AF1800A

600V, 1A, 300KHZ PWM Universal High Brightness LED Driver

Alfa-MOS Technology

General Description

The AF1800A is a peak current PWM high efficiency HBLED driver control IC. It allows HBLEDs from voltage sources ranging from 10VDC up to 600VDC. The AF1800A controls an external MOSFET at fixed switching frequency up to 300kHz. The frequency can be programmed using a single resistor. The LED string is driven at constant current rather than constant voltage, thus providing constant light output and enhanced reliability. The output current can be programmed between a few milliamps and up to more than 1.0A.

AF1800A uses a rugged high voltage junction isolated process that can withstand an input voltage surge of up to 600V. Output current to an LED string can be programmed to any value between zero and its maximum value by applying an external control voltage at the linear dimming control input of the AF1800A. The AF1800A provides a low-frequency PWM dimming input that can accept external control signal with a duty ratio of 0~100% and a frequency of up to few kilohertz.

Features

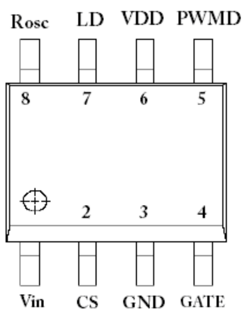
- 10V to 600V input range
- > 90% efficiency
- Constant current LED driver
- Applications from a few mA to more than 1.0A output
- LED string from one to hundreds of diodes
- PWM low frequency dimming via PWMD pin
- Input voltage surge ratings up to 600V
- SOP-8 and DIP-8 package

Application

- DC-DC or AC-DC LED driver applications
- RGB backlighting LED driver
- Back lighting of flat panel displays
- General purpose constant current source
- Signage and decorative LED lighting
- Automotive
- Chargers

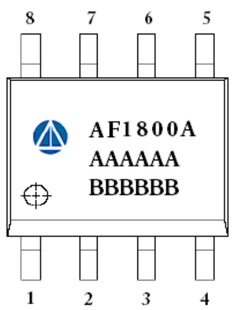
Pin Define

SOP-8

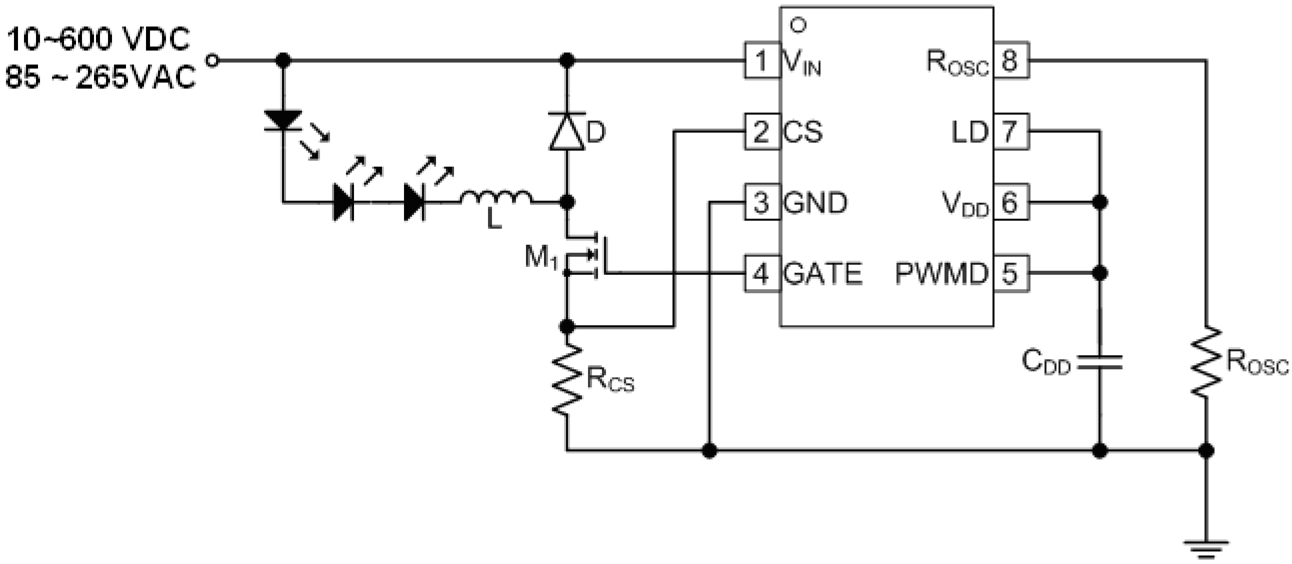


Marking Information

SOP-8



Typical Application Circuit



Pin Description

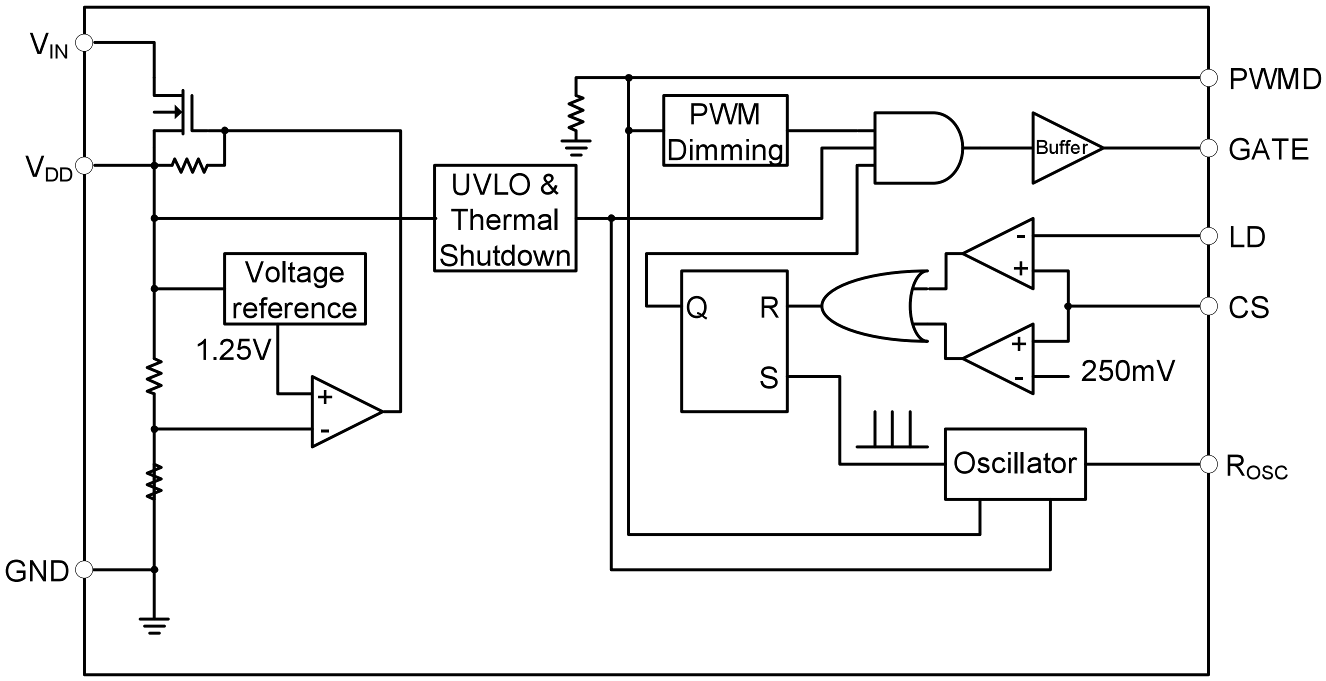
Pin	Symbol	Description
1	V_{IN}	Input voltage 10V to 600V DC
2	CS	Sense LED string current
3	GND	Device ground
4	GATE	Drive the gate of the external MOSFET
5	PWMD	Low frequency PWM dimming pin, also enable input. Internal 100kΩ pull-down to GND
6	V_{DD}	Internally regulated supply voltage. 7.5V nominal. Can supply up to 1 mA for external circuitry. A sufficient storage capacitor is used to provide storage when the rectified AC input is near the zero crossings.
7	LD	Linear dimming by changing the current limit threshold at current sense comparator
8	R_{OSC}	Oscillator control. A resistor connected between this pin and ground sets the PWM frequency.

Ordering Information

Part Ordering No.	Part Marking	Package	Unit	Quantity
AF1800AS8RG	AF1800A	SOP-8P	Tape & Reel	2500 EA

※ A Lot Code
※ B Date Code
※ AF1800AS8RG : Tape Reel ; Pb - Free ; Halogen- Free

Block Diagram



Absolute Maximum Ratings (TA=25℃ Unless otherwise noted)

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

Symbol	Parameter		Value	Unit
V_{IN} *1	V_{IN} pin voltage		- 0.3 to + 600	V
V_{DD} *1	Internal regulated voltage		+ 10	V
CS	Current sense pin voltage		- 0.3 to V_{DD} + 0.3	V
PWMD	PWM dimming pin voltage		- 0.3 to V_{DD} + 0.3	V
LD	Linear dimming pin voltage		- 0.3 to V_{DD} + 0.3	V
GATE	Gate pin voltage		- 0.3 to V_{DD} + 0.3	V
P_D	Power Dissipation	SOP-8	630	mW
		DIP-8	900	
T_{OPR}	Operating Temperature Range		-20 to +125	°C
T_{STG}	Storage Temperature Range		-40 to +150	°C

Caution:

1. The absolute maximum ratings are rated values exceeding which the product could suffer physical damage. These values must therefore not be exceeded under any conditions.

Electrical Characteristics

(T_A=25 °C, unless otherwise specified.)

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
V_{IN}	Input operating voltage range		10		600	V
I_{GND}	Supply quiescent Current	V_{PWMD} = 0V, V_{IN} = 10V	0.5		1.0	mA
V_{DD}	Internal regulated voltage	V_{IN} = 10V ~ 600V, pin GATE open	7	7.5	8	V
V_{DDmax}	Maximum V_{DD} voltage	When an external voltage applied to pin V_{DD}			10	V
$I_{DD(EXT)}$ *1	VDD current available for external circuitry	V_{IN} = 10V ~ 100V			0.7	mA
V_{UVLO}	V_{DD} under voltage lock out threshold	V_{IN} rising	6.45	6.7	6.95	V
ΔV_{UVLO}	V_{DD} under voltage lock out hysteresis	V_{IN} falling		500		mV
$V_{PWM(OFF)}$	Pin PWMD input low voltage	V_{IN} = 10 ~ 600V			0.8	V
$V_{PWM(ON)}$	Pin PWMD input high voltage	V_{IN} = 10 ~ 600V	2.0			V
R_{PWM}	Pin PWMD pull-down resistor	V_{PWM} = V_{DD}	50	100	150	kΩ
V_{CSTH}	Current sense threshold voltage	T_A = -40℃ ~ 85℃	0.225	0.25	0.275	V
$V_{GATE(H)}$	GATE high output voltage	I_{GATE} = 10mA	V_{DD}–0.3		V_{DD}	V
$V_{GATE(L)}$	GATE low output voltage	I_{GATE} = - 10mA	0		0.3	V
F_{OSC}	Oscillation Frequency	R_{OSC} = 1MΩ	20	25	30	KHz
		R_{OSC} = 226kΩ	80	100	120	
D_{MAX} *2	Maximum oscillator duty cycle	GATE duty, F_{OSC} = 25kHz, CS to GND			100	%
V_{LD} *2	Linear dimming pin voltage range	V_{IN} = 12V	0		0.25	V
T_{BLANK}	Current sense blanking interval	V_{CS} = 0.55V_{LD}, V_{LD} = V_{DD}	150	215	280	ns
T_{DELAY} *2	Delay from CS trip to V_{GATE}= $V_{GATE(L)}$	V_{IN} = 12V, V_{LD} = V_{DD}, V_{CS} > V_{CSTH} after T_{BLANK}		170	300	ns
T_{RISE}	V_{GATE} output rise time	C_{GATE} = 500pF	30		50	ns
T_{FALL}	V_{GATE} output fall time	C_{GATE} = 500pF	30		50	ns
T_{SD} *2	Thermal shutdown			160		℃
T_{HYS} *2	Thermal shutdown hysteresis			20		℃

Caution:

1. Also limited by package power dissipation limit, whichever is lower.
2. Guaranteed by design, not tested.

Application information

AC-DC off-line application

The AF1800A is a low-cost off-line buck, boost or buck-boost converter control IC specifically designed for driving multi-LED strings of arrays. It can be operated from either universal AC line or and DC voltage between 10 ~ 600V. Optionally, a passive power factor correction circuit can be used in order to pass the AC harmonic limits set by EN 61000-3-2 Class C for lighting equipment having input power less than 25W. The AF1800A can drive up to hundreds of High-Brightness (HB) LEDs or multiple strings of HB LEDs. The LED arrays can be configured as a series or series/parallel connection. The AF1800A regulates constant current that ensures controlled brightness and spectrum of the LEDs, and extends their lifetime. The AF1800A features an enable pin (PWMD) that allows PWM control of brightness.

The AF1800A can also control brightness of LEDs by programming continuous output current of the LED driver (so-called linear dimming) when a control voltage is applied to the LD pin.

The AF1800A is offered in standard 8-pin SOIC and DIP packages. It is also available in a high voltage rated package for applications that require V_{IN} greater than 250V.

The AF1800A includes an internal high-voltage linear regulator that powers all internal circuits and can also serve as a bias supply for low voltage external circuitry.

LED driver operation

The AF1800A can control all basic types of converters, isolated or non-isolated, operating in continuous or discontinuous conduction mode. When the gate signal enhances the external power MOSFET, the LED driver stores the input energy in an inductor or in the primary inductance of a transformer and, depending on the converter type, may partially deliver the energy directly to LEDs The energy stored in the magnetic component is further delivered to the output during the off-cycle of the power MOSFET producing current through the string of LEDs (Flyback mode of operation).

When the voltage at the V_{DD} pin exceeds the UVLO threshold the gate drive is enabled. The output current is controlled by means of limiting peak current in the external power MOSFET. A current sense resistor is connected in series with the source terminal of the MOSFET. The voltage from the sense resistor is applied to the CS pin of the AF1800A. When the voltage at CS pin exceeds a peak current sense voltage threshold, the gate drive signal terminates, and the power MOSFET turns off. The threshold is internally set to 250mV, or it can be programmed externally by applying voltage to the LD pin. When soft start is required, a capacitor can be connected to the LD pin to allow this voltage to ramp at a desired rate, therefore, assuring that output current of the LED ramps gradually.

Optionally, a simple passive power factor correction circuit, consisting of 3 diodes and 2 capacitors, can be added as shown in the application circuit diagram of Figure 1.

Supply Current

A current of 1mA is needed to start the AF1800A. As shown in block diagram, this current is internally generated in AF1800A without using bulky startup resistors typically required in the offline applications. Moreover, in many applications the AF1800A can be continuously powered using its internal linear regulator that provides a regulated voltage of 7.5V for all internal circuits.

Setting light output

When the buck converter topology of Figure 1 is selected, the peak CS voltage is a good representation of the average current in the LED. However, there is a certain error associated with this current sensing method that needs to be accounted for. This error is introduced by the difference between the peak and the average current in the inductor. For example if the peak-topeak ripple current in the inductor is 150mA, to get a 500mA LED current, the sense resistor should be 250mV/(500mA+ 0.5*150mA)=0.43Ω.

Dimming

Dimming can be accomplished in two ways, separately or combined, depending on the application. Light output of the LED can be controlled either by linear change of its current, or by switching the current on and off while maintaining it constant. The second dimming method (so-called PWM dimming) controls the LED brightness by varying the duty ratio of the output current.

The linear dimming can be implemented by applying a control voltage from 0 to 250mV to the LD pin. This control voltage overrides the internally set 250mV threshold level of the CS pin and programs the output current accordingly. For example, a potentiometer connected between V_{DD} and ground can program the control voltage at the CS pin. Applying a control voltage higher than 250mV will not change the output current setting. When higher current is desired, select a smaller sense resistor.

The PWM dimming scheme can be implemented by applying an external PWM signal to the PWMD pin. The PWM signal can be generated by a microcontroller or a pulse generator with a duty cycle proportional to the amount of desired light output. This signal enables and disables the converter modulating the LED current in the PWM fashion. In this mode, LED current can be in one of the two states: zero or the nominal current set by the current sense resistor. It is not possible to use this method to achieve average brightness levels higher than the one set by the current sense threshold level of the AF1800A. By using the PWM control method of the AF1800A, the light output can be adjusted between zero and 100%. The accuracy of the PWM dimming method is limited only by the minimum gate pulse width, which is a fraction of a percent of the low frequency duty cycle.

Programming operating frequency

The operating frequency of the oscillator is programmed between 25 and 300kHz using an external resistor connected to the R_{OSC} pin:

$$F_{OSC} = \frac{25000}{R_{OSC} + 22k} [kHz]$$

Power factor correction

When the input power to the LED driver does not exceed 25W, a simple passive power factor correction circuit can be added to the AF1800A application circuit of Figure 1 in order to pass the AC line harmonic limits of the EN61000-3-2 standard for Class C equipment. The typical application circuit diagram shows how this can be done without affecting the rest of the circuit significantly. A simple circuit consisting of 3 diodes and 2 capacitors is added across the rectified AC line input to improve the line current harmonic distortion and to achieve a power factor greater than 0.85.

Inductor design

Referring to the Typical Application Circuit below the value can be calculated from the desired peak-to-peak LED ripple current in the inductor. Typically, such ripple current is selected to be 30% of the nominal LED current. In the example given here, the nominal current I_{LED} is 350mA.

The next step is determining the total voltage drop across the LED string. For example, when the string consists of 10 High-Brightness LEDs and each diode has a forward voltage drop of 3.0V at its nominal current; the total LED voltage V_{LEDS} is 30V.

Knowing the nominal rectified input voltage V_{IN}=120V*1.41=169V, the switching duty ratio can be determined, as:

$$D = \frac{V_{LEDs}}{V_{IN}} = \frac{30}{169} = 0.177$$

Then, given the switching frequency, in this example fosc=50KHz, the required on-time of the MOSFET transistor can be calculated:

$$T_{on} = \frac{D}{F_{OSC}} = 3.5\mu s$$

The required value of the inductor is given by:

$$L = \frac{(V_{IN} - V_{LEDs}) * T_{on}}{0.3 * I_{LED}} = 4.6mH$$

Input bulk capacitor

An input filter capacitor should be designed to hold the rectified AC voltage above twice the LED string voltage throughout the AC line cycle. Assuming 15% relative voltage ripple across the capacitor, a simplified formula for the minimum value of the bulk input capacitor is given by:

$$C_{\min} = \frac{I_{LED} * V_{LEDs} * 0.06}{V_{IN}^2}$$

A passive PFC circuit at the input requires using two series connected capacitors at the place of calculated C_{MIN}. Each of these identical capacitors should be rated for ½ of the input voltage and have twice as much capacitance.

Enable

The AF1800A can be turned off by pulling the PWMD pin to ground. When disabled, the AF1800A draws quiescent current of less than 1mA.

Output open circuit protection

When the buck topology is used, and the LED is connected in series with the inductor, there is no need for any protection against an open circuit condition in the LED string. Open LED connection means no switching and can be continuous. However, in the case of the buck-boost or the Flyback topology the AF1800A may cause excessive voltage stress of the switching transistor and the rectifier diode and potential failure. In this case, the AF1800A can be disabled by pulling the PMWD pin to ground when the over voltage condition is detected.

DC-DC Low Voltage Applications

Buck converter operation

The buck power conversion topology can be used when the LED string voltage is needed to be lower than the input supply voltage. The design procedure for a buck LED driver outlined in the previous chapters can be applied to the low voltage LED drivers as well. However, the designer must keep in mind that the input voltage must be maintained higher than 2 times the forward voltage drop across the LEDs. This limitation is related to the output current instability that may develop when the AF1800A buck converter operates at a duty cycle greater than 0.5. This instability reveals itself as an oscillation of the output current at a sub-harmonic of the switching frequency

Flyback (Buck-Boost) Operation

This power conversion topology can be used when the forward voltage drop of the LED string is higher, equal or lower than the input supply voltage. For example, the buck-boost topology can be appropriate when input voltage is supplied by an automotive battery (12V) and output string consists of three to six HB LEDs, as the case may be for tail and break signal lights.

In the buck-boost converter, the energy from the input source is first stored in the inductor or a Flyback transformer when the switching transistor is ON. The energy is then delivered to the output during the OFF time of the transistor. When the energy stored in the Flyback inductor is not fully depleted by the next switching cycle (continuous conduction mode) the DC conversion between input and output voltage is given by:

$$V_{OUT} = -\frac{V_{IN} * D}{(1 - D)}$$

The output voltage can be either higher or lower than the input voltage, depending on duty ratio. Let us discuss the above example of an automotive LED driver that needs to drive three HB LEDs at 350mA. Knowing the nominal input voltage V_{IN}=12V, the nominal duty ratio can be determined, as D=V_{LEDs}/(V_{IN}+V_{LEDs})=9/(12+9)=0.43 Then, given the switching frequency, in this example f_{OSC}=50KHz, the required on-time of the MOSFET transistor can be calculated:

$$T_{on} = \frac{D}{f_{OSC}} = 8.6\mu s$$

The required value of the inductor is given by:

$$L = \frac{V_{IN} * T_{on}}{(0.3 * I_{LED})} = 0.98mH$$, use 1mH

Output capacitor

Unlike the buck topology, the buck-boost converter requires an output filter capacitor to deliver power to the LED string during the ON time of switching the transistor, when the Flyback inductor current is diverted from the output of the converter.

In order to average the current in the LED, this capacitor must present impedance to the switching output AC ripple current that is much lower than the dynamic impedance R_{OUT} of the LED string. If we assume R_{OUT}=3 Ohm in our example, in order to attenuate the switching ripple by a factor of 10, a capacitor with equivalent series resistance (ESR) of 0.3 Ω is needed. A chip SMT tantalum capacitor can be selected for this purpose.

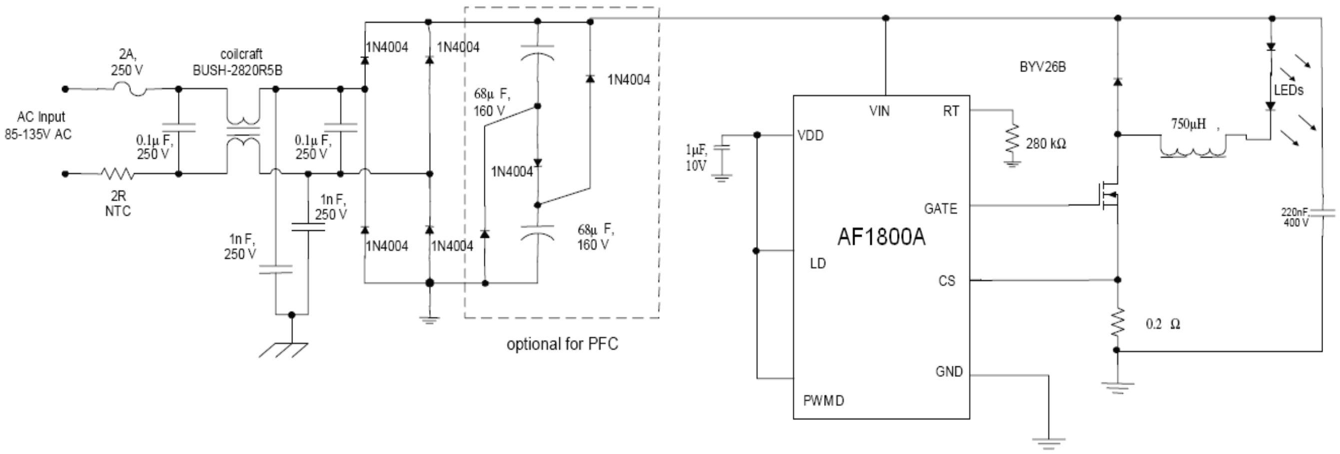


Figure 1. Typical Application Circuit

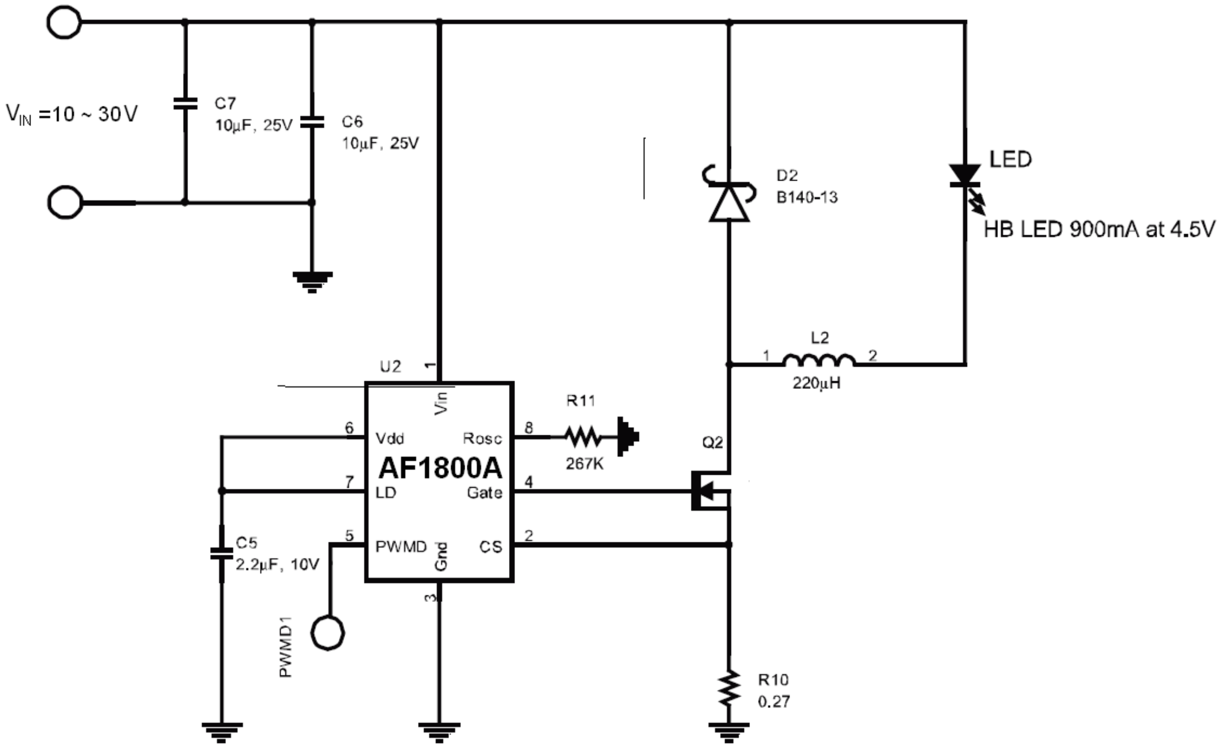


Figure 2. AF1800A Buck Driver for a single 900mA HB LED (V_{IN} = 10 – 30V)

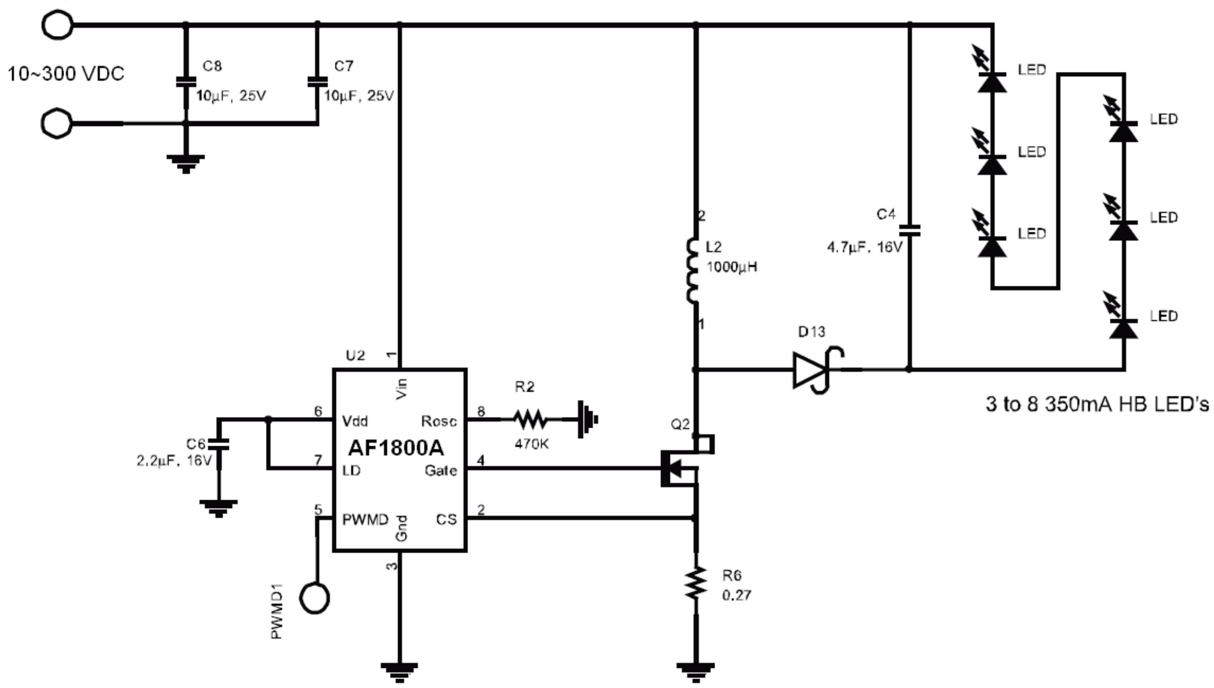
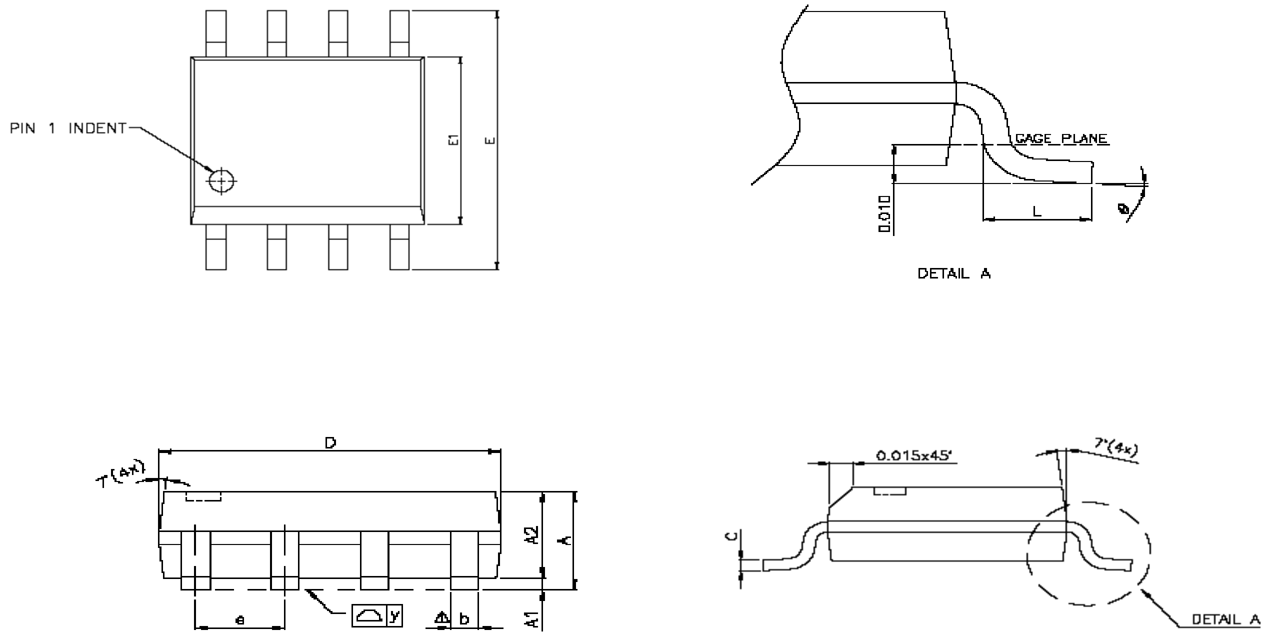


Figure 3. AF1800A Buck-Boost driver powering 3 to 8, 350mA HB LEDs (V_{IN} = 10 – 300V)

Package Information (SOP-8P)



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°

2F, No.80, Sec.1, Cheng Kung Rd., Nan Kang Dist., Taipei City 115, Taiwan (R.O.C.)
Tel : 886 2) 2651 3928
Fax : 886 2) 2786 8483
©http://www.alfa-mos.com