

## Small Package, High Performance, Asynchronous Boost LED Driver

### General Description

The RT8514 is a high frequency, asynchronous boost converter. The internal MOSFET can support up to 10 White LEDs for backlighting and OLED power application, and the internal soft-start function can reduce the inrush current. The device operates with 1MHz fixed switching frequency to allow small external components and to simplify possible EMI problems. For the protection, the RT8514 provides 37V OVP to allow inexpensive and small-output capacitors with lower voltage ratings. The LED current is initially set with the external sense resistor  $R_{SET}$ . The RT8514 is available in the tiny package type TSOT-23-6 package to provide the best solution for PCB space saving and total BOM cost.

### Ordering Information

RT8514□□

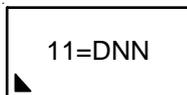
- Package Type  
J6 : TSOT-23-6
- Lead Plating System  
G : Green (Halogen Free and Pb Free)

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



11= : Product Code  
DNN : Date Code

### Features

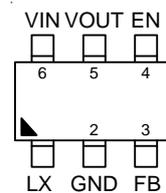
- VIN Operating Range : 2.5V to 5.5V
- Internal Power N-MOSFET Switch
- Wide Range for PWM Dimming (100Hz to 200kHz)
- Minimize the External Component Counts
- Internal Soft-Start
- Internal Compensation
- Under Voltage Protection
- Over Voltage Protection
- Over Temperature Protection
- Small TSOT-23-6 Package
- RoHS Compliant and Halogen Free

### Applications

- Cellular Phones
- Digital Cameras
- PDAs and Smart Phones and MP3 and OLED.
- Portable Instruments

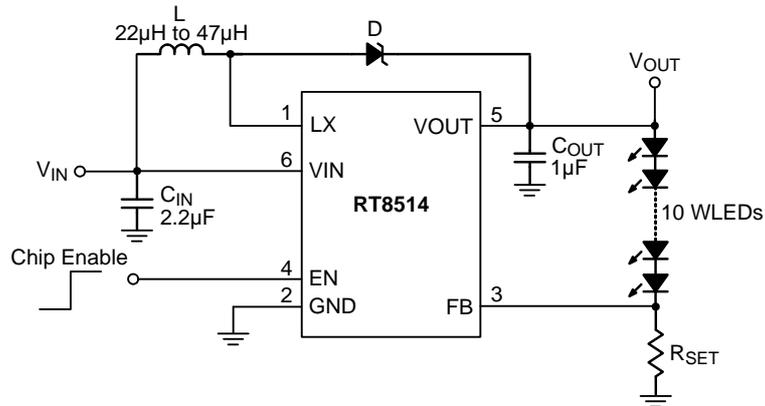
### Pin Configurations

(TOP VIEW)



TSOT-23-6

Typical Application Circuit

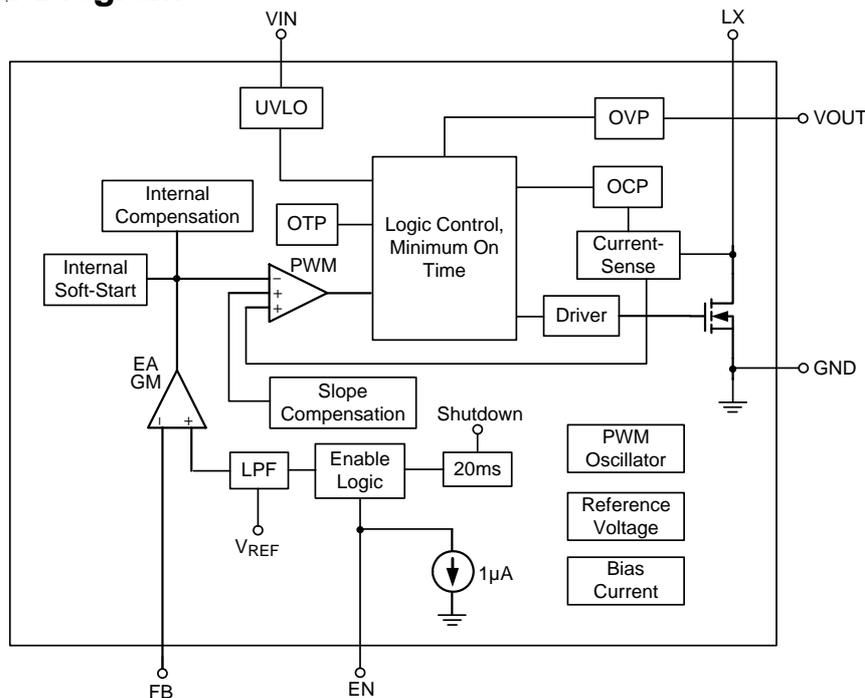


Note : The IC is not suitable for unstable supply applications which caused by the external components of VIN.

Functional Pin Description

Pin No.	Pin Name	Pin Function
1	LX	Switch Node. Open drain output of the internal N-MOSFET. Connect this pin to external inductor and diode.
2	GND	Ground.
3	FB	Feedback. Connect a resistor to GND to set output current.
4	EN	Chip Enable (Active High).
5	VOUT	Output Voltage. (For OVP detect function)
6	VIN	Supply Input.

Function Block Diagram



**Absolute Maximum Ratings** (Note 1)

- Supply Input Voltage,  $V_{IN}$  ----- -0.3V to 6V
- Switching Pin, LX ----- -0.3V to 50V
- VOUT ----- -0.3V to 46V
- Other Pins ----- -0.3V to 6V
- Power Dissipation,  $P_D$  @  $T_A = 25^\circ\text{C}$   
 TSOT-23-6 ----- 0.392W
- Package Thermal Resistance (Note 2)  
 TSOT-23-6,  $\theta_{JA}$  ----- 255°C/W
- Lead Temperature (Soldering, 10 sec.) ----- 260°C
- Junction Temperature ----- 150°C
- Storage Temperature Range ----- -65°C to 150°C
- ESD Susceptibility (Note 3)  
 HBM (Human Body Model) ----- 2kV  
 MM (Machine Model) ----- 200V

**Recommended Operating Conditions** (Note 4)

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

**Electrical Characteristics**

( $V_{IN} = 3.7\text{V}$ ,  $C_{IN} = 2.2\mu\text{F}$ ,  $C_{OUT} = 0.47\mu\text{F}$ ,  $I_{OUT} = 20\text{mA}$ ,  $L = 22\mu\text{H}$ ,  $T_A = 25^\circ\text{C}$ , unless otherwise specified)

Parameter		Symbol	Test Conditions	Min	Typ	Max	Unit
Input Voltage		$V_{IN}$		2.5	--	5.5	V
Under Voltage Lock Out		$V_{UVLO}$		2	2.2	2.45	V
UVLO Hysteresis				--	0.1	--	V
Quiescent Current		$I_Q$	FB = 1.5V, No Switching	--	400	600	$\mu\text{A}$
Supply Current		$I_{IN}$	FB = 0V, Switching	--	1	2	mA
Shutdown Current		$I_{SHDN}$	$V_{EN} < 0.4\text{V}$	--	1	4	$\mu\text{A}$
Line Regulation			$V_{IN} = 3\text{V to } 4.3\text{V}$	--	1	--	%
Load Regulation			1mA to 20mA	--	1	--	%
Operation Frequency		$f_{OSC}$		0.75	1	1.25	MHz
Maximum Duty Cycle				90	92	--	%
Clock Rate				0.1	--	200	kHz
Feedback Reference Voltage		$V_{REF}$		285	300	315	mV
On Resistance		$R_{DS(ON)}$		--	0.7	1.2	$\Omega$
EN Threshold Voltage	Logic-High	$V_{IH}$		1.4	--	--	V
	Logic-Low	$V_{IL}$		--	--	0.5	
EN Sink Current		$I_{IH}$		--	1	--	$\mu\text{A}$
EN Hysteresis				--	0.1	--	V
Over Voltage Threshold		$V_{OVP}$		35	37	39	V
Over Current Threshold		$I_{OCP}$		1	1.2	--	A

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
OTP	T <sub>OTP</sub>		--	160	--	°C
OTP Hysteresis			--	30	--	°C
Shutdown Delay	T <sub>SHDN</sub>		--	20	--	ms

**Note 1.** Stresses beyond those listed “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 may affect device reliability.

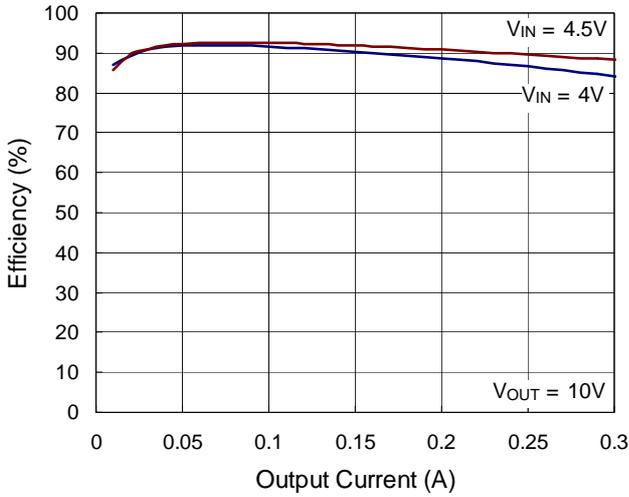
**Note 2.**  $\theta_{JA}$  is measured at  $T_A = 25^\circ\text{C}$  on a low effective thermal conductivity single-layer test board per JEDEC 51-3.

**Note 3.** Devices are ESD sensitive. Handling precaution is recommended.

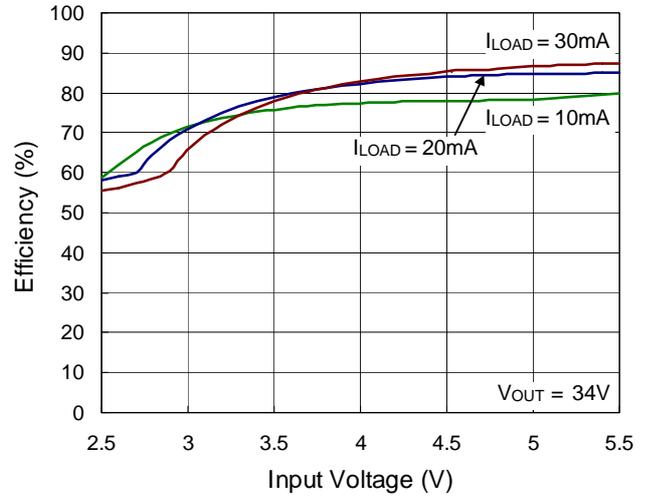
**Note 4.** The device is not guaranteed to function outside its operating conditions.

**Typical Operating Characteristics**

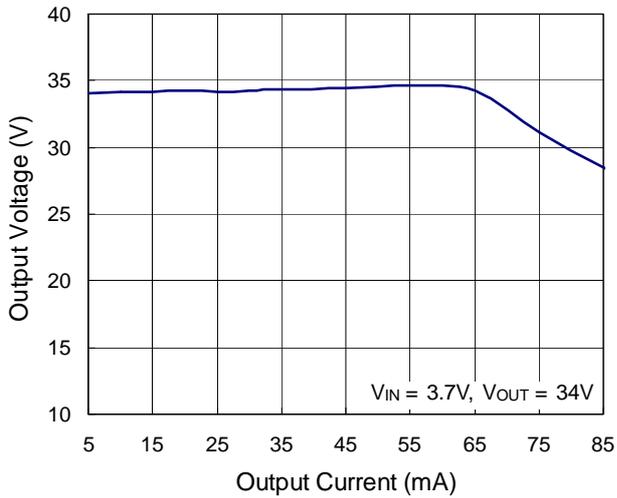
**Efficiency vs. Output Current**



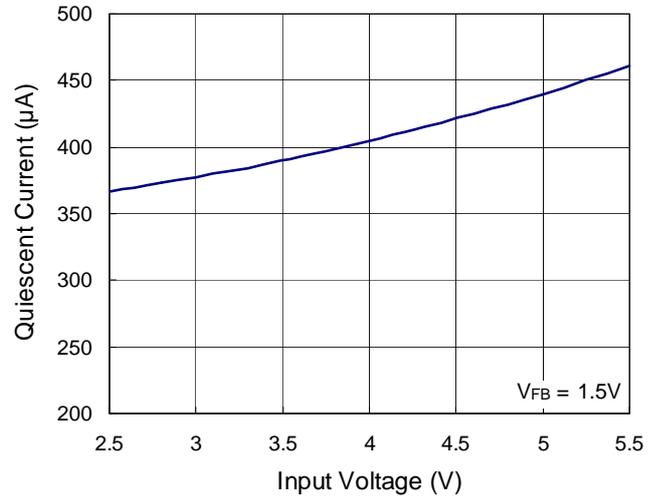
**Efficiency vs. Input Voltage**



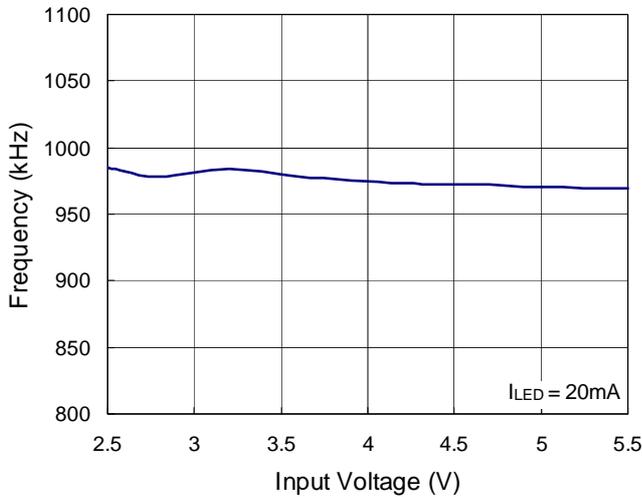
**Output Voltage vs. Output Current**



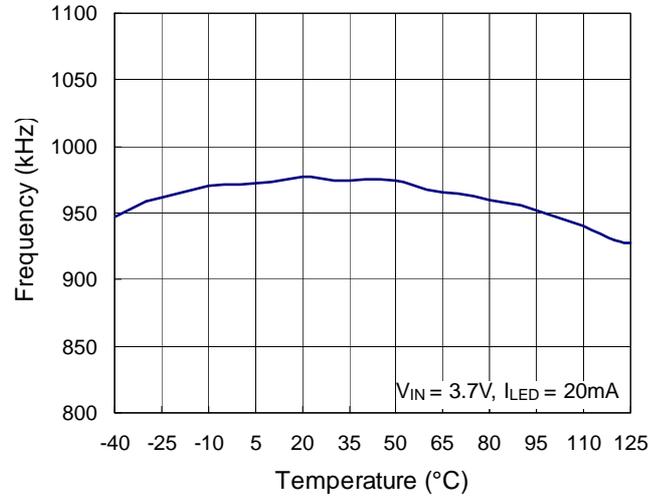
**Quiescent Current vs. Input Voltage**



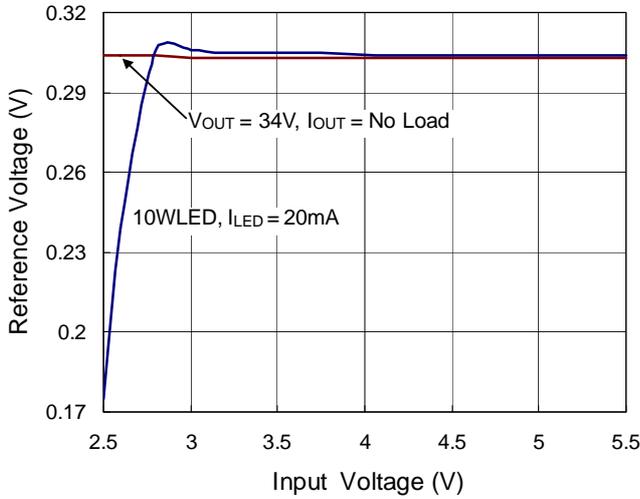
**Frequency vs. Input Voltage**



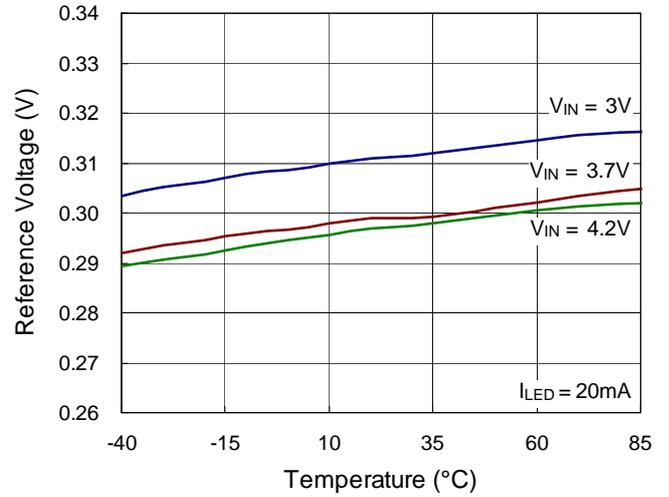
**Frequency vs. Temperature**



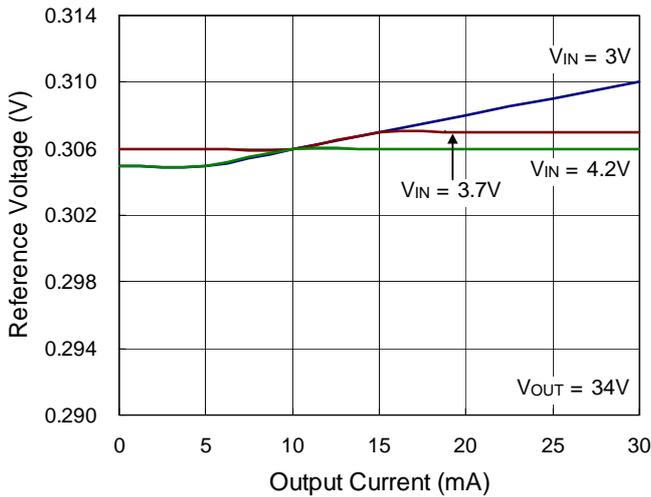
Reference Voltage vs. Input Voltage



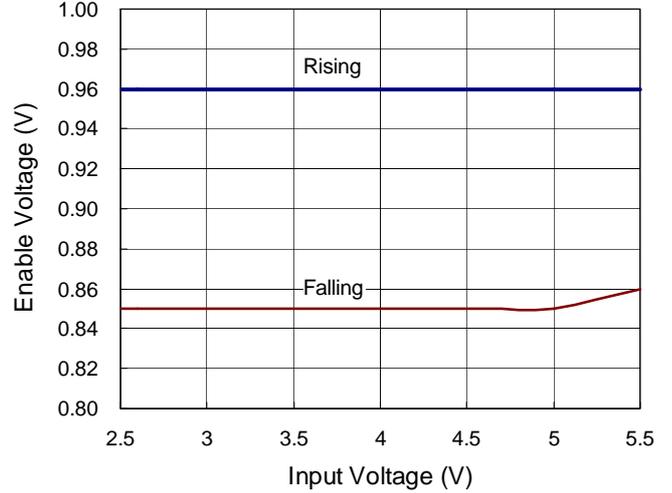
Reference Voltage vs. Temperature



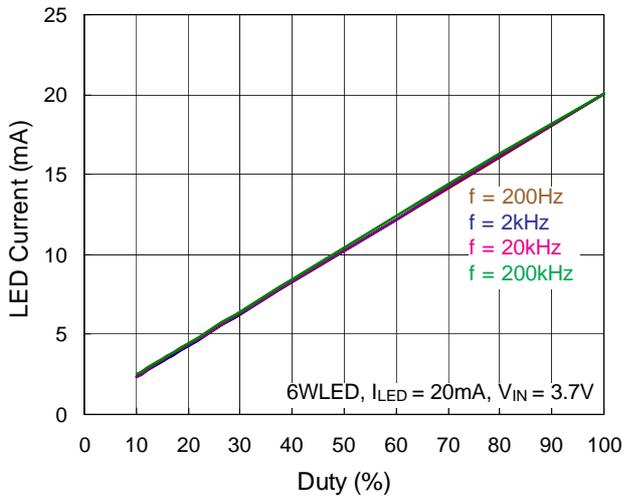
Reference Voltage vs. Output Current



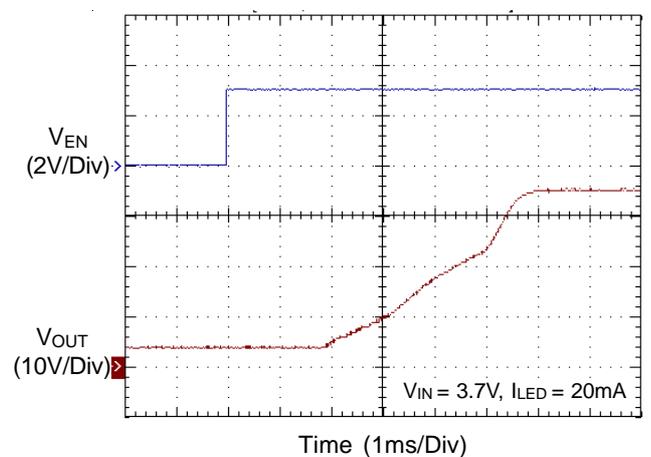
Enable Threshold vs. Input Voltage



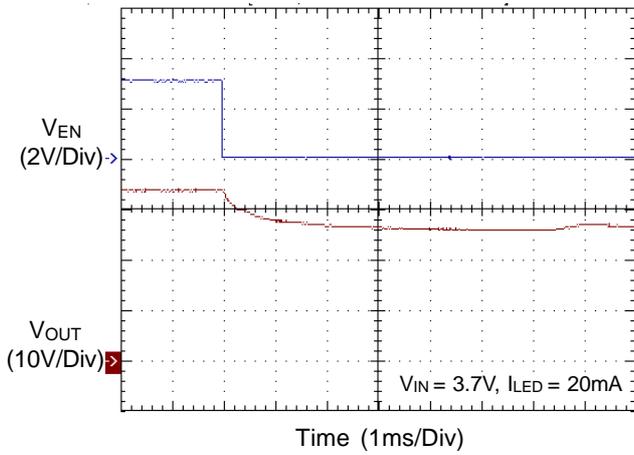
LED Current vs. Duty



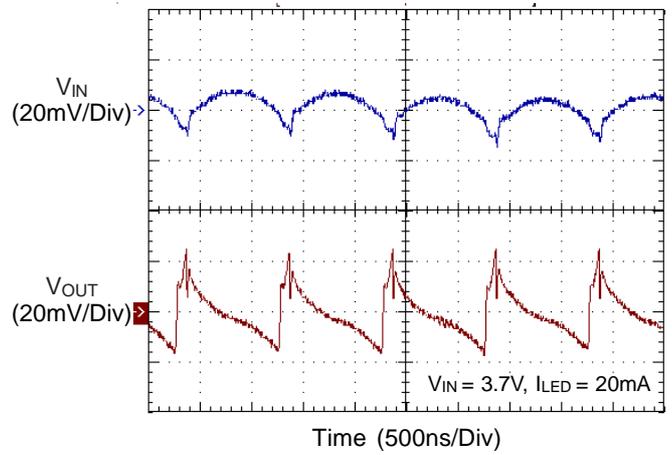
Power On from EN



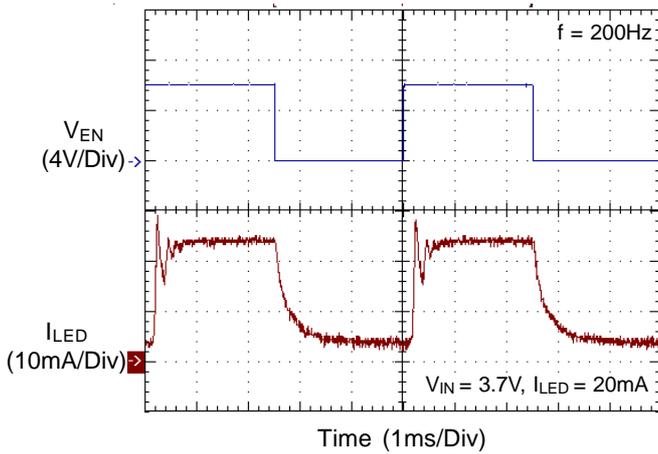
**Power Off from EN**



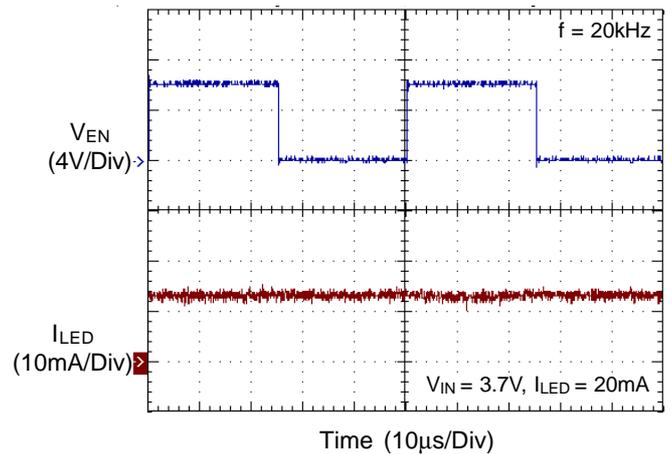
**Ripple Voltage**



**PWM Dimming from EN**



**PWM Dimming from EN**



## Applications Information

### LED Current Setting

The loop of Boost structure will keep the FB pin voltage equal to the reference voltage  $V_{REF}$ . Therefore, when  $R_{SET}$  connects FB pin and GND, the current flows from  $V_{OUT}$  through LED and  $R_{SET}$  to GND will be decided by the current on  $R_{SET}$ , which is equal to following equation :

$$I_{LED} = \frac{V_{REF}}{R_{SET}}$$

### Dimming Control

#### a. Using a PWM Signal to EN Pin

For the brightness dimming control of the RT8514, the IC provides typically 300mV feedback voltage when the EN pin is pulled constantly high. However, EN pin allows a PWM signal to reduce this regulation voltage by changing the PWM duty cycle to achieve LED brightness dimming control. The relationship between the duty cycle and FB voltage can be calculated as following equation :

$$V_{FB} = \text{Duty} \times 300\text{mV}$$

Where

Duty = duty cycle of the PWM signal

300mV = internal reference voltage

As shown in Figure 1, the duty cycle of the PWM signal is used to cut the internal 300mV reference voltage. An internal low pass filter is used to filter the pulse signal. And then the reference voltage can be made by connecting the output of the filter to the error amplifier for the FB pin voltage regulation.

However, the internal low pass filter 3db frequency is 500Hz. When the dimming frequency is lower than 500Hz,  $V_A$  is also a PWM signal and the LED current is controlled directly by this signal. When the frequency is higher than 500Hz, PWM is filtered by the internal low pass filter and the  $V_A$  approach a DC signal. And the LED current is a DC current which eliminate the audio noise. Two figures of PWM Dimming from EN are shown in Typical Operating Characteristics section and the PWM dimming frequency is 200Hz and 20kHz respectively.

For the RT8514, the minimum duty vs. frequency is listed in following table.

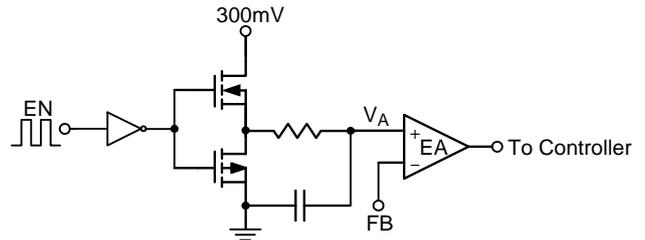


Figure 1. Block Diagram of Programmable FB Voltage Using PWM Signal

	PWM Minimum Duty
Dimming frequency < 500Hz	4%
Dimming frequency > 500Hz	10%

#### b. Using a DC Voltage

Using a variable DC voltage to adjust the brightness is a popular method in some applications. The dimming control using a DC voltage circuit is shown in Figure 2. As the DC voltage increases, the current flows through  $R_3$  increasingly and the voltage drop on  $R_3$  increase, i.e. the LED current decreases. For example, if the  $V_{DC}$  range is from 0V to 2.8V and assume the RT8514 is selected which  $V_{REF}$  is equal to 0.3V, the selection of resistors in Figure 2 sets the LED current from 21mA to 0mA. The LED current can be calculated by the following equation.

$$I_{LED} = \frac{V_{REF} - \frac{R_3 \times (V_{DC} - V_{REF})}{R_4}}{R_{SET}}$$

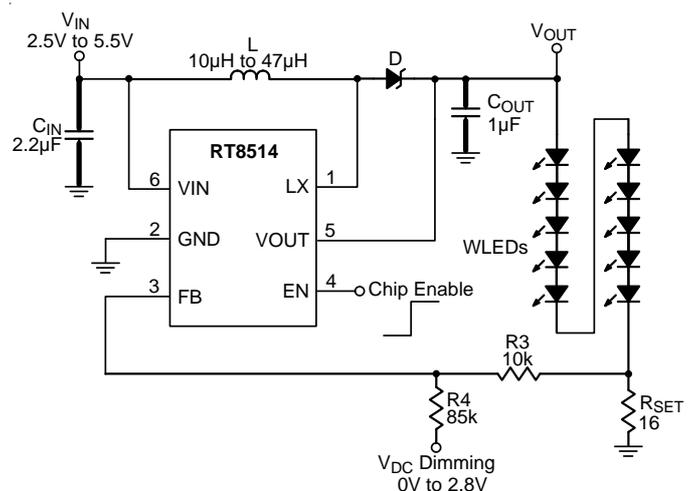


Figure 2. Dimming Control Using a DC Voltage

**c. Using a Filtered PWM signal**

Another common application is using a filtered PWM signal as an adjustable DC voltage for LED dimming control. A filtered PWM signal acts as the DC voltage to regulate the output current. The recommended application circuit is shown as Figure 3. In this circuit, the output ripple depends on the frequency of PWM signal. For smaller output voltage ripple (<100mV), the recommended frequency of 2.8V PWM signal should be above 2kHz. To fix the frequency of PWM signal and change the duty cycle of PWM signal can get different output current. The LED current can be calculated by the following equation :

$$I_{LED} = \frac{V_{REF} - \frac{R3 \times (V_{PWM} \times Duty - V_{REF})}{R4 + R_{DC}}}{R_{SET}}$$

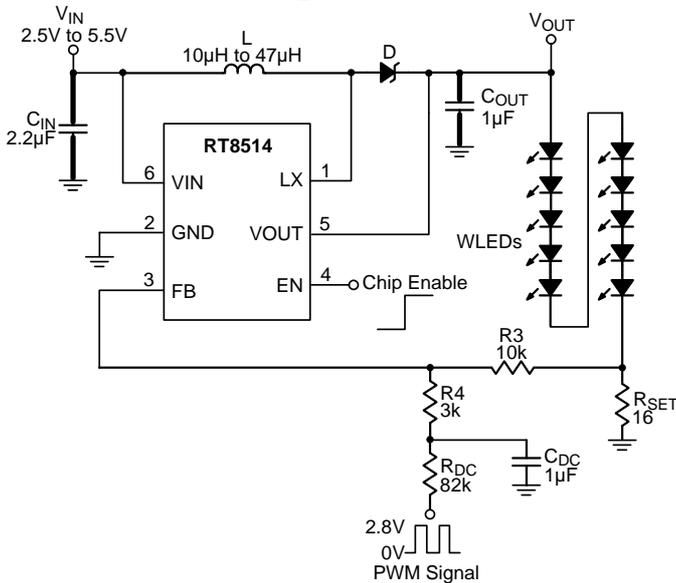


Figure 3. Dimming Control Using a Filtered PWM Signal

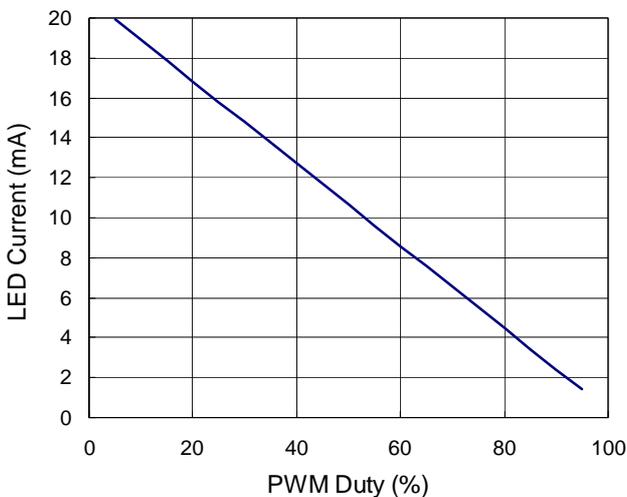


Figure 4. PWM Duty Cycle vs. LED Current

By the above equation and the application circuit shown in Figure 3, and assume the RT8514 is selected which V<sub>REF</sub> is equal to 0.3V. Figure 4 shows the relationship between the LED current and PWM duty cycle. For example, when the PWM duty is equal to 60%, the LED current will be equal to 8.6mA. When the PWM duty is equal to 40%, the LED current will be equal to 12.7mA.

**Constant Output Voltage Control**

The output voltage of the R8514 can be adjusted by the divider circuit on the FB pin. Figure 5 shows the application circuit for the constant output voltage. The output voltage can be calculated by the following equations :

$$V_{OUT} = V_{REF} \times \frac{R1 + R2}{R2} ; R2 > 10k$$

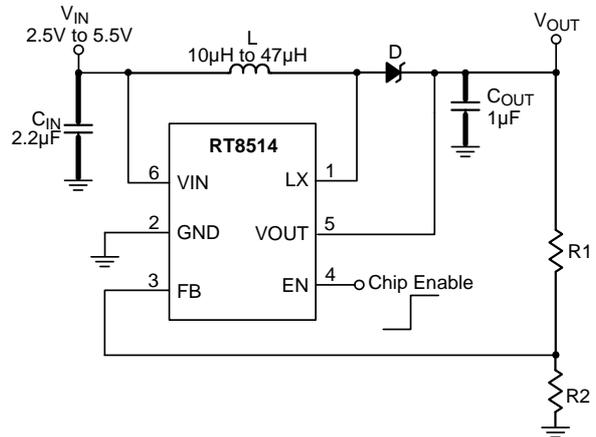


Figure 5. Constant Output Voltage Application

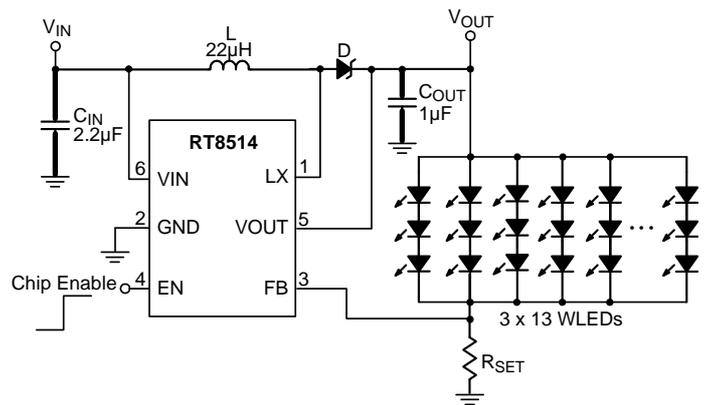


Figure 6. Application for Driving 3 X 13 WLEDs

### Application for Driving 3 x 13 WLEDs

The RT8514 can drive different WLEDs topology. For example, the Figure 6 shows the 3x13 WLEDs and total current is equal to 260mA. The total WLEDs current can be set by the R<sub>SET</sub> which is equal to following equation.

$$I_{\text{Total}} = \frac{V_{\text{REF}}}{R_{\text{SET}}}$$

### Power Sequence

In order to assure the normal soft-start function for suppressing the inrush current the input voltage should be ready before EN pulls high.

### Soft-Start

The function of soft-start is made for suppressing the inrush current to an acceptable value at the beginning of power-on. The RT8514 provides a built-in soft-start function by clamping the output voltage of error amplifier so that the duty cycle of the PWM will be increased gradually in the soft-start period.

### Current Limiting

The current flow through inductor as charging period is detected by a current sensing circuit. As the value comes across the current limiting threshold, the N-MOSFET will be turned off so that the inductor will be forced to leave charging stage and enter discharging stage. Therefore, the inductor current will not increase over the current limiting threshold.

### OVP/UVLO/OTP

The Over Voltage Protection is detected by a junction breakdown detecting circuit. Once V<sub>OUT</sub> goes over the detecting voltage, LX pin stops switching and the power N-MOSFET will be turned off. Then, the V<sub>OUT</sub> will be clamped to be near V<sub>OVP</sub>. As the output voltage is higher than a specified value or input voltage is lower than a specified value, the chip will enter protection mode to prevent abnormal function. As the die temperature is higher than 160°C, the chip also will enter protection mode. The power MOSFET will be turned off during protection mode to prevent abnormal operation.

### Inductor Selection

The recommended value of inductor for 10 WLEDs applications is from 10μH to 47μH. Small size and better efficiency are the major concerns for portable devices, such as the RT8514 used for mobile phone. The inductor should have low core loss at 1MHz and low DCR for better efficiency. The inductor saturation current rating should be considered to cover the inductor peak current.

### Capacitor Selection

Input ceramic capacitor of 2.2μF and output ceramic capacitor of 1μF are recommended for the RT8514 applications for driving 10 series WLEDs. For better voltage filtering, ceramic capacitors with low ESR are recommended. X5R and X7R types are suitable because of their wider voltage and temperature ranges.

### Thermal Considerations

For continuous operation, do not exceed absolute maximum operation junction temperature. The maximum power dissipation depends on the thermal resistance of IC package, PCB layout, the rate of surroundings airflow and temperature difference between junction to ambient. The maximum power dissipation can be calculated by following formula :

$$P_{D(\text{MAX})} = (T_{J(\text{MAX})} - T_A) / \theta_{JA}$$

Where T<sub>J(MAX)</sub> is the maximum operation junction temperature, T<sub>A</sub> is the ambient temperature and the θ<sub>JA</sub> is the junction to ambient thermal resistance.

For the recommended operating conditions specification of RT8514, the maximum junction temperature of the die is 125°C. The junction to ambient thermal resistance θ<sub>JA</sub> is layout dependent. For TSOT-23-6 package, the thermal resistance, θ<sub>JA</sub>, is 255°C/W on a standard JEDEC 51-3 single-layer thermal test board. The maximum power dissipation at T<sub>A</sub> = 25°C can be calculated by following formula :

$$P_{D(\text{MAX})} = (125^\circ\text{C} - 25^\circ\text{C}) / (255^\circ\text{C}/\text{W}) = 0.392\text{W for TSOT-23-6 package}$$

The maximum power dissipation depends on operating ambient temperature for fixed  $T_{J(MAX)}$  and thermal resistance  $\theta_{JA}$ . For RT8514 package, the Figure 7 of derating curves allows the designer to see the effect of rising ambient temperature on the maximum power allowed.

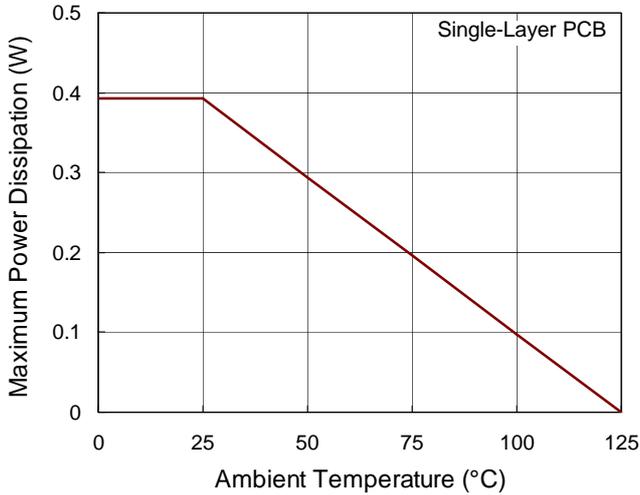


Figure 7. Derating Curves for RT8514 Package

**Layout Consideration**

For best performance of the RT8514, the following guidelines must be strictly followed.

- ▶ Input and Output capacitors should be placed close to the IC and connected to ground plane to reduce noise coupling.
- ▶ The GND should be connected to a strong ground plane for heat sinking and noise protection.
- ▶ Keep the main current traces as possible as short and wide.
- ▶ LX node of DC/DC converter is with high frequency voltage swing. It should be kept at a small area.
- ▶ Place the feedback components as close as possible to the IC and keep away from the noisy devices.

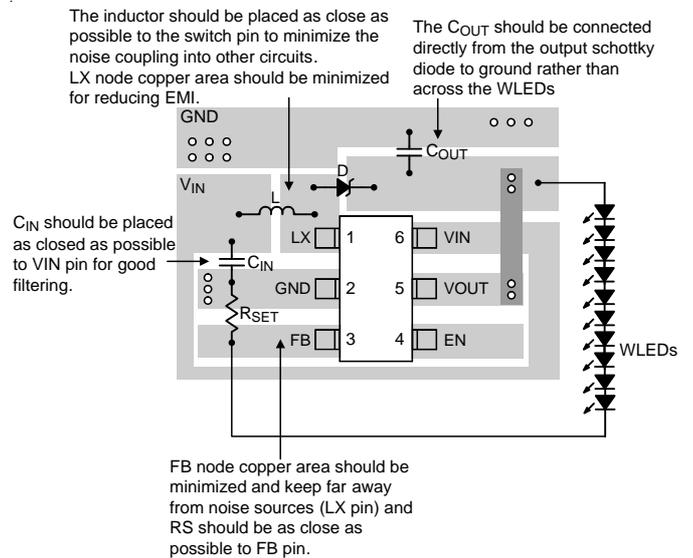
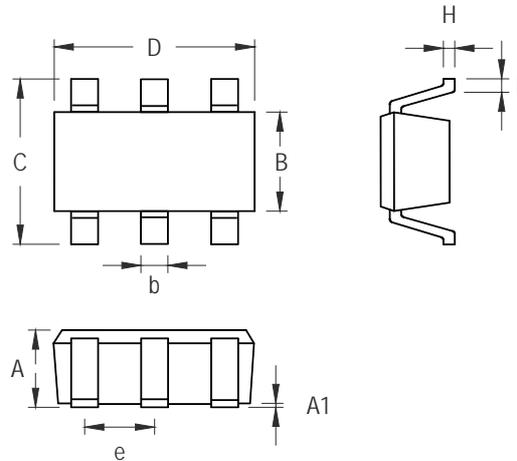


Figure 8. PCB Layout Guide

**Table 1. Recommended Components for Typical Application Circuit**

Reference	Qty	Part Number	Description	Manufacture
D	1	SR26	Schottky Diode	PANJIT
C <sub>IN</sub>	1	EMK107BJ225MA-T	Capacitor, Ceramic, 2.2μF/16V X5R	Taiyo Yuden
C <sub>OUT</sub>	1	GMK107BJ105KA	Capacitor, Ceramic, 1μF/50V X5R	Taiyo Yuden
R <sub>SET</sub>	1	RC0603FR	Resistor 15Ω, 1%	YAGEO
L	1	NR4018T220M	Inductor, 22μH	Taiyo Yuden

Outline Dimension



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	0.700	1.000	0.028	0.039
A1	0.000	0.100	0.000	0.004
B	1.397	1.803	0.055	0.071
b	0.300	0.559	0.012	0.022
C	2.591	3.000	0.102	0.118
D	2.692	3.099	0.106	0.122
e	0.838	1.041	0.033	0.041
H	0.080	0.254	0.003	0.010
L	0.300	0.610	0.012	0.024

TSOT-23-6 Surface Mount Package

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