

## 1.5A Flash LED Driver with I<sup>2</sup>C Compatible Interface

### General Description

The RT8540 is a high efficiency synchronous Boost converter capable of delivering up to 1.5A maximum output current. It is an ideal power solution for up to three LEDs photoflash applications in all single-cell Lithium-ion/polymer battery powered products.

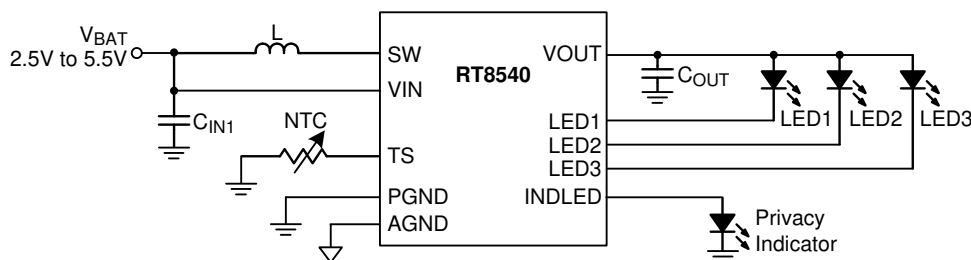
The RT8540 maintains output current regulation by switching the internal high-side and low-side switch transistors. The transistor switches are pulse width modulated at a fixed frequency of 2MHz. The high switching frequency allows the use of a small inductor and output capacitor, making the RT8540 ideally suited for small battery powered applications. The RT8540 also includes STRB0, STRB1, Tx-MASK input to simplify torch and flash synchronization with the camera module. The default timer can be used to terminate a flash event after a user programmed delay or as a safety feature. The device automatically optimizes the LED flash current budget with the battery voltage condition as a feature.

The RT8540 not only operates as a regulated current source, but also as a voltage Boost regulator with the capability of down output voltage mode. The RT8540 contains over-voltage protection, over-current protection and a thermal management system to protect the device. The shutdown feature reduces shutdown current to less than 1µA. The RT8540 is available in the tiny WL-CSP-20B 1.82x2.22 (BSC) package to achieve best solution for PCB space and total BOM cost saving.

### Features

- Input Voltage Range : 2.5V to 5.5V
- Three Flash LED Channel Output
- Operational Modes
  - ▶ Torch Mode and Flash Strobe
  - ▶ Voltage Regulation Converter with Down Output Voltage Mode
  - ▶ Shutdown Mode
- Up to 1.5A Regulated Output Current
- Up to 85% Efficiency with Small Magnetics at Current Regulation
- 2MHz Switching Frequency
- Dual Wire Camera Module Interface
- Tx-MASK Input to Inhibit Flash operation
- Shutdown Current < 1µA
- I<sup>2</sup>C Setting Torch Mode Current Level
- I<sup>2</sup>C Setting Flash Mode Current Level
- I<sup>2</sup>C Setting Safety Timer
- Over-Voltage (Open LED), Over-Current (Short Circuit), and Over-Temperature Protection
- Flash Current Optimization with VBAT
- LED Temperature Monitoring
- I<sup>2</sup>C Compatible Interface up to 3.4Mbits/s
- GPIO and Power Good Output
- Privacy Indicator LED Output
- Hardware Reset Input
- RoHS Compliant and Halogen Free

### Simplified Application Circuit



## Applications

- Single/Dual/Triple White LED Flash Supply for Cell Phones, Smart Phones, Tablet PC, Digital Cameras and other 3C productions
- Video Lighting for Digital Video Applications
- General LED Lighting Applications

## Ordering Information

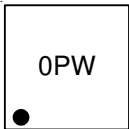
RT8540 □  
 Package Type  
 WSC : WL-CSP-20B 1.82x2.22 (BSC)

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.

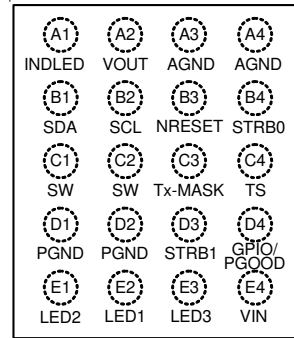
## Marking Information



0P : Product Code  
 W : Date Code

## Pin Configurations

(TOP VIEW)

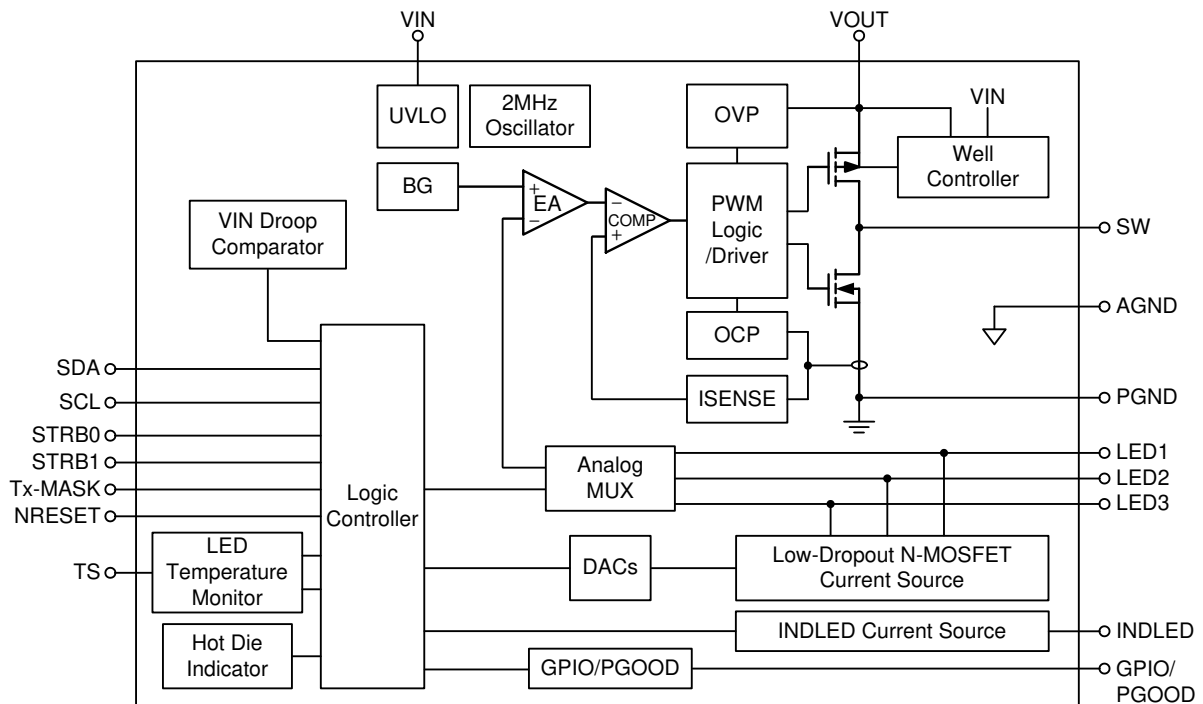


WL-CSP-20B 1.82x2.22 (BSC)

**Functional Pin Description**

Pin No.	Pin Name	Pin Function
A1	INDLED	Constant Current Source Output. This pin provides a constant current source to drive low VF LEDs. Connect to LED anode.
A2	VOUT	Output of Boost Converter. Connect a 10 $\mu$ F or larger ceramic capacitor from VOUT to ground as close as possible to IC.
A3, A4	AGND	Analog Ground.
B1	SDA	Serial Interface Address/Data Input. This pin must not be left floating and must be terminated.
B2	SCL	Serial Interface Clock Input. This pin must not be left floating and must be terminated.
B3	NRESET	Master Hardware Reset Input. NRESET = LOW : The device is forced to shutdown mode. The I <sup>2</sup> C control I/F and all internal control registers will be reset. NRESET = HIGH : The device operates normally.
B4	STRB0	LED1/2/3 Enable Control Input. This pin can be used to enable/disable the high power LEDs connected to the device. STRB0 = LOW : LED1, LED2 and LED3 current regulators are turned off. STRB0 = HIGH : LED2, LED2 and LED3 current regulators are active. The LED current level (video light or flash current) is defined according to the STRB1 logic level.
C1, C2	SW	Switch Node of Boost Converter. Connect an inductor between SW and VIN.
C3	Tx-MASK	LED Flash Inhibit Control Input. Pulling this pin high turns the LED from flash to video light operation, thereby reducing almost instantaneously the peak current loading from the battery.
C4	TS	NTC Resistor Connection. This pin can be used to monitor the LED temperature. Connect a 220k $\Omega$ NTC resistor from the TS to ground. If this function is not used, the TS pin should be tied to VIN or left floating.
D1, D2	PGND	Power Ground. Connect PGND to AGND underneath IC. The exposed pad must be soldered to a large PCB and connected to GND for maximum power dissipation.
D3	STRB1	LED Current Level Selection Input. Pulling this input high disables the video light watchdog timer. STRB1 = LOW : flash mode is enabled. STRB1 = HIGH : video light mode is enabled.
D4	GPIO/PGOOD	GPIO Input or Power Good Indicator.
E1	LED2	Current Source of LED Channel 2.
E2	LED1	Current Source of LED Channel 1.
E3	LED3	Current Source of LED Channel 3.
E4	VIN	Power Input. Connect Battery to the input power supply voltage. Connect a 4.7 $\mu$ F or larger ceramic capacitor from VIN to ground as close as possible to the IC.

Function Block Diagram



Operation

The RT8540 is a high efficiency synchronous Boost converter capable of delivering up to 1.5A maximum output current, and it maintains output current regulation by switching the internal high-side and low-side switch transistors. The transistor switches are pulse width modulated at a fixed frequency of 2MHz. The RT8540 also includes STRB0, STRB1, Tx-MASK input to simplify torch and flash synchronization with the camera module. The RT8540 is designed for one, two or three LEDs driving for torch and flash application, it provides an I<sup>2</sup>C software command or dedicated zero latency hardware signals to trigger the torch and flash operation. The OVP function prevents the RT8540 from damaging while open-LED or open-circuit condition is occurred.

**Absolute Maximum Ratings** (Note 1)

- Supply Voltage, VIN ----- -0.3V to 6.5V
- Boost Output Voltage, VOUT ----- -0.3V to 6.5V
- Switch Node Voltage, SW ----- -0.3V to 6.5V
- Current Source Voltage, LED1, LED2, LED3, INDLED ----- -0.3V to 6.5V
- Other Pins, STRB0, STRB1, SCL, SDA, Tx-MASK, TS, GPIO/PGOOD ----- -0.3V to 6V
- Power Dissipation,  $P_D @ T_A = 25^\circ\text{C}$   
 WL-CSP-20B 1.82x2.22 (BSC) ----- 2.72W
- Package Thermal Resistance (Note 2)  
 WL-CSP-20B 1.82x2.22 (BSC),  $\theta_{JA}$  ----- 36.7°C/W
- Junction Temperature ----- 150°C
- Lead Temperature (Soldering, 10 sec.) ----- 260°C
- Storage Temperature Range ----- -65°C to 150°C
- ESD Susceptibility (Note 3)  
 HBM (Human Body Model) ----- 2kV  
 MM (Machine Model) ----- 200V  
 CDM (Charge Device Model) ----- 500V

**Recommended Operating Conditions** (Note 4)

- Input Voltage, VIN ----- 2.5V to 5.5V
- Junction Temperature Range ----- -40°C to 125°C
- Ambient Temperature Range ----- -40°C to 85°C

**Electrical Characteristics**

(VIN = 3.7V, CIN = 4.7μF, COUT = 10μF, TA = 25°C, unless otherwise specified)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
<b>Power Supply</b>						
Under-Voltage Lockout	VUVLO		--	2.3	2.4	V
VIN Quiescent Current	IQ	IOUT = 0mA, no switching (Voltage regulation mode)	--	590	700	μA
VIN Shutdown Current	ISD		--	1	5	μA
<b>Output</b>						
Output Voltage Range	VOUT	Current Regulation Mode	VIN	--	5.5	V
		Voltage Regulation Mode	3.825	--	5.7	
Internal Feedback Voltage Accuracy	VFB	2.5V < VIN < 4.8V, Boost mode, PWM voltage regulation	-2	--	2	%
Output Over-Voltage Protection (OVP)	VOVP	VOUT Rising, 0000 ≤ OV [3:0] ≤ 0100	4.5	4.65	4.8	V
		VOUT Rising, 0101 ≤ OV [3:0] ≤ 1111	5.8	6	6.2	
OVP Hysteresis	VOVP_HYS	VOUT Falling	--	150	--	mV
<b>Current Source of LED Current</b>						
LED1/3 Current Accuracy	ILED1/3	0mA ≤ ILED1/3 ≤ 100mA	-10	--	10	%
		100mA ≤ ILED1/3 ≤ 400mA	-7.5	--	7.5	
LED1/3 Current Matching	IMAT		-10	--	10	%

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
LED2 Current Accuracy	I <sub>LED2</sub>	0mA ≤ I <sub>LED2</sub> ≤ 250mA	-10	--	10	%
		250mA ≤ I <sub>LED2</sub> ≤ 800mA	-7.5	--	7.5	
INDLED Current Accuracy	I <sub>IND</sub>	1.5V ≤ (V <sub>IN</sub> - V <sub>INDLED</sub> ) ≤ 2.5V, 2.6mA ≤ I <sub>IND</sub> ≤ 15.8mA	-20	--	20	%
LED1/2/3 Current Temperature Coefficient			--	0.05	--	%/°C
INDLED Current Temperature Coefficient			--	0.05	--	%/°C
LED1/2/3 Sense Voltage	V <sub>SEN</sub>	LED1/2/3 = Full-Scale Current	--	300	--	mV
LED1/2/3 Input Leakage Current	I <sub>LED_LKG</sub>	V <sub>LED1/2/3</sub> = 5V	--	0.1	4	μA
INDLED Input Leakage Current	I <sub>IND_LKG</sub>	V <sub>INDLED</sub> = 0V	--	0.1	1	μA
LED1 Start-Up Current	I <sub>ST1</sub>	LED Forward Voltage (V <sub>OUT</sub> - V <sub>LED1</sub> ) < 1V	55	--	--	μA
LED2 Start-Up Current	I <sub>ST2</sub>	LED Forward Voltage (V <sub>OUT</sub> - V <sub>LED2</sub> ) < 1V	55	--	--	μA
LED3 Start-Up Current	I <sub>ST3</sub>	LED Forward Voltage (V <sub>OUT</sub> - V <sub>LED3</sub> ) < 1V	55	--	--	μA
<b>Oscillator and Timer</b>						
Operating Frequency	F <sub>OSC</sub>	Flash Mode	1.8	2	2.2	MHz
Reset Pulse Width	t <sub>NRESET</sub>		10	--	--	μs
<b>Power Switch</b>						
N-MOSFET R <sub>ON</sub>	N <sub>RON</sub>	V <sub>OUT</sub> = 3.6V	--	75	--	mΩ
P-MOSFET R <sub>ON</sub>	P <sub>RON</sub>	V <sub>OUT</sub> = 3.6V	--	95	--	mΩ
Leakage into SW	I <sub>LKG_SW</sub>	V <sub>OUT</sub> = 0V, SW = 3.6V	--	0.3	4	μA
<b>Protection Function</b>						
Current Limit	I <sub>OC</sub>	V <sub>OUT</sub> = 4.95V, I <sub>LIM</sub> = 0	--	1650	--	mA
		V <sub>OUT</sub> = 4.95V, I <sub>LIM</sub> = 1	--	2150	--	mA
Thermal Shutdown Threshold	T <sub>SD</sub>		140	160	--	°C
Thermal Shutdown Hysteresis	T <sub>SD_HYS</sub>		--	20	--	°C
Temperature Sense Current Source	I <sub>O_TS</sub>	Thermistor Bias Current	--	23.8	--	μA
TS Resistance (Warning Temperature)		LEDWARN bit = 1	39	44.5	50	kΩ
TS Resistance (Hot Temperature)		LEDHOT bit = 1	12.5	14.5	16.5	kΩ
<b>Logic Control</b>						
SCL, SDA, GPIO/PGOOD, STRB0, STRB1, Tx-MASK, NRESET Input Voltage	High-Level	V <sub>IH</sub>		1.2	--	V
	Low-Level	V <sub>IL</sub>		--	0.4	
SDA Low-Level Output Voltage	V <sub>OL_SDA</sub>	I <sub>OL</sub> = 8mA	--	--	0.3	V
GPIO Output Voltage	High-Level	V <sub>OH_GPIO</sub>	DIR = 1, GPIOTYPE = 0, I <sub>OH</sub> = 8mA	V <sub>IN</sub> - 0.4	--	V
	Low-Level	V <sub>OL_GPIO</sub>	DIR = 1, I <sub>OL</sub> = 5mA	--	0.3	
STRB0, STRB1, NRESET, Tx-MASK Pull-Down Resistance	R <sub>PD</sub>	STRB0, STRB1, NRESET, Tx-MASK < 0.4V	--	400	--	kΩ

**I<sup>2</sup>C Interface Timing Characteristics (1)**

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
SCL Clock Frequency	f <sub>SCL</sub>	Standard mode	--	--	100	kHz
		Fast mode	--	--	400	
Bus Free Time Between a STOP and START Condition	t <sub>BUF</sub>	Standard mode	4.7	--	--	μs
		Fast mode	1.3	--	--	
Hold Time (Repeated) START Condition	t <sub>HD</sub> , t <sub>STA</sub>	Standard mode	4	--	--	μs
		Fast mode	600	--	--	ns
LOW Period of the SCL Clock	t <sub>LOW</sub>	Standard mode	4.7	--	--	μs
		Fast mode	1.3	--	--	
HIGH Period of the SCL Clock	t <sub>HIGH</sub>	Standard mode	4	--	--	μs
		Fast mode	600	--	--	ns
Setup Time for a Repeated START Condition	t <sub>SU</sub> , t <sub>STA</sub>	Standard mode	4.7	--	--	μs
		Fast mode	600	--	--	ns
Data Setup Time	t <sub>SU</sub> , t <sub>DAT</sub>	Standard mode	250	--	--	ns
		Fast mode	100	--	--	
Data Hold Time	t <sub>HD</sub> , t <sub>DAT</sub>	Standard mode	0	--	3.45	μs
		Fast mode	0	--	0.9	
Rising Time of SCL Signal	t <sub>RCL</sub>	Standard mode	20 + 0.1C <sub>B</sub>	--	1000	ns
		Fast mode	20 + 0.1C <sub>B</sub>	--	300	
Rising Time of SCL Signal After a Repeated START Condition and After an Acknowledge BIT	t <sub>RCL1</sub>	Standard mode	20 + 0.1C <sub>B</sub>	--	1000	ns
		Fast mode	20 + 0.1C <sub>B</sub>	--	300	
Falling Time of SCL Signal	t <sub>FCL</sub>	Standard mode	20 + 0.1C <sub>B</sub>	--	300	ns
		Fast mode	20 + 0.1C <sub>B</sub>	--	300	
Rising Time of SDA Signal	t <sub>RDA</sub>	Standard mode	20 + 0.1C <sub>B</sub>	--	1000	ns
		Fast mode	20 + 0.1C <sub>B</sub>	--	300	
Falling Time of SDA Signal	t <sub>FDA</sub>	Standard mode	20 + 0.1C <sub>B</sub>	--	300	ns
		Fast mode	20 + 0.1C <sub>B</sub>	--	300	
Setup Time for STOP Condition	t <sub>SU</sub> , t <sub>STO</sub>	Standard mode	4	--	--	μs
		Fast mode	600	--	--	ns
Capacitive Load for SDA and SCL	C <sub>B</sub>		--	--	400	pF

(1) Specified by design. Not tested in production.

**Note 1.** Stresses beyond those listed “Absolute Maximum Ratings” may cause permanent damage to the device. These are stress ratings only, and 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 may affect device reliability.

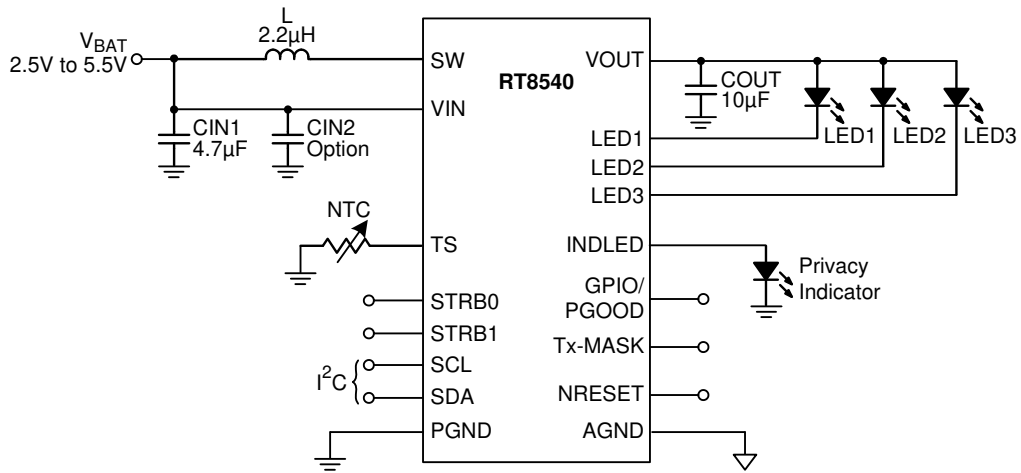
**Note 2.**  $\theta_{JA}$  is measured at  $T_A = 25^\circ\text{C}$  on a high effective thermal conductivity four-layer test board per JEDEC 51-7.

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

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

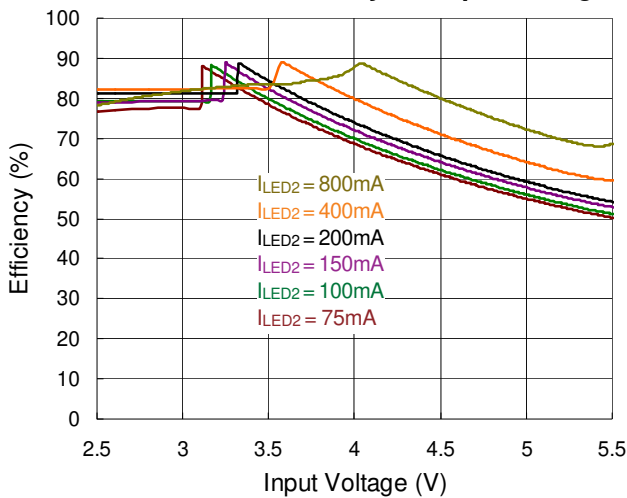


**Typical Application Circuit**

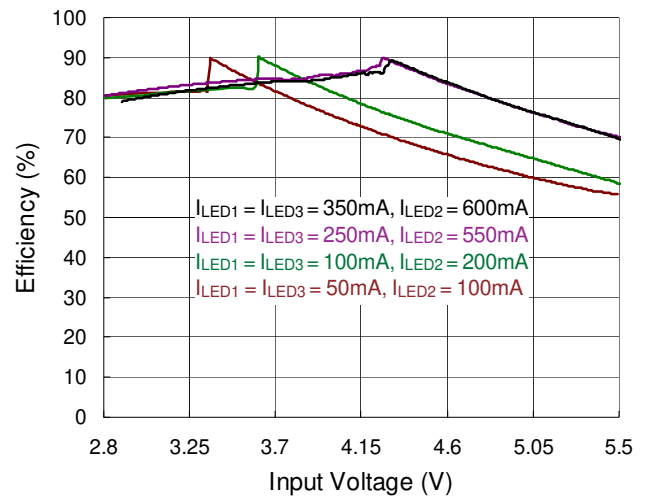


Typical Operating Characteristics

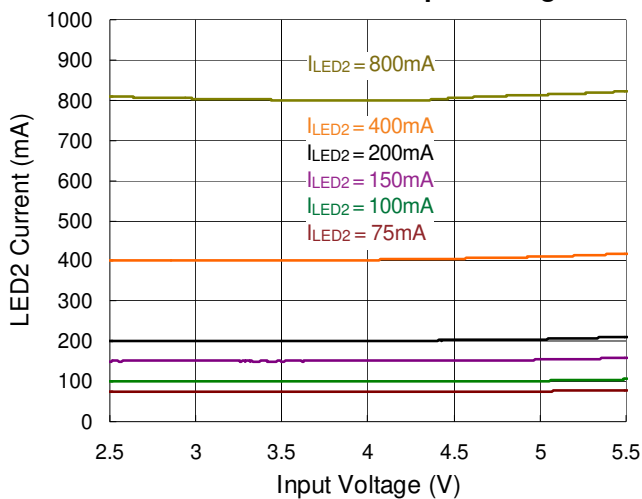
LED Power Efficiency vs. Input Voltage



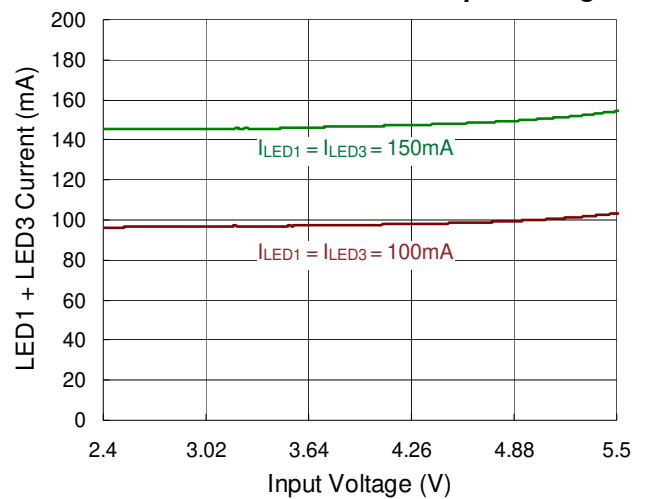
LED Power Efficiency vs. Input Voltage



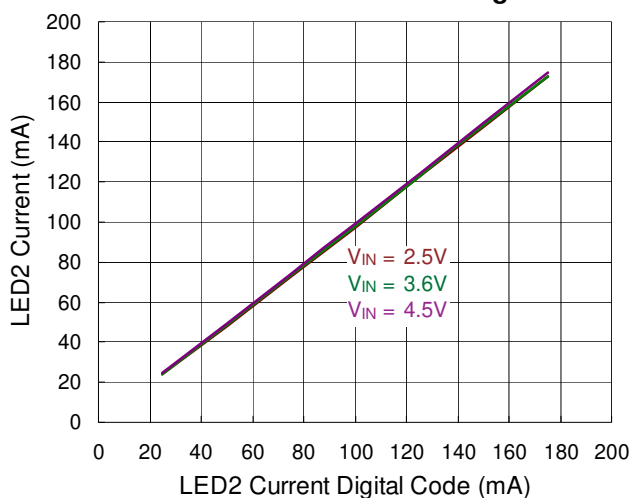
LED2 Current vs. Input Voltage



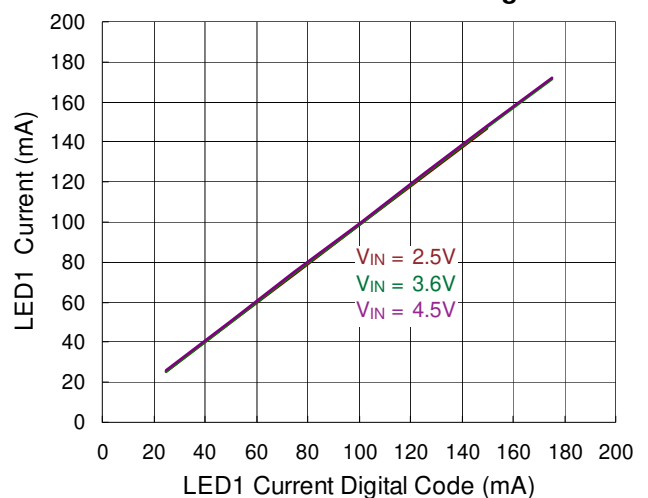
LED1 + LED3 Current vs. Input Voltage



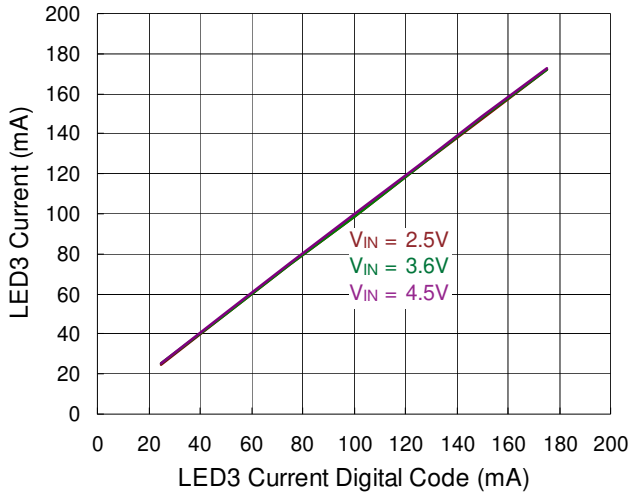
LED2 Current vs. LED2 Current Digital Code



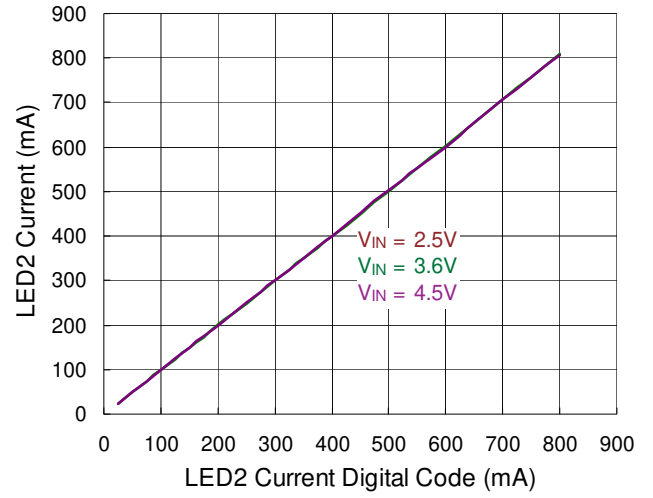
LED1 Current vs. LED1 Current Digital Code



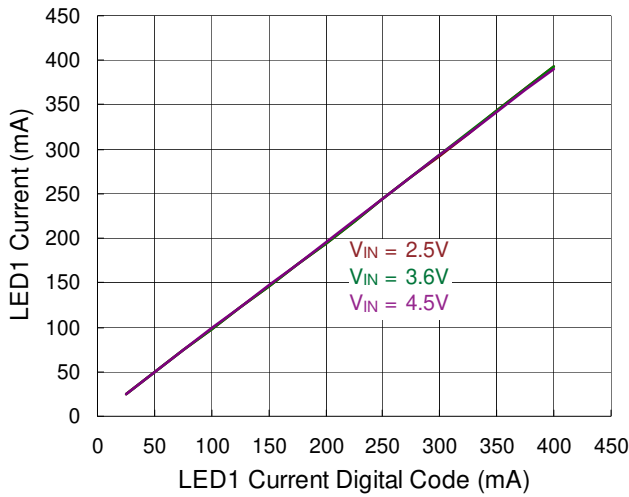
LED3 Current vs. LED3 Current Digital Code



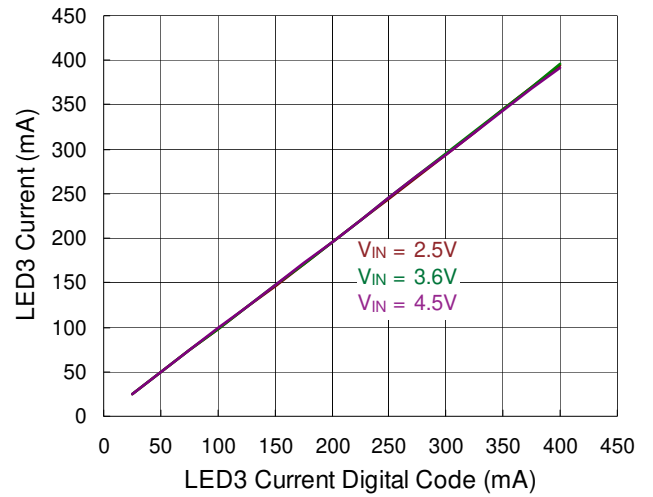
LED2 Current vs. LED2 Current Digital Code



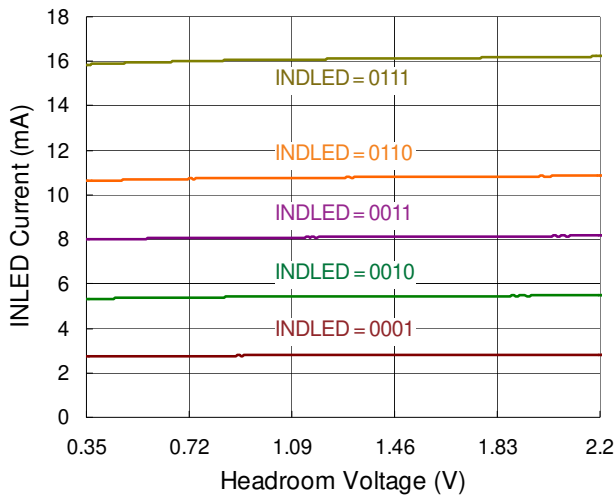
LED1 Current vs. LED1 Current Digital Code



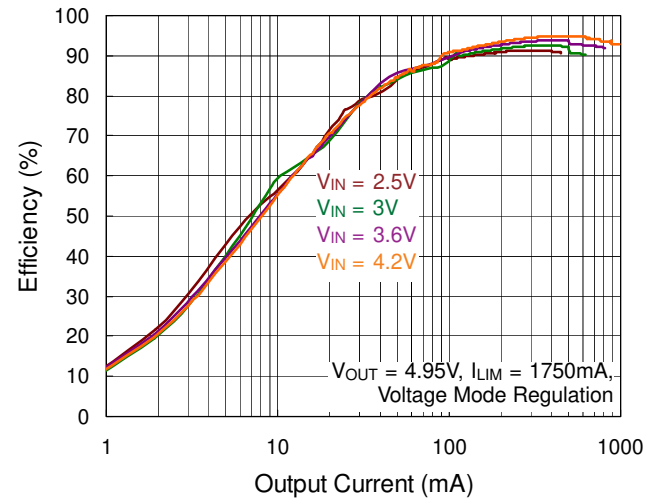
LED3 Current vs. LED3 Current Digital Code



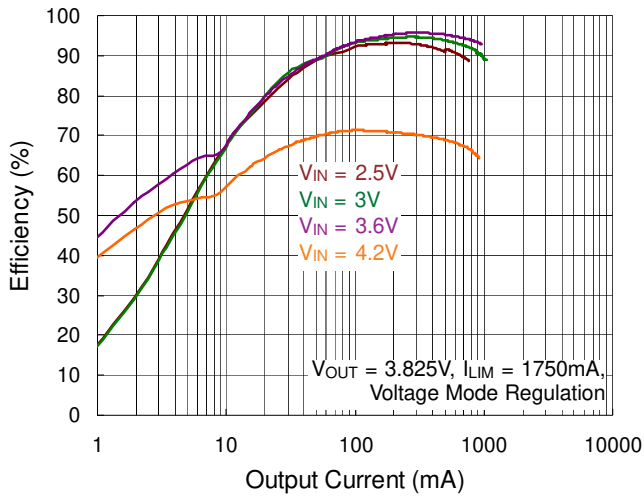
INDLED Current vs. Headroom Voltage



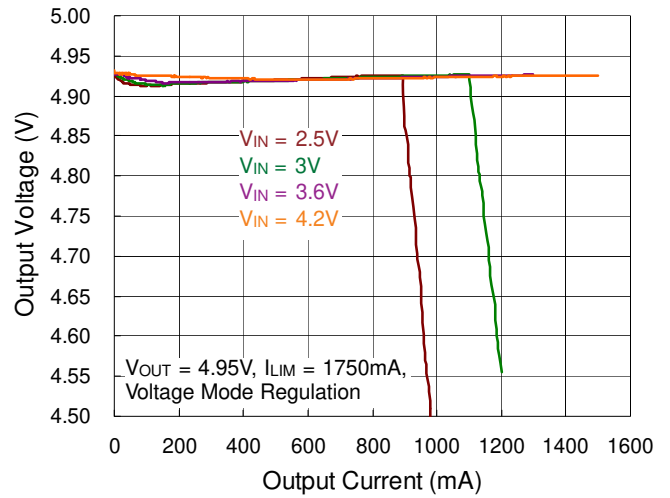
Efficiency vs. Output Current



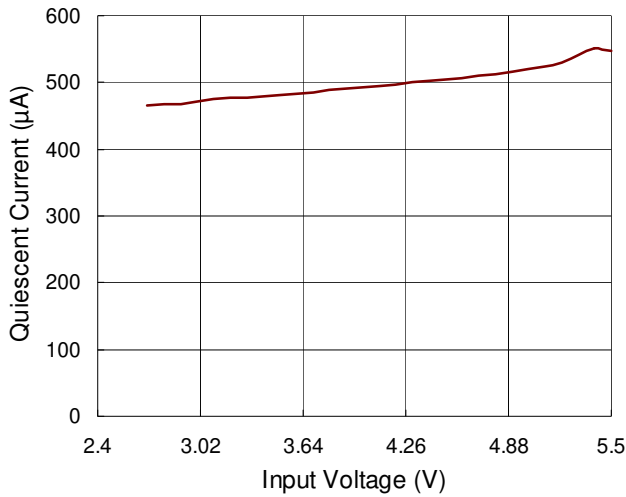
Efficiency vs. Output Current



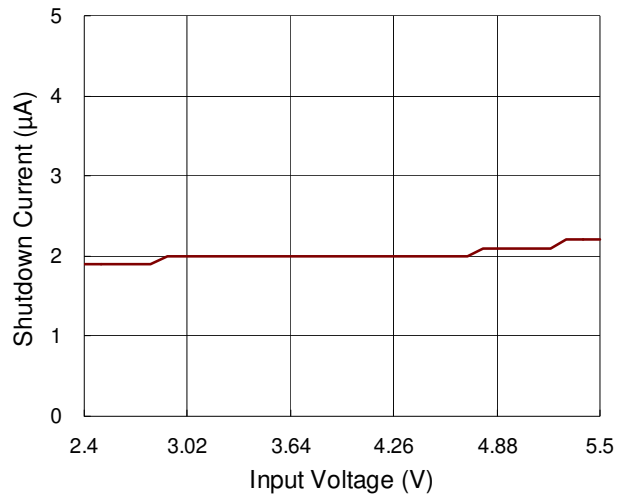
Output Voltage vs. Output Current



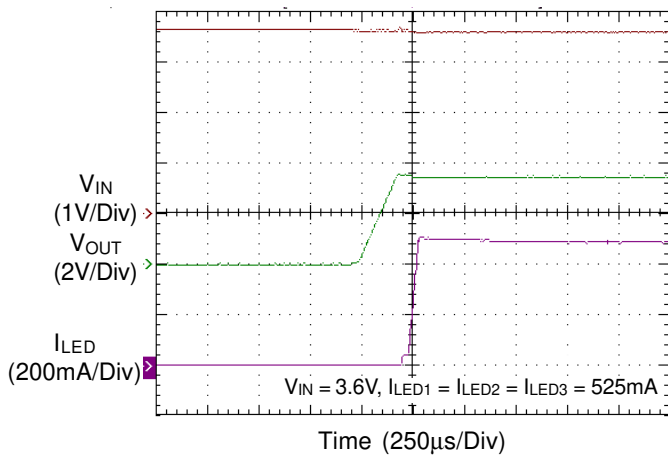
Quiescent Current vs. Input Voltage



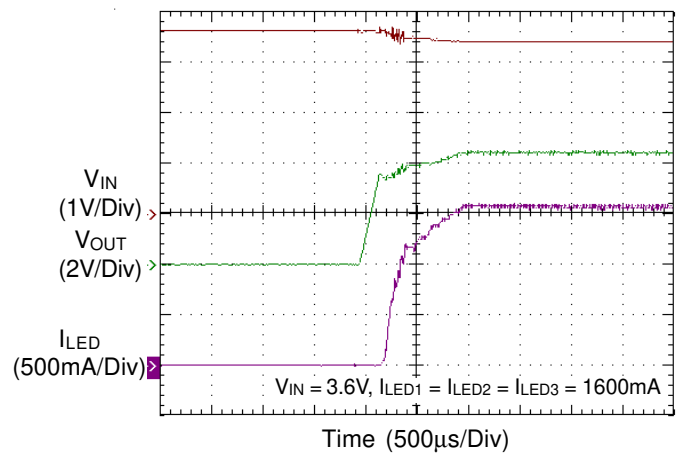
Shutdown Current vs. Input Voltage



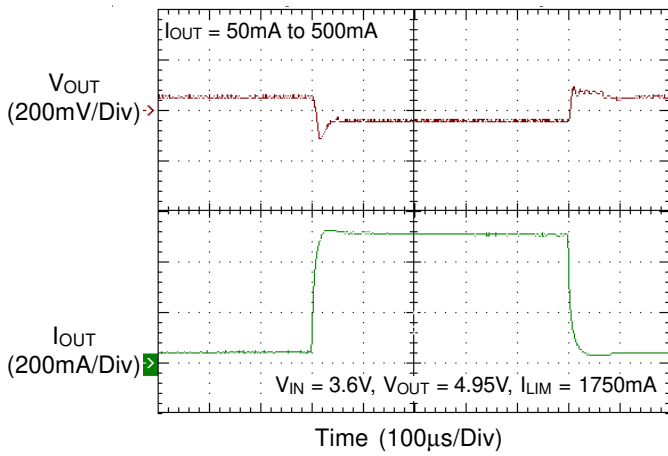
Torch Mode Power On



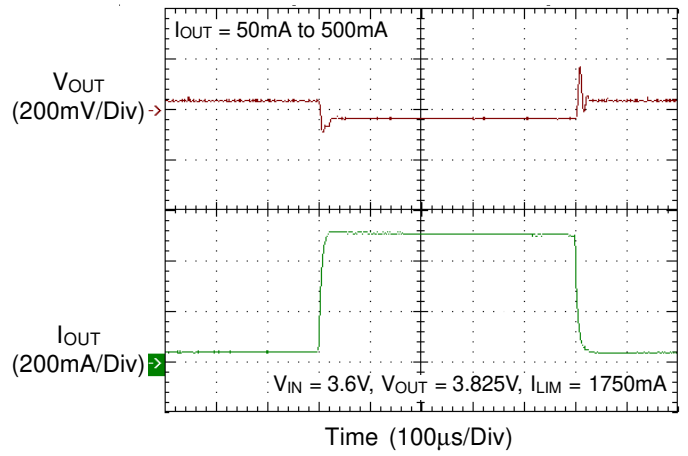
Flash Mode Power On



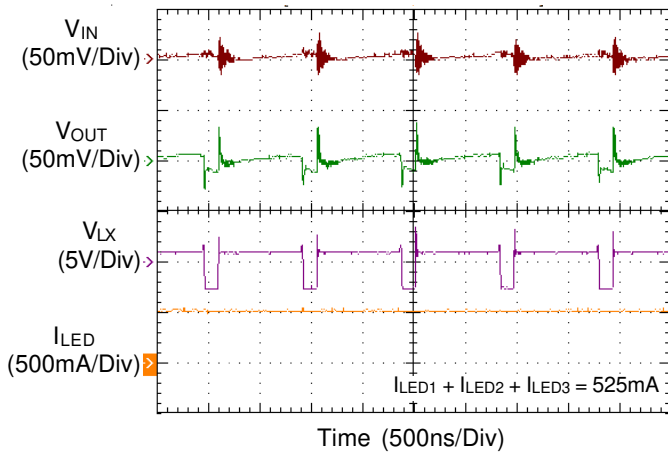
**Voltage Mode Load Transient**



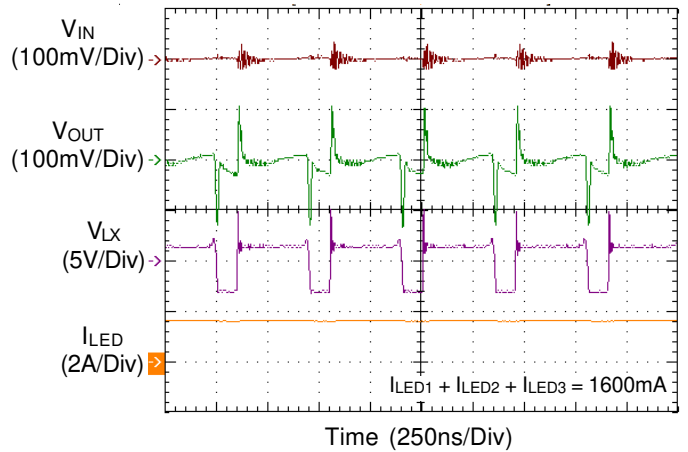
**Voltage Mode Load Transient**



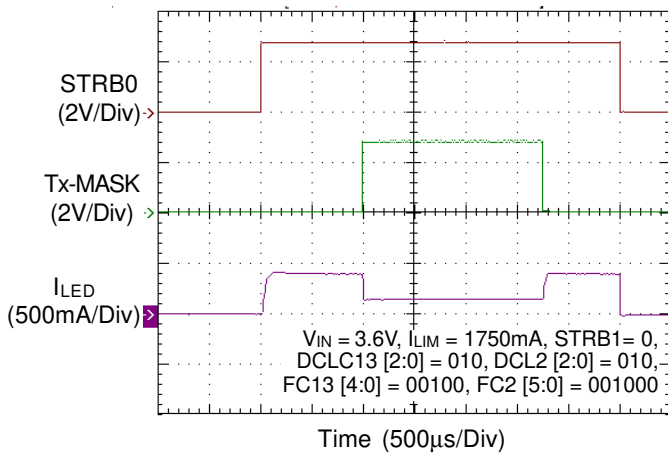
**Torch Mode Ripple & Spike**



**Flash Mode Ripple & Spike**



**Tx-MASK Operation**



## Application Information

The RT8540 is a Boost converter that provides a current regulated output to drive high current white LEDs for camera flash applications. The IC adopts three channels to provide accurately regulated current flow through three separate white LEDs.

The RT8540 provides the ability to regulate the input voltage that is higher than the designed output voltage with its down-conversion mode. The RT8540 turns off its down-conversion mode automatically once the input voltage falls to approximately 200mV below the output voltage.

### Soft-Start

The RT8540 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 inrush current for a typical period of 400μs.

### Input UVLO

The input operating voltage range of the LED driver is from 2.5V to 5.5V. The RT8540 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 2.3V typically with a hysteresis of 200mV.

### Over Voltage Protection (Open-LED, Open-Circuit)

The RT8540 provides an internal over-voltage protection to limit its output voltage. The OVP function prevents the RT8540 from damaging while open-LED or open-circuit condition is occurred. The switching will be re-started again once the open circuit condition is removed, and then the IC will return to normal operation.

### Over-Temperature Protection

The RT8540 provides an over-temperature protection to prevent the IC from overheating. When the junction temperature of the RT8540 rises above 160°C, the OTP function will be triggered and then the LED driver will be shutdown. The OTP of the RT8540 comes with a hysteresis of 20°C. Once the temperature is reduced below the over-temperature protection threshold by 20°C, the IC will enter normal operation again.

### Inductor Selection

The RT8540 adopts fixed frequency PWM control architecture. For stable operation and the 2MHz high switching frequency, it is recommended to use a 2.2μH inductor. Small size and high efficiency are the major concerns for portable device, so the inductor should have low core loss at 2MHz and low DCR for better efficiency.

### Capacitor Selection

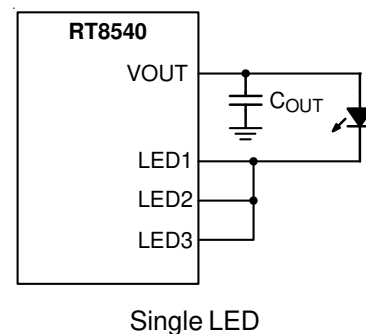
Input and output ceramic capacitors of 10μF are recommended for RT8540 applications. For better voltage filtering, ceramic capacitors with low ESR are recommended. The best performance of the RT8540 can be achieved by using the capacitor of large capacitance. X5R and X7R types are suitable because of their wider voltage and temperature ranges.

### Torch Mode and Flash Mode Operation

The RT8540 is designed for one, two or three LEDs driving for torch and flash application, it provides an I<sup>2</sup>C software command or dedicated zero latency hardware signals to trigger the torch and flash operation.

### LED Hardware Setup

In setting RT8540's hardware, the LED1, LED2 and LED3 pins must not be left floating to prevent the IC from over-voltage protection. For driving one or two LEDs with higher current, the LED1 to LED3 inputs should be connected together. Figure 1 shows the recommend LED setup for a single, dual or triple-LED application



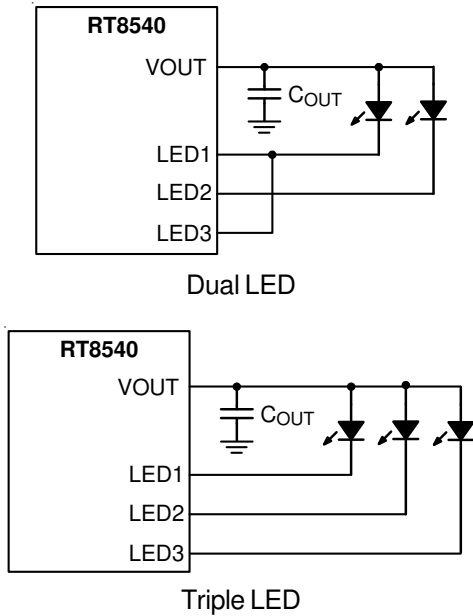


Figure 1. White LED Hardware Setup Options

**Triggering Torch and Flash**

The RT8540 provides several options for driving the video light and flash. The IC operates in different modes according to different settings of the MODE\_CTRL [1:0] bits for maximum system integration flexibility. The video light and flash can be triggered via hardware signals (STRB0, STRB1) or software I<sup>2</sup>C command. For torch lighting, the RT8540 provides a watchdog timer which must be refreshed within 13.0 seconds. This function can also be disabled as following description.

▶ MODE\_CTRL [1:0] = 01

The STRB0, STRB1 inputs are disabled. No matter what situation of the STRB0, STRB1 inputs and the START\_FLASH/TIMER (SFT) bit, the IC regulates the LED current in video light mode (DCLC bits).

MODE\_CTRL [1:0] must be refreshed within less than 13.0 seconds (STRB1 = 0) to prevent the IC from shutdown due to video light safety timeout. Moreover, by pulling the STRB1 signal high, the video light watchdog timer can be disabled.

▶ MODE\_CTRL [1:0] = 10

The STRB0, STRB1 inputs are enabled. The RT8540 triggers the flash pulse by synchronization signals or by a software command (START\_FLASH/TIMER (SFT) bit). According to the STRB0, STRB1 input, the LEDs can be enabled or disabled. Then, the flash safety timer will be activated and the video light watchdog timer will be disabled.

**Level-Sensitive Flash Trigger (STT = 0)**

In this mode, the RT8540 drives the high-power LEDs by flash-current level and the safety timer (STIM) is activated. The STIM [2:0] register determines the maximum duration of the flash pulse.

A rising edge triggers the safety timer and it can be stopped by a negative logic on the synchronization source (STRB0, STRB1 = 0) or by a timeout event (TO bit).

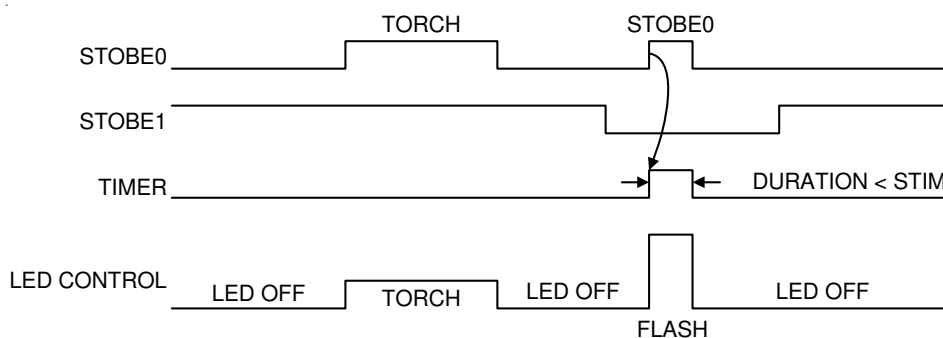


Figure 2. Hardware Synchronized Video Light and Flash Strobe

**Rising-Edge Flash Trigger (STT = 1)**

In this mode, the RT8540 drives the high power LEDs by flash-current level and the safety timer (STIM) is activated. The STIM [2:0] register determines the maximum duration

of the flash pulse. The RT8540 triggers the flash strobe by adopting a rising edge on the synchronization source (STRB0, STRB1 = 0) or a positive transition on the START-FLASH/TIMER (SFT) bit.

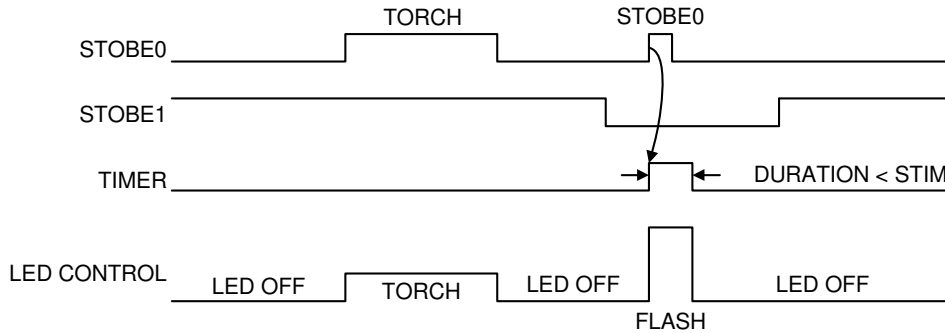


Figure 3. Edge Sensitive Timer (Single Trigger Event)

**Down Mode**

Normally, a Boost converter regulates output voltages which are higher than the input voltage. For better conversion when input voltages are higher than output voltages, a down mode is implemented. In the voltage-regulation mode, when the input voltage reaches or exceeds the output voltage, the converter enters down mode. In this mode, the behavior of internal P-MOSFET is changed and increases the power losses in the converter which should be taken into account for thermal design. As soon as the input voltage falls to approximately 200mV below the output voltage, the down mode is automatically turned off.

**Voltage Mode**

In this mode, the RT8540 operates as a constant output voltage Boost regulator. By setting the mode control bit MODE\_CTRL [1:0] = 11, the IC enters voltage mode operation. A constant output voltage can be regulated by the RT8540 according to the OV [3:0] bit settings (between 3.825V and 5.7V in 125mV steps). The LED current sinks LED1 to LED2 will be turned off in voltage mode.

The RT8540 provides an integrated software control bit (ENVM bit) to force the converter to enter voltage mode operation.

Internal Register Settings Mode_Ctrl [1:0]	ENVM bit	Operating Modes
11	0	LEDs are turned off and the converter operates in voltage regulation mode (VM); the output voltage is set via register OV [3:0].
00	1	
11	1	

**Indicator**

The RT8540 provides privacy indicator that can be used to indicate when a person is being photographed or filmed. The privacy indicator can be activated by adopting INDC [3:0] bits, ranging from 2.6mA to 15.8mA in 7 programmable current steps or by using the white LEDs with pulse width modulation.



**RT8540 Register Summary**

Address : 0110011x

Address	Name	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
0x00	Control10	RESET	FREE	DCLC13 [2:0]			DCLC2 [2:0]		
	Reset Value	0	0	0	0	1	0	1	0
	Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
0x01	Control1	MODE_CTRL [1:0]		FC2 [5:0]					
	Reset Value	0	0	0	1	0	0	0	0
	Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
0x02	Control2	MODE_CTRL [1:0]		ENVM	FC13 [4:0]				
	Reset Value	0	0	0	0	1	0	0	0
	Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
0x03	Control3	STIM [2:0]			HPLF	SELSTIM (W) TO (R)	STT	SFT	Tx-MASK
	Reset Value	1	1	0	0	0	0	0	0
	Read/Write	R/W	R/W	R/W	R	R	R/W	R/W	R/W
0x04	Control4	PG	HOTDIE [1:0]		ILIM	INC [3:0]			
	Reset Value	0	0	0	0	0	0	0	0
	Read/Write	R/W	R	R	R/W	R/W	R/W	R/W	R/W
0x05	Control5	NA	ENPSM	DIR(W) STSTRB1 (R)	GPIO	GPIO TYPE	ENLED3	ENLED2	ENLED1
	Reset Value	0	1	1	0	1	0	1	0
	Read/Write	R	R/W	R/W	R/W	R/W	R/W	R/W	R/W
0x06	Control6	ENTS	LEDHOT	LEDWARN	LEDHDR	OV [3:0]			
	Reset Value	0	0	0	0	1	0	0	1
	Read/Write	R/W	R/W	R	R	W	W	W	W
0x07	Control7	ENBATM ON	BATDROOP [2:0]			FREE	REVID [2:0]		
	Reset Value	0	1	0	0	0	1	1	0
	Read/Write	R/W	R/W	R/W	R/W	R/W	R	R	R

Address	Name	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
0x00	Control10	RESET	FREE	DCLC13 [2:0]			DCLC2 [2:0]		
	Reset Value	0	0	0	0	1	0	1	0
	Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
RESET		Register Reset bit. 0 : Normal operation. 1 : Default values are set to all internal registers.							
DCLC13 [2:0]		Video Light Current Control bits (LED1/3). 000 : 0mA 001 : 25mA 010 : 50mA 011 : 75mA 100 : 100mA 101 : 125mA 110 : 150mA 111 : 175mA							
DCLC2 [2:0]		Video Light Current Control bits (LED2). 000 : 0mA 001 : 25mA 010 : 50mA 011 : 75mA 100 : 100mA 101 : 125mA 110 : 150mA 111 : 175mA							
Address	Name	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
0x01	Control1	MODE_CTRL [1:0]			FC2 [5:0]				
	Reset Value	0	0	0	1	0	0	0	0
	Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
MODE_CTRL [1:0]		Register Reset bit. 00 : Device in shutdown mode. 01 : Device operations in video light mode. 10 : Device operation in Flash mode. 11 : Device operation as constant voltage source. To avoid device shutdown by video light safety timeout, MODE_CTRL [1 : 0] bits need to be refreshed within less than 13.0s. Writing to REGISTER1 [7 : 6] automatically updates REGISTER2 [7 : 6].							
FC2 [5:0]		Flash Current Control bits (LED2). 000000 : 0mA 000001 : 25mA 000010 : 50mA 000011 : 75mA 000100 : 100mA 000101 : 125mA 000110 : 150mA 000111 : 175mA 001000 : 200mA							

FC2 [5:0]		001001 : 225mA 001010 : 250mA 001011 : 275mA 001100 : 300mA 001101 : 325mA 001110 : 350mA 001111 : 375mA 010000 : 400mA 010001 : 425mA 010010 : 450mA 010011 : 475mA 010100 : 500mA 010101 : 525mA 010110 : 550mA 010111 : 575mA 011000 : 600mA 011001 : 625mA 011010 : 650mA 011011 : 675mA 011100 : 700mA 011101 : 725mA 011110 : 750mA 011111 : 775mA 100000...111111 : 800mA							
Address	Name	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
0x02	Control2	MODE_CTRL [1:0]		ENVM	FC13 [4:0]				
	Reset Value	0	0	0	0	1	0	0	0
	Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
MODE_CTRL [1:0]		Register Reset bit. 00 : Device in shutdown mode. 01 : Device operations in video light mode. 10 : Device operation in Flash mode. 11 : Device operation as constant voltage source. To avoid device shutdown by video light safety timeout, MODE_CTRL [1 : 0] bits need to be refreshed within less than 13.0s. Writing to REGISTER2 [6 : 5] automatically updates REGISTER1 [6 : 5] .							
ENVM		Enable Voltage Mode bit. 0 : Normal operation. 1 : Forces the device into a constant voltage source. In read mode, the ENVM bit is automatically updated to reflect the logic stats of the ENVM input pin.							
FC13 [4:0]		Flash Current Control bits (LED1/3). 00000 : 0mA 00001 : 25mA 00010 : 50mA 00011 : 75mA 00100 : 100mA 00101 : 125mA 00110 : 150mA 00111 : 175mA 01000 : 200mA							

FC13 [4:0]		01001 : 225mA 01010 : 250mA 01011 : 275mA 01100 : 300mA 01101 : 325mA 01110 : 350mA 01111 : 375mA 10000...11111 : 400mA																																					
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0x03	Control3	STIM [2:0]			HPLF	SELSTIM (W) TO (R)	STT	SFT	Tx-MASK																														
	Reset Value	1	1	0	0	0	0	0	0																														
	Read/Write	R/W	R/W	R/W	R	R	R/W	R/W	R/W																														
STIM [2:0]		Safety Timer bits. <table border="1" style="width:100%; border-collapse: collapse;"> <thead> <tr> <th>STIM [2:0]</th> <th>RANGE 0</th> <th>RANGE 1</th> </tr> </thead> <tbody> <tr> <td>000</td> <td>68.2ms</td> <td>5.3ms</td> </tr> <tr> <td>001</td> <td>102.2ms</td> <td>10.7ms</td> </tr> <tr> <td>010</td> <td>136.3ms</td> <td>16.0ms</td> </tr> <tr> <td>011</td> <td>170.4ms</td> <td>21.3ms</td> </tr> </tbody> </table> <table border="1" style="width:100%; border-collapse: collapse;"> <thead> <tr> <th>STIM [2:0]</th> <th>RANGE 0</th> <th>RANGE 1</th> </tr> </thead> <tbody> <tr> <td>100</td> <td>204.5ms</td> <td>26.6ms</td> </tr> <tr> <td>101</td> <td>340.8ms</td> <td>32.0ms</td> </tr> <tr> <td>110</td> <td>579.3ms</td> <td>37.3ms</td> </tr> <tr> <td>111</td> <td>852ms</td> <td>71.5ms</td> </tr> </tbody> </table>								STIM [2:0]	RANGE 0	RANGE 1	000	68.2ms	5.3ms	001	102.2ms	10.7ms	010	136.3ms	16.0ms	011	170.4ms	21.3ms	STIM [2:0]	RANGE 0	RANGE 1	100	204.5ms	26.6ms	101	340.8ms	32.0ms	110	579.3ms	37.3ms	111	852ms	71.5ms
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HPFL		High-Power LED Failure Flag. 0 : Proper LED operation. 1 : LED open or OCP.																																					
SELSTIM		Safety Timer Selection Range (Write Only). 0 : Safety timer range 0. 1 : Safety timer range 1.																																					
TO		Time-Out Flag (Read Only) 0 : No time-out event occurred. 1 : Time-out event occurred. Time-out flag is reset at re-start of the safety timer.																																					
STT		Safety Timer Trigger bit. 0 : LED safety timer is level sensitive. 1 : LED safety timer is rising edge sensitive. This bit is only valid for MODE_CTRL [1 : 0] =10																																					
SFT		Start/Flash Timer bit. In write mode, this bit initiates a flash strobe sequence. 0 : No change is the high-power LED current. 1 : High-power LED current ramps to the flash current level. In read mode, this bit indicates the high-power LED status. 0 : High-power LEDs are idle. 1 : Ongoing high-power LED flash strobe.																																					

Tx-MASK		<p>Flash Blanking Control bit.                  In write mode, this bit enables/disables the flash blanking/LED current reduction function.                  0 : Flash blanking disabled.                  1 : LED current is reduced to video light level when Tx-MASK input is high.                  In read mode, this flag indicates whether or not the flash masking input has been activated.                  Tx-MASK flag is reset after readout of the flag.                  0 : No flash blanking event occurred.                  1 : Tx-MASK input triggered.</p>																									
Address	Name	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0																		
0x04	Control4	PG	HOTDIE [1:0]		ILIM	INC [3:0]																					
	Reset Value	0	0	0	0	0	0	0	0																		
	Read/Write	R/W	R	R	R/W	R/W	R/W	R/W	R/W																		
PG		<p>Power Good bit.                  In write mode, this bit selects the functionality of the GPIO/PG output.                  0 : PG signal is routed to the GPIO port.                  1 : GPIO PORT VALUE bit is routed to the GPIO port.                  In read mode, this bit indicates the output voltage conditions.                  0 : The converter is not operating within the voltage regulation limits.                  1 : The output voltage is within its nominal value.</p>																									
HOTDIE [1:0]		<p>Instantaneous Die Temperature bits.                  00 : <math>T_J &lt; +55^{\circ}\text{C}</math>.                  01 : <math>+55^{\circ}\text{C} &lt; T_J &lt; +70^{\circ}\text{C}</math>.                  10 : <math>T_J &gt; +70^{\circ}\text{C}</math>.                  11 : Thermal shutdown tripped. Indicator flag reset after readout.</p>																									
ILIM		<p>Inductor Valley Current Limit bit.                  The ILIM bit can only be set before the device enters operation (i. e. initial shutdown state).</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 50%;">Valley Current Limit Setting</th> <th style="width: 50%;">ILIM Bit Setting</th> </tr> </thead> <tbody> <tr> <td style="text-align: center;">1650mA</td> <td style="text-align: center;">Low</td> </tr> <tr> <td style="text-align: center;">2150mA</td> <td style="text-align: center;">High</td> </tr> </tbody> </table>								Valley Current Limit Setting	ILIM Bit Setting	1650mA	Low	2150mA	High												
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2150mA	High																										
INDC [3:0]		<p>Indicator Light Control bits.</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 50%;">INDC [3:0]</th> <th style="width: 50%;">Privacy Indicator INDLED Channel</th> </tr> </thead> <tbody> <tr> <td style="text-align: center;">0000</td> <td>Privacy indicator turned off</td> </tr> <tr> <td style="text-align: center;">0001</td> <td>INDLED current = 2.6mA</td> </tr> <tr> <td style="text-align: center;">0010</td> <td>INDLED current = 5.2mA</td> </tr> <tr> <td style="text-align: center;">0011</td> <td>INDLED current = 7.9mA</td> </tr> <tr> <td style="text-align: center;">0100</td> <td>Privacy indicator turned off</td> </tr> <tr> <td style="text-align: center;">0101</td> <td>INDLED current = 5.2mA</td> </tr> <tr> <td style="text-align: center;">0110</td> <td>INDLED current = 10.4mA</td> </tr> <tr> <td style="text-align: center;">0111</td> <td>INDLED current = 15.8mA</td> </tr> </tbody> </table>								INDC [3:0]	Privacy Indicator INDLED Channel	0000	Privacy indicator turned off	0001	INDLED current = 2.6mA	0010	INDLED current = 5.2mA	0011	INDLED current = 7.9mA	0100	Privacy indicator turned off	0101	INDLED current = 5.2mA	0110	INDLED current = 10.4mA	0111	INDLED current = 15.8mA
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0110	INDLED current = 10.4mA																										
0111	INDLED current = 15.8mA																										

INDC [3:0]		INDC [3:0]		Privacy Indicator LED1/3 Channel (1)					
		0000		5% PWM dimming ratio					
		0001		11% PWM dimming ratio					
		0010		17% PWM dimming ratio					
		0011		23% PWM dimming ratio					
		0100		30% PWM dimming ratio					
		0101		36% PWM dimming ratio					
		0110		48% PWM dimming ratio					
		0111		67% PWM dimming ratio					
Address	Name	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
0x05	Control5	NA	ENPSM	DIR(W) STSTRB1(R)	GPIO	GPIOTYPE	ENLED3	ENLED2	ENLED1
	Reset Value	0	1	1	0	1	0	1	0
	Read/Write	R	R/W	R/W	R/W	R/W	R/W	R/W	R/W
ENPSM		Enable/Disable Power-Save Mode bit. 0 : Power-save mode disabled. 1 : Power-save mode enabled.							
STSTRB1		STRB1 Input Status bit (Read Only). This bit indicates the logic state on the STRB1 state.							
DIR		GPIS Direction bit. 0 : GPIO configured as input. 1 : GPIO configured as output.							
GPIO		GPIO Port Value. This bit contains the GPIO port value.							
GPIOTYPE		GPIO Port Type. 0 : GPIO is configured as push-pull output. 1 : GPIO is configured as open-drain output.							
ENLED3		Enable/Disable High-Current LED3 bit. 0 : LED3 input is disabled. 1 : LED3 input is enabled.							
ENLED2		Enable/Disable High-Current LED2 bit. 0 : LED2 input is disabled. 1 : LED2 input is enabled.							
ENLED1		Enable/Disable High-Current LED1 bit. 0 : LED1 input is disabled. 1 : LED1 input is enabled.							

Address	Name	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
0x06	Control6	ENTS	LEDHOT	LEDWARN	LEDHDR	OV [3:0]			
	Reset Value	0	0	0	0	1	0	0	1
	Read/Write	R/W	R/W	R	R	W	W	W	W
ENTS		Enable/Disable LED Temperature Monitoring. 0 : LED temperature monitoring disabled. 1 : LED temperature monitoring enabled.							
LEDHOT		LED Excessive Temperature Flag. This bit can be reset by writing a logic level zero. 0 : TS input voltage > 0.345V. 1 : TS input voltage < 0.345V.							
LEDWARN		LED Temperature Warning Flag (Read Only). This flag is reset after readout. 0 : TS input voltage > 1.05V. 1 : TS input voltage < 1.05V.							
LEDHDR		LED High-Current Regulator Headroom Voltage Monitoring bit. This bit returns the headroom voltage status of the LED high-current regulators. This value is being updated at the end of a flash strobe, prior to the LED current ramp-down phase. 0 : Low headroom voltage. 1 : Sufficient headroom voltage.							
OV [3:0]		Output Voltage Selection bits. In write mode, these bits are used to set the target output voltage (refer to voltage regulation mode). In applications requiring dynamic voltage control, care should be taken to set the new target code after voltage mode operation has been enabled (MODE_CTRL [1:0] = 11 and/or ENVM bit = 1).							
		OV [3:0]		Target Output Voltage					
		0000		3.825V					
		0001		3.950V					
		0010		4.075V					
		0011		4.200V					
		0100		4.325V					
		0101		4.450V					
		0110		4.575V					
		0111		4.700V					
		1000		4.825V					
		1001		4.950V					
		1010		5.075V					
		1011		5.200V					
		1100		5.325V					
		1101		5.450V					
		1110		5.575V					
		1111		5.700V					

Address	Name	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
0x07	Control7	ENBATMON	BATDROOP [2:0]			FREE	REVID [2:0]		
	Reset Value	0	1	0	0	0	1	1	0
	Read/Write	R/W	R/W	R/W	R/W	R/W	R	R	R
ENBATMON		Enable/Disable Battery Voltage Droop Monitoring Bit. 0 : Battery voltage droop monitoring disable. 1 : Battery voltage droop monitoring enable.							
BATDROOP [2:0]		Battery Voltage Droop. 000 : 50mV. 001 : 75mV. 010 : 100mV. 011 : 125mV. 100 : 150mV. 101 : 175mV. 110 : 200mV. 111 : 225mV							
REVID [2:0]		Silicon Revision ID.							



**Thermal Considerations**

For continuous operation, do not exceed absolute maximum junction temperature. The maximum power dissipation depends on the thermal resistance of the IC package, PCB layout, rate of surrounding airflow, and difference between junction and ambient temperature. The maximum power dissipation can be calculated by the following formula :

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

where  $T_{J(MAX)}$  is the maximum junction temperature,  $T_A$  is the ambient temperature, and  $\theta_{JA}$  is the junction to ambient thermal resistance.

For recommended operating condition specifications, the maximum junction temperature is 125°C. The junction to ambient thermal resistance,  $\theta_{JA}$ , is layout dependent. For WL-CSP-20B 1.82x2.22 (BSC) package, the thermal resistance,  $\theta_{JA}$ , is 36.7°C/W on a standard JEDEC 51-7 four-layer thermal test board. The maximum power dissipation at  $T_A = 25^\circ\text{C}$  can be calculated by the following formula :

$$P_{D(MAX)} = (125^\circ\text{C} - 25^\circ\text{C}) / (36.7^\circ\text{C/W}) = 2.72\text{W for WL-CSP-20B 1.82x2.22 (BSC) package}$$

The maximum power dissipation depends on the operating ambient temperature for fixed  $T_{J(MAX)}$  and thermal resistance,  $\theta_{JA}$ . The derating curve in Figure 4 allows the designer to see the effect of rising ambient temperature on the maximum power dissipation.

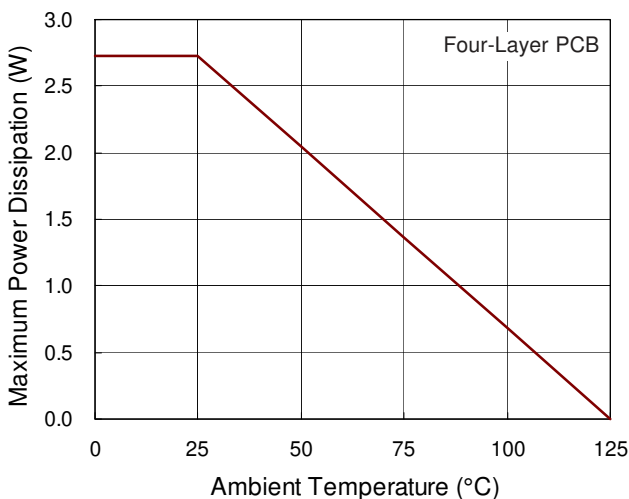


Figure 4. Derating Curve of Maximum Power Dissipation

**Layout Consideration**

For the best performance of the RT8540, following PCB layout guidelines should be strictly followed.

- ▶ The AGND and PGND of the IC should be connected to the ground plane of the PCB.
- ▶ The output bypass capacitor should be placed as close to the IC as possible.
- ▶ The trace lengths from the IC to the inductor, input capacitor and the output capacitor must be kept as short, direct and wide as possible.
- ▶  $C_{IN}$  and  $C_{OUT}$  of the RT8540 should be placed as close as possible and connected to PGND of the IC.
- ▶ It is recommended to add additional PCB exposed pad area for the flash LEDs for maximized heat-sinking ability. This is necessary for high current application and long flash duration application.

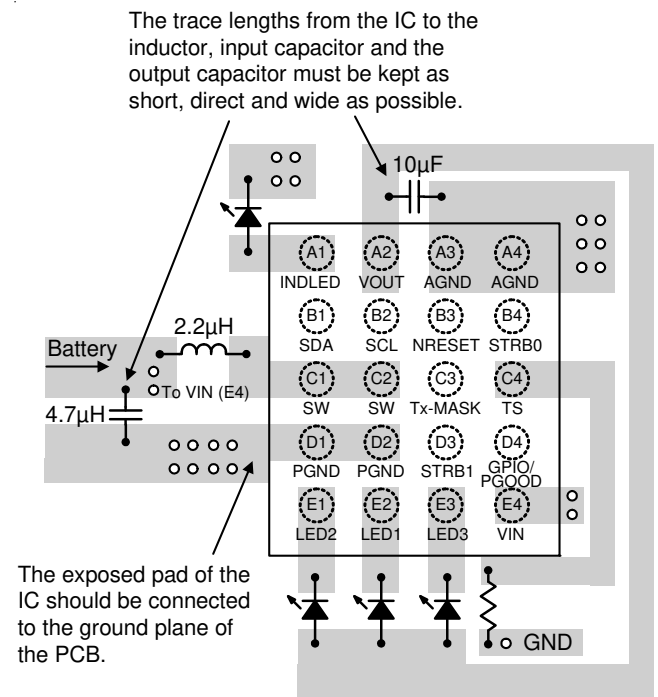
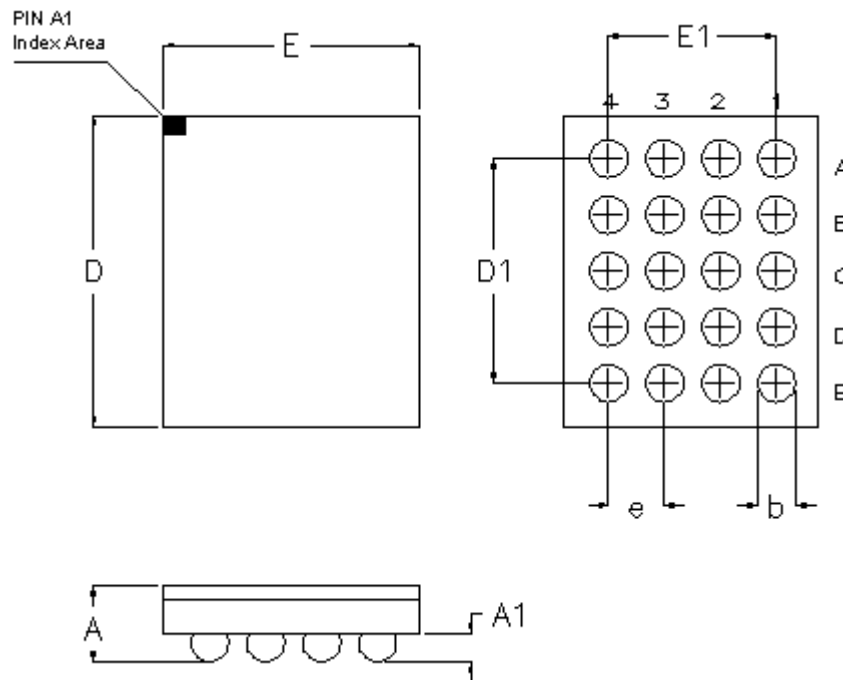


Figure 5. PCB Layout Guide for WL-CSP-20B 1.82x2.22 (BSC)

Outline Dimension



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min.	Max.	Min.	Max.
A	0.500	0.600	0.020	0.024
A1	0.200	0.260	0.008	0.010
b	0.290	0.350	0.011	0.014
D	2.170	2.270	0.085	0.089
D1	1.600		0.063	
E	1.770	1.870	0.070	0.074
E1	1.200		0.047	
e	0.400		0.016	

20B WL-CSP 1.82x2.22 Package (BSC)

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