



**Distributor of Richtek USA Inc.: Excellent Integrated System Limited**  
Datasheet of RT8560GQW - IC LED Driver DC DC Regulator Analog, PWM Dimming 30mA  
Backlight 20-WQFN (4x4)

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## High Voltage 4 Channel LED Driver

### General Description

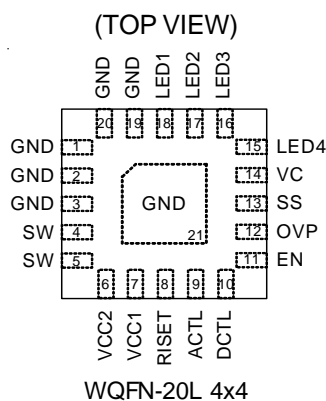
The RT8560 is a 60V 4-channel LED driver capable of delivering 30mA to each channel with 15 LEDs (3.6V per diode) total 60 LEDs with one driver. The RT8560 is a current mode boost converter operated at 1MHz switching frequency, wide  $V_{IN}$  range covers from 7V to 40V and the on-chip current switch is rated at 1.5A.

The PWM output voltage loop selects and regulates the LED pin with the highest voltage string to 0.9V allowing voltage mismatches between LED strings. The RT8560 automatically detects and disconnects any unconnected and/or broken strings during operation from PWM loop to prevent  $V_{OUT}$  from over voltage.

The 3% matched LED currents on all channels are simply programmed with a resistor or a current sink. Both analog dimming and digitally controlled PWM dimming are supported by RT8560. Analog dimming is linearly controlled by an external voltage. With an on-chip output clamping amplifier and a 200k $\Omega$  resistor, PWM dimming signal is easily low-pass filtered to an analog dimming signal with one external capacitor for noise-free PWM dimming. A very high contrast ratio true digital PWM dimming can be achieved by driving EN pin to PWM shutdown the chip or by driving ACTL pin.

Other protecting features include programmable PWM output over voltage protection, LED current limit, PWM switch current limit and thermal shutdown. The RT8560 is packaged with a tiny footprint package of WQFN-20L 4x4 packages.

### Pin Configurations



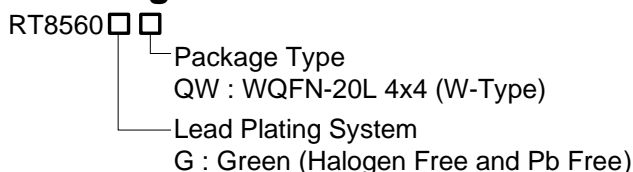
### Features

- High Voltage :  $V_{IN}$  up to 40V,  $V_{OUT}$  up to 60V, Driving up to 60 x 3.6V LEDs (15 each channel)
- Channel Current Programmable 4mA to 30mA and Matched to 3% Accuracy
- Current Mode PWM 1MHz Boost Converter
- Easy Analog and Digital Dimming Control
- Programmable Soft Start
- Automatic Detecting Unconnected and/or Broken Channel
- Programmable Over Voltage Protection
- Disconnects LED in Digital Dimming : Providing High Accuracy Digital Dimming by PWM at ACTL Pin or EN Pin
- $V_{IN}$  Under Voltage Lockout
- Over Temperature Protection
- Current Limiting Protection
- Small 20-Lead WQFN Package
- RoHS Compliant and Halogen Free

### Applications

- UMPC and Notebook Computer Backlight
- GPS, Portable DVD Backlight
- Desk Lights and Room Lighting

### Ordering Information



Note :

Richtek products are :

- ▶ RoHS compliant and compatible with the current requirements of IPC/JEDEC J-STD-020.
- ▶ Suitable for use in SnPb or Pb-free soldering processes.

### Marking Information

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

# RT8560



## Typical Application Circuit

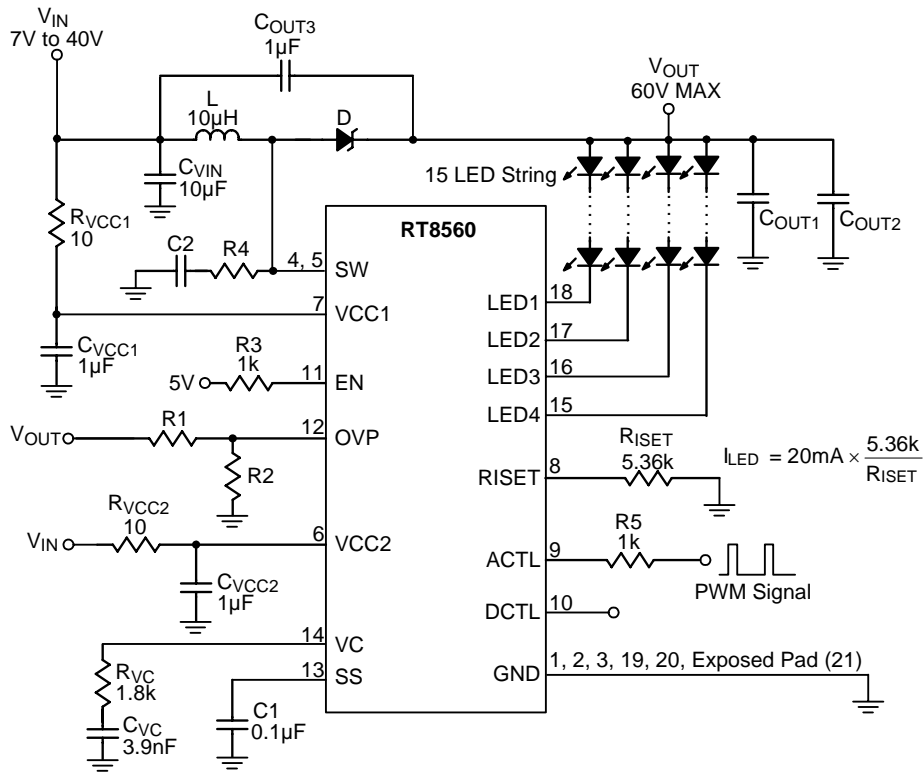


Figure 1. 1MHz, 20mA Full Scale Current Digital PWM Dimming Control

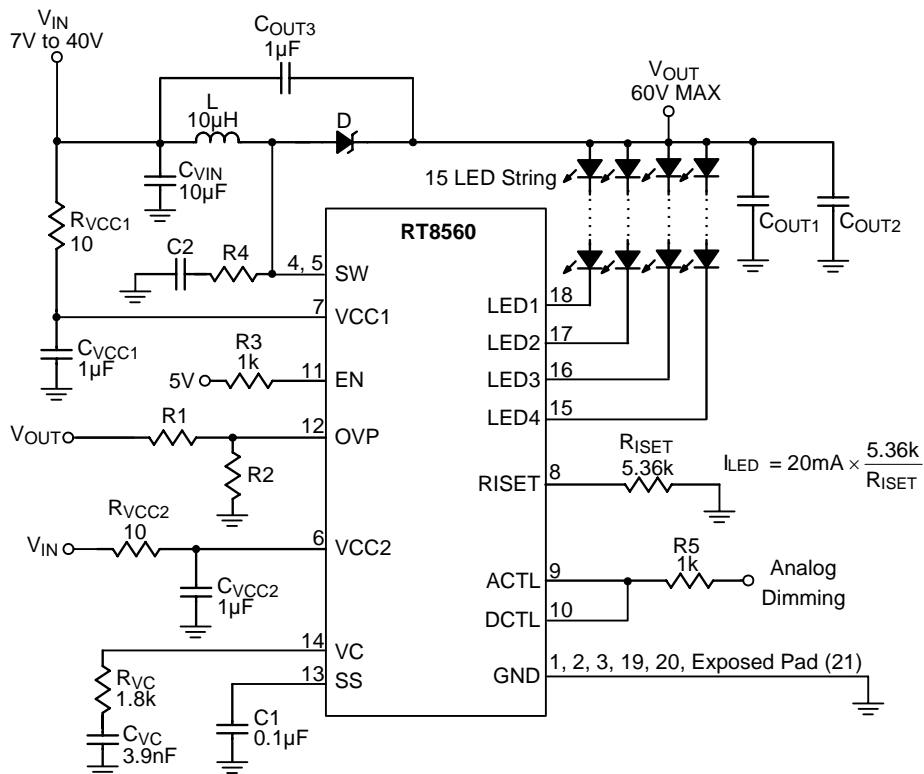


Figure 2. 1MHz, 20mA Full Scale Current Analog Dimming Control

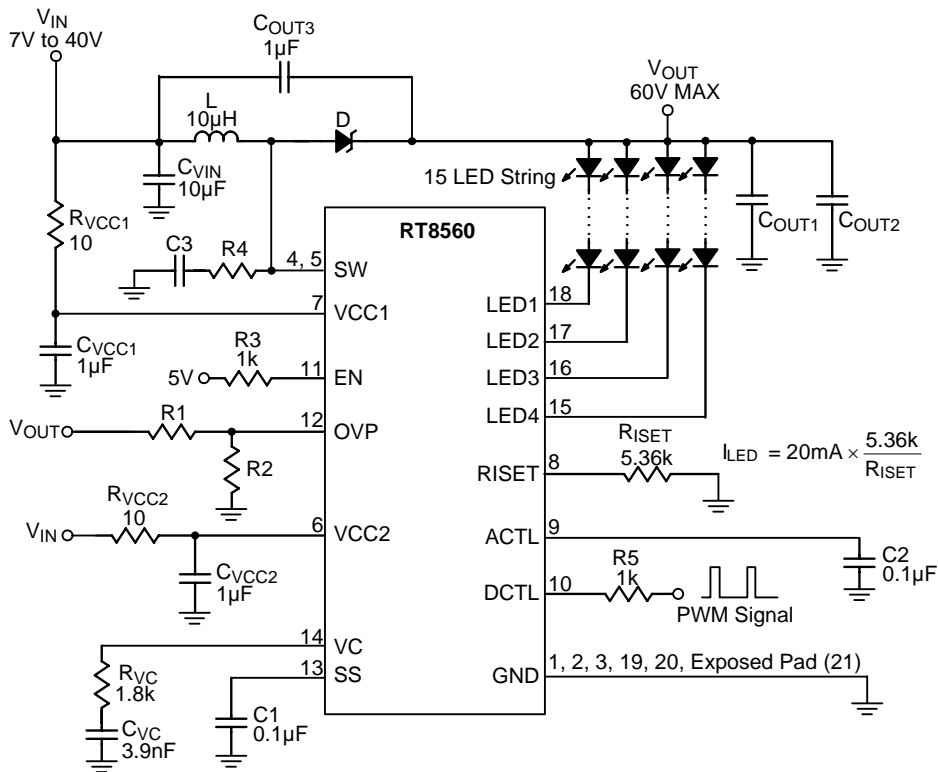


Figure 3. 1MHz, 20mA Full Scale Current PWM to Analog Dimming Control

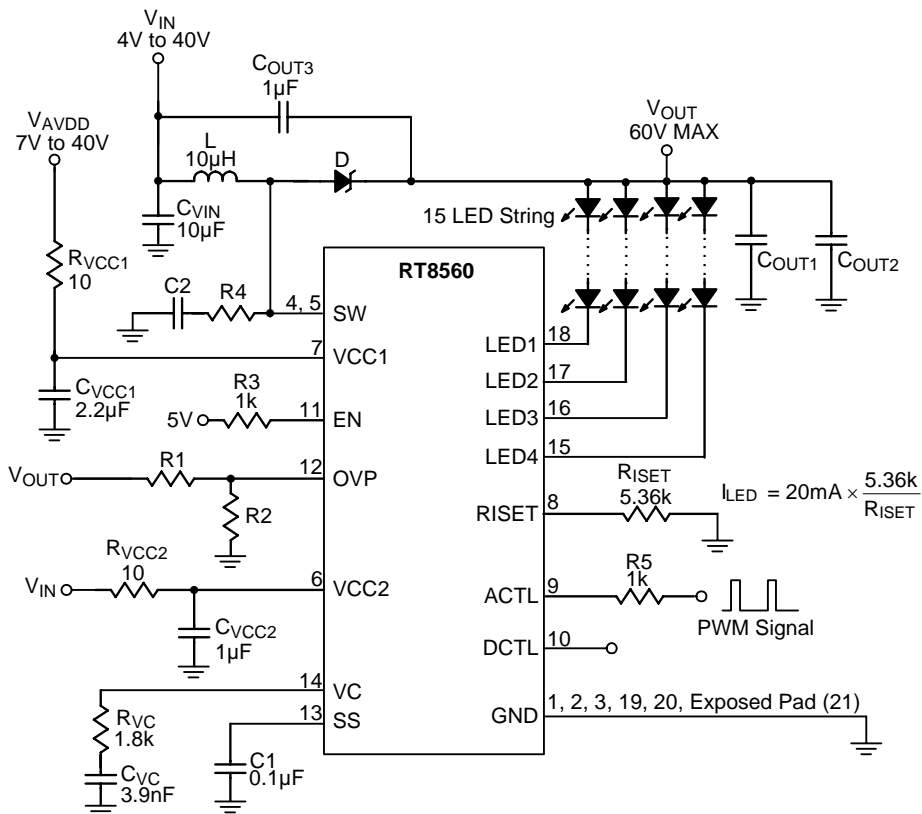
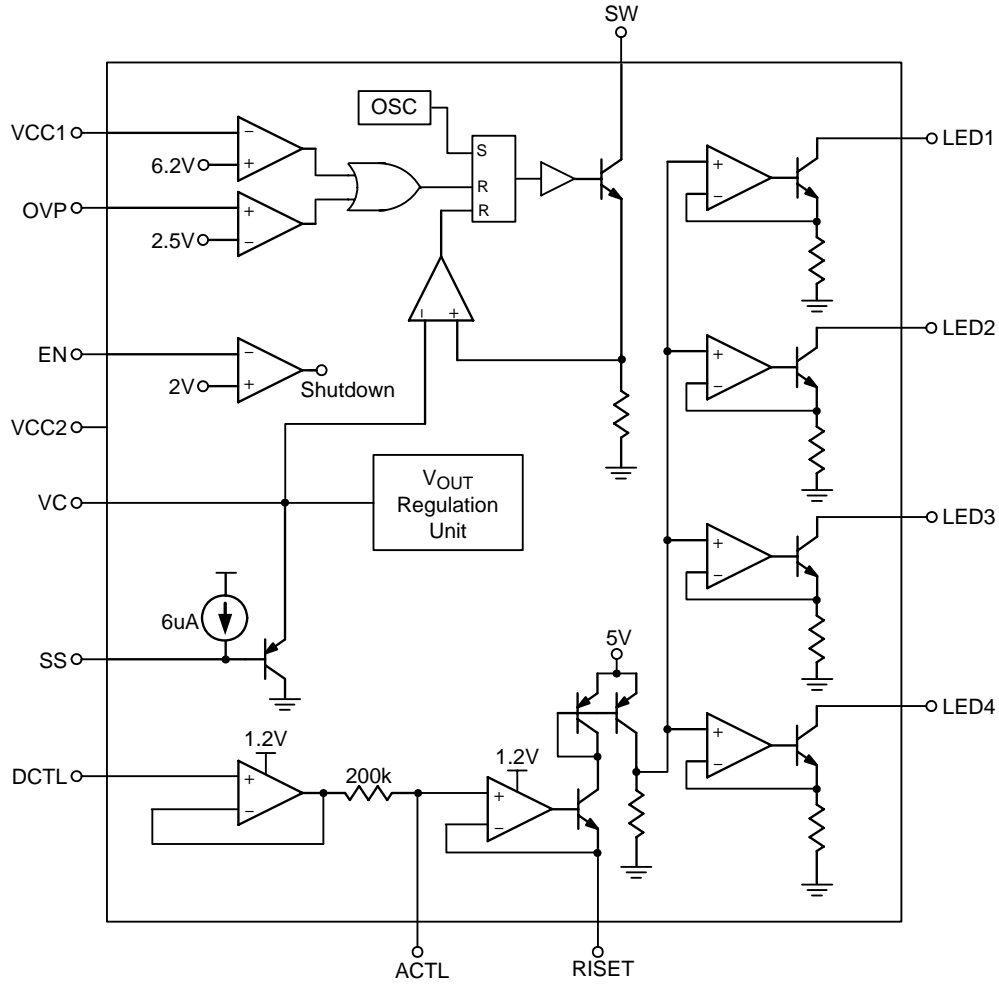


Figure 4. Wide Range VIN Application by Connecting VCC1 to LCD Driver Power AVDD

# RT8560



## Function Block Diagram



## Functional Pin Description

Pin Number	Pin Name	Pin Function
1, 2, 3, 19, 20, 21 (Exposed Pad)	GND	Ground pin of the chip. The exposed pad must be soldered to a large PCB and connected to GND for maximum power dissipation.
4, 5	SW	PWM boost converter switch node.
6	VCC2	Bipolar power switch base current supply. Typical beta of the power NPN switch is approximately 70. VCC2 can be connected either to VCC1 or to a separate lower voltage, as low as 3V, for better system efficiency and/or heat concern. A good bypass is necessary.
7	VCC1	Power supply of the chip. For good bypass, a low ESR capacitor is required.
8	RISSET	A resistor or a current from DAC on this pin programs the full LED current.
9	ACTL	Analog/Digital dimming control. When using analog dimming, $I_{LED} = 20mA \times \frac{5.36k}{R_{RISSET}}$ for $V_{ACTL} \geq 1.2V$ .
10	DCTL	By adding a 0.1uF filtering capacitor on ACTL pin, the PWM dimming signal on DCTL pin will be averaged out and converted into analog dimming signal on ACTL pin.
11	EN	Chip enable pin, when low chip is in shutdown mode.
12	OVP	Over voltage protection. PWM boost converter turns off when $V_{OVP}$ goes higher than 2.5V.
13	SS	Soft start pin, a capacitor of at least 10nF is required for soft start.
14	VC	PWM boost converter loop compensation node.
18, 17, 16, 15	LED1, LED2, LED3, LED4	Channel 1 to Channel 4 LED current sink. Leave the pin unconnected if not used.

# RT8560



## Absolute Maximum Ratings (Note 1)

• Supply Voltage, VCC1, VCC2	-----	42V
• SW Pin Voltage at Switching Off	-----	65V
• LED1, LED2, LED3, LED4 Pin	-----	25V
• EN Pin Voltage	-----	20V
• RISET Pin Voltage	-----	4V
• ACTL, DCTL, OVP, SS, VC Pin Voltage	-----	8V
• Power Dissipation, P <sub>D</sub> @ T <sub>A</sub> = 25°C		
WQFN-20L 4x4	-----	1.852W
• Package Thermal Resistance (Note 2)		
WQFN-20L 4x4, θ <sub>JA</sub>	-----	54°C/W
WQFN-20L 4x4, θ <sub>JC</sub>	-----	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 Mode)	-----	2kV
MM (Machine Mode)	-----	200V

## Recommended Operating Conditions (Note 4)

• Supply Input Voltage, VCC1, VCC2	-----	7V to 40V
• Junction Temperature Range	-----	-40°C to 125°C
• Ambient Temperature Range	-----	-40°C to 85°C

## Electrical Characteristics

(V<sub>CC1</sub> = 17V, T<sub>A</sub> = 25°C, unless otherwise specified)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
V <sub>CC1</sub> UVLO Threshold	V <sub>UVLO</sub>	V <sub>CC1</sub> Rising	--	6.2	6.5	V
Supply Current	I <sub>VCC1</sub>	V <sub>C</sub> ≤ 0.4V (Switching off)	--	4	7	mA
Shutdown Current	I <sub>SHDN</sub>	V <sub>EN</sub> ≤ 0.7V	--	12	--	μA
EN Threshold	Logic-High Voltage	V <sub>EN_H</sub>	2	--	5	V
	Logic-Low Voltage	V <sub>EN_L</sub>	--	--	0.8	
ACTL Threshold	Logic-High Voltage	V <sub>ACTL_H</sub>	2	--	5	V
	Logic-Low Voltage	V <sub>ACTL_L</sub>	--	--	0.15	
EN Pin Input Current	I <sub>EN</sub>	V <sub>EN</sub> ≤ 5V	--	--	2	μA
<b>LED Current Programming</b>						
LED Current	I <sub>LED</sub>	2V > V <sub>LED</sub> > 0.7V, R <sub>RISET</sub> = 5.36kΩ, V <sub>ACTL</sub> > 1.28V	19	20	21	mA
LED's Current Matching		2V > V <sub>LED</sub> > 0.7V, R <sub>RISET</sub> = 5.36kΩ, V <sub>ACTL</sub> > 1.28V, Calculating (I <sub>(MAX)</sub> - I <sub>(MIN)</sub> ) / I <sub>AVERAGE</sub> × 100%	--	--	3	%
RISET Pin Voltage	V <sub>RISET</sub>	R <sub>RISET</sub> = 5.36kΩ, V <sub>ACTL</sub> > 1.28V	--	1.21	--	V
Input Current of ACTL	I <sub>ACTL</sub>	0.3V ≤ V <sub>ACTL</sub> ≤ 1.2V	--	--	2	μA

To be continued

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Threshold of ACTL	V <sub>ACTL</sub>	LED Current Off	--	0.2	--	V
Input Current of DCTL	I <sub>DCTL</sub>	0.3V ≤ V <sub>DCTL</sub> ≤ 6V	--	--	1	μA
<b>PWM Boost Converter</b>						
Switching Frequency			840	1000	1160	kHz
Maximum Duty Cycle			--	88	--	%
Minimum On Time			--	200	--	ns
Regulated V <sub>LED</sub>		Highest Voltage LED String	--	0.9	--	V
Amplifier gm	GM		--	220	--	μA/V
Amplifier (gm) Output Current		2.4V > V <sub>C</sub> > 0.2V	--	±30	--	μA
VC Threshold		PWM Switch Off	--	0.7	--	V
SW On Voltage		I <sub>SW</sub> = 0.5A	--	0.4	--	V
SW Current Limit	I <sub>LIM</sub>		1.2	1.5	--	A
<b>OVP &amp; Soft Start</b>						
OVP Threshold	V <sub>OVP</sub>		--	2.5	--	V
OVP Input Current	I <sub>OVP</sub>	V <sub>OVP</sub> ≤ 2.5V	--	--	50	nA
Soft Start Current	I <sub>SS</sub>	V <sub>SS</sub> = 0V	--	7	--	μA

**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.** θ<sub>JA</sub> is measured in the natural convection at T<sub>A</sub> = 25°C on a high effective four layers thermal conductivity test board of JEDEC 51-7 thermal measurement standard. The case point of θ<sub>JC</sub> is on the expose pad for the WQFN package.

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

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

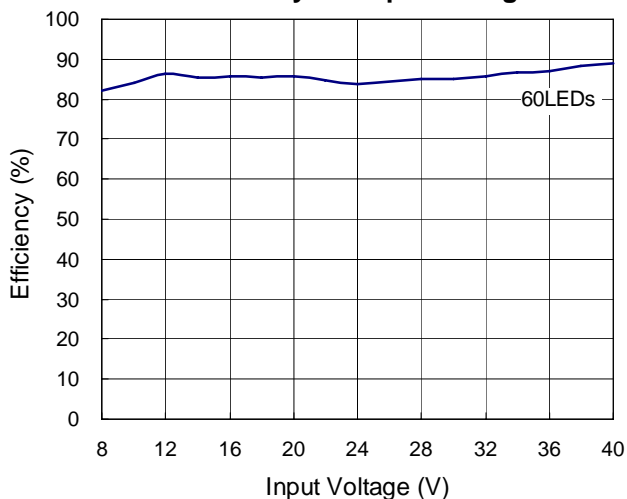


# RT8560

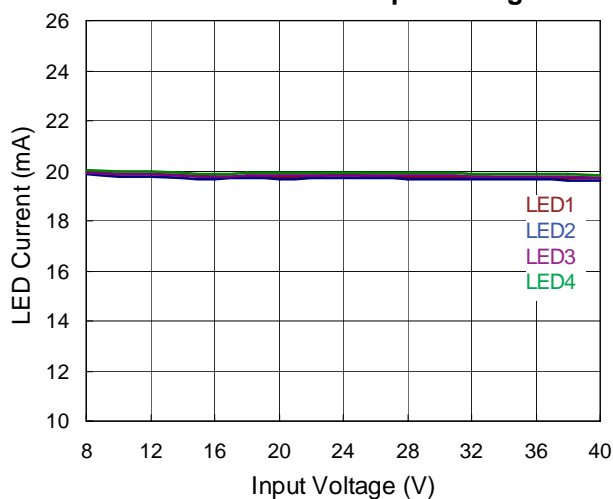


## Typical Operating Characteristics

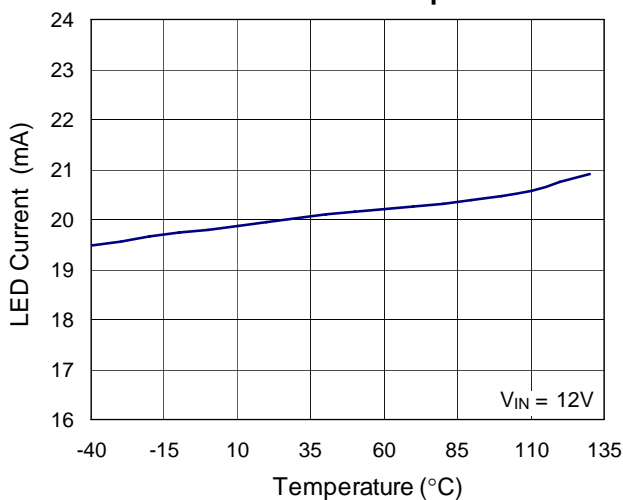
Efficiency vs. Input Voltage



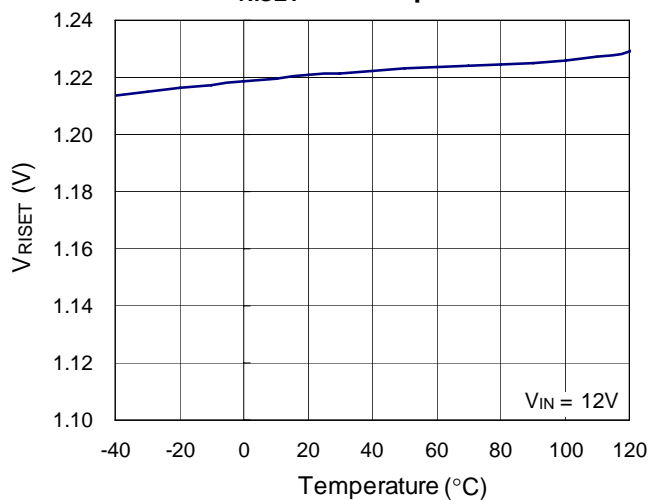
LED Current vs. Input Voltage



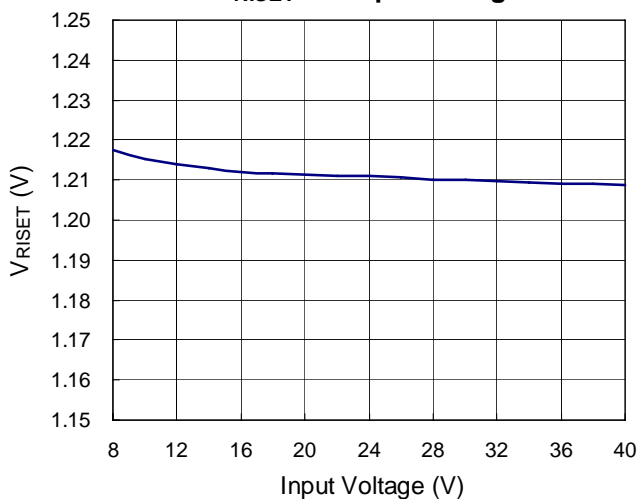
LED Current vs. Temperature



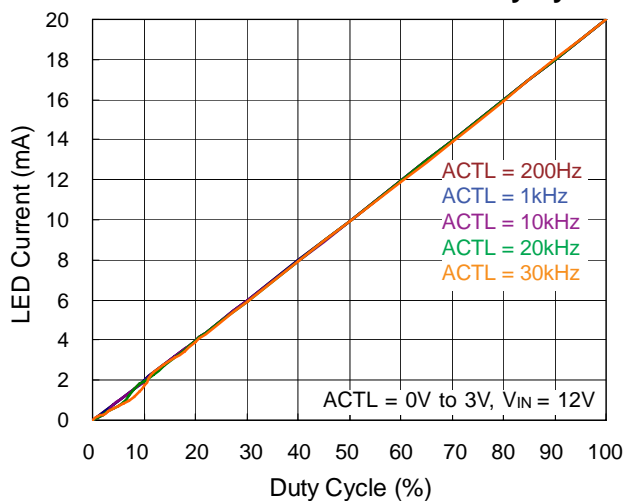
V<sub>RISET</sub> vs. Temperature



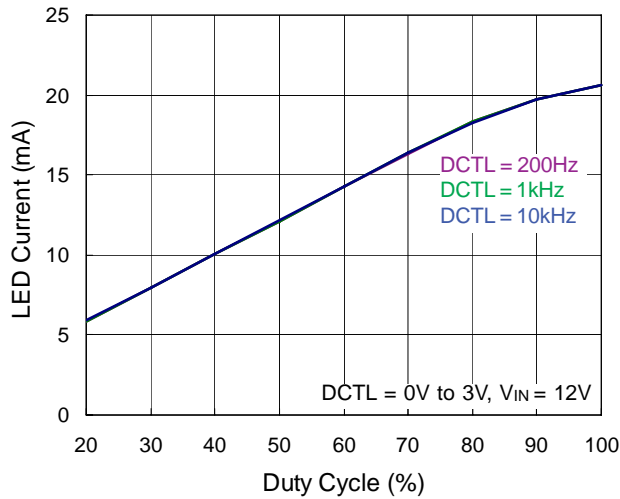
V<sub>RISET</sub> vs. Input Voltage



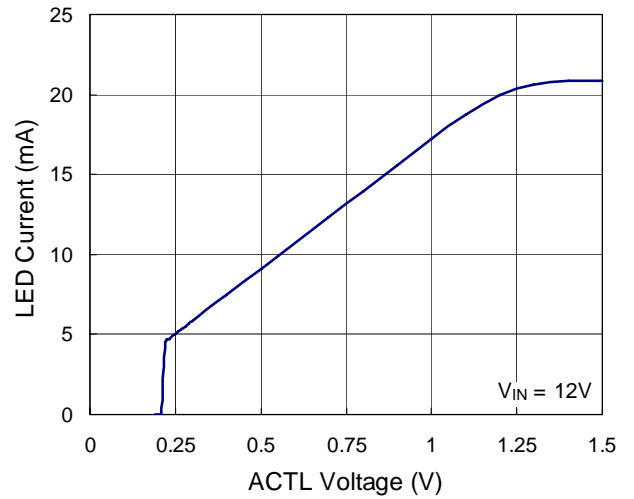
LED Current vs. ACTL PWM Duty Cycle



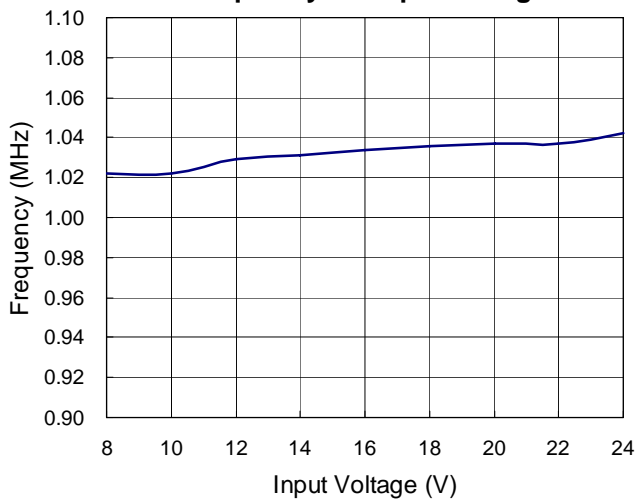
**LED Current vs. DCTL PWM Duty Cycle**



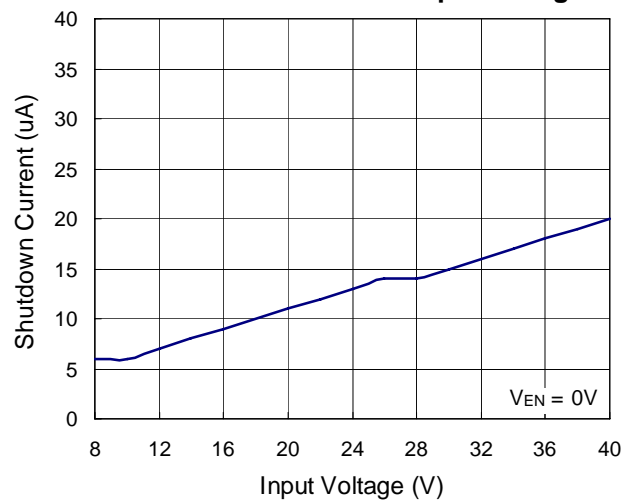
**LED Current vs. ACTL Voltage**



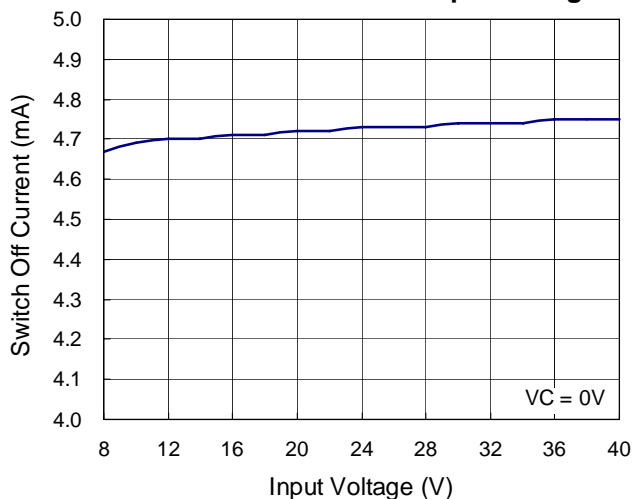
**Frequency vs. Input Voltage**



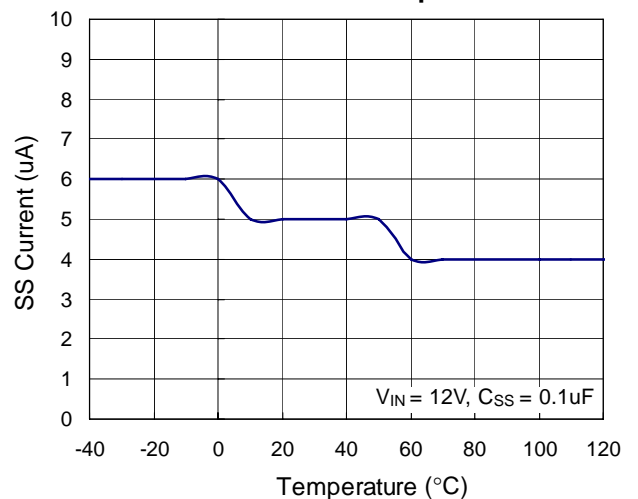
**Shutdown Current vs. Input Voltage**



**Switch Off Current vs. Input Voltage**



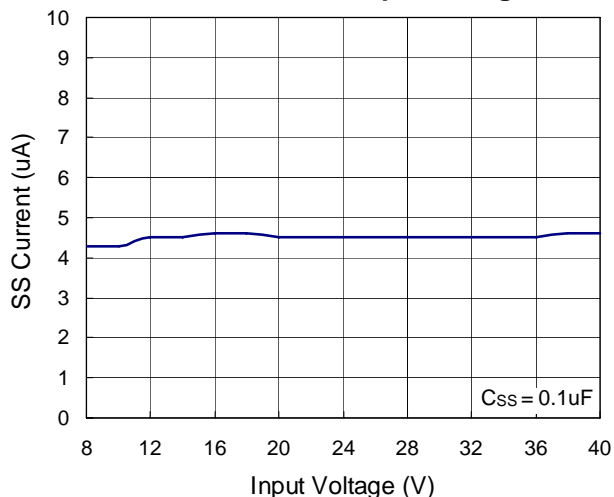
**SS Current vs. Temperature**



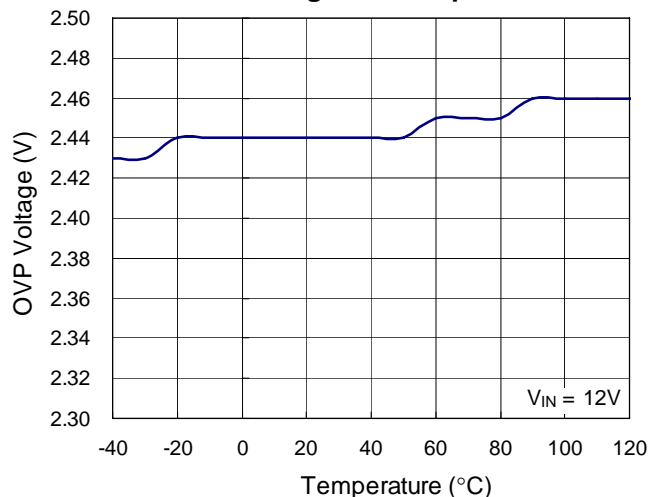
# RT8560



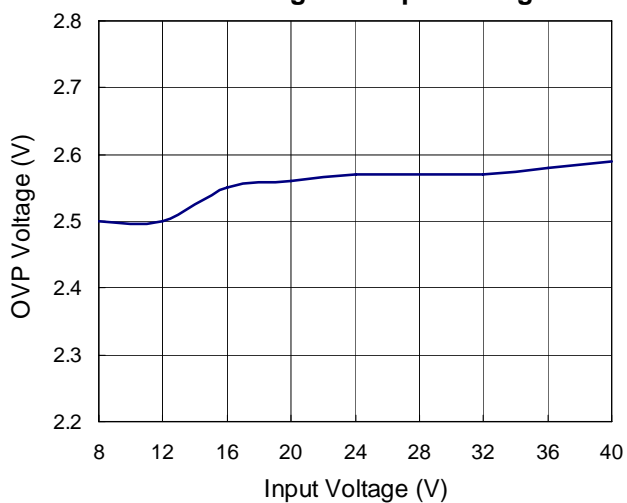
**SS Current vs. Input Voltage**



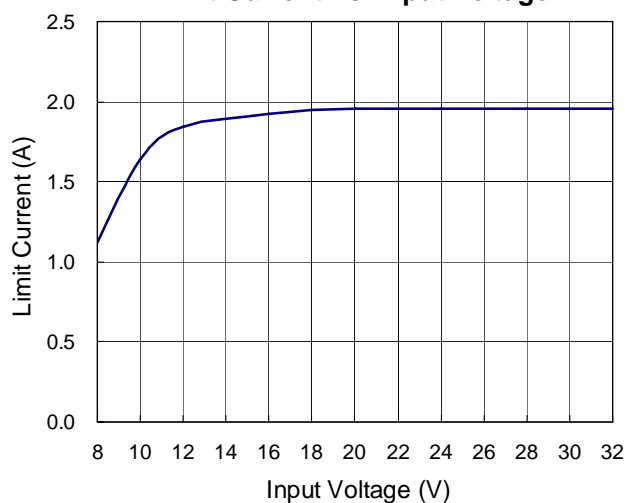
**OVP Voltage vs. Temperature**



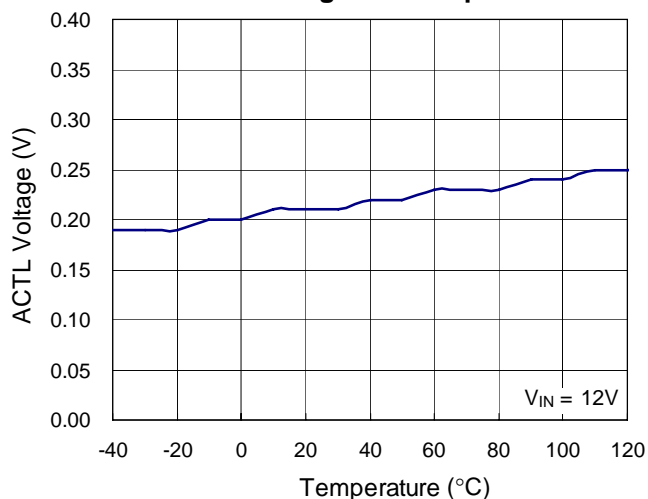
**OVP Voltage vs. Input Voltage**



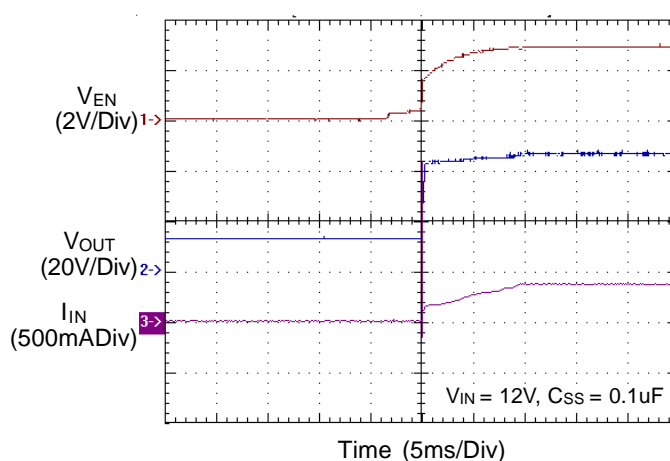
**Limit Current vs. Input Voltage**



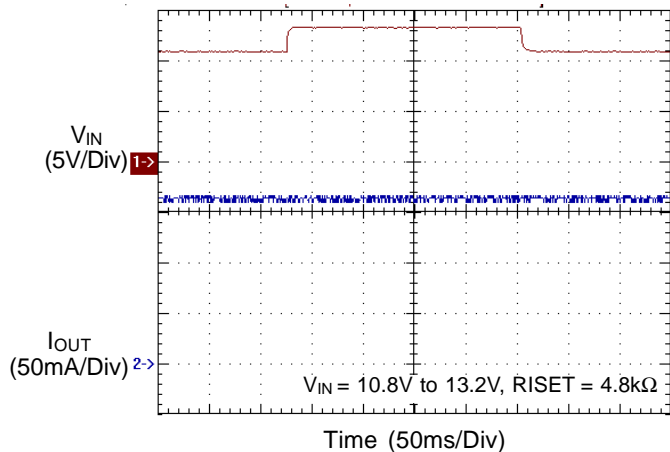
**ACTL Voltage vs. Temperature**



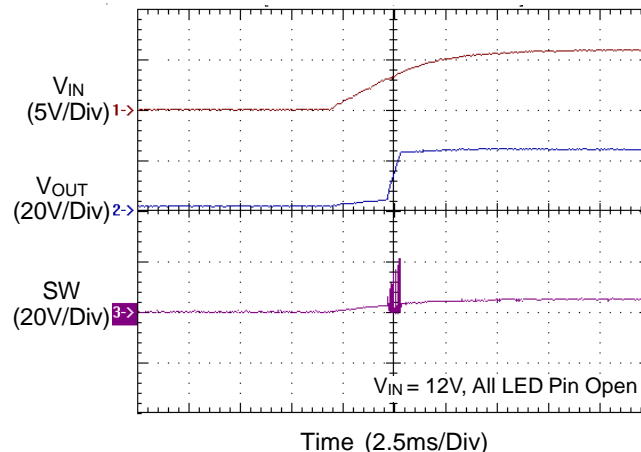
**Power On from EN**



**Line Transient Response**



**OVP**



# RT8560



## Applications Information

The RT8560 is a current mode boost converter operated at 1MHz to power up to 60 white LEDs with a programmable current for uniform intensity. The part integrates current sources, soft-start, and easy analog and digital dimming control. The protection block provides the circuitry for over-temperature, over-voltage and current-limit protection features.

### Input UVLO

The input operating voltage range of the RT8560 is 7V to 40V. An input capacitor at the VCC1 and VCC2 pin can reduce ripple voltage. It is recommended to use a ceramic 10uF or larger capacitance as the input capacitor. This IC provides an under voltage lockout (UVLO) function to enhance the stability when startup. The UVLO threshold of input rising voltage is around 6.2V.

### Power Sequence

Please refer to the below Figure 5 and 7. The recommended power-on sequence is that the PWM ready before EN and/or VIN ready. If not, the Soft-Start function will be disabled. As to power-off sequence, the EN/VIN must be pulled low within 10ms to prevent "Hard-Start" shown as Figure 7.

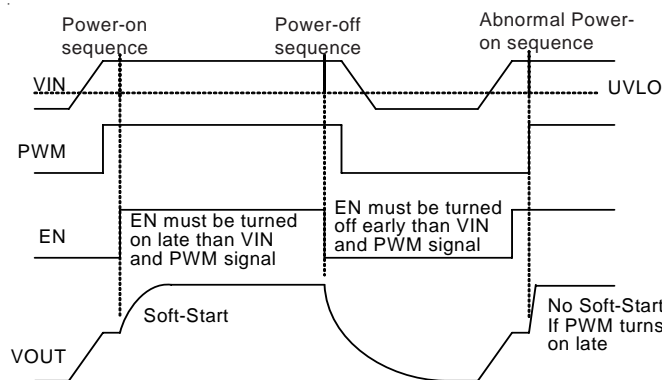


Figure 5. Power-On Sequence Control by EN

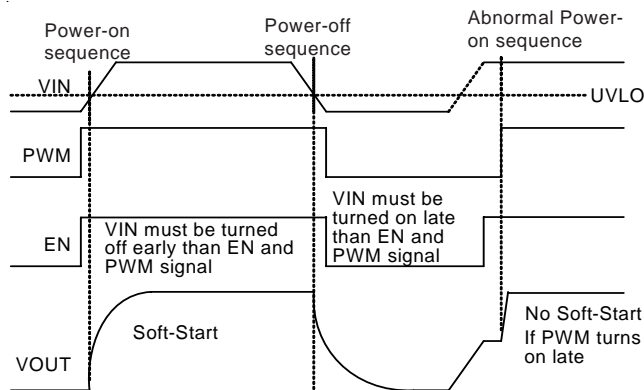


Figure 6. Power-On Sequence Control by VIN

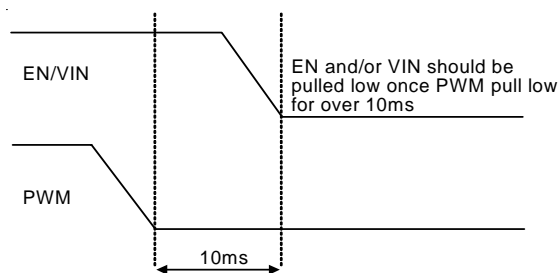


Figure 7. To Prevent "Hard-Start" Sequence

### Soft Start

The RT8560 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 time is determined by capacitor  $C_{SS}$  connected to SS with a 7uA constant current to charge  $C_{SS}$ . The value of capacitor  $C_{SS}$  is user-defined to satisfy designer' requirement.

### LED connection

The RT8560 equips 4 channel LED drivers and each channel supports up to 15 LEDs. The 4 LED strings are connected from VOUT to pin 15, 16, 17 and 18 respectively. If one of the LED channel is not used, the LED pin should be opened directly.

### Setting and Regulation of LED current

The LED current can be calculated by the following equation :

$$I_{LED} = 20mA \times \frac{5.36k}{R_{SET}}$$

Where,

$V_{RISSET}$  is the voltage of the RISSET pin (1.21V typ.) and the  $R_{RISSET}$  is the resistor between RISSET pin and GND.

This setting is the reference for the LED current at LED1-4 and represents the sensed LED current for each string. The DC/DC converter regulates the LED current according to the setting.

### Brightness Control

The RT8560 features both analog and digital dimming control. Analog dimming is linearly controlled by an external voltage ( $0.3V < V_{ACTL} < 1.2V$ ). With an on-chip output clamping amplifier and a 200kΩ resistor, PWM dimming signal is easily low-pass filtered to an analog dimming signal with one external capacitor for noise-free PWM dimming. A very high contrast ratio true digital PWM dimming can be achieved by driving ACTL pin with a PWM signal and suggest PWM frequency is from 200Hz to 10kHz. Refer to Figure 8, the minimum dimming duty can be as low as 1% for the frequency range from 100Hz to 300Hz. For the dimming frequency from 300Hz to 1kHz, the duty is about 5%. If the frequency is increased to 1kHz to 30kHz, the duty will be about 10%.

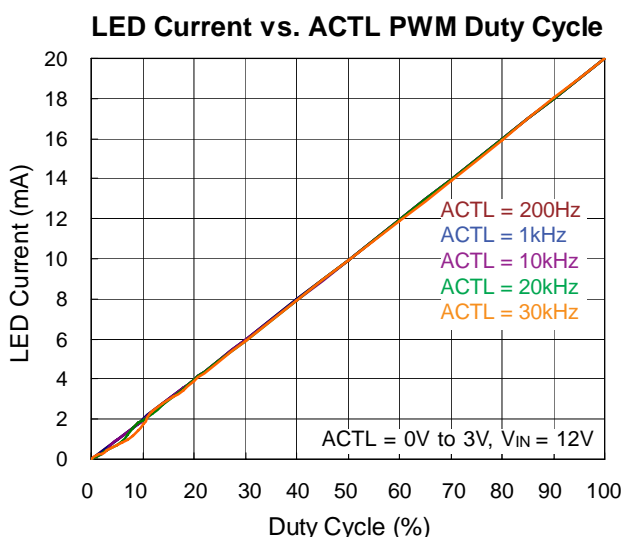


Figure 8. LED Current vs. PWM Dimming Duty Cycle

### Over Voltage Protection

The RT8560 equips over voltage protection (OVP) function. When the voltage at OVP pin reaches a threshold of approximately 2.5V, the MOSFET drive output (SW) will turn "OFF". The MOSFET drive output (SW) will turn "ON" again once the voltage at OVP drops below the threshold of approximately 2.5V.

So, the output voltage can be clamped at a certain voltage level and it can be calculated by the following equation :

$$V_{OUT, OVP} = 2.5 \times \left( 1 + \frac{R1}{R2} \right)$$

Where,

R1 and R2 are the voltage divider connected to OVP pin.

If at least one string is in normal operation, the controller will automatically ignore the open strings and continue to regulate the current for the string(s) in normal operation.

### Current-limit Protection

The RT8560 can limit the peak current to achieve over current protection. The RT8560 senses the inductor current of on period that flows through SW pin. The duty cycle depend on current signal and internal slope compensation compared with error signal. The internal N-MOSFET will be turned off when the current signal is large than internal slope compensation. In the off period, the inductor current will be descended until the internal N-MOSFET is on by the oscillator.

### Over Temperature Protection

The RT8560 has over temperature protection (OTP) function to prevent the excessive power dissipation from overheating. OTP will shut down the IC while junction temperature exceeds 150°C. Main converter starts switching once the junction temperature is cooled approximately 20°C.

### Inductor Selection

The value of the output inductor (L), where the transition from discontinuous to continuous mode occurs is approximated by the following equation :

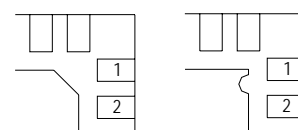
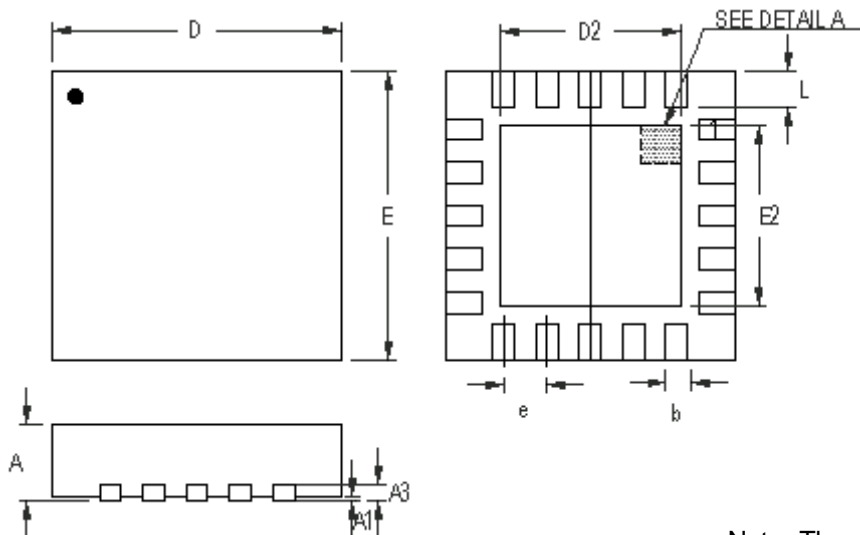
$$L = \frac{(V_{OUT} - V_{IN}) \times V_{IN}^2}{2 \times I_{OUT} \times f \times V_{OUT}^2}$$



# RICHTEK

# RT8560

## 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	0.150	0.300	0.006	0.012
D	3.950	4.050	0.156	0.159
D2	2.650	2.750	0.104	0.108
E	3.950	4.050	0.156	0.159
E2	2.650	2.750	0.104	0.108
e	0.500		0.020	
L	0.350	0.450	0.014	0.018

### W-Type 20L QFN 4x4 Package

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