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

## General Description

The RT9285C 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 250mV. Tiny package type TSOT-23-6, XDFN-8L 2x2 and WDFN-8L 2x2 packages provide the best solution for PCB space saving and total BOM cost.

## Ordering Information

RT9285C□□

- Package Type
  - QW : WDFN-8L 2x2 (W-Type)
  - QX : XDFN-8L 2x2 (X-Type)
  - J6 : TSOT-23-6
- Lead Plating System
  - P : Pb Free
  - G : Green (Halogen Free and Pb Free)
  - Z : ECO (Ecological Element with 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

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

## Features

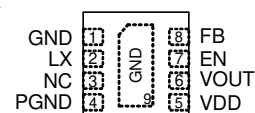
- $V_{IN}$  Operating Range : 2.7V to 5.5V
- Up to 85% Efficiency
- 22V Internal Power NMOS
- 1MHz Switching Frequency
- Built-in Diode
- Digital Dimming with Zero-Inrush
- Input UVLO Protection
- Output Over Voltage Protection
- Internal Soft Start and Compensation
- TSOT-23-6, 8-Lead XDFN and WDFN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

## Applications

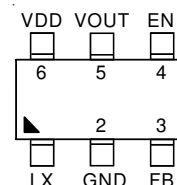
- Cellular Phones
- Digital Cameras
- PDAs and Smart Phones
- Portable Instruments
- MP3 Player
- OLED Power

## Pin Configurations

(TOP VIEW)

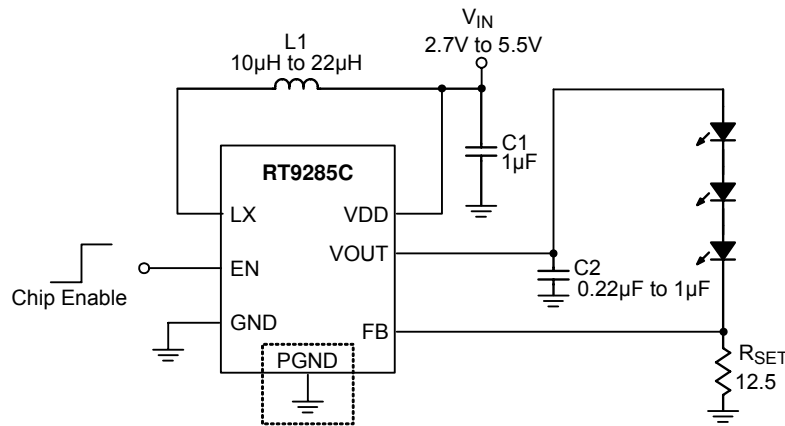


XDFN/WDFN-8L 2x2



TSOT-23-6

## Typical Application Circuit



PGND pin for XDFN/WDFN-8L Packages

## Function Pin Description

Pin No.		Pin Name	Pin Function
XDFN/WDFN-8L	TSOT-23-6		
1, 9 (Exposed Pad)	2	GND	Ground Pin. The exposed pad must be soldered to a large PCB and connected to GND for maximum power dissipation.
2	1	LX	LX Pin. Connect this Pin to an inductor. Minimize the track area to reduce EMI.
3	--	NC	No Internal Connection.
4	--	PGND	Power Ground Pin.
5	6	VDD	Supply Input Voltage Pin. Bypass 1µF 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.

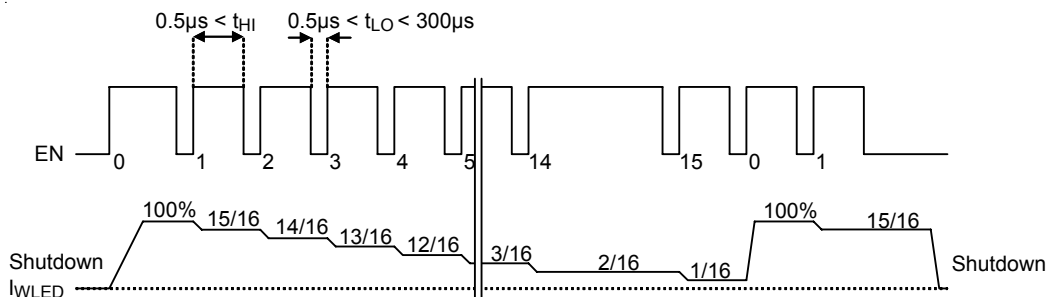
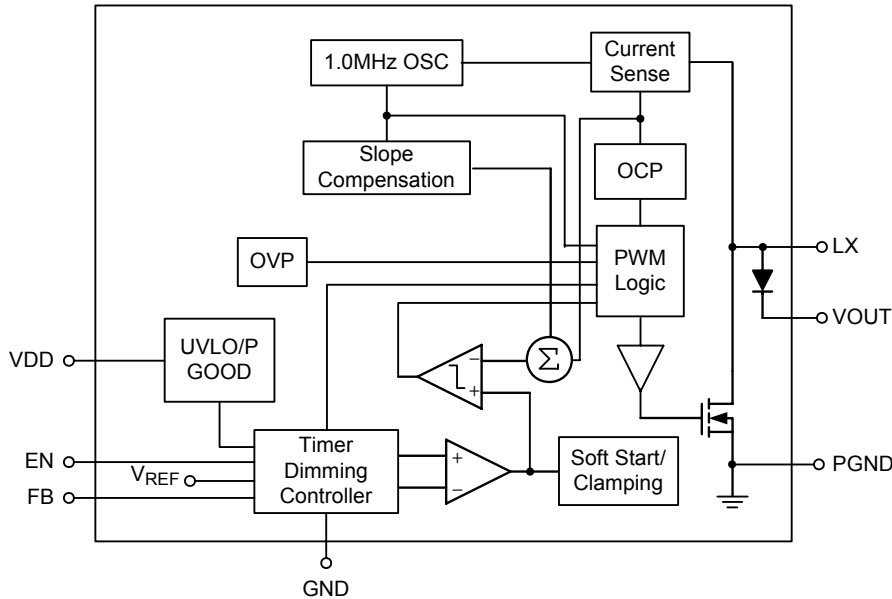


Figure 1. Operation of Digital Pulse Dimming Control



**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 RT9285C 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.

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

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)	$R_{SET}$ ( $\Omega$ )
5	49.9
10	24.9
12	21
15	16.5
20	12.4

**Digital Pulse Dimming Control**

RT9285C implements the pulse dimming method being used to control the brightness of white LEDs. There are 16 steps to set the current of white LEDs. The maximum LED current is up to 20mA that is sufficient for most application in backlight. The detail operation of brightness dimming is showed in the Figure 1.

**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,  $P_D$  @  $T_A = 25^\circ\text{C}$ 
  - TSOT23-6 ----- 0.392W
  - XDFN/WDFN-8L 2x2 ----- 0.606W
- Package Thermal Resistance (Note 2)
  - TSOT23-6,  $\theta_{JA}$  ----- 255°C/W
  - XDFN/WDFN-8L 2x2,  $\theta_{JA}$  ----- 165°C/W
  - XDFN/WDFN-8L 2x2,  $\theta_{JC}$  ----- 20°C/W
- Junction Temperature ----- 150°C
- Lead Temperature (Soldering, 10 sec.) ----- 260°C
- Storage Temperature Range ----- -65°C to 150°C

## Recommended Operating Conditions (Note 3)

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

## Electrical Characteristics

( $V_{IN} = 3.7\text{V}$ , FREQ left floating,  $T_A = 25^\circ\text{C}$ , Unless Otherwise specification)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
<b>System Supply Input</b>						
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	$\mu\text{A}$
Supply Current	$I_{IN}$	FB = 0V, Switch	--	--	2	mA
Shut Down Current	$I_{SHDN}$	$V_{EN} < 0.4\text{V}$	--	2	5	$\mu\text{A}$
<b>Output</b>						
Line Regulation		$V_{IN} = 3\text{V to } 4.3\text{V}$	--	--	3	%
<b>Oscillator</b>						
Operation Frequency	$f_{OSC}$		--	1	--	MHz
Maximum Duty Cycle			85	90	--	%
<b>Reference Voltage</b>						
Feedback Reference Voltage	$V_{REF}$		0.237	0.25	0.263	V
<b>Diode</b>						
Forward Voltage	$V_{FW}$	$I_{FW} = 100\text{mA}$	--	0.9	--	V
<b>MOSFET</b>						
On Resistance of MOSFET	$R_{DS(ON)}$		0.5	0.75	1	$\Omega$
<b>Protection</b>						
OVP Threshold	$V_{OVP}$		--	20	--	V
OCP			--	400	--	mA

*To be continued*

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
<b>Control Interface</b>						
EN Threshold	Logic-Low Voltage	$V_{IL}$	–	--	0.4	V
	Logic-High Voltage	$V_{IH}$	1.4	--	--	
EN Low Time for Dimming	$T_{LO}$	Refer to Figure 1	0.5	--	300	$\mu$ s
Delay Between Steps Time	$T_{HI}$	Refer to Figure 1	0.5	--	--	$\mu$ s
EN Low Time for Shut Down	$T_{SHDN}$	Refer to Figure 1	1	--	--	ms

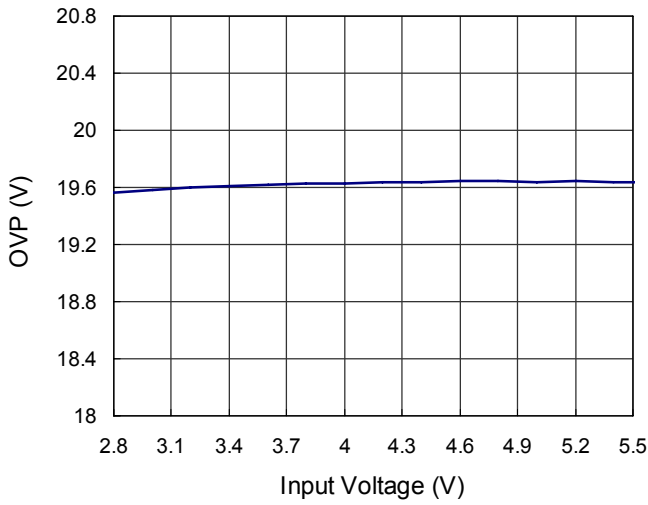
**Note 1.** Stresses listed as the above "Absolute Maximum Ratings" may cause permanent damage to the device. These are for stress ratings. Functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure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

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

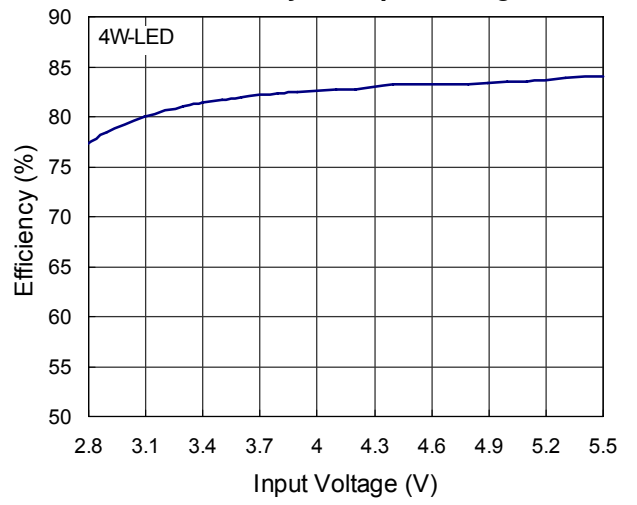
**Note 3.** The device is not guaranteed to function outside its operating conditions.

Typical Operating Characteristics

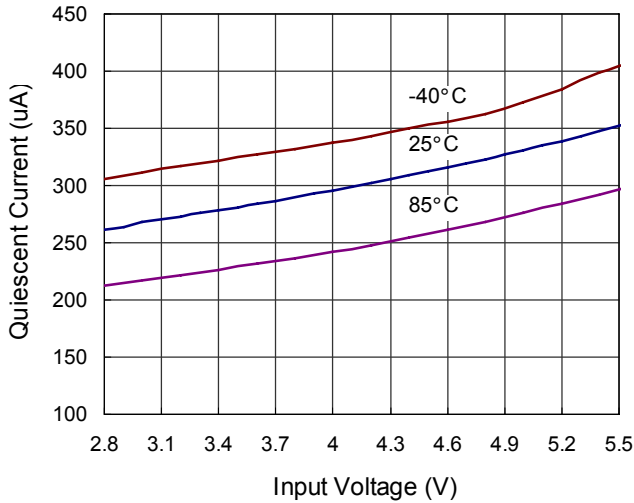
OVP vs. Input Voltage



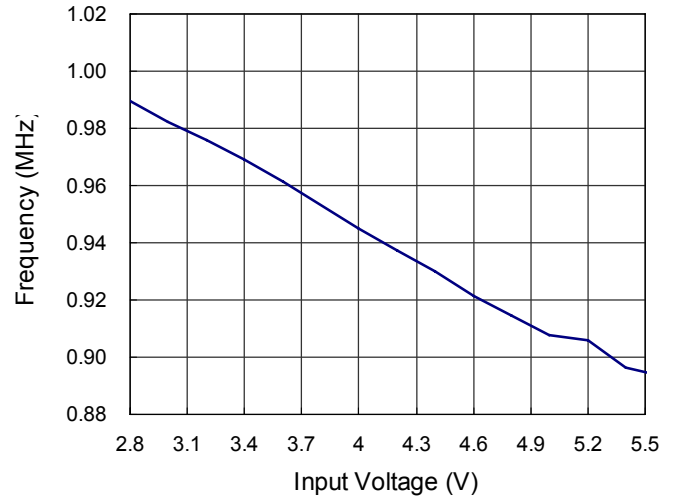
Efficiency vs. Input Voltage



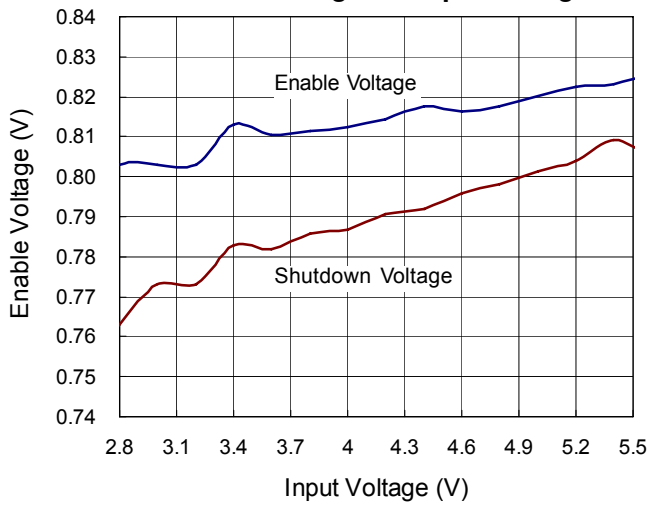
Quiescent Current vs. Input Voltage



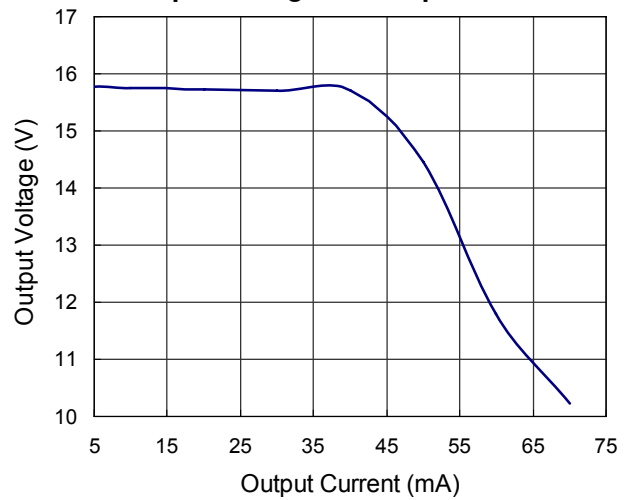
Frequency vs. Input Voltage



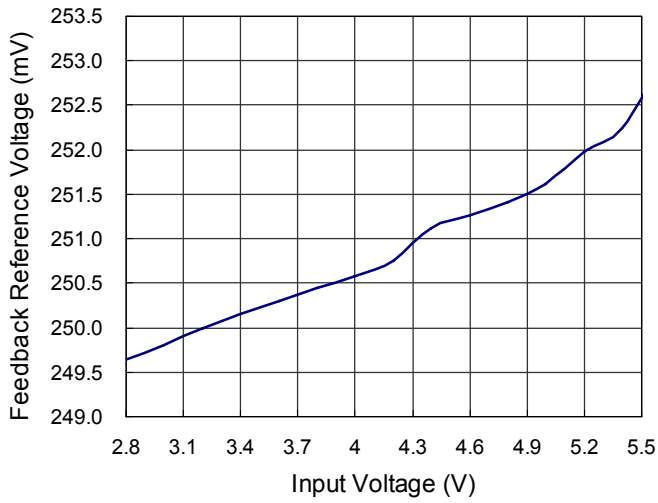
Enable Voltage vs. Input Voltage



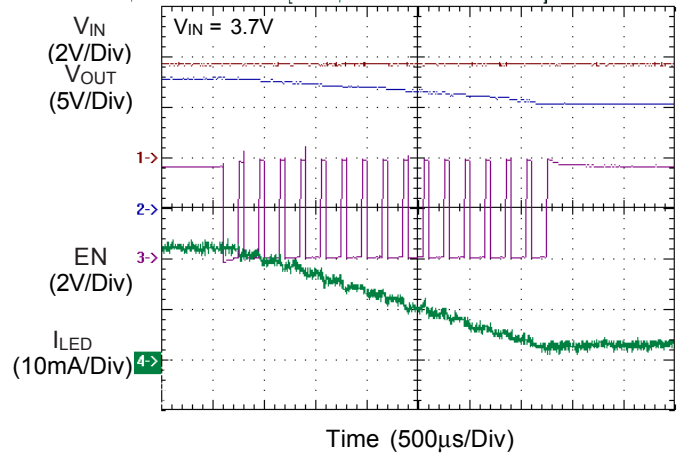
Output Voltage vs. Output Current



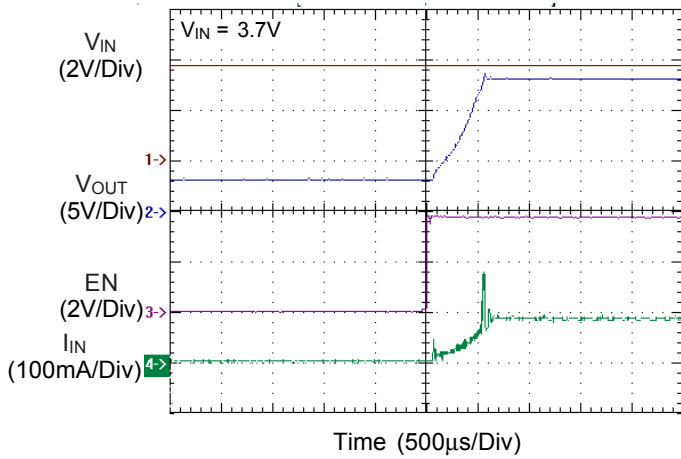
**Feedback Reference Voltage vs. Input Voltage**



**Dimming Operation @ Decrease**



**Inrush Current Response**





## Application Information

### LED Current Control

The RT9285C 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).

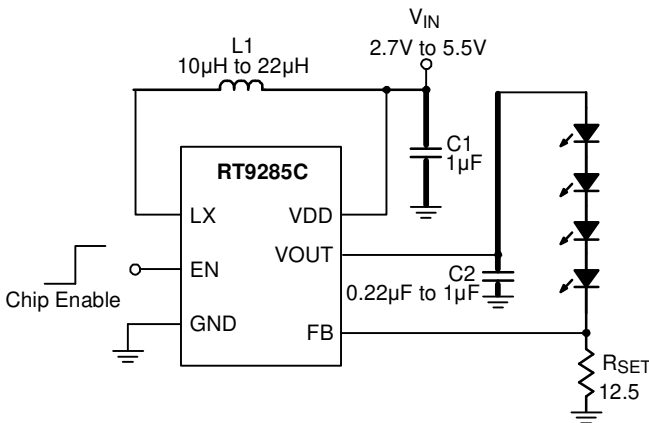


Figure 2. Application for Driving 4 Series WLEDs

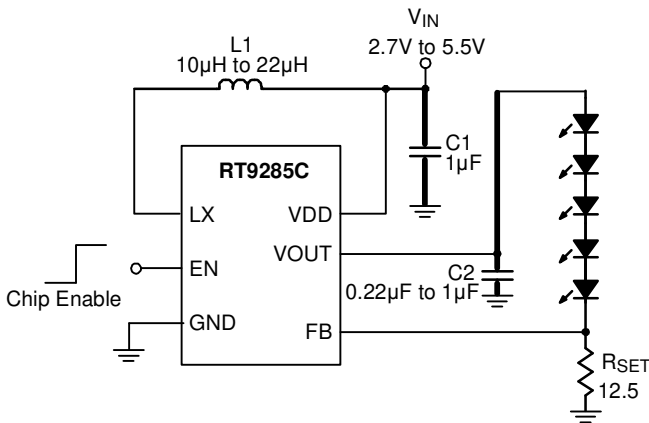


Figure 3. Application for Driving 5 Series WLEDs

### 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 RT9285C 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 RT9285C 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 R9285C can be adjusted by the divider circuit on FB pin. Figure 5 shows a 2-level voltage control circuit for OLED application. The output voltage can be calculated by the following equations in Figure 5.

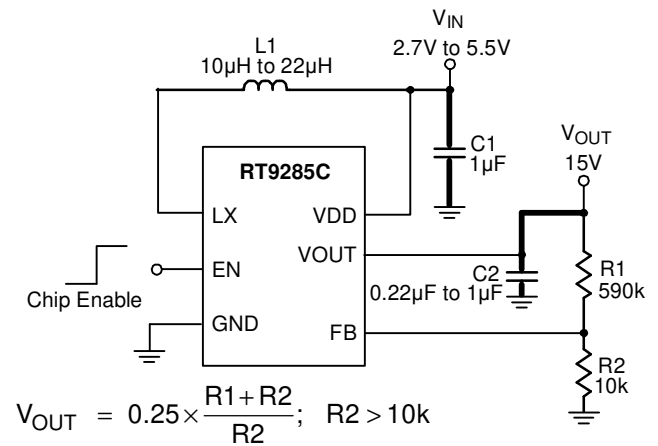


Figure 4. Application for Constant Output Voltage

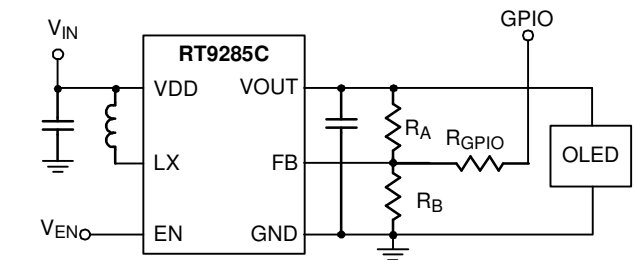


Figure 5. Application Circuit for Output Voltage Control and Related Equations

$$V_{OUT} = R_A \times \left\{ \left( \frac{FB}{R_B} \right) + \left( \frac{FB - GPIO}{R_{GPIO}} \right) \right\} + FB \quad (1)$$

As  $GPIO = 0V$ ,

$$V_{OUT} = R_A \times \left\{ \left( \frac{0.25}{R_B} \right) + \left( \frac{0.25}{R_{GPIO}} \right) \right\} + 0.25 \quad (2)$$

As  $GPIO = 2.8V$ ,

$$V_{OUT} = R_A \times \left\{ \left( \frac{0.25}{R_B} \right) + \left( \frac{0.25 - 2.8}{R_{GPIO}} \right) \right\} + 0.25 \quad (3)$$

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

For Efficiency Consideration :

Set  $R_A = 990k\Omega$ ,

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

Get  $R_B = 16k\Omega$ ,  $R_{GPIO} = 890k\Omega$

**Table 2. Suggested Resistance for Output Voltage Control**

Conditions	$R_A$ (k $\Omega$ )	$R_B$ (k $\Omega$ )	$R_{GPIO}$ (k $\Omega$ )
Case A : Normal Voltage = 16V (GPIO = 0V) Dimming Voltage = 12V (GPIO = 1.8V)	1100	18	495
Case B : Normal Voltage = 16V (GPIO = 0V) Dimming Voltage = 12V (GPIO = 2.8V)	1200	19.5	840

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

**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:

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

Where  $T_{J(MAX)}$  is the maximum operation junction temperature  $125^\circ C$ ,  $T_A$  is the ambient temperature and the  $\theta_{JA}$  is the junction to ambient thermal resistance.

For recommended operating conditions specification of RT9285C, where  $T_{J(MAX)}$  is the maximum junction

temperature of the die ( $125^\circ C$ ) and  $T_A$  is the maximum ambient temperature. The junction to ambient thermal resistance  $\theta_{JA}$  is layout dependent. For XDFN/WDFN 2x2 packages, the thermal resistance  $\theta_{JA}$  is  $165^\circ C/W$  on the standard JEDEC 51-3 single layer thermal test board. The maximum power dissipation at  $T_A = 25^\circ C$  can be calculated by following formula:

$$P_{D(MAX)} = (125^\circ C - 25^\circ C) / (165^\circ C/W) = 0.606 W \text{ for WDFN/XDFN 2x2 packages}$$

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

The maximum power dissipation depends on operating ambient temperature for fixed  $T_{J(MAX)}$  and thermal resistance  $\theta_{JA}$ . For RT9285C packages, the Figure 6 of derating curves allows the designer to see the effect of rising ambient temperature on the maximum power allowed.

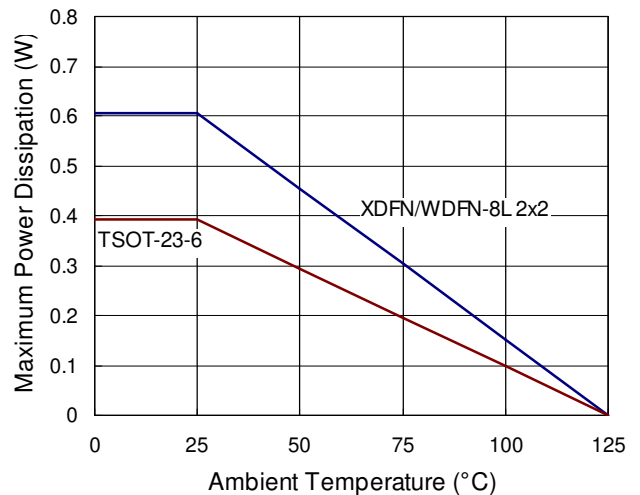


Figure 6. Derating Curves for RT9285C Packages

**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  $1\mu F$  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 RT9285C.
- ▶ The embedded antenna is far away and different side RT9285C.
- ▶ R1 should be placed as close as RT9285C.
- ▶ The through hole of RT9285C's GND pin is recommended as large and many as possible.

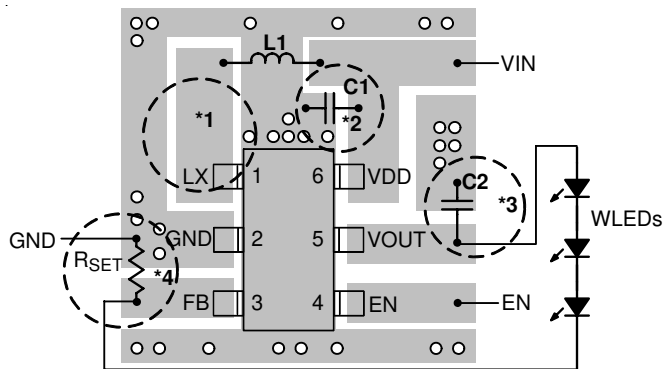


Figure 7. TOP

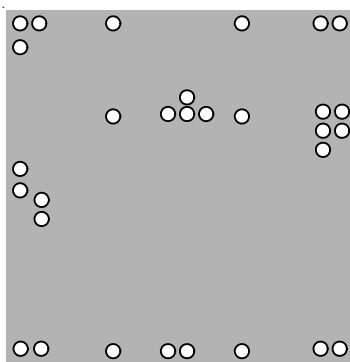
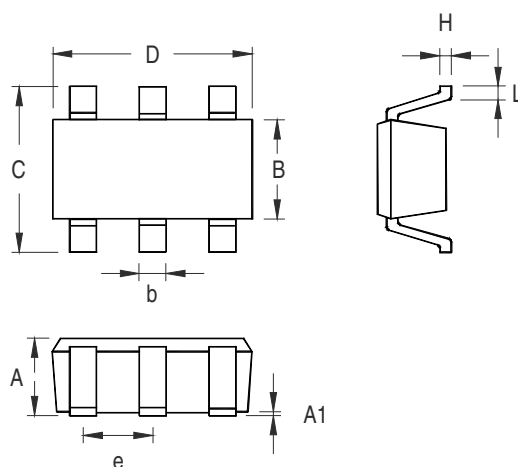


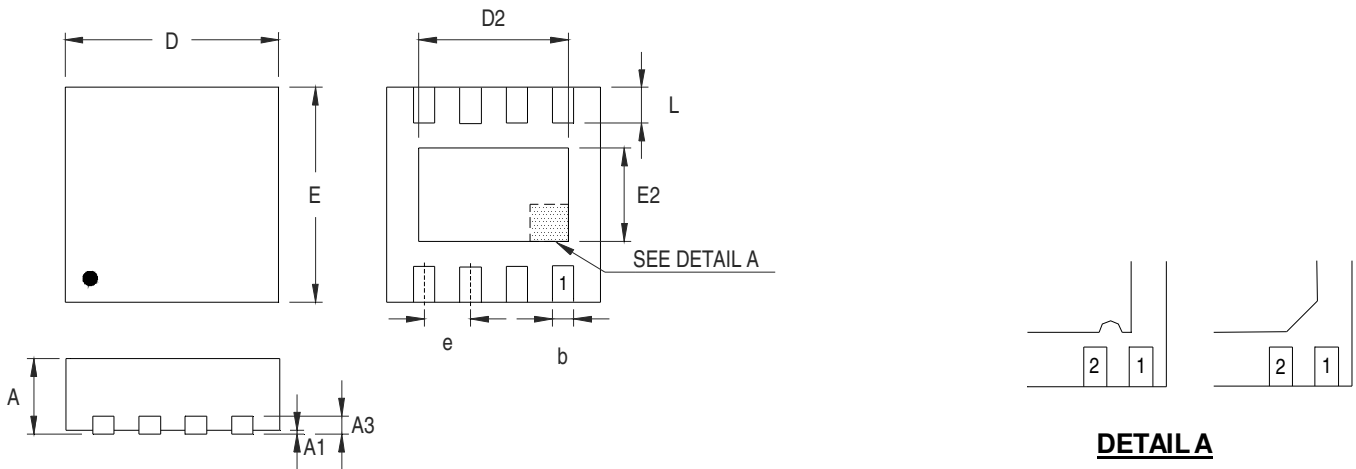
Figure 8. Bottom

**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**

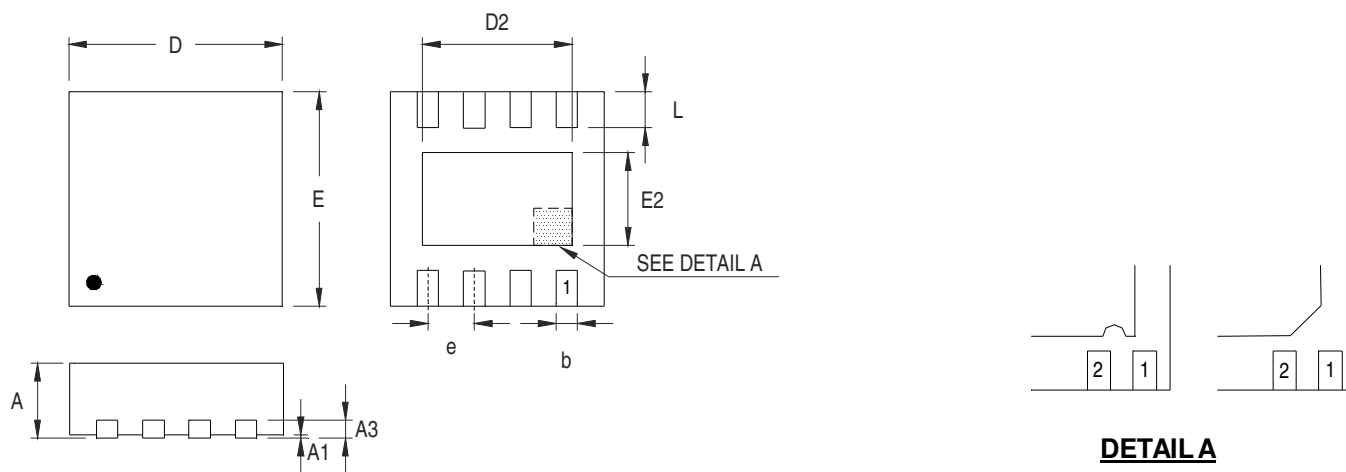
Pin #1 ID and Tie Bar Mark Options

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**





**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	0.400	0.500	0.016	0.020
A1	0.000	0.050	0.000	0.002
A3	0.102	0.152	0.004	0.006
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

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

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