Isolated Secondary Side 6-CH LED Driver with Optocoupler Driver

General Description

The RT8464 is an isolated secondary side 6-CH LED driver that delivers well matched LED current to each channel of LED strings. A built-in optocoupler driver supports the transformer primary side control circuit to regulate the LED current.

The LED current is linearly controlled by a high gain amplifier that drives the optocoupler to control the primary side, thus making the conventional secondary DC/DC PWM switching stage unnecessary. The RT8464 selects and regulates the LED strings with the highest voltage, hence it allows voltage mismatches between LED strings. The RT8464 automatically detects and disconnects any unconnected and/or broken strings during operation from the PWM loop to prevent V_{OUT} from over voltage.

The LED currents on all channels can be simply programmed with a resistor on each channel. Three convenient dimming methods are provided : 1. Analog dimming is linearly controlled by an external voltage; 2. True digitally controlled PWM dimming controls duty cycle of LED current; 3. PWM dimming signal can also be easily filtered into analog dimming signal for noise-free PWM dimming by the low pass filter with an external capacitor at ACTL pin. Other protecting features include output over voltage protection and thermal shutdown.

The RT8464 is available in the SOP-28 package.

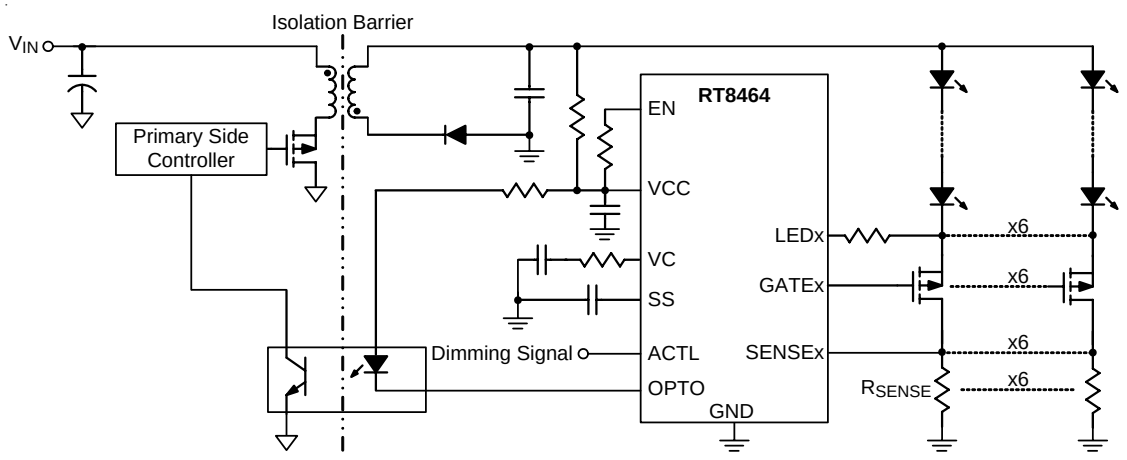
Features

- **High Voltage : V_{CC} up to 32V**
- **Channel Current Programmable**
- **3% Current Sense Threshold Voltage**
- **Easy Analog and Digital Dimming Control**
- **Adjustable Soft-Start to Avoid Inrush Current**
- **Automatic Detecting Unconnected Channel**
- **Adjustable Over Voltage Protection to Limit Output Voltage**
- **Thermal Shutdown Under Voltage Lockout**
- **SOP-28 Package**
- **RoHS Compliant and Halogen Free**

Applications

- Building and Street Lighting
- LED TV Backlight
- LED Monitor Backlight
- Industrial Display Backlight

Simplified Application Circuit



Ordering Information

RT8464 □□

Package Type
S : SOP-28

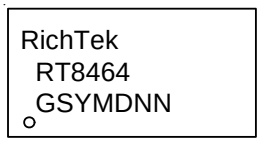
Lead Plating System
G : Green (Halogen Free and Pb Free)

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

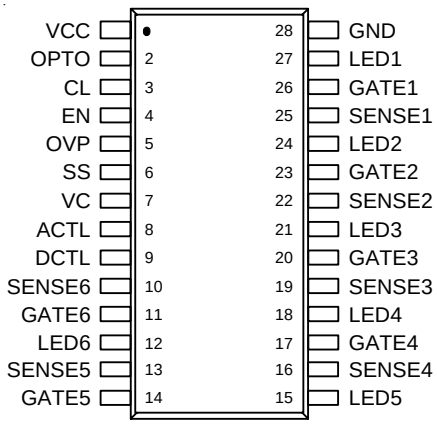


RT8464GS : Product Number

YMDNN : Date Code

Pin Configurations

(TOP VIEW)

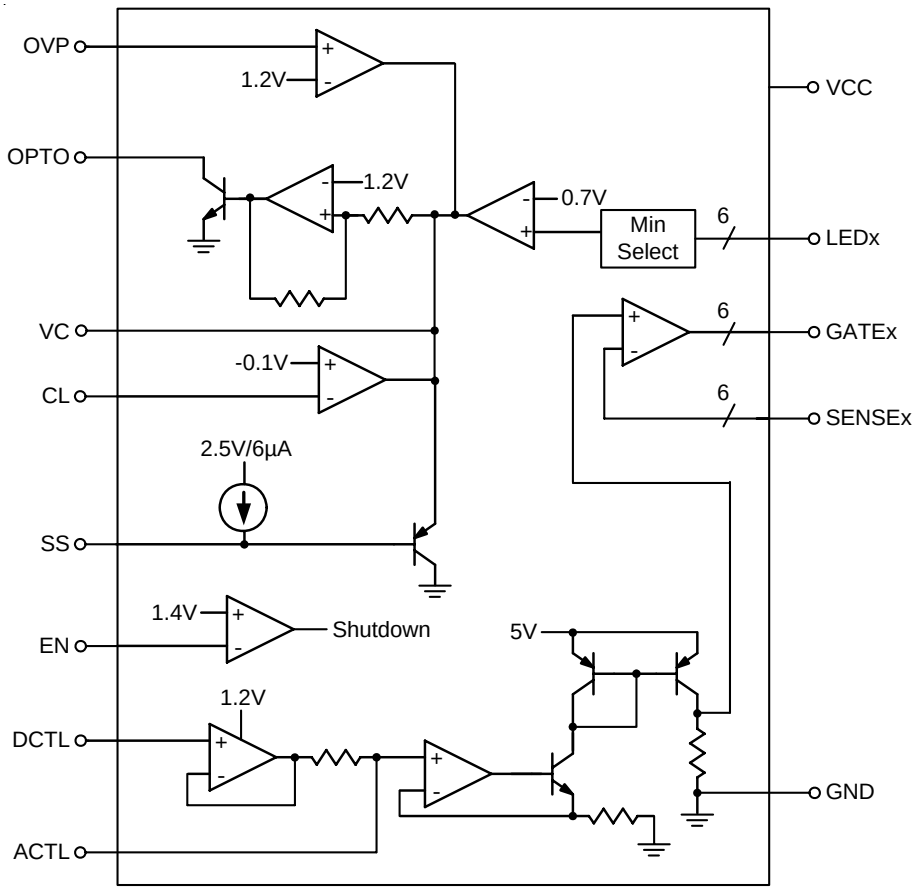


SOP-28

Functional Pin Description

Pin No.	Pin Name	Pin Function
1	VCC	Power Supply Input of the Chip. For good bypass, a low ESR capacitor is needed between this pin and GND.
2	OPTO	Optocoupler Driver. It is an open collector output of the internal NPN transistor.
3	CL	Current Limit. Current limit threshold is 100mV.
4	EN	Chip Enable. The chip is active when V_{EN} > 1.4V.
5	OVP	Over Voltage Detection Input. OVP pin threshold is 1.2V (typ.).
6	SS	Soft-Start. There is an internal constant current (6μA) to the SS pin during startup. Connect a capacitor to set soft-start time.
7	VC	PWM Loop Compensation.
8	ACTL	Analog/PWM Dimming Control Input. When using in analog dimming, ACTL control range is from 0.4V to 1.2V.
9	DCTL	Digital Dimming Control Input. By adding a 0.1μF filter capacitor at ACTL, the digital dimming signal at DCTL pin will be averaged out and converted into analog dimming signal at ACTL pin.
10, 13, 16, 19, 22, 25	SENSE6 to SENSE1	Current Sense Input for LED Current. The threshold is 215mV and I_{LED} = 0.215V / R_{SENSE}
11, 14, 17, 20, 23, 26	GATE6 to GATE1	Gate Drive Output for External Current Source MOSFETs.
12, 15, 18, 21, 24, 27	LED6 to LED1	LED String Voltage Sensing Input. This pin is connected to the Drain of external current source MOSFET.
28	GND	Ground.

Function Block Diagram



Operation

The RT8464 regulates the lowest cathode voltage of LED strings and generates a feedback control signal to a primary controller to regulate LED current. Each LED channel current is accurately matched and controlled by sensing an external resistor in series with the MOSEFT. LED current dimming in all six channels can be precisely controlled by either a PWM signal via the DCTL input pin or by an analog dimming voltage applied at the ACTL pin. Internal protection is provided for over current and over voltage at the secondary output. The device can be operated in low current shutdown mode by pulling the EN pin low.

Absolute Maximum Ratings (Note 1)

- Supply Voltage, VCC ---------- –0.3V to 34V
- SENSEx ---------- –0.3V to 12V
- LEDx (1) ---------- –0.3V to 20V
- DCTL, ACTL, EN, OVP (2) ---------- –0.3V to 10V
- CL ---------- –1V to 0.3V
- Power Dissipation, P_D @ T_A = 25°C
  SOP-28 ---------- 1.31W
- Package Thermal Resistance (Note 2)
  SOP-28, θ_{JA} ---------- 76.5°C/W
- Junction Temperature ---------- 150°C
- Lead Temperature (Soldering, 10 sec.) ---------- 260°C
- Storage Temperature Range ---------- –65°C to 150°C
- ESD Susceptibility (Note 3)
  HBM (Human Body Model) ---------- 2kV
  MM (Machine Model) ---------- 200V

Notes :

(1) Add a series resistor of at least 30kΩ for higher pin voltage.

(2) Add a series resistor of at least 20kΩ for higher pin voltage.

Recommended Operating Conditions (Note 4)

- Supply Voltage, VCC ---------- 10V to 32V
- Junction Temperature Range ---------- –40°C to 125°C
- Ambient Temperature Range ---------- –40°C to 85°C

Electrical Characteristics

(V_{CC} = 24V, No load on any output, T_A = 25°C, unless otherwise specified)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
OVERALL						
VCC Supply Current	I_{VCC}	$V_{VC} \leq 0.4V$ (Not Switching)	--	5	8	mA
Shutdown Current	I_{SHDN}	$V_{EN} \leq 0.7V$	--	15	--	μA
Shutdown Threshold at EN	V_{EN}		--	1.4	1.6	V
Input Current at EN	I_{EN}	$V_{EN} \leq 5V$	--	--	0.1	μA
LED Current Programming						
SENSEx Threshold		$6V > V_{GATEx} > 2V$	204	215	226	mV
Analog Dimming Input Current at ACTL		$0.3V \leq V_{ACTL} \leq 1.3V$	--	--	0.5	μA
LED Current Off Threshold at ACTL	V_{ACTL}		--	0.4	0.5	V
Input Current at DCTL	I_{DCTL}	$0.3V \leq V_{DCTL} \leq 6V$	--	--	0.5	μA
V_{SENSEx} Threshold for No Connection			--	0.1	--	V
Regulated V_{LEDx}		Highest Voltage LED String	--	--	0.1	V
Amplifier gm Output Current	I_{VC}	$2.4V > V_{VC} > 0.2V$	--	±30	--	μA

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Optocoupler Driver						
OPTO Low Voltage		I_{OPTO} = 2mA, V_{VC} = 1.6V	--	0.15	--	V
LED Current Sources Gate Driver						
GATEx High Voltage		I_{GATEx} = −1mA	4.2	4.8	--	V
		I_{GATEx} = −0.1mA	4.5	5	--	
GATEx Low Voltage		I_{GATEx} = 1mA	--	0.8	1.1	V
		I_{GATEx} = 0.1mA	--	0.7	1	
OVP and Soft-Start						
OVP Threshold	V_{OVP}		1.17	1.2	1.25	V
OVP Input Current		$V_{OVP} \leq 1.2V$	--	--	−100	nA
Soft-Start Current at SS		$V_{SS} \leq 2.5V$	--	6	--	μA
Thermal Protection						
Thermal Shutdown Temperature	T_{SD}		--	150	--	°C

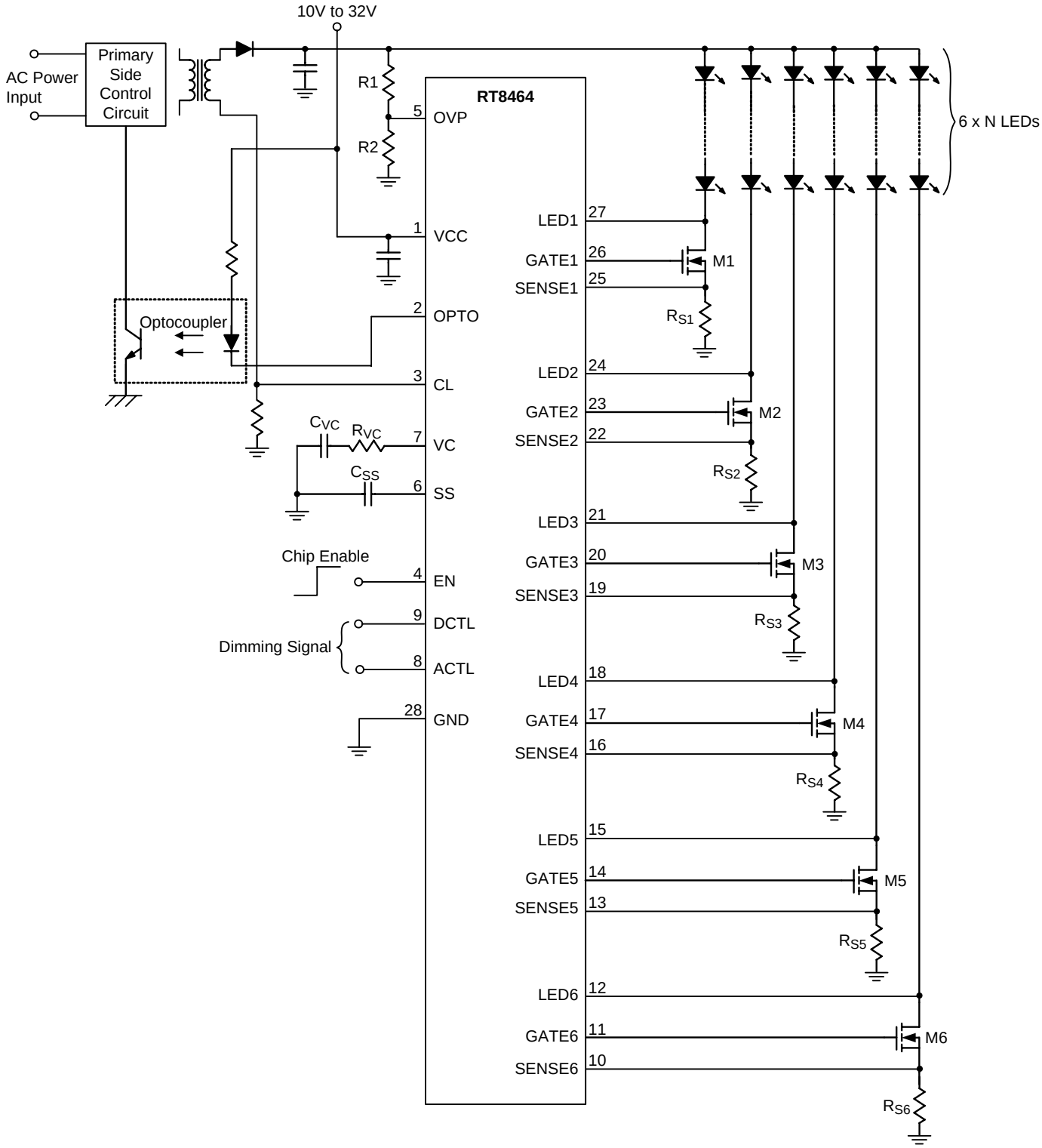
Note 1. Stresses beyond those listed "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions may affect device reliability.

Note 2. θ_{JA} is measured at T_A = 25°C on a low effective thermal conductivity single-layer test board per JEDEC 51-3.

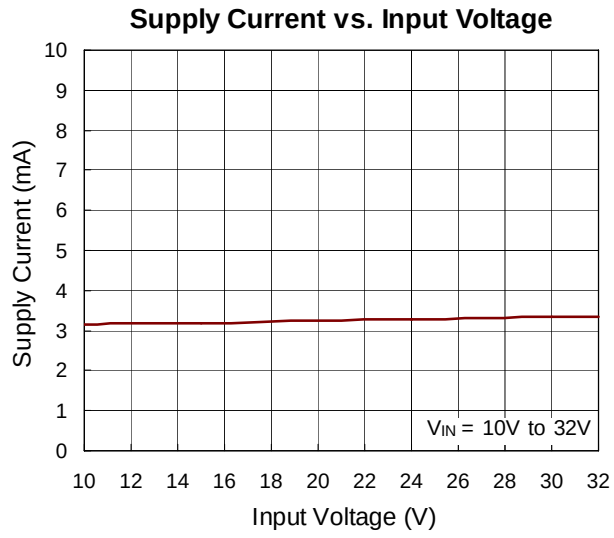
Note 3. Devices are ESD sensitive. Handling precaution is recommended.

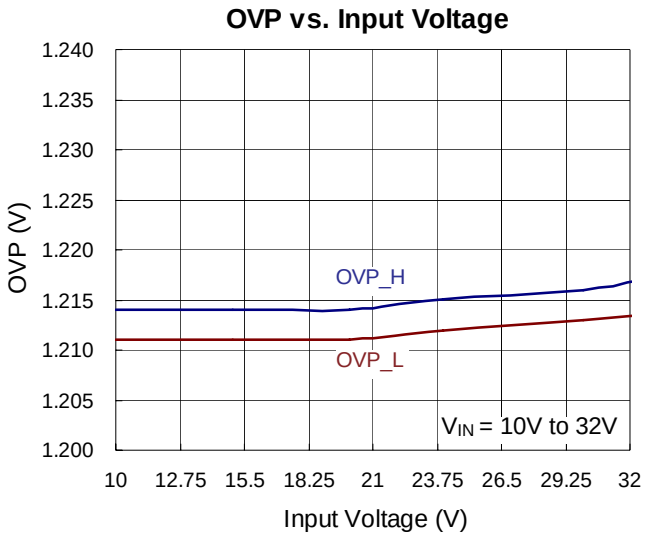
Note 4. The device is not guaranteed to function outside its operating conditions.

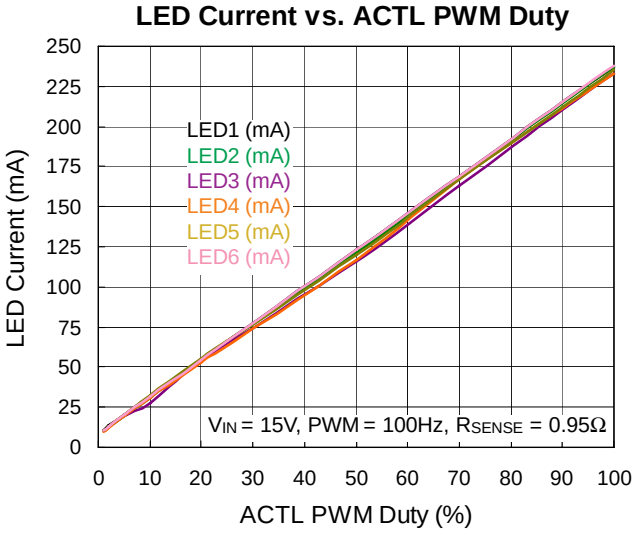
Typical Application Circuit

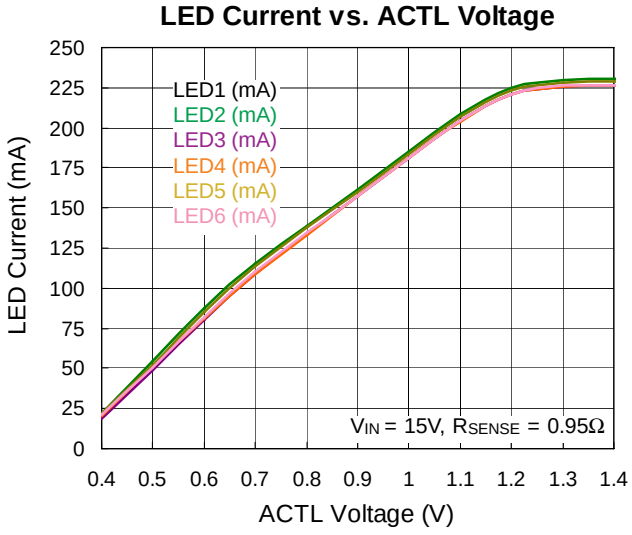


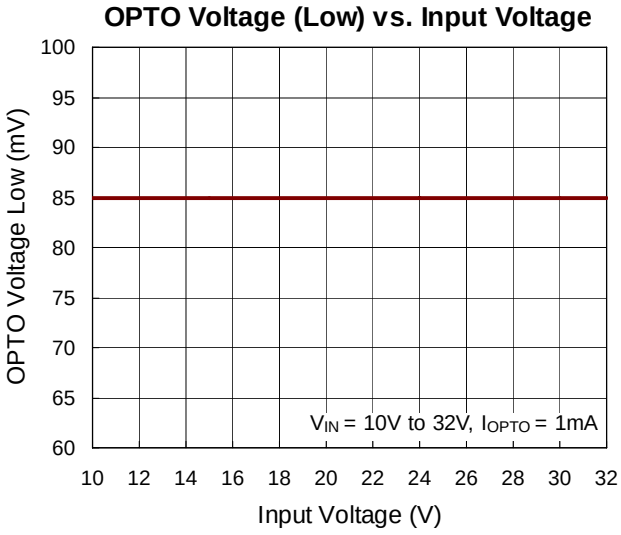
Typical Operating Characteristics

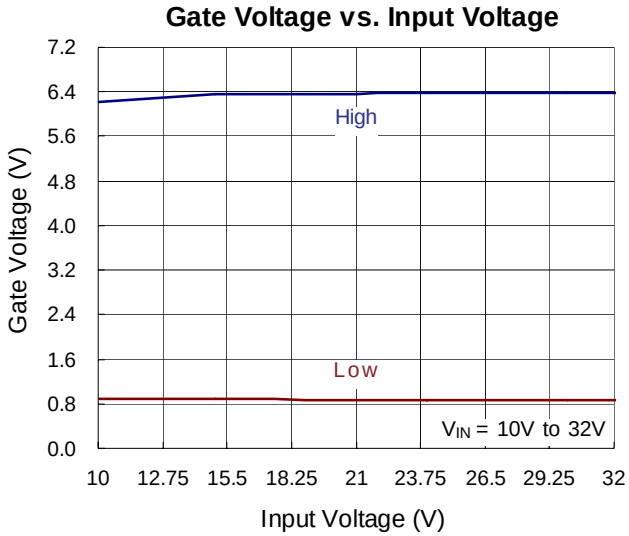












Application Information

The RT8464 regulates the lowest cathode voltage of LED strings and generates a feedback control signal to a primary controller to regulate LED current. Each LED channel current is accurately matched and controlled by sensing an external resistor in series with the MOSEFT. LED current dimming in all six channels can be precisely controlled by either a PWM signal via the DCTL input pin or by an analog dimming voltage applied at the ACTL pin. Internal protection is provided for over current and over voltage at the secondary output. The device can be operated in low current shutdown mode by pulling the EN pin low.

Under Voltage Lockout

The input operating voltage range of the RT8464 is from 10V to 32V. Placing an input capacitor at the VCC pin can reduce ripple voltage. It is recommended to use a 10μF ceramic capacitor or larger capacitance as the input capacitor. This IC provides an Under Voltage Lockout (UVLO) function to enhance the stability when start up. The UVLO rising input voltage threshold is set at 7V typically with a 0.7V hysteresis.

Soft-Start

Soft-start of the RT8464 can be achieved by connecting a capacitor from the SS pin to GND. The built-in soft-start circuit reduces the start-up current spike and output voltage overshoot. The soft-start time is determined by the external capacitor charged by an internal 6μA constant charging current. The SS pin directly limits the rate of voltage rise at the VC pin, which in turn limits the peak switch current.

The soft-start interval is set by the soft-start capacitor selection according to the following equation :

$$t_{SS} = C_{SS} \times \frac{2.5V}{6\mu A}$$

A typical value for the soft-start capacitor is 0.1μF. The soft-start pin reduces the oscillator frequency and the maximum current in the switch. The soft-start capacitor is discharged when EN/UVLO falls below its threshold or during an over temperature event.

Optocouple Driver

The OPTO output directly drives the diode side of an optocoupler to give isolated feedback control of a primary side PWM controller. The guaranteed sink current of the opto pin is 1mA.

When the LEDx (x = 1 to 6) voltage decreases to below 0.7V, the error amplifier reacts by lowering the VC pin voltage, thereby decreasing the current from optocoupler. The decreased optocoupler bias signals the primary side controller to increase the amount of power and then raise the output voltage back to its regulated value.

The output voltage of OPTO also responds to different protection conditions. When OVP or current limit occurs, the OPTO pin will sink more current immediately from the optocoupler. The increased optocoupler bias signal on the primary side controller will decrease secondary side output power.

Compensation

The RT8464 uses an internal error amplifier, in which through its compensation pin (VC) allows the loop response to be optimized for specific application. The error amplifier is a true voltage mode error amplifier and frequency compensation is performed around the amplifier. VC also ties to the overshoot control amplifier logic that detects if the VC pin is at its high clamp level. An external resistor in series with a capacitor is connected from the VC pin to GND to provide a pole and a zero for proper loop compensation.

LED Current Setting

The maximum current of channel 1 to 6 is programmed by placing an appropriate sense resistor for each LED string. When the voltage of ACTL is higher than 1.4V, the LED current can be calculated by the following equation :

$$I_{LED,\,MAX} = \frac{215mV}{R_{SENSE}} \quad (mA)$$

where R_{SENSE} is the resistor between the external regulating N-MOSFET and GND.

The ACTL pin should be tied to a voltage higher than 1.4V to get the full-scale 215mV (typical) threshold across the sense resistor. The ACTL pin can also be used to dim the

LED current to zero, although relative accuracy decreases with decreasing voltage sense threshold. When the ACTL pin voltage is less than 1.4V, the LED current is :

$$I_{LED} = \frac{(V_{ACTL} - 0.4) \times 215mV}{R_{SENSE}} \quad (mA)$$

The ACTL pin can also be used in conjunction with a thermistor to provide over temperature protection for the LED load, or with a resistive voltage divider to VCC to reduce output power and switching current when VCC is low.

Brightness Control

For LED applications where a wide dimming range is required, two methods are available: analog dimming and PWM dimming. The easier method is to simply vary the DC current through the LED by analog dimming.

The other dimming method is PWM dimming, which turns the LED on and off by different duty cycle to control the average LED current. The PWM dimming offers several advantages over analog dimming and is more preferred by LED manufacturers. One advantage is the chromaticity of the LEDs which remains unchanged in this scheme since the LED current is either zero or at a programmed current. Another advantage of PWM dimming is that a wider dimming range is available.

The RT8464 features both analog and digital dimming control. Analog dimming is linearly controlled by an external voltage (0.4V to 1.2V) at the ACTL pin. A very high contrast ratio can be obtained by true digital PWM dimming which is achieved by driving the ACTL pin with a PWM signal. The recommended PWM frequency is from 100Hz to 10kHz.

The PWM dimming frequency can be sufficiently adjusted from 100Hz 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 the internal switching frequency.

Output Over Current Protection

The current limit amplifier senses the voltage drop across an external sense resistor via the CL pin to implement over current protection. A voltage drop of 100 mV, gives a maximum current limit of 2A with a 0.5Ω sense resistor.

Output Over Voltage Protection

The RT8464 is equipped with Over Voltage Protection (OVP) function. When the voltage at the OVP pin exceeds threshold value typically 1.2V, the power switch is turned off. The power switch can be turned on again once the voltage at the OVP pin drops below 1.2V. The output voltage can be clamped at a certain voltage level set by the following equation :

$$V_{OUT, OVP} = 1.2 \times (1 + \frac{R1}{R2})$$

where R1 and R2 are the resistors in the resistive voltage divider from V_{OUT} to GND with the divider center node 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 string(s) in normal operation.

Over Temperature Protection

The RT8464 has Over Temperature Protection (OTP) function to prevent excessive power dissipation from overheating the device. The OTP function will shut down switching operation when the die junction temperature exceeds 150°C. The chip will automatically start to switch again when the die junction temperature cools down by approximately 20°C.

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 SOP-28 package, the thermal resistance, θ_{JA}, is

76.5°C/W on a standard JEDEC 51-3 single-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) / (76.5°C/W) = 1.31W for SOP-28 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.

Layout Considerations

PCB layout is very important when designing power switching converter circuits. Some recommended layout guidelines are as follows :

- The input capacitor C_{VCC} must be placed as close to the VCC pin as possible.
- Place the compensation components as close to the VC pin as possible to avoid noise pick up.

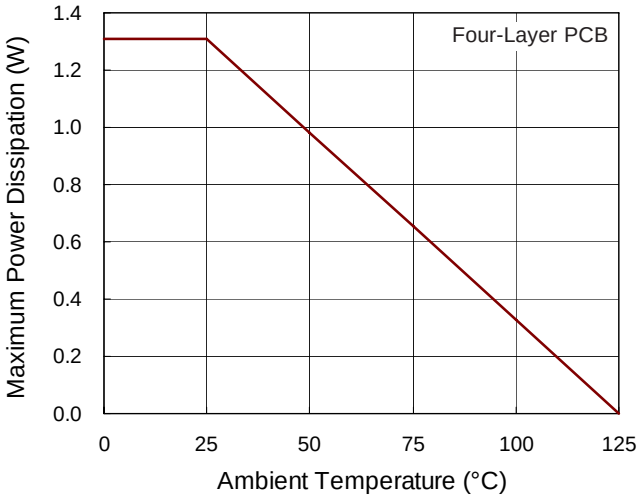


Figure 1. Derating Curve of Maximum Power Dissipation

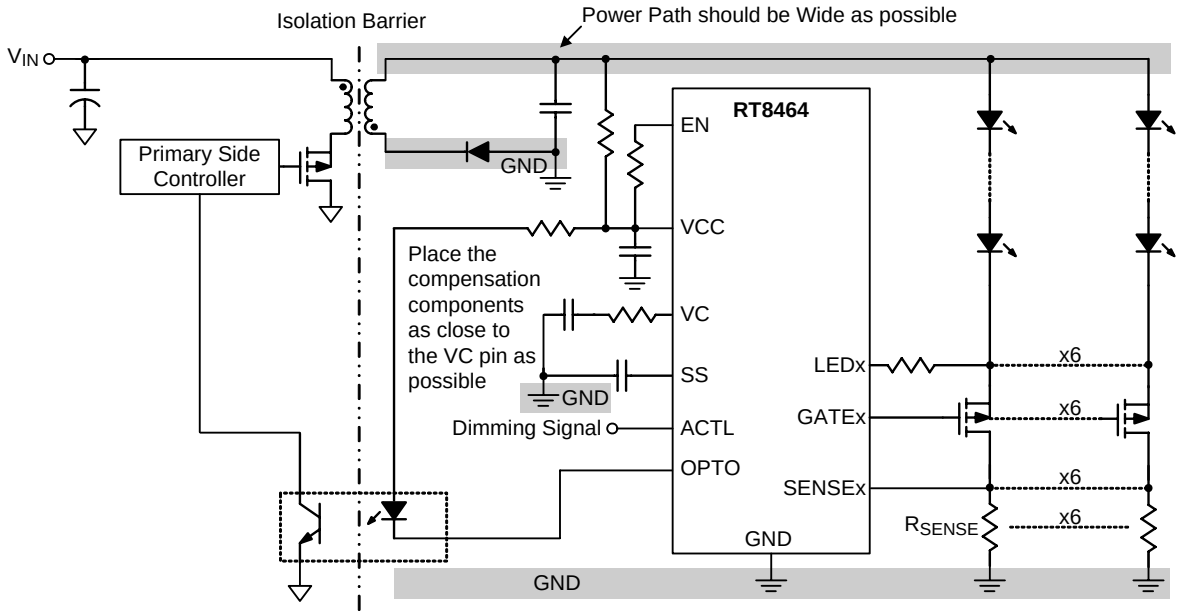
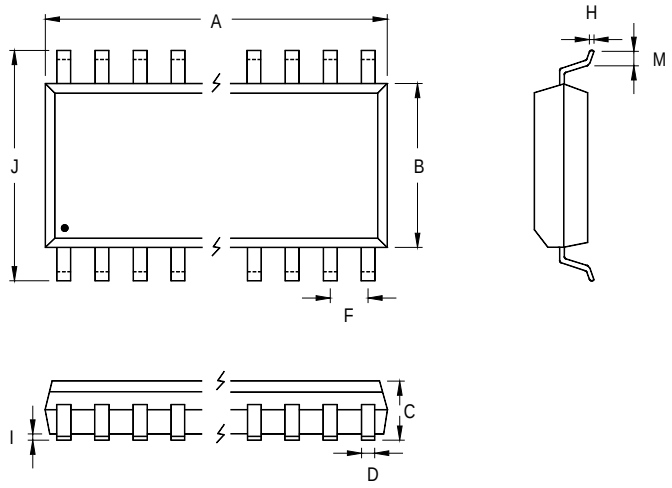


Figure 2. PCB Layout Guide

Outline Dimension



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	17.704	18.110	0.697	0.713
B	7.391	7.595	0.291	0.299
C	2.362	2.642	0.093	0.104
D	0.330	0.508	0.013	0.020
F	1.194	1.346	0.047	0.053
H	0.229	0.330	0.009	0.013
I	0.102	0.305	0.004	0.012
J	10.008	10.643	0.394	0.419
M	0.381	1.270	0.015	0.050

28-Lead SOP Plastic Package

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