

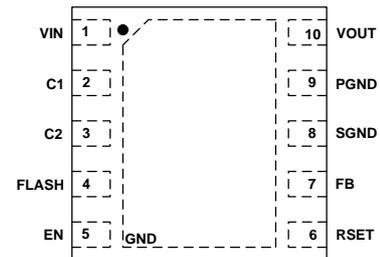
# WD3609DC

## 800mA Buck/Boost Charge Pump Flash LED Driver

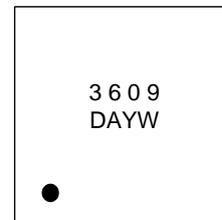
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**DFN3x3-10L**



**Pin configuration (Top view)**



**WD3609DC**

**3609DC** = Device code  
**Y** = Year code  
**W** = Week code  
**Marking**

### Description

The WD3609DC is a current-regulated charge pump ideal for powering high brightness LEDs for camera flash applications. The charge pump can be set to regulate two current levels for FLASH and TORCH modes.

The WD3609DC automatically switches modes between step-up and step-down ensuring that LED current does not depend on the forward voltage. It switches at 2.4MHz, allowing the use of tiny components. The supply voltage ranges from 2.7V to 5.5V and is ideally suited for all applications powered by a single LI-Ion battery cell or three to four NiCd, NiMH, or Alkaline battery cells.

The WD3609DC also features a very low shutdown current, an automatic soft-start mode to limit inrush current, as well as over current, over voltage and over-Thermal shutdown control.

A low current sense reference voltage (50mV) allows the use of small 0603 current sensing resistors.

The WD3609DC is available in Green DFN3x3-10L package and is specified over an ambient temperature range of -40°C to +85°C.

### Features

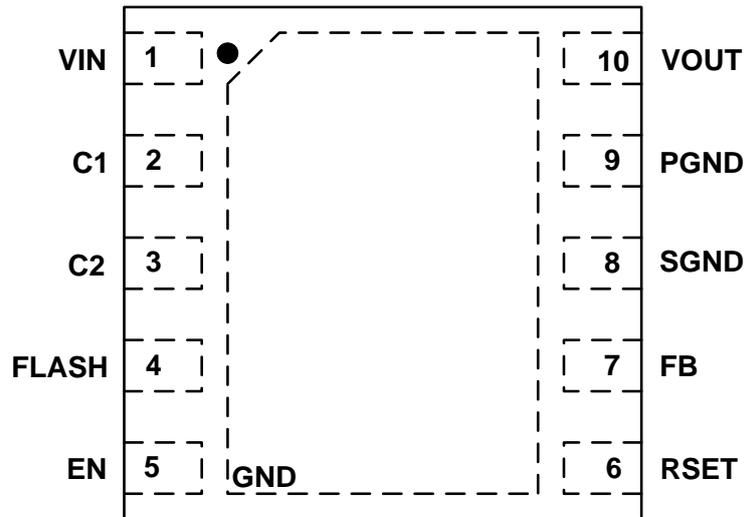
- Output Current up to 800mA
- Up to 95% Efficiency in Torch Mode
- Adjustable FLASH Mode Current
- Automatic Buck/Boost Mode Switchover
- Wide Input Voltage Range: 2.7V to 5.5V
- Minimum External Components: No Inductors
- High Frequency Operation: 2.4MHz
- Low 50mV Reference for Low Loss Sensing
- PWM Dimming Control
- Automatic Soft Start Limits Inrush Current
- Low Ripple and EMI

### Order Information

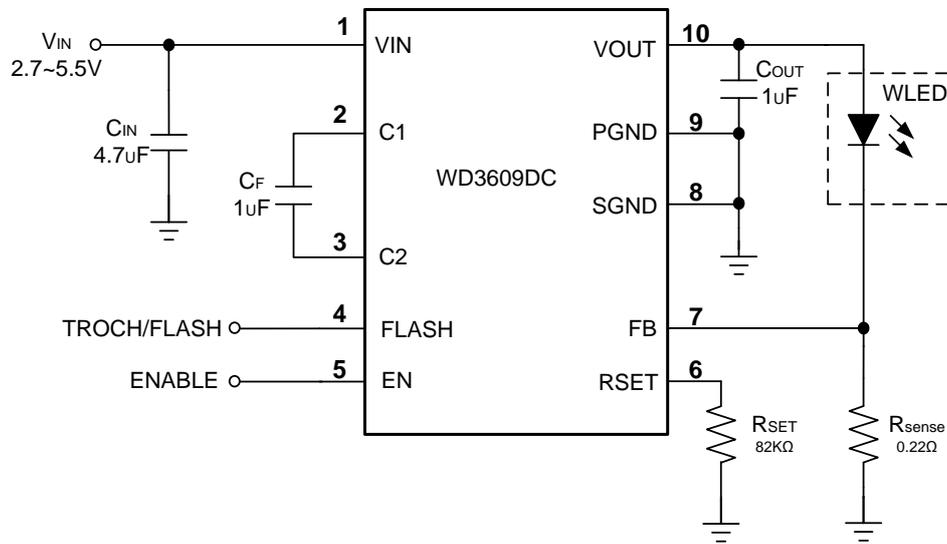
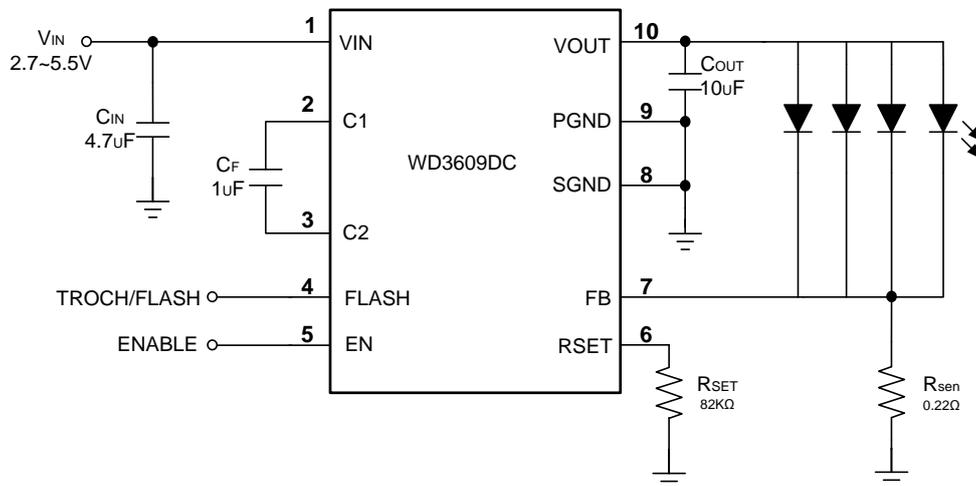
<b>Device</b>	WD3609DC-10/TR
<b>Function</b>	With timeout
<b>Package</b>	DFN3x3-10L
<b>Shipping</b>	3000/Reel&Tape

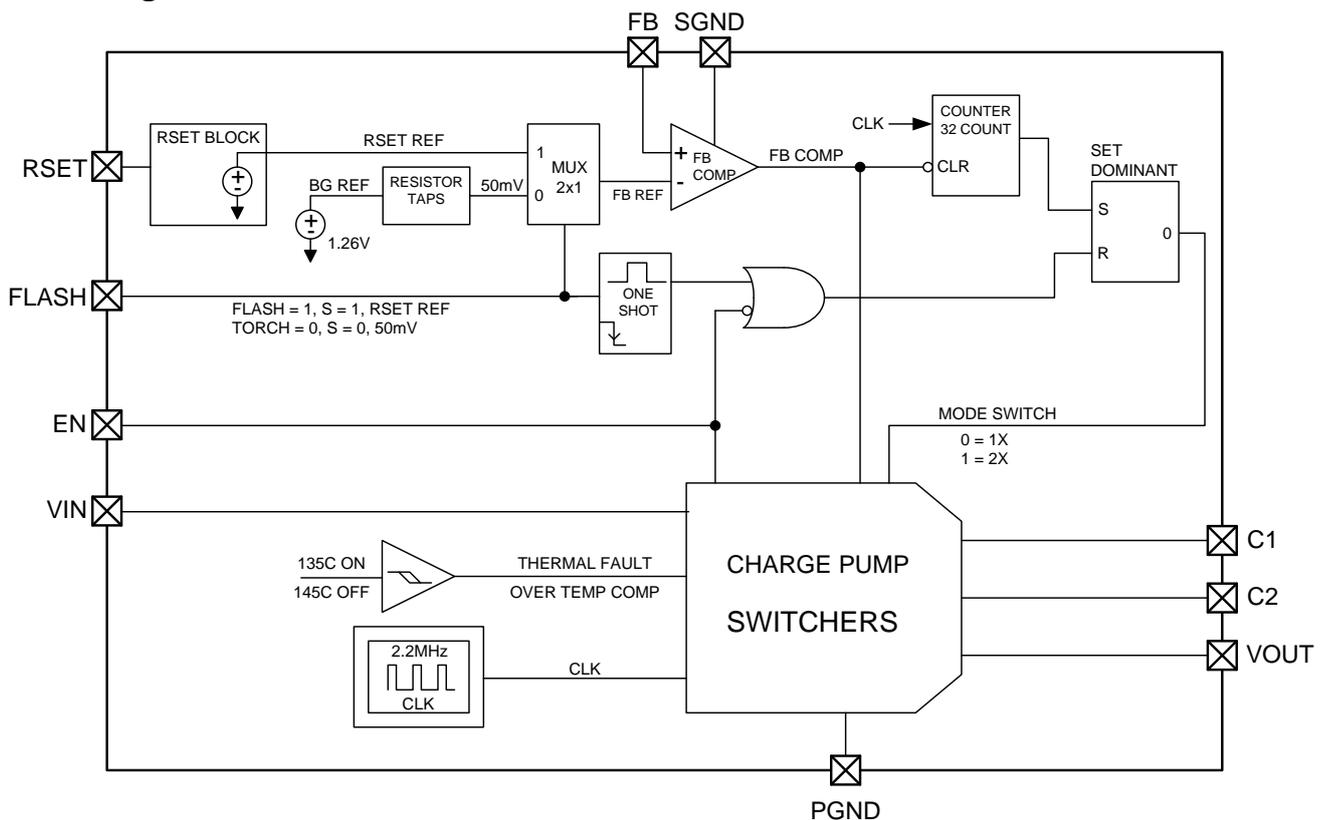
### Applications

- Cellphones
- PADs

**Pin configuration (Top view)**

**Pin descriptions**

Symbol	DFN3x3-10L	Descriptions
VIN	1	Input voltage for the charge pump. Decouple with 4.7 $\mu$ F or 10 $\mu$ F ceramic capacitor close to the pins of the IC.
C1	2	Positive input for the external flying capacitor. Connect a ceramic 1 $\mu$ F capacitor close to the pins of the IC.
C2	3	Negative input for the external flying capacitor. Connect a ceramic 1 $\mu$ F capacitor close to the pins of the IC.
FLASH	4	Logic input to toggle operation between FLASH and TORCH mode. In TORCH mode FB is regulated to the internal 50mV reference. In FLASH mode FB reference voltage can be adjusted by changing the resistor from R <sub>SET</sub> pin to ground. Choose the external current sense resistor (R <sub>SENSE</sub> ) based on desired current in TORCH mode and Flash mode.
EN	5	Shutdown control input. Connect to VIN for normal operation, connect to ground for shutdown. For normal operation, suggest connecting to VIN only after the VIN has settled if the VIN ramping up is slow.
R <sub>SET</sub>	6	Connect a resistor from this pin to ground. When in FLASH mode (FLASH = High) this resistor sets the current regulation point according to the following: $V_{FB} = (1.26V / R_{SET}) \times 11.2k\Omega$
FB	7	Feedback input for the current control loop. Connect directly to the current sense resistor.
SGND	8	Internal ground pin. Control circuitry returns current to this pin.
PGND	9	Power ground pin. Flying capacitor current returns through this pin.
VOUT	10	Charge Pump Output Voltage. Decouple with an external capacitor. At least 1 $\mu$ F is recommended. If Higher value capacitor is used, output ripple is smaller.

**Typical applications**

**Figure1. Single LED flash circuit @ 800mA flash current**

**Figure 2. Multiple LED flash circuit @800mA flash current**

**Block diagram**

**Absolute maximum ratings**

Parameter	Symbol	Value	Unit
VIN,VOUT pin voltage range	V	-0.3~6	V
EN, FB pin voltage range	-	-0.3~5.5	V
Output Current Pulse(Flash)	$I_{O(Flash)}$	1.5	A
Output Current Continuous(Torch)	$I_{O(Torch)}$	0.4	A
Power Dissipation (Note 1)		3	W
Junction to Ambient Thermal Resistance (Note 1)	$R_{\theta JA}$	57	°C/W
Junction temperature	$T_J$	150	°C
Lead temperature(Soldering, 10s)	$T_L$	260	°C
Operating ambient temperature	$T_{opr}$	-40 ~ 85	°C
Storage temperature	$T_{stg}$	-55 ~ 150	°C
ESD Ratings	HBM	8000	V
	MM	400	V

These are stress ratings only. Stresses exceeding the range specified under “Absolute Maximum Ratings” may cause substantial damage to the device. Functional operation of this device at other conditions beyond those listed in the specification is not implied and prolonged exposure to extreme conditions may affect device reliability.

**Note 1:** Surface mounted on FR-4 Board using 1 square inch pad size, dual side, 1oz copper

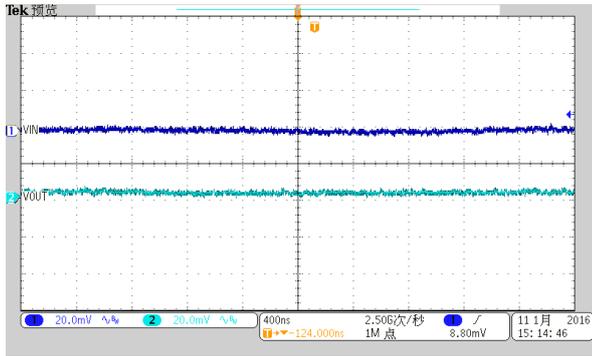
**Electronics Characteristics**

(Full= -40°C to +85°C ,  $V_{IN}= 3.6V$ ,  $C_{IN} = 4.7\mu F$ ,  $C_F = C_{OUT} = 1\mu F$ ,  $V_{EN}= V_{IN}$ , typical values at +25°C, unless otherwise noted)

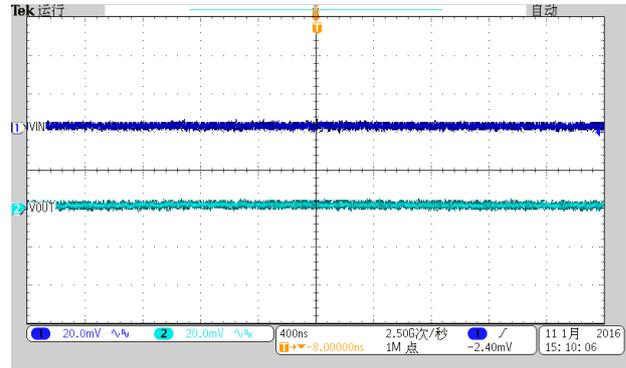
Parameter	Symbol	Conditions	Min.	Typ.	Max.	Units
Input Voltage Range	$V_{IN}$		2.7		5.5	V
Quiescent Current	$I_Q$	$V_{IN}=2.7V-5.5V$ FLASH=GND, 1X Mode $I_{LOAD}=100\mu A$		0.3		mA
	$I_Q$	FLASH = High, 2x mode		2		mA
Shutdown Supply Current	$I_{SHDN}$	$V_{EN} = 0V$ , $V_{IN}=5.5V$			1	$\mu A$
Feedback reference Voltage	$V_{FB}$	FLASH = $V_{IN}$ , $R_{SET} = 82k\Omega$	163	170	187	mV
		FLASH = GND	45	50	55	mV
FB Pin Current	$I_{FB}$	$V_{FB} = 0.3V$			1	$\mu A$
Oscillator Frequency	$f_{OSC}$			2.4		MHz
Charge Pump Equivalent Resistance (1x mode)		$V_{IN} = 3.6V$		0.8	1	$\Omega$
Charge Pump Equivalent Resistance (2x mode)				5		$\Omega$
EN, FLASH Logic Low	$V_{EN,FLASH H}$				0.4	V
EN, FLASH Logic High	$V_{EN,FLASH L}$		1.3			V
EN, FLASH Pin Current	$I_{EN,FLASH}$				1	$\mu A$
$V_{OUT}$ Turn-on Time		$V_{IN} = 3.6V$ , FB within 90% of regulation		250		$\mu s$
Thermal Shutdown Temperature	$T_{SHDN}$			150		$^{\circ}C$
Maximum Flash ON time		$V_{IN} = 3.6V$	0.8	1.2	1.6	S
Current Limit	$I_{limit}$	$V_{IN}=3.6 V$	0.85	1.2	1.5	A

Typical Characteristics (Ta=25°C, C<sub>IN</sub> = 4.7uF, C<sub>OUT</sub> = 4.7uF, C<sub>F</sub>=1uF, unless otherwise noted)

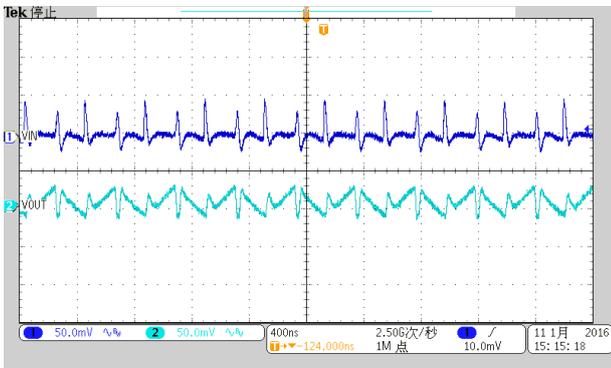
**Ripple 1X Flash 800mA**



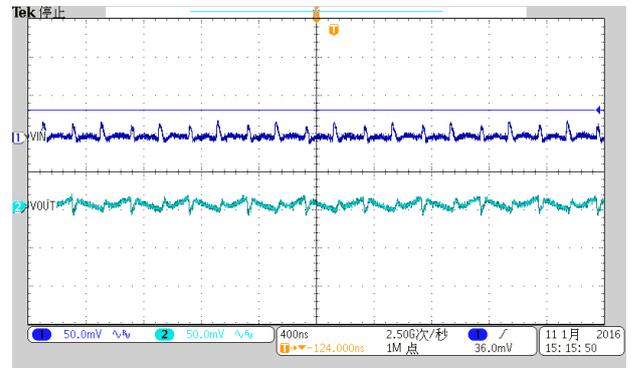
**Ripple 1X Torch 250mA**



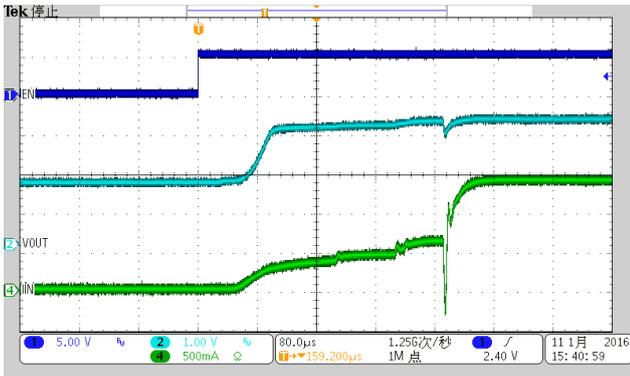
**Ripple 2X Flash 800mA**



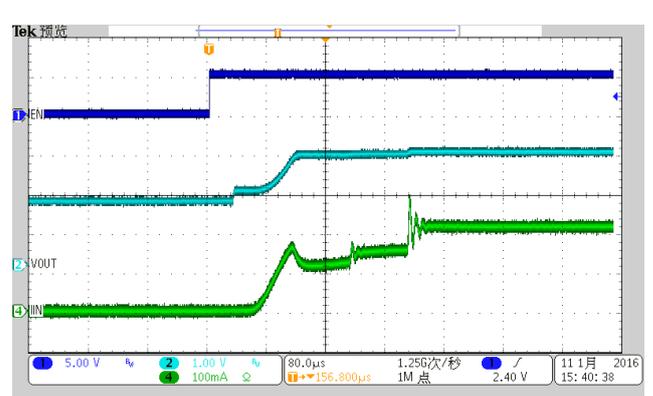
**Ripple 2X Torch 250mA**

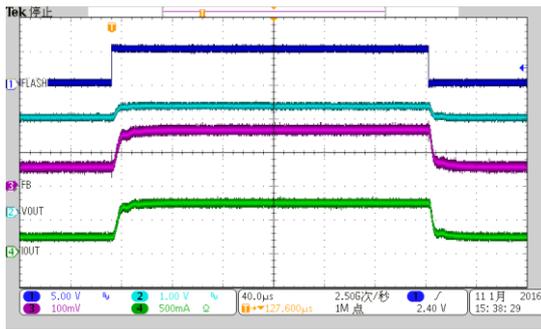
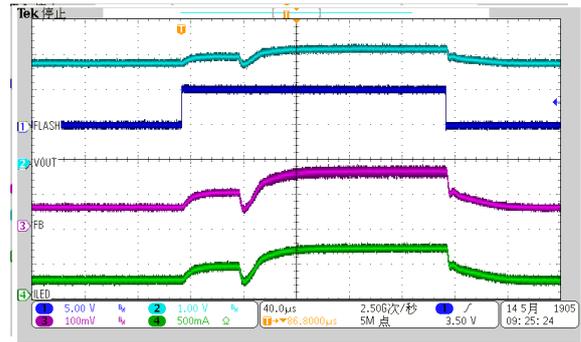
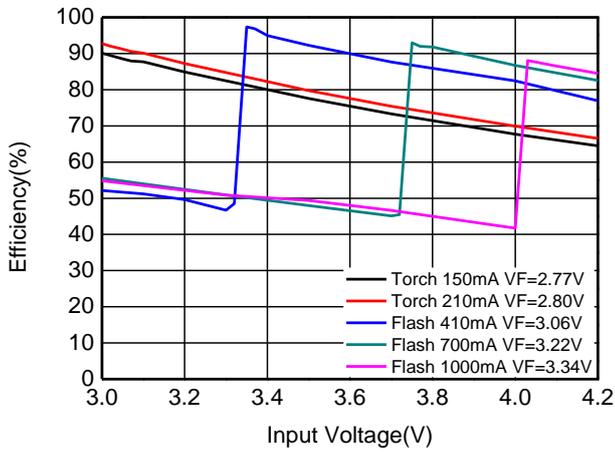
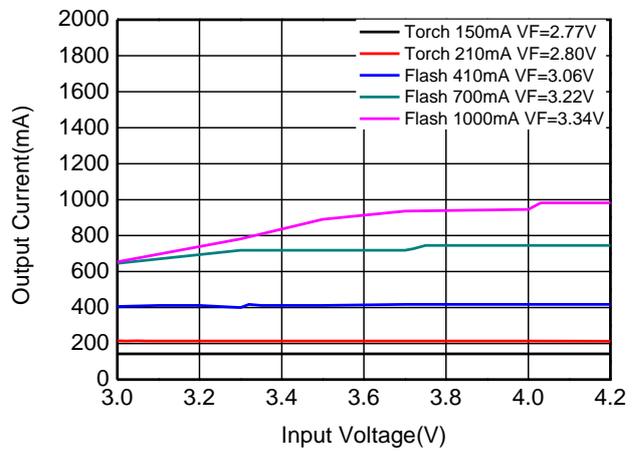
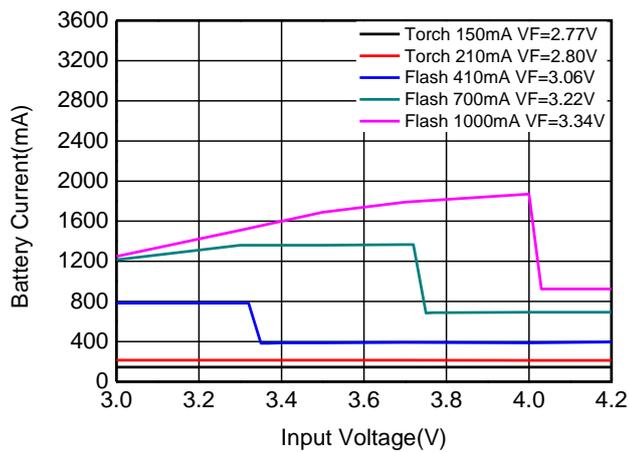


**Startup 800mA Flash**



**Startup 250mA Torch**



**Torch in 1X to Flash in 1X Mode**

**Torch in 1X to Flash in 2X Mode**

**Efficiency vs. Input Voltage**

**Output Current vs. Input Voltage**

**Battery Current vs. Input Voltage**


## Operation Information

The WD3609DC is a charge pump regulator designed for converting a Li-Ion battery voltage of 2.7V to 4.2V to drive a white LED used in digital still camera Flash and Torch applications. Flash mode of WD3609DC is usually used with a pulse about 1.2 seconds to generate a high intensity Flash. Torch of WD3609DC can be used continuously at a lower output current than Flash and is often used for several seconds in a digital still camera “movie” mode.

The WD3609DC also has two modes of operation to control the output current: the 1X mode and 2X mode. Operation begins after the enable pin EN receives a logic high, and then WD3609DC goes through a soft-start mode designed to reduce inrush current. The WD3609DC starts in the 1X mode, which acts like a linear regulator to control the output current by continuously monitoring the feedback pin FB. In 1X mode, as FB pin is below the regulation point, the WD3609DC automatically switches to the 2X mode. The WD3609DC remains in the 2X mode until one of four things happens:

- 1) The enable pin EN has been toggled.
- 2) The Flash pin has changed from high to low.
- 3) VIN is cycled or VIN recovers
- 4) A thermal fault occurs.

The 2X mode is the charge pump mode where the output can be pumped as high as two times the input voltage, provided the output does not exceed the maximum voltage for the WD3609DC, which is internally limited to about 5.5V. In the 2X mode, as in the 1X mode, the output current is regulated by the voltage at the FB pin.

In the Torch mode, (Flash = “GND”) the Flash pin is set to logic low and the WD3609DC FB pin regulates to typical 50mV output:

$$V_{FB} = 50\text{mV (Torch Mode)}$$

When in Flash mode, (Flash = “High”), the FB regulation voltage is set by the resistor  $R_{SET}$  connected between the  $R_{SET}$  pin and SGND and the equation:

$$V_{FB} = (1.26\text{V} / R_{SET}) \times 11.2\text{k}\Omega (\text{Flash Mode})$$

The output current is then set in either Flash or Torch mode by the equation:

$$I_{OUT} = V_{FB} / R_{SENSE}$$

Typical values of  $R_{SET}$  are 82k $\Omega$  to 150k $\Omega$  for a range of  $V_{FB} = 177\text{mV}$  to 93mV in Flash mode

## Application Information

### Flash timeout protection

Due to the high currents typically available in Flash mode, it is necessary to protect the white LED from damage if left on too long. The WD3609DC has a timeout in Flash mode of approximately 1.2 seconds after which it will shut down operation. Operation will not begin again in Flash mode until the Enable pin or Flash pin have been set Low and then High again.

### Over Temperature Protection

When the temperature of WD3609DC rises above 150°C, the over temperature protection circuitry turns off the output switches to prevent damage to the device. If the temperature drops back down below 135°C, the part automatically recovers and executes a soft start cycle.

### Over Voltage Protection

The WD3609DC has over voltage protection. If the output voltage rises above the 5.5V threshold, the over voltage protection shuts off all of the output switches to prevent the output voltage from rising further. When the output decreases below 5.3V, the device resumes normal operation.

### Over Current Protection

The over current protection circuitry monitors the average current out of the  $V_{OUT}$  pin. If the average output current exceeds approximately 1.2Amp, then the over current protection circuitry shuts off the output switches to protect the chip.

### Brightness Control Using PWM

Dimming control can be achieved by applying a PWM control signal to the EN pin. The brightness of the white LEDs is controlled by increasing and decreasing the duty cycle of the PWM signal. While the operating frequency range of the PWM control is from 60Hz to 700Hz, the recommended maximum brightness frequency range of the PWM signal is

from 60Hz to 200Hz. A repetition rate of at least 60Hz is required to prevent flicker.

### Component Selection

The WD3609DC charge pump circuit requires 3 capacitors (recommended values): 4.7µF input, 4.7µF output and 1µF flying capacitors. For the input capacitor, a larger value of 10µF will help reduce input voltage ripple for applications sensitive to ripple on the battery voltage. All the capacitors should be surface mount ceramic for low lead inductance necessary at the 2.4MHz switching frequency of the WD3609DC and to obtain low ESR, which improves bypassing on the input and output and improves output voltage drive by reducing output resistance. Ceramic capacitors with X5R or X7R temperature grade are recommended for most applications. A selection of recommended capacitors included in below table:

Part Number	Capacitance /voltage	CapacitorSize /Type /Thickness	ESR @100 K
C1005X5R0I105M	1uF/6.3V	0402/X5R/0.5mm	0.03
C1608X5R0J475K	4.7uF/6.3V	0603/X5R/0.9mm	0.02
C2012X5R0J106M	10uF/6.3V	0805/X5R/1.35mm	0.02
GRM155R60J105KE19B	1uF/6.3V	0402/X5R/0.55mm	0.03
GRM188R60J475KE19	4.7uF/6.3V	0603/X5R/0.9mm	0.02
GRM21BR60J106KE19L	10uF/6.3V	0805/X5R/1.35mm	0.02

The input and output capacitors should be located as close to the  $V_{IN}$  and  $V_{OUT}$  pins as possible to obtain best bypassing, and the returns should be connected directly to the PGND pin or to the thermal pad ground located under the WD3609DC. The flying capacitor should be located as close to the C1 and C2 pins as possible. To obtain lower output ripple, the  $C_{OUT}$  value can be increased from 1µF to 2.2µF or 4.7µF with a corresponding decrease in output ripple. For output currents of 500mA to 800mA, the recommended  $C_F$  flying capacitor value of 1µF should be used.

### Resistor Selection

The sense resistor  $R_{SENSE}$  is determined by the value needed in the Torch mode for the desired output current by the equation:

$$R_{SENSE} = V_{FB} / I_{OUT} \text{ where } V_{FB} = 50mV \text{ (Torch Mode).}$$

Once the  $R_{SENSE}$  resistor has been selected for Torch mode, the  $V_{FB}$  voltage can be selected for Flash mode using the following equation:

$V_{FB} = I_{OUT} \times R_{SENSE}$  (Flash Mode) where  $I_{OUT}$  is for Flash Mode.

Next, the  $R_{SET}$  resistor can be selected for Flash mode using the following equation:

$$R_{SET} = (1.26V/V_{FB}) \times 11.2k\Omega \text{ (Flash Mode)}$$

For an example of 200mA Torch mode and 800mA Flash mode, the values  $R_{SENSE} = 0.25\Omega$ ,  $V_{FB} = 150mV$  (Flash, Mode), and  $R_{SET} = 93k\Omega$  are calculated. The power, obtained in the Flash mode

would be:

$$P_{FLASH} = V_{FB} \times I_{OUT} = 150mV \times 800mA = 90mW$$

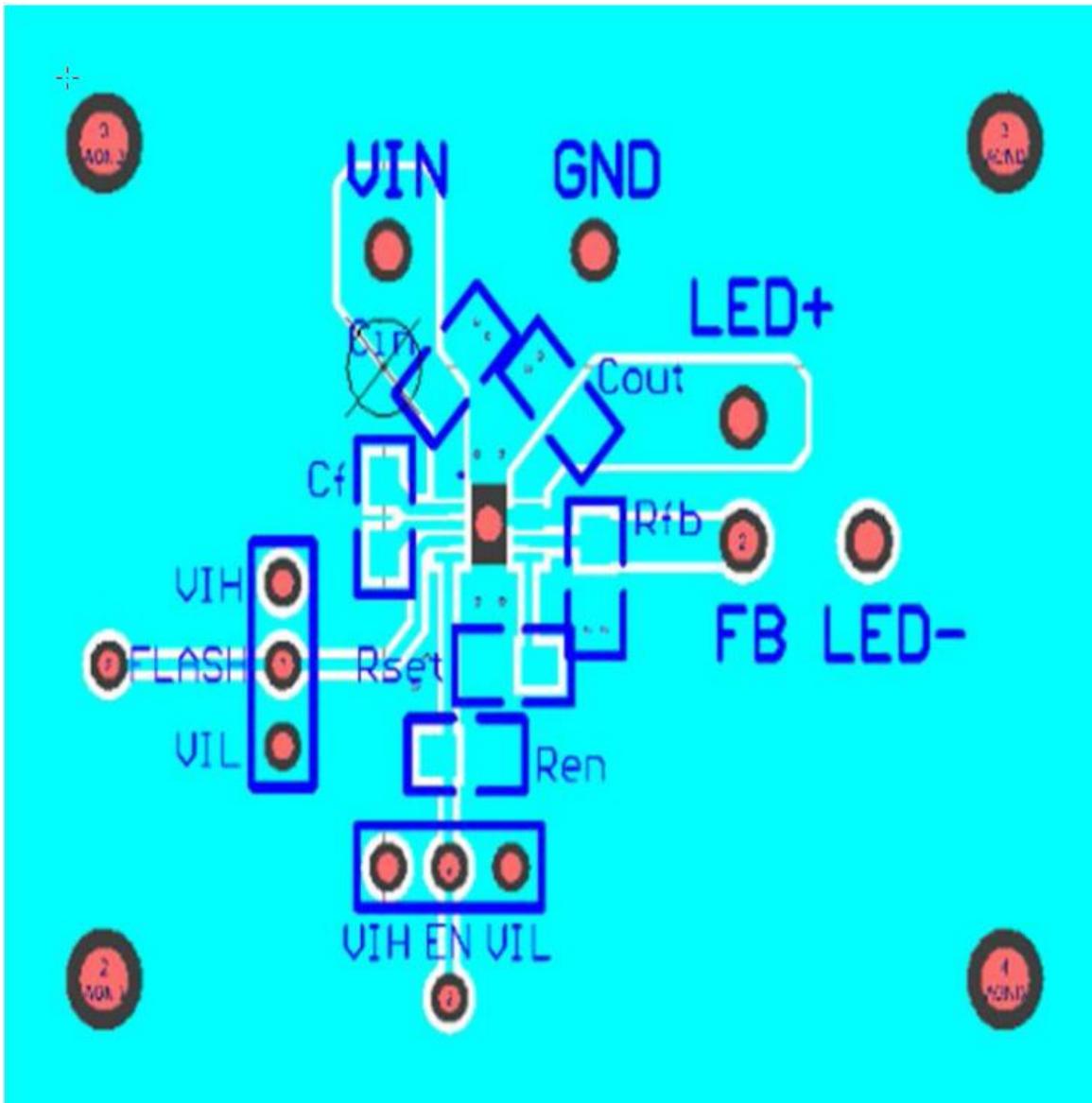
The typical 0603 surface mount resistor is rated 1/10, Watt continuous power and 1/5 Watt pulsed power, more than enough for this application. For other applications, the  $P_{FLASH}$  power can be calculated and resistor size selected. The  $R_{SENSE}$  resistor is recommended to be size 0603 for most applications. The range of typical resistor values and sizes are shown in below table:

**Reference R<sub>SET</sub> Resistor:**

Part Reference	Value (Ω)	Tolerance	Package Size	Flash Current (mA) @ R <sub>SENSE</sub> =				
				0.22Ω	0.27 Ω	0.33 Ω	0.39 Ω	0.47 Ω
R <sub>SET</sub>	75K	5%	0402	850	692	566	479	397
R <sub>SET</sub>	82K	5%	0402	777	633	518	438	363
R <sub>SET</sub>	91K	5%	0402	700	570	466	394	327
R <sub>SET</sub>	100K	5%	0402	636	518	424	358	297
R <sub>SET</sub>	120K	5%	0402	531	433	354	300	248
R <sub>SET</sub>	140K	5%	0402	457	370	303	256	212
R <sub>SET</sub>	150K	5%	0402	422	343	281	238	197

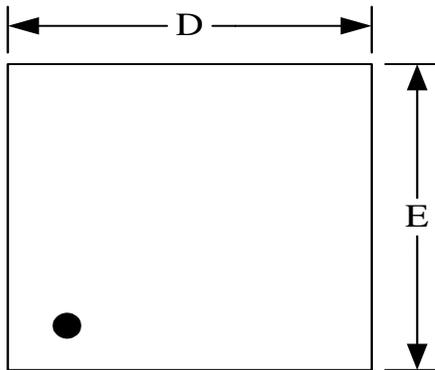
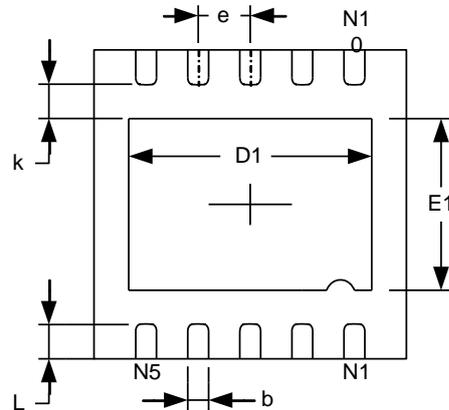
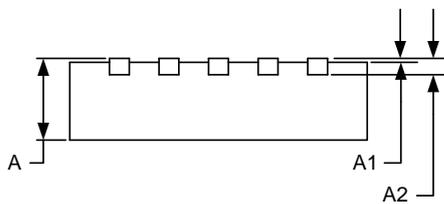
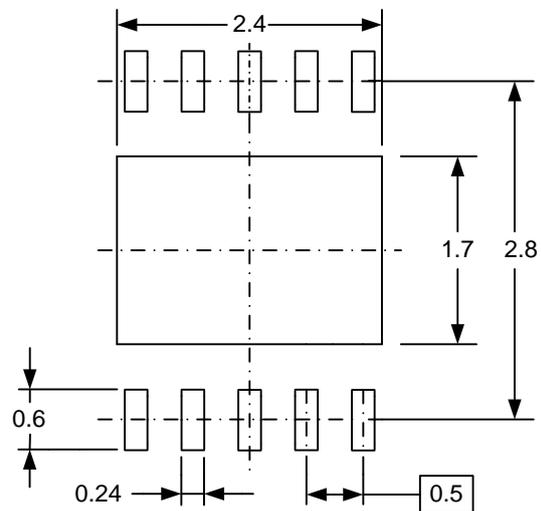
**Reference R<sub>SENSE</sub> Resistor:**

Part Reference	Value (Ω)	Tolerance	Package Size	Torch Current (mA)
R <sub>SENSE</sub>	0.22	5%	0603	227
R <sub>SENSE</sub>	0.27	5%	0603	185
R <sub>SENSE</sub>	0.33	5%	0603	151
R <sub>SENSE</sub>	0.39	5%	0603	128
R <sub>SENSE</sub>	0.47	5%	0603	106

**EVALUATION BOARD LAYOUT**

**Printed Circuit Board Layout Recommendations**

Follow the PCB layout guidelines for optimal performance:

1. Place the flying capacitor CF as close to the chip as possible as possible; otherwise 2x mode performance will be compromised. Also keep analog components away from this capacitor.
2. Place input and output decoupling capacitors as close to the chip as possible to reduce switching noise and output ripple.
3. The power traces, consisting of the VIN/GND trace, the VOUT trace and the WLED trace should be kept short and wide. Also minimize the feedback loop area (consisting of WLED/FB) small.
4. Connect the exposed pad to the GND plane to achieve the best power dissipation.

**Package outline dimensions**
**TDFN3x3-10L**

**TOP VIEW**

**BOTTOM VIEW**

**SIDE VIEW**

**RECOMMENDED LAND PATTERN (Unit:mm)**

SYMBOL	Dimensions In Inches		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
A2	0.203REF		0.008REF	
D	2.900	3.100	0.114	0.122
D1	2.300	2.500	0.091	0.098
E	2.900	3.100	0.114	0.112
E1	1.600	1.800	0.063	0.071
k	0.200MIN		0.008MIN	
b	0.180	0.300	0.007	0.012
e	0.500TPY		0.020TYP	
L	0.300	0.500	0.012	0.020