2MHz High-Brightness LED Drivers With High-Side Current Sense And 5000:1 Dimming

■ General Description

The XT1750, step-down constant-current high-brightness LED (HB LED) drivers provide a cost-effective solution for automotive interior/exterior lighting, architectural and ambient lighting, LED bulbs such as MR16 and other LED illumination applications.

The XT1750 operate from a 4.5V to 28V input voltage range and feature a 5V/10mA on-board regulator. A high-side current-sense resistor adjusts the output current and a dedicated PWM input (DIM) enables a wide range of pulsed dimming.

The XT1750 are well suited for applications requiring a wide input voltage range. The high-side current-sensing and an integrated current-setting circuitry minimize the number of external components while delivering an LED current with ±5% accuracy. A hysteretic control algorithm ensures excellent input-supply rejection and fast response during load transients and PWM dimming. The XT1750 features a 10% current ripple. These devices operate up to 2MHz switching frequency, thus allowing for small component size.

The XT1750 operate over the -40°C to +125°C automotive temperature range and are available in 3mm x 3mm x 0.8mm, 6-pin TDFN packages.

■ Features

- High-Side Current Sense
- Dedicated Dimming Control Input
- 20kHz Maximum Dimming Frequency
- Hysteretic Control: No Compensation
- Up to 2MHz Switching Frequency
- ±5% LED Current Accuracy
- Adjustable Constant LED Current
- 4.5V to 28V Input Voltage Range
- Over 25W Output Power
- 5V, 10mA On-Board Regulator
- -40°C to +125°C Operating Temperature Range

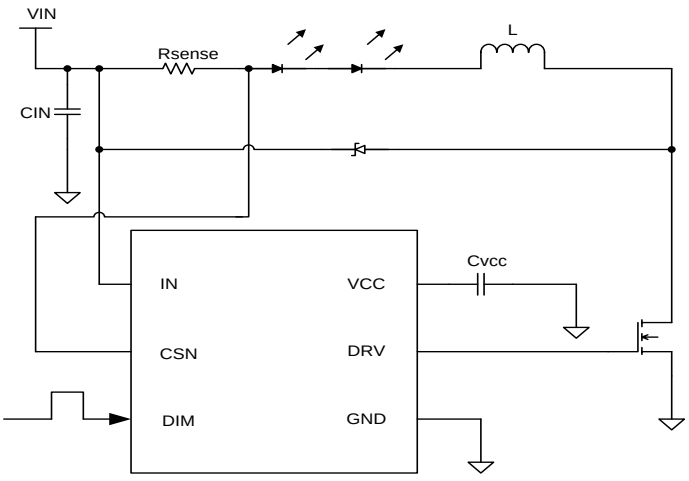
■ Applications

- Architectural, Industrial, and Ambient Lighting
- Automotive RCL, DRL, and Fog Lights
- MR16 and Other LED Bulbs
- Indicators and Emergency Lighting

■ Package

- 6-pin TDFN

■ Typical Application Circuit

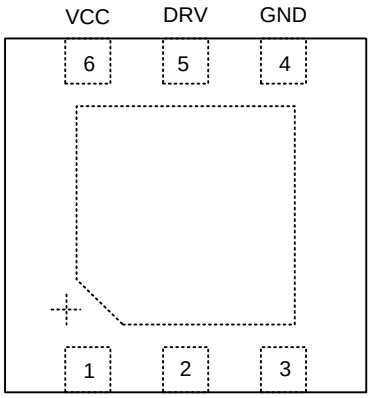


■ Ordering Information

XT1750 ①②③④⑤

Designator	Represents	Symbol	Description
① ②	Output Voltage	25-50/AD	Output Voltage: e.g. 33= 3.3V etc. Adjustable version: ①② fixed as AD
③	Frequency	M	1.5MHZ
④	Package	M	SOT-23-6
⑤	Device Orientation	S	Embossed Tape :Standard Feed
		R	Embossed Tape :Reverse Feed

■ Pin Configuration

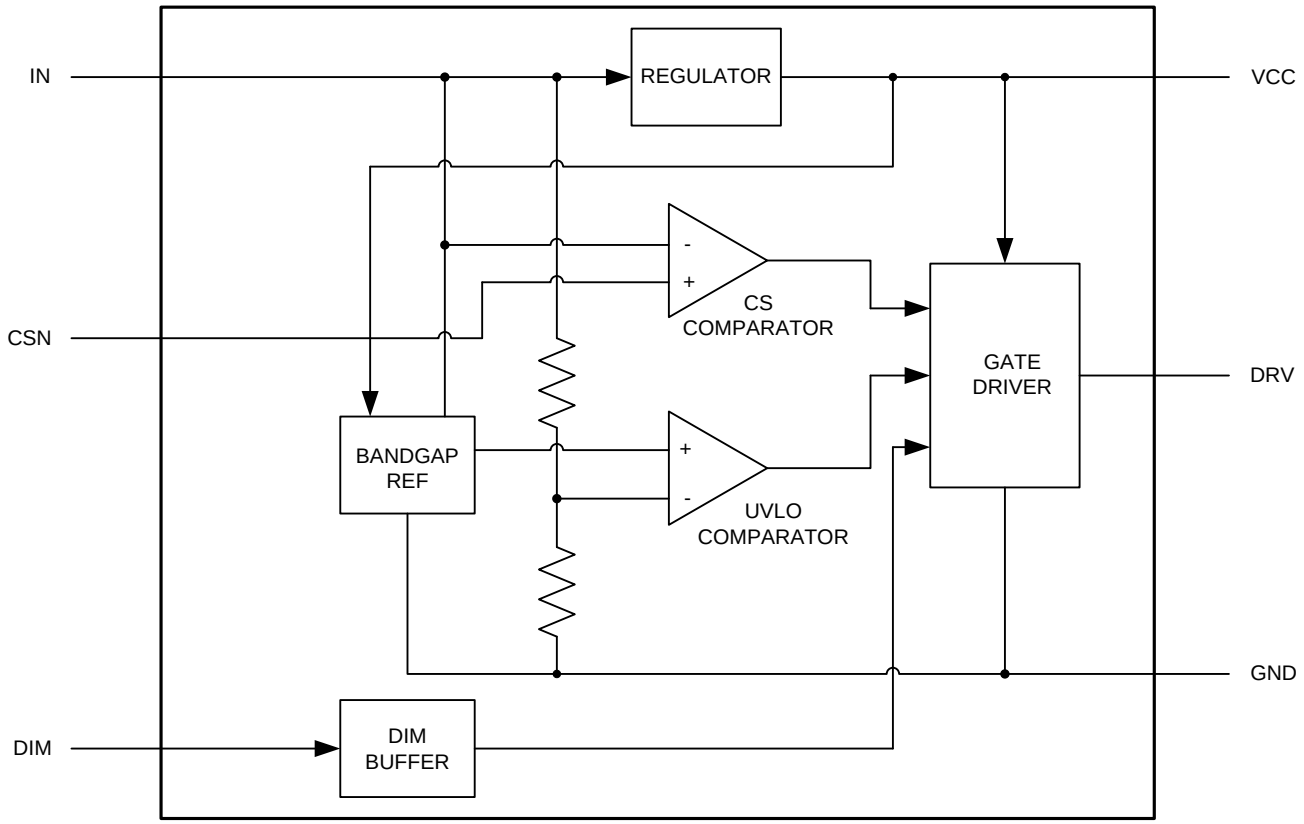


TDFN-6

■ Functional Pin Description

Pin Number	Pin Name	Function
1	IN	Positive supply voltage input.
2	CSN	Current-sense input.
3	DIM	Logic-level dimming input. High level is active.
4	GND	Ground.
5	DRV	Gate drive output. Connect to the gate of an external n-channel MOSFET.
6	VCC	Voltage regulator output. Connect a 1μF capacitor from VCC to GND.
EP	-	Exposed paddle. Connect to a large-area ground plane.

■ Function Block Diagram



■ Absolute Maximum Ratings

Item	Min	Max
IN,CSN,DIM to GND	-0.3V	30V
VCC,DRV to GND	-0.3V	6V
CSN to IN	-0.3V	0.3V
Operating Temperature Range	-40℃	125℃
Storage Temperature Range	-60℃	150℃
Lead Temperature(soldering,10s)		300℃
Junction Temperature		150℃
ESD(HBM)	2.5K	

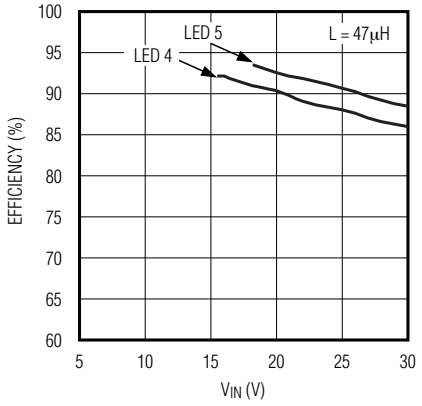
■ Electrical Characteristics

Parameter	Symbol	Conditions	Min	Typ	Max	Units
Input Voltage Range	V_{IN}		4.5		28	V
Maximum current regulator Switching frequency	f_{SW}				2	MHz
Supply current	I_{IN}	V_{DIM}<0.6V			425	μA
Ground current	I_{GND}	DRV open			1.5	mA
Sense voltage threshold high	V_{SNSHI}	（V_{IN}-V_{CSN}）rising from 0V until V_{DRV}<0.5V	195	210	225	mV
Sense voltage threshold low	V_{SNSLO}	（V_{IN}-V_{CSN}）rising from 0.26V until V_{DRV}>(V_{CC}-0.5V)	176	190	204	mV
Current-sense input current	I_{CSN}	(V_{IN}-V_{CSN})=200mV			1	μA
Gate driver source current		V_{CSN}=V_{IN},V_{DRV}=0.5×V_{CC}		0.5		A
Gate driver sink current		V_{CSN}=V_{IN}-250mV,V_{DRV}=0.5×V_{CC}		1		A
Gate driver output-voltage high	V_{CH}	I_{DRV}=10mA	V_{CC}-0.5			V
Gate driver output-voltage low	V_{CL}	I_{DRV}=-10mA			0.5	V
Maximum DIM frequency	f_{DIM}				20	KHz
DIM input-voltage high	V_{IH}	V_{CSN}=VI_N, increase DIM until V_{DRV}>(V_{CC}-0.5V)	2.8			V
DIM input-voltage low	V_{IL}	V_{CSN}=VI_N, decrease DIM until V_{DRV}>(V_{CC}-0.5V)			0.6	V
DIM hysteresis	DIM_{HYS}			200		mV
Regulator output voltage	V_{CC}	I_{VCC}=0.1mA to 10mA	4.5		5.5	V
		I_{VCC}=0.1mA to 10mA	4.0		5.5	V
Load regulation		I_{VCC}=0.1mA to 10mA,V_{IN}=12V		4		Ω
Line regulation		V_{IN}=6V to 28V,I_{VCC}=10mA		11		mV
Power-supply rejection ratio	PSRR	V_{IN}=12V,I_{VCC}=5mA,f_{IN}=20KHZ		-35		dB
Current limit	I_{LIM}	V_{IN}=4.5V,V_{CC}=0V		45		mA
		VI_N=4.5V,V_{CC}=4V		18		mA
Regulator startup time	t_{STRAT}	V_{CC}=0 to 4.5V		350		μs

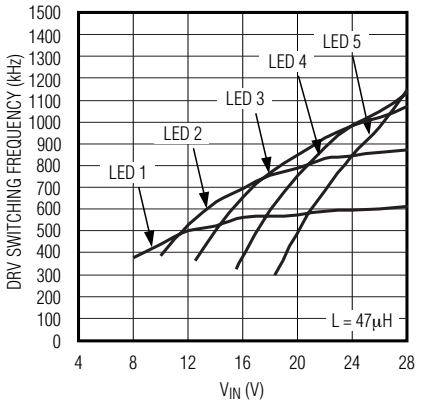
■ Typical Operating Characteristic

(V_{IN}=V_{DIM}=12V,CVCC=1μF,R_{SENSE}=0.5Ω connected between IN and CSN.Typical values at TA=25℃,unless otherwise noted)

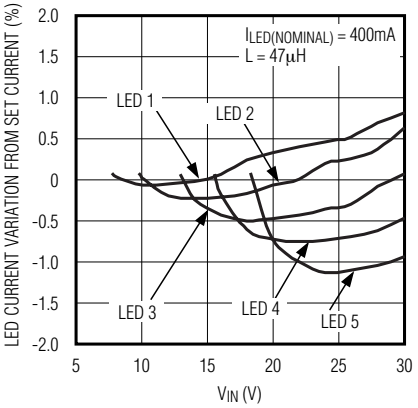
EFFICIENCY vs. V_{IN}



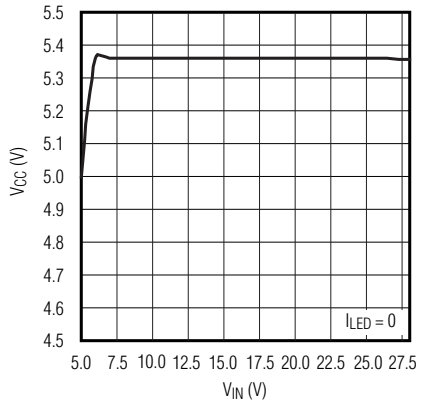
DRV SWITCHING FREQUENCY vs. V_{IN}



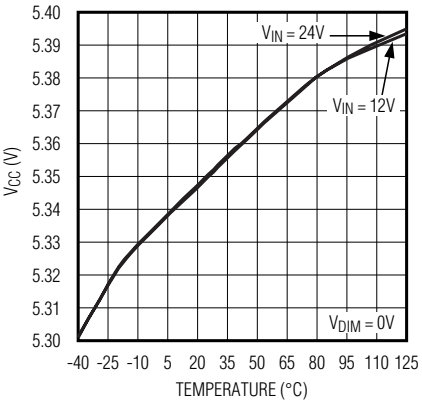
LED CURRENT VARIATION vs. V_{IN}



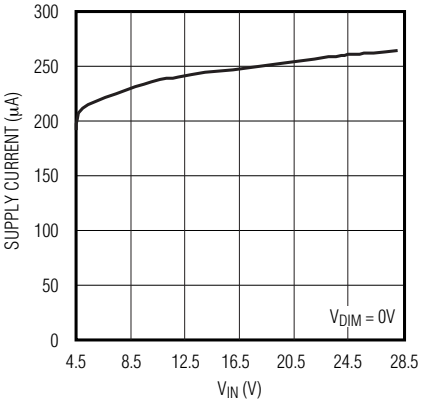
V_{CC} vs. V_{IN}



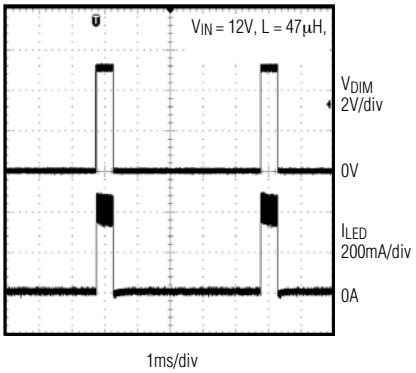
V_{CC} vs. TEMPERATURE



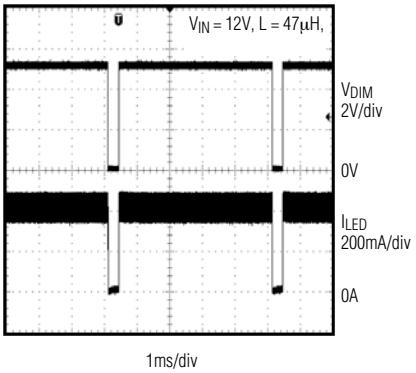
SUPPLY CURRENT vs. V_{IN}



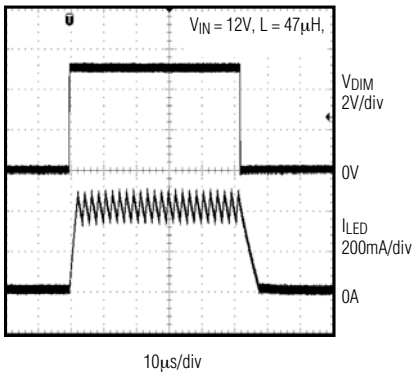
PWM DIMMING AT 200Hz (10% DUTY CYCLE)



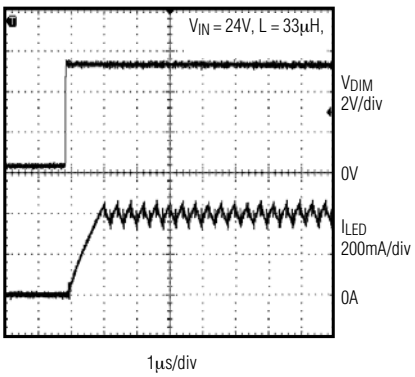
PWM DIMMING AT 200Hz (90% DUTY CYCLE)



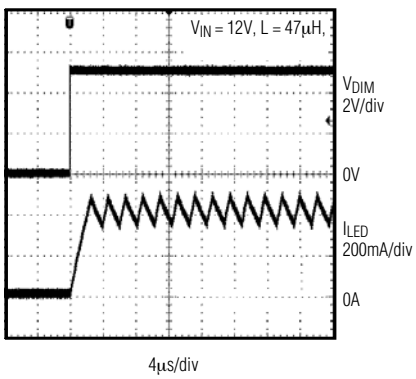
PWM DIMMING AT 200Hz (1% DUTY CYCLE)



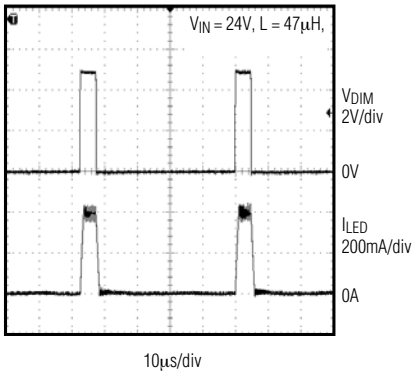
PWM DIMMING EXPANDED (50% DUTY CYCLE)



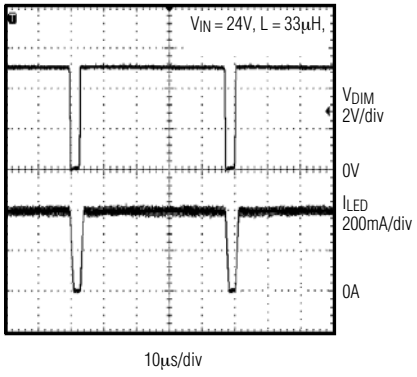
PWM DIMMING EXPANDED (50% DUTY CYCLE)



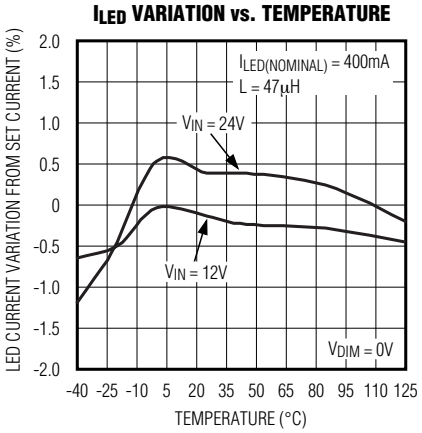
PWM DIMMING AT 20kHz (10% DUTY CYCLE)



PWM DIMMING AT 20kHz (90% DUTY CYCLE)



I_{LED} VARIATION vs. TEMPERATURE



■ Application Information

- **Selecting RSENSE to set the LED current**

The XT1750 feature a programmable LED current using a resistor connected between IN and CSN. Use the following equation to calculate the sense resistor:

$$R_{SENSE}(\Omega) = \frac{(V_{SNSHI} + V_{SNSLO})(V)}{2I_{LED}(A)}$$

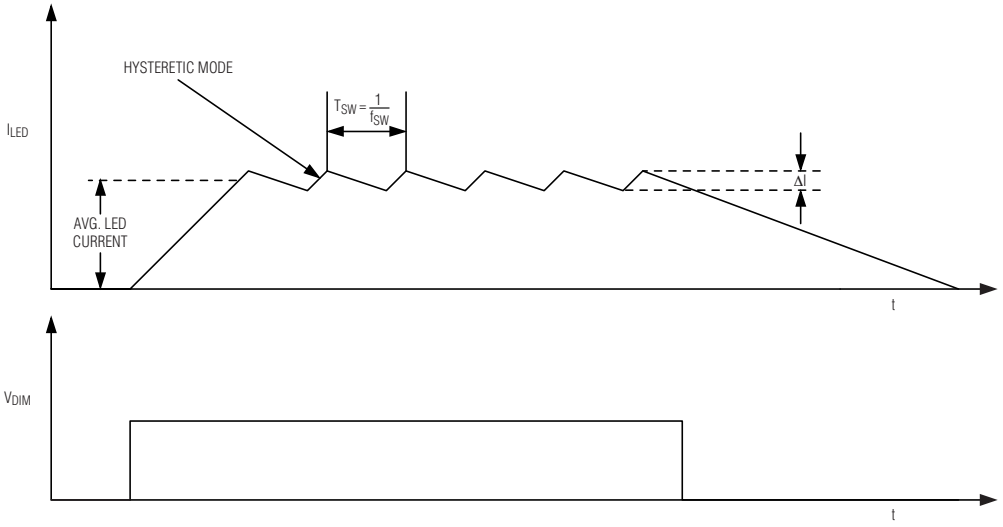
For the values of VSNSHI and VSNSLO, see the electrical characteristics.

- **Rent regulator operation**

The XT1750 regulate the LED output current using an input comparator with hysteresis (Figure 1). As the current through the inductor ramps up and the voltage across the sense resistor reaches the upper threshold, the voltage at DRV goes low, turning off the external MOSFET. The MOSFET turns on again when the inductor current ramps down through the freewheeling diode until the voltage across the sense resistor equals the lower threshold. Use the following equation to determine the operating frequency:

$$fsw = \frac{(V_{IN} - n \times V_{LED}) \times n \times V_{LED} \times R_{SENSE}}{V_{IN} \times \Delta V \times L}$$

where n = number of LEDs, VLED = forward voltage drop of one LED, and ΔV = (VSNSHI - VSNSLO).



Current Regulator Operation

- **MOSFET Selection**

The XT1750's gate driver is capable of sourcing 0.5A and sinking 1A of current. MOSFET selection is based on the maximum input operating voltage VIN, output current ILED, and operating switching frequency. Choose a MOSFET that has a higher break down voltage than the maximum operation voltage, low RDS(ON), and low total charge for better efficiency.

MOSFET threshold voltage must be adequate if operated at the low end of the input-voltage operating range.

- **Freewheeling Diode Selection**

The forward voltage of the freewheeling diode should be as low as possible for better efficiency. A Schottky diode is a good choice as long as the breakdown voltage is high enough to withstand the maximum operating voltage. The forward current rating of the diode must be at least equal to the maximum LED current.

- **PCB Layout Guidelines**

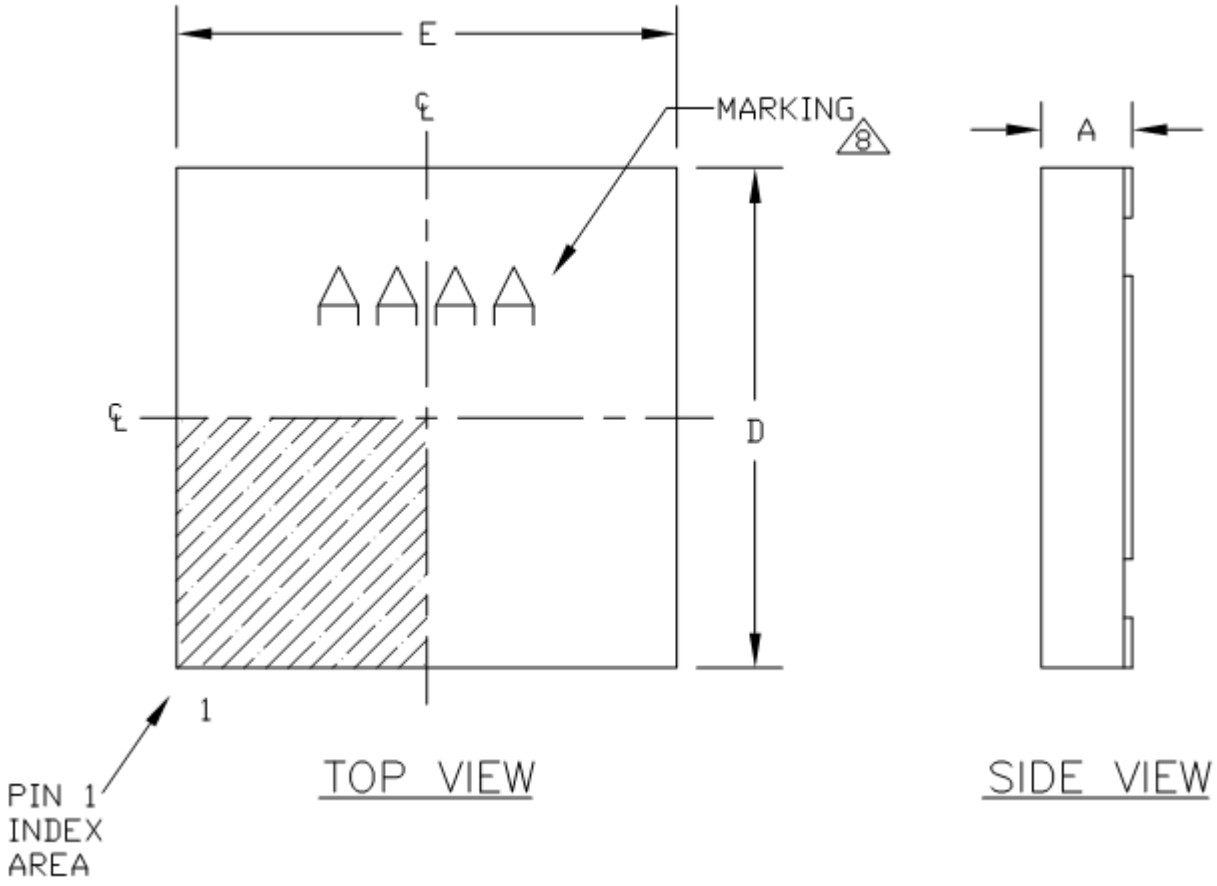
Careful PCB layout is critical to achieve low switching losses and stable operation. Use a multilayer board whenever possible for better noise immunity. Minimize ground noise by connecting high-current ground returns, the input bypass-capacitor ground lead, and the output-filter ground lead to a single point (star ground configuration). In normal operation, there are two power loops. One is formed when the MOSFET is on and the high current flows through IN—RSENSE—LEDs—Inductor—MOSFET—GND. The other loop is formed when the MOSFET is off when the high current circulates through RSENSE—LEDs—Inductor —freewheeling diode. To minimize noise interaction, each loop area should be as small as possible.

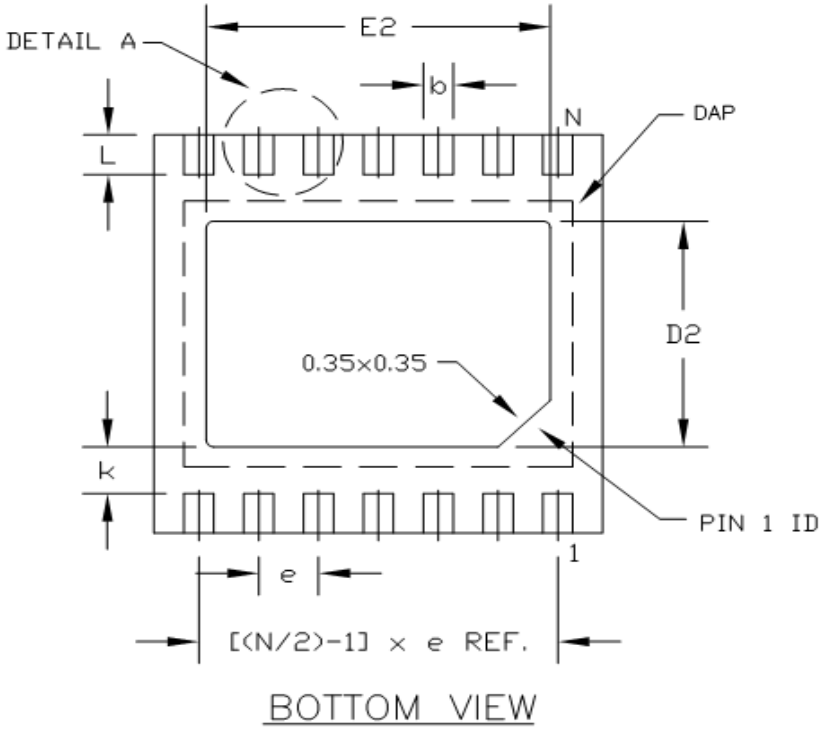
Place RSENSE as close as possible to the input filter and IN. For better noise immunity, a Kelvin connection is strongly recommended between CSN and RSENSE.

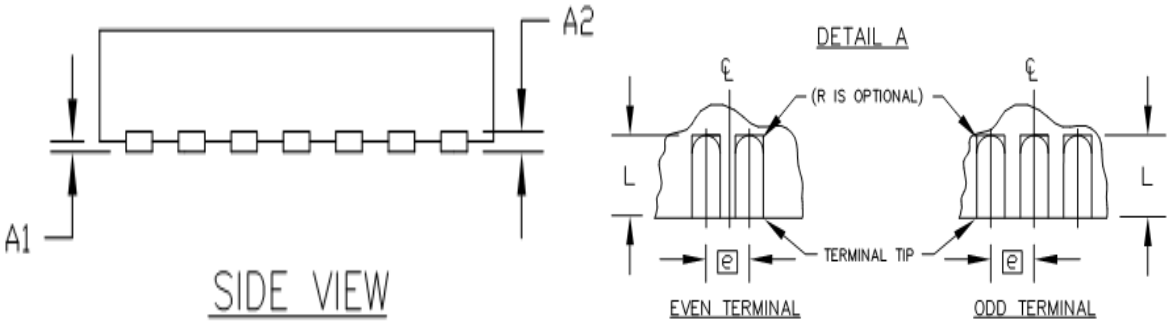
Connect the exposed paddle to a large-area ground plane for improved power dissipation.

■ Package Information

- **6-pin TDFN**







COMMON DIMENSIONS		
SYMBOL	MIN.	MAX.
A	0.70	0.80
D	2.90	3.10
E	2.90	3.10
A1	0.00	0.05
L	0.20	0.40
k	0.25 MIN.	
A2	0.20 REF.	

PACKAGE VARIATIONS							
PKG. CODE	N	D2	E2	e	JEDEC SPEC	b	[(N/2)-1] x e
T633-2	6	1.50±0.10	2.30±0.10	0.95 BSC	MO229 / WEEA	0.40±0.05	1.90 REF
T833-2	8	1.50±0.10	2.30±0.10	0.65 BSC	MO229 / WEEC	0.30±0.05	1.95 REF
T833-3	8	1.50±0.10	2.30±0.10	0.65 BSC	MO229 / WEEC	0.30±0.05	1.95 REF
T1033-1	10	1.50±0.10	2.30±0.10	0.50 BSC	MO229 / WEED-3	0.25±0.05	2.00 REF
T1033MK-1	10	1.50±0.10	2.30±0.10	0.50 BSC	MO229 / WEED-3	0.25±0.05	2.00 REF
T1033-2	10	1.50±0.10	2.30±0.10	0.50 BSC	MO229 / WEED-3	0.25±0.05	2.00 REF
T1433-1	14	1.70±0.10	2.30±0.10	0.40 BSC	- - - -	0.20±0.05	2.40 REF
T1433-2	14	1.70±0.10	2.30±0.10	0.40 BSC	- - - -	0.20±0.05	2.40 REF
T1433-3F	14	1.70±0.10	2.30±0.10	0.40 BSC	- - - -	0.20±0.05	2.40 REF