High Voltage Multi-Topology LED Driver

General Description

The RT8450/B is a current mode PWM regulator for LED driving applications. With an 1.5A switch on board and wide input (4.5V to 40V) and/or output (up to 50V)ranges the RT8450/B can operate in any of the three common topologies : Buck, Boost or Buck-Boost.

With 800k/500kHz operating frequency, the external PWM inductor and input/output capacitors can all be small. High efficiency is achieved by a 190mV current sensing.

Dimming can be done either analog or PWM signal. An unique built-in clampping comparator and filtering resistor allow easy low noise analog dimming conversion from PWM signal with only one external capacitor.

The RT8450/B is available in a TSSOP-16 (Exposed Pad) and WDFN-12L 3x3 packages.

Ordering Information

RT8450/B □□

- Package Type
  - CP : TSSOP-16 (Exposed Pad)
  - QW : WDFN-12L 3x3 (W-Type) (Exposed Pad-Option 1)
- Lead Plating System
  - G : Green (Halogen Free and Pb Free)
- Switching Frequency
  - 500kHz
  - 800kHz

Note :

Richtek products are :

- RoHS compliant and compatible with the current requirements of IPC/JEDEC J-STD-020.
- Suitable for use in SnPb or Pb-free soldering processes.

Marking Information

For marking information, contact our sales representative directly or through a Richtek distributor located in your area.

Features

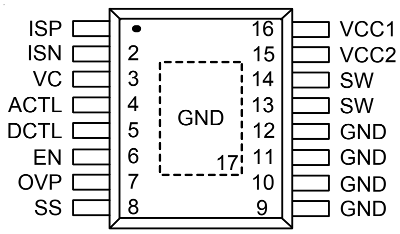
- **High Voltage : V_{IN} Up to 40V, V_{OUT} Up to 50V**
- **1.5A Switch Current**
- **Buck, Boost or Buck-Boost Operation**
- **Current Mode PWM with 800kHz (RT8450) and 500kHz (RT8450B) Switching Frenquency**
- **Easy Dimming : Analog, PWM Digital or PWM Converting to Analog with One External Capacitor**
- **Programmable Soft-Start to Avoid Inrush Current**
- **Programmable Over Voltage Protection to Limit Output Voltage**
- **V_{IN} Under Voltage Lockout and Thermal Shutdown**
- **RoHS Compliant and Halogen Free**

Applications

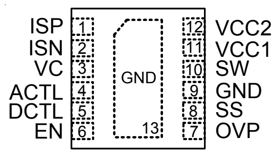
- GPS, Portable DVD Backlight
- Desk Lights and Room Lighting
- Industrial Display Backlight

Pin Configurations

(TOP VIEW)



TSSOP-16 (Exposed Pad)



WDFN-12L 3x3

Typical Application Circuit

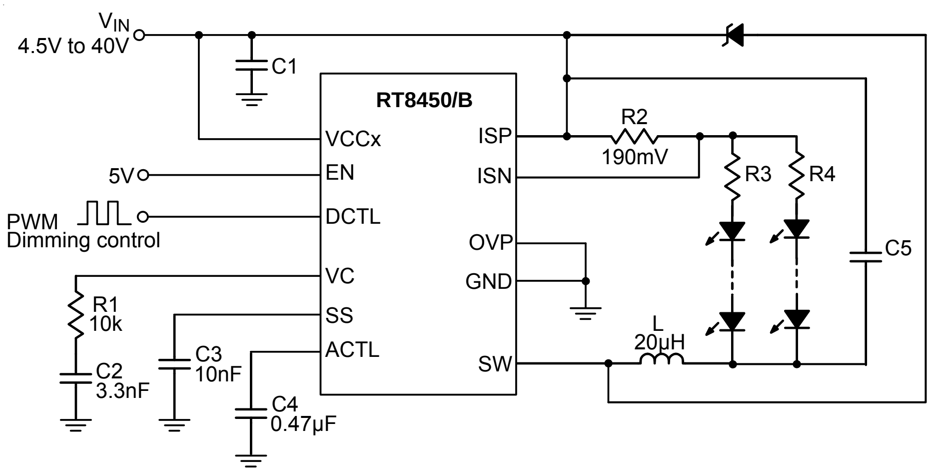


Figure 1. PWM to Analog Dimming Buck Configuration

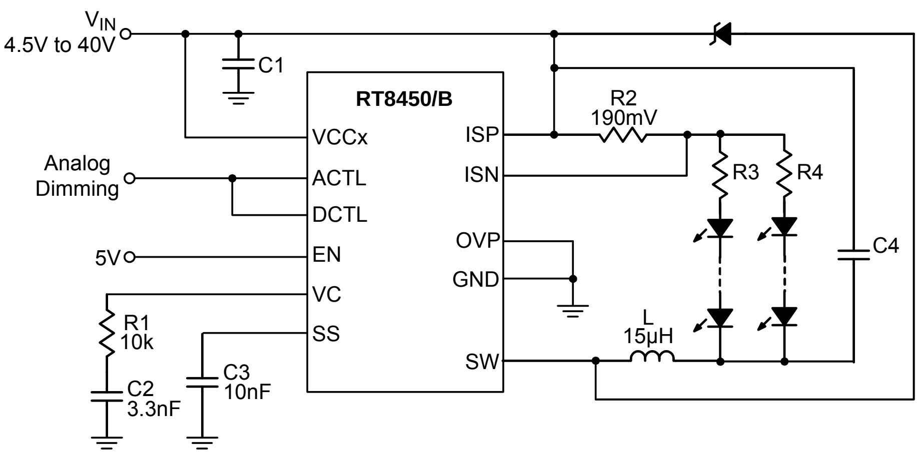


Figure 2. Analog Dimming Buck Configuration

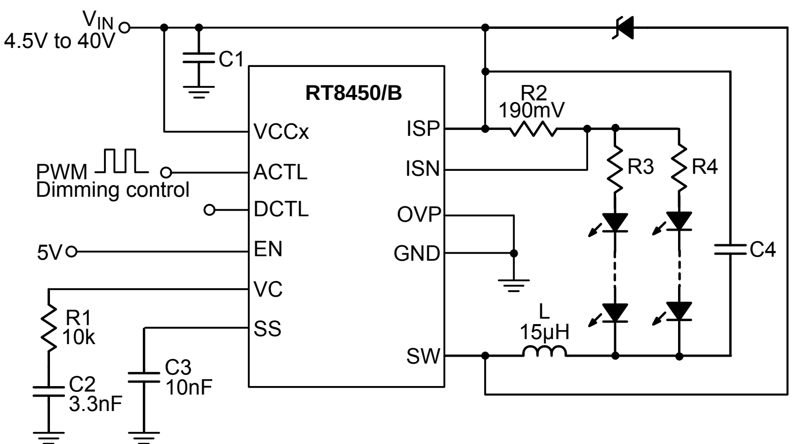


Figure 3. PWM Dimming Buck Configuration Through ACTL Pin

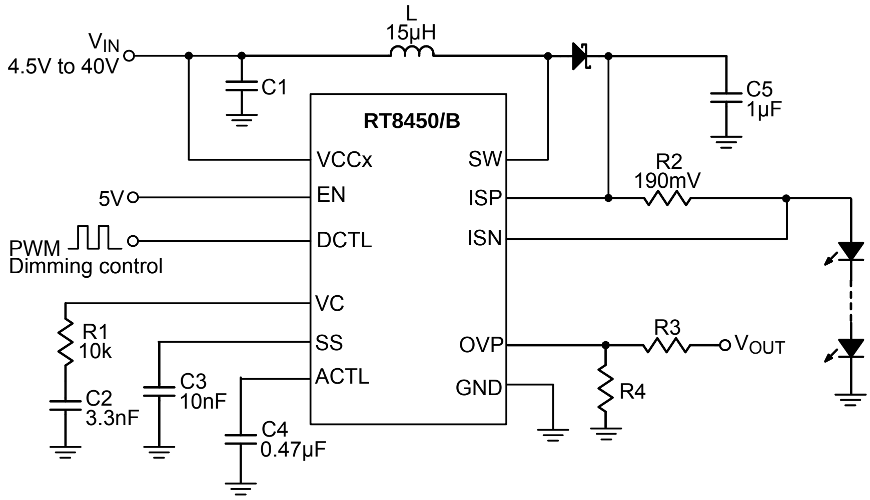


Figure 4. PWM to Analog Dimming Boost Configuration

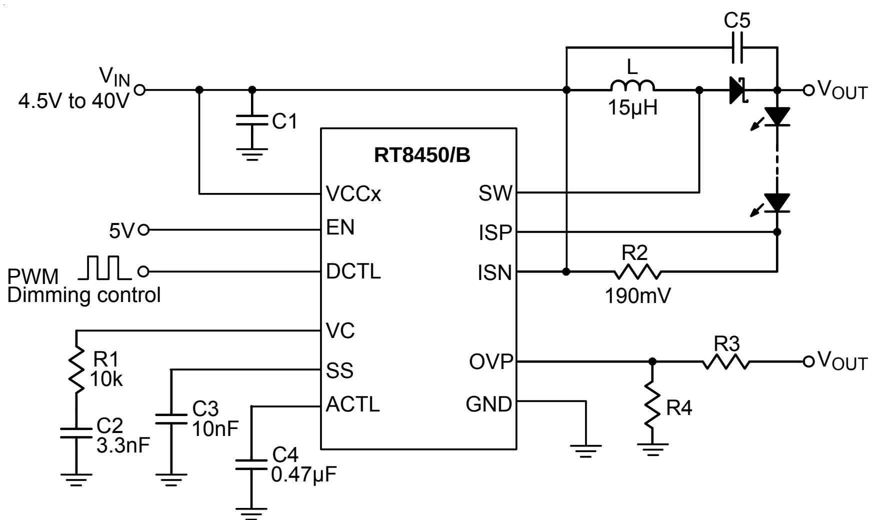


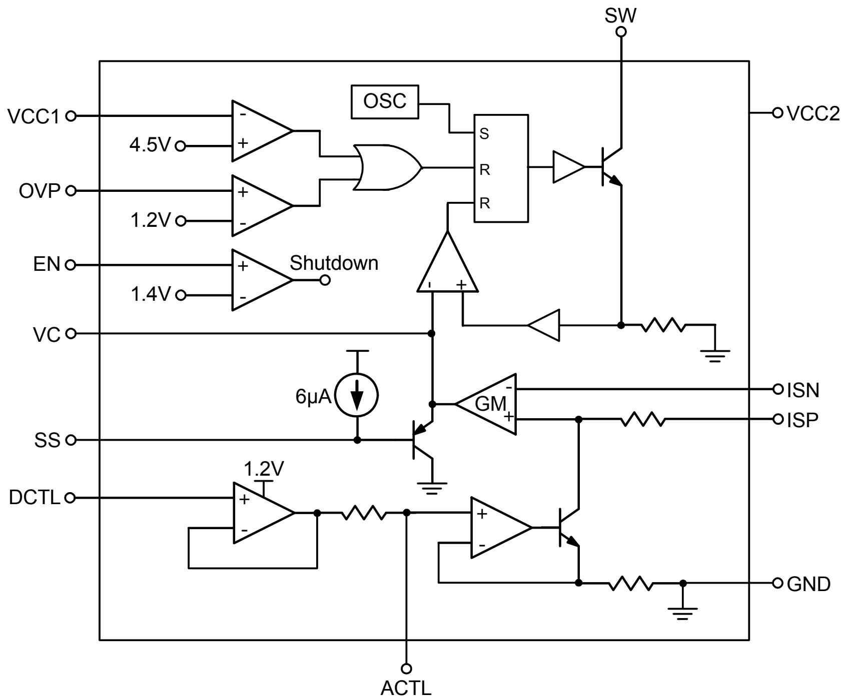
Figure 5. PWM to Analog Dimming Buck-Boost Configuration

Functional Pin Description

Pin No.		Pin Name	Pin Function
TSSOP-16 (Exposed Pad)	WDFN-12L 3x3		
1	1	ISP	Current Sense Amplifier Positive Input.
2	2	ISN	Current Sense Amplifier Negative Input. Voltage threshold between ISP and ISN is 190mV.
3	3	VC	PWM Boost Converter Loop Compensation Node.
4	4	ACTL	Analog Dimming Control. Effective programming range is between 0.3V and 1.2V.
5	5	DCTL	By Adding a 0.47µF Filtering Capacitor on ACTL Pin, the PWM dimming signal on DCTL pin will be averaged and converted into analog dimming signal on ACTL pin. V_{ACTL} = 1.2V x PWM dimming duty cycle .
6	6	EN	Chip Enable (Active High), when low chip is in shutdown mode.

Pin No.		Pin Name	Pin Function
TSSOP-16 (Exposed Pad)	WDFN-12L 3x3		
7	7	OVP	Over voltage protection. PWM boost converter turns off when V_{OVP} goes higher than 1.2V.
8	8	SS	Soft-Start Pin, a capacitor of at least 10nF is required for soft-start.
9, 10, 11, 12, 17 (Exposed Pad)	9, 13 (Exposed Pad)	GND	Ground. The exposed pad must be soldered to a large PCB and connected to GND for maximum power dissipation.
13, 14	10	SW	PWM Boost Converter Switch Node.
15	12	VCC2	Bipolar Power Switch Base Current Supply. VCC2 can be connected either to VCC1 or to a separate lower voltage, as low as 3V, for better system efficiency and/or heat concern. A good bypass is necessary.
16	11	VCC1	Power Supply of the Chip. For good bypass, a low ESR capacitor is required.

Function Block Diagram



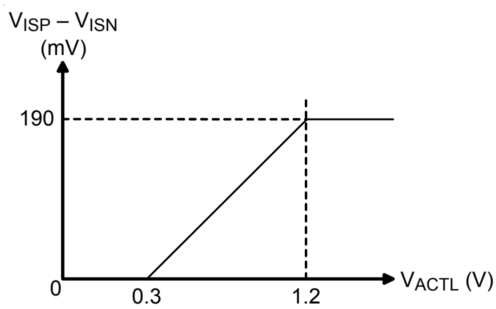


Figure 6

Absolute Maximum Ratings (Note 1)

- Supply Input Voltage, V_{CC1}, V_{CC2} ---------- 45V
- SW Pin Voltage at Switching Off, ISP, ISN ---------- 55V
- DCTL, ACTL, OVP Pin Voltage ---------- 8V (Note 2)
- EN Pin Voltage ---------- 20V
- Power Dissipation, P_D @ T_A = 25°C
  TSSOP-16 ---------- 2.66W
  WDFN-12L 3x3 ---------- 1.667W
- Package Thermal Resistance (Note 3)
  TSSOP-16, θ_{JA} ---------- 47°C/W
  WDFN-12L 3x3, θ_{JA} ---------- 60°C/W
  WDFN-12L 3x3, θ_{JC} ---------- 8.2°C/W
- Junction Temperature ---------- 150°C
- Lead Temperature (Soldering, 10 sec.) ---------- 260°C
- Storage Temperature Range ---------- –65°C to 150°C
- ESD Susceptibility (Note 4)
  HBM (Human Body Mode) ---------- 2kV
  MM (Machine Mode) ---------- 200V

Recommended Operating Conditions (Note 5)

- Junction Temperature Range ---------- –40°C to 125°C
- Ambient Temperature Range ---------- –40°C to 85°C

Electrical Characteristics

(V_{CC1} = V_{CC2} = 12V, No Load on any Output, T_A = 25°C, unless otherwise specified)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Overall						
Supply Voltage	V_{CC1}		4.5	--	40	V
Supply Voltage VCC2 for Switch Base Drive	V_{CC2}		3	--	40	V
Supply Current	I_{VCC1}	VC ≤ 0.4V (Switching off)	--	4	6	mA
Supply Current	I_{VCC2}	V_{CC1} = V_{CC2} = 24V, I_{SW} ≤ 1A	--	I_{SW}/70	I_{SW}/40	A
Shutdown Current	I_{SHDN_VCC1}	V_{EN} ≤ 0.7V	--	12	--	μA
Shutdown Threshold	V_{EN}		1	1.4	--	V
EN Input Current		V_{EN} = 3V	--	--	0.5	μA
Current Sense Amplifier						
Input Threshold (V_{ISP} – V_{ISN})		4.5V ≤ common mode ≤ 50V	170	190	210	mV
Input Current	I_{ISP}	V_{ISP} = 24V	--	100	--	μA
Input Current	I_{ISN}	V_{ISN} = 24V	--	40	--	μA
Output Current	I_{VC}	2.4V > VC > 0.2V	--	±20	--	μA
VC Threshold for PWM Switch Off			--	0.7	--	V

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
LED Dimming						
Analog Dimming ACTL Pin Input Current	I_{ACTL}	$0.3V \le V_{ACTL} \le 1.2V$	--	--	3	μA
LED Current Off Threshold at ACTL	V_{ACTL}		--	0.2	–	V
DCTL Input Current	I_{DCTL}	$0.3V \le V_{DCTL} \le 6V$	--	--	0.5	μA
PWM BOOST Converter						
Switching Frequency	f_{SW}	RT8450	600	800	1000	kHz
		RT8450B	400	500	600	kHz
Maximum Duty Cycle (Note 6)	D_{MAX}	RT8450	--	80	–	%
		RT8450B	--	86	–	
Minimum on Time			--	250	–	ns
SW On-Voltage	V_{SW}	I_{SW} = 0.5A	--	0.4	–	V
SW Current Limit	I_{LIM_SW}		1.25	1.5	–	A
OVP and Soft Start						
OVP Threshold	V_{OVP}		--	1.2	–	V
OVP Input Current	I_{OVP}	$0.7V \le V_{OVP} \le 1.5V$	--	--	0.5	μA
Soft Start SS Pin Current	I_{SS}	$V_{SS} \le 2V$	--	6	–	μA

Note 1. Stresses beyond those listed under "Absolute Maximum Ratings" may 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 in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Note 2. If connected with a 20kΩ serial resistor, ACTL and DCTL can go up to 40V.

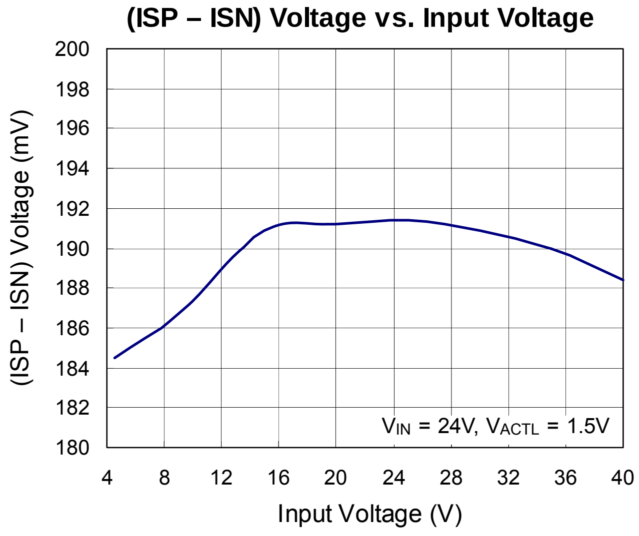
Note 3. θ_{JA} is measured in the natural convection at T_A = 25°C on a high effective four layers thermal conductivity test board of JEDEC 51-7 thermal measurement standard.

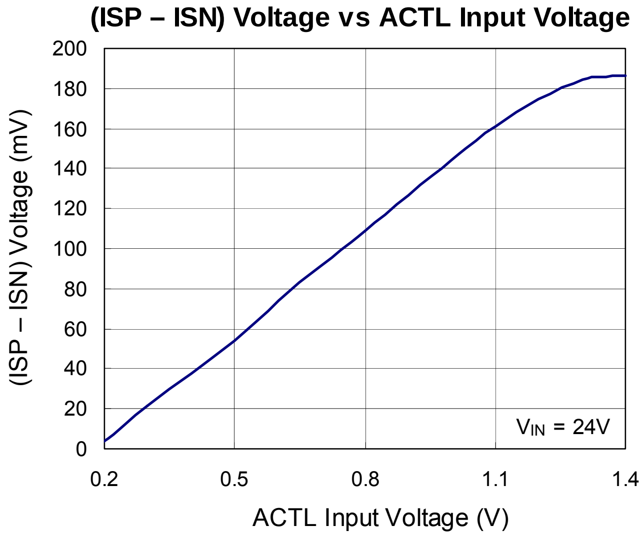
Note 4. Devices are ESD sensitive. Handling precaution is recommended.

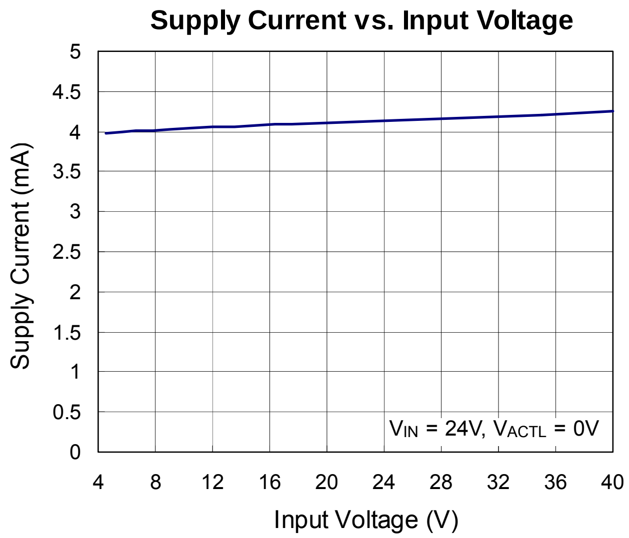
Note 5. The device is not guaranteed to function outside its operating conditions.

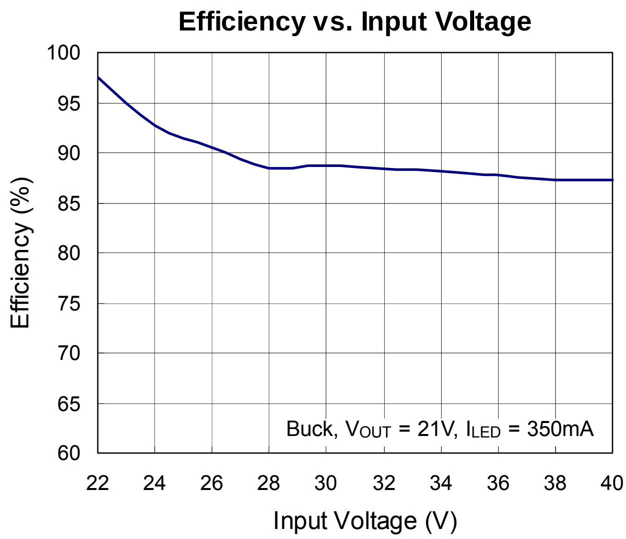
Note 6. When the natural maximum duty cycle of the switching frequency is reached, the switching cycle will be skipped (not reset) as the operating condition requires to effectively stretch and achieve higher on cycle than the natural maximum duty cycle set by the switching frequency.

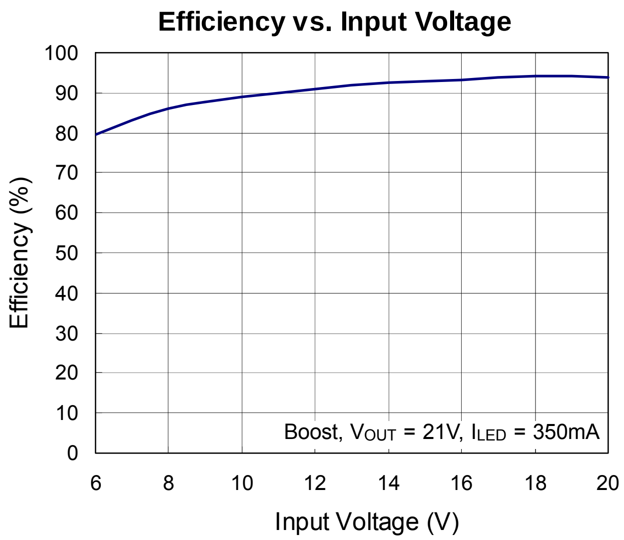
Typical Operating Characteristics

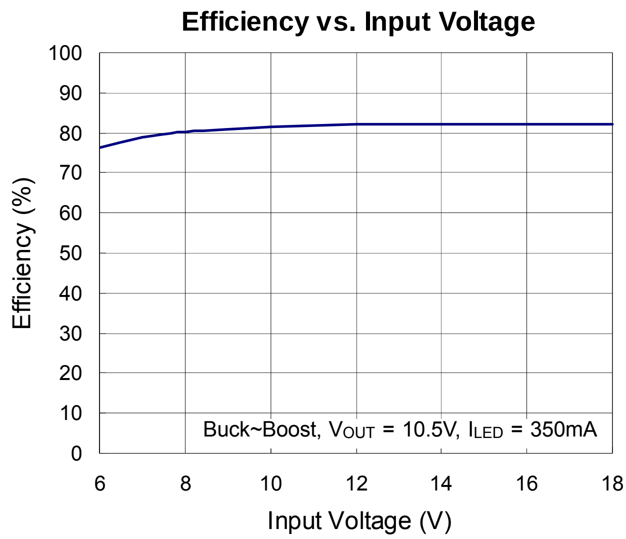


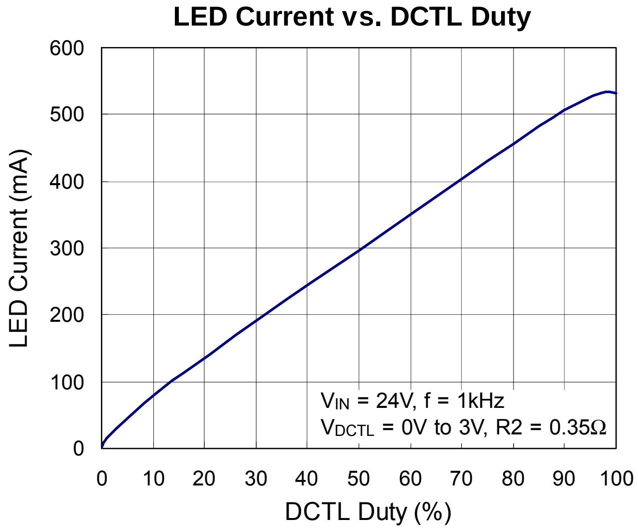


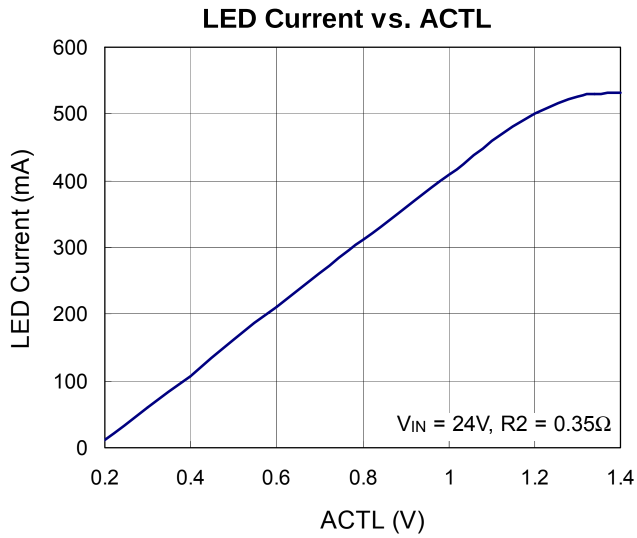


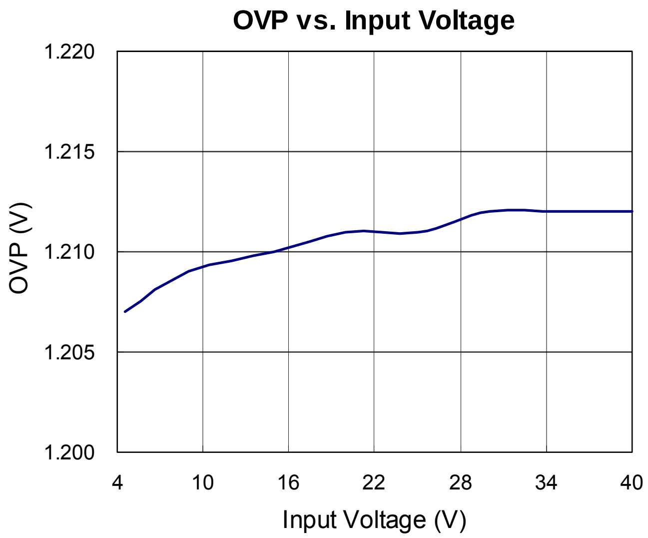


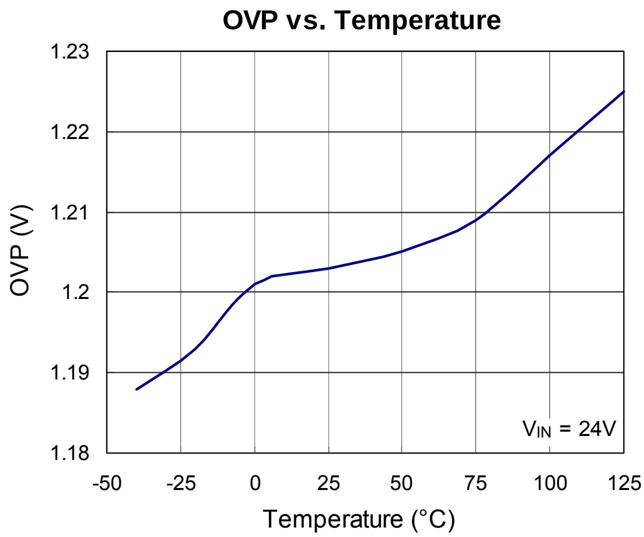


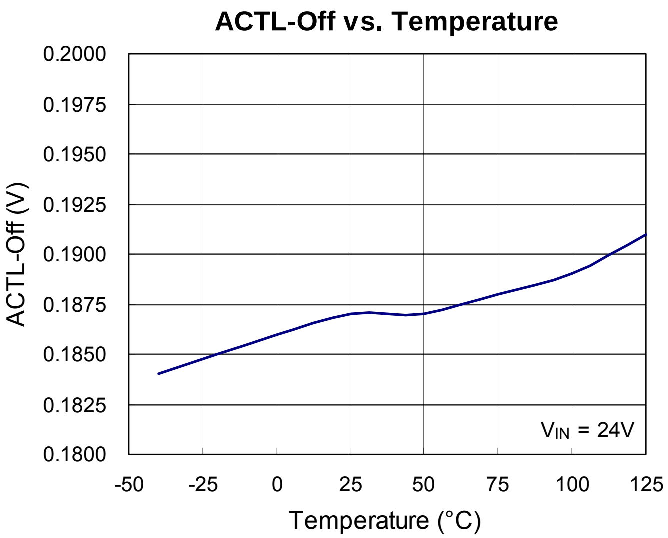


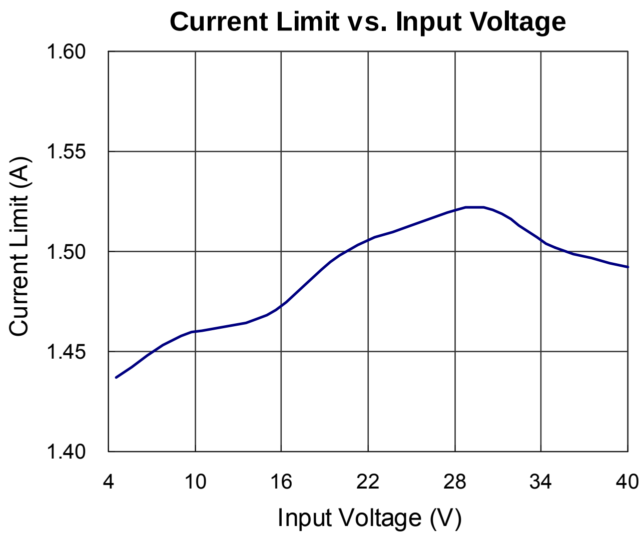

LED Current vs. DCTL Duty
LED Current (mA)
DCTL Duty (%)
VIN = 24V, f = 1kHz
VDCTL = 0V to 3V, R2 = 0.35Ω
0
100
200
300
400
500
600
0
10
20
30
40
50
60
70
80
90
100


LED Current vs. ACTL
LED Current (mA)
ACTL (V)
VIN = 24V, R2 = 0.35Ω
0
100
200
300
400
500
600
0.2
0.4
0.6
0.8
1
1.2
1.4

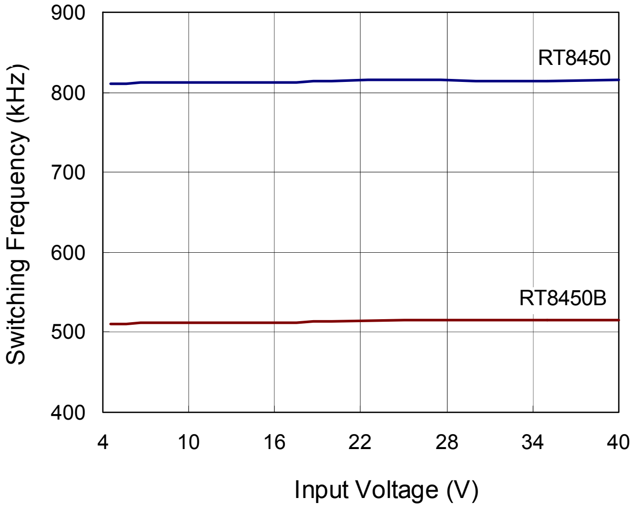

OVP vs. Input Voltage
OVP (V)
Input Voltage (V)
1.200
1.205
1.210
1.215
1.220
4
10
16
22
28
34
40


OVP vs. Temperature
OVP (V)
Temperature (°C)
VIN = 24V
1.18
1.19
1.2
1.21
1.22
1.23
-50
-25
0
25
50
75
100
125

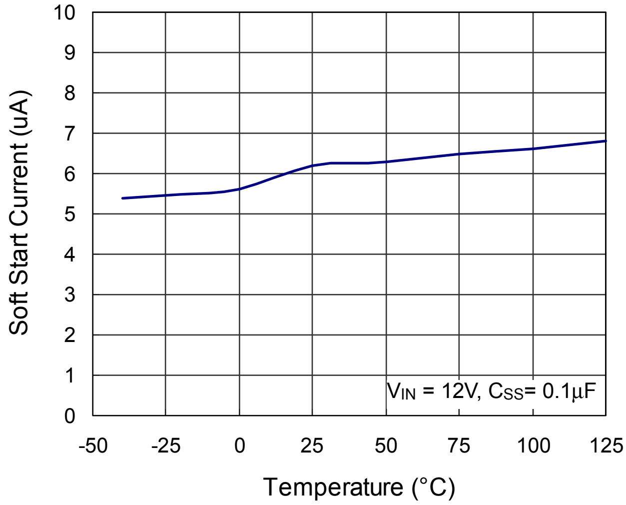

ACTL-Off vs. Temperature
ACTL-Off (V)
Temperature (°C)
VIN = 24V
0.1800
0.1825
0.1850
0.1875
0.1900
0.1925
0.1950
0.1975
0.2000
-50
-25
0
25
50
75
100
125


Current Limit vs. Input Voltage
Current Limit (A)
Input Voltage (V)
1.40
1.45
1.50
1.55
1.60
4
10
16
22
28
34
40

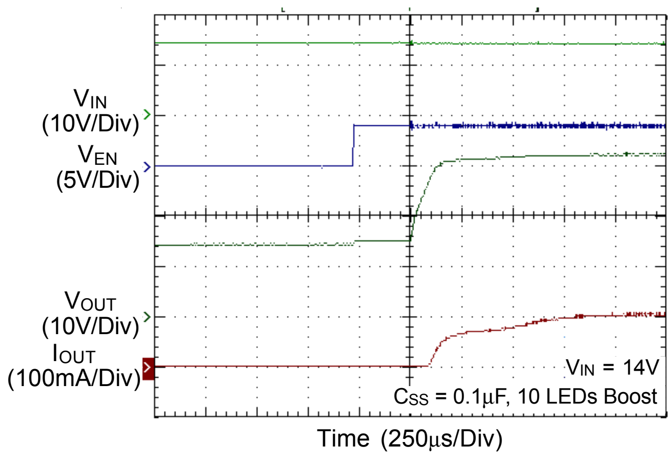
Switching Frequency vs. Input Voltage



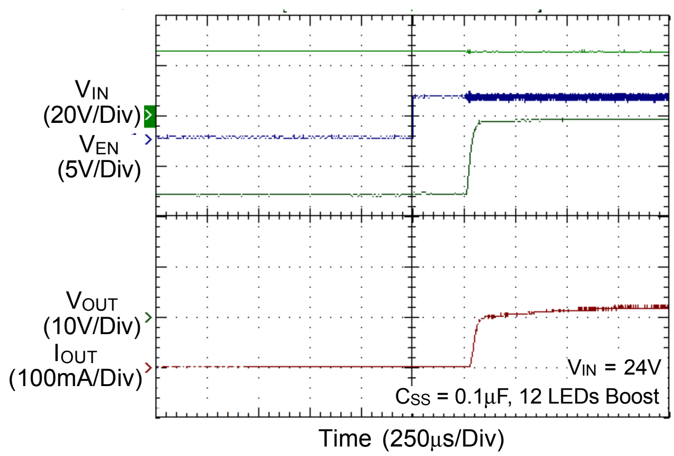
SS pin Current vs. Temperature



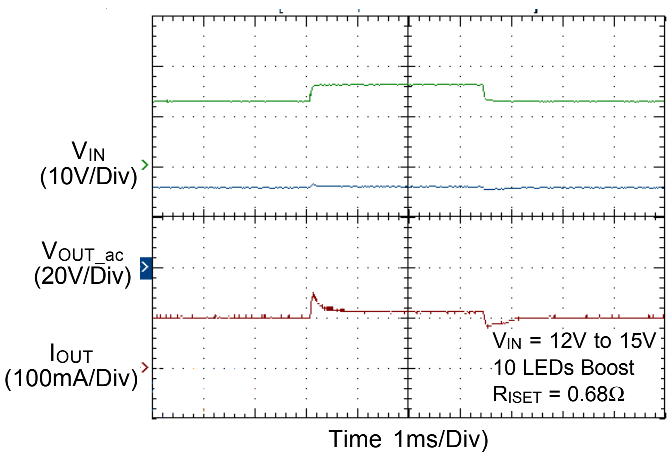
Power On from EN



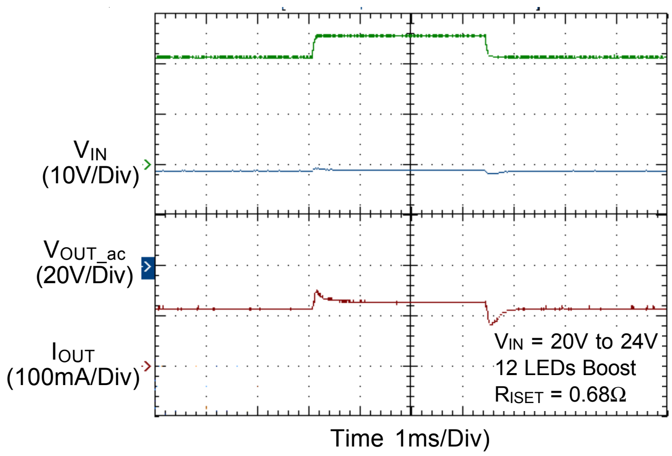
Power On from EN



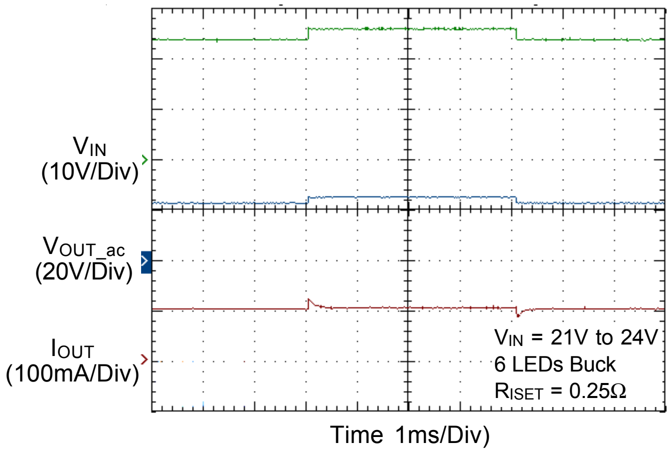
Line Transient Response



Line Transient Response



Line Transient Response



Application Information

The RT8450/B is specifically designed to be operated in buck, buck -boost and boost converter applications. This device uses a fixed frequency, current mode control scheme to provide excellent line and load regulation. The control loop has a current sense amplifier to sense the voltage between the ISP and ISN pins and provides an output voltage at the VC pin. A PWM comparator then turns off the internal power switch when the sensed power switch current exceeds the compensated VC pin voltage. The power switch will not reset by the oscillator clock in each cycle. If the comparator does not turn off the switch in a cycle, the power switch is on for more than a full switching period until the comparator is tripped. In this manner, the programmed voltage across the sense resistor is regulated by the control loop.

The current through the sense resistor is set by the programmed voltage and the sense resistance. The voltage across the sense resistor can be programmed by either the analog or PWM signals at the ACTL pin, or the PWM signal at the DCTL pin.

The protection schemes in the RT8450/B include over temperature, input voltage under voltage, output voltage over-voltage, and switch current limit.

Loop Compensation

The RT8450/B has an external compensation pin (VC) allowing the loop response optimized for specific application. An external resistor in series with a capacitor is connected from the VC pin to GND to provide a pole and a zero for proper loop compensation. The recommended compensation resistance and capacitance for the RT8450/B are 10k and 3.3nF.

Soft-Start

The soft-start of the RT8450/B can be achieved by connecting a capacitor from the SS pin to GND. The built-in soft-start circuit reduces the start-up current spike and output voltage overshoot. The soft-start time is determined by the external capacitor charged by an internal 6μA constant charging current. The SS pin directly limits the rate of voltage rise on the VC pin, which in turn limits the peak switch current. The value of the soft-start capacitor is user-defined to satisfy the designer' s requirement.

LED Current Setting

The LED current could be calculated by the following equation :

$$I_{LED,MAX} = \frac{V(ISP\text{-}ISN)}{R2}$$

Where V(ISP-ISN) is the voltage between ISP and ISN (190mV typ. if ACTL or DCTL dimming is not applied) and the R2 is the resister between ISP and ISN.

Brightness / Dimming Control

The RT8450/B features both analog and digital dimming control. Analog dimming is linearly controlled by an external voltage (0.3V < V_{ACTL} < 1.2V). With an on-chip output clamping amplifier and a resistor, PWM dimming signal fed at DCTL pin can be easily low-pass filtered to an analog dimming signal with one external capacitor from ACTL pin to GND for noise-free PWM dimming. A very high contrast ratio true digital PWM dimming can be achieved by driving ACTL pin with a PWM signal from 100Hz to 10kHz.

Output Over Voltage Setting

The RT8450/B is equipped with over voltage protection (OVP) function. When the voltage at OVP pin exceeds a threshold of approximately1.2V, the power switch is turned off. The power switch can be turned on again once the voltage at OVP pin drops below 1.2V.

For the Boost Application, the output voltage could be clamped at a certain voltage level. The OVP voltage can be set by the following equation :

$$V_{OUT,OVP} = 1.2 \times \left(1 + \frac{R3}{R4}\right)$$

Where R3 and R4 are the voltage divider from V_{OUT} to GND with the divider center node connected to OVP pin.

Current-Limit Protection

The RT8450/B can limit the peak switch current by the internal over current protection feature. In normal operation, the power switch is turned off when the switch current hits the loop-set value. The over current protection function will turn off the power switch independent of the loop control when the peak switch current reaches around 1.5A.

Over Temperature Protection

The RT8450/B has over temperature protection (OTP) function to prevent the excessive power dissipation from overheating. The OTP function will shut down switching operation when the die junction temperature exceeds 150°C. The chip will automatically start to switch again when the die junction temperature cools off.

Inductor Selection

Choose an inductor that can handle the necessary peak current without saturating, and ensure that the inductor has a low DCR (copper-wire resistance) to minimize I^2R power losses. A 4.7μH to 10μH inductor will meet the demand for most of the RT8450/B applications. Inductor manufacturers specify the maximum current rating as the current where the inductance falls to certain percentage of its nominal value typically 65%.

In Boost application where the transition between discontinuous and continuous modes occurs, the value of the required output inductor (L), can be approximated by the following equation :

$$L = \frac{V_{OUT} \times D \times (1-D)^2}{2 \times I_{OUT} \times f}$$

The Duty Cycle (D) could be calculated as follows :

$$D = \frac{V_{OUT} - V_{IN}}{V_{OUT}}$$

Where V_{OUT} = maximum output voltage.

V_{IN} = minimum input voltage.

f = operating frequency.

I_{OUT} = sum of current from all LED strings.

The boost converter operates in discontinuous mode over the entire input voltage range can have inductor value L1 less than the calculated value L by the formula above. With an inductance value L2 greater than L, the converter will operate in continuous mode at the minimum input voltage and maybe operate in discontinuous mode at higher voltages.

The inductor must be selected with a saturation current rating greater than the peak current provided by the following equation :

$$I_{PEAK} = \frac{V_{OUT} \times I_{LED}}{\eta \times V_{IN}} + \frac{V_{IN} \times D \times T}{2 \times L}$$

Where ç is the efficiency of the power converter.

Schottky Diode Selection

The Schottky diode, with low forward voltage drop and fast switching speed, is necessary for the RT8450/B applications. In addition, power dissipation, reverse voltage rating and pulsating peak current are the important parameters of the Schottky diode that must be considered. Choose a suitable Schottky diode whose reverse voltage rating is greater than the maximum output voltage. The diode′ s average current rating must exceed the average output current. The diode conducts current only when the power switch is turned off (typically less than 50% duty cycle).

Capacitor Selection

The input capacitor reduces current spikes from the input supply and minimizes noise injection to the converter. For most RT8450/B applications, a 4.7μF ceramic capacitor is sufficient. A value higher or lower may be used depending on the noise level from the input supply and the input current to the converter.

In Boost Application, the output capacitor is typically a ceramic capacitor and is selected based on the output voltage ripple requirements. The minimum value of the output capacitor C_{OUT} is approximately given by the following equation :

$$C_{OUT} = \frac{I_{LED} \times D \times T}{V_{RIPPLE}}$$

Layout Consideration

PCB layout is very important to design power switching converter circuits. Some recommended layout guidelines are suggested as follows:

- The power components L1, D1, C_{VIN}, and C_{OUT} must be placed as close to each other as possible to reduce the ac current loop area. The PCB trace between power components must be as short and wide as possible due to large current flow through these traces during operation.
- Place L1 and D1 connected to SW pin as close as possible. The trace should be as short and wide as possible.
- The input capacitors C_{VCC1} and C_{VCC2} must be placed as close to VCC1 and VCC2 pin as possible.

- Place the compensation components to the VC pin as close as possible to avoid noise pick up.

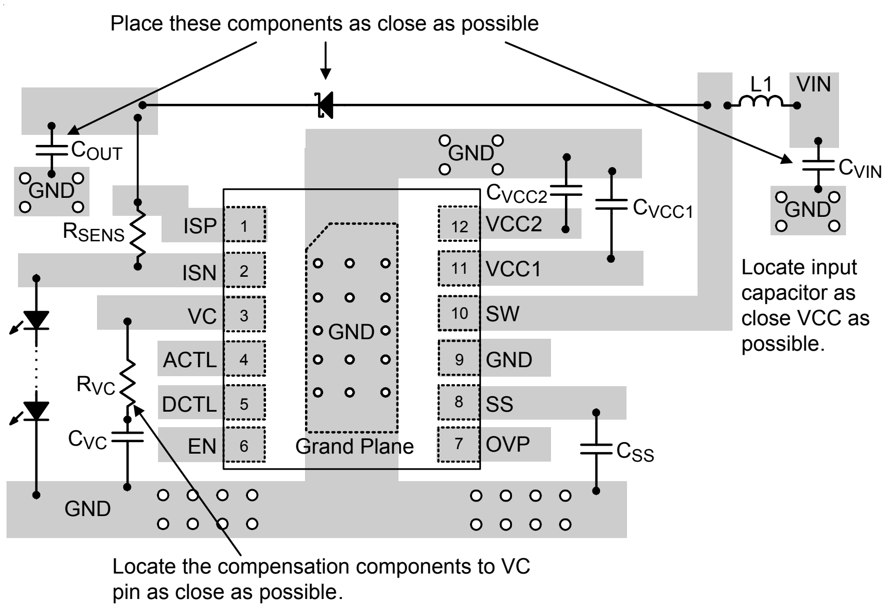
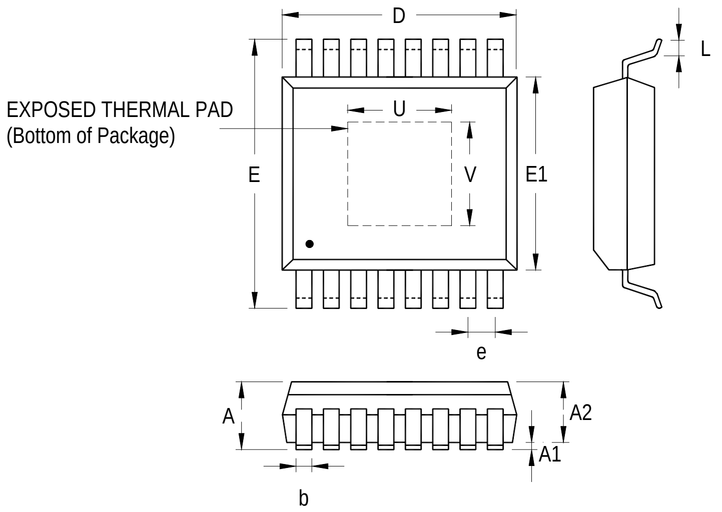


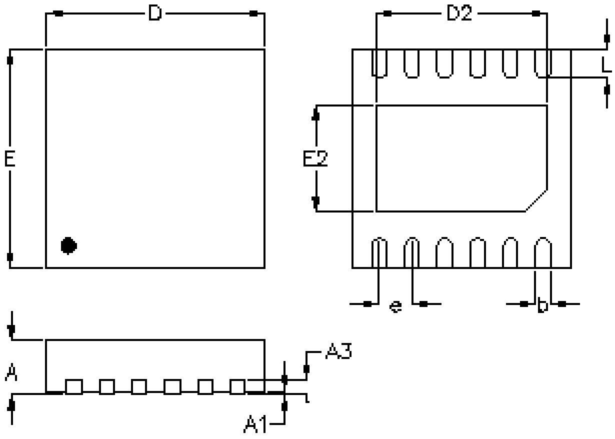
Figure 7. PCB Layout Guide

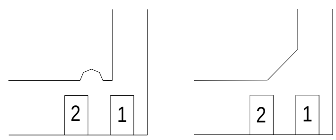
Outline Dimension



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	1.000	1.200	0.039	0.047
A1	0.000	0.150	0.000	0.006
A2	0.800	1.050	0.031	0.041
b	0.190	0.300	0.007	0.012
D	4.900	5.100	0.193	0.201
e	0.65		0.026	
E	6.300	6.500	0.248	0.256
E1	4.300	4.500	0.169	0.177
L	0.450	0.750	0.018	0.030
U	2.000	3.000	0.079	0.118
V	2.000	3.000	0.079	0.118

16-Lead TSSOP (Exposed Pad) Plastic Package





DETAIL A

Pin #1 ID and Tie Bar Mark Options

Note : The configuration of the Pin #1 identifier is optional, but must be located within the zone indicated.

Symbol		Dimensions In Millimeters		Dimensions In Inches	
		Min.	Max.	Min.	Max.
A		0.700	0.800	0.028	0.031
A1		0.000	0.050	0.000	0.002
A3		0.175	0.250	0.007	0.010
b		0.150	0.250	0.006	0.010
D		2.950	3.050	0.116	0.120
D2	Option1	2.300	2.650	0.091	0.104
	Option2	1.970	2.070	0.078	0.081
E		2.950	3.050	0.116	0.120
E2	Option1	1.400	1.750	0.055	0.069
	Option2	1.160	1.260	0.046	0.050
e		0.450		0.018	
L		0.350	0.450	0.014	0.018

W-Type 12L DFN 3x3 Package

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