1.5A Flash LED Driver with High-Side Current Source

General Description

The RT4505 is a maximum 4MHz frequency synchronous Boost converter plus a 1.5A constant current driver for a high current white LED. The high-side current source allows for grounded cathode LED operation providing flash current up to 1.5A. An adaptive regulation method ensures the current source remains in regulation and maximizes efficiency.

The RT4505 is controlled via an I^2C-compatible interface. Features include a hardware flash enable (STROBE) allowing a logic input to trigger the flash pulse as well as a TX input which forces the flash pulse into a low current, allowing for synchronization to RF power amplifier events or other high-current conditions.

The maximum 4MHz switching frequency, over-voltage protection and adjustable current limit settings allow the use of tiny, low-profile inductors and ceramic capacitors. The device is available in a small WL-CSP-9B 1.3x1.37 (BSC) package, and operates within the –40°C to 85°C temperature range.

Ordering Information

RT4505 □

Package Type
WSC : WL-CSP-9B 1.3x1.37 (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.

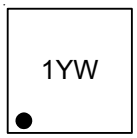
Features

- **1.5A High-Side Current Source for Single LED**
- **Up to 90% Efficiency in Torch Mode and Flash Mode**
- **Typical 5% LED Current Accuracy**
- **Typical 7.5% Timeout Accuracy**
- **Programmable Flash LED Current from 93.74mA to 1.5A**
- **Programmable Torch LED Currents from 49.6mA to 375mA**
- **Built-In Soft-Start Operation for Battery Protection**
- **Built-In Over-Voltage Protection, Over-Current Protection, and Over-Temperature Protection**
- **VIN Flash Monitor Optimization**
- **Hardware Strobe Enable**
- **Synchronization Input for RF Power Amplifier Pulse Events**
- **400KHz I^2C Control Interface**
- **9-Ball WL-CSP Package**
- **RoHS Compliant and Halogen Free**

Applications

- Camera Phone LED Flash

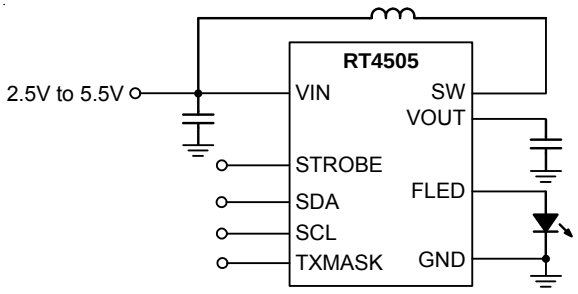
Marking Information



1Y : Product Code

W : Date Code

Simplified Application Circuit



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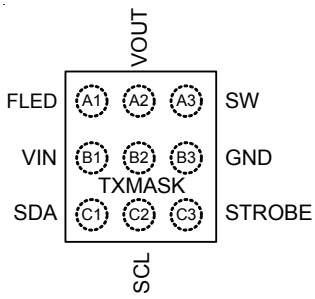
Pin Configurations

(TOP VIEW)



WL-CSP-9B 1.3x1.37 (BSC)

Functional Pin Description

Pin No.	Pin Name	Pin Function
A1	FLED	High-Side Current Source Output for Flash LED.
A2	VOUT	Step-Up DC/DC Converter Output. Connect a 4.7μF ceramic capacitor between this pin and GND.
A3	SW	Drain Connection for Internal NMOS and Synchronous P-MOSFET Switches.
B1	VIN	Input Voltage Connection. Connect IN to the input supply, and bypass to GND with a 4.7μF or larger ceramic capacitor.
B2	TXMASK	Configurable Power Amplifier Synchronization Input or Configurable Active High Torch Enable. There is an internal pull-down resistor of 400kΩ between TX and GND.
B3	GND	Ground.
C1	SDA	Serial Data Input/Output.
C2	SCL	Serial Clock Input.
C3	STROBE	Active High Hardware Flash Enable. Drive STROBE high to turn on Flash pulse. There is an internal pull-down resistor of 400kΩ between STROBE and GND.

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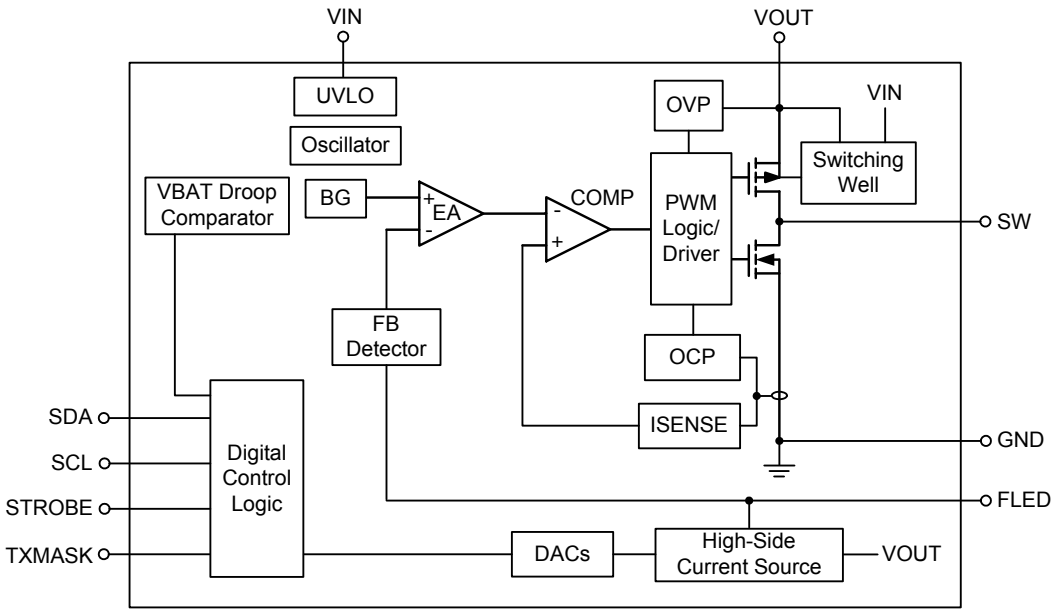
Function Block Diagram



Operation

PWM Logic/ Driver

The PWM duty control power MOS through the driver.

OSC

It generates the optimized clock signal. The maximum frequency is 4MHz.

BG

Generates the reference voltage for Error-amp and other bias circuits.

EA

Error amplifier generates COMP signal by the difference between FB and BG.

Digital Control Logic

Digital logic and registers part.

Switching Well

It compares VIN and VOUT. It will decide the big P-MOSFET well potential.

High-Side Current Source

The current source is connected between VOUT and FLED.

Protection Circuit

OCP, OVP, UVLO, VIN droop comparator.

DACs

It transfers digital signals to analog reference voltage.

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Absolute Maximum Ratings (Note 1)

- Supply Input Voltage, VIN, SW, VOUT ---------- –0.3V to 6V
- SCL, SDA, STROBE, TXMASK, FLED ---------- –0.3V to 6V
- Power Dissipation, P_D @ T_A = 25°C
  WL-CSP-9B 1.3x1.37 (BSC) ---------- 1.22W
- Package Thermal Resistance (Note 2)
  WL-CSP-9B 1.3x1.37 (BSC), θ_{JA} ---------- 81.4°C/W
- Lead Temperature (Soldering, 10 sec.) ---------- 260°C
- Junction Temperature ---------- 150°C
- Storage Temperature Range ---------- –65°C to 150°C
- ESD Susceptibility (Note 3)
  HBM (Human Body Model) ---------- 2kV
  MM (Machine Model) ---------- 200V

Recommended Operating Conditions (Note 4)

- Supply 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

(V_{IN} = 3.6V, T_A = 25°C, unless otherwise specified)

Parameter	Symbol	Test Condition	Min	Typ	Max	Unit
Current Source Specifications						
Current Source Accuracy	I_{LED}	1.5A Flash, Flash current[4:0] = 11111	–5	--	5	%
		1.031A Flash, Flash current[4:0] = 01010	–5	--	5	
		49.6mA Torch, Torch current[2:0] = 000	–10	--	10	
Current Source Regulation Voltage	V_{HR}	I_{LED} = 1.5A Flash, Flash current[4:0] = 11111	--	200	--	mV
		I_{LED} = 49.6mA Torch, Torch current[2:0] = 000	--	80	--	
Output Over-Voltage Protection Trip Point	V_{OVP}		--	5.3	--	V
Step-Up DC/DC Converter Specifications						
P-MOSFET Switch On-Resistance	$R_{DS(ON)\_P}$	I_{PMOS} = 400mA, WL-CSP package	--	90	--	mΩ
N-MOSFET Switch On-Resistance	$R_{DS(ON)\_N}$	I_{NMOS} = 400mA, V_{OUT} = 4V, WL-CSP package	--	60	--	mΩ
Input Current Limit	I_{LIM}	V_{IN} = 2.5V, V_{OUT} = 4V	2.1	2.5	2.9	A
LED Current Source Start-Up Current	I_{ST}		2	2.5	--	mA

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Parameter		Symbol	Test Condition	Min	Typ	Max	Unit
Input Voltage Flash Monitor Trip Threshold		V_{IVFM}	LVP[7:4] = 0000	--	3	--	V
Under Voltage Threshold		UVLO	VIN Falling	–5%	2.3	5%	V
Switching Frequency		f_{SW}	Flash mode V_{IN} = 2.5V, V_{OUT} = 5V, I_{LED} = 1.5A	--	4	--	MHz
Flash Time-out period		T_O	Set FTO = 000 to 111, I_{LED} = 1.5A from STROBE rising edge to I_{LED} falling edge	–7.5	--	7.5	%
Quiescent Supply Current		I_Q	Device Not Switching Pass Mode	--	0.45	--	mA
Shutdown Current		I_{SHDN}	Device Disabled	--	1	4	μA
Thermal Shutdown		T_{SD}		--	150	--	°C
Thermal Shutdown Hysteresis		ΔT_{SD}		--	25	--	°C
Strobe, TX Voltage Specifications							
Input Voltage	High-Level	V_{IH}		1.2	--	--	V
	Low-Level	V_{IL}		--	--	0.4	
STROBE and TXMASK Pin Pull Down Resistor		Rpd		--	400	--	kΩ
I^2C Interface Specification (SCL, SDA)							
Input Voltage	High-Level	V_{IH}		1.2	--	--	V
	Low-Level	V_{IL}		--	--	0.4	
Output Logic Low		V_{OL}	I_{LOAD} = 3mA	--	--	400	mV
SCL Clock Frequency		T1		2.4	--	--	μs
Data In Setup Time to SCL High		T2		100	--	--	ns
Data Out Stable After SCL Low		T3		0	--	--	ns
SDA Low Setup Time to SCL Low (START)		T4		600	--	--	ns
SDA High Hold Time After SCL High (STOP)		T5		600	--	--	ns

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. θ_{JA} is measured at T_A = 25°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.

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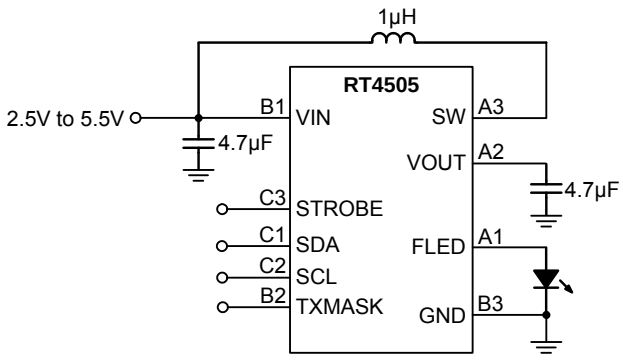
Typical Application Circuit



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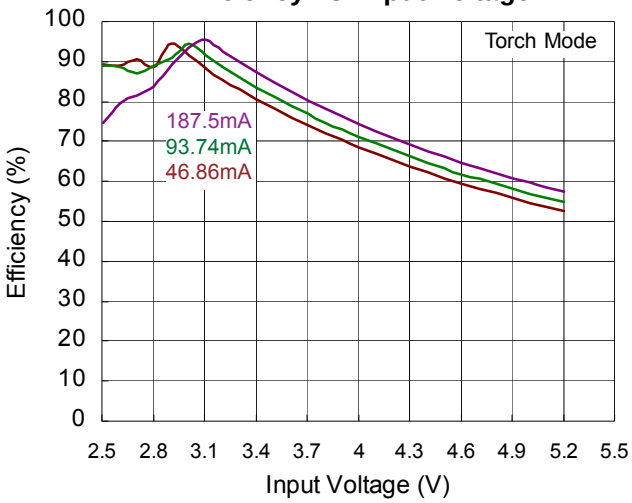
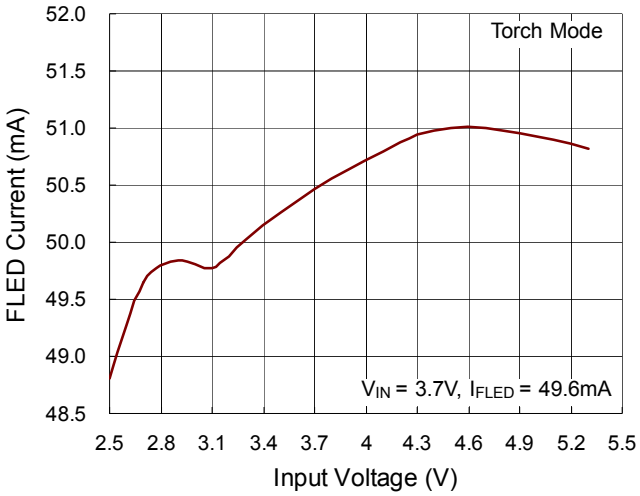
Typical Operating Characteristics

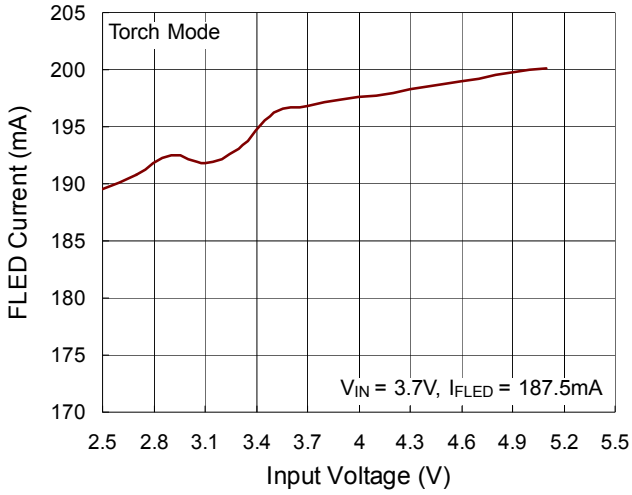
Efficiency vs. Input Voltage



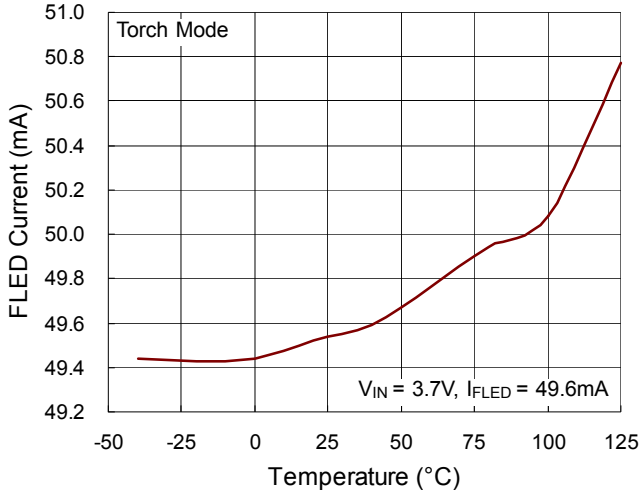
LED Current vs. Input Voltage



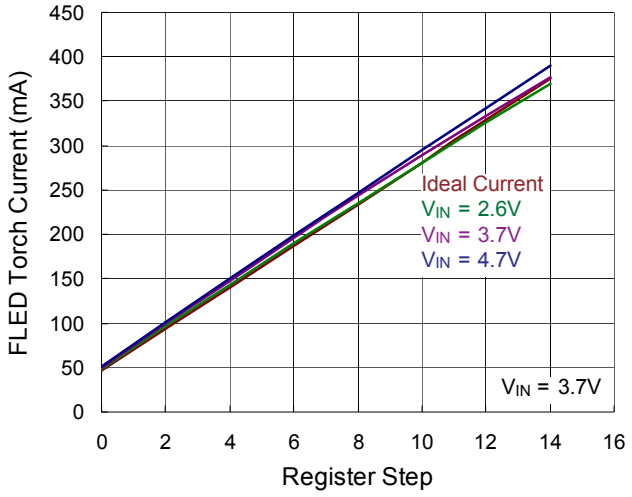
LED Current vs. Input Voltage



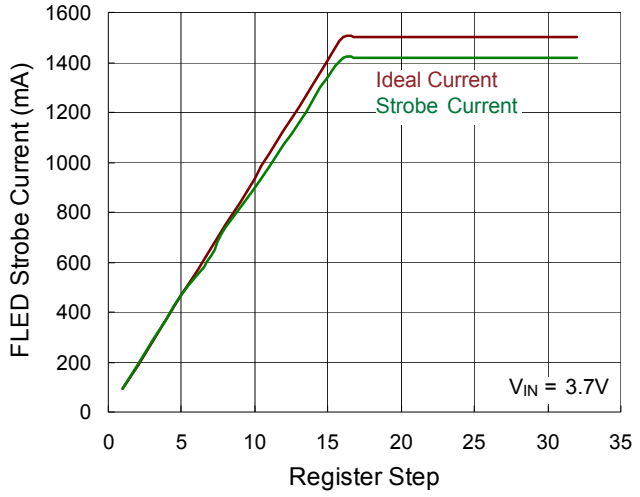
LED Current vs. Temperature



FLED Torch Current vs. Register Step



FLED Strobe Current vs. Register Step



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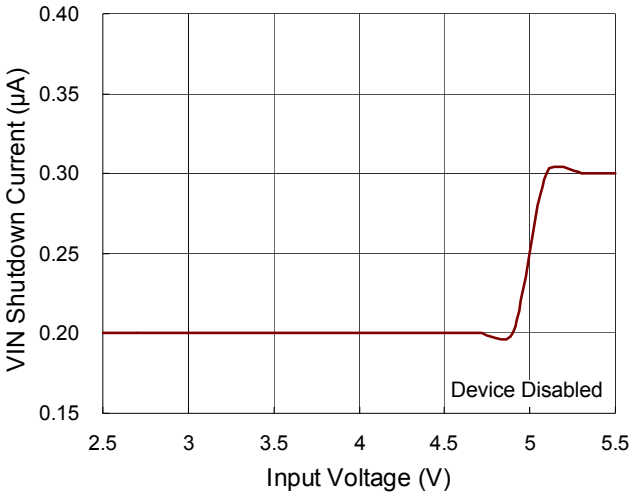
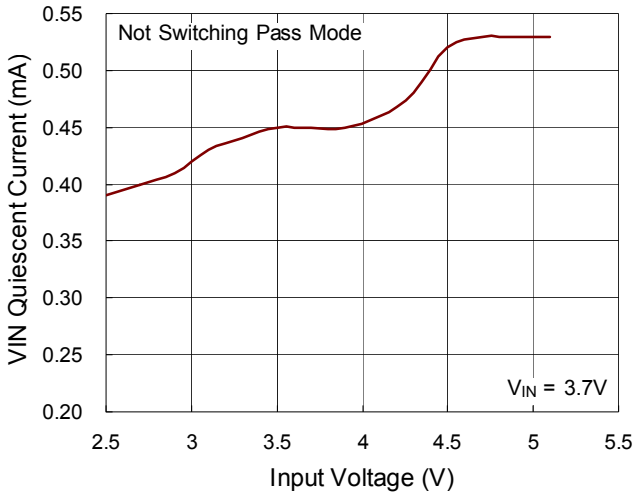
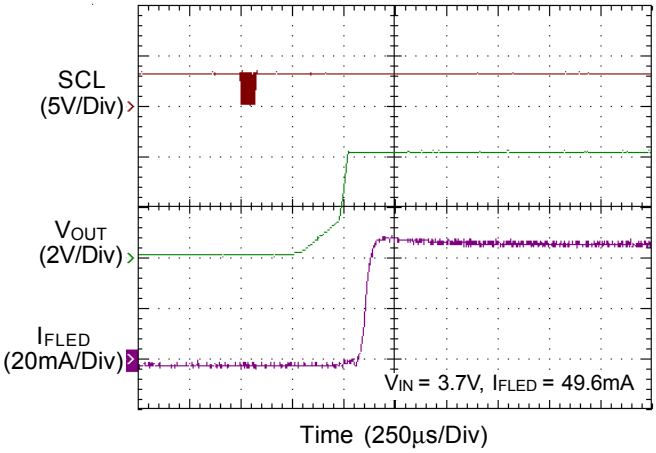
VIN Shutdown Current vs. Input Voltage



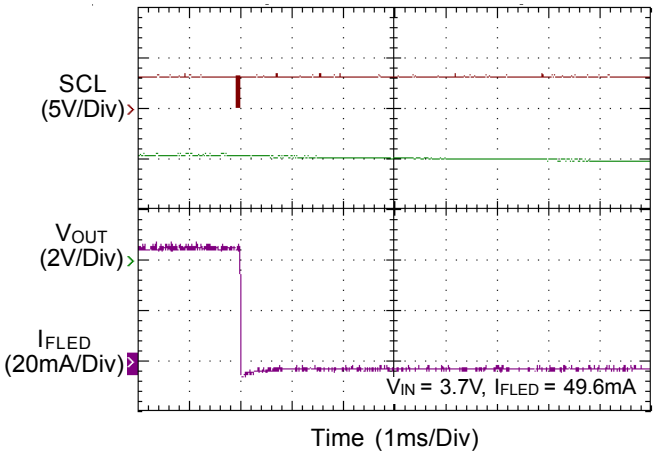
VIN Quiescent Current vs. Input Voltage



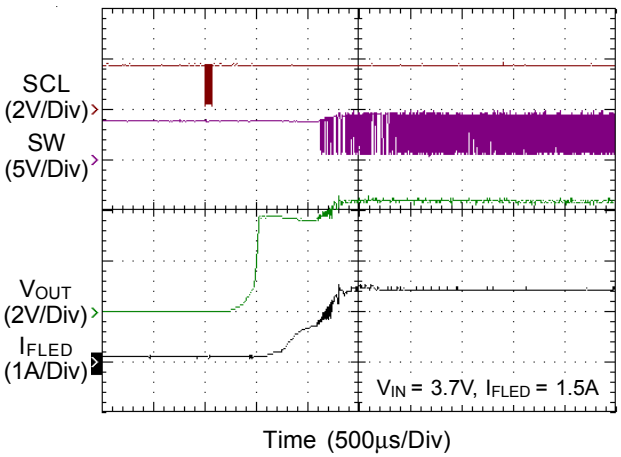
Power On in Torch Mode



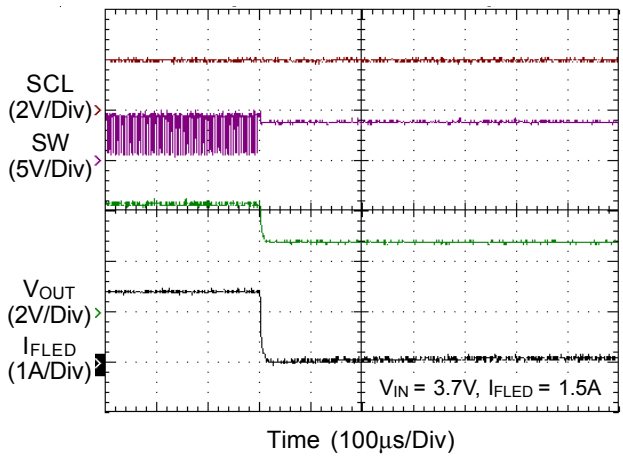
Power Off in Torch Mode



Power On in Strobe Mode



Power Off in Strobe Mode



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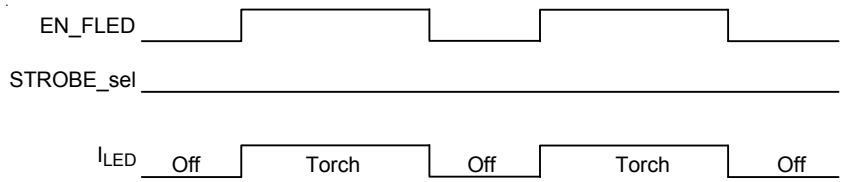
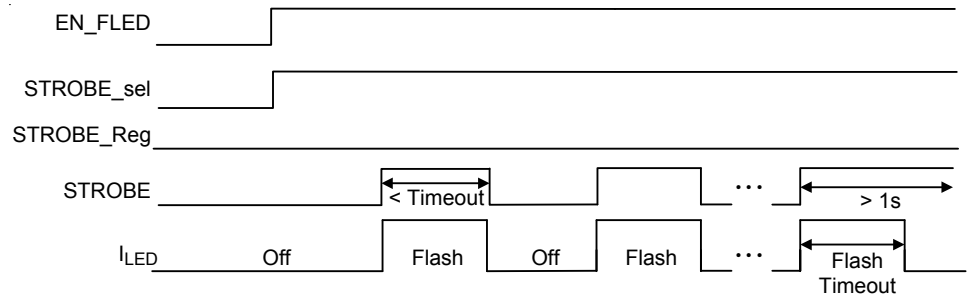
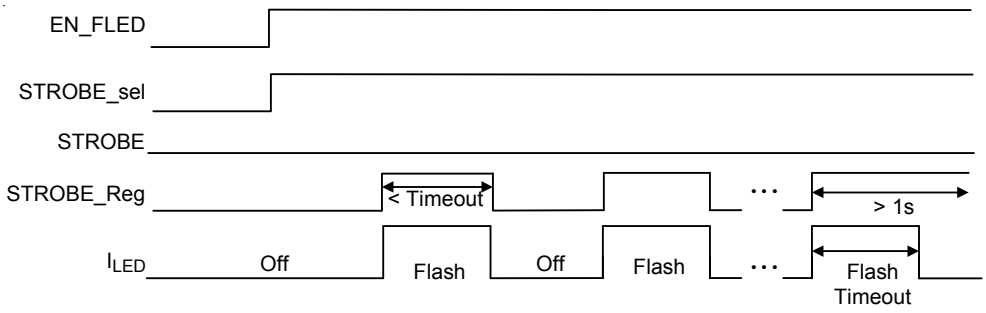
Timing Diagram

Torch Mode

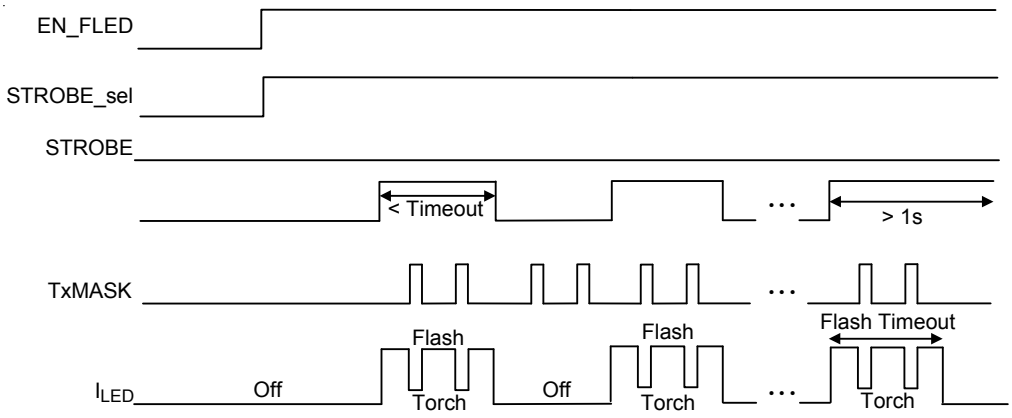


Flash Mode





Flash Mode with TXMASK



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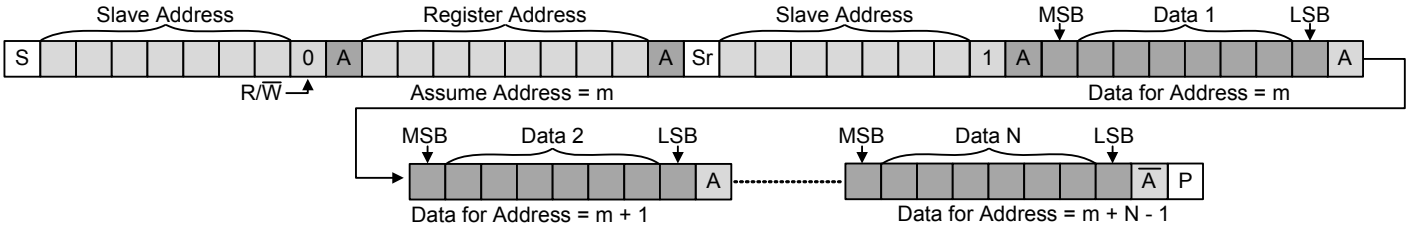
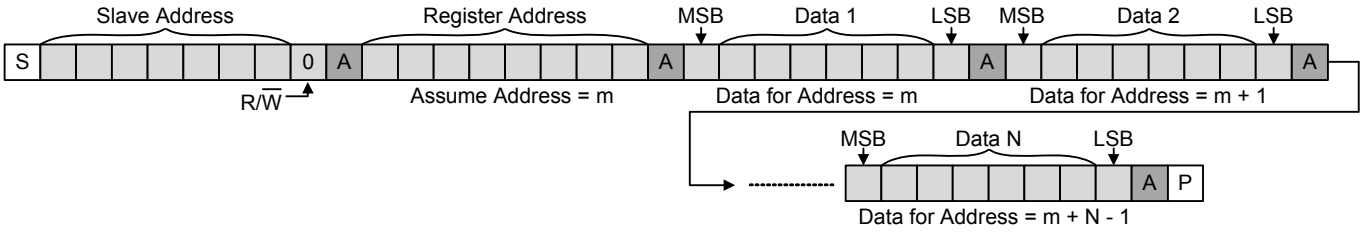
I²C Interface

RT4505 I²C slave address = 7'b1100011. I²C interface supports fast mode (bit rate up to 400kb/s).

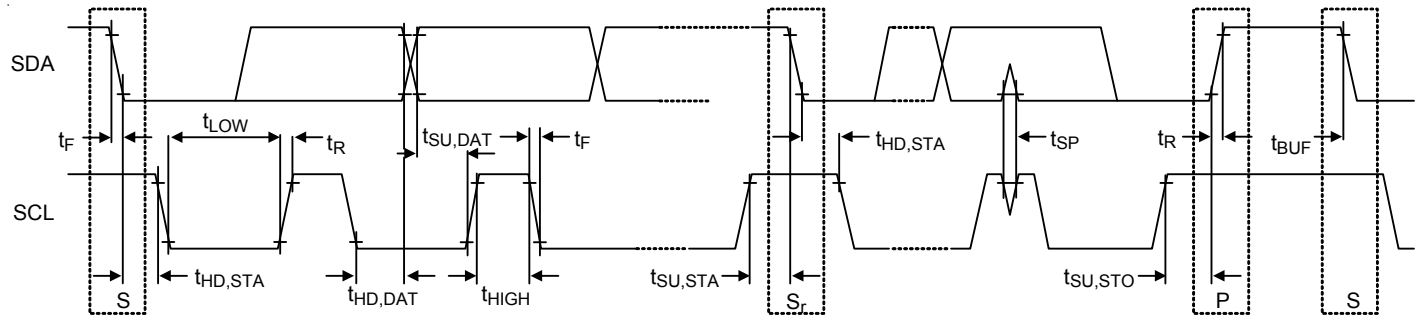
Read N bytes from RT4505



Write N bytes to RT4505



Driven by Master, Driven by Slave (RT4505), P Stop, S Start, Sr Repeat Start



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I²C Register Map

Address Name	Register Address		Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
Reset	0X00	Meaning	Reset	FREE	FREE	FREE	FREE	FREE	FREE	FREE
		Default	0	0	0	0	0	0	1	1
		Read/Write	R/W	R	R	R	R	R	R/W	R/W
Reset			It's used to reset software and registers							
			0	normal						
			1	Software reset						

Address Name	Register Address		Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
Flash features	0X08	Meaning	LVP[7:4]				FREE	FTO[2:0]		
		Default	0	0	0	0	0	0	1	0
		Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
FTO[2:0]			Flash Time-Out Time							
			Code	Time	Code	Time	Code	Time	Code	Time
			000	100ms	001	200ms	010	300ms	011	400ms
			100	500ms	101	600ms	110	700ms	111	800ms
LVP[7:4]			The LVP detects VIN pin voltage to protect battery							
			Code	Voltage	Code	Voltage	Code	Voltage	Code	Voltage
			0000	3V	0001	3.1V	0010	3.2V	0011	3.3V
			0100	3.4V	0101	3.5V	0110	3.6V	0111	3.7V
			1000	3.8V	1001	3.8V	1010	3.8V	1011	3.8V
			1100	3.8V	1101	3.8V	1110	3.8V	1111	3.8V

Address Name	Register Address		Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
ILED	0X09	Meaning	Torch current [2:0]			Flash current [4:0]				
		Default	0	0	0	0	1	1	1	1
		Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Torch current[2:0]			Torch current level							
			Code	Current	Code	Current	Code	Current	Code	Current
			000	49.60mA	001	93.74mA	010	140.63mA	011	187.5mA
			100	234.38mA	101	281.25mA	110	328.13mA	111	375mA
Flash current[4:0]			Flash current level							
			Code	Current	Code	Current	Code	Current	Code	Current
			00000	93.74mA	00001	187.5mA	00010	281.25mA	00011	375mA
			00100	468.75mA	00101	562.5mA	00110	656.25mA	00111	750mA
			01000	843.75mA	01001	937.5mA	01010	1031.25mA	01011	1125mA
			01100	1218.75mA	01101	1312.5mA	01110	1406.25mA	01111 to 11111	1500mA

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Address Name	Register Address		Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
Enable	0X0A	Meaning	EN_IVFM	EN_TX	EN _STROBE	EN_CS	FREE	STROBE _Reg	STROBE _sel	EN_FLED
		Default	0	1	1	1	0	0	0	0
		Read /Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

EN_IVFM	IVFM enable	
	0	disable
	1	enable
EN_TX	TXMASK Pin enable	
	0	disable
	1	enable
EN_Strobe	Strobe Pin enable	
	0	disable
	1	enable
EN_CS	LED current source enable	
	0	disable
	1	enable
STROBE_Reg	It could be used to control LED flash function	
	0	no strobe
	1	strobe one shut
STROBE_sel	This bit is used to set the operation mode	
	0	Torch mode
	1	Flash mode
EN_FLED	Mode control	
	0	Shutdown
	1	Turn on

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Address Name	Register Address		Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
Flags	0X0B	Meaning	FREE	FREE	IVFM	FREE	OVP	LED or VOUT short	OTP	TO
		Default	0	0	0	0	0	0	0	0
		Read/Write	R	R	R	R	R	R	R	R

IVFM	IVFM down threshold crossed. (readout reset)	
	0	No IVFM down threshold crossed.
	1	IVFM down threshold crossed.
OVP	OVP Flag (readout reset)	
	0	No OVP event
	1	Over-voltage Protection tripped or open LED
LED or VOUT short	LED short Flag (readout reset)	
	0	No short event
	1	LED short detected
OTP	OTP Flag (readout reset)	
	0	No OTP event
	1	OTP shutdown
TO	Flash time-out Flag (readout reset)	
	0	No flash time-out event
	1	Flash time-out event

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Application Information

Soft-Start

The RT4505 employs a soft-start feature to limit the inrush current. The soft-start circuit prevents the excessive inrush current and input voltage drop.

Input UVLO

The input voltage range of the LED driver is from 2.5V to 5.5V. The RT4505 provides an Under Voltage Lockout (UVLO) function to prevent it from unstable issue during startup. The UVLO threshold of input falling voltage is set at 2.3V typically.

Over Voltage Protection (Open LED, Open Circuit)

The RT4505 provides an internal over voltage protection to limit its output voltage. The OVP function prevents the RT4505 from damaging while open LED or open circuit condition occurs. Once the open circuit condition is removed, and the RT4505 will return to normal operation.

Over Temperature Protection

The RT4505 provides an over temperature protection to prevent the IC from overheating. When the junction temperature rises above 150°C, the OTP function will be triggered and then the LED driver will be shut down. The OTP hysteresis is 25°C. Once the junction temperature reduces below the over temperature protection threshold by 25°C, the IC will enter normal operation again.

Low Input Voltage Protection

When the input voltage is lower than the specified value, the converter will stop switching. Until the input voltage rises above the low input voltage protection threshold plus hysteresis voltage value, the converter resumes switching. The low input voltage protection can be programmed with 16 different levels (3V to 3.8V).

Torch mode and Strobe Mode Operation

The RT4505 is designed for one LED driving for torch and flash application, it provides an I^2C interface to operate at torch or flash mode.

Flash Mode

In Flash Mode, FLED provides 16 different current levels from typically 93.74mA to 1500mA in step of 93.75mA. The flash currents are adjusted via the register for flash brightness.

Torch Mode

In Torch Mode, FLED provides 8 different current levels from 49.6mA to 375mA. Torch Mode is activated by setting reg0x09 bits [2:0]. Once Torch Mode is enabled, the current sources will ramp up to the programmed torch current level by stepping through all of the torch currents until the programmed torch current level is reached.

Inductor Selection

The recommended value of inductor for LED photo flash applications is 1μH. Small size and better efficiency are the major concerns for portable devices which is used for single cell Lithium-ion/polymer battery applications. The inductor should have low core loss at 2MHz and low DCR for better efficiency. The inductor saturation current rating should be considered to cover the inductor peak current.

When VIN is larger than for ward voltage of flash LED at set current. RT 4505 will enter by pass mode.

$I_{LED(MAX)}$ is maximum led current, which is usually equal to flash mode current. For normal operation, we suggest customers to recon firm RDC of inductor as below formula.

RT4505 formula :

When VIN_operation > VF($I_{LED(MAX)}$) :

[240mV/(1.1 x $I_{LED(MAX)}$ (A))] - 75(mΩ) = Suggested Inductor RDC (mΩ)

Please make sure VIN - VOUT on PCB is smaller than 240mV in bypass mode.

Capacitor Selection

Input ceramic capacitor of 4.7μH and output ceramic capacitor of 4.7μH are recommended for the RT4505 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.

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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 θ_{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, θ_{JA}, is layout dependent. For WL-CSP-9B 1.3x1.37 (BSC) package, the thermal resistance, θ_{JA}, is 81.4°C/W on a standard JEDEC 51-7 four-layer thermal test board. The maximum power dissipation at T_A = 25°C can be calculated by the following formula :

$P_{D(MAX)}$ = (125°C – 25°C) / (81.4°C/W) = 1.22W for WL-CSP-9B 1.3x1.37 (BSC) package

The maximum power dissipation depends on the operating ambient temperature for fixed $T_{J(MAX)}$ and thermal resistance, θ_{JA}. The derating curve in Figure 1 allows the designer to see the effect of rising ambient temperature on the maximum power dissipation.

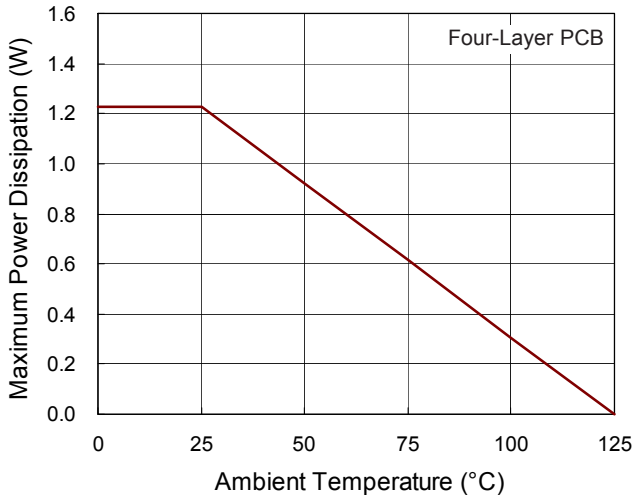

Figure 1. Derating Curve of Maximum Power Dissipation

Layout consideration

For best performance of the RT4505, the following PCB layout guidelines should be strictly followed. GND should be connected to the ground plane of the PCB.

- Input and output capacitors should be connected to a strong ground plane for heat sinking and noise protection.
- SW node of DC/DC converter is with high frequency voltage swing. It should be kept at a small area.
- Keep the main current traces as short and wide as possible.
- It is recommended to add additional PCB exposed pad area or the flash LED for maximized heat-sinking ability. This is necessary for high current application and long flash duration application.

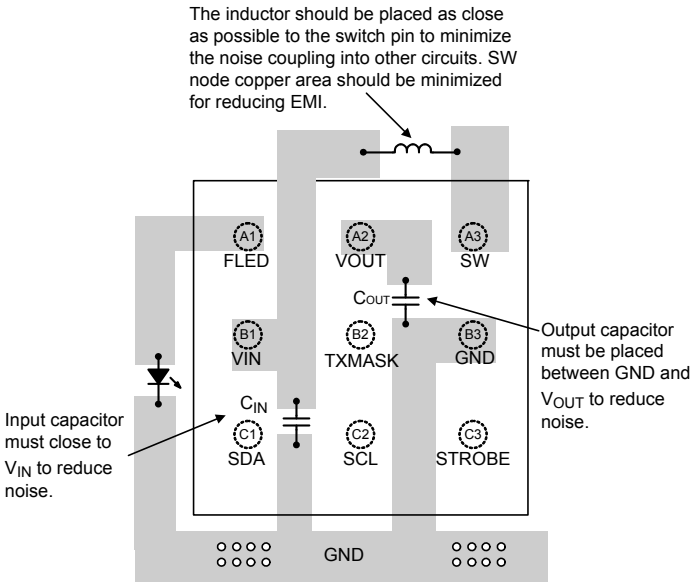

Figure 2. PCB Layout Guide

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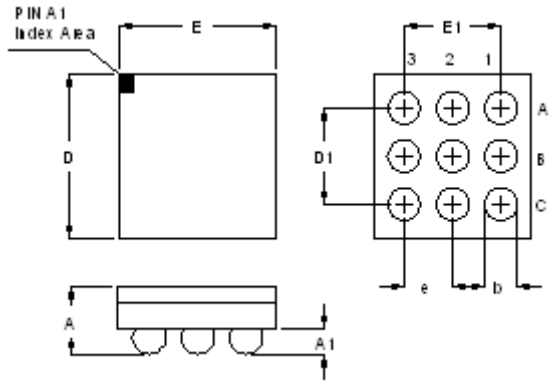
Outline Dimension



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min.	Max.	Min.	Max.
A	0.500	0.600	0.020	0.024
A1	0.170	0.230	0.007	0.009
b	0.240	0.300	0.009	0.012
D	1.320	1.420	0.052	0.056
D1	0.800		0.031	
E	1.250	1.350	0.049	0.053
E1	0.800		0.031	
e	0.400		0.016	

9B WL-CSP 1.3x1.37 Package (BSC)

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