# Tiny Package, High Performance, Diode Embedded White LED Driver

## General Description

The RT9285 is a high frequency asynchronous boost converter with internal diode, which can support 2 to 5 White LEDs for backlighting and OLED power supply. 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. The device comes with 20V over voltage protection to allow inexpensive and small-output capacitors with lower voltage rating. The LED current is initially set with the external sense resistor $R_{SET}$, and the feedback voltage is 250 mV. Tiny package type TSOT-23-6 and WDFN-8L 2x2 packages provide the best solution for PCB space saving and total BOM cost.

## Ordering Information

RT9285□□□

- Package Type
  - QW : WDFN-8L 2x2 (W-Type)
  - J6 : TSOT-23-6
- Operating Temperature Range
  - P : Pb Free with Commercial Standard
  - G : Green (Halogen Free with Commercial Standard)
- Dimming
  - A : Digital Pulse Dimming
  - B : PWM Clock Dimming

Note :

Richtek Pb-free and Green 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.
- }100%matte tin (Sn) plating.

## Marking Information

For marking information, contact our sales representative directly or through a Richtek distributor located in your area, otherwise visit our website for detail.

## Features

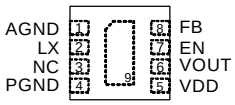
- **$V_{IN}$ Operating Range : 2.7V to 5.5V**
- **Up to 85% Efficiency**
- **22V Internal Power N-MOSFET**
- **1MHz Switching Frequency**
- **Built-in Diode**
- **Digital Dimming with Zero-Inrush**
- **Input UVLO Protection**
- **Output Over Voltage Protection**
- **Internal Soft Start and Compensation**
- **TSOT-23-6 and 8-Lead WDFN Package**
- **RoHS Compliant and 100% Lead (Pb)-Free**

## Applications

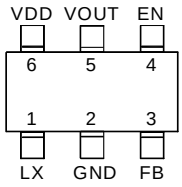
- Cellular Phones
- Digital Cameras
- PDAs and Smart Phones
- Porbable Instruments
- MP3 Player
- OLED Power

## Pin Configurations

(TOP VIEW)



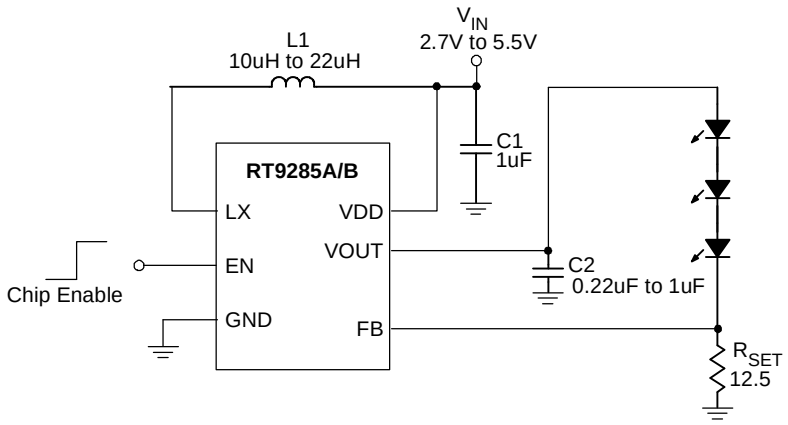

WDFN-8L 2x2




TSOT-23-6

**Note** : There is no pin1 indicator on top mark for TSOT-23-6 type, and pin 1 will be lower left pin when reading top mark from left to right.

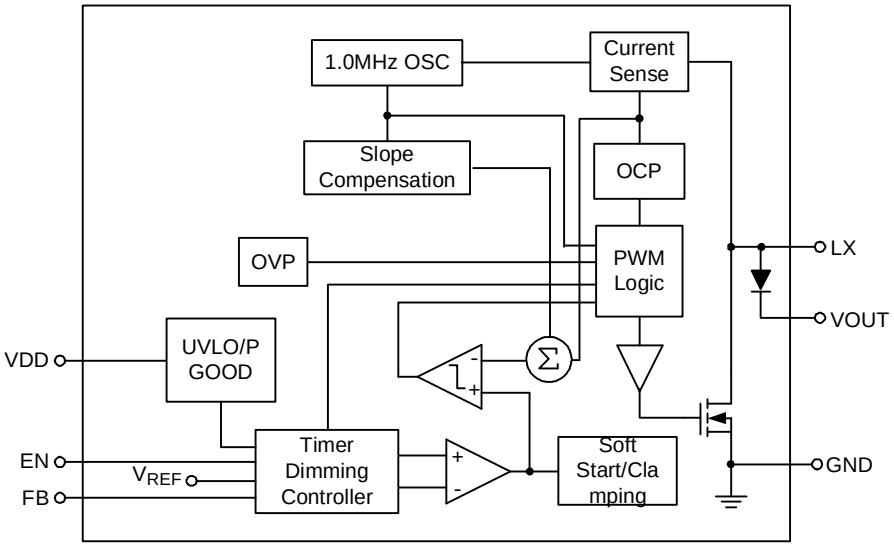
## Typical Application Circuit




## Functional Pin Description

| Pin No. | | Pin Name | Pin Function |
|---|---|---|---|
| WDFN-8L | TSOT-23-6 | | |
| 1 | -- | AGND | Analog Ground Pin. |
| 2 | 1 | LX | LX Pin. Connect this Pin to an inductor. Minimize the track area to reduce EMI. |
| -- | 2 | GND | Ground Pin. |
| 3, Exposed Pad (9) | -- | NC | No Internal Connection. |
| 4 | -- | PGND | Power Ground Pin. |
| 5 | 6 | VDD | Supply Input Voltage Pin. Bypass 1uF capacitor to GND to reduce the input ripple. |
| 6 | 5 | VOUT | Output Voltage pin. The pin internally connects to OVP diode to limit output voltage while LEDs are disconnected. |
| 7 | 4 | EN | Chip Enable (Active High). Note that this pin has an internal pull-down resistance around 300kΩ. |
| 8 | 3 | FB | Feedback Pin. Series connecting a resistor between WLED and ground as a current sense. Sense the current feedback voltage to set the current rating. |
| | -- | GND | Exposed pad should be soldered to PCB board and connected to GND. |

## Function Block Diagram




## Operation

### Soft-Start

The Soft-Start function is made by clamping the output voltage of error amplifier with another voltage source that is increased slowly from zero to near $V_{IN}$ in the Soft-Start period. Therefore, the duty cycle of the PWM will be increased from zero to maximum in this period. The soft-start time is decided by a timer of 1.5ms. The charging time of the inductor will be limited as the smaller duty so that the inrush current can be reduced to an acceptable value.

### Over Voltage Protection

The Over Voltage Protection is detected by a junction breakdown detecting circuit. Once $V_{OUT}$ goes over the detecting voltage, LX pin stops switching and the power NMOS is turned off. Then, the $V_{OUT}$ is clamped to be near $V_{OVP}$.

### LED Current Setting

The RT9285 regulates the LED current by setting the current sense resistor ($R_{SET}$) connecting to feedback and ground. The internal feedback reference voltage is 0.25V. The LED current can be set from following equation easily.

$I_{LED}$ (mA) = 0.25/$R_{SET}$

In order to have an accurate LED current, precision resistors are preferred (1% is recommended). The table for $R_{SET}$ selection is shown below.

**Table 1. $R_{SET}$ Value Selection**

| $I_{LED}$ (mA) | $R_{SET}$ (W) |
|---|---|
| 5 | 49.9 |
| 10 | 24.9 |
| 12 | 21 |
| 15 | 16.5 |
| 20 | 12.4 |

### Digital Pulse Dimming (RT9285A)

The digital pulse dimming is implemented by checking the low-level duration time of EN pin. As the duration time is in the range of $T_{UP}$, the LED current will increase 1/16. If the duration time is in the range of $T_{DOWN}$, the LED current will decrease 1/16. The high-level duration time of EN pin needs larger than $T_{DELAY}$ to make sure the logic can be detected correctly. As the LED current is set to MAX (16/16), it will keep MAX until the decreasing signal is detected. On the other hand, as the LED current is set to MIN (1/16), it will keep MIN until the increasing signal is detected. When the chip turns on, the initial state of LED current is MAX.

**Table 2**

| Feedback Voltage | Time | Symbol |
|---|---|---|
| Increase | 0.5µs to 75µs | $T_{UP}$ |
| Decrease | 180µs to 300µs | $T_{DOWN}$ |
| Delay between steps | > 0.5µs | $T_{DELAY}$ |
| Shutdown | > 1ms | $T_{SHDN}$ |

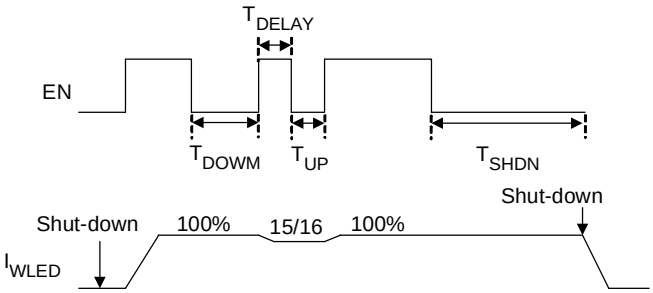



Figure 1

**PWM Dimming (RT9285B)**

For controlling the LED brightness, the RT9285B can perform the dimming control by applying a PWM signal to EN pin. A low pass filter is implemented inside chip to reduce the slew rate of $I_{LED}$ to prevent the audio noise. 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.

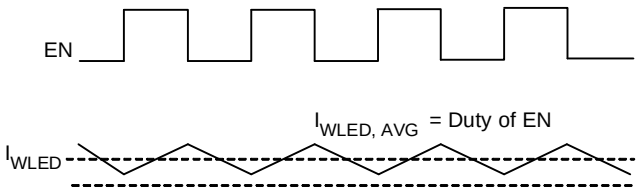



Figure 2

**Current Limiting**

The current flow through the inductor as charging period is detected by a current sensing circuit. As the value over the current limiting, the NMOS 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.

## Absolute Maximum Ratings (Note 1)

- Supply Voltage, $V_{IN}$ ---------- –0.3 to 6V
- LX Input Voltage ---------- –0.3V to 22V
- Output Voltage ---------- –0.3V to 21V
- The other pins ---------- –0.3V to 6V
- Power Dissipation, $P_D$ @ $T_A$ = 25°C
  - TSOT23-6 ---------- 0.455W
  - WDFN-8L 2x2 ---------- 0.606W
- Package Thermal Resistance (Note 4)
  - TSOT23-6, $\theta_{JA}$ ---------- 220°C/W
  - WDFN-8L 2x2, $\theta_{JA}$ ---------- 165°C/W
- Junction Temperature ---------- 150°C
- Lead Temperature (Soldering, 10 sec.) ---------- 260°C
- Storage Temperature Range ---------- –65°C to 150°C
- ESD Susceptibility (Note 2)
  - HBM (Human Body Mode) ---------- 2kV
  - MM (Machine Mode) ---------- 200V

## Recommended Operating Conditions (Note 3)

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

## Electrical Characteristics

($V_{IN}$ = 3.7V, FREQ left floating, $T_A$ = 25°C, unless otherwise specification)

| Parameter | Symbol | Test Condition | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| **System Supply Input** | | | | | | |
| Operation voltage Range | $V_{IN}$ | | 2.7 | -- | 5.5 | V |
| Under Voltage Lock Out | $V_{UVLO}$ | | 1.7 | 2 | 2.3 | V |
| Quiescent Current | $I_Q$ | FB = 1.5V, No switch | -- | 300 | 450 | µA |
| Supply Current | $I_{IN}$ | FB = 0V, Switch | -- | -- | 2 | mA |
| Shut Down Current | $I_{SHDN}$ | $V_{EN}$ < 0.4V | -- | 2 | 5 | uA |
| **Output** | | | | | | |
| Line Regulation | | $V_{IN}$ = 3V to 4.3V | -- | -- | 3 | % |
| **Oscillator** | | | | | | |
| Operation Frequency | $f_{OSC}$ | | -- | 1 | -- | MHz |
| Maximum Duty Cycle | | | 85 | 90 | -- | % |
| **Reference Voltage** | | | | | | |
| Feedback Reference Voltage | $V_{REF}$ | | 0.237 | 0.25 | 0.263 | V |
| **Diode** | | | | | | |
| Forward Voltage | $V_{FW}$ | $I_{FW}$ = 100mA | -- | 0.9 | -- | V |
| **MOSFET** | | | | | | |
| On Resistance of MOSFET | $R_{DS(ON)}$ | | 0.5 | 0.75 | 1 | Ω |

*To be continued*

| Parameter | | Symbol | Test Condition | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|---|
| **Protection** | | | | | | | |
| OVP Threshold | | $V_{OVP}$ | | -- | 20 | -- | V |
| OCP | | | | -- | 400 | -- | mA |
| **Control Interface** | | | | | | | |
| EN Threshold | Logic-Low Voltage | $V_{IL}$ | | -- | -- | 0.4 | V |
| | Logic-High Voltage | $V_{IH}$ | | 1.4 | -- | -- | V |
| **Digital Dimming (for RT9285A)** | | | | | | | |
| Up Brightness Time | | $T_{UP}$ | Refer to Figure 1 | 0.5 | -- | 75 | µs |
| Down Brightness Time | | $T_{DOWN}$ | Refer to Figure 1 | 180 | -- | 300 | µs |
| Delay Between Steps Time | | $T_{DELAY}$ | Refer to Figure 1 | 0.5 | -- | -- | µs |
| Shut Down Delay Time | | $T_{SHDN}$ | Refer to Figure 1 | 1 | -- | -- | ms |

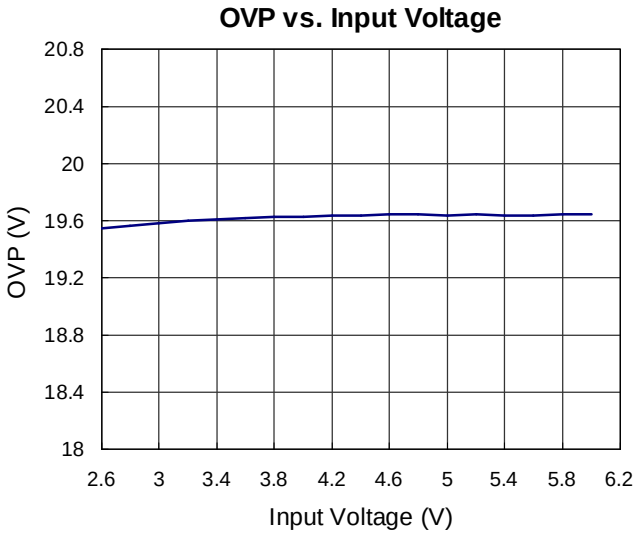
**Note 1.** Stresses listed as the above "Absolute Maximum Ratings" may cause permanent damage to the device. These are for stress ratings. Functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may remain possibility to affect device reliability.

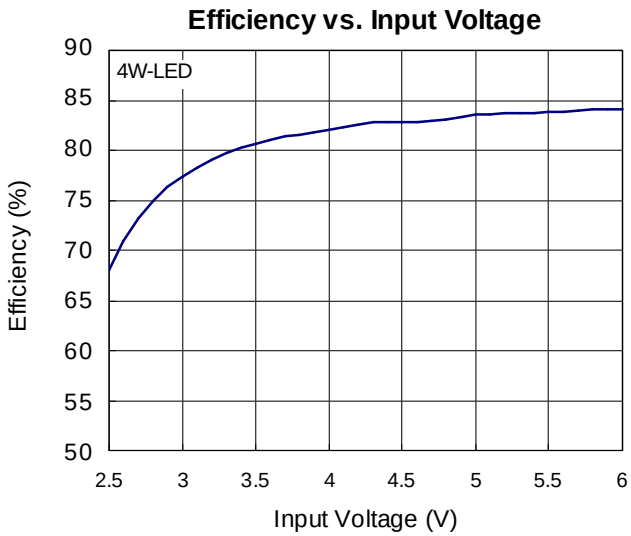
**Note 2.** Devices are ESD sensitive. Handling precaution recommended.

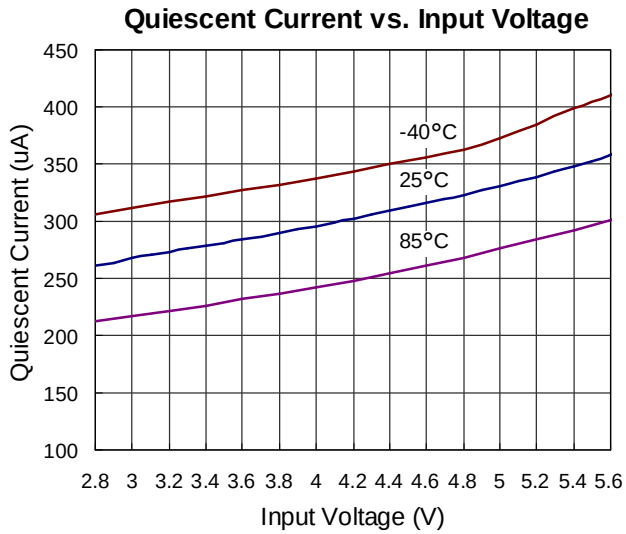
**Note 3.** The device is not guaranteed to function outside its operating conditions.

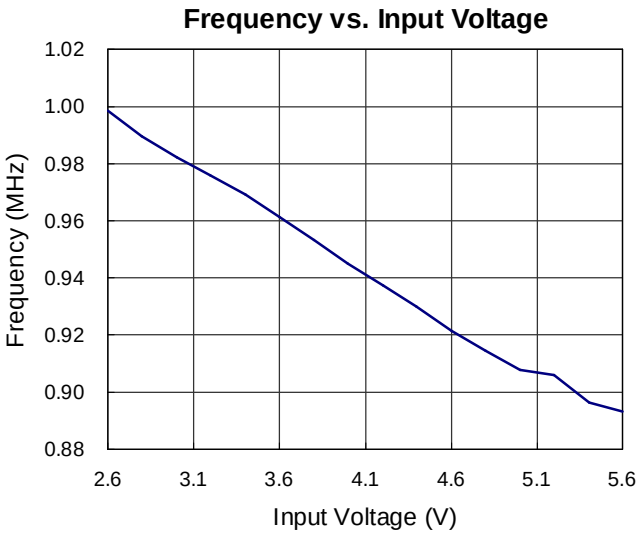
**Note 4.** $\theta_{JA}$ is measured in the natural convection at $T_A$ = 25°C on a low effective thermal conductivity test board of JEDEC 51-3 thermal measurement standard.

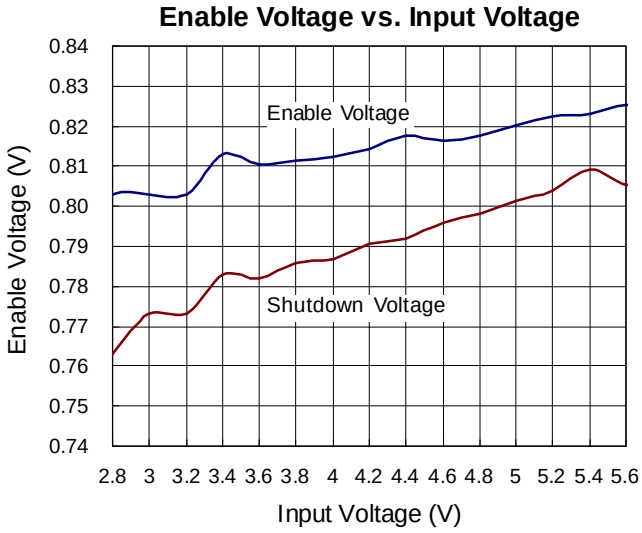
## Typical Operating Characteristics

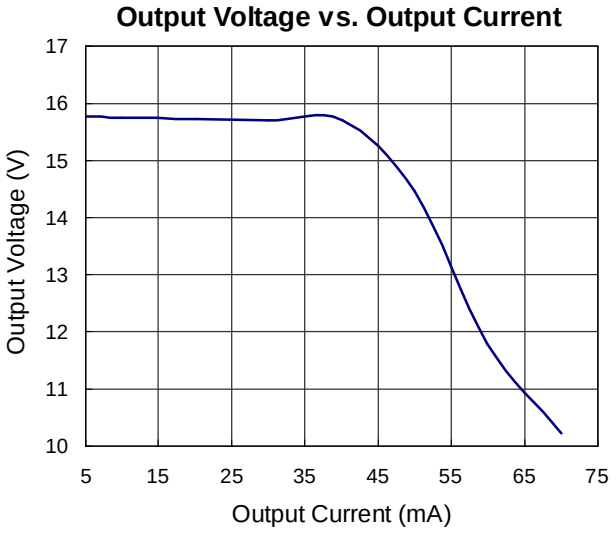


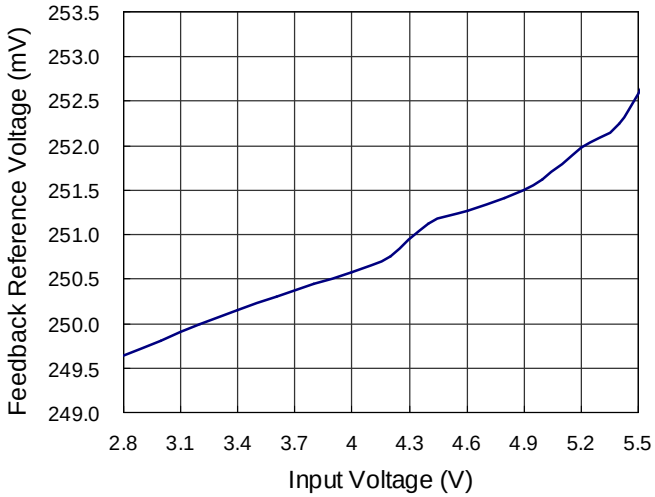



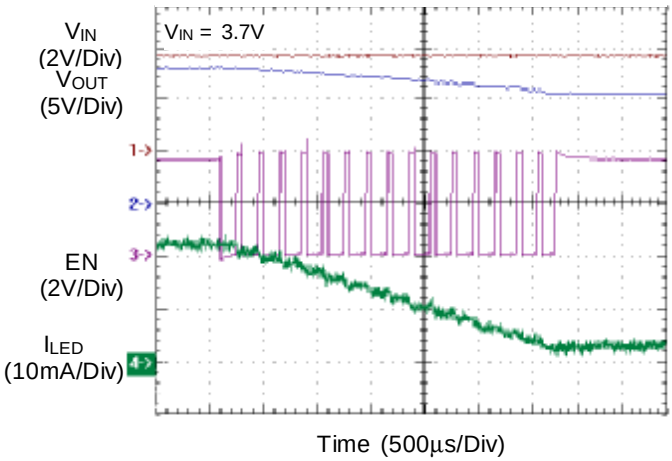



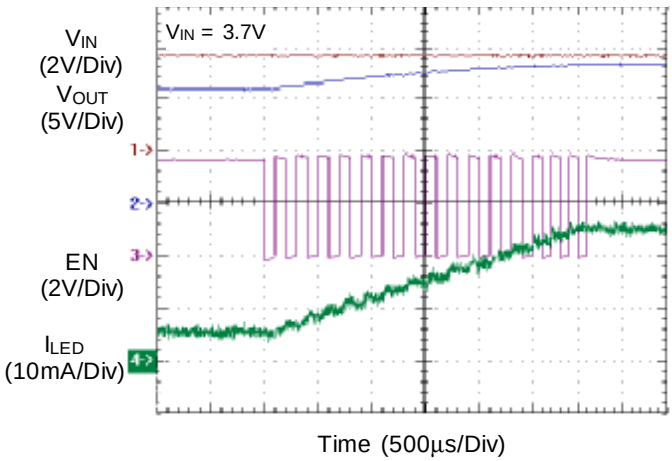
**Feedback Reference Voltage vs. Input Voltage**



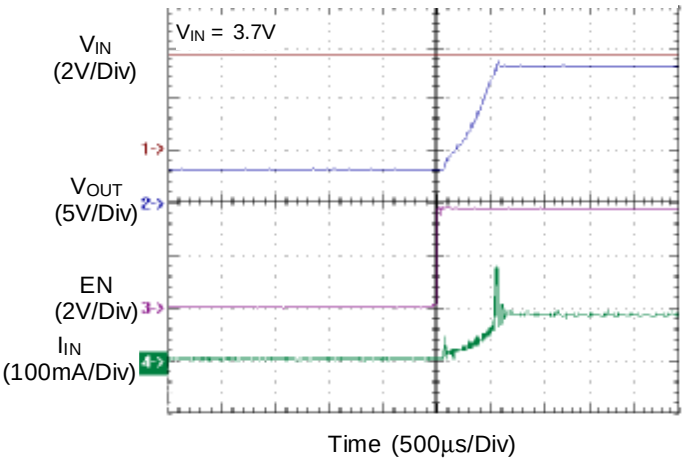

**Dimming Operation @ Decreace**




**Dimming Operation @ Increase**




**Inrush Current Response**



## Application Information

### LED Current Control

The RT9285A/B regulates the LED current by setting the current sense resistor ($R_{SET}$) connecting to feedback and ground. The RT9284A/B feedback voltage ($V_{FB}$) is 0.25V. The LED current ($I_{LED}$) can be set by a resistor $R_{SET}$.

$I_{LED} = 0.25/R_{SET}$

In order to have an accurate LED current, a precision resistor is preferred (1% is recommended).

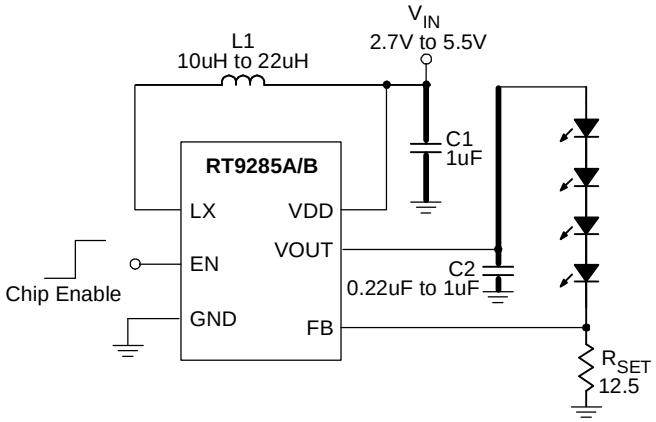



Figure 3. Application for Driving 4 Series WLEDs

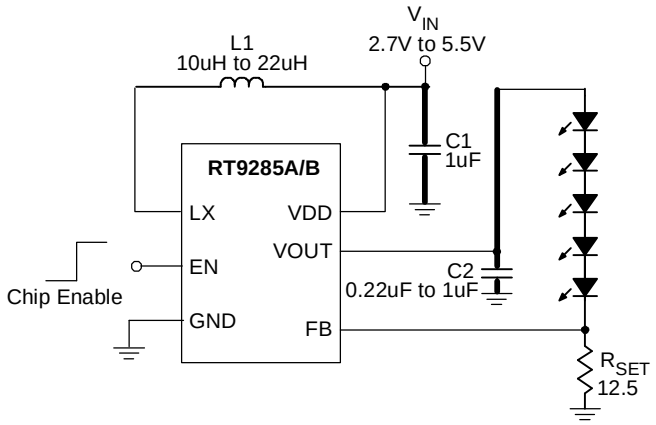



Figure 4. Application for Driving 5 Series WLEDs

### Inductor Selection

The recommended value of inductor for 4 to 5WLEDs applications are 10μH to 22μH. For 3WLEDs, the recommended value of inductor is 4.7μH to 22μH. Small size and better efficiency are the major concerns for portable device, such as **RT9285A/B** used for mobile phone. The inductor should have low core loss at 1MHz and low DCR for better efficiency.

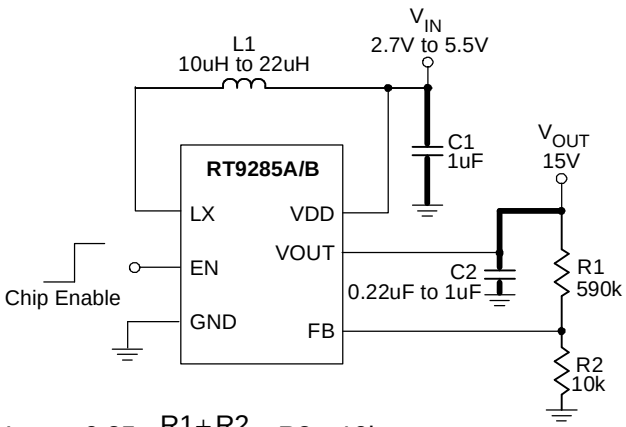
The inductor saturation current rating should be considered to cover the inductor peak current.

### Capacitor Selection

Input and output ceramic capacitors of 1μF are recommended for **RT9285A/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.

### Output Voltage Control

The output voltage of R9285 can be adjusted by the divider circuit on FB pin. Figure 6 shows a 2-level voltage control circuit for OLED application. The output voltage can be calculated by the following equations in Figure 6.




$$V_{OUT} = 0.25 \times \frac{R1+R2}{R2};\ R2 > 10k$$

Figure 5. Application for Constant Output Voltage

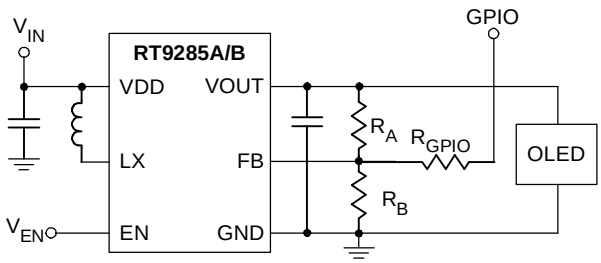



Figure 6. Application Circuit for Output Voltage Control and Related Equations

$V_{OUT} = R_A \times \{(FB/R_B) + (FB-GPIO)/R_{GPIO}\} + FB$ (1)

As GPIO = 0V,

$V_{OUT} = R_A \times \{(0.25/R_B) + (0.25/R_{GPIO})\} + 0.25$ (2)

As GPIO = 2.8V,

$V_{OUT} = R_A \times \{(0.25/R_B) + (0.25-2.8)/R_{GPIO})\} + 0.25$ (3)

As GPIO = 1.8V, $V_{OUT} = R_A \times \{(0.25/R_B) + (0.25-1.8)/R_{GPIO})\} + 0.25$ (4)

For Efficiency Consideration :

Set $R_A$ = 990kΩ,

If 2 levels are 16V (GPIO = 0V) and 14V (GPIO = 1.8V)

Get $R_B$ = 16kΩ, $R_{GPIO}$ = 890kΩ

**Table 3. Suggested Resistance for Output Voltage Control**

| Conditions | $R_A$ (kW) | $R_B$ (kW) | $R_{GPIO}$ (kW) |
|---|---|---|---|
| Case A :<br>Normal Voltage = 16V<br>(GPIO = 0V)<br>Dimming Voltage = 12V<br>(GPIO = 1.8V) | 1100 | 18 | 495 |
| Case B :<br>Normal Voltage = 16V<br>(GPIO = 0V)<br>Dimming Voltage = 12V<br>(GPIO = 2.8V) | 1200 | 19.5 | 840 |

Considering the output voltage deviation from the GPIO voltage tolerance, as GPIO voltage vibrated by 0 ± 50mV and 1.8(2.8) ±5% ,the output voltage could be kept within ±2.5%.

### Layout guide

} A full GND plane without gap break.

} Traces in bold need to be routed first and should be kept as short as possible.

} VDD to GND noise bypass : Short and wide connection for the 1uF MLCC capacitor between Pin 6 and Pin 2.

} LX node copper area should be minimized for reducing EMI. (*1)

} The input capacitor C1 should be placed as closed as possible to Pin 6. (*2)

} The output capacitor C2 should be connected directly from the Pin 5 to ground rather than across the LEDs. (*3)

} FB node copper area should be minimized and keep far away from noise sources (Pin 1, Pin 5, Pin 6). (*4)

} The Inductor is far away receiver and microphone.

} The voice trace is far away RT9285.

} The embedded antenna is far away and different side RT9285.

} R1 should be placed as close as RT9285.

} The through hole of RT9285's GND pin is recommended as large and many as possible.

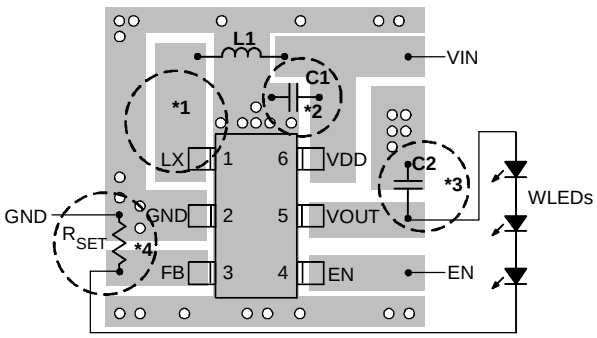



Figure 7. TOP

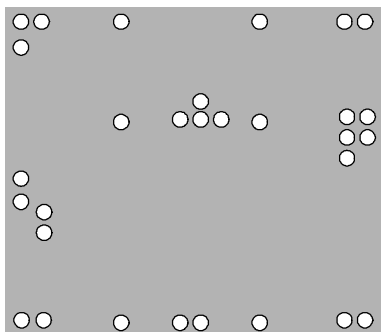
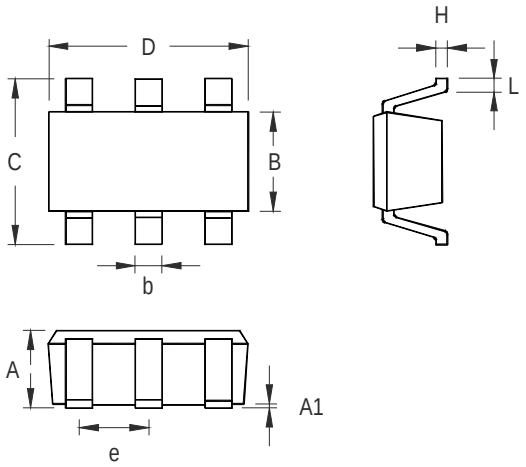


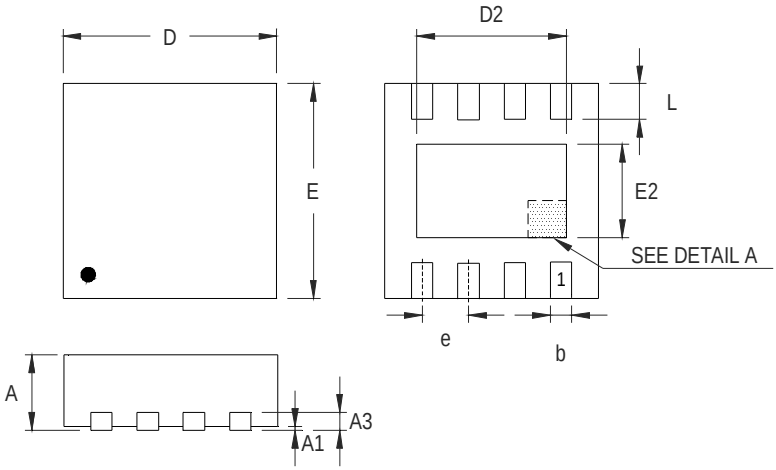
Figure 8. Bottom

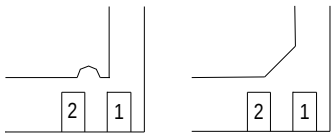
## Outline Dimension




| 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**




**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 | 0.200 | 0.300 | 0.008 | 0.012 |
| D | 1.950 | 2.050 | 0.077 | 0.081 |
| D2 | 1.000 | 1.250 | 0.039 | 0.049 |
| E | 1.950 | 2.050 | 0.077 | 0.081 |
| E2 | 0.400 | 0.650 | 0.016 | 0.026 |
| e | 0.500 | | 0.020 | |
| L | 0.300 | 0.400 | 0.012 | 0.016 |

**W-Type 8L DFN 2x2 Package**

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