High Voltage Multiple-Topology LED Driver with Dimming Control

General Description
The RT8474 is a current-mode LED driver supporting wide input voltage range from 4.5V to 50V and output voltage up to 50V. With internal 490kHz operating frequency, the size of the external PWM inductor and input/output capacitors can be minimized. High efficiency is achieved by a 100mV current sensing control. LED dimming control can be done from either analog or PWM signal. The RT8474 provides an internal soft-start function to avoid inrush current and thermal shutdown to prevent the device from overheat.

The RT8474 is available in the SOP-8 (Exposed pad) package.

Ordering Information
RT8474 □ □ □ □ □ □ □ □
Package Type
- SP : SOP-8 (Exposed-Option 2)
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.

Features
- High Voltage : \( V_{IN} \) Up to 50V, \( V_{OUT} \) Up to 50V
- Support Multiple-Topologies (Buck / Boost / Buck-Boost)
- Built-In 2A Power Switch
- Current-Mode PWM Control
- 490kHz Fixed Switching Frequency
- Analog or PWM Control Signal for LED Dimming
- Internal Soft-Start to Avoid Inrush Current
- Under-Voltage Lockout
- Thermal Shutdown
- RoHS Compliant and Halogen Free

Applications
- Desk Lights and Room Lighting
- Industrial Display Backlight

Marking Information
RT8474GSP : Product Number
YMDNN : Date Code

Pin Configuration
(TOP VIEW)

Simplified Application Circuit
Functional Pin Description

<table>
<thead>
<tr>
<th>Pin No.</th>
<th>Pin Name</th>
<th>Pin Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>VCC</td>
<td>Supply voltage input. For good bypass, connect a low ESR capacitor between this pin and GND.</td>
</tr>
<tr>
<td>2</td>
<td>ISP</td>
<td>Positive current sense input.</td>
</tr>
<tr>
<td>3</td>
<td>ISN</td>
<td>Negative current sense input. Voltage threshold between ISP and ISN is 100mV.</td>
</tr>
<tr>
<td>4</td>
<td>NC</td>
<td>No internal connection.</td>
</tr>
<tr>
<td>5</td>
<td>VC</td>
<td>Compensation node for current loop.</td>
</tr>
<tr>
<td>6</td>
<td>CTL</td>
<td>Analog dimming control input. Effective programming range is 0.2V to 1.2V.</td>
</tr>
<tr>
<td>7</td>
<td>SW</td>
<td>Switch node of the PWM converter.</td>
</tr>
<tr>
<td>8</td>
<td>CREG</td>
<td>Regulator output for internal circuit. Place a 1μF capacitor to stabilize the 5V output regulator.</td>
</tr>
<tr>
<td>9 (Exposed Pad)</td>
<td>GND</td>
<td>Ground. The exposed pad must be soldered to a large PCB and connected to GND for maximum power dissipation.</td>
</tr>
</tbody>
</table>

Functional Block Diagram

Operation

The RT8474 is specifically designed to be operated in Buck converter applications. This device uses a fixed frequency, current-mode control scheme to provide excellent line and load regulation. The control loop has a current sense amplifier which senses the voltage between the ISP and ISN pins and provides an output voltage at the VC pin. A PWM comparator then turns off the internal power switch when the sensed power switch current exceeds the compensated VC pin voltage. The power switch will not be reset by the oscillator clock in each cycle. If the comparator does not turn off the switch in a cycle, the power switch will be on for more than a full switching period until the comparator is tripped. In this manner, the programmed voltage across the sense resistor is regulated by the control loop.

The current through the sense resistor is set by the programmed voltage and the sense resistance. The voltage across the sense resistor can be programmed by the analog or digital signal at the CTL pin. The RT8474 provides protection functions which include over-temperature, and switch current limit to prevent abnormal situations.
Absolute Maximum Ratings  (Note 1)

- Supply Input Voltage, VCC .......................................................................................................................... −0.3V to 60V
- SW Pin Voltage at Switching Off, ISP, ISN ...................................................................................................... −0.3V to 60V
- CREG Voltage ............................................................................................................................................. −0.3V to 6V
- CTL Voltage (Note 2) .................................................................................................................................. −0.3V to 20V
- Power Dissipation, PD @ TA = 25°C
  SOP-8 (Exposed Pad) ...................................................................................................................................... 3.44W
- Package Thermal Resistance (Note 3)
  SOP-8 (Exposed Pad), θJA .............................................................................................................................. 29°C/W
  SOP-8 (Exposed Pad), θJC .............................................................................................................................. 2°C/W
- Junction Temperature .................................................................................................................................. −150°C
- Lead Temperature (Soldering, 10 sec.) .......................................................................................................... 260°C
- Storage Temperature Range ......................................................................................................................... −65°C to 150°C
- ESD Susceptibility (Note 4)
  HBM (Human Body Model) ......................................................................................................................... 2kV
  MM (Machine Model) ................................................................................................................................. 200V

Recommended Operating Conditions  (Note 5)

- Supply Input Voltage .................................................................................................................................. 4.5V to 50V
- Junction Temperature Range ....................................................................................................................... −40°C to 125°C
- Ambient Temperature Range ...................................................................................................................... −40°C to 85°C

Electrical Characteristics  
(VCC = 5V, CIN = 1μF, TA = 25°C, unless otherwise specified)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Test Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regulator Output Voltage</td>
<td>VCREG</td>
<td>ICREG = 20mA</td>
<td>4.5</td>
<td>5</td>
<td>5.5</td>
<td>V</td>
</tr>
<tr>
<td>Supply Current</td>
<td>IVCC</td>
<td>VC ≤ 0.4V</td>
<td>--</td>
<td>--</td>
<td>3</td>
<td>mA</td>
</tr>
<tr>
<td>VIN Under-Voltage Lockout Threshold</td>
<td>VUVLO</td>
<td>Vin rising</td>
<td>--</td>
<td>4.2</td>
<td>--</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Vin falling</td>
<td>--</td>
<td>3.8</td>
<td>--</td>
<td>V</td>
</tr>
<tr>
<td>Current Sense Amplifier</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input Threshold (VISP – VISN)</td>
<td>VCTL ≥ 1.25V</td>
<td></td>
<td>97</td>
<td>100</td>
<td>103</td>
<td>mV</td>
</tr>
<tr>
<td>Input Current</td>
<td>IISP</td>
<td>VISP = 24V</td>
<td>--</td>
<td>200</td>
<td>--</td>
<td>μA</td>
</tr>
<tr>
<td>Input Current</td>
<td>IISN</td>
<td>VISN = 24V</td>
<td>--</td>
<td>20</td>
<td>--</td>
<td>μA</td>
</tr>
<tr>
<td>Output Current</td>
<td>IVC</td>
<td>2.4V &gt; VC &gt; 0.3V</td>
<td>--</td>
<td>±10</td>
<td>--</td>
<td>μA</td>
</tr>
<tr>
<td>VC Threshold for CTL Switch Off</td>
<td>--</td>
<td>0.4</td>
<td>--</td>
<td>V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LED Dimming</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input Current of CTL Pin</td>
<td>ICTL</td>
<td>0.2V ≤ VCTL ≤ 1.2V</td>
<td>--</td>
<td>1</td>
<td>2</td>
<td>μA</td>
</tr>
<tr>
<td>LED Current off Threshold at CTL</td>
<td>VCTL_OFF</td>
<td>--</td>
<td>0.2</td>
<td>0.25</td>
<td>V</td>
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### PWM Converter

<table>
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<th>Parameter</th>
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<th>Min</th>
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<th>Max</th>
<th>Unit</th>
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<tr>
<td>Switch Frequency</td>
<td>$f_{SW}$</td>
<td></td>
<td>440</td>
<td>490</td>
<td>540</td>
<td>kHz</td>
</tr>
<tr>
<td>Maximum Duty Cycle</td>
<td>$D_{MAX}$</td>
<td></td>
<td>--</td>
<td>--</td>
<td>100</td>
<td>%</td>
</tr>
<tr>
<td>Minimum On-Time</td>
<td></td>
<td>--</td>
<td>100</td>
<td>200</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>SW $R_{DS(ON)}$</td>
<td></td>
<td>--</td>
<td>0.15</td>
<td>--</td>
<td>--</td>
<td>Ω</td>
</tr>
<tr>
<td>SW Current Limit</td>
<td>$I_{LIM_SW}$</td>
<td></td>
<td>2</td>
<td>2.5</td>
<td>--</td>
<td>A</td>
</tr>
<tr>
<td>Soft-Start Time</td>
<td></td>
<td>--</td>
<td>5.7</td>
<td>--</td>
<td>--</td>
<td>ms</td>
</tr>
</tbody>
</table>

### Over-Temperature Protection

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Test Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal Shutdown Threshold</td>
<td>$T_{SD}$</td>
<td></td>
<td>--</td>
<td>150</td>
<td>--</td>
<td>°C</td>
</tr>
<tr>
<td>Thermal Shutdown Hysteresis</td>
<td>$\Delta T_{SD}$</td>
<td></td>
<td>--</td>
<td>20</td>
<td>--</td>
<td>°C</td>
</tr>
</tbody>
</table>

**Note 1.** Stresses beyond those listed under “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.** If connected with a 20kΩ serial resistor, PWM can go up to 40V.

**Note 3.** $\theta JA$ is measured at $T_A = 25^\circ$C on a high effective thermal conductivity four-layer test board per JEDEC 51-7. $\theta JC$ is measured at the exposed pad of the package.

**Note 4.** Devices are ESD sensitive. Handling precaution is recommended.

**Note 5.** The device is not guaranteed to function outside its operating conditions.
Typical Application Circuit

Buck Configuration

Boost Configuration

Note: VIN, VSW, VISP, VISN < 50V

Note:
1. VIN, VSW, VISP, VISN < 50V
2. VLED : the voltage across the LED string
3. Vz : Zener diode breakdown voltage
Buck-Boost Configuration

Note:
1. $V_{SW} < 50V$, $V_{IN} + V_{LED} < 50V$
2. $V_{LED}$: the voltage across the LED string
3. $V_z$: Zener diode breakdown voltage
Typical Operating Characteristics

**Efficiency vs. Input Voltage**

- LED = 6pcs
- LED = 5pcs
- LED = 4pcs
- LED = 3pcs
- LED = 2pcs
- LED = 1pcs

![Efficiency vs. Input Voltage Graph](image)

Efficiency (%)

Input Voltage (V)

Efficiency vs. Input Voltage

**LED Current vs. VCTL**

- RSENS = 300mΩ, LED = 6pcs

![LED Current vs. VCTL Graph](image)

LED Current (mA)

VCTL (V)

LED Current vs. VCTL

**Supply Current vs. VCC**

![Supply Current vs. VCC Graph](image)

Supply Current (mA)

VCC (V)

Supply Current vs. VCC

**ISP-ISN Threshold vs. Temperature**

- VCC = 24V

![ISP-ISN Threshold vs. Temperature Graph](image)

ISP-ISN Threshold (mV)

Temperature (°C)

ISP-ISN Threshold vs. Temperature

**SW R_DSON (Ω) vs. VCC**

- VCC = 24V

![SW R_DSON (Ω) vs. VCC Graph](image)

R_DSON (Ω)

VCC (V)

SW R_DSON (Ω) vs. VCC

**SW R_DSON (Ω) vs. Temperature**

- VCC = 24V

![SW R_DSON (Ω) vs. Temperature Graph](image)

R_DSON (Ω)

Temperature (°C)

SW R_DSON (Ω) vs. Temperature
**Frequency vs. VCC**

- Frequency (kHz)
- Time (25ms/Div)

**Power On from VCC**

- VIN (20V/Div)
- VOUT (20V/Div)
- IOUT (20mA/Div)

VIN = 24V, IOUT = 340mA, L = 47μH, LED = 6pcs

**Power Off from VCC**

- VIN (20V/Div)
- VOUT (20V/Div)
- IOUT (200mA/Div)

VIN = 24V, IOUT = 340mA, L = 47μH, LED = 6pcs

**Switching**

- VIN (10V/Div)
- VOUT (10V/Div)
- IOUT (200mA/Div)

VIN = 24V, IOUT = 340mA, L = 47μH, LED = 6pcs

Time (50ms/Div)
Application Information

The RT8474 is specifically designed to be operated in Buck converter applications. This device uses a fixed frequency, current-mode control scheme to provide excellent line and load regulation. The control loop has a current sense amplifier which senses the voltage between the ISP and ISN pins and provides an output voltage at the VC pin. A PWM comparator then turns off the internal power switch when the sensed power switch current exceeds the compensated VC pin voltage. The power switch will not be reset by the oscillator clock in each cycle. If the comparator does not turn off the switch in a cycle, the power switch will be on for more than a full switching period until the comparator is tripped. In this manner, the programmed voltage across the sense resistor is regulated by the control loop.

Frequency Compensation

The RT8474 has an external compensation pin, allowing the loop response to be optimized for specific applications. 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. The typical value for the RT8474 is 10k and 3.3nF.

LED Current Setting

The LED current can be calculated by the following equation:

\[ I_{\text{LED(MAX)}} = \frac{(V_{\text{ISP}} - V_{\text{ISN}})}{R_{\text{SENSE}}} \]

where \((V_{\text{ISP}} - V_{\text{ISN}})\) is the voltage between the ISP and ISN pins (100mV typ. if CTL dimming is not applied) and the \(R_{\text{SENSE}}\) is the resister between the ISP and ISN pins.

Current Limit

The RT8474 can limit the peak switch current with its internal over-current protection feature. In normal operation, the power switch is turned off when the switch current hits the loop-set value. The over-current protection function will turn off the power switch independent of the loop control when the peak switch current reaches around 2A.

Over-Temperature Protection

The RT8474 has Over-Temperature Protection (OTP) function to prevent the excessive power dissipation from overheating. 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 off.

Inductor Selection

Choose an inductor that can handle the necessary peak current without saturating and ensure that the inductor has a low DCR (copper-wire resistance) to minimize IR power losses. A 4.7mH to 22mH inductor will meet the demand of most of the RT8474 applications. Inductor manufacturers specify the maximum current rating as the current where the inductance falls to certain percentage of its nominal value, typically 65%. In Multiple-Topology application where the transition between discontinuous and continuous modes occurs, the value of the required output inductor, \(L\), can be approximated by the following equation:

For Buck application:

\[ L = \left( \frac{V_{\text{OUT}}}{f \times \Delta L} \right) \times \left( 1 - \frac{V_{\text{OUT}}}{V_{\text{IN(MAX)}}} \right) \]

The ripple current \(\Delta L\) and peak current \(I_{\text{PEAK}}\) can be calculated:

\[ \Delta L = \left( \frac{V_{\text{OUT}}}{f \times L} \right) \times \left( 1 - \frac{V_{\text{OUT}}}{V_{\text{IN}}} \right) \]

\[ I_{\text{PEAK}} = I_{\text{OUT}} + \frac{\Delta L}{2} \]

For Boost application:

\[ L = \frac{V_{\text{OUT}} - V_{\text{IN}}}{f \times \Delta L} \times \left( \frac{V_{\text{IN}}}{V_{\text{OUT}}} \right)^2 \]

The ripple current \(\Delta L\) and peak current \(I_{\text{PEAK}}\) can be calculated:

\[ \Delta L = \frac{V_{\text{OUT}} - V_{\text{IN}}}{f \times L} \times \left( \frac{V_{\text{IN}}}{V_{\text{OUT}}} \right)^2 \]

\[ I_{\text{PEAK}} = \left( \frac{I_{\text{OUT}} \times V_{\text{OUT}}}{\eta \times V_{\text{IN}}} \right) + \frac{\Delta L}{2} \]
Thermal Considerations

For continuous operation, do not exceed the maximum operation junction temperature 125°C. The maximum power dissipation depends on the thermal resistance of IC package, PCB layout, the rate of surrounds airflow and temperature difference between junction to ambient. The maximum power dissipation can be calculated by following formula:

\[
PD_{\text{MAX}} = \frac{(T_{J\text{MAX}} - T_A)}{\theta_{JA}}
\]

where, \( T_{J\text{MAX}} \) is the maximum operation junction temperature, \( T_A \) is the ambient temperature and the \( \theta_{JA} \) is the junction to ambient thermal resistance.

For recommended operating conditions specifications, the maximum junction temperature is 125°C. The junction to ambient thermal resistance, \( \theta_{JA} \), is layout dependent. For SOP-8 (Exposed Pad) package, the thermal resistance \( \theta_{JA} \) is 29°C/W on the standard JEDEC 51-7 four-layer thermal test board. The maximum power dissipation at \( T_A = 25°C \) can be calculated by following formula:

\[
P_{D\text{MAX}} = (125°C - 25°C) / (29°C/W) = 3.44W \text{ for SOP-8 (Exposed Pad) package}
\]

The maximum power dissipation depends on operating ambient temperature for fixed \( T_{J\text{MAX}} \) and thermal resistance \( \theta_{JA} \). The deration curve in Figure 1 allows the designer to see the effect of rising ambient temperature on the maximum power allowed.
**Layout Considerations**

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

- The power components L1, D1 and C4 must be placed as close to each other as possible to reduce the ac current loop area. The PCB trace between power components must be as short and wide as possible due to large current flow through these traces during operation.
- Place L1 and D1 as close to each other as possible. The trace should be as short and wide as possible.
- The input capacitor C5 must be placed as close to the VCC pin as possible.
- Place the compensation components to the VC pin as close as possible to avoid noise pickup.

![Figure 2. PCB Layout Guide](image-url)
## Outline Dimension

![Diagram of 8-Lead SOP (Exposed Pad) Plastic Package](image)

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Dimensions In Millimeters</th>
<th>Dimensions In Inches</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Min</td>
<td>Max</td>
</tr>
<tr>
<td>A</td>
<td>4.801</td>
<td>5.004</td>
</tr>
<tr>
<td>B</td>
<td>3.810</td>
<td>4.000</td>
</tr>
<tr>
<td>C</td>
<td>1.346</td>
<td>1.753</td>
</tr>
<tr>
<td>D</td>
<td>0.330</td>
<td>0.510</td>
</tr>
<tr>
<td>F</td>
<td>1.194</td>
<td>1.346</td>
</tr>
<tr>
<td>H</td>
<td>0.170</td>
<td>0.254</td>
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<tr>
<td>I</td>
<td>0.000</td>
<td>0.152</td>
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<tr>
<td>J</td>
<td>5.791</td>
<td>6.200</td>
</tr>
<tr>
<td>M</td>
<td>0.406</td>
<td>1.270</td>
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**Option 1**

<table>
<thead>
<tr>
<th></th>
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<th>Y</th>
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<td></td>
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<td>2.300</td>
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**Option 2**

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</tr>
<tr>
<td></td>
<td>3.000</td>
<td>3.500</td>
</tr>
</tbody>
</table>

8-Lead SOP (Exposed Pad) Plastic Package

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