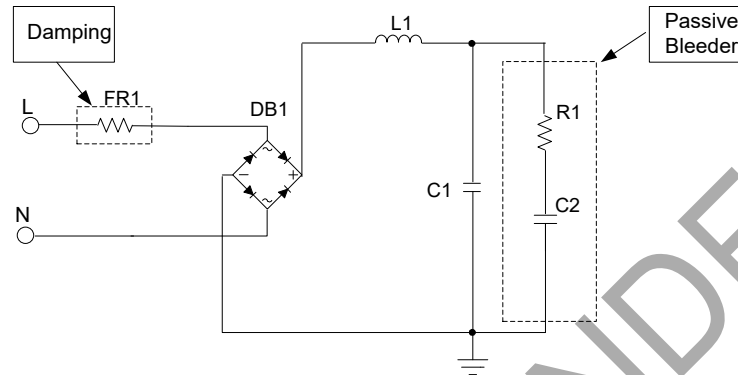


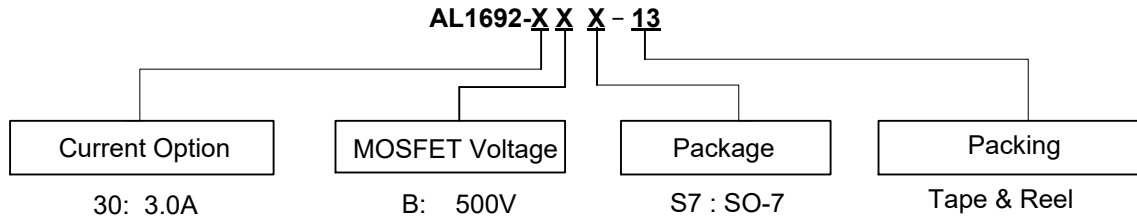
Figure.3 LED Driver Schematic with Passive Bleeder

The passive bleeder includes a capacitor (C2, in hundreds of nF) to provide latching current. A resistor (R1) is necessary to dampen the current spike. Because a large C2 will affect the PF, THD and efficiency, the value of the capacitor (C2) should be selected accordingly. Generally, 100nF/400V to 330nF/400V is recommended. R1 is used to limit the latching current. If R1 is too large, the latching current is not enough and the TRIAC dimmer will misfire causing LED flicker. If R1 is too small, it will result in greater power dissipation. Generally speaking, a 200Ω to 2kΩ resistor is selected for R1.

Passive Damping Design

FR-1 is the damper for reducing the spike current caused by quick charging of C2 at firing. In general, FR-1 is selected from 20Ω to 100Ω for low line like 120V_{AC} application, and 51Ω to 200Ω for high line like 230V_{AC} application.

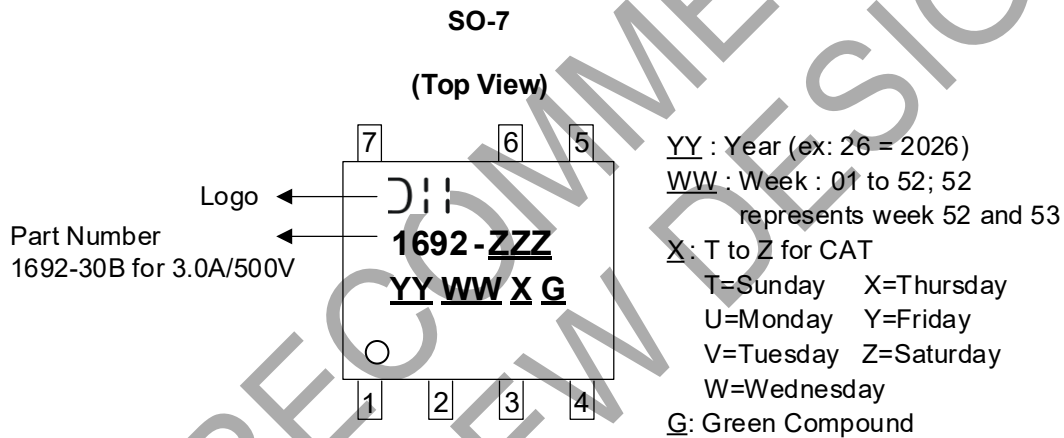
Ordering Information (Note 10)



Orderable Part Number	Package Code	Package	Packing	
			Qty.	Carrier
AL1692-30BS7-13	S7	SO-7	4000	13" Tape and Reel

Note: 10. For packaging details, go to our website at <https://www.diodes.com/design/support/packaging/diodes-packaging/>.

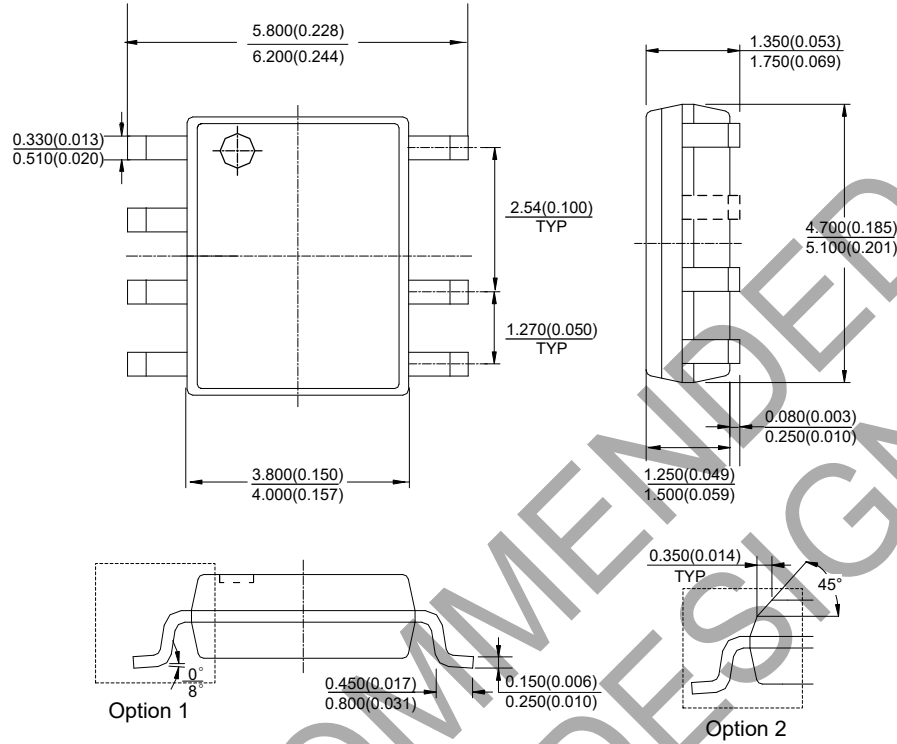
Marking Information



Package Outline Dimensions (All dimensions in mm.)

Please see <http://www.diodes.com/package-outlines.html> for the latest version.

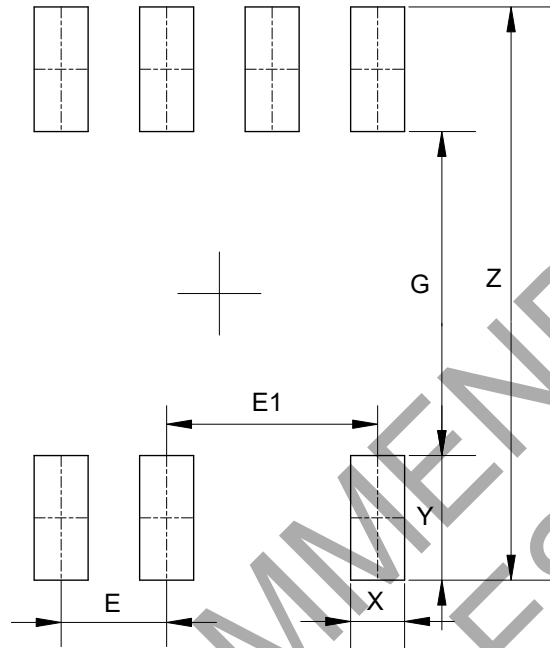
(1) Package Type: SO-7



Suggested Pad Layout

Please see <http://www.diodes.com/package-outlines.html> for the latest version.

(1) Package Type: SO-7



Dimensions	Z (mm)/(inch)	G (mm)/(inch)	X (mm)/(inch)	Y (mm)/(inch)	E (mm)/(inch)	E1 (mm)/(inch)
Value	6.900/0.272	3.900/0.154	0.650/0.026	1.500/0.059	1.270/0.050	2.540/0.100

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