High Voltage 4 Channel LED Driver

General Description

The RT8560A 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 RT8560A is a current mode boost converter opearated at 1MHz switching frequency, wide V_{IN} range covers from 6V to 40V and the on-chip current switch is rated at 1.5A.

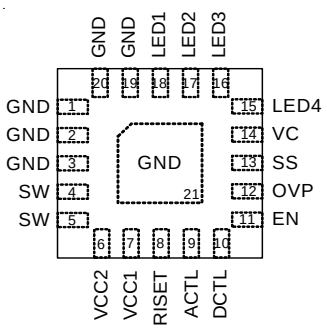
The PWM output voltage loop selects and regulates the LED pin with the highest voltage string to 0.9V allowing voltage mismatches between LED strings. The RT8560A automatically detects and disconnects any unconnected and/or broken strings during operation from PWM loop to prevent V_{OUT} from over voltage.

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 RT8560A. Analog dimming is linearly controlled by an external voltage. With an on-chip output clampping 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 EN pin to PWM shutdown the chip or by driving ACTL pin.

Other protecting features include programmable PWM output over voltage protection, LED curren limit, PWM switch current limit and thermal shutdown. The RT8560A is packaged with a tiny footprint package of WQFN-20L 4x4 packages.

Pin Configurations

(TOP VIEW)



WQFN-20L 4x4

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 Programmabe 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

RT8560A □□

Package Type
QW : WQFN-20L 4x4 (W-Type)

Lead Plating System
G : Green (Halogen Free and Pb Free)

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.

Typical Application Circuit

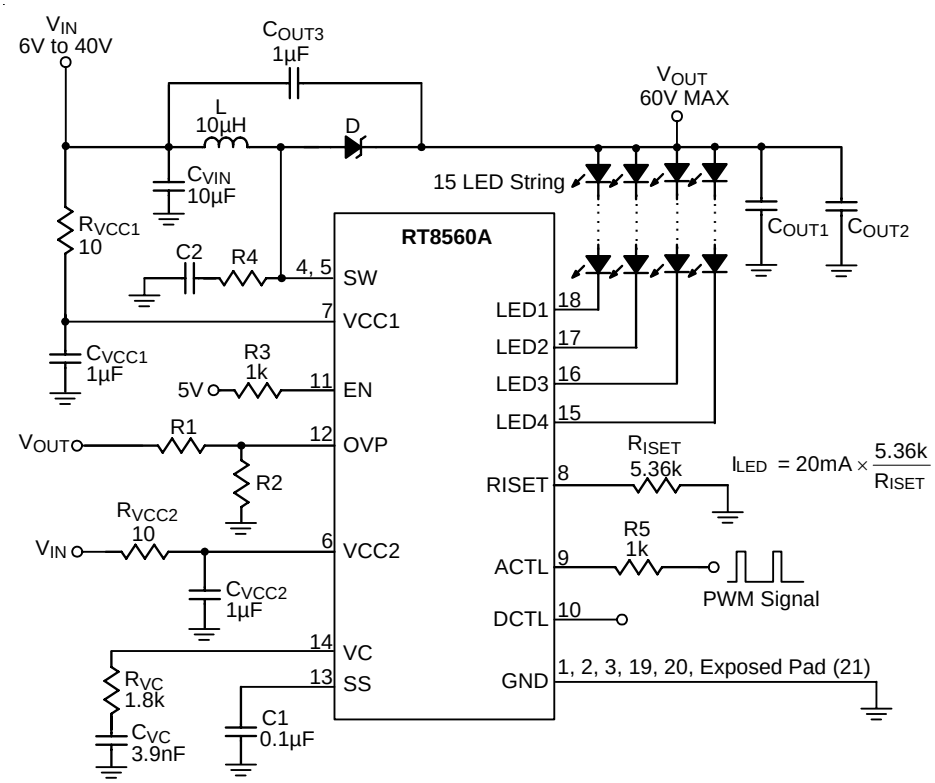


Figure 1. 1MHz, 20mA Full Scale Current Digital PWM Dimming Control

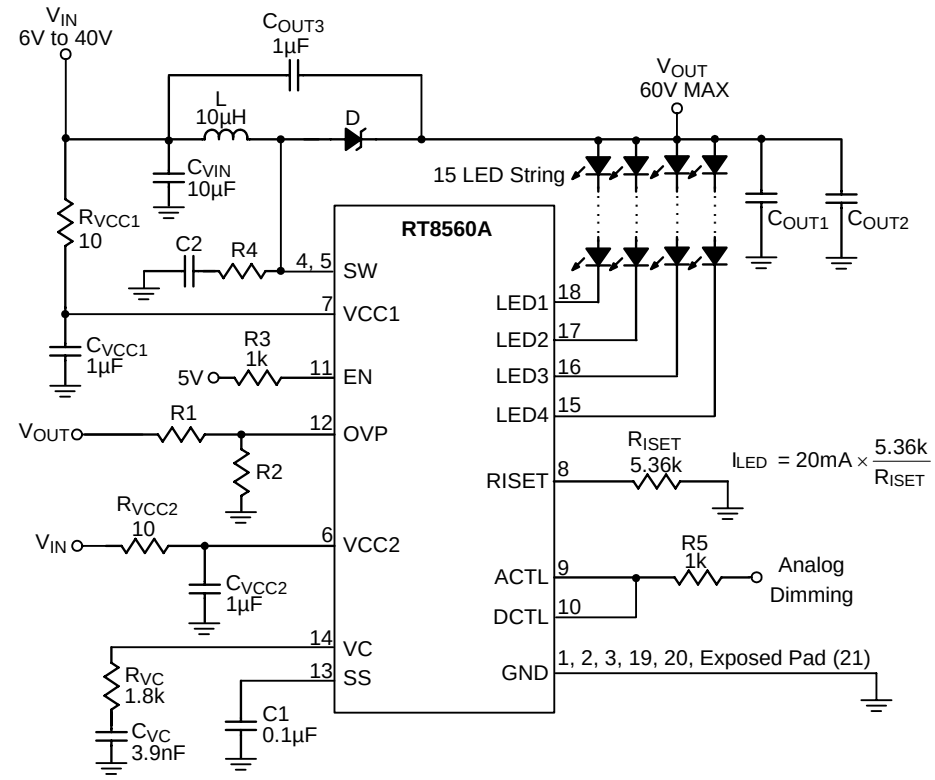


Figure 2. 1MHz, 20mA Full Scale Current Analog Dimming Control

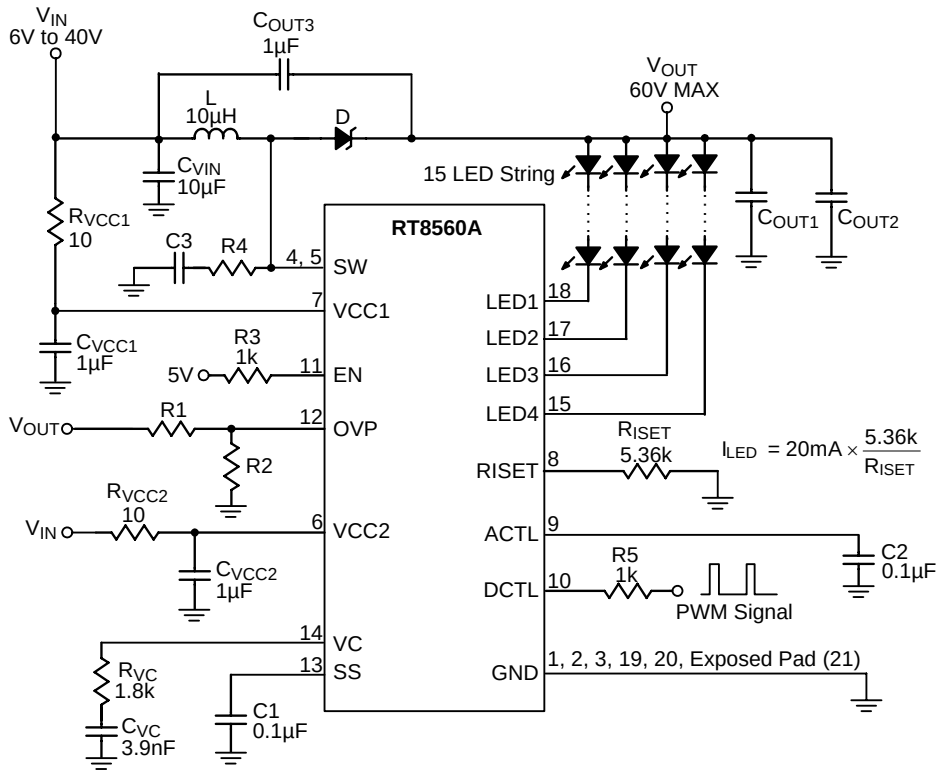


Figure 3. 1MHz, 20mA Full Scale Current PWM to Analog Dimming Control

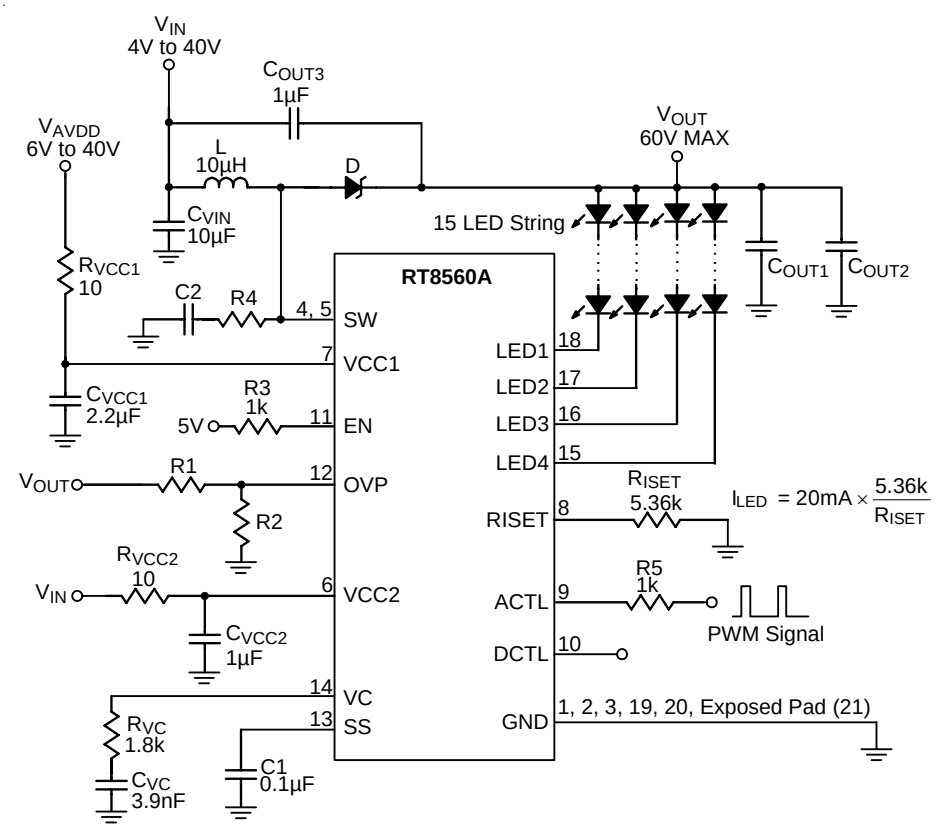
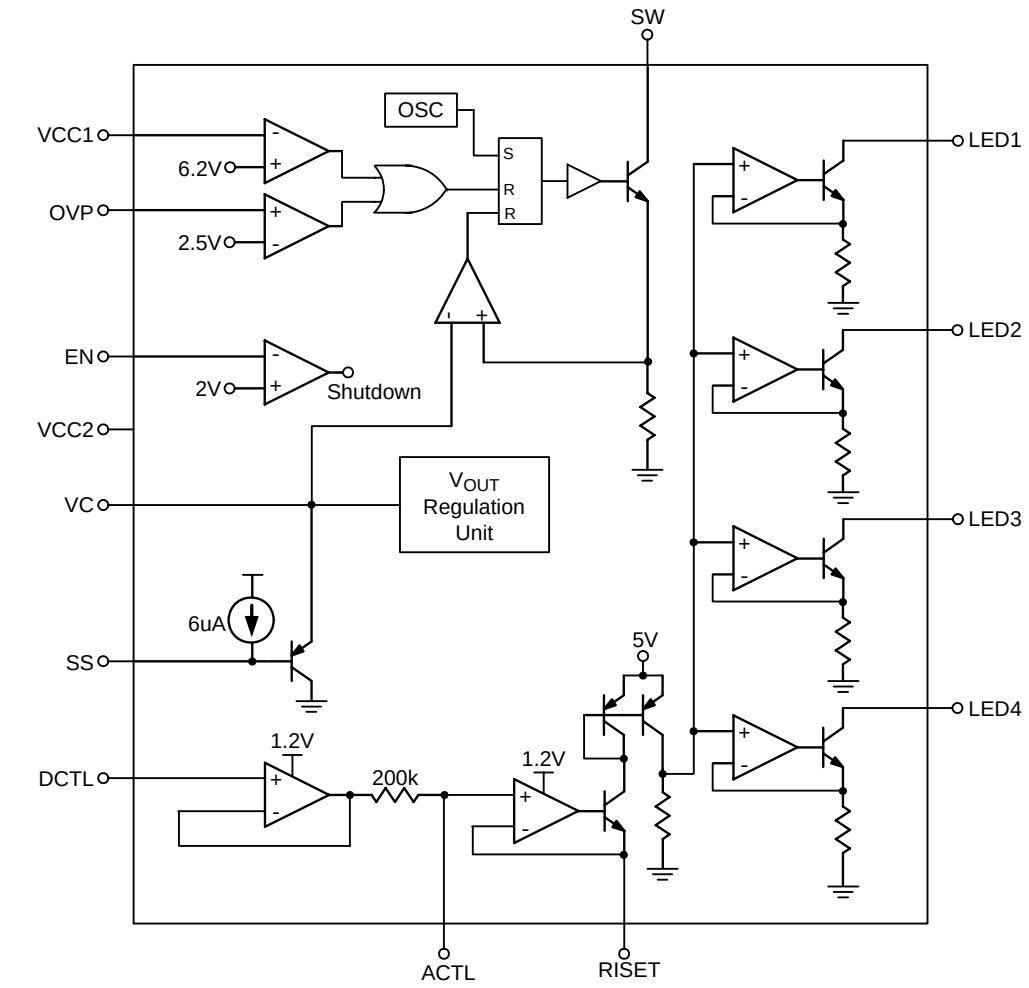


Figure 4. Wide Range VIN Application by Connecting VCC1 to LCD Driver Power AVDD

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	RISET	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, $I_{LED} = 20mA \times \frac{5.36k}{R_{ISET}}$ 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.

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 Pins Voltage ---------- 8V
- Power Dissipation, P_D @ T_A = 25°C
  WQFN-20L 4x4 ---------- 1.852W
- Package Thermal Resistance (Note 2)
  WQFN-20L 4x4, θ_{JA} ---------- 54°C/W
  WQFN-20L 4x4, θ_{JC} ---------- 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 ---------- 6V to 40V
- Junction Temperature Range ---------- –40°C to 125°C
- Ambient Temperature Range ---------- –40°C to 85°C

Electrical Characteristics

(V_{CC1} = 17V, T_A = 25°C, unless otherwise specified)

Parameter		Symbol	Test Conditions	Min	Typ	Max	Unit
V_{CC1} UVLO Threshold		V_{UVLO}	V_{CC1} Rising	--	5.5	5.95	V
Supply Current		I_{VCC1}	VC ≤ 0.4V (Switching off)	--	4	7	mA
Shutdown Current		I_{SHDN}	V_{EN} ≤ 0.7V	--	12	--	μA
EN Threshold	Logic-High Voltage	V_{EN_H}		2	--	5	V
	Logic-Low Voltage	V_{EN_L}		--	--	0.8	
ACTL Threshold	Logic-High Voltage	V_{ACTL_H}		2	--	5	V
	Logic-Low Voltage	V_{ACTL_L}		--	--	0.15	
EN Pin Input Current		I_{EN}	V_{EN} ≤ 5V	--	--	2	μA
LED Current Programming							
LED Current		I_{LED}	2V > V_{LED} > 0.7V, R_{ISET} = 5.36kΩ, V_{ACTL} >1.28V	19	20	21	mA
LED´s Current Matching			2V > V_{LED} > 0.7V, R_{ISET} = 5.36kΩ, V_{ACTL} >1.28V, Calculating ($I_{(MAX)}$ – $I_{(MIN)}$ / $I_{AVERAGE}$ x 100%)	--	--	3	%
RISET Pin Voltage		V_{RISET}	R_{ISET} = 5.36kΩ, V_{ACTL} > 1.28V	--	1.21	--	V
Input Current of ACTL		I_{ACTL}	0.3V ≤ V_{ACTL} ≤ 1.2V	--	--	2	μA

To be continued

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

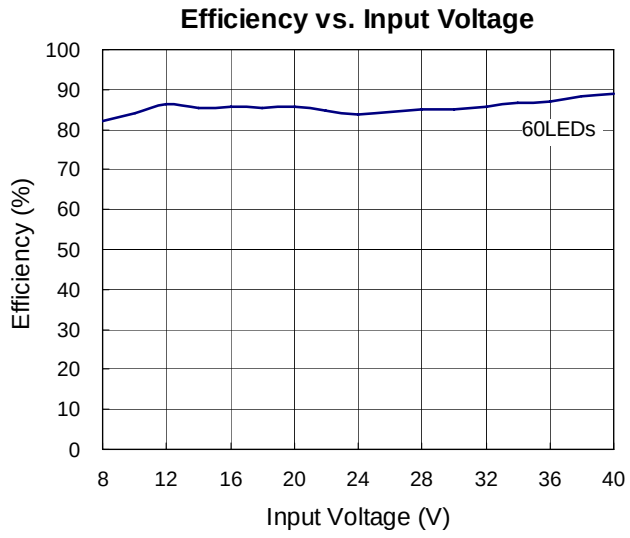
Note 1. Stresses listed as the above "Absolute Maximum Ratings" may cause permanent damage to the device. These are for stress ratings. Functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure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

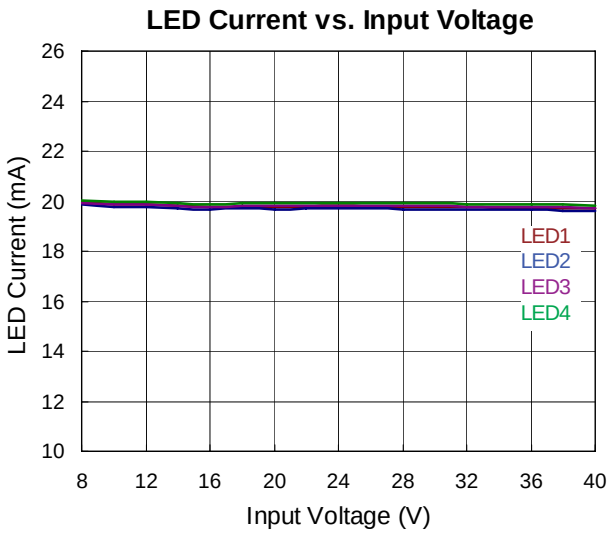
Note 2. θ_{JA} is measured in the natural convection at T_A = 25°C on a high effective four layers thermal conductivity test board of JEDEC 51-7 thermal measurement standard. The case point of θ_{JC} is on the expose pad for the WQFN package.

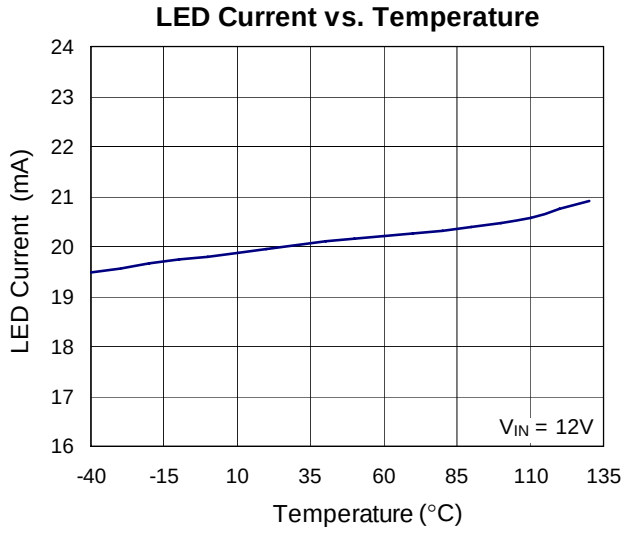
Note 3. Devices are ESD sensitive. Handling precaution is recommended.

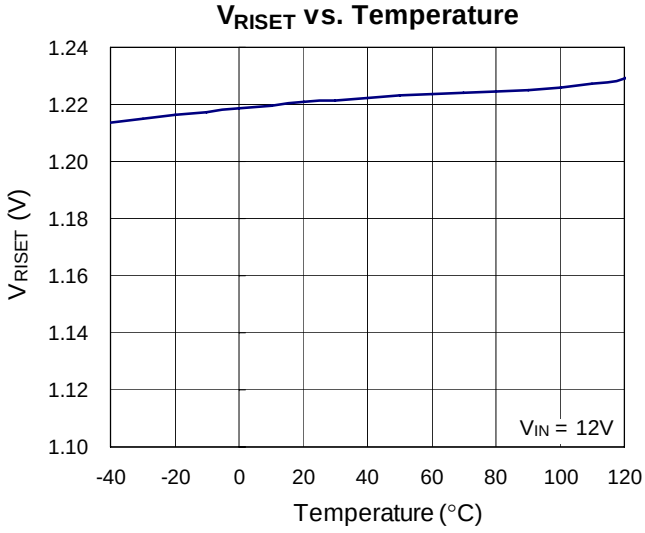
Note 4. The device is not guaranteed to function outside its operating conditions.

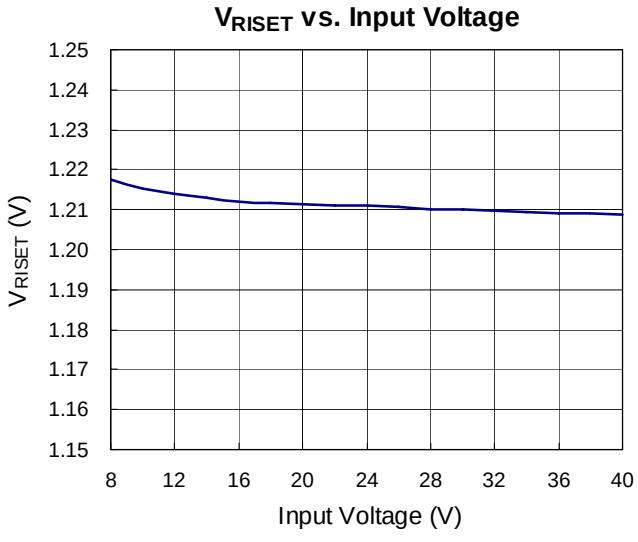
Typical Operating Characteristics

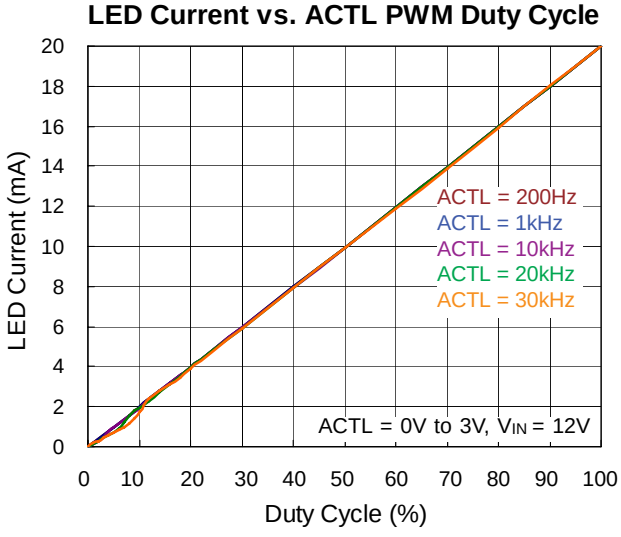


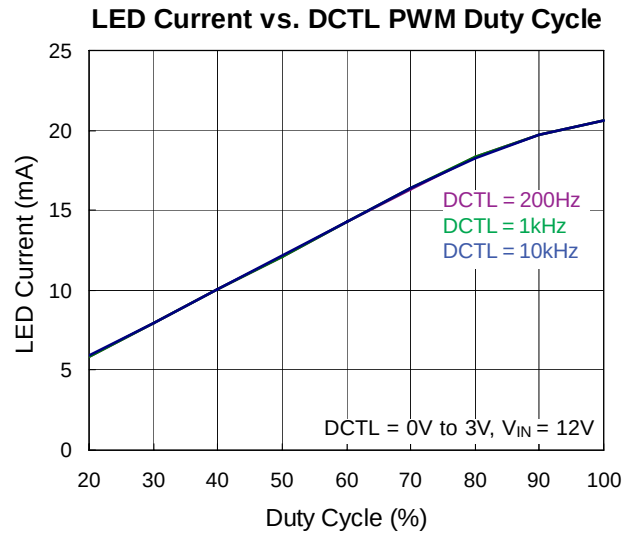


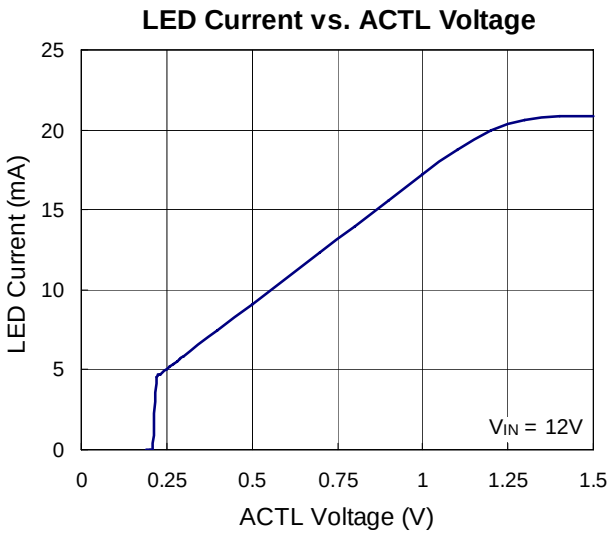


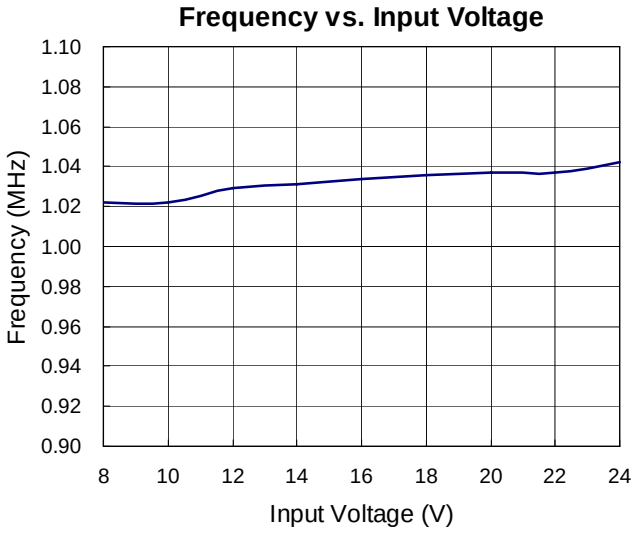


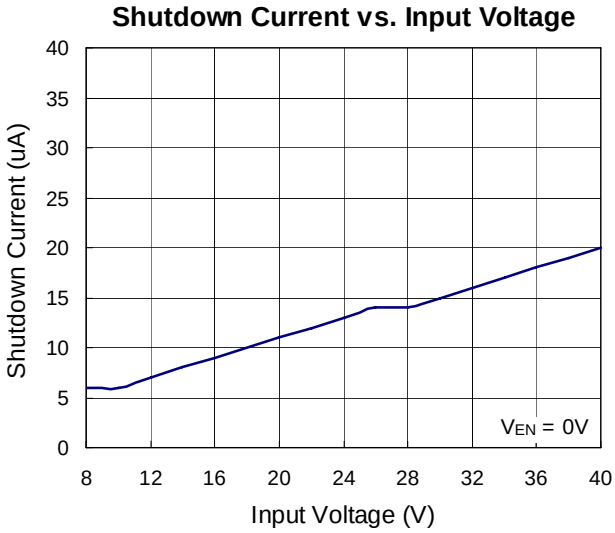


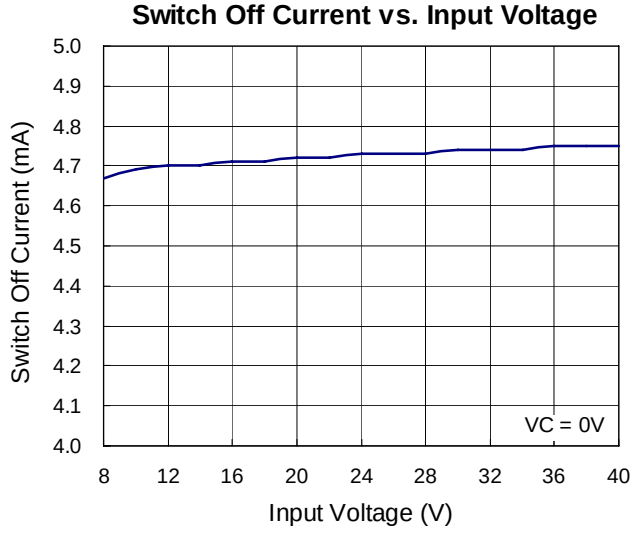


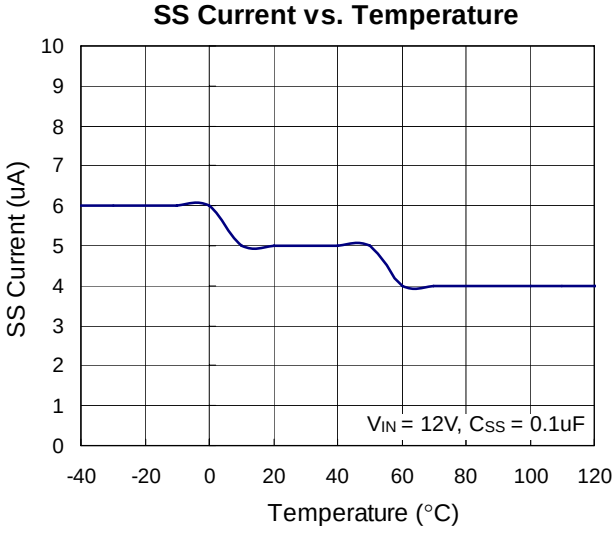

LED Current vs. DCTL PWM Duty Cycle
LED Current (mA)
Duty Cycle (%)
DCTL = 200Hz
DCTL = 1kHz
DCTL = 10kHz
DCTL = 0V to 3V, VIN = 12V


LED Current vs. ACTL Voltage
LED Current (mA)
ACTL Voltage (V)
VIN = 12V

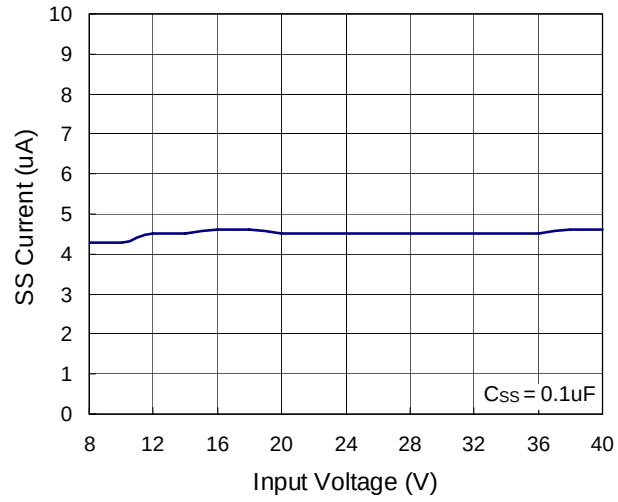

Frequency vs. Input Voltage
Frequency (MHz)
Input Voltage (V)


Shutdown Current vs. Input Voltage
Shutdown Current (uA)
Input Voltage (V)
VEN = 0V

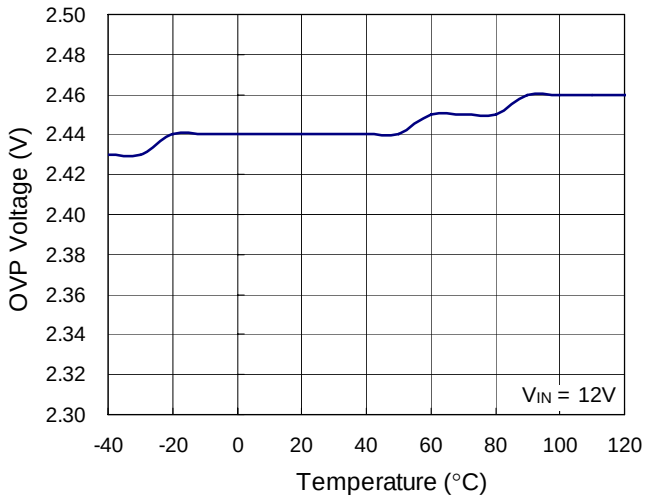

Switch Off Current vs. Input Voltage
Switch Off Current (mA)
Input Voltage (V)
VC = 0V


SS Current vs. Temperature
SS Current (uA)
Temperature (°C)
VIN = 12V, CSS = 0.1uF

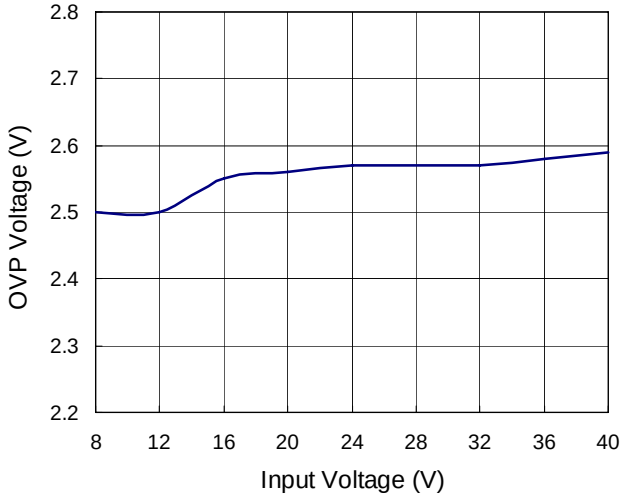
SS Current vs. Input Voltage



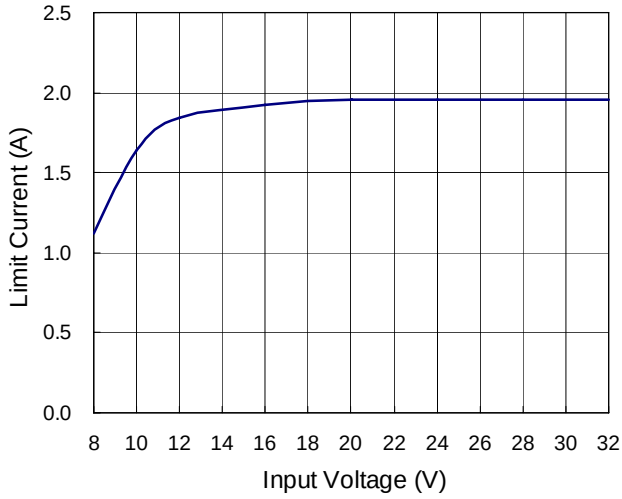
OVP Voltage vs. Temperature



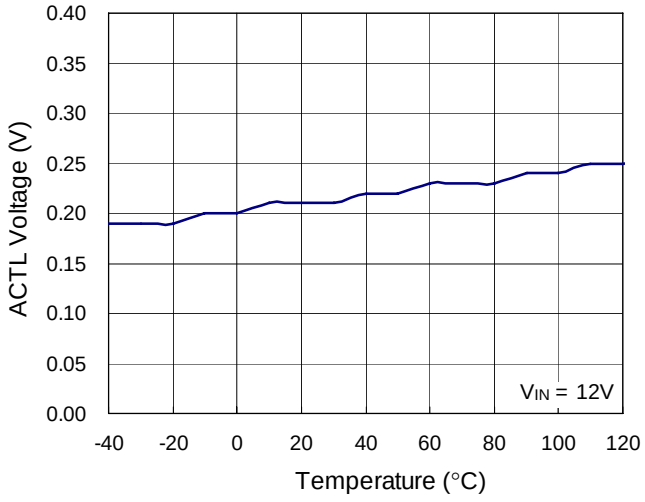
OVP Voltage vs. Input Voltage



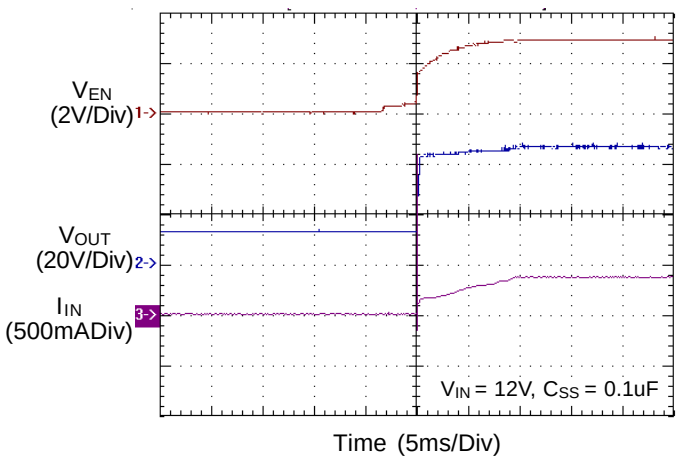
Limit Current vs. Input Voltage



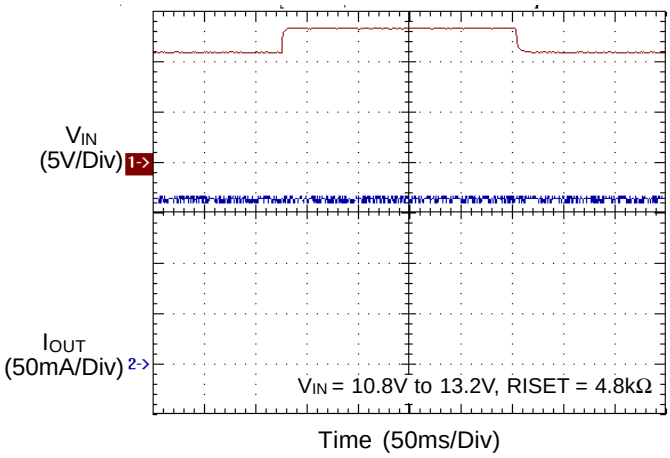
ACTL Voltage vs. Temperature



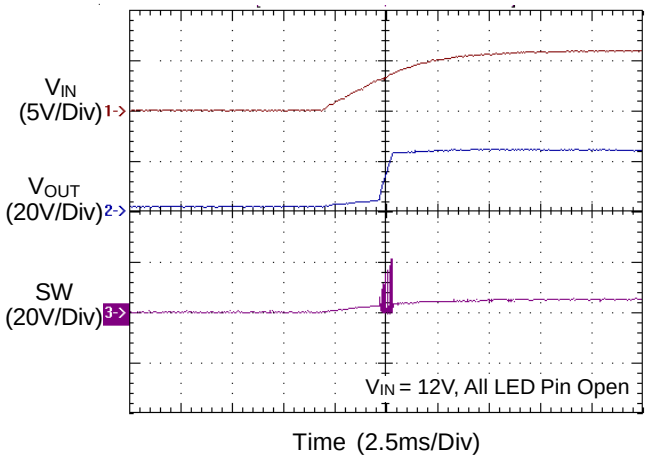
Power On from EN



Line Transient Response



OVP



Applications Information

The RT8560A 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 RT8560A is 6V 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 5.5V.

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.

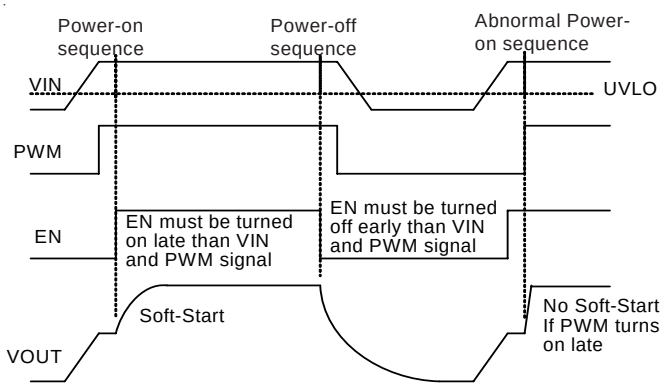


Figure 5. Power-On Sequence Control by EN

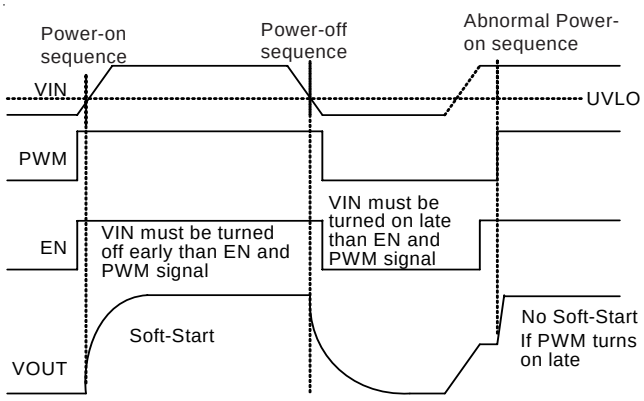


Figure 6. Power-On Sequence Control by VIN

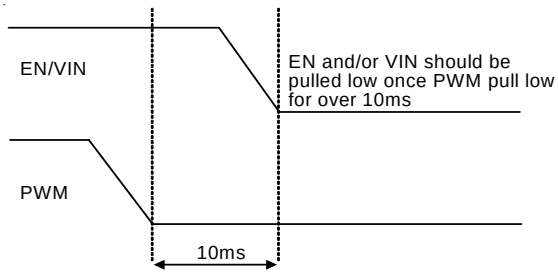


Figure 7. To Prevent "Hard-Start" Sequence

Soft Start

The RT8560A 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 RT8560A equips 4 channel LED divers 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 :

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

Where,

V_{RISET} is the voltage of the RISET pin (1.21V typ.) and the R_{ISET} is the resister between RISET 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 RT8560A 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%.

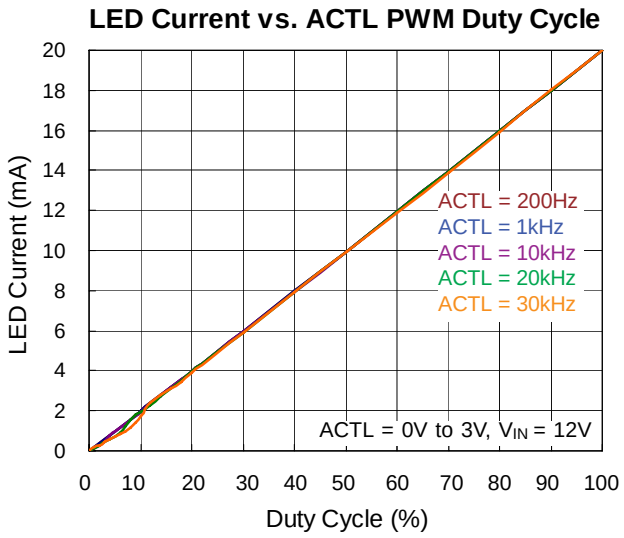


Figure 8. LED Current vs. PWM Dimming Duty Cycle

Over Voltage Protection

The RT8560A 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 RT8560A can limit the peak current to achieve over current protection. The RT8560A 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 RT8560A 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 :

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

Where,

V_{OUT} = maximum output voltage.

V_{IN} = minimum input voltage.

f = operating frequency.

I_{OUT} = sum of current from all LED strings.

The boost converter operates in discontinuous mode over the entire input voltage range when the L1 inductor value is less than this value L. With an inductance greater than L, the converter operates in continuous mode at the minimum input voltage and may be discontinuous at higher voltages.

The inductor must be selected with a saturated current rating that is greater than the peak current provided by the following equation :

$$I_{PEAK} = \frac{V_{OUT} \times I_{OUT}}{\eta \times V_{IN}} + \frac{V_{IN} \times T}{2 \times L \times} \left(\frac{V_{OUT} - V_{IN}}{V_{OUT}} \right)$$

Where,

η is the efficiency of the power converter.

Diode Selection

Schottky diode is a good choice for an asynchronous Boost converter due to the small forward voltage. However, power dissipation, reverse voltage rating and pulsating peak current are the important parameters for Schottky diode selection. Choose a suitable diode whose reverse voltage rating is greater than the maximum output voltage.

Capacitor Selection

The input capacitor reduces current spikes from the input supply and minimizes noise injection to the converter. For most applications, a 10uF ceramic capacitor is sufficient. A value higher or lower may be used depending on the noise level from the input supply and the input current to the converter.

It is recommended to choose a ceramic capacitor bases on the output voltage ripple requirements. The minimum value of the output capacitor C_{OUT} is approximately given by the following equation :

$$C_{OUT} = \frac{(V_{OUT} - V_{IN}) \times I_{OUT}}{\eta \times V_{RIPPLE} \times V_{OUT} \times f}$$

Layout Guideline

PCB layout is very important for designing power switching converter circuits. Some recommended layout guides that should be strictly be followed are shown as follows :

- The power components L, D, C_{VIN}, C_{OUT1} and C_{OUT2} must be placed as close as possible to reduce the ac current loop. The PCB trace between power components must be as short and wide as possible due to large current stream flows through these traces during operation.
- Place L and D connected to SW pin as close as possible. The trace should be short and wide as possible.
- It is recommended to place C_{Vcc1} and C_{Vcc2} close to V_{CC1} and V_{CC2} pins.
- Pin14 is the compensation point to adjust system stability. Place the compensation components to pin14 as close as possible, no matter the compensation is RC or capacitance.

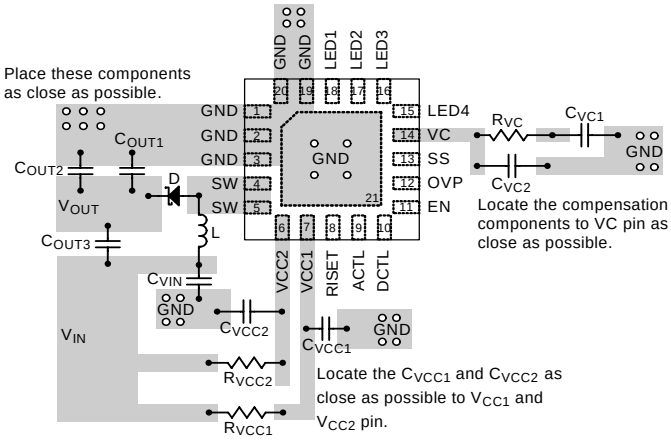
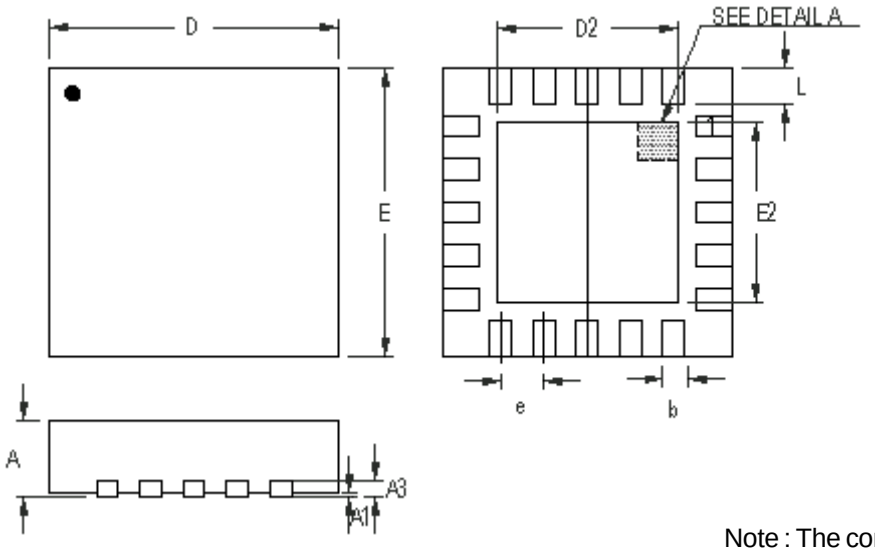
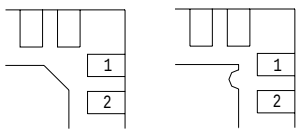


Figure 9. PCB Layout Guide

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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