43V 4-CH LED Driver

General Description

The RT8510 is a high efficiency driver for white LEDs. It is designed for LCD panels that employ an array of LEDs as the lighting source. An integrated switch current mode boost controller drives four strings in parallel and supports up to 12 pieces of LED per string. The internal current sinks support a maximum of ±2% current mismatching for excellent brightness uniformity in each string of LED. To provide enough headroom for current sink operation the boost controller monitors the minimum voltage of feedback pins and regulates an optimized output voltage for power efficiency.

The RT8510 has a wide input voltage range from 4.2V to 24V and provide an adjustable 10mA to 40mA LED current. The internal 200mΩ, 43V power switch with current-mode control provides cycle-by-cycle over current protection. RT8510 also integrates PWM dimming function for accurate LED current control. The input PWM dimming frequency can operate from 120Hz to 30kHz without inducing any inrush current through the LED or inductor. The switching frequency of the RT8510 is adjustable from 500kHz to 2MHz, allowing the user flexibility between efficiency and component size.

The RT8510 is available in a WQFN-16L 3x3 package.

Ordering Information

RT8510□□

- Package Type
  QW : WQFN-16L 3x3 (W-Type)
- Lead Plating System
  G : Green (Halogen Free and Pb Free)
  Z : ECO (Ecological Element with 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.

Features

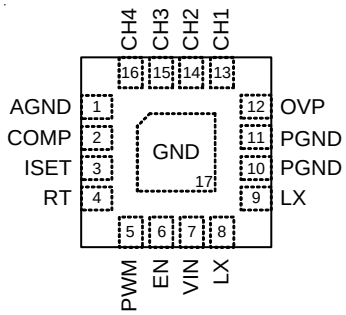
- **Wide Input Voltage : 4.2V to 24V**
- **High Output Voltage : Up to 43V**
- **Adjustable Channel Current : 10mA to 40mA**
- **Channel Current Accuracy : ±3%**
- **Channel Current Matching : ±2%**
- **PWM Dimming Frequency : 120Hz to 30kHz**
- **Adjustable Switching Frequency : 500kHz to 2MHz**
- **Built-In Soft-Start**
- **Disconnects LED in Shutdown**
- **Open Current Sink Detection**
- **Adjustable Over Voltage Protection**
- **Over Temperature Protection**
- **Current Limit Protection**
- **Thin 16-Lead WQFN Package**
- **RoHS Compliant and Halogen Free**

Applications

- UMPC and Notebook Computer Backlight
- GPS, Portable DVD Backlight

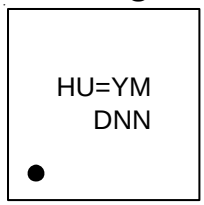
Pin Configurations

(TOP VIEW)



WQFN-16L 3x3

Marking Information



HU= : Product Code

YMDNN : Date Code

Typical Application Circuit

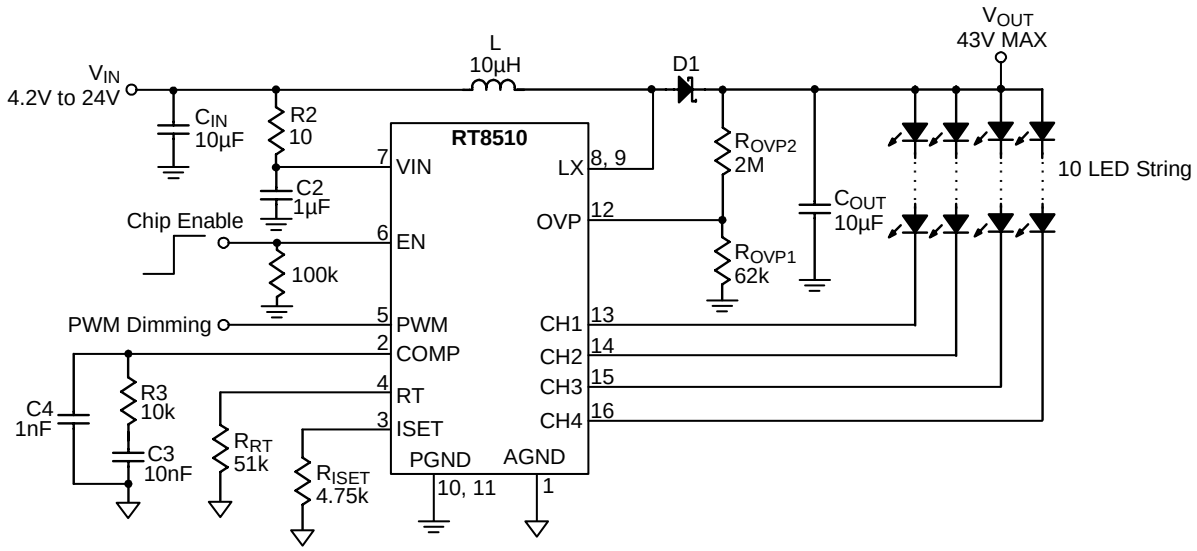


Figure 1. General Application Circuit

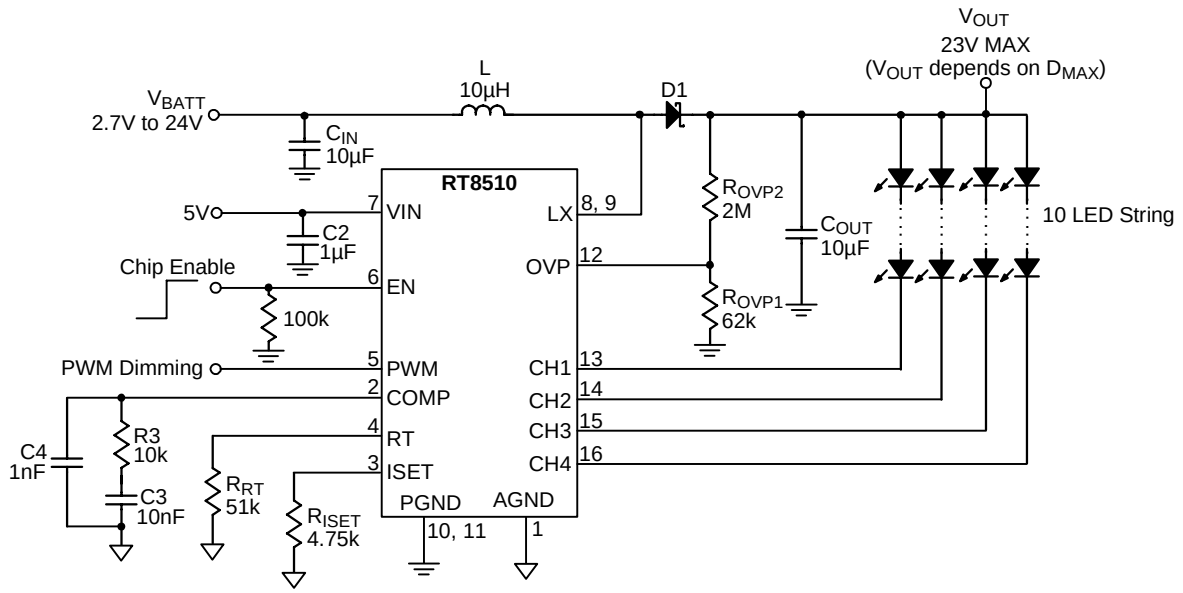
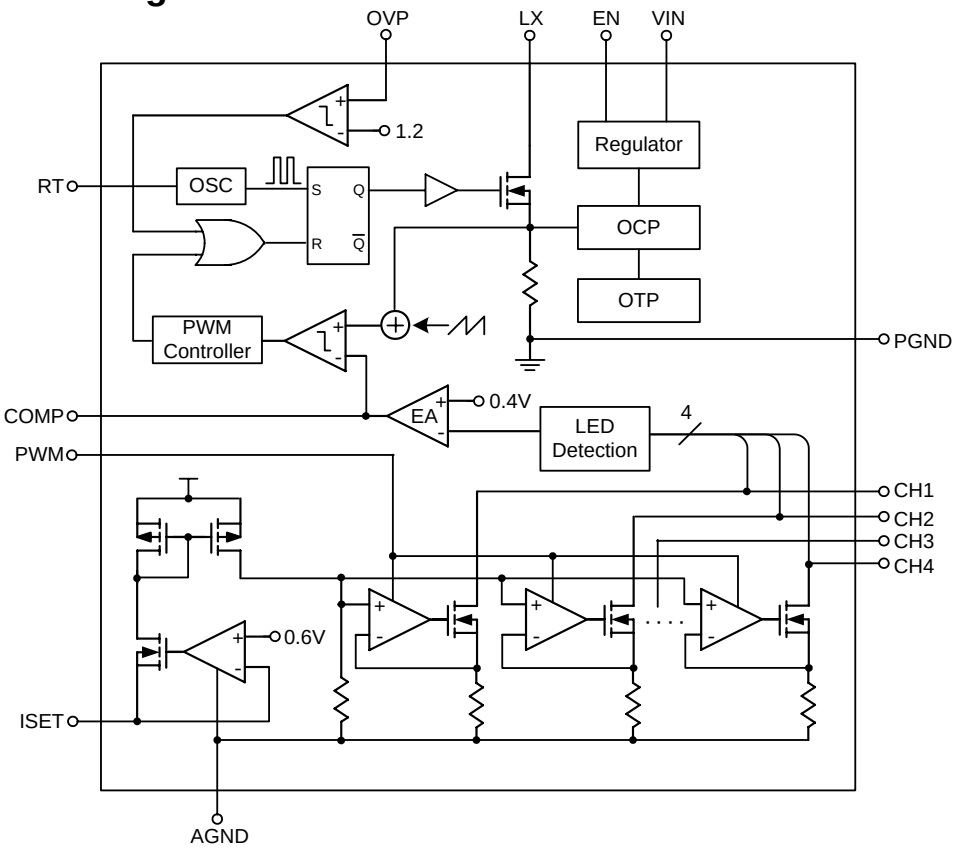


Figure 2. Low Input Voltage Application Circuit

Function Pin Description

Pin No.	Pin Name	Pin Function
1	AGND	Analog Ground of LED Driver.
2	COMP	Compensation Pin for Error Amplifier. Connect a compensation network to ground.
3	ISET	LED Current Set Pin. LED current is set by the value of the resistor R_{ISET} connected from the ISET pin to ground. Do not short the ISET pin. V_{ISET} is typically 0.6V. $I_{LED} = \frac{95}{R_{ISET}}$
4	RT	Frequency Adjust Pin. This pin allows setting the switching frequency with a resistor to 500kHz to 2MHz.
5	PWM	Dimming Control Input.
6	EN	Chip Enable (Active High). Note that this pin is high impedance. There should be a pull low 100kΩ resistor connected to GND when the control signal is floating.
7	VIN	Power Supply Input.
8, 9	LX	Switching Pin of Boost Converter.
10, 11	PGND	Power Ground of Boost Converter.
12	OVP	Sense Input for Over Voltage Protection. The detecting threshold is 1.2V.
13, 14, 15, 16	CH1 to CH 4	Current Sink for LED. Leave the pin unconnected, if not used.
17 (Exposed Pad)	GND	The exposed pad must be soldered to a large PCB and connected to GND for maximum power dissipation.

Function Block Diagram



Absolute Maximum Ratings (Note 1)

- Supply Input Voltage to GND ---------- –0.3V to 26.5V
- EN, PWM, ISET, COMP, RT to GND ---------- –0.3V to 26.5V
- LX, OVP, CH1, CH2, CH3, CH4 to GND ---------- –0.3V to 48V
- Power Dissipation, P_D @ T_A = 25°C
  WQFN-16L 3x3 ---------- 1.471W
- Package Thermal Resistance (Note 2)
  WQFN-16L 3x3, θ_{JA} ---------- 68°C/W
  WQFN-16L 3x3, θ_{JC} ---------- 7.5°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 ---------- 2kV
  MM ---------- 200V

Recommended Operating Conditions (Note 4)

- Supply Input Voltage, V_{IN} ---------- 4.2V to 24V
- Junction Temperature Range ---------- –40°C to 125°C
- Ambient Temperature Range ---------- –40°C to 85°C

Electrical Characteristics

(V_{IN} = 4.5V, T_A = 25°C unless otherwise specified)

Parameter		Symbol	Test Conditions	Min	Typ	Max	Unit
VIN Quiescent Current		I_Q	V_{COMP} = 0V, No Switching	--	1	1.5	mA
			V_{COMP} = 2V, Switching		2	3	
VIN Shutdown Current		I_{SHDN}	V_{IN} = 4.5V, EN = 0V	--	--	10	μA
VIN Under Voltage Lockout		UVLO	Rising	--	2.2	--	V
			Falling	--	2.1	--	
Control Input							
EN, PWM Threshold Voltage	Logic-High	V_{IH}	V_{IN} = 4.2V to 24V	2	--	--	V
	Logic-Low	V_{IL}		--	--	0.8	
PWM Dimming Frequency		f_{PWM}		120	--	30k	Hz
EN, PWM Leakage Current		I_{LKG}		2	--	6	μA
EN Shutdown Delay		t_{EN}	R_{RT} = 51kΩ	--	32	--	ms
Boost Converter							
Switching Frequency		f_{OSC}	R_{RT} = 25kΩ	--	2	--	MHz
			R_{RT} = 51kΩ	--	1	--	
			R_{RT} = 102kΩ	--	0.5	--	
LX On Resistance (N-MOSFET)		$R_{DS(ON)_N}$	V_{IN} > 4.5V	--	0.2	0.32	Ω
Minimum ON Time		t_{MON}		--	120	--	ns
Maximum Duty		D_{MAX}	V_{COMP} = 2V, Switching	--	90	--	%
LX Current Limit		I_{LIM}		--	2	--	A

To be continued

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
LED Current Programming						
LED Current Matching	I_{LEDM}	2V > CHx > 0.4V Calculating $(I_{(MAX)} - I_{(AVG)}) / I_{(AVG)}$ x 100%, R_{ISET} = 4.75kΩ	--	--	±2	%
ISET Pin Voltage	V_{ISET}		--	0.6	--	V
LED Current	I_{CHx}	2V > CHx > 0.4V, R_{ISET} = 4.75kΩ	19.4	20	20.6	mA
Fault Protection						
OVP Threshold	V_{OVP}		1.16	1.2	1.24	V
OVP Fail Threshold	V_{OVPF}		--	50	--	mV
Thermal Shutdown Temperature	T_{SD}		--	160	--	°C
LED Pin Under Voltage Threshold	V_{LSD}	No Connection	--	50	--	mV
Regulated V_{CHx}	V_{CHx}	Highest LED String Voltage, R_{ISET} = 4.75kΩ	--	0.4	--	V

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.

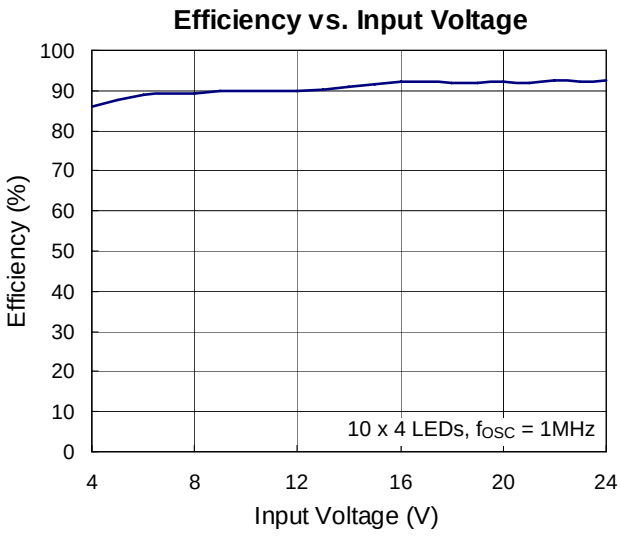
Note 2. θ_{JA} is measured in natural convection at T_A = 25°C on a high-effective thermal conductivity four-layer test board of JEDEC 51-7 thermal measurement standard. The measurement case position of θ_{JC} is on the exposed pad of the package

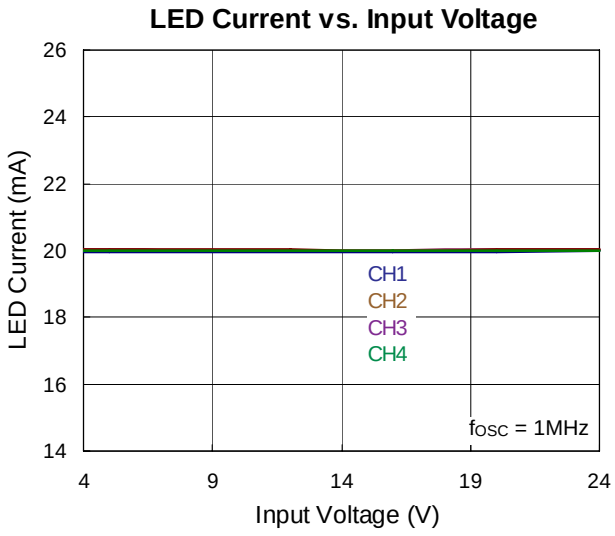
Note 3. Devices are ESD sensitive. Handling precaution is recommended.

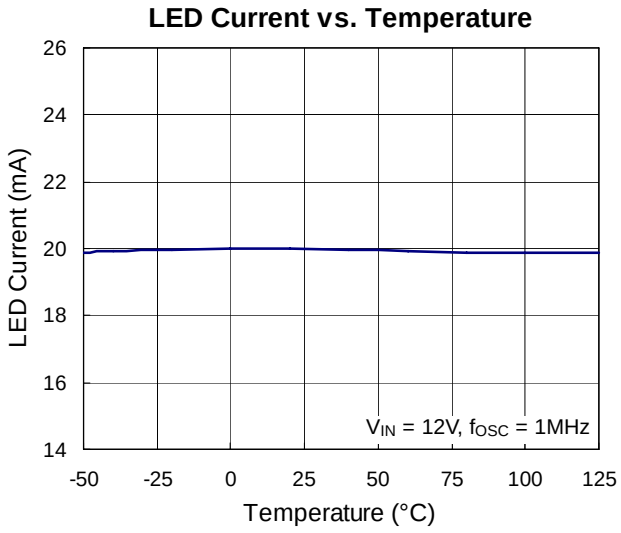
Note 4. The device is not guaranteed to function outside its operating conditions.

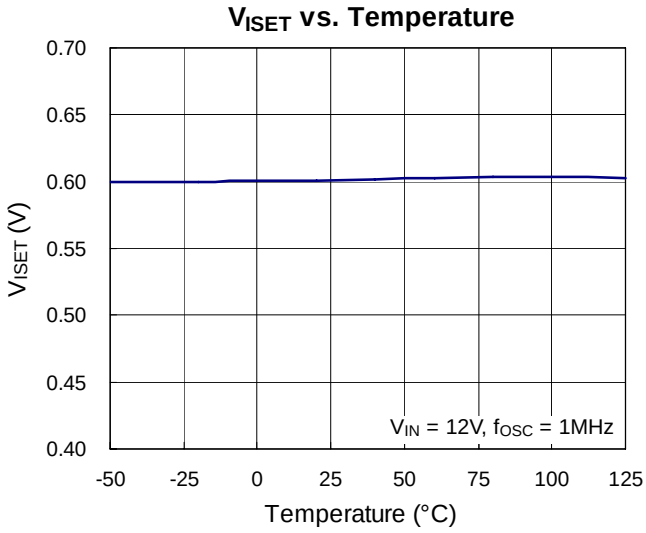
Note 5. Guaranteed by design; not subject to production testing.

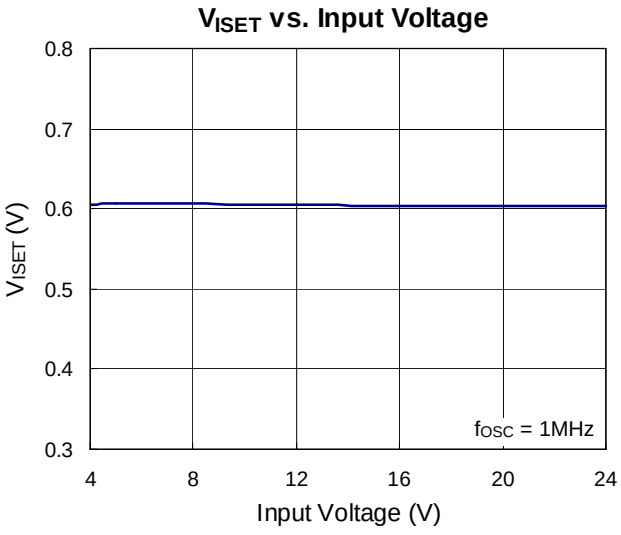
Typical Operating Characteristics

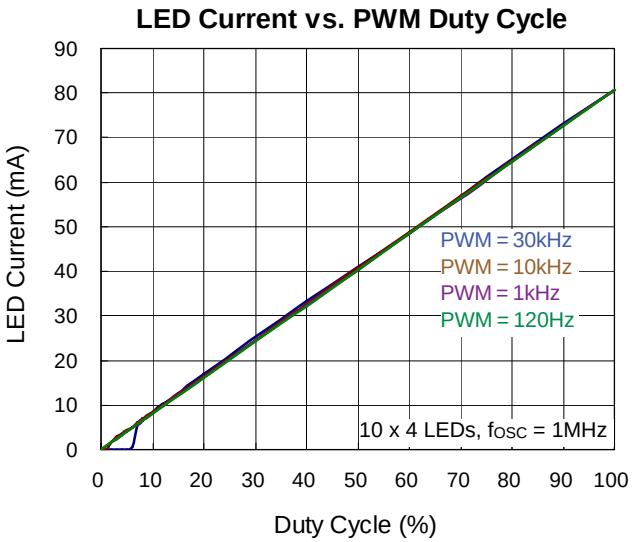


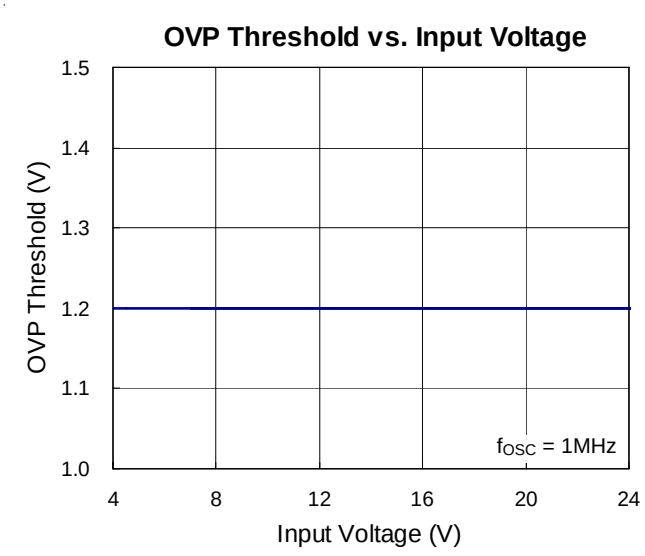


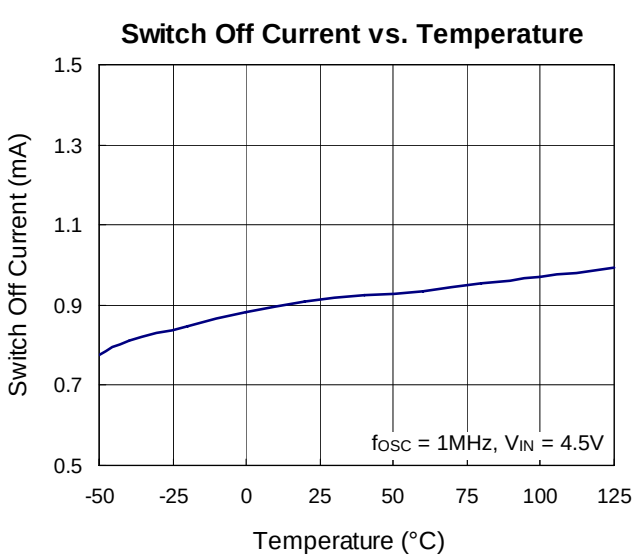


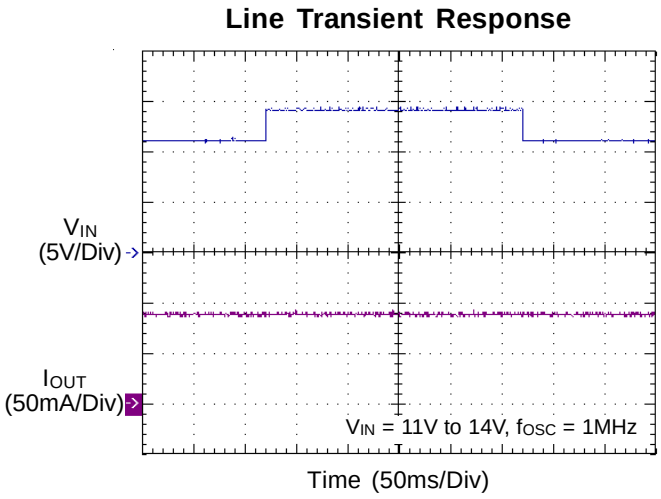


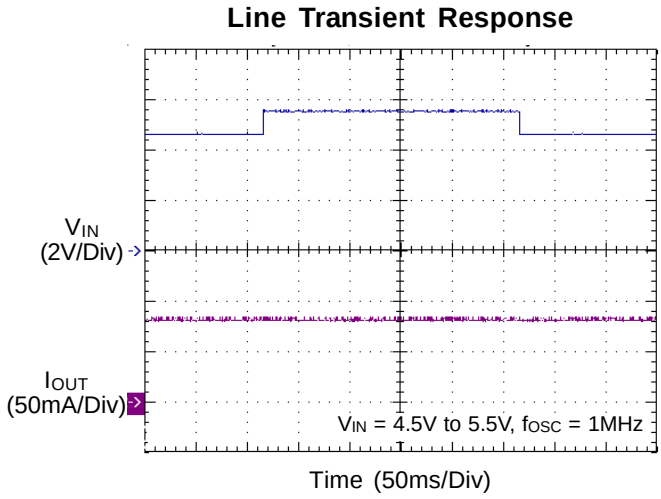





OVP Threshold vs. Input Voltage
OVP Threshold (V)
1.5
1.4
1.3
1.2
1.1
1.0
4
8
12
16
20
24
Input Voltage (V)
fOSC = 1MHz


Switch Off Current vs. Temperature
Switch Off Current (mA)
1.5
1.3
1.1
0.9
0.7
0.5
-50
-25
0
25
50
75
100
125
Temperature (°C)
fOSC = 1MHz, VIN = 4.5V


Line Transient Response
VIN
(5V/Div)
IOUT
(50mA/Div)
VIN = 11V to 14V, fOSC = 1MHz
Time (50ms/Div)


Line Transient Response
VIN
(2V/Div)
IOUT
(50mA/Div)
VIN = 4.5V to 5.5V, fOSC = 1MHz
Time (50ms/Div)

Application Information

The RT8510 is a general purpose 4-CH LED driver capable of delivering an adjustable 10 to 40mA LED current. The IC is a current mode boost converter integrated with a 43V/2A power switch and can cover a wide V_{IN} range from 4.2V to 24V. The switching frequency is adjustable by an external resistor from 500kHz to 2MHz. The part integrates built-in soft start, with PWM dimming control; moreover, it provides over voltage, over temperature and current limiting protection features.

Soft-Start

The RT8510 equips a built-in soft-start feature to prevent high inrush current during start-up. The soft-start function prevents excessive input current and input voltage droop during power on state.

Compensation

The control loop can be compensates by adjusting the external components connected to the COMP pin. The COMP pin is the output of the internal error amplifier. The compensation capacitors, C3 and C4, will adjust the integrator zero and pole respectively to maintain stability. Moreover, the resistor, R3, will adjust the frequency integrator gain for fast transient response.

Switching Frequency

The LED driver switching frequency is able to adjusted as the following equation :

$$f_{OSC} \cong \frac{51k}{R_{RT}} \text{ (MHz)}$$

LED Connection

The RT8510 equips 4-CH LED divers with each channel supporting up to 12 LEDs. If the boost converter input voltage too close to the output voltage, V_{OUT} ripple will be increased. To prevent this phenomenon, please keep V_{OUT} higher than 1.2 x V_{IN}. The LED strings are connected from the output of the boost converter to pins 13, 14, 15 and 16 respectively. If one of the LED channel is not used, the LED pin should be opened directly.

Duty pulse close to minimum on time and small than 120ns, we will skip duty clock. The Figure 3. shows the pulse skipped time diagram.

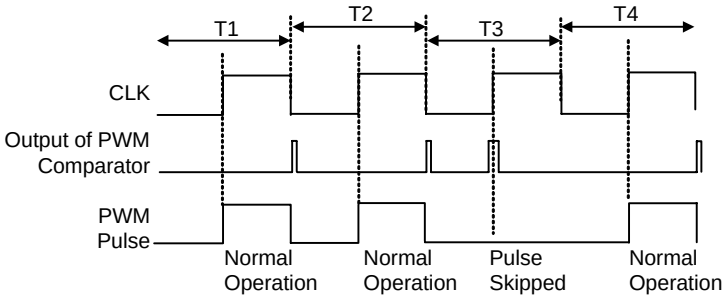


Figure 3. Pulse Skip Mode

Setting and Regulation of LED Current

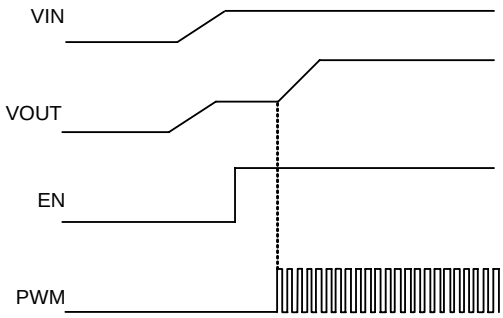
The LED current can be calculated by the following equation :

$$I_{LED} \cong \frac{95}{R_{ISET}}$$

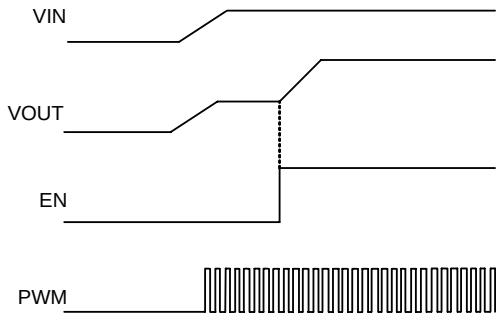
where R_{ISET} is the resistor between the ISET pin and GND. This setting is the reference for the LED current at channel 1-4 and represents the sensed LED current for each string. The DC/DC converter regulates the LED current according to R_{ISET}.

Power Sequence

LED Driver is without power sequence concern. Figure 4, Figure 5 and Figure 6 are different power sequences respectively. There is no concern in the above condition.

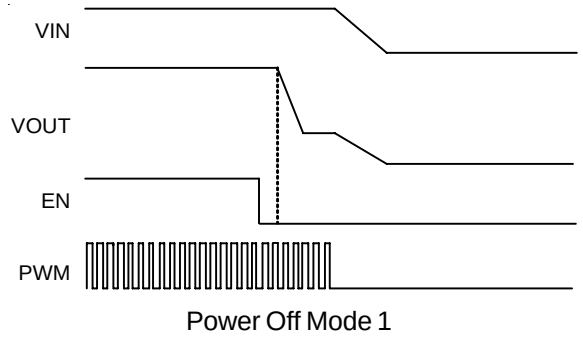


Power On Mode 1

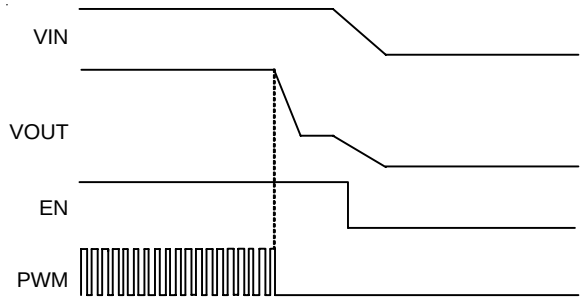


Power On Mode 2

Figure 4

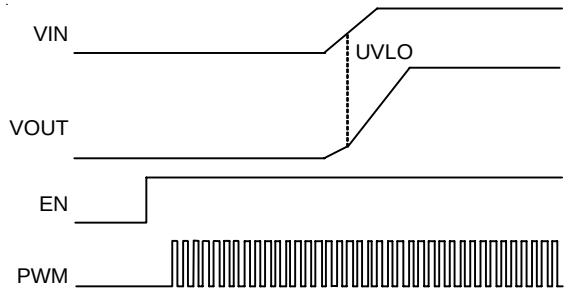


Power Off Mode 1

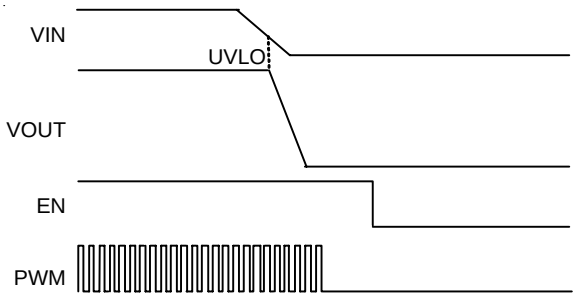


Power Off Mode 2

Figure 5



Power On Mode 3



Power On Mode 3

Figure 6

Over Voltage Protection

The RT8510 integrates over voltage protection (OVP) function. When the voltage at the OVP pin reaches the threshold voltage, the internal switch will be turned off. The internal switch will be turned on again once the voltage at OVP pin drops below its threshold voltage.

The OVP threshold voltage is adjustable and can be clamped at a certain voltage level and it can be calculated by the following equation :

$$V_{OUT(OVP)} = V_{OVP} \times \left(1 + \frac{R_{OVP2}}{R_{OVP1}}\right)$$

where V_{OVP} = 1.2V (typ.).

R_{OVP1} and R_{OVP2} are the resistors in the voltage divider connected to the 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 strings in normal operation. It is suggested to use 2MΩ for R_{OVP2} to reduce loading effect.

Current Limit Protection

The RT8510 can limit the peak current to achieve over current protection. The RT8510 senses the inductor current during the "ON" period that flows through the LX pin. The duty cycle depends on the current signal and internal slope compensation in comparison with the error signal. The internal switch will be turned off when the current signal is larger than the internal slope compensation. In the "OFF" period, the inductor current will be decreased until the internal switch is turned on by the oscillator.

Brightness Control

The RT8510 brightness dimming control is determined by the signal on the PWM pin with a suggested PWM frequency range from 120Hz to 30kHz. However, the LED current cannot be 100% proportional to duty cycle especially for high frequency and low duty ratio because of physical limitation caused by inductor rising time. Please refer to Table 1 and Figure 7.

Table 1.

Dimming Frequency (Hz)	Duty (Min.)	Duty (Max.)
120 < f_{PWM} ≤ 500	0.2%	100%
500 < f_{PWM} ≤ 1k	0.4%	100%
1k < f_{PWM} ≤ 2k	0.8%	100%
2k < f_{PWM} ≤ 5k	1.5%	100%
5k < f_{PWM} ≤ 10k	3%	100%
10k < f_{PWM} ≤ 30k	10%	100%

Note : The minimum duty in Table 1 is based on the application circuit and does not consider the deviation of current linearity.

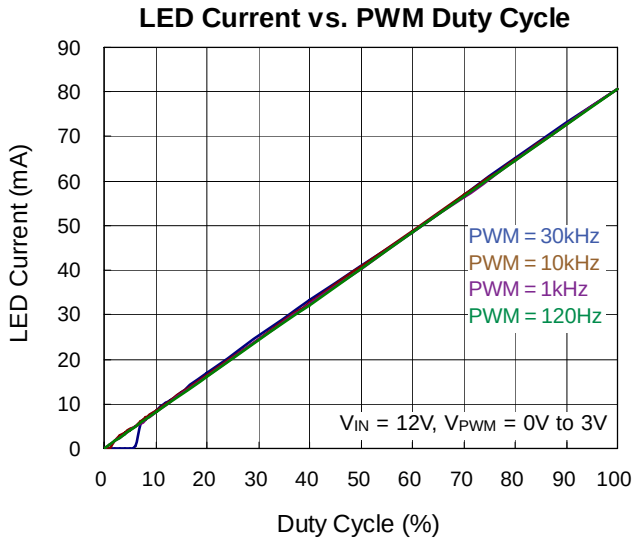


Figure 7

Over Temperature Protection

The RT8510 has over temperature protection function to prevent the IC from overheating due to excessive power dissipation. The OTP function will shutdown the IC when junction temperature exceeds 160°C .

Inductor Selection

The value of the inductance L can be approximated by the following equation, where the transition is from discontinuous conduction mode (DCM) to continuous conduction mode (CCM) :

$$L = \frac{D \times (1-D)^2 \times V_{OUT}}{2 \times f_{OSC} \times I_{OUT}}$$

The duty cycle can be calculated according to the following equation :

$$D = \frac{V_{OUT} - V_{IN}}{V_{OUT}}$$

where V_{OUT} is the maximum output voltage, V_{IN} is the minimum input voltage, f_{OSC} is the operating frequency and I_{OUT} is the total current from all LED strings.

The boost converter operates in DCM over the entire input voltage range when the inductor value is below this value L. When inductance greater is than L, the converter operates in CCM 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 :

$$I_{PEAK} = \frac{V_{OUT} \times I_{OUT}}{\eta \times V_{IN}} + \frac{V_{IN} \times D \times T}{2 \times L}$$

where η is the efficiency of the power converter and T is the operating period.

Diode Selection

Schottky diodes are recommended for most applications because of their fast recovery time and low forward voltage. The power dissipation, reverse voltage rating and pulsating peak current are the important parameters for Schottky diode selection. Make sure that the diode's peak current rating exceeds I_{PEAK} and reverse voltage rating exceeds the maximum output voltage.

Output Capacitor Selection

The input capacitor reduces current spikes from the input supply and minimizes noise injection to the converter. For most applications, a 10μF 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.

For lower output voltage ripple, a low ESR ceramic capacitor is recommended. The output voltage ripple consists of two components: one is the pulsating output ripple current flowing through the ESR, and the other is

$$V_{RIPPLE} = V_{RIPPLE_ESR} + V_{RIPPLE_C}$$

$$\cong I_{PEAK} \times R_{ESR} + \frac{I_{PEAK}}{C_{OUT1}} \left(\frac{V_{AVDD} - V_{IN1}}{V_{AVDD} \times f \times \eta} \right)$$

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 of RT8510, the maximum junction temperature is 125°C and T_A is the ambient temperature. The junction to ambient thermal resistance, θ_{JA}, is layout dependent. For WQFN-16L 3x3 packages, the thermal resistance, θ_{JA}, is 68°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) / (68°C/W) = 1.471W for WQFN-16L 3x3 package

The maximum power dissipation depends on the operating ambient temperature for fixed $T_{J(MAX)}$ and thermal resistance, θ_{JA}. For RT8510 package, the derating curve in Figure 8 allows the designer to see the effect of rising ambient temperature on the maximum power dissipation.

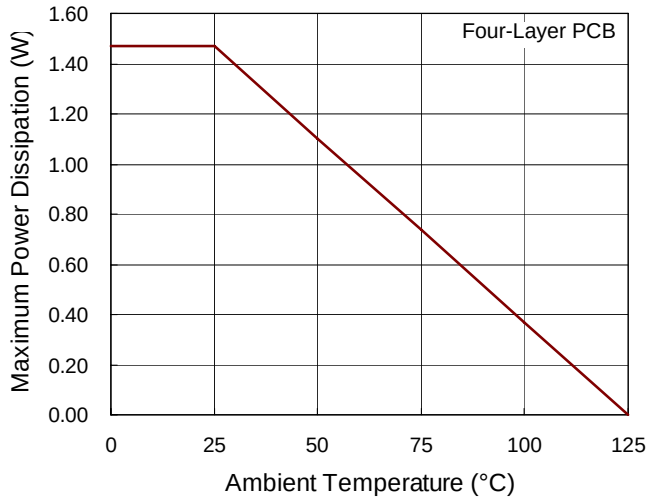


Figure 8. Derating Curve for RT8510 Package

Layout Considerations

PCB layout is very important for designing switching power converter circuits. The following layout guides should be strictly followed for best performance of the RT8510.

- The power components, L1, D1, C_{IN}, C_{OUT} must be placed as close as possible to reduce current loop. The PCB trace between power components must be as short and wide as possible.
- Place L1 and D1as close as possible to LX pin . The trace should be as short and wide as possible.
- The compensation circuit should be kept away from the power loops and should be shielded with a ground trace to prevent any noise coupling. Place the compensation components as close as possible to COMP pin.
- The exposed pad of the chip should be connected to ground plane for thermal consideration.

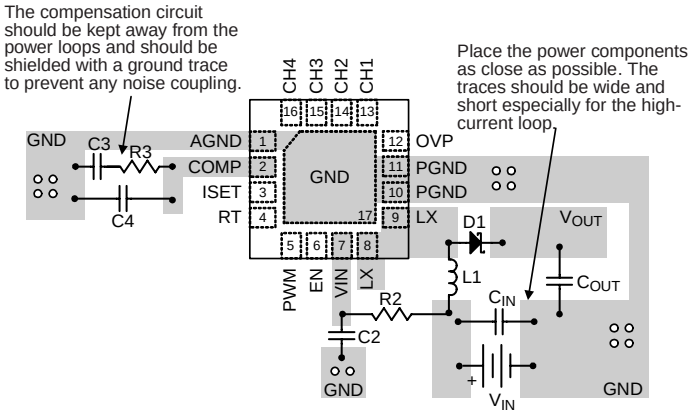
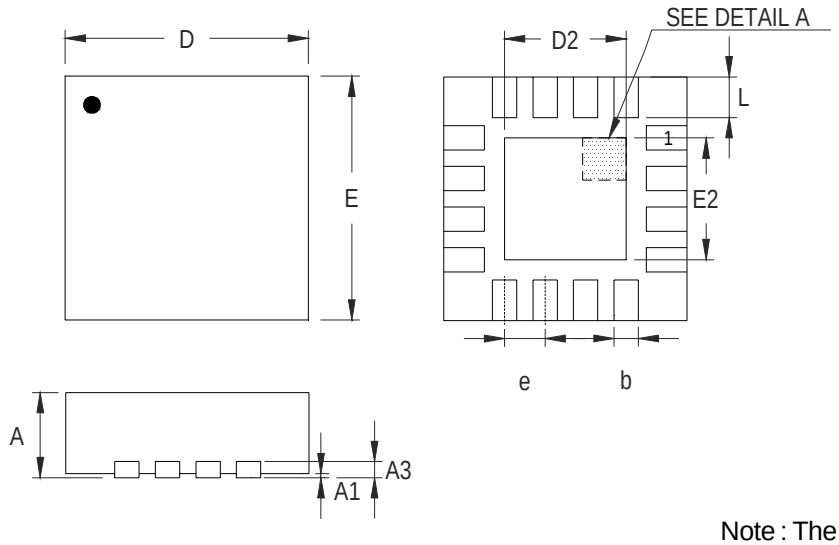
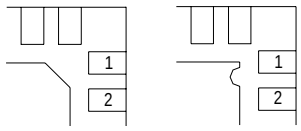


Figure 9. PCB Layout Guide

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	0.180	0.300	0.007	0.012
D	2.950	3.050	0.116	0.120
D2	1.300	1.750	0.051	0.069
E	2.950	3.050	0.116	0.120
E2	1.300	1.750	0.051	0.069
e	0.500		0.020	
L	0.350	0.450	0.014	0.018

W-Type 16L QFN 3x3 Package

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