DESCRIPTION

The PT16753 is buck topology switching regulator with constant current output for high-power LEDs driving purpose. It integrates a 50V high side N-channel MOSFET switch for step down conversion. The output current control loop operating in average current mode and the switch current is controlled cycle-by-cycle with an adaptive on-time structure.

Output current is user-defined by an external current sense resistor and output voltage depends on numbers of total series LEDs in a single string. This ensures the optimal system efficiency.

LED dimming is accomplished by a direct logic input pulse width modulation (PWM) signal at the EN pin. The device has thermal pad on the bottom side for enhanced thermal dissipation.

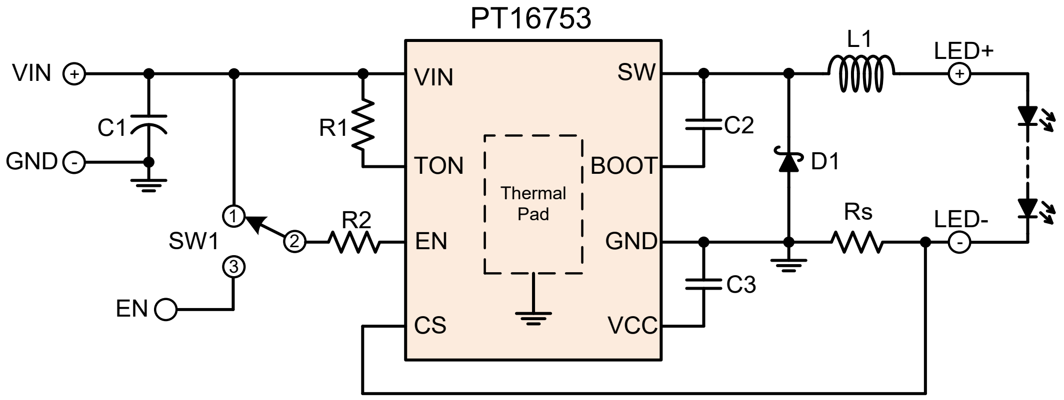
APPLICATIONS

- Daytime running lights
- Front and rear fog lights
- Turn signal lights
- Decoration spot light
- Dimmable interior lights

FEATURES

- AEC-Q100 Grade 1, operating temperature range T_A = -40°C ~ 125°C
- 6 to 48 V supply voltage
- Asynchronous rectifier buck regulator with average output current mode control
- 2.5 Amps continue output current on a 2-layer PC board
- 3 Amps maximum output current in T_A=25°C on a 4-layer PC board with additional heatsink
- Cycle-by-cycle current limit
- Integrated high side MOSFET switch
- PWM dimming controlled by logic level signal
- Internal loop compensation
- Under voltage lockout (UVLO) and thermal shutdown protection
- Low power shutdown (1μA typical)
- Robust protection against:
  - Adjacent pin-to-pin short
  - Pin-to-GND short
  - LED open/short faults
- Spread-Spectrum switching frequency reduces EMI conduction emission.
- Operation switching frequency from 200KHz to 2MHz
- HSOP 8 pins package with exposed thermal pad

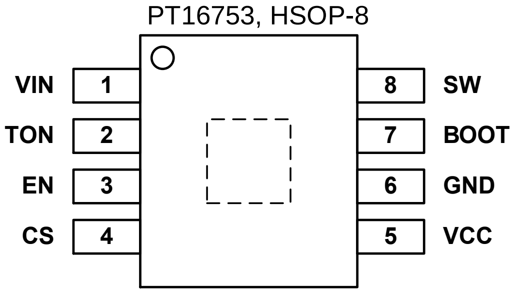
TYPICAL APPLICATION



ORDER INFORMATION

Valid Part Number	Package Type	Top Code
PT16753-HS	8 Pins, HSOP	PT16753-HS

PIN CONFIGURATION



PIN DESCRIPTION

PIN Name	I/O	Description	PIN NO.
VIN	-	Supply voltage input	1
TON	I	Connects a resistor to VIN to determinate the on-time of buck converter. The on-time will shorten when VIN increasing, to maintain the a stable switching frequency	2
EN	I	Enable or PWM dimming signal input, trigger by logic level or VIN directly with a ballast resistor	3
CS	I	LED current sense input	4
VCC	O	Internal LDO regulator output; connects a 0.1μF bypass capacitor to GND for stabilization.	5
GND	-	Ground	6
BOOT	O	Gate driver bootstrap supply input for high side N-MOSFET switch	7
SW	O	High side N-MOSFET switch output	8
Thermal PAD	-	Exposed pad on the bottom side of package, connect to GND with thermal VIA for enhanced heat dissipation.	-

BLOCK DIAGRAM

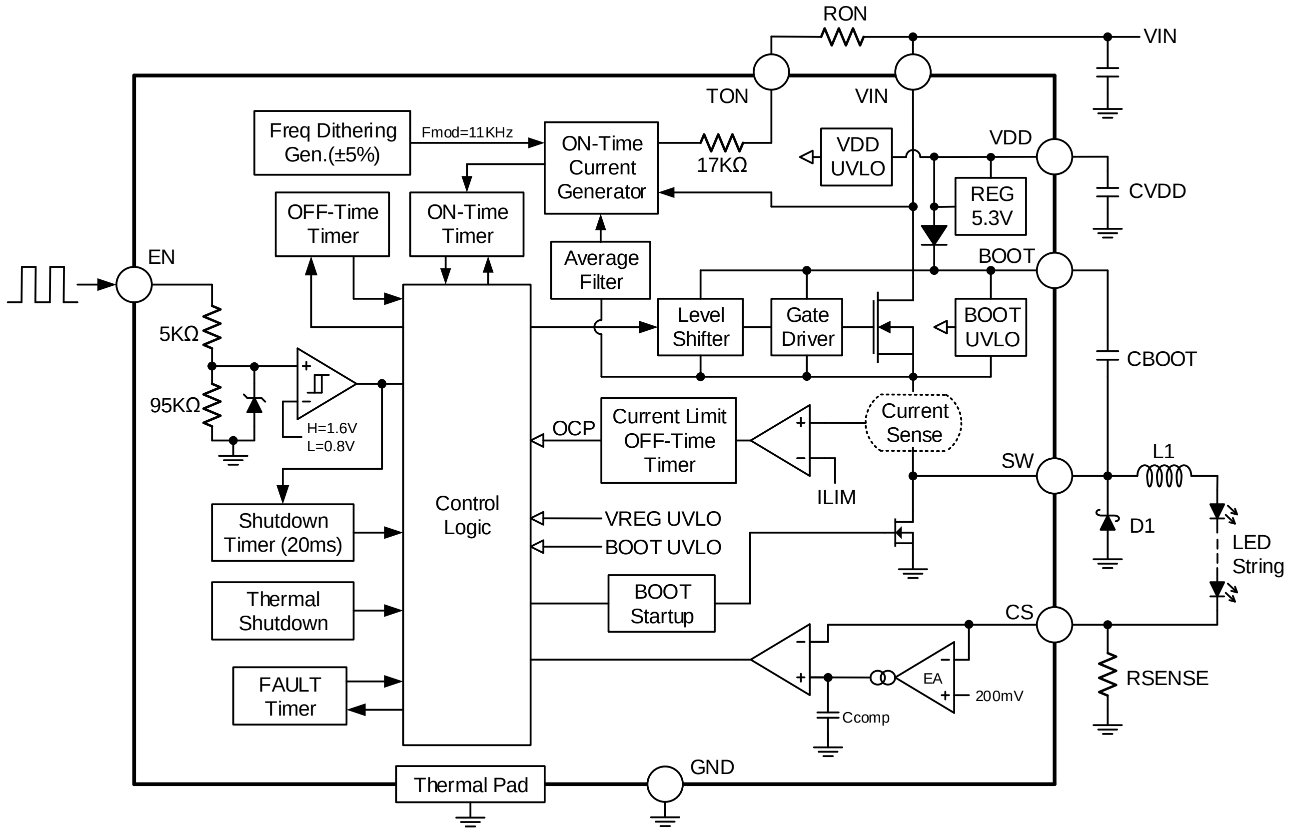


Figure 1, block diagram

FUNCTION DESCRIPTION

LED CURRENT SETTING

The PT16753 is a buck current regulator designed for driving high-current LED string; it uses average current mode to maintain the LED current constantly and consistent brightness. The inductor current flows through the cathode of LED and a current sense resistor, the R_{CS}, is placed in between the anode of LED terminal and GND. The LED current could be programmable by sense resistance, the voltage drops on the CS pin will compares to an internal reference voltage V_{CS} (typical 200mV), therefore the LED current can be determined as follow:

$$\text{LED Current } (i_{LED}) = V_{CS} / R_{CS} \qquad \text{(Eq1)}$$

SWITCHING FREQUENCY AND SPREAD SPECTRUM

The high side switch on-time programmed by a timing resistor (R_{ON}) connected in between the VIN and TON pins, and inside the TON pin has a ballast resistor (R_{INT}, 17KΩ equivalent) to limiting the input bias current and prevent it short circuit to the VIN, and a simplified reference on-time (t_{ON}) determinate equations shown on following:

$$t_{ON}\,(\mu s) = 0.013 \times (RON + RINT) \times (VOUT \div VIN) \qquad \text{(Eq2)}$$

$$f_{SW}\,(\text{MHz}) \approx 1/(0.013 \times (RON + RINT)\,) + 0.1 \qquad \text{(Eq3)}$$

Based on above equation, the RON and RINT series resistance is a constant value, therefore TON input bias current is roughly proportional to VIN voltage, means higher VIN voltage will shorten the on-time period (t_{ON}), and off-time determinate by the ratio of VOUT/VIN, because of the LED forward voltage drops on the output terminal is nearly constant if the LED current is no changed, it means the VOUT also no changed. When VIN increasing it will shorten the t_{ON} period and extend the off-time to reduce the duty cycle and stabilize the switching frequency.
To reducing the harmonic energy emission under EMC certification, a spread spectrum frequency oscillator was applied to the main switching frequency (f_{SW}) internally to reducing the peak value, the modulation signal is a fixed frequency triangle wave in 11KHz, and modulation index is internally sets at ±5% of f_{SW}.

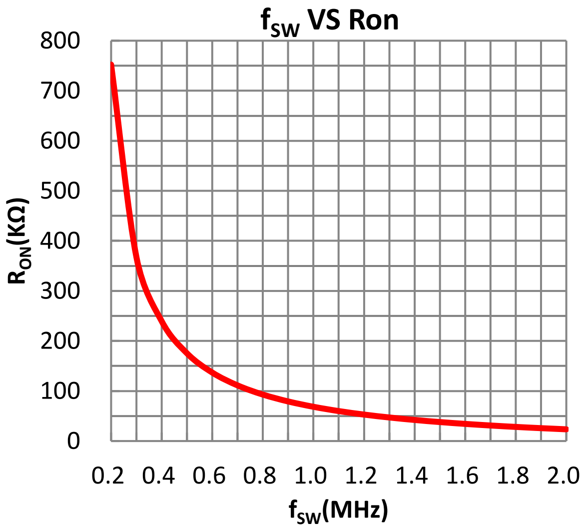


Figure 2, switching frequency versus RON resistance

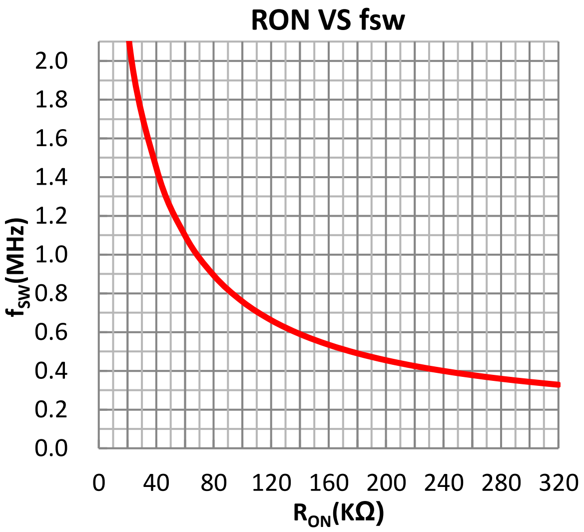
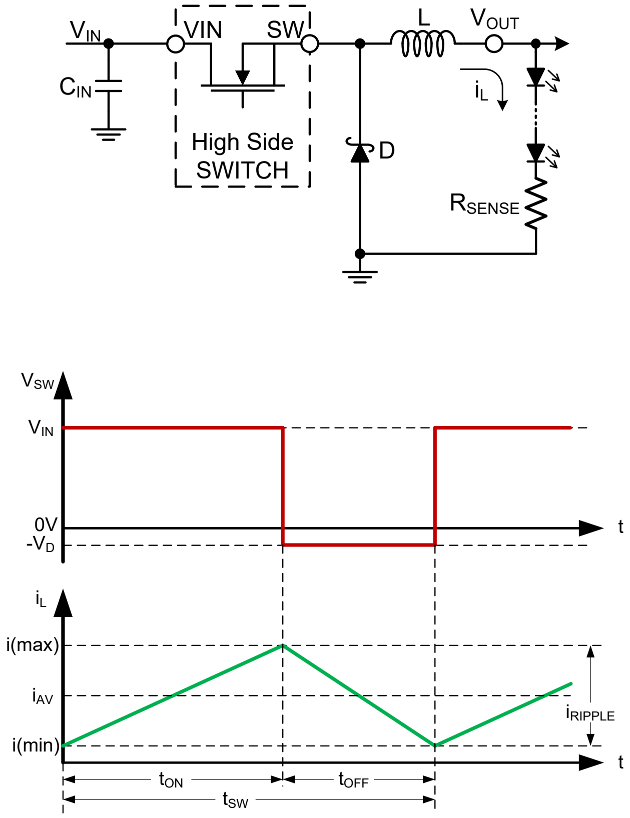


Figure 3, RON resistance versus switching frequency

OUTPUT VOLTAGE AND DUTY CYCLE

BASIC BUCK CONVERTER EQUATION



a) During SW on-time:
$i_{RIPPLE} = [(V_{IN} - V_{OUT}) / L] \times t_{ON}$
$= [(V_{IN} - V_{OUT}) / L] \times t_{SW} \times D$, where $D = t_{ON} / t_{SW}$

b) During SW off-time:
$i_{RIPPLE} = [(V_{OUT} - V_D) / L] \times t_{OFF}$
$= [(V_{OUT} - V_D) / L] \times t_{SW} \times (1 - D)$

c) A simplified equation for output voltage is:
$V_{OUT} = V_{IN} \times D - V_D \times (1 - D)$,
If $V_D << V_{OUT}$, then $V_{OUT} = V_{IN} \times D$

d) Detail expression about V_{OUT}:
$V_{OUT} = (V_{IN} - i_{AV} \times R_{DS(on)}) \times D - V_D \times (1 - D) - R_L \times i_{AV}$
$R_L =$ inductor dc resistance,
$i_{AV} =$ average LED current,

$R_{DS(on)} =$ high side switch conduction resistance.

Figure 4, buck convertor equation

The PT16753 is a step-down converter with current regulation function, in general condition the output voltage of the LED positive terminal determinate by the LED forward conduction voltage and series counts. For a given input voltage, the maximum output voltage depends on the switching frequency and minimum off-time $t_{OFF(MIN)}$, for example, if $t_{OFF(MIN)} = 200$ ns and $f_{SW} = 1$ MHz, then the maximum duty cycle is 80%. For a 24V input, the maximum output is 19.2V, it means up to 6 LEDs can be operated in series assuming the $V_F = 3.2$ V or less for each LED. The minimum output voltage depends on minimum on-time $t_{ON(MIN)}$ and switching frequency. For example, if the $t_{ON(MIN)} = 160$ ns and $f_{SW} = 1$ MHz, then the minimum duty cycle is 16%. At VIN = 24V, the minimum VOUT = 3.84 V. To a lesser degree, the output voltage is also affected by other factors such as LED current, on-resistance of the high-side switch, DCR of the inductor, and forward drop of the low-side free-wheeling diode. Consider above description, choose lower switching frequencies allows a wider range of VOUT, and hence more flexible LED configurations. From the Figure 5 to the Figure 8 shows how the minimum and maximum output voltages vary with LED current (assuming RDS(on) = 0.4 Ω, inductor DCR = 0.1Ω, and free-wheeling diode $V_F = 0.6$ V).

The more precise equation is shown in Eq4 for calculate the output voltage, it's based on a fundamental buck converter theory, where DU is the duty cycle, and V_D is the forward drop of the Schottky diode (<0.5 V in typical application) is approximately given as:

$$V_{OUT} = V_{IN} \times DU - V_D \times (1 - DU) \approx V_{IN} \times DU, \text{ if } V_D << V_{OUT},\ DU = t_{ON} / (t_{ON} + t_{OFF}) \qquad \text{(Eq4)}$$

If the required output voltage is lower than that permitted by the $t_{ON(MIN)}$, the controller will automatically extend the t_{OFF} in order to reduce the duty cycle for correct voltage output, this means that the switching frequency will becomes lower while the LED current is kept in regulation at all times.

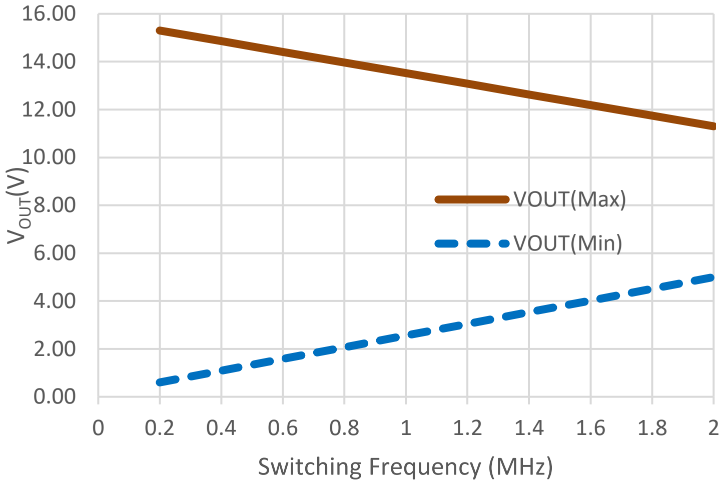


Figure 5, minimum and maximum output voltage versus switching frequency(f_{SW}), VIN=16 V, I_{LED}=1 A, predefined $t_{ON(MIN)}$ = 160ns, $t_{OFF(MIN)}$ = 200ns

ENABLE AND DIMMING

The buck converter beginning startup and output current to the LED when the EN pin sets to logic high state, the EN pin is high-voltage tolerant and available connecting to the VIN power rail or higher level always, in this case a series ballast resistor (1KΩ~10KΩ) is required to limit the input current flows into the EN pin. This series resistor is not necessary if the EN pin is driven by a logic level signal.

When the EN pin is forced from high to low state, the buck converter will be turned off, but the internal circuits still remain in standby mode for up to 12ms. If the EN goes to high again within this period, the soft-start procedure will be ignored and LED current is turned on immediately. This mechanism could speed-up output current ramps up time and minimize the output current on-duty, and thank for this benefit, a logic level PWM dimming signal could apply to the EN pin to achieve PWM dimming function, the resulting LED brightness is proportional to the duty cycle of the PWM dimming signal.
A practical range for PWM dimming frequency is between 100Hz (Period=10ms) and 2KHz. At a 200Hz PWM frequency, the dimming duty cycle can be varied from 100% down to 1% or lower. Higher PWM dimming frequency may degrade the output current linearity in low on-duty period.

If the EN pin stay in low state for more than 20ms, the IC entering shutdown mode to reduce power consumption. The next logic high signal on the EN pin will initialize a new startup sequence, which includes a startup delay of approximately 90 μs, this startup delay is not present during PWM dimming operation.

PWM DIMMING RATIO

The brightness of the LED string can be reduced by adjusting the PWM duty cycle at the EN pin as follows:

Dimming ratio = PWM on-time / PWM period **(Eq5)**

For example, a PWM dimming signal period is 5ms (PWM frequency=200Hz) and a PWM on-time of 50μs, a dimming ratio of 1% can be achieved and with good average output current linearity.

In an actual application, the minimum dimming ratio is determined by various system parameters, including VIN, VOUT, inductance, LED current, switching frequency and PWM frequency. As a general guideline, the minimum

PWM dimming on-time is mainly affected by V_{IN} and inductance, higher V_{IN} and lower inductance will induce higher ripple current ratio also means faster current slew rate, therefore a shorter PWM dimming on-time is possible.

PROTECTION AND FAULT

The PT16753 can handle such operating faults:

(1) **SW pin short to GND**
If the SW pin short to GND and switch output current exceeds the overcurrent trip threshold (~4.2 A) after a short deglitch time (approx. to t_{ONmin} ,160ns), the device will shut down immediately and re-startup after 660us retry time.

(2) **CS pin short to GND**
The SW output current flows through the inductor and LED and directly short to GND, it will cause the current feedback signal missing and force the high side switch continue switching, finally the output current exceeds overcurrent trip threshold and shuts down the device.

(3) **VCC or BOOT short to GND**
The VCC and BOOT have output current limiter to protect this kind of fault.

(4) **BOOT short circuit to SW, or BOOT capacitor open circuit**
The BOOT has under voltage lock out to monitor the BOOT-SW voltage, if the voltage less than the UVLO threshold the device will not startup until the fault condition is removed.

(5) **TON short to VIN**
The TON pin internal ballast resistance (R_{INT}, 6KΩ) will limiting the maximum input bias current, and shorten the switch on-time to minimum period.

(6) **Thermal shutdown**
Whatever ambient temperature rises up or high output current causes device itself power dissipation increase, when die temperature exceeds thermal shutdown trip threshold, the device will temporary shutdown the output and wait a period to cooling down, and device will go back to normal operation until the die temperature lower than the hysteresis window.

COMPONENT SELECTIONS

INDUCTOR SELECTION

There have many characteristics should be concern for choose a proper inductance for a buck regulator: the switching frequency, output current and output ripple ratio.

In most of automotive application, setting the switching frequency (f_{SW}) of a dc-dc converter within the AM broadcast band (0.5~1.7MHz) should be avoid because hardly passing the electromagnetic emission test, a lower f_{SW} (around 300~430KHz) is welcomed in most case, and higher f_{SW} (>1.8MHz) may significant reducing inductor's size, but it also limiting the possible operating voltage range and has higher switching losses.

The inductor ripple current ratio should not less than 10% of the average current over whole V_{IN} operation voltage range, the lower ripple current ratio will present in lowest V_{IN}. If ripple current ratio less than 10%, the low ripple voltage will not enough for the error amplifier detection and will induce the switching frequency jitter, however, the average LED current is still regulated. In a general application, the inductance larger than 100uH is not recommended.

There is no strictly limit on the highest ripple current ratio, means no specified lowest inductance, a 60% ripple current ratio is still acceptable, but please ensure the inductor and LEDs can handle such peak current (average current × 1.3 in this case). However, the ripple peak current may highly increase in the highest V_{IN} voltage (which implies a 200% ripple current), and ripple valley current may drop to zero which is possible happens in lower average current + lower inductance application. If the f_{SW} runs up to 1.5~2MHz, choose a minimum inductance from 4.7uH is recommended.

If the inductance is achieved, check the inductor's datasheet to ensure the saturation current (Isat) is higher than the I_{RIPPLE} peak value, this can be done by simply adding at least 20% margin to the average LED current (I_{LED}).

INDUCTANCE CALCULATION

The inductor is the most critical component for this buck converter, following procedure derives the correct parameters for the inductor:

- Determine the inductor ripple current peak-to-peak value. As a general rule, ripple current ratio should be kept between 10% and 30% of the average LED current.

$$0.1 < I_{RIPPLE(pk\text{-}pk)} / I_{LED} < 0.3 \qquad \textbf{(Eq6)}$$

- Calculate the inductance based on the formula Eq7. Where DUTY is the duty cycle, t is the period 1/ f_{SW}, and V_{SBD} is the forward voltage drop of the Schottky diode.

$$L = (V_{IN} - V_{OUT}) \times DUTY \times t / I_{RIPPLE}, \text{ and } DUTY = (V_{OUT} + V_{SBD}) / (V_{IN} + V_{SBD}) \qquad \textbf{(Eq7)}$$

EXAMPLE:

A LED lamp is consisting by 2 LED chips in serial connection (VF=6V), LED output current = 2.0 Amps and works on a 12V battery system. The minimum and maximum operation voltage from 9V to 18V. During load dump test the VIN will rise up to 35V.

(1) Consider the automotive EMC regulation, choosing 400KHz as switching frequency, the switching cycle time (t) = 2.5us.
(2) Predefine the ripple current ratio is 20% and Schottky barrier diode forward voltage (V_{SBD})=0.45V.
(3) Based on above parameters, calculated inductance ranges from 21uH to 54uH.

VIN	VOUT	V_{SBD}	DUTY	t(us)	I_{AVG}(A)	Ripple Ratio	I_{RIPPLE}(A)	Inductance
9	6	0.4	0.682	2.5	2.0	20%	0.4	12.8uH
12	6	0.4	0.518	2.5	2.0	20%	0.4	19.4uH
18	6	0.4	0.349	2.5	2.0	20%	0.4	26.2uH
35	6	0.4	0.181	2.5	2.0	20%	0.4	34.9uH

(4) Refer to above results, choose a 22uH inductor and recheck the ripple ratio, the minimum value (11.6%) at VIN=9V and maximum value (30%) at VIN=35V all within the recommend ripple current ratio range, therefore a 22uH inductor is optimized for this application.

VIN	VOUT	VSBD	DUTY	t(us)	I_{AVG}(A)	Ripple Ratio	I_{RIPPLE}(A)	Inductance
9	6	0.45	0.682	2.5	2.0	11.6%	0.23	22uH
12	6	0.45	0.518	2.5	2.0	17.7%	0.35	22uH
18	6	0.45	0.349	2.5	2.0	23.8%	0.47	22uH
35	6	0.45	0.181	2.5	2.0	30%	0.6	22uH

(5) The figure 6 and 7 shows quick reference charts for inductor selection

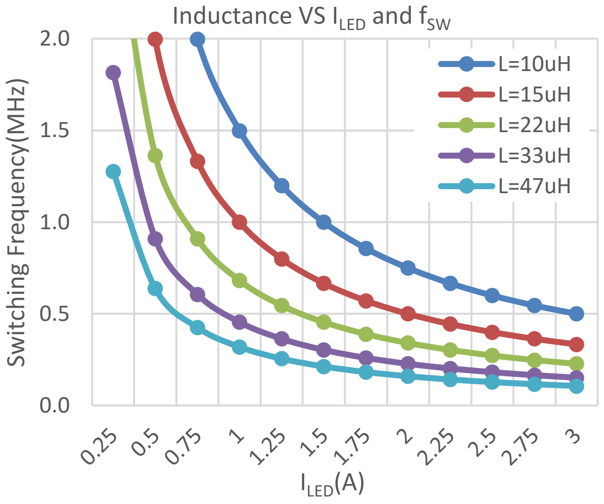


Figure 6, minimum f_{SW} VS inductance based on ripple current ratio=20%, VIN=12V, VOUT=6.2V

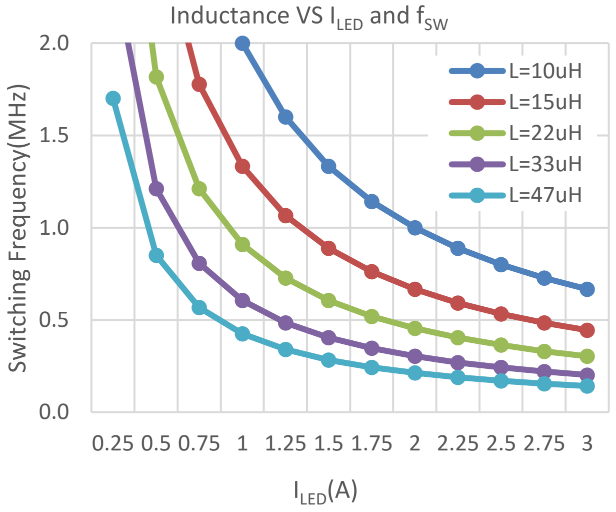


Figure 7, minimum f_{SW} VS inductance based on ripple current ratio=30%, VIN=24V, VOUT=12.2V

INPUT AND OUTPUT CAPACITOR

The input capacitance of the buck converter is strongly affect the input ripple voltage, for a smaller output current application (<0.5 Amps) at least a 10uF low ESR electrolytic capacitor is necessary. For higher output current (1~1.5Amps) increasing the CIN capacitance to 47uF, and this recommendation is for switching frequency under 400KHz. If the switching frequency up to 1MHz and above, add 1uF to 4.7uF ceramic capacitor for further reducing the ESR of the capacitor.

The output current regulation is mainly depending on the inductor current ripple, it flows through the LED string and current sense resistor to retrieve ripple voltage on the CS pin (Figure 11), therefore, the LED positive output terminal (LED+) should not add output filter capacitor to GND, it will shunt the ripple current direct to GND and cause control loop instability. Meanwhile, no output capacitor could reduce cost and saving the PCB size.

For EMC emission test reason, if the LED string is connected through a long wire harness, lower ripple current on the LED string is preferred, a simple solution is add a ceramic capacitor (such from 0.47μF~2.2μF) between the LED+ and LED-. In this case, the inductor ripple current (I_L) remains high, and high frequency ripple current (I_{RIPPLE}) will shunt by the C_{OUT} as local bypassing, only nearly dc current (I_{AVG}) will flows through the LED string (Figure 12), the ripple components were greatly reduced.

The addition of shunt capacitor C_{OUT} introduces a significant startup delay in LED current during PWM dimming operation, therefore, the maximum PWM dimming ratio will be limited.

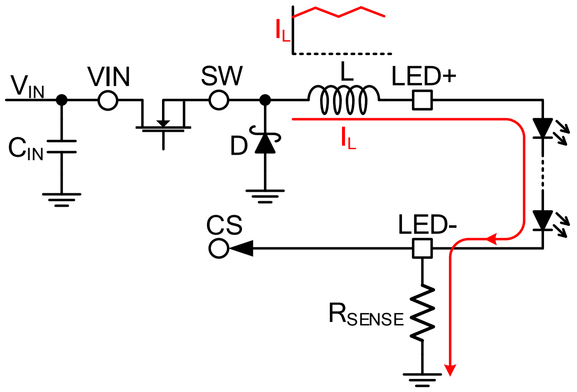


Figure 8, Without output shunt capacitor

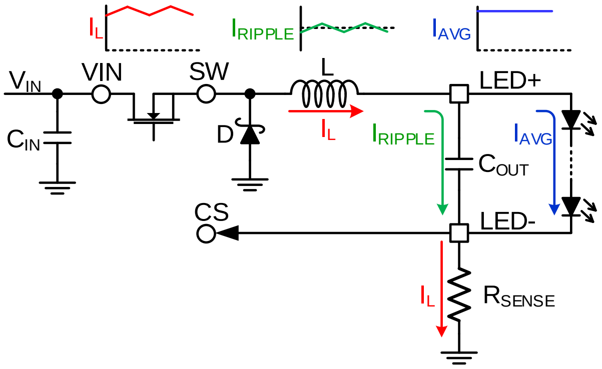


Figure 9, With output shunt capacitor across LED string

FREEWHEEL DIODE

The freewheel diode in the asynchronous type buck converter is a key component, it will affect the system efficiency and stability. We recommend choosing a low forward conduction voltage Schottky barrier diode(SBD) as low side freewheel diode. In an automotive application, the peak repetitive reverse voltage(V_{RRM}) of SBD should not less than 50V because of stresses from the load dump test, and diode forward conduction voltage(V_F) in typical LED output current should never exceeding the SW pin absolutely maximum rating.

APPLICATION CIRCUITS

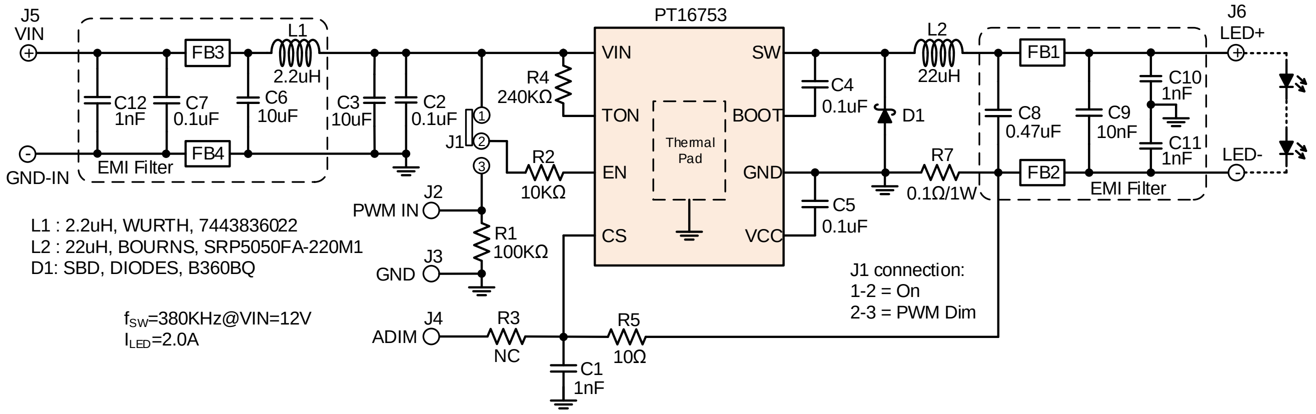


Figure 10, typical circuit for automotive application

Application circuit of the PT16753 evaluation board shown in figure 13, two optional EMI filters were attached to VIN and LED output terminal. The switching frequency is 400KHz determinate by R4, a 0.47μF ceramic capacitor (C8) across LED output terminal is for bypassing the high frequency ripple current out of LED string. A ballast resistor (R2) limiting the input current of the EN pin, it is necessary if the EN is always connected to the VIN with higher voltage. An optional SMD ceramic capacitor (C1) near the CS pin could improves the EMS test performance in such like BCI test, if the EMC performance is not a critical issue, the components inside the “EMI Filter” block and C1 can be removed to saving the BOM cost.

ANALOG DIMMING CIRCUITS

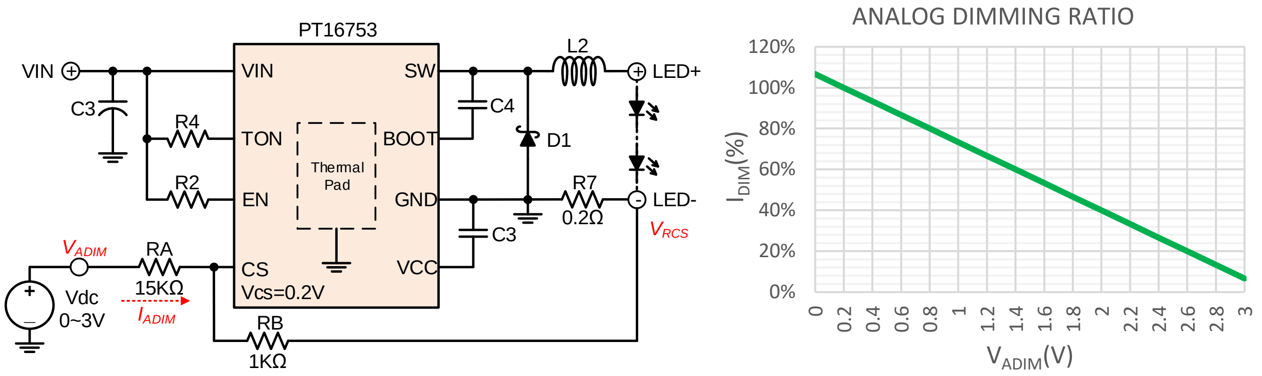


Figure 11, analog dimming of LED current with an external V_{ADIM} voltage

Apply an external dc source and resistor divider network across the CS and LED- terminal can shift the virtual sensing voltage of the current sense resistor (V_{RCS}), therefore the output LED current can be controlled by the V_{ADIM} voltage.

(1) Determinate the input dimming current (I_{ADIM}) from the RA resistance and V_{ADIM}:

$$I_{ADIM} = (V_{ADIM} - V_{CS}) / RA, \text{ where } V_{CS} = 0.2V \qquad \textbf{(Eq8)}$$

(2) Calculate the virtual current sense resistor voltage:

$$V_{RCS} = (V_{CS} - I_{ADIM} \times RB) / R_{CS} \qquad \textbf{(Eq9)}$$

(3) Calculate the dimmed LED current:

$$I_{DIM} = V_{RCS} / R_{CS} \qquad \textbf{(Eq10)}$$

EXAMPLE:

The R_{CS} is 0.2Ω means the programmed I_{LED} =1 Amp, and RA=15KΩ and RB=1KΩ, the external Vdc range from 0 to 3V. Refer to the figure 14 analog dimming chart, if choose 2.6Vdc as the V_{ADIM} voltage, the dimmed LED current (I_{DIM}) will drops to 20% of programmed I_{LED}, only 0.2A. Because of the buck converter is based on average current mode, the valley ripple current may limit the minimum analog dimming range.

PCB LAYOUT RECOMMEDATION

COMPONENTS PLACEMENT

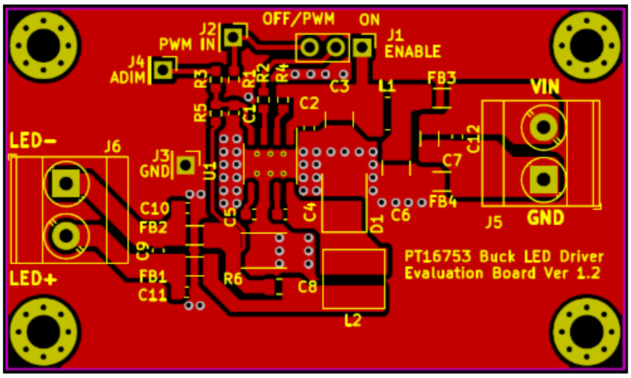


Figure 12: Top side of the PT16753 evaluation board

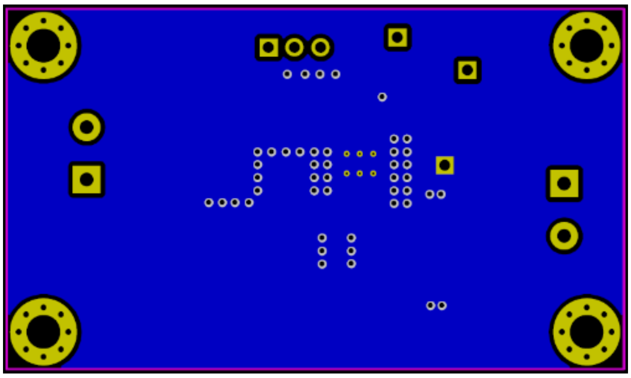


Figure 13: Bottom side of the PT16753 evaluation board.

The evaluation board is a 2-layers board with 1oz cupper foil thickness. The parts arrangement is optimized for minimized the hot loop area and enhance the thermal dissipation. The EMI filter components should be placed near power input and LED output terminal to reducing the conducted emissions. For lowest radiation emission, a molded iron powder magnetic shielded inductor is recommended. The driver chip, Schottky barrier diode and inductor should be place in the center area and far away from the board edge, and another side of the board should be covered by a none-cutting ground plane for EMI shield.

MINIMIZE CURRENT LOOP AREA

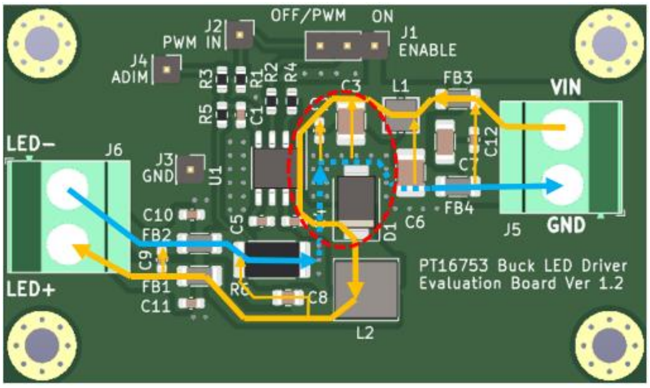


Figure 14, current path during high side switch on

→ LED load current (PCB top side)
→ Capacitor bypass current
→ Return current path (PCB top side)
⇢ Return current path (PCB bottom side)

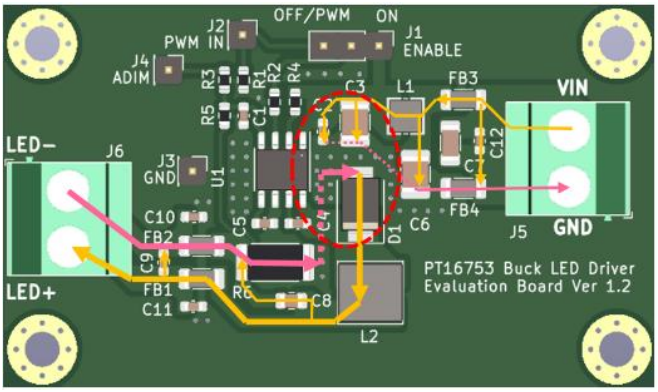


Figure 15, current path during high side switch off

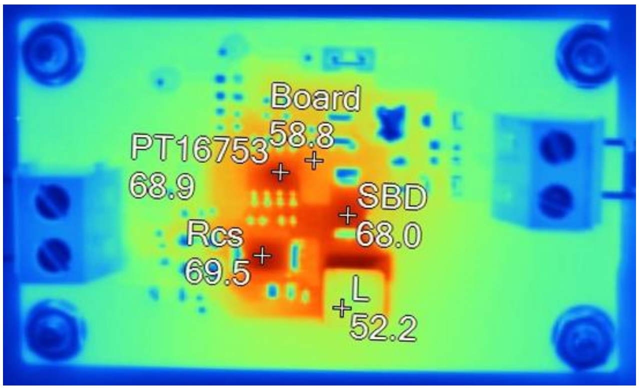
→ LED load current (PCB top side)
→ Capacitor bypass current
→ Return current path (PCB top side)
⇢ Return current path (PCB bottom side)

Compare the current path in figure 17 and figure 18, the LED output current of a buck converter is continuity whatever the high side switch on and off, but the VIN current is not the same. When the high side switch on, the LED return current will flow through the output to input terminal. During the high side switch off, the LED return current will only be loop between the Schottky barrier diode and output terminal, no current will return to the VIN terminal. This current interrupted behavior introduces a very high *dv/dt* spike in the red circle area (buck input current path) and causes high EMI radiation emissions, therefore, shrinking the red circle area is a key factor for suppress GND spikes. Another critical issue is the current path arrangement, the positive load and negative return current path should be in parallel with each other, an un-fragment GND plane on the bottom side of the board is necessary.

THERMAL DISSIPATION

The amount of heat that can pass from the silicon of the PT16753 to the surrounding ambient environment depends on the thermal resistance of the structures connected to the PT16753. The thermal resistance, R_{JA}, is a measure of the temperature rise created by power dissipation and is usually measured in degrees Celsius per watt (°C/W). The temperature rise, ΔT, is calculated from the power dissipated, P_D , and the thermal resistance, R_{JA} , as:

$$\Delta T = P_D \times R_{JA} \qquad \text{(Eq11)}$$



Test Condition:
VIN=12 V, VOUT=6.2 V (2×LED), T_A=25°C
I_{LED}=2.0 Amps, Switching Frequency: 400KHz
Board dimension: 60mm × 35mm
Schottky barrier diode V_F: 0.48V

Figure 16: Thermal image of the PT16753 evaluation board.

PERFORMANCE CHARTS

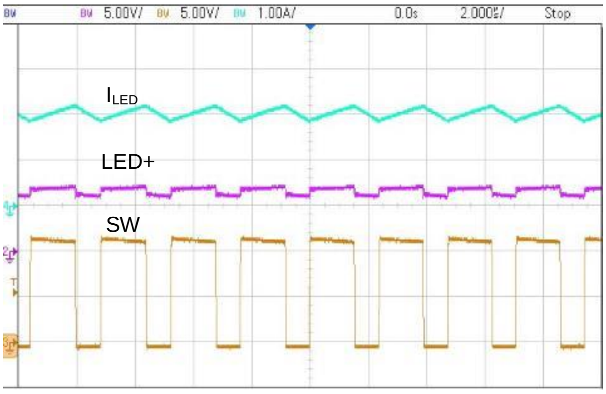


Figure 17, V_{IN} = 12V, LED+ = 6.2V, I_{LED} = 2A
Without LED shunt capacitor

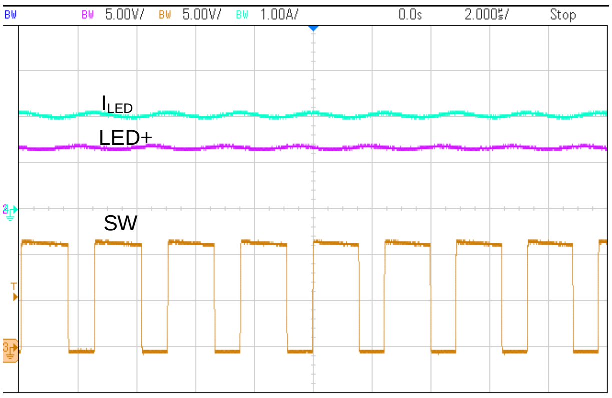


Figure 18, V_{IN} = 12V, LED+ = 6.2V, I_{LED} = 2A
With 0.47uF LED shunt capacitor

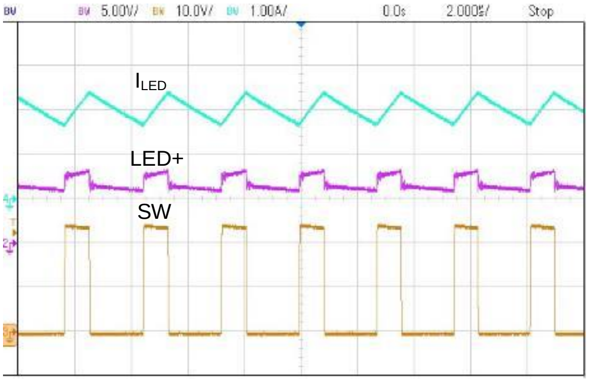


Figure 19, V_{IN} = 24V, LED+ = 6.2V, I_{LED} = 2A
Without LED shunt capacitor

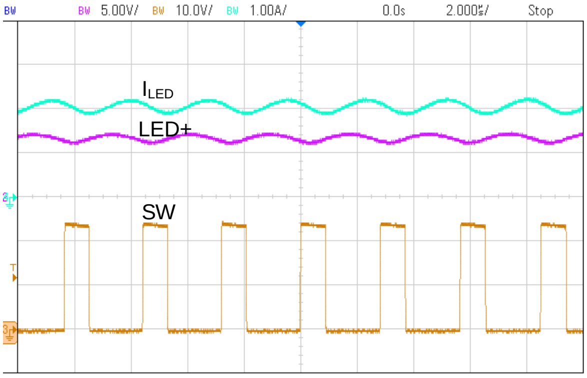


Figure 20, V_{IN} = 24V, LED+ = 6.2V, I_{LED} = 2A
With 0.47uF LED shunt capacitor

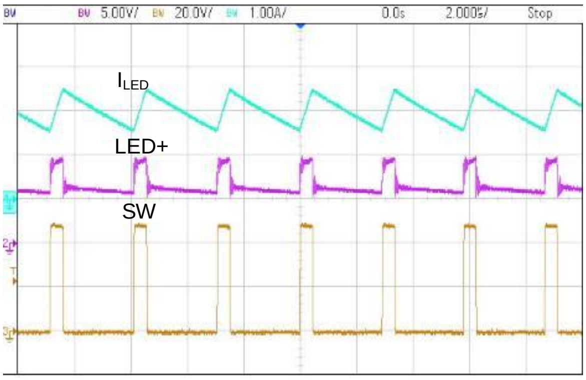


Figure 21, V_{IN} = 48V, LED+ = 6.2V, I_{LED} = 2A
Without LED shunt capacitor

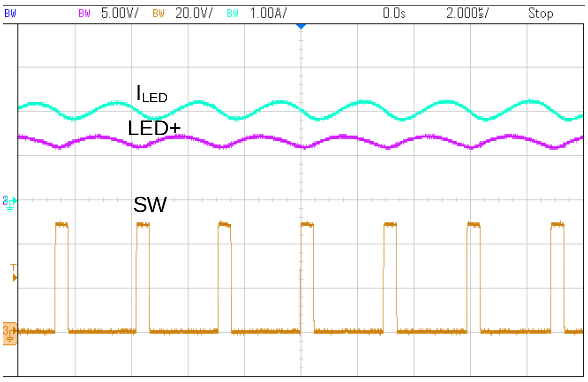


Figure 22, V_{IN} = 48V, LED+ = 6.2V, I_{LED} = 2A
With 0.47uF LED shunt capacitor

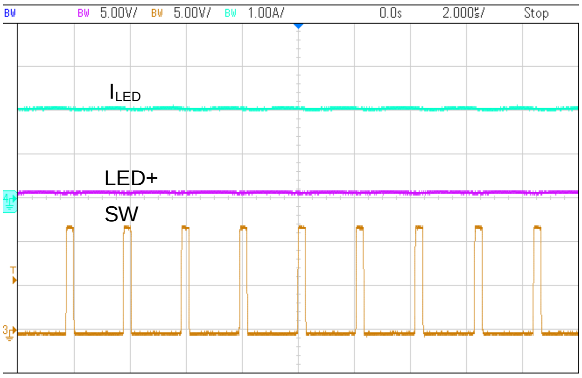


Figure 23, LED+ & LED- short circuit, V_{IN} = 12V, I_{LED} = 2A

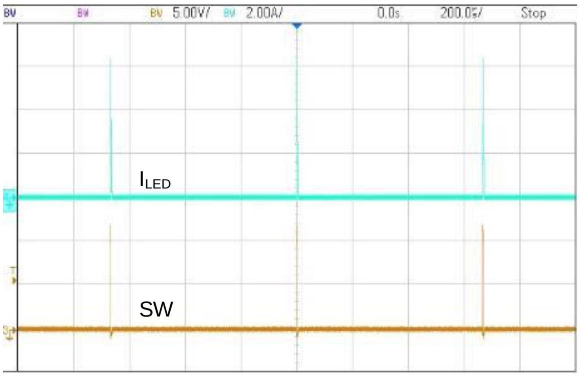


Figure 24, SW short circuit to GND, V_{IN} = 12V

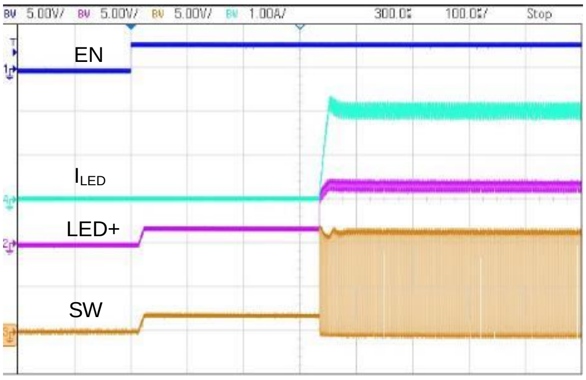


Figure 25, EN normal start time, V_{IN} = 12V, I_{LED} = 2A

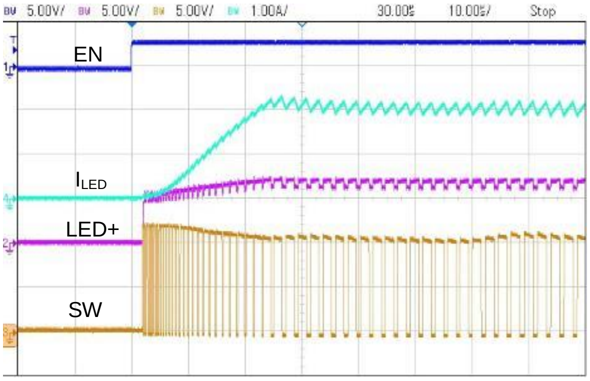


Figure 26, EN PWM dim start up time, V_{IN} = 12V, I_{LED} = 2A

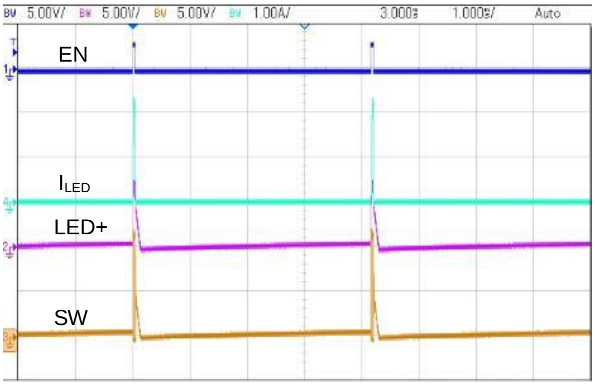


Figure 27, V_{IN} = 12V, LED+ = 6.2V, I_{LED} = 2A
f_{PWM} = 240Hz, Duty Cycle = 1%

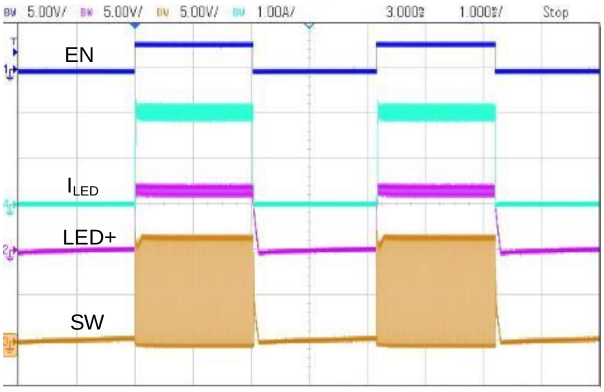


Figure 28, V_{IN} = 12V, LED+ = 6.2V, I_{LED} = 2A
f_{PWM} = 240Hz, Duty Cycle = 50%

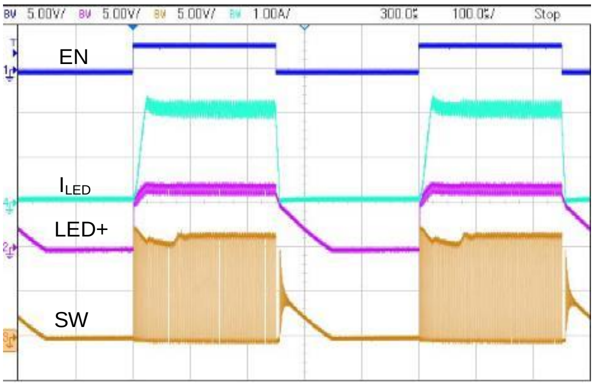


Figure 29, V_{IN} = 12V, LED+ = 6.2V, I_{LED} = 2A
f_{PWM} = 2KHz, Duty Cycle = 50%
Without LED shunt capacitor

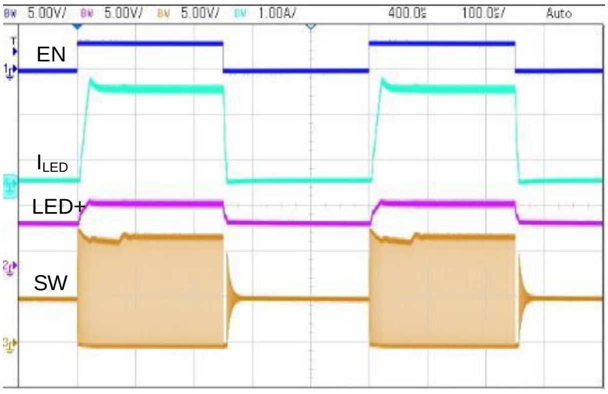


Figure 30, V_{IN} = 12V, LED+ = 6.2V, I_{LED} = 2A
f_{PWM} = 2KHz, Duty Cycle = 50%
With 0.47uF LED shunt capacitor

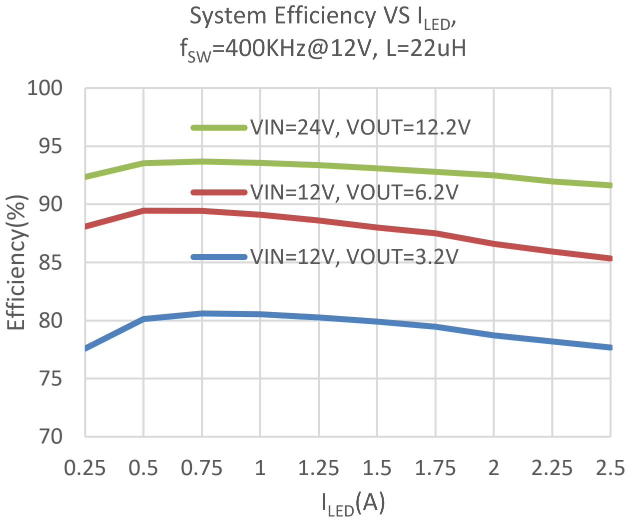


Figure 31: System Efficiency versus LED Current at various LED voltages Operating conditions, f_{SW} = 400KHz.

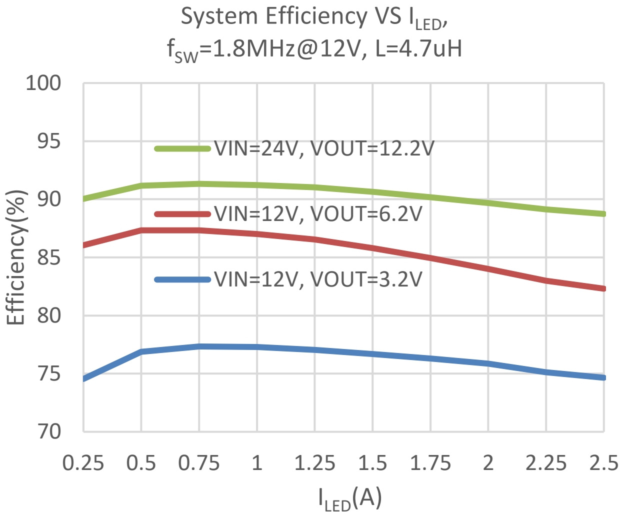


Figure 32: System Efficiency versus LED Current at various LED voltages Operating conditions, f_{SW} = 1.8MHz.

ABSOLUTE MAXIMUM RATINGS

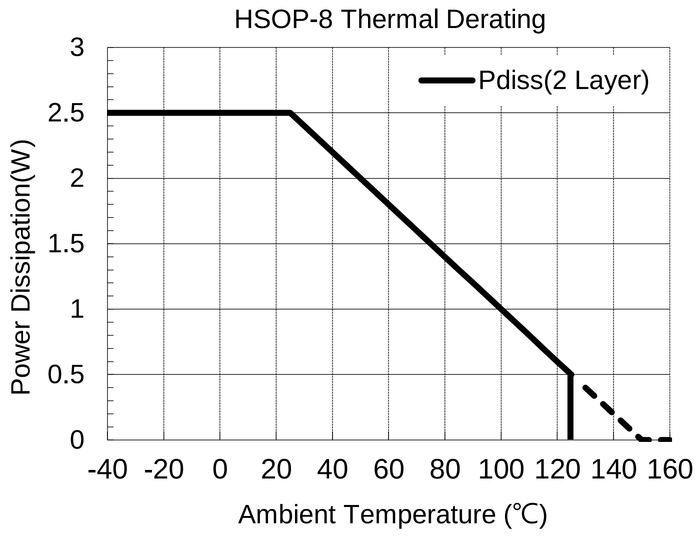
Parameter	Symbol	Min.	Max.	Unit
Supply voltage	V_{IN}	-0.3	50	V
Bootstrap drive voltage	V_{BOOT}	-0.3	V_{IN}+7	V
Switching node voltage, t>200ns	V_{SW}	-0.6	V_{IN}+0.3	V
Switching node voltage, t<20ns	V_{SW}	-3	V_{IN}+0.3	V
Enable input	V_{EN}	-0.3	V_{IN}+0.3	V
TON input	V_{TON}	-0.3	V_{IN}+0.3	V
Linear regulator output	V_{CC}	-0.3	7	V
Current sense input	V_{CS}	-0.3	7	V
Maximum junction temperature	T_J(max)		150	°C
Operating ambient temperature	T_A	-40	125	°C
Storage temperature	T_{STG}	-50	150	°C
ESD, human body model	HBM	-2000	+2000	V
ESD, charge device model	CDM	+500	-500	V

PACKAGE THERMAL CHARACTERISTIC

Parameter	Symbol	Condition	Typ	Unit
Package thermal resistance, from junction to ambient	Rja	2 Layer PCB(Note 1)	45	°C/W
		4 Layer PCB(Note 2)	35	
Package thermal resistance, from junction to thermal pad	Rjtp	-	2	°C/W

Note 1: The thermal resistance of HSOP 8 pin package measured on specified PCB: dimension=60mm x 35mm, FR-4, 2 layers, board thickness=1.6mm, copper thickness=1oz (35μm), GND plane metal coverage>65%, still airflow.

Note 2: The thermal via under the thermal pad: 6 pcs, diameter=0.3mm, all internal layers connect to the GND plane



ELECTRICAL CHARACTERISTICS

Typical value at T_A=25°C, V_{IN}=12 V. Operates in V_{IN}=6~48 V, T_J = -40°C to 150°C (unless otherwise noted)

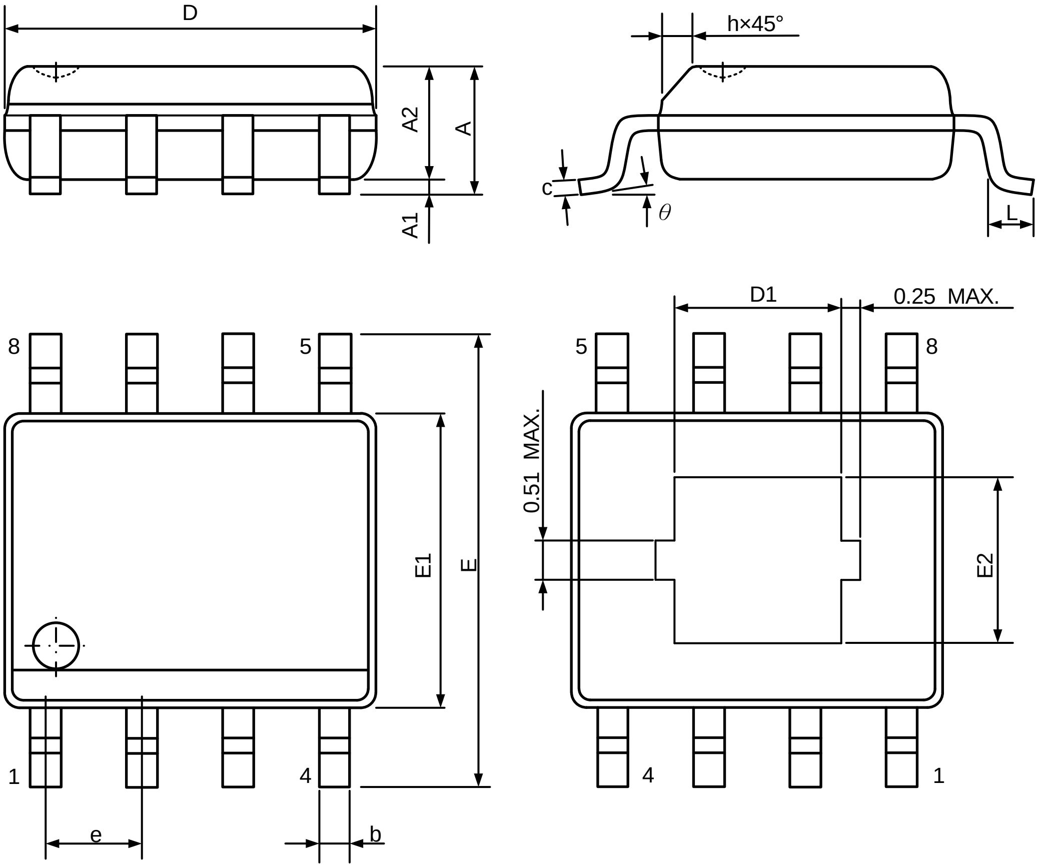
Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Power Supply						
V_{IN} supply voltage	V_{IN}		6		48	V
V_{IN} under voltage lockout threshold	V_{UVLO}	V_{IN} increasing	-	4.8	-	V
V_{IN} under voltage lockout hysteresis	V_{UVLO_HYS}	V_{IN} decreasing		400		mV
V_{IN} Pin supply current	I_{IN}	V_{CS} = 0.5V, EN = High		2		mA
V_{IN} pin standby current	I_{INSB}	V_{CS} = 0.5V, EN from high to low within 10ms	-	1.8	-	mA
V_{IN} pin shutdown current	I_{INSD}	EN tight to GND after 20ms	-	1	10	µA
Internal Linear Regulator						
V_{CC} regulator output	V_{CC}	0 mA < I_{CC} < 5 mA, V_{IN} > 6 V	5.2	5.5	5.8	V
V_{CC} current limit [Note1]	I_{CCLIM}	V_{CC} = 0 V	5	20	-	mA
High Side Switch						
Output over current threshold	I_{OCP}		3	4	5	A
Switch on-resistance	$R_{DS(on)}$	V_{BOOT} = V_{IN} + 4.3 V, T_A = 25°C, I_{SW} = 1A	-	0.25	0.4	Ω
High Side Bootstrap						
BOOT under voltage lockout Threshold	V_{BTUV}	V_{BOOT} to V_{SW} increasing	2.7	3.5	4.3	V
BOOT under voltage lockout Hysteresis	V_{BTHYS}	V_{BOOT} to V_{SW} decreasing	-	550	-	mV
Switching Characteristics						
Switching rise/fall time	t_{SR}	V_{IN} =12V, I_{OUT}=1A	5	-	15	ns
Switching minimum off-time	t_{OFFmin}	V_{CS} = 0 V	-	200	230	ns
Switching minimum on-time	t_{ONmin}		-	160	200	ns
Specified on-time	t_{ONS}	V_{IN} = 12V, V_{OUT} = 6V, R_{ON} = 240KΩ	1.00	1.25	1.5	us
Specified switching frequency	f_{SWS}	V_{IN} = 12V, V_{OUT} = 6V, R_{ON} = 240KΩ	370	390	409	KHz
Spread spectrum frequency range	f_{SS}	R_{ON} = 240KΩ	-	±5	-	%
Spread spectrum modulation frequency	f_{SSM}	R_{ON} = 240KΩ	-	11	-	KHz
Current Sense Comparator						
Current sense threshold [Note2]	V_{CSREG}	Vin=12V V_{CS} downward and SW turns on	190	200	210	mV
Current sense input bias current	I_{CS}	V_{CS} = 0.2 V, EN = low	-	0.9	-	µA
Enable Input						
Logic high voltage	V_{IH}	V_{EN} increasing	1.8	-	-	V
Logic low voltage	V_{IL}	V_{EN} decreasing	-	-	0.4	V
EN pin pull-down resistance	R_{ENPD}	V_{EN} = 5 V	-	100	-	KΩ
Maximum PWM dimming off-time	t_{PWML}	Measured while EN = low, during dimming control, and internal references are powered on (exceeding t_{PWML} causes shutdown)	12	20	-	ms
Thermal Shutdown						
Thermal shutdown threshold	T_{SD}			170		°C
Thermal shutdown hysteresis	T_{SDHYS}			25		°C

Note 1: The internal linear regulator is not allowing to drive an external load.

Note 2: The V_{CSREG} value is tested by a ramp signal applied at CS pin to determine the internal reference voltage, the output average current will be regulated by V_{CSREG} regardless of ripple voltage.

PACKAGE INFORMATION

8 PINS, HSOP

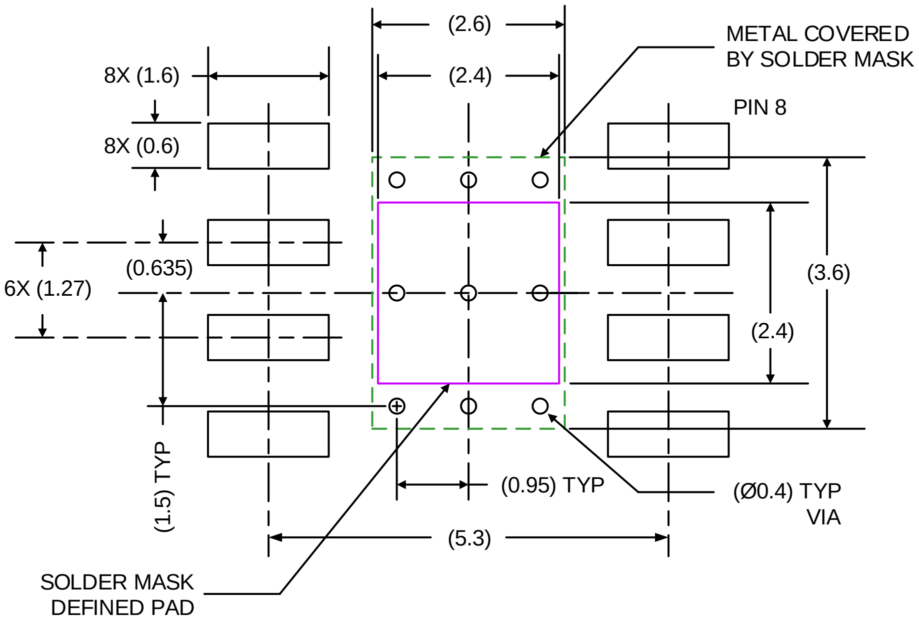


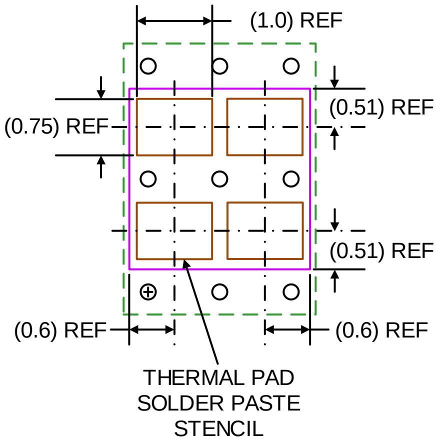
Top Side **Bottom Side**

Symbol	Dimensions(mm)		
	Min.	Nom.	Max.
A	-	-	1.70
A1	0.00	-	0.15
A2	1.25	-	-
b	0.31	-	0.51
c	0.10	-	0.25
D1	1.94	2.21 REF	2.44
E2	1.94	2.21 REF	2.44
D	4.90 BSC		
e	1.27 BSC		
E	6.00 BSC		
E1	3.90 BSC		
L	0.40	0.60	1.27
θ	0°	-	8°

Note: Refer to JEDEC MS-012 BA

PCB FOOTPRINT





IMPORTANT NOTICE

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