IT1611

High-Efficiency 40V 1.2A DC/DC LED Driver

General Description

IT1611 is a high efficiency, constant current, DC/DC converter and can be used for buck and boost application circuit. With the supply voltage source of 40V, this converter can drive up to 8 LEDs (depending on its forward voltage drop) connected in series. The maximum output current of IT1611 can be configured by an external resistor, and LED dimming can be controlled through DIM pin by using either a DC voltage or a PWM signal at DIM pin. IT1611 employs hysteretic control scheme without any compensation components, thus very fast load transient response can be achieved. Moreover, the exposed pad of MSOP-8L package enhances the thermal dissipation so that large driving current can be handled.

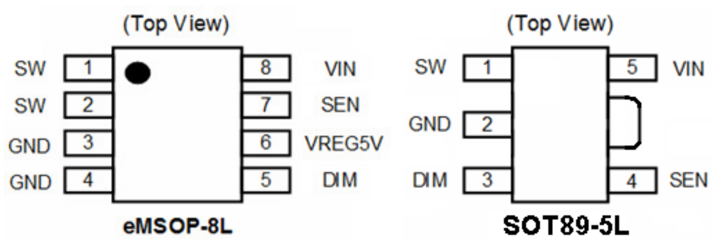
Applications

- High-Power LED driver
- Constant Current Sources
- Display Backlight
- General Illumination Lamps

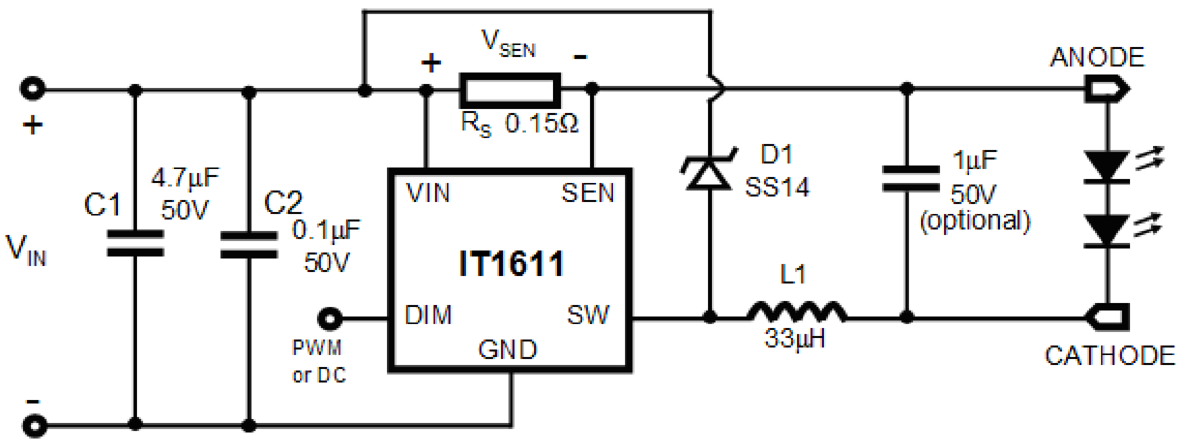
Features

- Up to 1.2A constant current output
- Better than 5% current accuracy
- Wide 6V to 40V operating input range
- 95% Efficiency @ V_{IN}=15V, 350mA, 4-LED
- Lightening up to 8 LEDs in series
- PWM/DC input dimming control
- Built-in soft-start / under voltage lock-out / LED open/short circuit protection functions
- Only 4 external components required
- Available in MSOP-8 and SOT89-5L with thermal PAD

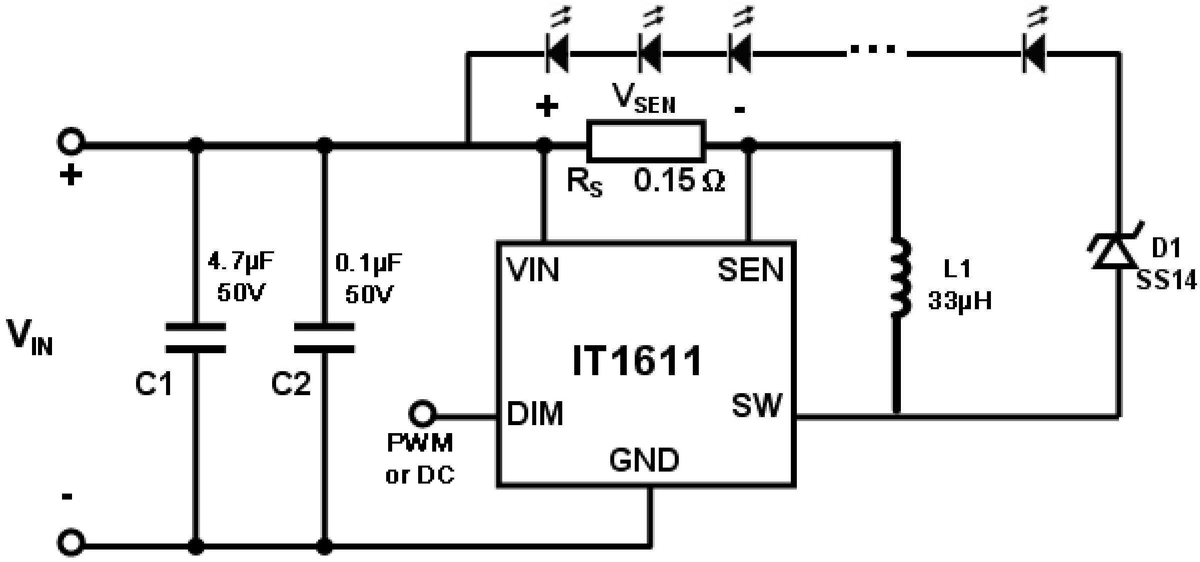
Pin Configuration



- Typical Application For Buck Circuit



- Typical Application For Boost Circuit



Pin Functions

No.	Name	Description
1	DIM	Dimming control and enable function pin: − Leave floating for normal operation. (V_{DIM} = 2.5V giving nominal average output current of 0.1/Rs) − Drive to below 0.2V to turn off output current − Drive with DC voltage (0.3V≦V_{DIM}≦2.5V) to adjust output current from 25% to 100% − Drive with PWM signal (low level < 0.4V and high level > 2.5V; transition time < 1us) allows the output current to be adjusted below the current level set by Rs. The current level is proportional to the duty cycle of the input PWM signal.
2	VREG5V	5V regulator output pin. By connecting a 0.1μF capacitor to GND, this pin can provide a load current less than 30mA.
3, 4	GND	GND pin. The exposed pad of eMSOP-8L package can be connected with this GND pin to enhance thermal resistance.
5, 6	SW	Switch pin. Connect inductor (L1) and freewheeling diode (D1) here. The track length of this pin should be minimized to reduce EMI.
7	VIN	Input voltage supply pin. Connecting a 4.7uF (>40V) ceramic capacitor from this pin to GND is a must.
8	SEN	Configure the output current of the device. By connecting a resistor Rs between VIN and this pin, the output current is set to 0.1/Rs (A).

Absolute Maximum Rating

Symbol	Parameter	Rating	Units
ESD HBM	Human Body Model for ESD protection	2000	kV
ESD MM	Machine Model for ESD protection	200	V
V_{IN}	Continuous V_{IN} pin voltage relative to GND	-0.3 ~ 45	V
V_{SW}	SW voltage relative to GND	-0.3 ~ 45	V
V_{DIM}	DIM pin input voltage	-0.3 ~ 6	V
I_{SW-RMS}	DC or RMS switch current	1.3	A
I_{SW-PK}	Peak switch current	2	A
T_J	Junction temperature	150	℃
T_{LEAD}	Lead soldering temperature	300	℃
T_{ST}	Storage temperature	-65 ~ 150	℃

Cautions: Stress beyond those listed under “Absolute Maximum Rating” may cause permanent damage to the device. Device reliability may be affected by exposure to absolute maximum rating conditions for extend period of times. Semiconductors devices are ESD sensitive and may be damaged by exposure to ESD events. Suitable ESD precautions should be taken when handling and transporting these devices

Recommended Operating Conditions

Symbol	Parameter	Min	Max	Units
V_{IN}	Operating input voltage relative to GND	6	40	V
$V_{DIM,H}$	Voltage “HIGH” for PWM dimming relative to GND	1.3	5.5	V
$V_{DIM,L}$	Voltage “LOW” for PWM dimming relative to GND	0	0.3	V
$V_{DIM,DC}$	Voltage range for to 100% DC dimming relative to GND	0.4	2.5	V
f_{SW}	Maximum switching frequency		1	MHz
I_{SW}	Continuous switch current		1.2	A
T_J	Junction temperature range	-40	125	℃

Electrical Characteristics

V_{IN}=12V, L1=68μH, C_{IN}=10μF, T_A = 25°C unless otherwise specified

Parameter	Symbol	Condition	Min.	Typ.	Max.	Unit
Quiescent current	I_Q	Output not switching	--	320	--	μA
Supply current	I_S	DIM pin floating, f_{SW}=250kHz	--	1.5	--	mA
Efficiency	η	I_{SW}=660mA, V_{OUT}=10.8V	--	95	--	%
Switch on resistance	$R_{DS(ON)}$		--	0.25	--	Ω
SW rise time	t_R	V_{SEN}=0.1V, R_S=0.15Ω,	--	10	--	ns
SW fall time	t_F	C_L=15pF, V_{SW} 10%~90%	--	20	--	ns
Recommended duty cycle range	D_{SW}		20	--	80	%
SW leakage current	--		--	--	0.3	μA
CURRENT SENSE						
SEN pin input current	I_{SEN}		--	47	--	μA
Mean current sense voltage	V_{SEN}		--	120	--	mV
Sense threshold hysteresis	$\triangle V_{SEN}$		--	±20	--	mV
UNDER VOLTAGE LOCK-OUT						
Lock-out threshold	--		--	5.4	---	V
Recovery threshold	--		--	5.6	--	V
THERMAL SHUTDOWN						
Shutdown threshold	T_{SD}		--	160	--	°C
Recovery hysteresis	T_{SD-HYS}		--	30	--	°C
PWM DIMMING						
Output current rising time	t_{ON}	C_{OUT}=1μF,f_{DIM}=1kHz,	--	8	--	μs
Output current falling time	t_{OFF}	D_{DIM}=50%, I_{SW}=660mA	--	15	--	μs
Duty cycle range of PWM DIM	D_{DIM}	f_{DIM}=1kHz	1	--	100	%
Recommended PWM frequency	f_{DIM}		0.5	1	5	kHz
DIM pin input resistance	R_{DIM-IN}	Referred to internal reference	--	20	--	kΩ
THERMAL RESISTANCE						
Junction to ambient	θ_{JA}		--	69	--	°C/W
Junction to case	θ_{JC}		--	4.3	--	°C/W

Typical Performance Characteristics

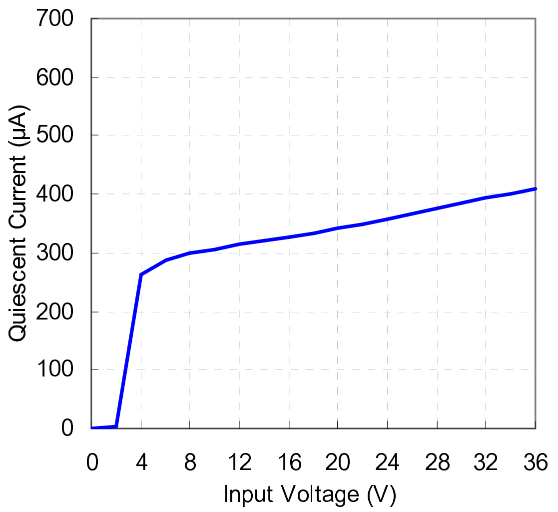


Fig. 1 Quiescent Current vs. Input Voltage

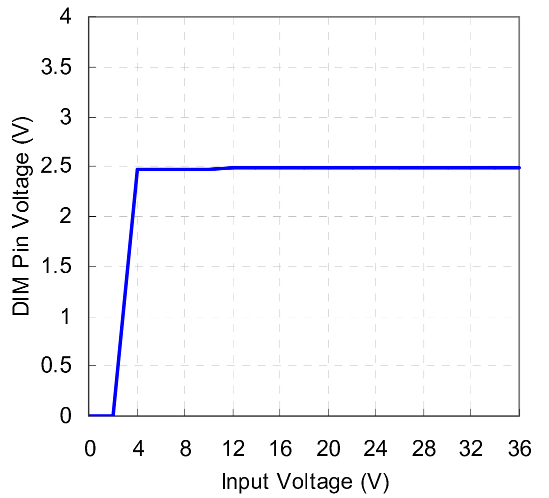


Fig. 2 DIM Pin Voltage vs. Input Voltage

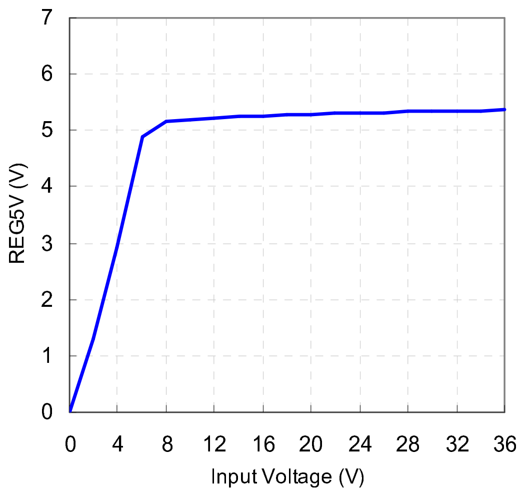


Fig. 3 VREG5V Voltage vs. Input Voltage

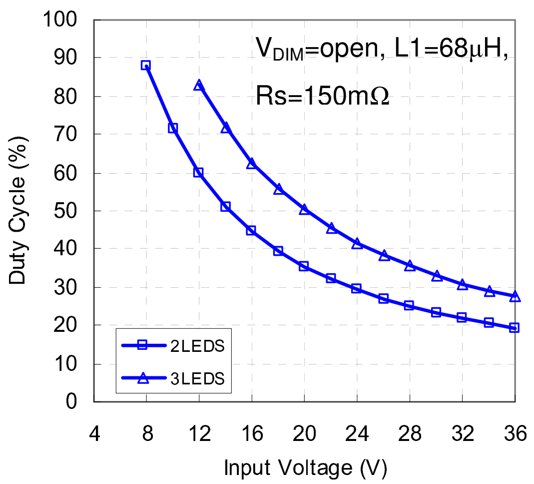


Fig. 4 Duty cycle v.s. Input Voltage

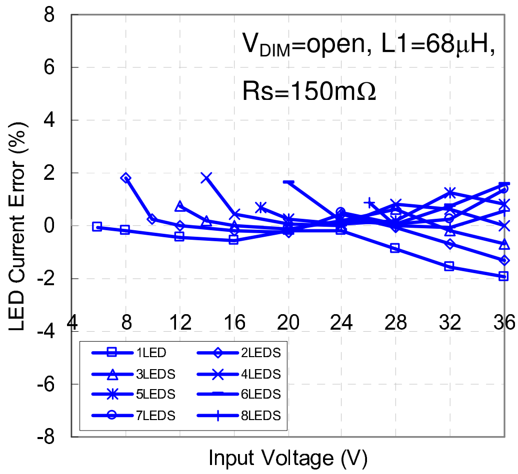


Fig. 5 Current Accuracy v.s. Input Voltage

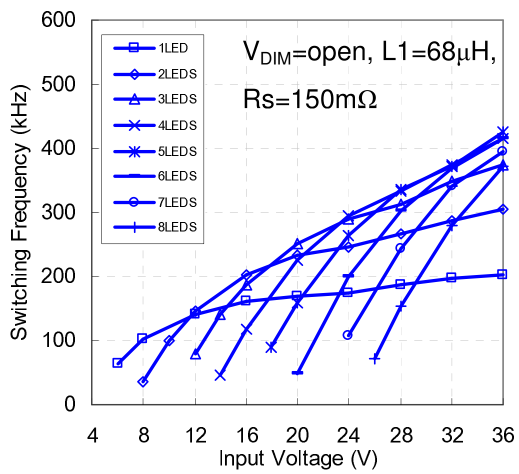


Fig. 6 Switching Frequency v.s. Input Voltage

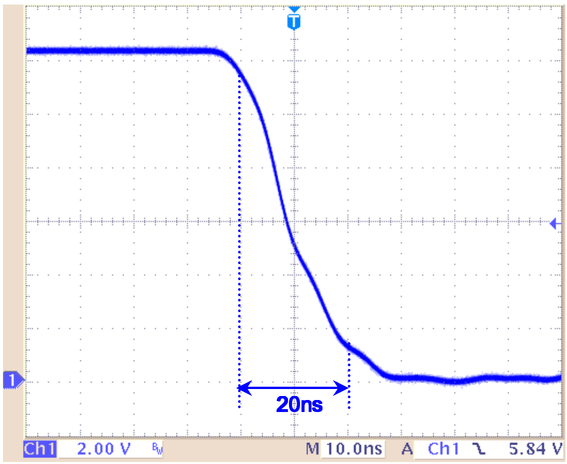


Fig. 7 SW Output Fall Time

(V_{SEN}=0.1V, R_S=0.15Ω, C_L=15pF)

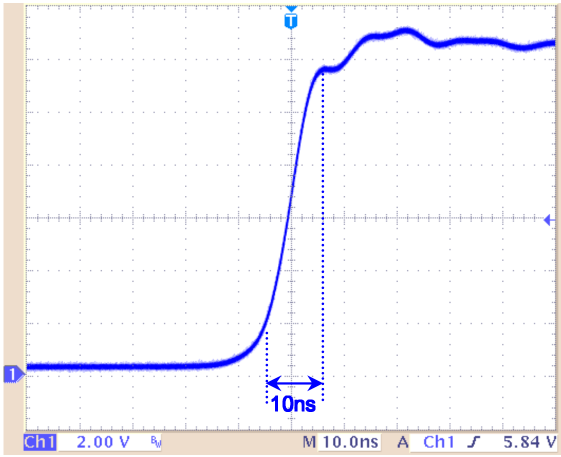


Fig. 8 SW Output Rise Time

(V_{SEN}=0.1V, R_S=0.15Ω, C_L=15pF)

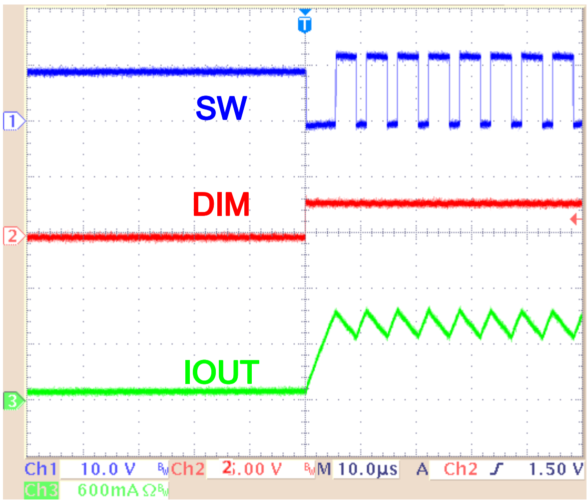


Fig. 9 Rise Time of Output Current

(C_{OUT}=1µF,f_{DIM}=1kHz, D_{DIM}=50%, I_{SW}=660mA)

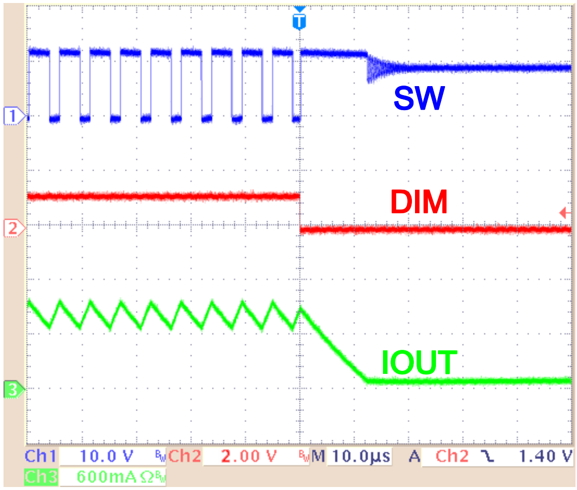


Fig. 10 Fall Time of Output Current

(C_{OUT}=1µF,f_{DIM}=1kHz, D_{DIM}=50%, I_{SW}=660mA)

Functional Block Diagram

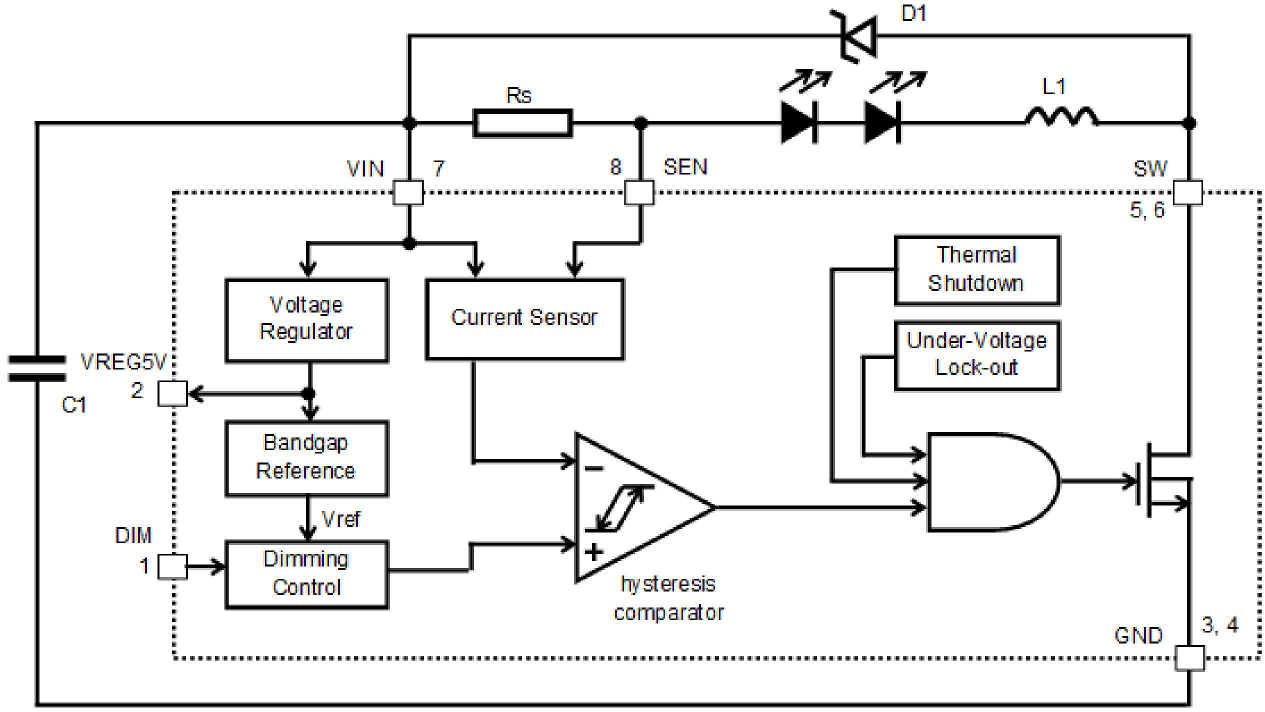


Fig. 11 Function Block Diagram with Pin Connection

Application Information

IT1611 Operation

IT1611 is a hysteretic (or equal ripple) DC/DC converter with integrated power switch. Fig. 11 shows the circuitry connection of the chip and the external devices for buck application. The internal feedback loop with external sense resistor Rs and inductor L1 forms a self-oscillating buck converter. When the SW is ON, the pin SW is shorted to GND. There is a current flowing from VIN to GND through the resistor Rs, LED and inductor L1. This current is increased during the ON time and energy is stored in this inductor. When the SW pin is suddenly OFF, the energy stored in the inductor generates a high voltage at the SW. This voltage value is related to the stored energy due to the current flowing through the inductor. If this high voltage value is higher than the sum of the forward bias of the D1 and the voltage of the pin VIN, the D1 is turn on and maintain constant current loop. This sequence of events repeats at a constant frequency to regulate the output current, which is then supply to the series of LED.

Under-Voltage Lock-out Function

IT1611 has a built-in under voltage lock-out (UVLO) protection circuit. With lower supply voltage, the switch duty cycle of IT1611 will be high and the device power dissipation will be larger. The UVLO protection circuit monitors the input voltage to prevent any damages on the chip caused by the undesired input voltage. IT1611 will turn off the LED output current whenever it detects the input voltage lower than 5.4V and recovery to normal operation when the input voltage is increased above the release voltage, 5.6V.

Thermal Shutdown Protection Function

When driving large load current, care must be taken to avoid exceeding the thermal dissipation limitation of the package. If the junction temperature exceeds 160℃, the thermal shutdown protection circuit will turn off the output current. When the junction temperature is decreased to ~130℃, the output current will be turned on again.

Resistor Selection for LED Current Control

The current-setting resistor is used to control the output current flowing through the LED. This resistor is connected between VIN and SEN, and the average current I_{OUT} is defined by this voltage and R_S according to $I_{OUT} = V_{SEN} / R_S = 120mV / R_S$. If $R_S = 0.15\Omega$, the output average current is 800mA.

PWM Dimming

LED output current can be adjusted by applying a low frequency PWM signal to the DIM pin to turn the device on and off, as shown in Fig. 12. This will produce an average output current proportional to duty cycle of the dimming signal. For better current accuracy, the switching frequency should be increased and PWM dimming frequency should be decreased.

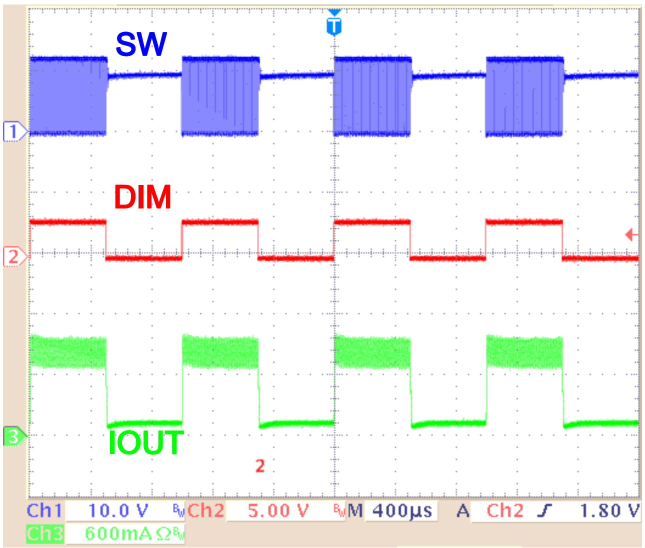


Fig. 12 Typical Waveform with PWM Dimming

DC Dimming

LED output current can be further controlled by driving an external DC voltage between 0.3V and 2.5V to DIM pin. If V_{DIM} is higher than 2.5V, the LED current will be clamped to ~100% of the current level set by 0.1/Rs. When V_{DIM} voltage falls below the threshold, 0.2V, the output switch is turned off.

Built-in Regulator

IT1611 has a built-in regulator with fixed 5V output voltage at VREG5V pin. It provides a fixed 5V voltage output when V_{IN} is larger than 6V. This pin can be used as the supply voltage for other logic ICs (if used) on the system PCB with the load current less than 30mA. A small size ceramic capacitors ~0.1µF between VREG5V and GND is recommended as its decoupling.

Diode Selection

For better performance, the rectifier (D1) should be a fast low capacitance Schottky Barrier Diode (SBD) with low reverse leakage at the maximum operating voltage and temperature. The SBD also provides better efficiency due to a low forward voltage drop and a short reverse recovery time. Since the circuit transfer energy from an inductor into V_{IN} through a SBD, large current may flow through the SBD. The peak/continuous current rating of the SBD should be larger than the peak/continuous inductor current.

Capacitor Selection

Switching converters draw current from the input supply in pulse forms with very fast rise and fall times. The input capacitor C1 is required to reduce the resulting voltage ripple at the input supply. The voltage rating of the capacitor has to be higher than the voltage it is suffered. For example, since the input voltage range is from 6V to 40V, the voltage rating for the input capacitor should be larger than 40V. The capacitance values may be higher for the security reason. IT1611 recommends the small size ceramic capacitors with its value larger than 4.7μF. X5R and X7R types are recommended because they retained capacitances over wider temperature range than other types such as Z5U or Y5V. Moreover, another C2 with 0.1μF can be employed to further improve the high frequency decoupling.

Inductor Selection

When the inductor is chosen, its DC resistance and the maximum current rating have to be considered. This inductor connected between the LED and the pin SW is an important device to store and transfer the energy. Considering the DC resistance of the inductor strongly affects the power efficiency, IT1611 recommends a low DC resistance inductor. The recommend the inductor value for IT1611 are in the range of 33μH to 100μH. Larger inductances are recommended at higher supply voltages in order to minimize the current error due to switching delays. The current flow through the inductor can not exceed its maximum current rating; otherwise the device will be destroyed. The chosen inductor should have a saturation current higher than peak current and a continuous current rating above the required mean output current.

Output Ripple Reduction

Peak-to-peak current ripple can be reduced, if required, by shunting a capacitor across the LEDs (refer to the typical application circuit). A value of 1μF will reduce the ripple current by ~3x. Proportionally lower ripple can be achieved with higher values. The capacitor will not affect the operating frequency or efficiency, but it will increase start-up delay.

PCB layout consideration

IT1611 is a switching regulator with fast SW rising and falling edges. Therefore, careful considerations of PCB layout and decoupling should be taken to obtain stable operation and better noise immunity. There are several factors to be considered.

1. **Ground plane:** Keep a complete ground plane is helpful to eliminate the switching noise. By soldering the IC’s GND pin directly to the ground plane, the output power and the efficiency can be maximized and the output voltage ripple can be reduced. To enhance the heat dissipation, the area of ground plane, which IC’s heat sink (if used) is soldered on, should be as large as possible.

2. **Resonant loop:** As illustrated in Fig. 13, a resonant loop from SW pin to the anode if the Schottky diode, D1, and then from D1's cathode to the decoupling capacitors C2. SW pin is a fast switching node, and thus the high frequency noise (di/dt) at this resonant loop will affect other sensitive analog signals. This loop area on PCB should be as small as possible.

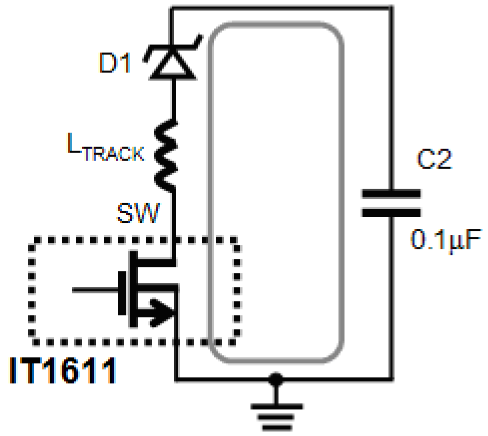


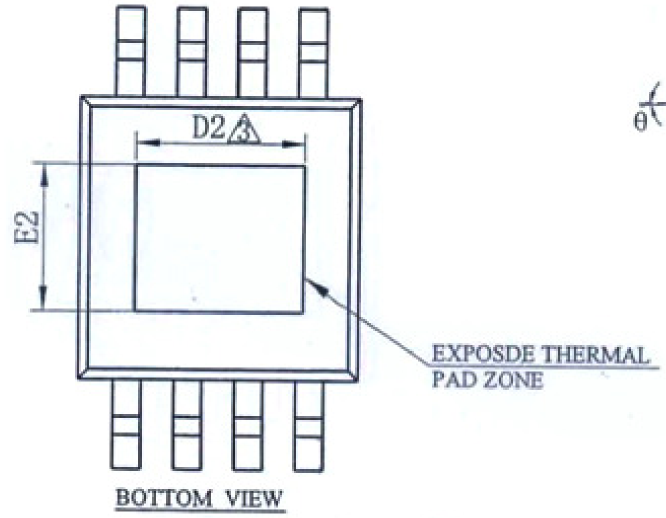
Fig. 13 PCB resonant loop

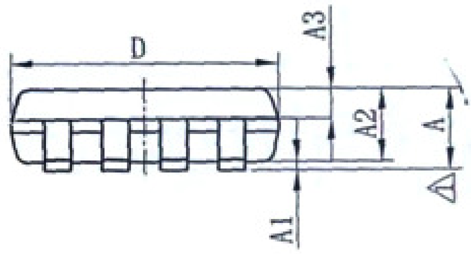
3. **Decoupling capacitor:** The input capacitor should be placed as close to IC's VIN pin and D1's cathode as possible. It is recommended to keep the IC's GND pin and the ground leads of input capacitor less than 5mm.

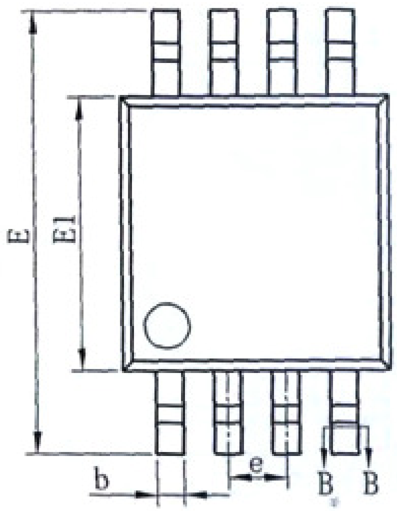
4. **Current sense resistor:** It is important to minimize any track resistance in series with Rs. The cathode current of the Schottky diode and other high frequency nodes of the resonant loop mentioned above should not cross the PCB track between Rs and VIN.
5. **DIM pin:** This pin is a high-impedance input, when left floating, PCB tracks to this pin should be as short as possible and the high voltage tracks should be far away from this pin to reduce noise pickup.
6. **Inductor:** Mount the coil as close to the device pin as possible to minimize parasitic resistance and inductance. which wil degrade the efficiency. The freewheeling diode D1, SW pin, and the inductor should be as close as possible to each other to avoid ringing.

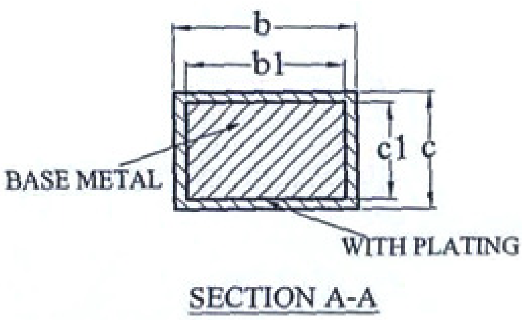
Package Information

eMSOP-8L



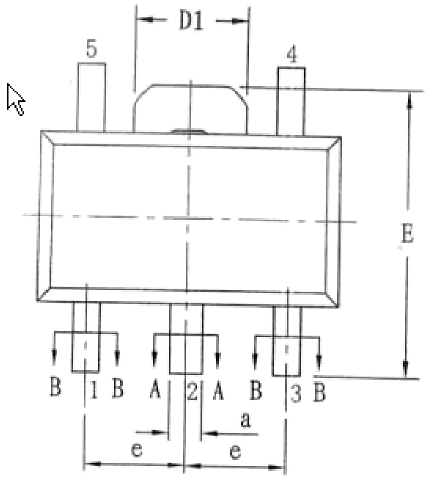


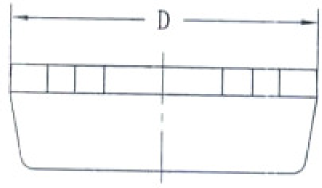


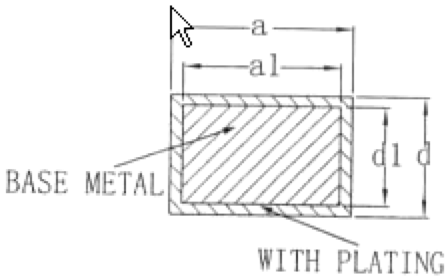


SYMBOL	MILLIMETER		
	MIN	NOM	MAX
A	—	—	1.10
A1 (△2)	0.05	—	0.15
A2	0.75	0.85	0.95
A3	0.30	0.35	0.40
b	0.29	—	0.38
b1	0.28	0.30	0.33
c	0.15	—	0.20
c1	0.14	0.152	0.16
D	2.90	3.00	3.10
D2 (△3)	1.80REF		
E	4.70	4.90	5.10
E1	2.90	3.00	3.10
E2	1.55REF		
e	0.65BSC		
L	0.40	—	0.70
L1	0.95BSC		
θ	0	—	8°

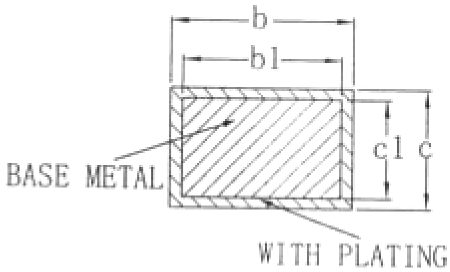
SOT89-5L



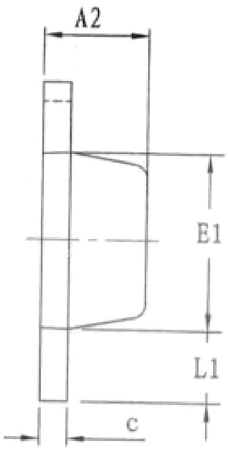




SECTION A-A



SECTION B-B



SYMBOL	MILLIMETER		
	MIN	NOM	MAX
A2	1.40	1.50	1.60
b	0.38	--	0.47
b1	0.37	0.40	0.43
c	0.36	--	0.46
c1	0.35	0.38	0.41
a	0.46	--	0.56
a1	0.45	0.48	0.51
d	0.36	--	0.46
d1	0.35	0.38	0.41
D	4.30	4.50	4.70
D1	1.70REF		
E	4.00	4.20	4.40
E1	2.30	2.50	2.70
e	1.50BSC		
L1	0.80	1.00	1.20