# Tiny Package, High Performance, Constant Current Switching Regulator for White LED

## General Description

The RT9284A/B is a compact, high efficient and high integration LED driver. Internal 22V MOSFET can support 2 to 5 White LEDs for backlighting and camera flashing.

Highly integration and internal compensation network minimizes as 5 external component counts. Optimized operation frequency can meet the requirement of small LC filters value and low operation current with high efficiency. Internal soft start function can reduce the inrush current. Tiny package type of TSOT-23-5 and TSOT-23-6 packages provide the best solution for PCB space saving and total BOM cost.

## Features

- **$V_{IN}$ Operating Range : 2.7V to 5.5V**
- **Maximum Output Voltage up to 20V**
- **Dimming with Zero-inrush and Wide Frequency Range of 100 to 100kHz**
- **Over Voltage Protection**
- **Output Current up to 100mA at $V_{OUT}$ : 12V**
- **Zero Shutdown Supply Current**
- **Minimize the External Component**
- **Small LC Filter**
- **Internal Soft Start**
- **RoHS Compliant and 100% Lead (Pb)-Free**

## Ordering Information

RT9284□(-□□)□□

- Package Type
  - J5 : TSOT-23-5
  - J6 : TSOT-23-6
- Lead Plating System
  - P : Pb Free
  - G : Green (Halogen Free and Pb Free)
- OVP Voltage
  - 15 : 15V
  - 20 : 20V
- FB Voltage
  - A : 1.235V
  - B : 0.25V

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

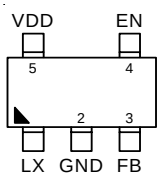
For marking information, contact our sales representative directly or through a Richtek distributor located in your area.

## Applications

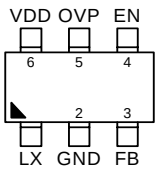
- Camera Flash White LED
- Mobile Phone, Smart Phone LED Backlight
- PDA LED Backlight
- Digital Still Camera
- Camcorder

## Pin Configurations

TOP VIEW




TSOT-23-5




TSOT-23-6

## Typical Application Circuit

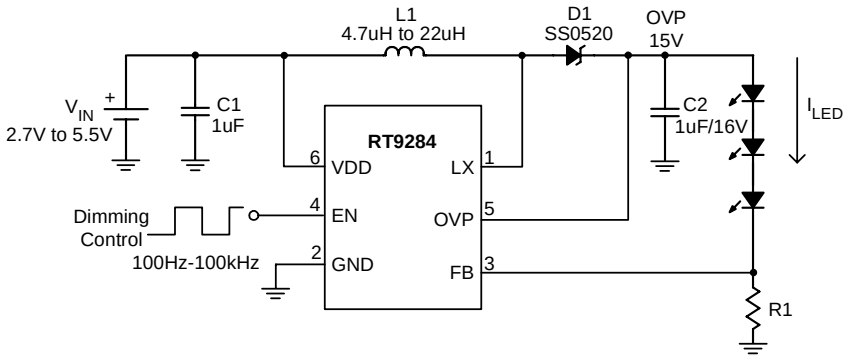



Figure 1. Application for Driving 3 Series WLEDs

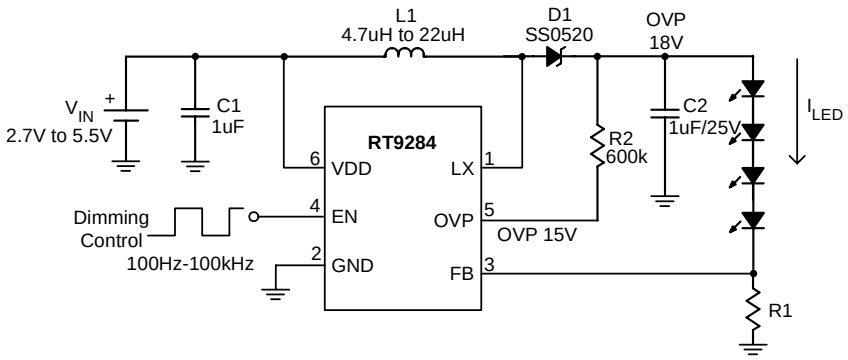



Figure 2. Application for Driving 4 Series WLEDs

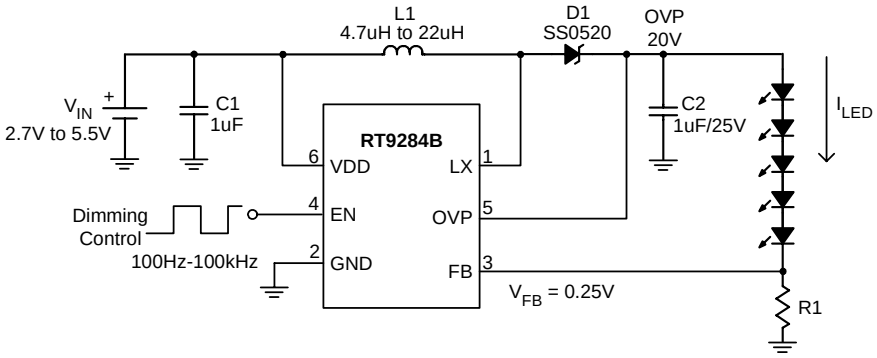



Figure 3. Application for Driving 5 Series WLEDs

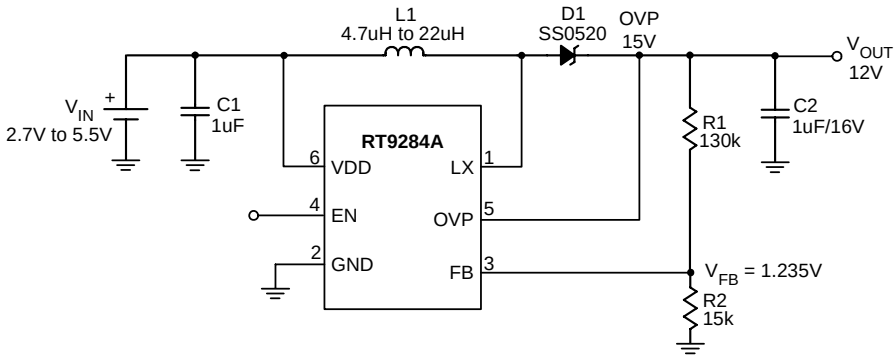
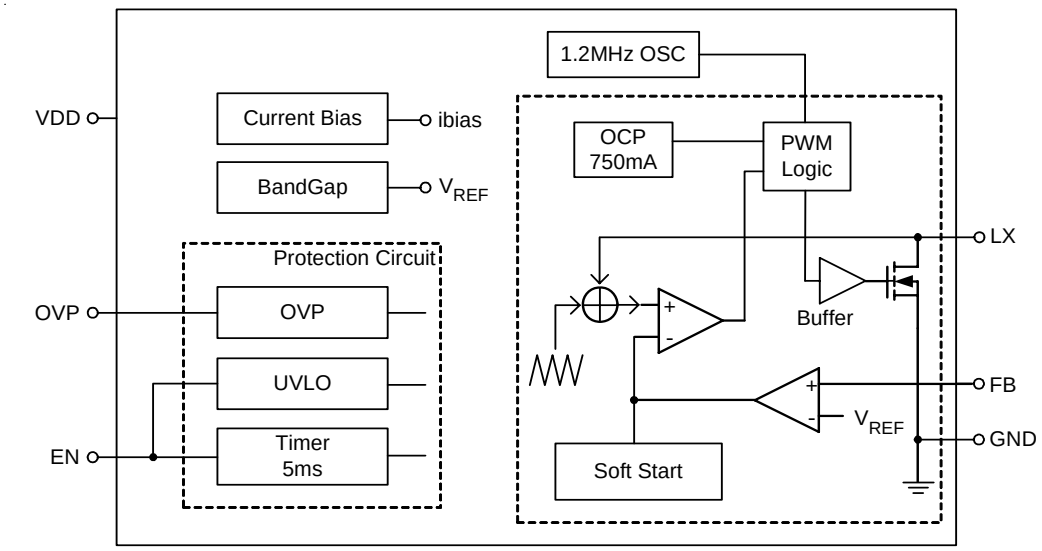



Figure 4. Application for Constant Output Voltage

## Pin Description

| Pin No. | | Pin Name | Pin Function |
|---|---|---|---|
| TSOT-23-5 | TSOT-23-6 | | |
| 1 | 1 | LX | Switch Pin. Connect this Pin to inductor and catch diode. Minimize the track area to reduce EMI. |
| 2 | 2 | GND | Ground Pin |
| 3 | 3 | FB | Feedback Reference Voltage Pin. Series connect a resistor between WLED and ground as a current sense. Sense the current feedback voltage to set the current rating. |
| 4 | 4 | EN | Chip Enable (Active High). Voltage sensing input to trigger the function of over voltage protection. Note that this pin is high impedance. There should be a pull low 100kΩ resistor connected to GND when the control signal is floating. |
| -- | 5 | OVP | Over Voltage Protection Pin. Voltage sensing input to trigger the function of over voltage protection. Leave it unconnected to disable this function. |
| 5 | 6 | VDD | Supply Input Voltage Pin. Bypass 1uF capacitor to GND to reduce the input noise. |

## Function Block Diagram



## Absolute Maximum Ratings (Note 1)

- Supply Input Voltage ---------- –0.3V to 7V
- LX Input Voltage ---------- –0.3V to 22V
- OVP Voltage ---------- –0.3V to 22V
- The Other Pins ---------- –0.3V to 6V
- Power Dissipation, $P_D$ @ $T_A$ = 25°C
  TSOT-23-5 ---------- 0.455W
  TSOT-23-6 ---------- 0.455W
- Package Thermal Resistance (Note 2)
  TSOT-23-5, $\theta_{JA}$ ---------- 220°C/W
  TSOT-23-6, $\theta_{JA}$ ---------- 220°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 Mode) ---------- 2kV
  MM (Machine Mode) ---------- 200V

## Recommended Operating Conditions (Note 4)

- Supply Input Voltage ---------- 2.7V to 5.5V
- Junction Temperature Range ---------- –40°C to 125°C
- Ambient Temperature Range ---------- –40°C to 85°C

## Electrical Characteristics

($V_{IN}$ = 3.7V, $T_A$ = 25°C unless otherwise specified)

| Parameter | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| **System Supply Input** | | | | | | |
| Operation voltage Range | $V_{DD}$ | | 2.7 | -- | 5.5 | V |
| Under Voltage Lock Out | $V_{DD}$ | | 1.8 | 2.2 | 2.5 | V |
| Quiescent Current | $I_{DD}$ | FB = 1.5V, No switch | 50 | 300 | 1000 | uA |
| Supply Current | $I_{DD}$ | FB = 0V, Switch | 0.1 | 2 | 3 | mA |
| Shut Down Current | $I_{DD}$ | $V_{EN}$ < 0.4V | -- | -- | 1 | uA |
| Line Regulation | | $V_{IN}$ : 3.0~4.3V | -- | 3 | -- | % |
| **Oscillator** | | | | | | |
| Operation Frequency | $f_{OSC}$ | | 0.9 | 1.2 | 1.5 | MHz |
| Maximum Duty Cycle | | | 85 | -- | -- | % |
| Dimming Frequency | | | 100 | -- | 100k | Hz |
| **Reference Voltage** | | | | | | |
| Feedback Voltage (Note 5) | RT9284A | | 1.173 | 1.235 | 1.296 | V |
| | RT9284B | | 0.237 | 0.25 | 0.263 | |

*To be continued*

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| **MOSFET** | | | | | | |
| On Resistance of MOSFET | $R_{DS(ON)}$ | | -- | 0.75 | -- | Ω |
| **Protection** | | | | | | |
| OVP Threshold | $V_{OVP}$ | for 2,3,4 WLEDs application | 14 | 15 | 16 | V |
| | | for 5 WLED application | 19 | 20 | 21 | |
| OVP Sink Current | | | -- | 5 | -- | μA |
| OCP | | | -- | 750 | -- | mA |
| Shut Down Voltage | $V_{EN}$ | | -- | -- | 0.4 | V |
| Enable Voltage | $V_{EN}$ | | 1.5 | -- | -- | V |

**Note 1.** Stresses listed as the above "Absolute Maximum Ratings" may cause permanent damage to the device. These are for stress ratings. 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 remain possibility to affect device reliability.

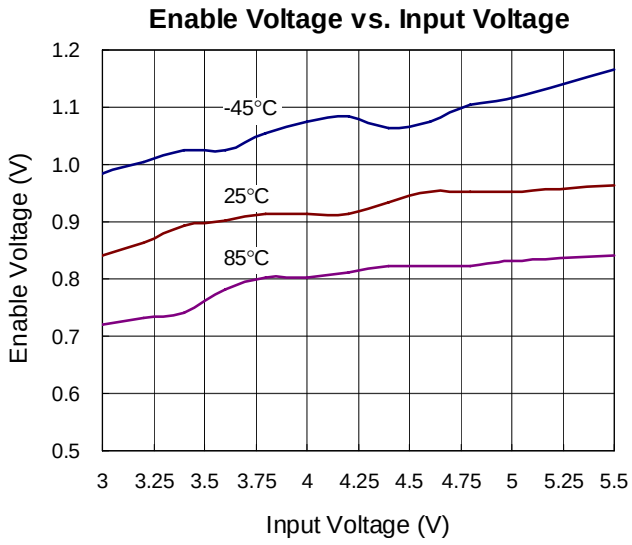
**Note 2.** $\theta_{JA}$ is measured in the natural convection at $T_A$ = 25°C on a low effective thermal conductivity test board of JEDEC 51-3 thermal measurement standard.

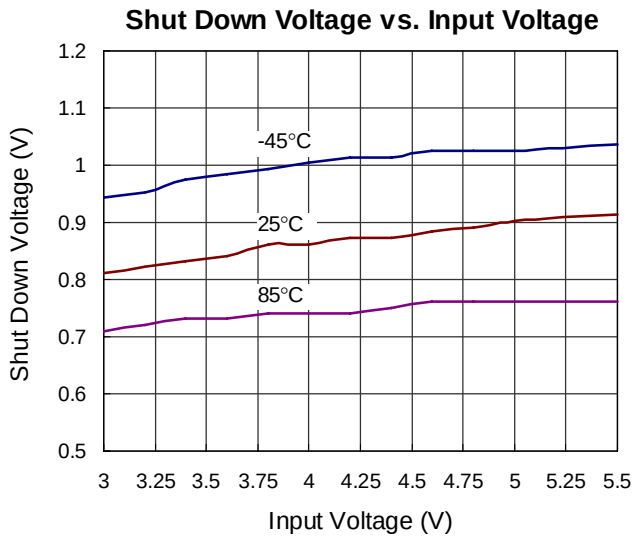
**Note 3.** Devices are ESD sensitive. Handling precaution recommended.

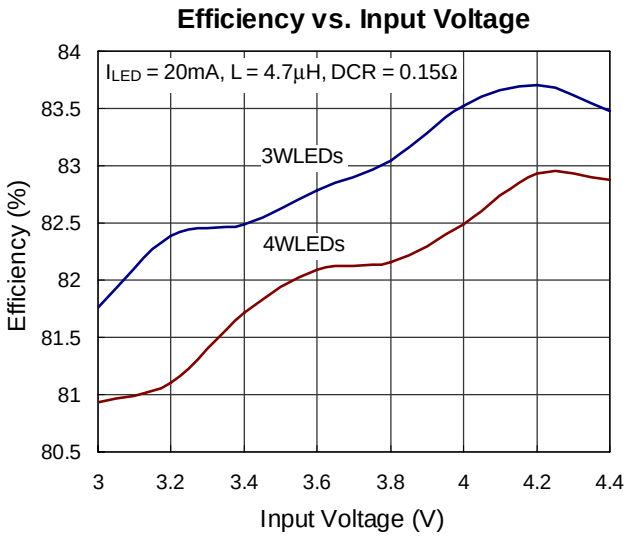
**Note 4.** The device is not guaranteed to function outside its operating conditions.

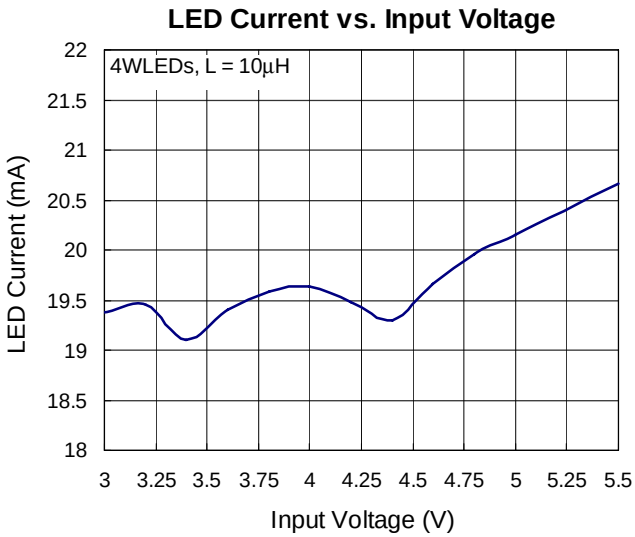
**Note 5.** Floating the OVP pin to disable OVP function.

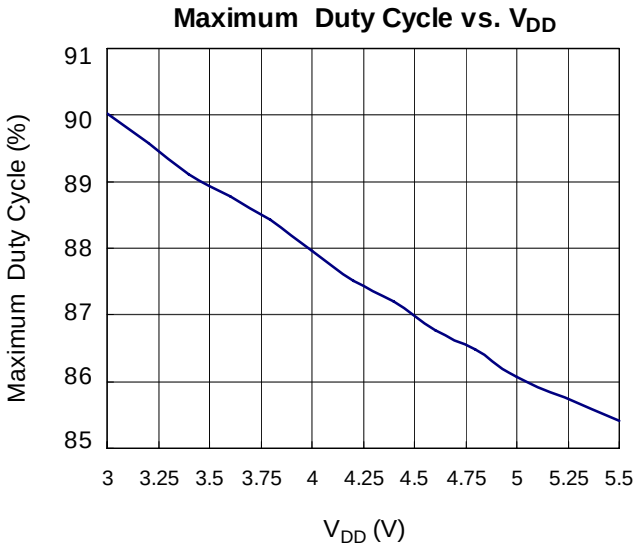
## Typical Operating Characteristics

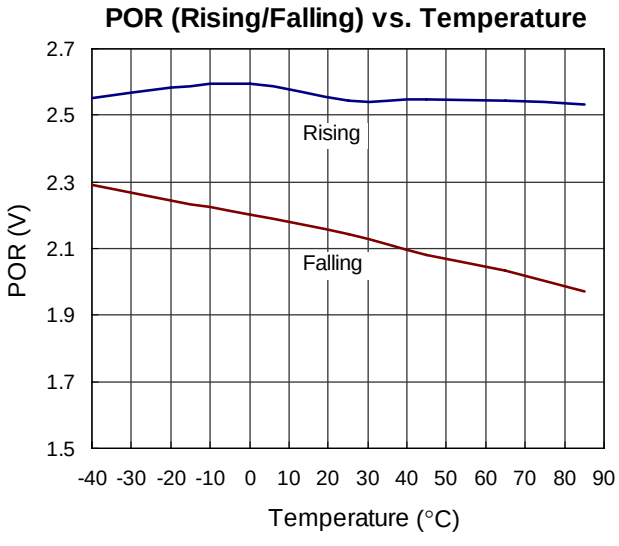


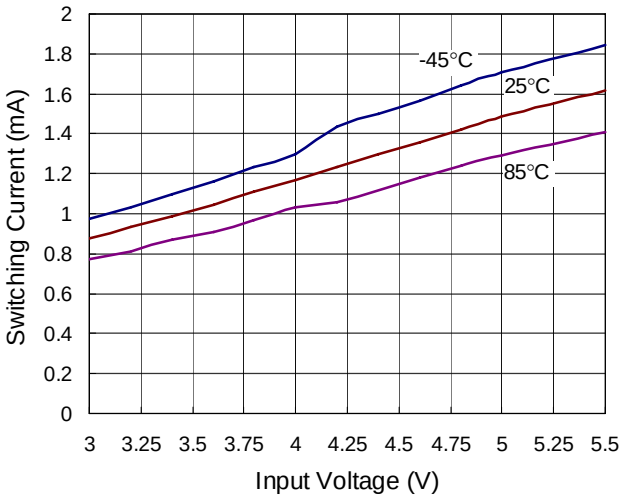



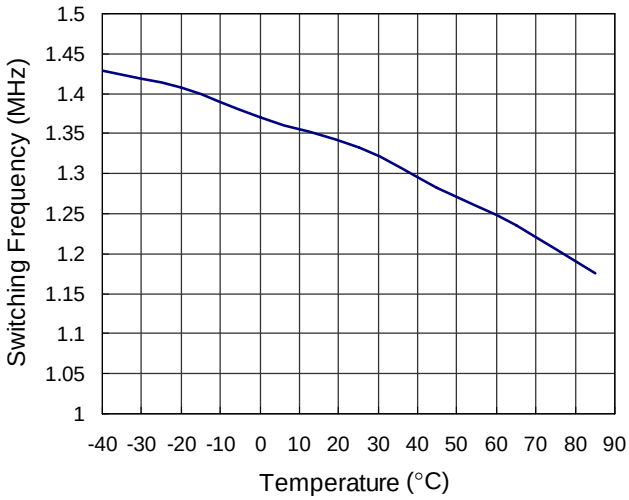



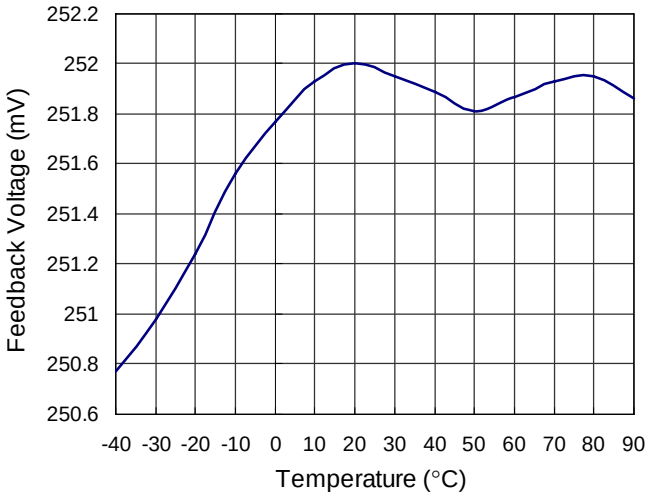
**Switching Current vs. Input Voltage**



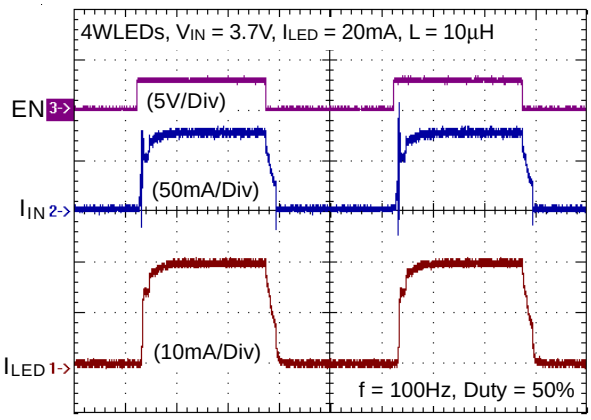

**Switching Frequency vs. Temperature**



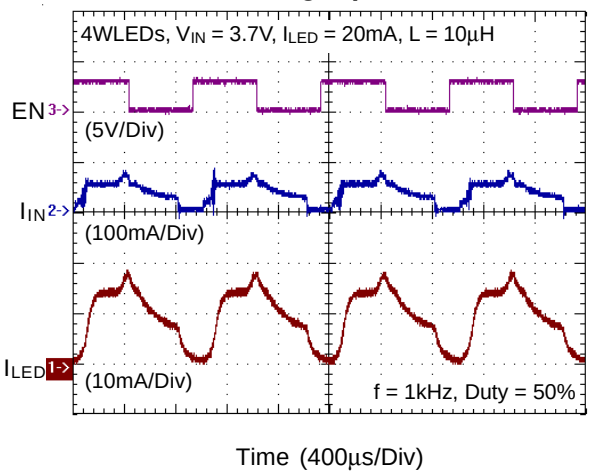

**Feedback Voltage vs. Temperature**



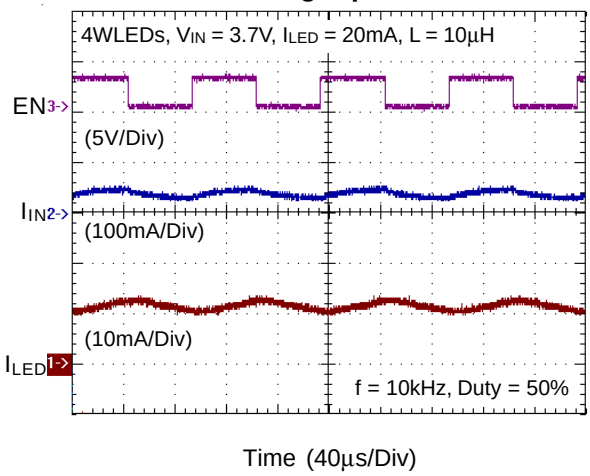

**Dimming Operation**



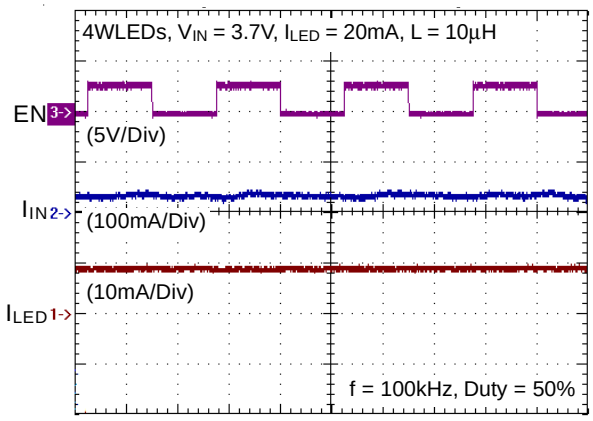

**Dimming Operation**




**Dimming Operation**

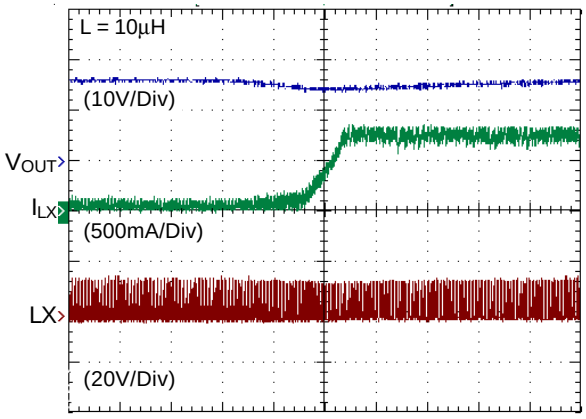


### Dimming Operation



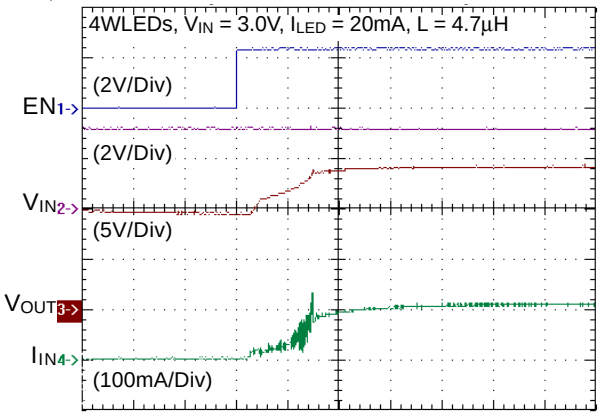

Time (4µs/Div)

### OCP



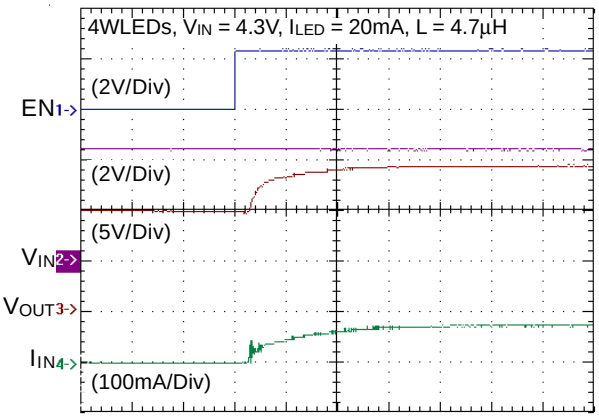

Time (25µs/Div)

### Inrush Current



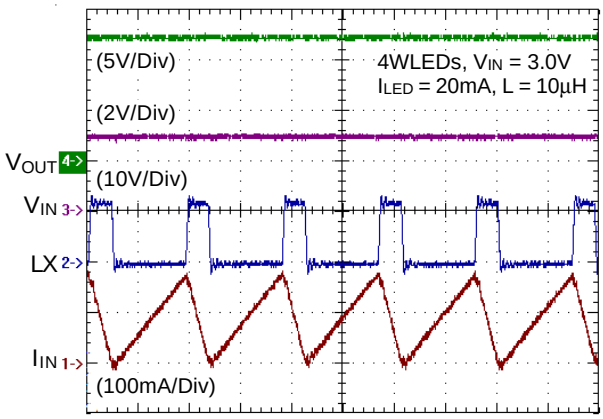

Time (500µs/Div)

### Inrush Current



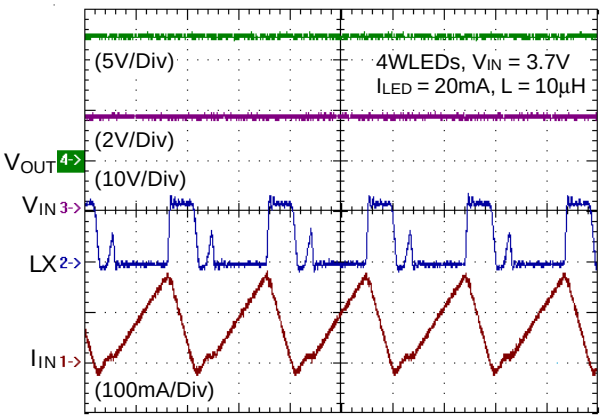

Time (500µs/Div)

### Normal Operation



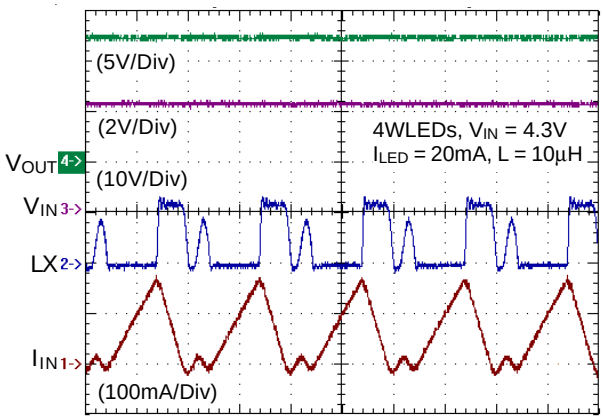

Time (400ns/Div)

### Normal Operation



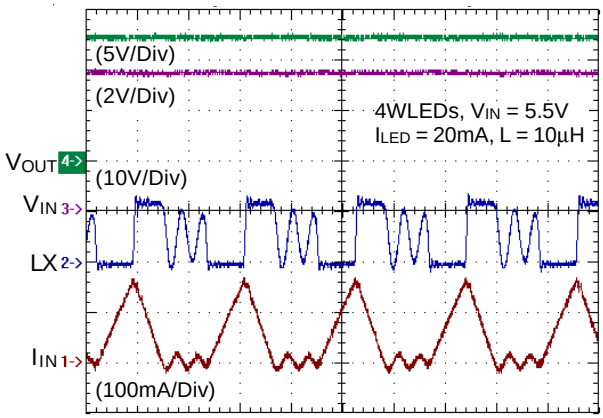

Time (400ns/Div)

**Normal Operation**




Time (400ns/Div)

**Normal Operation**




Time (400ns/Div)

## Application Information

### Power Sequence

The RT9284A/B must take notice of the power sequence. The power sequence of RT9284A/B has to VDD early than EN or else the RT9284A/B maybe fall into the unknown state to result in RT9284A/B turn off.

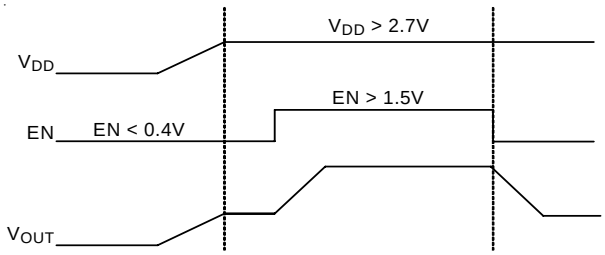



Figure 5

### LED Current Control

The RT9284A/B regulates the LED current by setting the current sense resistor (R1) connecting to feedback and ground. As shown in Table 1, the RT9284A feedback voltage ($V_{FB}$) is 1.235V and the RT9284B feedback voltage ($V_{FB}$) is 0.25V. The LED current ($I_{LED}$) can be set by a resistor R1. In order to have an accurate LED current, a precision resistor is preferred (1% is recommended).

**Table 1**

| Version | Feedback Reference Voltage $V_{FB}$ (V) | LED Current Setting $I_{LED}$ (A) |
|---|---|---|
| RT9284A | 1.235 | $I_{LED}$ = 1.235/R1 |
| RT9284B | 0.25 | $I_{LED}$ = 0.25/R1 |

### Dimming Control

a. Using a PWM Signal to EN Pin

For controlling the LED brightness, the RT9284A/B can perform the dimming control by applying a PWM signal to EN pin. The internal soft start and the wide range dimming frequency from100 to100kHz can eliminate inrush current and audio noise when dimming. The average LED current is proportional to the PWM signal duty cycle. The magnitude of the PWM signal should be higher than the maximum enable voltage of EN pin, in order to let the dimming control perform correctly.

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 6. According to the Superposition Theorem, as the DC voltage increases, the voltage contributed to $V_{FB}$ increases and the voltage drop on R2 decreases, i.e. the LED current decreases. For example, if the $V_{DC}$ range is from 0V to 2.8V, the selection of resistors in Figure 6 sets dimming control of LED current from 20mA to 0mA.

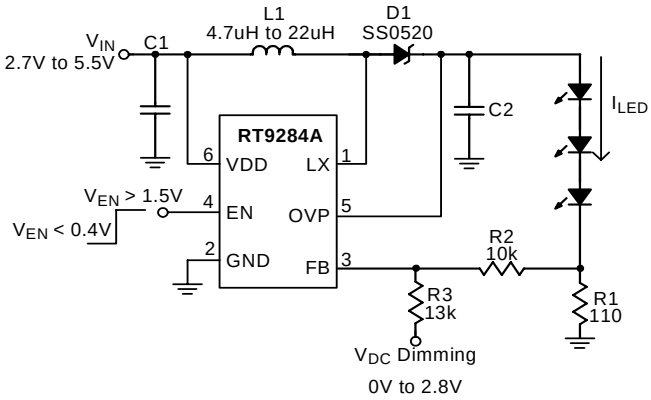



Figure 6. Dimming Control Using a DC Voltage for RT9284A

The LED current can be calculated by the following equation.

$$I_{LED} = \frac{V_{FB} - \frac{R2 \times (V_{DC} - V_{FB})}{R3}}{R1}$$

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 in the Figure 7. 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. Figure 8. shows the relationship between LED current and PWM duty cycle.

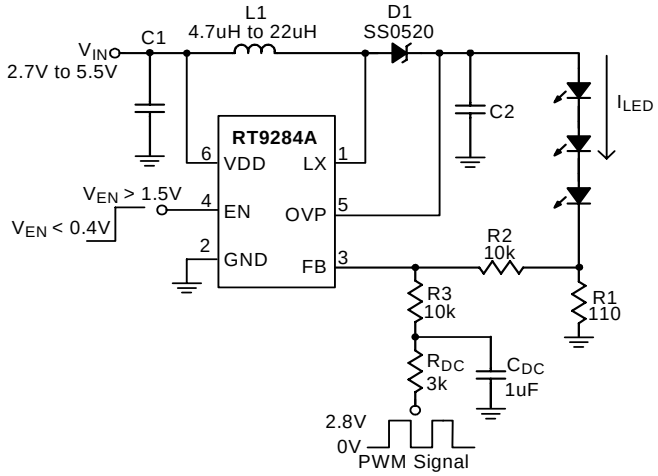



Figure 7. Filtered PWM Signal for LED Dimming Control of RT9284A

The LED current can be calculated by the following equation.

$$I_{LED} = \frac{V_{FB} - \frac{R2 \times (V_{PWM} \times Duty - V_{FB})}{R3 + R_{DC}}}{R1}$$

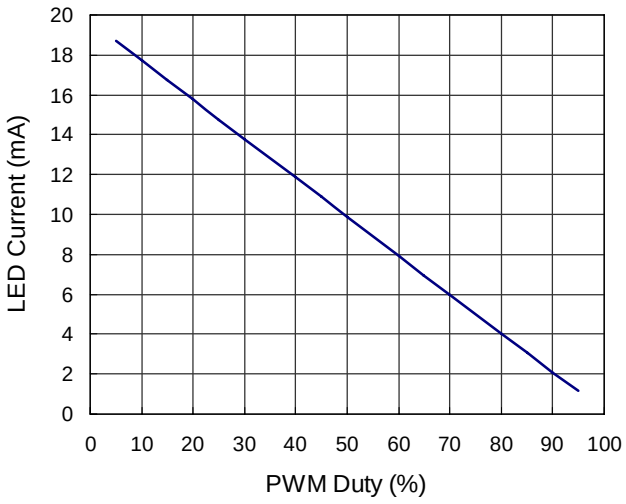



Figure 8

### Inductor Selection

The recommended value of inductor for 3 to 5 WLEDs applications are 4.7 to 22μH. Small size and better efficiency are the major concerns for portable device, such as RT9284A/B used for mobile phone. The inductor should have low core loss at 1.2MHz and low DCR for better efficiency. To avoid inductor saturation current rating should be considered.

### Capacitor Selection

Input and output ceramic capacitors of 1μF are recommended for RT9284A/B applications. 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.

### Diode Selection

Schottky diode is a good choice for RT9284A/B because of its low forward voltage drop and fast reverse recovery.

Using Schottky diode can get better efficiency. The high-speed rectification is also a good characteristic of Schottky diode for high switching frequency. Current rating of the diode must meet the root mean square of the peak current and output average current multiplication as following :

$$I_D(RMS) \approx \sqrt{(I_{OUT} \times I_{PEAK})}$$

The diode' s reverse breakdown voltage should be larger than the output voltage. SS0520 is recommended Schottky diode for rectifier.

### Layout Guide

- A full GND plane without gap break.
- VCC to GND noise bypass–Short and wide connection for the 1μF MLCC capacitor between Pin6 and Pin2.
- Minimized LX node copper area to reduce EMI.
- Minimized FB node copper area and keep far away from noise sources.

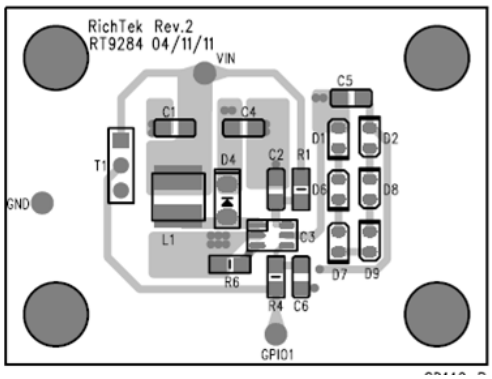



Figure 9. Top Layer

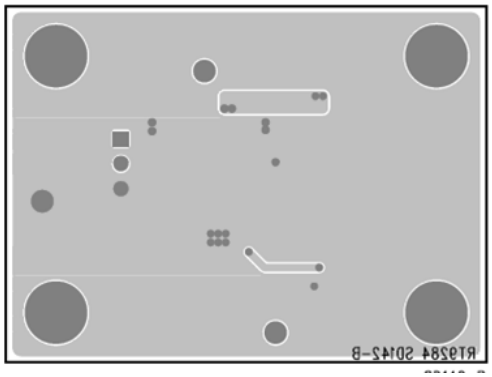
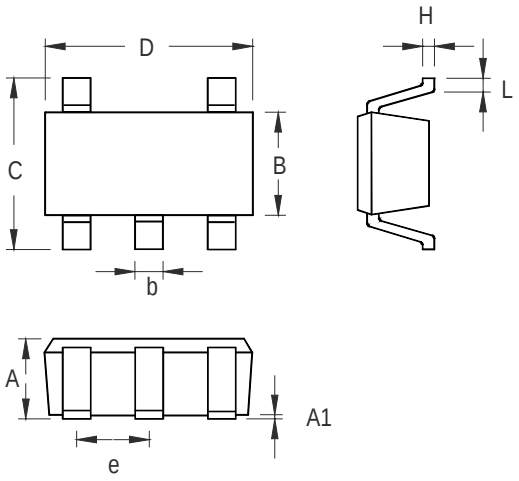


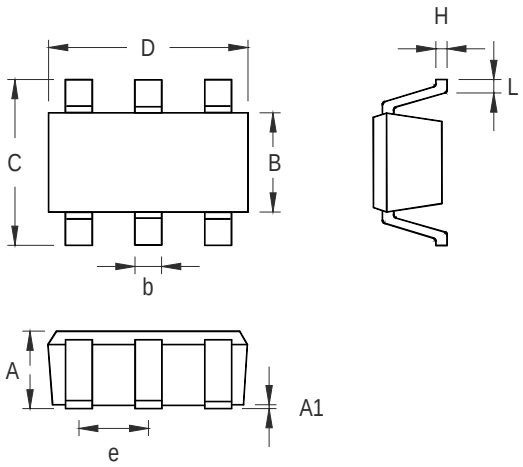
Figure 10. Bottom Layer

## 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-23-5 Surface Mount Package**




| 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**


## Richtek Technology Corporation

Headquarter
5F, No. 20, Taiyuen Street, Chupei City
Hsinchu, Taiwan, R.O.C.
Tel: (8863)5526789 Fax: (8863)5526611

## Richtek Technology Corporation

Taipei Office (Marketing)
5F, No. 95, Minchiuan Road, Hsintien City
Taipei County, Taiwan, R.O.C.
Tel: (8862)86672399 Fax: (8862)86672377
Email: marketing@richtek.com


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