

# 100mA 5-Channel Charge Pump White LED Driver with Low Dropout Current Source

## General Description

The RT9365 is a high performance white LED driver. It integrates current sources and automatic mode selection charge pump. The part maintains the high efficiency by utilizing an x1/x1.5 fractional charge pump and low dropout current sources. The small equivalent x1 mode open loop resistance and ultra-low dropout voltage of current source extend the operating time of x1 mode and optimize the efficiency of Li-ion battery in white LED applications.

The RT9365 supports up to 5 white LEDs and regulates a constant current for uniform intensity. The part implements a 4-bit DAC for brightness control. Users can easily configure the LED current from 1.25mA to 20mA by a serial pulse. The dimming of white LEDs current can be achieved by applying a pulse signal to the EN pin. There are totally 16 steps of current could be set by users. The operating voltage range is 2.8V to 5.0V. Internal soft start circuitry effectively reduces the in-rush current while both start-up and mode transition. The load is disconnected from  $V_{IN}$  while shutdown and the shutdown current is less than 1 $\mu$ A.

RT9365 is available in a WQFN 3x3-16L package.

## Ordering Information

RT9365 □ □

- Package Type  
QW : WQFN-16L 3x3 (W-Type)
- Operating Temperature Range  
P : Pb Free with Commercial Standard  
G : Green (Halogen Free with Commercial Standard)

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.

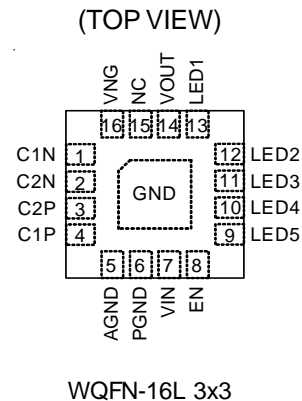
## Features

- 85% Average Efficiency Over Battery Life
- Support up to 5 White LEDs
- 80mV Typical Current Source Dropout
- Support up to 100mA Output Current
- 1% Typical LED Current Accuracy
- 0.7% Typical LED Current Matching
- Soft Start Function
- Auto Charge Pump Mode Selection
- 250kHz Fixed Frequency Oscillator
- Output Over Voltage Protection
- 16-Step Brightness Control
- Low Input Noise and EMI
- Low 0.3 $\mu$ A Shutdown Current
- RoHS Compliant and 100% Lead (Pb)-Free

## Applications

- Mobile Phone, DSC, MP3
- White LED Backlighting
- LCD Display Supply

## Pin Configurations



Typical Application Circuit

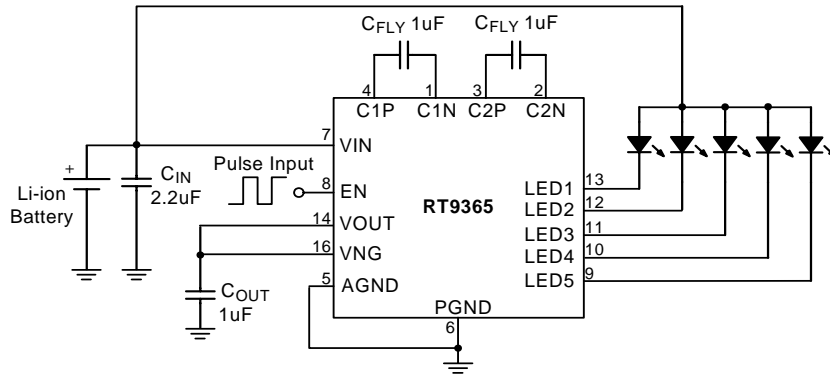


Figure 1. For 5-WLEDs Application Circuit

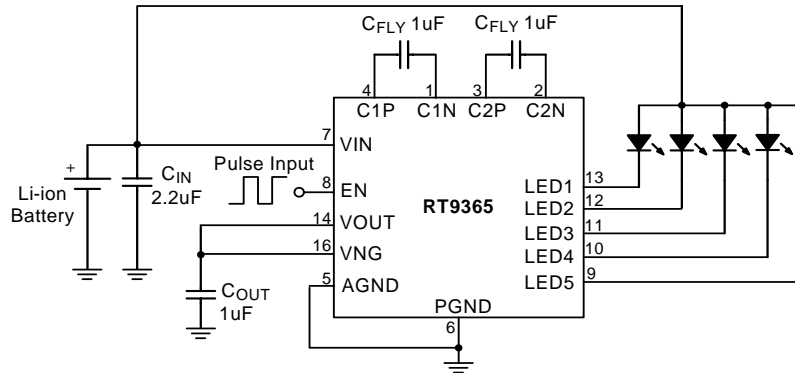


Figure 2. For 4-WLEDs Application Circuit

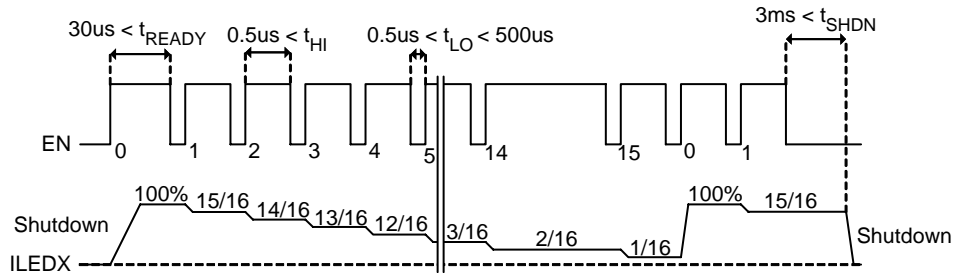
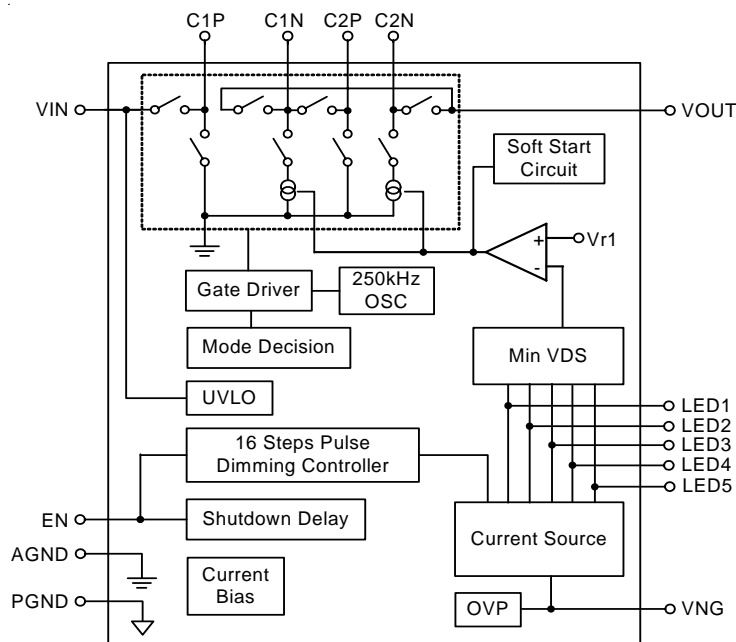


Figure 3. Brightness Control by Pulse Dimming

**Functional Pin Description**

| Pin Number  | Pin Name | Pin Function   |
|-------------|----------|--|
| 1           | C1N      | Negative Terminal of Bucket Capacitor 1.                               |
| 2           | C2N      | Negative Terminal of Bucket Capacitor 2.                               |
| 3           | C2P      | Positive Terminal of Bucket Capacitor 2.                               |
| 4           | C1P      | Positive Terminal of Bucket Capacitor 1.                               |
| 5           | AGND     | Analog Ground.   |
| 6           | PGND     | Power Ground.  |
| 7           | VIN      | Power Input Voltage.   |
| 8           | EN       | Chip Enable (Active High), and connects to GPIO pin of MCU.            |
| 9           | LED 5    | Current Sink for LED5. (If not in use, pin should be connected to VIN) |
| 10          | LED 4    | Current Sink for LED4. (If not in use, pin should be connected to VIN) |
| 11          | LED 3    | Current Sink for LED3. (If not in use, pin should be connected to VIN) |
| 12          | LED 2    | Current Sink for LED2. (If not in use, pin should be connected to VIN) |
| 13          | LED 1    | Current Sink for LED1. (If not in use, pin should be connected to VIN) |
| 14          | VOUT     | Output Voltage Source for LED1 to LED5.                                |
| 15          | NC       | No Internal Connection.  |
| 16          | VNG      | Charge Pump Output.  |
| Exposed Pad | GND      | Exposed pad should be soldered to PCB board and connected to GND.      |

**Function Block Diagram**



**Absolute Maximum Ratings** (Note 1)

- Supply Input Voltage ----- -0.3V to 6V
- Other I/O Pin Voltage ----- -0.3V to 6V
- Power Dissipation, PD @ T<sub>A</sub> = 25°C  
 WQFN-16L 3x3 ----- 1.47W
- Package Thermal Resistance (Note 4)  
 WQFN-16L 3x3, θ<sub>JA</sub> ----- 68°C/W
- Junction Temperature ----- 150°C
- Lead Temperature (Soldering, 10 sec.) ----- 260°C
- Storage Temperature Range ----- -40°C to 150°C
- ESD Susceptibility (Note 2)  
 HBM (Human Body Mode) ----- 2kV  
 MM (Machine Mode) ----- 200V

**Recommended Operating Conditions** (Note 3)

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

**Electrical Characteristics**

(V<sub>IN</sub> = 3.6V, V<sub>F</sub> = 3.4V, C<sub>IN</sub> = C<sub>OUT</sub> = C<sub>FLY</sub> = 1μF (ESR = 30mΩ), I<sub>LED1 to 5</sub> = 15mA, T<sub>A</sub> = 25°C, unless otherwise specification)

| Parameter                               | Symbol                   | Test Condition   | Min | Typ | Max | Units |
|---|--------------------------|--|-----|-----|-----|-------|
| <b>Input</b>                            |                          |  |     |     |     |       |
| Input Supply Voltage                    | V <sub>IN</sub>          |  | 2.8 | --  | 5.0 | V     |
| Under-Voltage Lockout Threshold         | V <sub>UVLOH</sub>       | V <sub>IN</sub> Rising                                 | --  | 2.2 | --  | V     |
| Under-Voltage Lockout Hysteresis        |                          |  | --  | 200 | --  | mV    |
| EN Pull Low Current                     |                          | V <sub>EN</sub> = 1.8V                                 | --  | 1   | --  | uA    |
| Quiescent of x1 Mode                    | I <sub>Q_x1</sub>        | x1 Mode, V <sub>IN</sub> = 5.5V, LED off               | --  | 1   | --  | mA    |
| Shutdown Current                        | I <sub>SHDN</sub>        | V <sub>EN</sub> = 0V, V <sub>IN</sub> = 5.5V           | --  | 0.4 | 7   | μA    |
| <b>Output</b>                           |                          |  |     |     |     |       |
| x1 Mode to x1.5 Mode Transition Voltage | V <sub>TRAN</sub>        | V <sub>LED</sub> = 3.4V, I <sub>LED1 to 5</sub> = 15mA | --  | 3.5 | --  | V     |
| Mode Transition Hysteresis              |                          |  | --  | 200 | --  | mV    |
| I <sub>LEDx</sub> Accuracy              | I <sub>LED-ERR</sub>     | 100% Setting, I <sub>LED1 to 5</sub>                   | -8  | --  | +8  | %     |
| Current Matching                        | I <sub>LED-LED-ERR</sub> | 100% Setting, I <sub>LED1 to 5</sub>                   | -5  | --  | +5  | %     |
| <b>Enable</b>                           |                          |  |     |     |     |       |
| EN Low Time for Shut Down               | T <sub>SHDN</sub>        |  | 3   | --  | --  | ms    |
| EN Low Time for Dimming                 | T <sub>LO</sub>          |  | 0.5 | --  | 500 | μs    |
| EN High Time for Dimming                | T <sub>HI</sub>          |  | 0.5 | --  | --  | μs    |
| EN Threshold                            | Logic-High Voltage       | V <sub>IH</sub>  | 1.5 | --  | --  | V     |
|   | Logic-Low Voltage        | V <sub>IL</sub>  | --  | --  | 0.4 | V     |
| <b>Frequency</b>                        |                          |  |     |     |     |       |
| Oscillator Frequency                    | f <sub>OSC</sub>         |  | --  | 250 | --  | kHz   |
| <b>Protection</b>                       |                          |  |     |     |     |       |
| Over Voltage Protection                 | V <sub>OVP</sub>         | V <sub>IN</sub> - V <sub>OUT</sub>                     | --  | 5.5 | --  | V     |

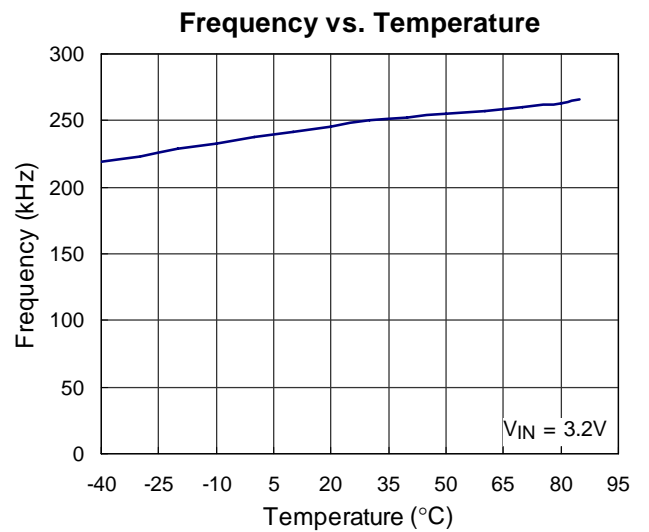
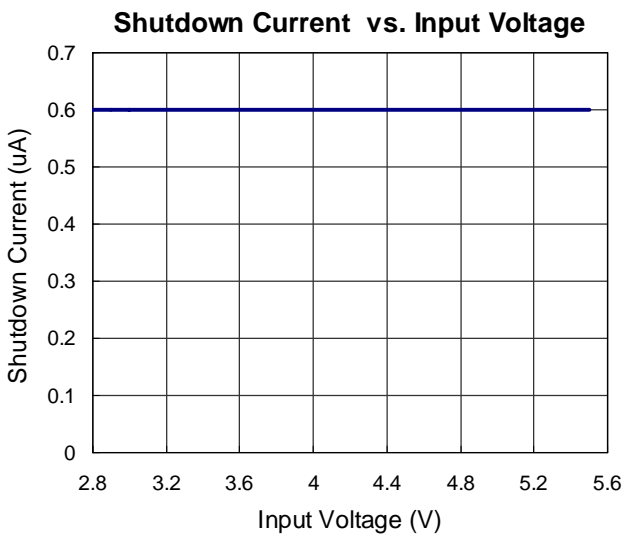
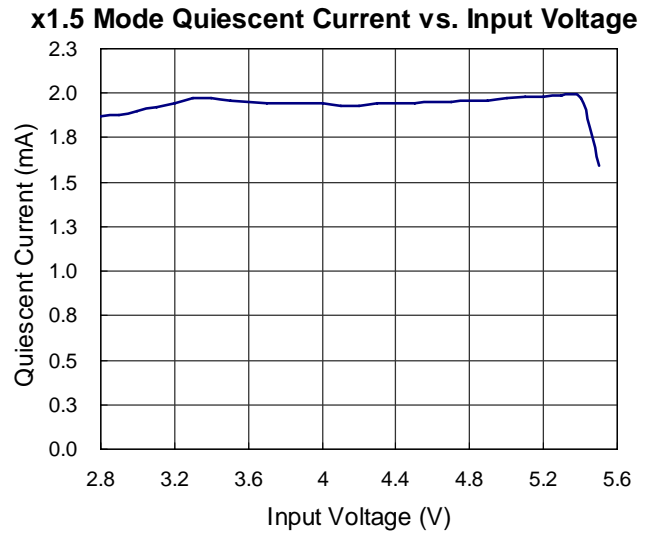
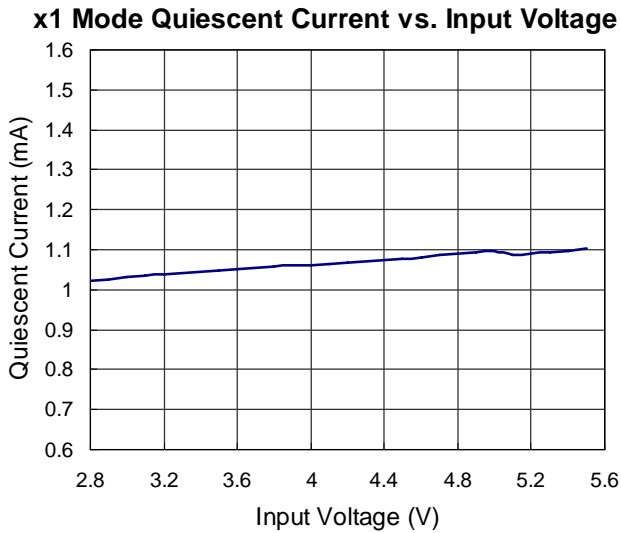
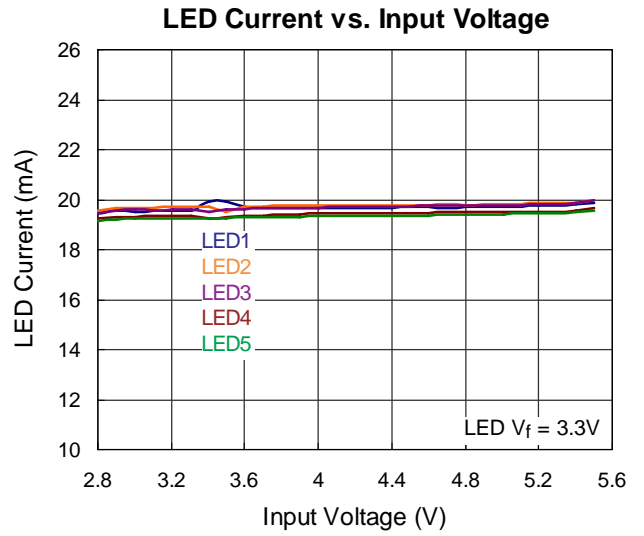
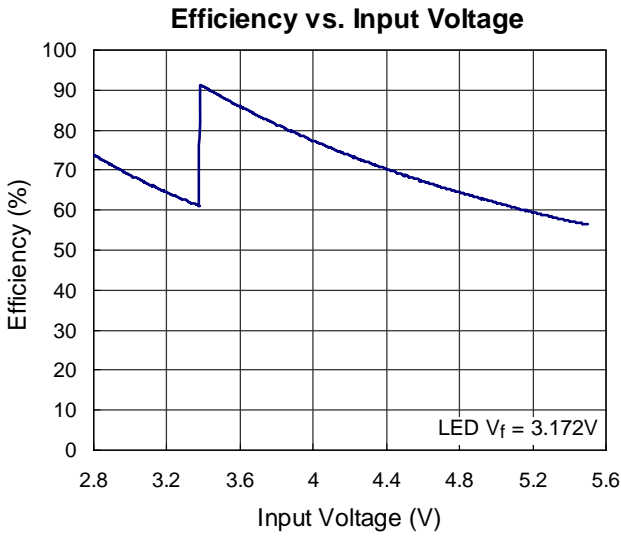
**Note 1.** Stresses listed as the above "Absolute Maximum Ratings" may cause permanent damage to the device. These are for stress ratings. Functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure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

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

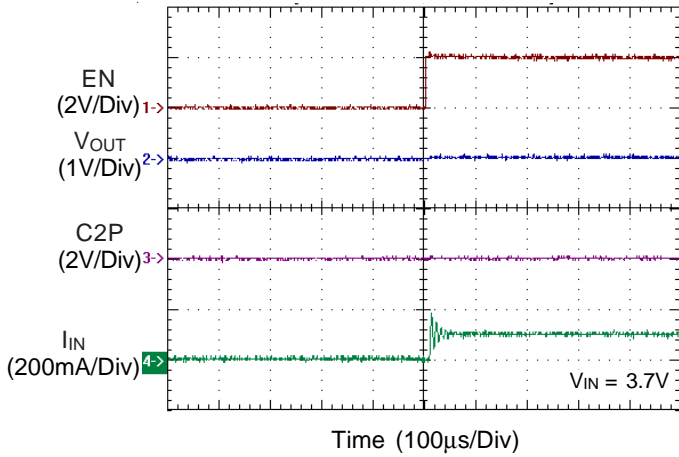
**Note 3.** The device is not guaranteed to function outside its operating conditions.

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

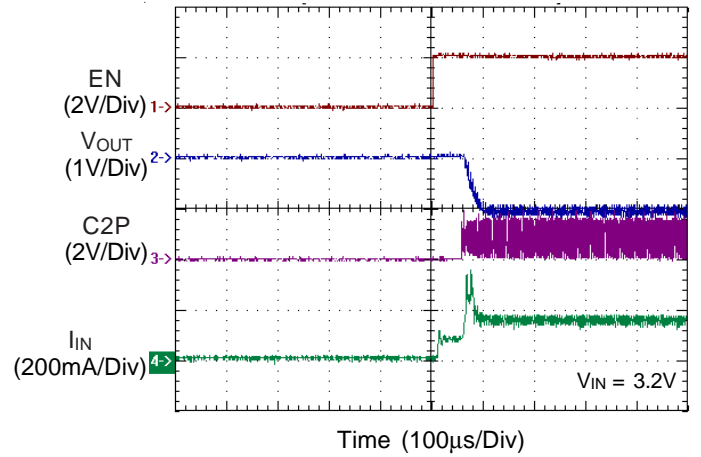
Typical Operating Characteristics



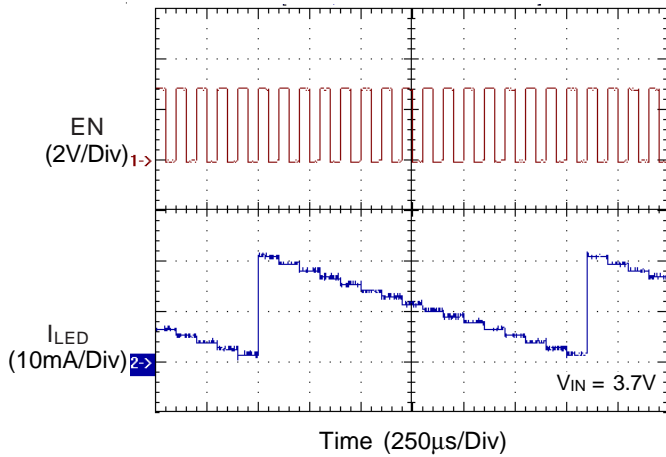
**x1 Mode Inrush Current Response**



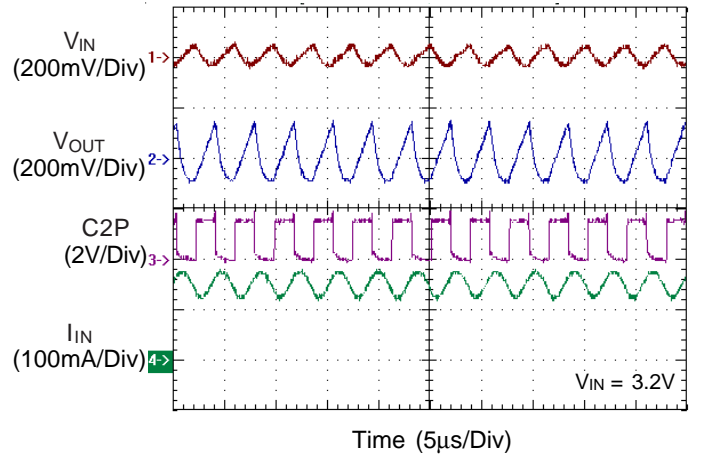
**x1.5 Mode Inrush Current Response**



**x1 Mode Dimming Operation**



**Ripple & Spike**



## Applications Information

The RT9365 uses a fractional switched capacitor charge pump to power up to four white LEDs with a programmable current for uniform intensity. The part integrates current sources and automatic mode selection charge pump. It maintains the high efficiency by utilizing an x1/x1.5 fractional charge pump and current sources. The small equivalent x1 mode open loop resistance and ultra-low dropout voltage of current source extend the operating time of x1 mode and optimize the efficiency in white LED applications.

### Input UVLO

The input operating voltage range of the RT9365 is from 2.8V to 5.5V. An input capacitor at the VIN pin could reduce ripple voltage. It is recommended to use a ceramic 1 $\mu$ F or larger capacitance as the input capacitor. This IC provides an under voltage lockout (UVLO) function to prevent it from unstable issue when startup. The UVLO threshold of input rising voltage is set at 2.2V typically with a hysteresis 0.2V.

### Soft Start

The RT9365 employs a soft start feature to limit the inrush current. The soft-start circuit prevents the excessive inrush current and input voltage droop. The soft-start clamps the input current over a typical period of 50 $\mu$ s.

### Mode Decision

The RT9365 uses a smart mode selection method to decide the working mode for optimizing the efficiency. Mode decision circuit senses the output and LED voltage for up/down selection. The RT9365 automatically switches to x1.5 mode whenever the dropout condition is detected from the current source and returns to x1 mode whenever the dropout condition releases.

### LED connection

The RT9365 supports up to 5 white LEDs. The five LEDs are connected from VIN to pin 9, 10, 11, 12, and 13 respectively. If the LED is not used, the LED pin should be connected to VIN directly. Figure 2 shows the connection for 4-WLEDs application, pin 9 is connected to VIN.

### Selecting Capacitors

To get the better performance of RT9365, the selection of peripherally appropriate capacitor and value is very important. These capacitors determine some parameters such as input/output ripple voltage, power efficiency and maximum supply current by charge pump. To reduce the input and output ripple effectively, the low ESR ceramic capacitors are recommended. For LED driver applications, the input voltage ripple is more important than output ripple. Input ripple is controlled by input capacitor  $C_{IN}$ , increasing the value of input capacitance can further reduce the ripple. Practically, the input voltage ripple depends on the power supply impedance. The flying capacitor C1 and C2 determine the supply current capability of the charge pump to influence the overall efficiency of system. The lower value will improve efficiency, but it will limit the LED's current at low input voltage. For 5 X 20mA load over the entire input range of 2.8 to 5.5V, it is recommended to use a 1 $\mu$ F ceramic capacitor on the flying capacitor C1 & C2.

### Brightness Control

The RT9365 implements a pulse dimming method to control the brightness of white LEDs. Users can easily configure the LED current from 1.25mA to 20mA by a serial pulse. The dimming of white LEDs' current can be achieved by applying a pulse signal to the EN pin. There are totally 16 steps of current could be set by users. The detailed operation of brightness dimming is shown in the Figure 3.

### Over Voltage Protection

The RT9365 equips over voltage protection function. When LED is open, the voltage between input and output will be clamped at a certain voltage level.



**Layout Consideration**

The RT9365 is a high-frequency switched-capacitor converter. Careful PCB layout is necessary. For best performance, place all peripheral components as close to the IC as possible. Place CIN, COUT, CFLY1, and CFLY2 near to VIN, VOUT, CP1, CN1, CP2, CN2, and GND pin respectively. A short connection is highly recommended. The following guidelines should be strictly followed when designing a PCB layout for the RT9365.

1. The exposed pad, PGND, AGND must be soldered to a large ground plane for heat sinking and noise prevention. The through-hole vias located at the exposed pad is connected to ground plane of internal layer.
2. VIN traces should be wide enough to minimize inductance and handle the high currents. The trace running from battery to chip should be placed carefully and shielded strictly.
3. Input and output capacitors must be placed close to the part. The connection between pins and capacitor pads should be copper traces without any through-hole via connection.
4. The flying capacitors must be placed close to the part. The traces running from the pins to the capacitor pads should be as wide as possible. Long traces will also produce large noise radiation caused by the large dv/dt on these pins. Short trace is recommended.
5. All the traces of LED and VIN running from pins to LCM module should be shielded and isolated by ground plane. The shielding prevents the interference of high frequency noise coupled from the charge pump.
6. Output capacitor must be placed between VNG and VOUT to reduce noise coupling from charge pump to LEDs.

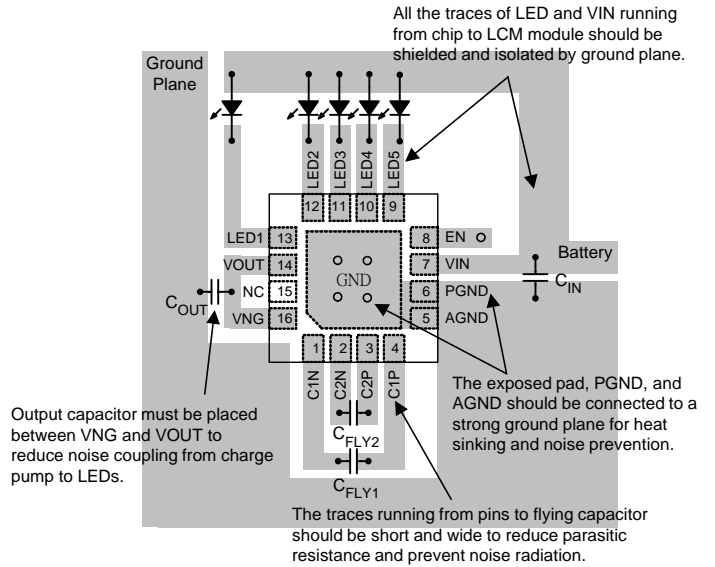
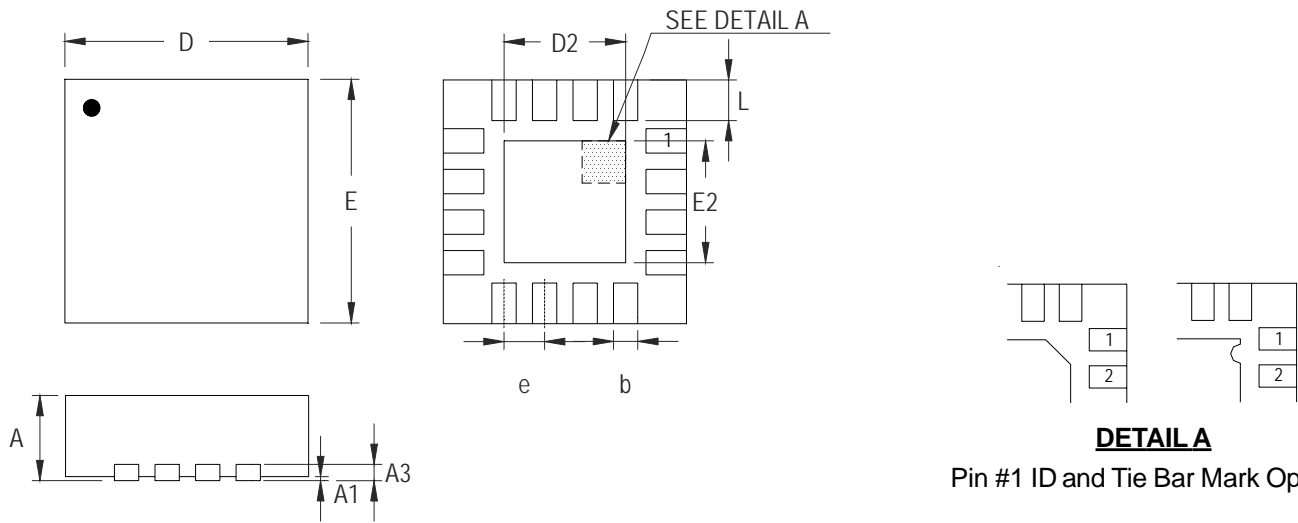


Figure 4

Outline Dimension



**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      | 0.180                     | 0.300 | 0.007                | 0.012 |
| D      | 2.950                     | 3.050 | 0.116                | 0.120 |
| D2     | 1.300                     | 1.750 | 0.051                | 0.069 |
| E      | 2.950                     | 3.050 | 0.116                | 0.120 |
| E2     | 1.300                     | 1.750 | 0.051                | 0.069 |
| e      | 0.500                     |       | 0.020                |       |
| L      | 0.350                     | 0.450 | 0.014                | 0.018 |

**W-Type 16L QFN 3x3 Package**

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