43V Asynchronous Boost WLED Driver

General Description
The RT8511A is an LED driver IC that can support up to 10 WLED in series. It is composed of a current mode boost converter integrated with a 43V/1.2A power switch running at a fixed 1MHz frequency and covering a wide VIN range from 2.7V to 24V.

The white LED current is set with an external resistor, and the feedback voltage is regulated to 200mV (typ.). During operation, the LED current can be controlled by the PWM input signal in which the duty cycle determines the feedback reference voltage.

For brightness dimming, the RT8511A is able to maintain steady control of the LED current. Therefore, no audible noises are generated on the output capacitor. The RT8511A also has programmable over voltage pin to prevent the output from exceeding absolute maximum ratings during open LED conditions. The RT8511A is available in WDFN-8L 2x2 and WDFN-8L 3x3 packages.

Features
- Wide Input Voltage Range: 2.7V to 24V
- High Output Voltage: up to 43V
- Direct PWM Dimming Control and Frequency from 100Hz to 1kHz
- Internal Soft-Start and Compensation
- 200mV Reference Voltage
- PWM Dimming with Internal Filter
- Programmable Over Voltage Protection
- Over Temperature Protection
- Current Limit Protection
- Thin 8-Lead 2x2 and 8-Lead 3x3 WDFN Packages
- RoHS Compliant and Halogen Free

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

Pin Configurations

Ordering Information
RT8511A
- Package Type
  - QW: WDFN-8L 2x2 (W-Type)
  - QWA: WDFN-8L 3x3 (W-Type)
- Lead Plating System
  - G: Green (Halogen Free and Pb Free)

Marking Information
RT8511AGQW
- 14: Product Code
- W: Date Code

RT8511AGQWA
- 22: Product Code
- YMDNN: Date Code

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.
### 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>OVP</td>
<td>Over Voltage Protection for Boost Converter. The detecting threshold is 1.2V.</td>
</tr>
<tr>
<td>2</td>
<td>FB</td>
<td>Feedback Pin. Connect a resistor between this pin and GND to set the LED current.</td>
</tr>
<tr>
<td>3</td>
<td>DIMC</td>
<td>PWM Filter Pin. Filter the PWM signal to a DC voltage.</td>
</tr>
<tr>
<td>4</td>
<td>GND</td>
<td>Ground Pin.</td>
</tr>
<tr>
<td>5</td>
<td>LX</td>
<td>Switch Node for Boost Converter.</td>
</tr>
<tr>
<td>6</td>
<td>VIN</td>
<td>Power Supply Input.</td>
</tr>
<tr>
<td>7</td>
<td>PWM</td>
<td>Dimming Control Input.</td>
</tr>
<tr>
<td>8</td>
<td>EN</td>
<td>Chip Enable (Active High) for Boost Converter.</td>
</tr>
<tr>
<td>9 (Exposed Pad)</td>
<td>GND</td>
<td>The exposed pad must be soldered to a large PCB and connected to AGND for maximum power dissipation.</td>
</tr>
</tbody>
</table>
Function Block Diagram
**Absolute Maximum Ratings**  (Note 1)

- VIN, EN, PWM, DIMC to GND  
  -0.3V to 26.5V
- LX, FB, OVP to GND  
  -0.3V to 48V
- Power Dissipation, \( P_D @ T_A = 25^\circ C \)
  - WDFN-8L 2x2  
    0.833W
  - WDFN-8L 3x3  
    1.429W
- Package Thermal Resistance  (Note 2)
  - WDFN-8L 2x2, \( \theta_{JA} \)  
    120°C/W
  - WDFN-8L 2x2, \( \theta_{JC} \)  
    8.2°C/W
  - WDFN-8L 3x3, \( \theta_{JA} \)  
    70°C/W
  - WDFN-8L 3x3, \( \theta_{JC} \)  
    8.2°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 (Human Body Model)  
  2kV
  MM (Machine Model)  
  200V

**Recommended Operating Conditions**  (Note 4)

- Supply Input Voltage, \( V_{IN} \)  
  2.7V to 24V
- Junction Temperature Range  
  -40°C to 125°C
- Ambient Temperature Range  
  -40°C to 85°C

**Electrical Characteristics**  
(\( V_{IN} = 4.5V, T_A = 25^\circ C, \) 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>VIN Quiescent Current</td>
<td>( I_Q )</td>
<td>( V_{FB} = 1.5V, ) No Switching</td>
<td>--</td>
<td>725</td>
<td>--</td>
<td>( \mu A )</td>
</tr>
<tr>
<td></td>
<td>( I_{Q,SW} )</td>
<td>( V_{FB} = 0V, ) Switching</td>
<td>--</td>
<td>--</td>
<td>2.2</td>
<td>mA</td>
</tr>
<tr>
<td>VIN Shutdown Current</td>
<td>( I_{SHDN} )</td>
<td>( V_{IN} = 4.5V, V_{EN} = 0V )</td>
<td>--</td>
<td>1</td>
<td>4</td>
<td>( \mu A )</td>
</tr>
<tr>
<td>Control Input</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EN, PWM Threshold Voltage</td>
<td>Logic-High</td>
<td>( V_{IH} )</td>
<td>( V_{IN} = 2.7V ) to 24V</td>
<td>1.6</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>Logic-Low</td>
<td>( V_{IL} )</td>
<td>( V_{IN} = 2.7V ) to 24V</td>
<td>--</td>
<td>--</td>
<td>0.8</td>
</tr>
<tr>
<td>EN Sink Current</td>
<td>( I_{IH} )</td>
<td>( V_{EN} = 3V )</td>
<td>1</td>
<td>--</td>
<td>10</td>
<td>( \mu A )</td>
</tr>
<tr>
<td>Shutdown Delay</td>
<td>( t_{SHDN} )</td>
<td>EN high to low</td>
<td>26</td>
<td>32</td>
<td>40</td>
<td>ms</td>
</tr>
<tr>
<td>PWM Dimming Frequency</td>
<td></td>
<td></td>
<td>0.1</td>
<td>--</td>
<td>1</td>
<td>kHz</td>
</tr>
<tr>
<td>Boost Converter</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Switching Frequency</td>
<td>( f_{OSC} )</td>
<td>( V_{IN} = 2.7V ) to 24V</td>
<td>0.8</td>
<td>1</td>
<td>1.2</td>
<td>MHz</td>
</tr>
<tr>
<td>LX On Resistance (N-MOSFET)</td>
<td>( R_{DS(ON)} )</td>
<td>( V_{IN} &gt; 5V )</td>
<td>--</td>
<td>0.4</td>
<td>0.6</td>
<td>( \Omega )</td>
</tr>
<tr>
<td>Minimum ON Time</td>
<td></td>
<td></td>
<td>--</td>
<td>100</td>
<td>--</td>
<td>ns</td>
</tr>
<tr>
<td>Maximum Duty Cycle</td>
<td>( D_{MAX} )</td>
<td>( V_{FB} = 0V, ) Switching</td>
<td>--</td>
<td>92</td>
<td>--</td>
<td>%</td>
</tr>
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</table>
### LED Current

<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>Minimum PWM Dimming Duty Cycle</td>
<td>(D_{\text{MIN}})</td>
<td>Dimming Freq. = 100Hz to 1kHz</td>
<td>5</td>
<td>--</td>
<td>--</td>
<td>%</td>
</tr>
<tr>
<td>Feedback Voltage</td>
<td>(V_{\text{FB}})</td>
<td></td>
<td>--</td>
<td>200</td>
<td>--</td>
<td>mV</td>
</tr>
</tbody>
</table>

### Fault 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>LX Current Limit</td>
<td>(I_{\text{LIM}})</td>
<td></td>
<td>0.85</td>
<td>1.2</td>
<td>1.55</td>
<td>A</td>
</tr>
<tr>
<td>Over Voltage Protection Threshold</td>
<td>(V_{\text{OVP}})</td>
<td></td>
<td>--</td>
<td>1.2</td>
<td>--</td>
<td>V</td>
</tr>
<tr>
<td>Thermal Shutdown Temperature</td>
<td>(T_{\text{SD}})</td>
<td></td>
<td>--</td>
<td>160</td>
<td>--</td>
<td>°C</td>
</tr>
<tr>
<td>Thermal Shutdown Hysteresis</td>
<td>(\Delta T_{\text{SD}})</td>
<td></td>
<td>--</td>
<td>30</td>
<td>--</td>
<td>°C</td>
</tr>
</tbody>
</table>

**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.** \(\theta_{JA}\) 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 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

- **Efficiency vs. Input Voltage**
  - Input Voltage (V): 4 to 24
  - Frequency (kHz): 900 to 1100
  - Efficiency (%): 60 to 100
  - VOUT = 29.5V

- **FB Reference Voltage vs. Input Voltage**
  - Input Voltage (V): 4 to 24
  - FB Reference Voltage (mV): 198.0 to 199.5

- **FB Reference Voltage vs. Temperature**
  - Temperature (°C): -20 to 125
  - FB Reference Voltage (mV): 190 to 200
  - VIN = 4.5V

- **Frequency vs. Input Voltage**
  - Input Voltage (V): 4 to 24
  - Frequency (kHz): 900 to 1100

- **Frequency vs. Temperature**
  - Temperature (°C): -50 to 125
  - Frequency (kHz): 900 to 1100
  - VIN = 4.5V

- **LED Current vs. PWM Duty Cycle**
  - PWM Duty Cycle (%): 0 to 100
  - LED Current (mA): 0 to 60
  - PWM = 100Hz
  - PWM = 1kHz
Application Information

The RT8511A is a current mode boost converter which operates at a fixed frequency of 1MHz. It is capable of driving up to 10 white LEDs in series and integrates functions such as soft-start, compensation, and internal analog dimming control. The protection block also provides over-voltage, over-temperature, and current-limit protection features.

LED Current Setting

The loop structure of the boost converter keeps the FB pin voltage equal to the reference voltage \( V_{FB} \). Therefore, by connecting the resistor, \( R_{SET} \) between the FB pin and GND, the LED current will be determined by the current through \( R_{SET} \). The LED current can be calculated by the following equation:

\[
I_{LED} = \frac{V_{FB}}{R_{SET}}
\]

Brightness Control

For the brightness dimming control of the RT8511A, the IC provides typically 200mV reference voltage when the PWM pin is constantly pulled high. However, the PWM pin allows a PWM signal to adjust the reference voltage by changing the PWM duty cycle to achieve LED brightness dimming control. The relationship between the duty cycle and the FB voltage can be calculated according to the following equation:

\[
V_{FB} = 200mV \times \text{Duty}
\]

where 200mV is the typical internal reference voltage and Duty is the duty cycle of the PWM signal.

As shown in Figure 3, the duty cycle of the PWM signal is used to modify the internal 200mV reference voltage. With an on-chip output clamping amplifier and a serial resistor, the PWM dimming signal is easily low-pass filtered to an analog dimming signal with one external capacitor, \( C_{DIMC} \), for noise-free PWM dimming. Dimming frequency can be sufficiently adjusted from 100Hz to 1kHz. However, the LED current cannot be 100% proportional to the duty cycle. Referring to Table 1, the minimum dimming duty can be as low as 1% for the frequency range from 100Hz to 1kHz. It should be noted that the accuracy of 1% duty is not guaranteed.

Because the voltage of DIMC and FB is small to 2mV and easily affected by LX switching noise.

![Figure 3. Block Diagram of Programmable FB Voltage.](image)

Table 1. Minimum Duty for Dimming Frequency

<table>
<thead>
<tr>
<th>Dimming Frequency</th>
<th>Minimum Duty Cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>100Hz to 1kHz</td>
<td>5%</td>
</tr>
</tbody>
</table>

It also should be noted that when the input voltage is too close to the output voltage \((V_{OUT}−V_{IN}) < 6V\), excessive audible noise may occur. Additionally, for accurate brightness dimming control, the input voltage should be kept lower than the LEDs' turn on voltage. When operating in the light load, excessive output ripple may occur.

Soft-Start

The RT8511A provides a built-in soft-start function to limit the inrush current, while allowing for an increased PWM frequency for dimming.

Current Limiting Protection

The RT8511A can limit the peak current to achieve over current protection. The IC senses the inductor current through the LX pin in the charging period. When the value exceeds the current limiting threshold, the internal N-MOSFET will be turned off. In the off period, the inductor current will descend. The internal MOSFET is turned on by the oscillator during the beginning of the next cycle.

In addition, the LX current limit threshold is about 0.8V. If the voltage of LX is over 0.8V, and the fault signal accumulates 3 times with 32μs, the MOSFET will be latched off.
Power Sequence

In order to assure that the normal soft start function is in place for suppressing the inrush current, the input voltage and enable voltage should be ready before PWM pulls high.

Figure 4 and Figure 5 show the power on and power off sequences.
Over Voltage Protection

The RT8511A equips over voltage protection (OVP) function. When the voltage at the OVP pin reaches a threshold of approximately 1.2V, the MOSFET drive output will turn off. The MOSFET drive output will turn on again once the voltage at the OVP pin drops below the threshold. Thus, the output voltage can be clamped at a certain voltage level, as shown in the following equation:

\[ V_{\text{OUT, OVP}} = V_{\text{OVP}} \times \frac{1 + R_2}{R_1} \]

where \( R_1 \) and \( R_2 \) make up the voltage divider connected to the OVP pin.

Over Temperature Protection

The RT8511A has an over temperature protection (OTP) function to prevent overheating caused by excessive power dissipation from overheating the device. The OTP will shut down switching operation if the junction temperature exceeds 160°C. The boost converter will start switching again when the junction temperature is cooled down by approximately 30°C.

Inductor Selection

The inductance depends on the maximum input current. As a general rule, the inductor ripple current range is 20% to 40% of the maximum input current. If 40% is selected as an example, the inductor ripple current can be calculated according to the following equation:

\[ I_{\text{RIPPLE}} = 0.4 \times I_{\text{IN(MAX)}} \]

\[ I = \eta \times \frac{V_{\text{OUT}}}{V_{\text{IN}}(\text{MIN})} \times I_{\text{IN(MIN)}} \]

where \( \eta \) is the efficiency of the boost converter, \( I_{\text{IN(MAX)}} \) is the maximum input current, \( I_{\text{OUT}} \) is the total current from all LED strings, and \( I_{\text{RIPPLE}} \) is the inductor ripple current. The input peak current can be calculated by maximum input current plus half of inductor ripple current shown as following equation:

\[ I_{\text{PEAK}} = 1.2 \times I_{\text{IN(MAX)}} \]

Note that the saturated current of the inductor must be greater than \( I_{\text{PEAK}} \). The inductance can eventually be determined according to the following equation:

\[ L = \frac{\eta \times (V_{\text{IN}})^2 \times (V_{\text{OUT}} - V_{\text{IN}})}{0.4 \times (V_{\text{OUT}})^2 \times I_{\text{OUT}} \times f_{\text{OSC}}} \]

where \( f_{\text{OSC}} \) is the switching frequency. For better efficiency, it is suggested to choose an inductor with small series resistance.

Diode Selection

The Schottky diode is a good choice for an asynchronous boost converter due to its small forward voltage. However, when selecting a Schottky diode, important parameters such as power dissipation, reverse voltage rating, and pulsating peak current must all be taken into consideration. A suitable Schottky diode’s reverse voltage rating must be greater than the maximum output voltage, and its average current rating must exceed the average output current.

Capacitor Selection

Two 1µF ceramic input capacitors and two 1µF ceramic output capacitors are recommended for driving 10 WLEDs in series. For better voltage filtering, ceramic capacitors with low ESR are recommended. Note that the X5R and X7R types are suitable because of their wide voltage and temperature ranges.

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:

\[ P_{\text{D(MAX)}} = (T_{\text{J(MAX)}} - T_{\text{A}_b}) / \theta_{\text{JA}} \]

where \( T_{\text{J(MAX)}} \) is the maximum junction temperature, \( T_{\text{A}_b} \) is the ambient temperature, and \( \theta_{\text{JA}} \) 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, \( \theta_{\text{JA}} \), is layout dependent. For WDFN-8L 2x2 packages, the thermal resistance, \( \theta_{\text{JA}} \), is 120°C/W on a standard JEDEC 51-7 four-layer thermal test board. For WDFN-8L 3x3 packages, the thermal resistance, \( \theta_{\text{JA}} \), is 70°C/W on a standard JEDEC 51-7 four-layer thermal test board. The maximum power
dissipation at $T_A = 25^\circ C$ can be calculated by the following formulas:

\[ P_{D(\text{MAX})} = \frac{(125^\circ C - 25^\circ C)}{(120^\circ C/W)} = 0.833W \text{ for WDFN-8L 2X2 package} \]

\[ P_{D(\text{MAX})} = \frac{(125^\circ C - 25^\circ C)}{(70^\circ C/W)} = 1.429W \text{ for WDFN-8L 3X3 package} \]

The maximum power dissipation depends on operating ambient temperature for fixed $T_{J(\text{MAX})}$ and thermal resistance, $\theta_{JA}$. The derating curves in Figure 6 allow the designer to see the effect of rising ambient temperature on the maximum power dissipation.

**Layout Consideration**

For high frequency switching power supplies, the PCB layout is important to obtain good regulation, high efficiency and stability. The following descriptions are the suggestions for better PCB layout.

- Input and output capacitors should be placed close to the IC and connected to the ground plane to reduce noise coupling.
- The GND and Exposed Pad should be connected to a strong ground plane for heat sinking and noise protection.
- The components L, D, C\text{IN} and C\text{OUT} must be placed as close as possible to reduce current loop. Keep the main current traces as possible as short and wide.
- The LX node of the DC/DC converter experiences is with high frequency voltage swings. It should be kept in a small area.
- The component R\text{SET} should be placed as close as possible to the IC and kept away from noisy devices.

![Figure 6. Derating Curve of Maximum Power Dissipation](image)

![Figure 7. PCB Layout Guide](image)
Outline Dimension

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Dimensions In Millimeters</th>
<th>Dimensions In Inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.700 0.800</td>
<td>0.028 0.031</td>
</tr>
<tr>
<td>A1</td>
<td>0.000 0.050</td>
<td>0.000 0.002</td>
</tr>
<tr>
<td>A3</td>
<td>0.175 0.250</td>
<td>0.007 0.010</td>
</tr>
<tr>
<td>b</td>
<td>0.200 0.300</td>
<td>0.008 0.012</td>
</tr>
<tr>
<td>D</td>
<td>1.950 2.050</td>
<td>0.077 0.081</td>
</tr>
<tr>
<td>D2</td>
<td>1.000 1.250</td>
<td>0.039 0.049</td>
</tr>
<tr>
<td>E</td>
<td>1.950 2.050</td>
<td>0.077 0.081</td>
</tr>
<tr>
<td>E2</td>
<td>0.400 0.650</td>
<td>0.016 0.026</td>
</tr>
<tr>
<td>e</td>
<td>0.500</td>
<td>0.020</td>
</tr>
<tr>
<td>L</td>
<td>0.300 0.400</td>
<td>0.012 0.016</td>
</tr>
</tbody>
</table>

W-Type 8L DFN 2x2 Package

Note: The configuration of the Pin #1 identifier is optional, but must be located within the zone indicated.

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.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Dimensions In Millimeters</th>
<th>Dimensions In Inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.700 - 0.800</td>
<td>0.028 - 0.031</td>
</tr>
<tr>
<td>A1</td>
<td>0.000 - 0.050</td>
<td>0.000 - 0.002</td>
</tr>
<tr>
<td>A3</td>
<td>0.175 - 0.250</td>
<td>0.007 - 0.010</td>
</tr>
<tr>
<td>b</td>
<td>0.200 - 0.300</td>
<td>0.008 - 0.012</td>
</tr>
<tr>
<td>D</td>
<td>2.950 - 3.050</td>
<td>0.116 - 0.120</td>
</tr>
<tr>
<td>D2</td>
<td>2.100 - 2.350</td>
<td>0.083 - 0.093</td>
</tr>
<tr>
<td>E</td>
<td>2.950 - 3.050</td>
<td>0.116 - 0.120</td>
</tr>
<tr>
<td>E2</td>
<td>1.350 - 1.600</td>
<td>0.053 - 0.063</td>
</tr>
<tr>
<td>e</td>
<td>0.650</td>
<td>0.026</td>
</tr>
<tr>
<td>L</td>
<td>0.425 - 0.525</td>
<td>0.017 - 0.021</td>
</tr>
</tbody>
</table>

W-Type 8L DFN 3x3 Package