Current Mode Boost Controller

General Description
The RT8525D is a wide input operating voltage range step up controller. High voltage output and large output current are feasible by using an external N-MOSFET. The RT8525D input operating range is from 4.5V to 25V.

The RT8525D is an optimized design for wide output voltage range applications. The output voltage of the RT8525D can be adjusted by the FB pin.

Ordering Information

- **Package Type**: WDFN-12L 3x3 (W-Type) (Exposed Pad-Option 2)
- **Lead Plating System**: 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

- 0F=YM: Product Code
- DNN: Date Code

Features
- **VIN Range**: 4.5V to 25V
- Programmable Soft-Start Time
- Programmable Boost SW Frequency from 50kHz to 600kHz
- Output Over Voltage Protection
- Output Under Voltage Protection
- 12-Lead WDFN Package
- RoHS Compliant and Halogen Free

Applications
- LCD TV, Monitor Display Backlight
- LED Driver Application
- High Current High Output Voltage DC/DC Converters
- High Input Voltage DC/DC Converters

Pin Configurations

- **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>VDC</td>
<td>Output of Internal Pre-Regulator.</td>
</tr>
<tr>
<td>2</td>
<td>VIN</td>
<td>IC Power Supply.</td>
</tr>
<tr>
<td>3</td>
<td>COMP</td>
<td>Compensation for Error Amplifier. Connect a compensation network to ground.</td>
</tr>
<tr>
<td>4</td>
<td>SS</td>
<td>External Capacitor to Adjust Soft-Start Time.</td>
</tr>
<tr>
<td>5</td>
<td>FSW</td>
<td>Frequency Adjust Pin. This pin allows setting the switching frequency with a resistor from 50kHz to 600kHz.</td>
</tr>
<tr>
<td>6</td>
<td>FAULT</td>
<td>Open Drain Output for Fault Detection.</td>
</tr>
<tr>
<td>7</td>
<td>FB</td>
<td>Feedback to Error Amplifier Input.</td>
</tr>
<tr>
<td>8</td>
<td>OVP</td>
<td>Sense Output Voltage for Over Voltage Protection and Under Voltage Protection.</td>
</tr>
<tr>
<td>9</td>
<td>ISW</td>
<td>External MOSFET Switch Current Sense Pin. Connect the current sense resistor between the external N-MOSFET switch and ground.</td>
</tr>
<tr>
<td>10, 13 (Exposed Pad)</td>
<td>GND</td>
<td>Ground of Boost Controller. The exposed pad must be soldered to a large PCB and connected to GND for maximum power dissipation.</td>
</tr>
<tr>
<td>11</td>
<td>DRV</td>
<td>Drive Output for the N-MOSFET.</td>
</tr>
<tr>
<td>12</td>
<td>EN</td>
<td>Chip Enable (Active High).</td>
</tr>
</tbody>
</table>
Function Block Diagram

**Operation**
The RT8525D is a wide input operating voltage range and current mode step up controller. High voltage output and large output current are feasible by using an external N-MOSFET.

The error amplifier EA adjusts COMP voltage by comparing the feedback signal from the output voltage with the internal 1.25V reference.

**Blanking**
N-MOSFET current is measured by external RS. The slope compensator works together with sensing voltage of $R_{S\text{ENSE}}$ to the ISW pin. There is need blanking time to avoid noise and parasitism effect.

**Fault Protection**
The protection functions include output over voltage, output under voltage, over temperature protection. The FAULT pin will be pulled low once a protection is triggered, and a suitable pulled-high $R_{FLT}$ is required. The detail description can refer to the Figure 2. Fault Protection Function Block.
Absolute Maximum Ratings  
(Note 1)

- VIN to GND: -0.3V to 26.4V
- VDC, DRV, FAULT to GND: -0.3V to 13.2V
- EN, COMP, SS, FSW, FB, OVP, ISW to GND: -0.3V to 6V
- Power Dissipation, Pd @ TA = 25°C: 1.667W
- Package Thermal Resistance (Note 2) WDFN-12L 3x3, θJA: 60°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, VIN: 4.5V to 25V
- Junction Temperature Range: -40°C to 125°C
- Ambient Temperature Range: -40°C to 85°C

Electrical Characteristics

\( \text{VIN} = 21V, \ C_{IN} = 10\mu F, \ TA = 25°C \), 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>Input Power Supply</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Quiescent Current</td>
<td>( I_Q )</td>
<td>No Switching, ( R_{SW} = 56k\Omega )</td>
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<td>1.3</td>
<td>2</td>
<td>mA</td>
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<tr>
<td>Shutdown Current</td>
<td>( I_{SHDN} )</td>
<td>( V_{EN} = 0V )</td>
<td>--</td>
<td>10</td>
<td>--</td>
<td>μA</td>
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<tr>
<td>Under Voltage Lockout Threshold</td>
<td>( V_{UVLO} )</td>
<td>( V_{IN} ) Rising</td>
<td>--</td>
<td>3.8</td>
<td>--</td>
<td>V</td>
</tr>
<tr>
<td>Under Voltage Lockout Hysteresis</td>
<td>( \Delta V_{UVLO} )</td>
<td></td>
<td>--</td>
<td>500</td>
<td>--</td>
<td>mV</td>
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<tr>
<td>12V Regulator</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Regulator Output Voltage</td>
<td>( V_{DC} )</td>
<td>( 13.5V &lt; V_{IN} &lt; 16V, 1mA &lt; I_{LOAD} &lt; 100mA )</td>
<td>11.4</td>
<td>12</td>
<td>12.6</td>
<td>V</td>
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<tr>
<td></td>
<td></td>
<td>( 16V &lt; V_{IN} &lt; 20V, 1mA &lt; I_{LOAD} &lt; 50mA )</td>
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<tr>
<td></td>
<td></td>
<td>( 20V &lt; V_{IN} &lt; 25V, 1mA &lt; I_{LOAD} &lt; 20mA )</td>
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<tr>
<td>Dropout Voltage</td>
<td>( V_{DROP} )</td>
<td>( V_{IN} - V_{DC}, V_{IN} = 12V, I_{LOAD} = 100mA )</td>
<td>--</td>
<td>500</td>
<td>--</td>
<td>mV</td>
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<tr>
<td>Short-Circuit Current Limit</td>
<td>( I_{SC} )</td>
<td>( V_{DC} ) Short to GND</td>
<td>--</td>
<td>270</td>
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<td>mA</td>
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Control Input

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<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Logic-High</th>
<th>Logic-Low</th>
<th>Test Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
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<tbody>
<tr>
<td>EN Threshold Voltage</td>
<td>( V_{IH} )</td>
<td>2</td>
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<td>V</td>
<td></td>
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<td></td>
<td>( V_{IL} )</td>
<td>--</td>
<td>--</td>
<td>0.8</td>
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<tr>
<td>EN Sink Current</td>
<td>( I_{IH} )</td>
<td>( V_{EN} = 5V )</td>
<td>--</td>
<td>5</td>
<td>--</td>
<td>μA</td>
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<td>Parameter</td>
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<td>Min</td>
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<td>Max</td>
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<td>Sleeping Mode tSLEEP</td>
<td>RSW = 56kΩ, EN = L, 12V Regular Shutdown</td>
<td>55</td>
<td>--</td>
<td>--</td>
<td>ms</td>
<td></td>
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<td>Shutdown Mode tSHDN</td>
<td>RSW = 56kΩ, EN = L, IC Shutdown</td>
<td>110</td>
<td>--</td>
<td>--</td>
<td>ms</td>
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<td>Boost Controller</td>
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<td>Switching Frequency fSW</td>
<td>RSW = 56kΩ</td>
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<td>200</td>
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<td>kHz</td>
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<td>Minimum On-Time tMON</td>
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<td>250</td>
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<td>ns</td>
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<td>Maximum Duty DMAX</td>
<td>Switching</td>
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<td>90</td>
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<td>%</td>
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<td>Feedback Voltage VFB</td>
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<td>--</td>
<td>1.25</td>
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<td>V</td>
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<td>Slope Compensation</td>
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<td>Peak Magnitude of Slope</td>
<td>ISLOPE, PK</td>
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<td>--</td>
<td>50</td>
<td>--</td>
<td>μA</td>
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<td>Compensation Current</td>
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<td>Soft-Start</td>
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<tr>
<td>Soft-Start Current ISS</td>
<td></td>
<td></td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>μA</td>
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<td>Gate Driver</td>
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<tr>
<td>DRV On-Resistance RDS(ON)_N</td>
<td>ISINK = 100mA (N-MOSFET)</td>
<td>--</td>
<td>1</td>
<td>--</td>
<td>Ω</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>RDS(ON)_P</td>
<td>ISOURCE = 100mA (P-MOSFET)</td>
<td>--</td>
<td>1.5</td>
<td>--</td>
<td>Ω</td>
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<tr>
<td>Peak Sink Current</td>
<td>IPEAKsk</td>
<td>CLOAD = 1nF</td>
<td>--</td>
<td>2.2</td>
<td>--</td>
<td>A</td>
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<tr>
<td>Peak Source Current</td>
<td>IPEAKsr</td>
<td>CLOAD = 1nF</td>
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<td>2.55</td>
<td>--</td>
<td>A</td>
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<td>Rise Time</td>
<td>tr</td>
<td>CLOAD = 1nF</td>
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<td>6</td>
<td>--</td>
<td>ns</td>
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<tr>
<td>Fall Time</td>
<td>tf</td>
<td>CLOAD = 1nF</td>
<td>--</td>
<td>5</td>
<td>--</td>
<td>ns</td>
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<td></td>
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<tr>
<td>Protection Function</td>
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<tr>
<td>OCP Threshold VOCP</td>
<td></td>
<td>Including Slope Compensation Magnitude</td>
<td>--</td>
<td>0.4</td>
<td>--</td>
<td>V</td>
<td></td>
<td></td>
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<tr>
<td>VOUT OVP Threshold VOV</td>
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<td></td>
<td>--</td>
<td>2.5</td>
<td>--</td>
<td>V</td>
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<tr>
<td>VOUT UVP Threshold VUP</td>
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<td>0.1</td>
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<td>V</td>
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<tr>
<td>Thermal Shutdown Temperature TSD</td>
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<td></td>
<td>--</td>
<td>150</td>
<td>--</td>
<td>°C</td>
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<tr>
<td>Thermal Shutdown Hysteresis ATSD</td>
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<td>--</td>
<td>50</td>
<td>--</td>
<td>°C</td>
<td></td>
<td></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.** θJA is measured at TA = 25°C on a high effective thermal conductivity four-layer test board per JEDEC 51-7. θJC 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 Application Circuit

- **VIN (5V)**
- **CIN (22µF)**
- **CVCIN (1µF)**
- **CVCDC (2.4k)**
- **RS (50m)**
- **RFB1 (43k)**
- **RFB2 (3k)**
- **RFLT (62k)**
- **COVP (5.6k)**
- **CSS (27nF)**
- **CC1 (22µF)**
- **CC2 (1µF)**
- **RC (6.8k)**
- **RCV (0.33µF)**
- **VIN (22µF x 2)**
- **12V**
- **L1 (10µH)**
- **D1**
- **VOUT (12V)**
- **RSLP (100k)**
- **M1**
- **COMP**
- **ISW**
- **GND**
- **FB**
- **FAULT**
- **EN**
- **DRV**
- **FB**
- **OVP**
- **COMP**
- **FSW**
- **SS**
- **5V**
- **12V**
- **10µH**

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**Note:**
- **Chip Enable (3)**
- **Chip Disable (2)**
- **Exposed Pad (13)**

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Typical Application Circuit

Quiescent Current vs. Input Voltage

Feedback Voltage vs. Input Voltage

Switching Frequency vs. Temperature

Boost Efficiency vs. Load Current

RSW = 56kΩ
Applications Information

The RT8525D is a wide input operating voltage range step up controller. High voltage output and large output current are feasible by using an external N-MOSFET. The protection functions include output over voltage, output under voltage, over temperature and current limiting protection.

Boost Output Voltage Setting

The regulated output voltage is set by an external resistor divider according to the following equation:

\[ V_{OUT} = V_F B \times \left(1 + \frac{R_{FB1}}{R_{FB2}}\right) \]

where \( V_{FB} = 1.25V \) (typ.)

The recommended value of \( R_{FB2} \) should be at least 1kΩ for saving sacrificing. Moreover, placing the resistor divider as close as possible to the chip can reduce noise sensitivity.

Boost Switching Frequency

The RT8525D boost driver switching frequency is able to be adjusted by a resistor \( R_{SW} \) ranging from 18kΩ to 220kΩ. The following figure illustrates the corresponding switching frequency within the resistor range.

![Switching Frequency vs. RSW](image)

- Switching Frequency vs. RSW

Boost Loop Compensation

The voltage feedback loop can be compensated by an external compensation network consisted of \( R_C \), \( C_{C1} \) and \( C_{C2} \). Choose \( R_C \) to set high frequency gain for fast transient response. Select \( C_{C1} \) and \( C_{C2} \) to set the zero and pole to maintain loop stability. A typical compensation for the RT8525D is choosing 3kΩ for \( R_C \) and 27nF for \( C_{C1} \).

Soft-Start

The soft-start of the RT8525D 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 external capacitor charged by an internal 4μA constant charging current determines the soft-start time. The SS pin limits the rising rate of the COMP pin voltage and thereby limits the peak switch current. The soft-start interval is set by the soft-start capacitor according to the following equation:

\[ t_{SS} \approx C_{SS} \times 5 \times 10^5 \]

A typical value for the soft-start capacitor is 0.33μF. The soft-start capacitor is discharged when EN voltage falls below its threshold after shutdown delay or UVLO occurs.

Slope Compensation and Current Limiting

A slope compensation is applied to avoid sub-harmonic oscillation in current-mode control. The slope compensation voltage is generated by the internal ramp current flow through a slope compensation resistor \( R_{SLP} \). The inductor current is sensed by the sensing resistor \( R_S \). Both of them are added and presented on the ISW pin. The internal ramp current is rising linearly form zero at the beginning of each switching cycle to 50μA in maximum on-time of each cycle. The slope compensation resistor \( R_{SLP} \) can be calculated by the following equation:

\[ R_{SLP} > \left(\frac{V_{OUT} - V_N}{2L \times 50μA}\right) \times R_S \]

where \( R_S \) is current sensing resistor, \( L \) is inductor value, and \( f_{SW} \) is boost switching frequency.

The current flow through inductor during charging period is detected by a sensing resistor \( R_S \). Besides, the slope compensation voltage also attributes magnitude to ISW. As the voltage at the ISW pin is over 0.4V, the DRV will be pulled low and turn off the external N-MOSFET. So that the inductor will be forced to leave charging stage and enter discharging stage to prevent over current. The current limiting can be calculated by the following equation:
Output Over Voltage Protection

The output voltage can be clamped at the voltage level determined by the following equation:

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

where \( V_{\text{OVP}} = 2.5 \text{V (typ.)} \)

where \( R_{\text{OVP1}} \) and \( R_{\text{OVP2}} \) are the voltage divider connected to the OVP pin.

Fault Protection

The FAULT pin will be pulled low once a protection is triggered, and a suitable pulled-high \( R_{\text{FLT}} \) is required. The suggested \( R_{\text{FLT}} \) is 100kΩ if the pulled-high voltage was 12V. The following figure illustrates the fault protection function block. If one of the OUV and OTP occurs, the switch 1 will be turned on, and the voltage at node A will be under 0.25V. Then the protection function will perform action 2 to turn off the driver. When protection function is released, the RT8525D will re-start.

On the other hand, if the triggered protection is OVP, the voltage at node A will be decided by voltage divider composed of \( R_{\text{FLT}} \) and the internal 8kΩ resistor. This voltage must be designed between 0.25V and 1.25V by choosing \( R_{\text{FLT}} \) appropriately. Once the OVP turns on the Switch 2, the divided FAULT voltage will activate action 1 to turn off the driver without resetting soft-start. Therefore, when protection function OVP is released, the RT8525D will be in normal operation.

Power MOSFET Selection

For the applications operating at high output voltage, switching losses dominate the overall power loss. Therefore, the power N-MOSFET switch is typically chosen for drain voltage, VDS, rating and low gate charge. Consideration of switch on-resistance \( R_{\text{DS(on)}} \) is usually secondary. The VDC regulator in the RT8525D has a fixed output current limit to protect the IC and provide 12V DRV voltage for N-MOSFET switch gate driver.

Inductor Selection

The boundary value of the inductance \( L \) between Discontinuous Conduction Mode (DCM) and Continuous Conduction Mode (CCM) can be approximated by the following equation:

\[ L = \frac{D \times (1-D)^2 \times V_{\text{OUT}}}{2 \times f_{\text{SW}} \times I_{\text{OUT}}} \]

where

\( V_{\text{OUT}} \) is the maximum output voltage,
\( V_{\text{IN}} \) is the minimum input voltage,
\( f_{\text{SW}} \) is the operating frequency,
\( I_{\text{OUT}} \) is the sum of current from all LED strings,

and \( D \) is the duty cycle calculated by the following equation:

\[ D = \frac{V_{\text{OUT}} - V_{\text{IN}}}{V_{\text{OUT}}} \]

The boost converter operates in DCM over the entire input voltage range if the inductor value is less than the boundary value \( L \). With an inductance greater than \( L \), the converter operates in CCM at the minimum input voltage and may transit to DCM at higher voltages. The inductor must be selected with a saturated current rating greater than the peak current provided by the following equation:

\[ I_{\text{LPK}} = \frac{V_{\text{OUT}} \times I_{\text{OUT}}}{\eta \times V_{\text{IN}}} + \frac{V_{\text{IN}} \times D \times T}{2 \times L} \]

where \( \eta \) is the efficiency of the power converter.
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 \( I_{PK} \), and reverse voltage rating exceeds the maximum output voltage.

Capacitor Selection
Output ripple voltage is an important index for estimating the performance. This portion consists of two parts, one is the product of input current and ESR of output capacitor, another part is formed by charging and discharging process of output capacitor. Refer to figure 3, evaluate \( \Delta V_{OUT1} \) by ideal energy equalization. According to the definition of \( Q \), the \( Q \) value can be calculated as following equation:

\[
Q = \frac{1}{2} \left[ \left( I_N + \frac{1}{2} \Delta I_L - I_{OUT} \right) + \left( I_N - \frac{1}{2} \Delta I_L - I_{OUT} \right) \right] \times \frac{V_{IN}}{V_{OUT}}
\]

\[
\times \frac{1}{f_{SW}} = C_{OUT} \times \Delta V_{OUT1}
\]

where \( f_{SW} \) is the switching frequency, and \( \Delta I_L \) is the inductor ripple current. Move \( C_{OUT} \) to the left side to estimate the value of \( \Delta V_{OUT1} \) as the following equation:

\[
\Delta V_{OUT1} = \frac{D \times I_{OUT}}{\eta \times C_{OUT} \times f_{SW}}
\]

Finally, by taking ESR into consideration, the overall output ripple voltage can be determined as the following equation:

\[
\Delta V_{OUT} = I_N \times ESR + \frac{D \times I_{OUT}}{\eta \times C_{OUT} \times f_{SW}}
\]

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:

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

where \( T_{J(MAX)} \) is the maximum junction temperature, \( T_A \) is the ambient temperature, and \( \theta_{JA} \) 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, \( \theta_{JA} \), is layout dependent. For WDFN-12L 3x3 package, the thermal resistance, \( \theta_{JA} \), is 60°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:

\[
P_{D(MAX)} = \frac{(125°C - 25°C)}{(60°C/W)} = 1.667W
\]

The maximum power dissipation depends on the operating ambient temperature for fixed \( T_{J(MAX)} \) and thermal
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 RT8525D.

- The power components L1, D1, CIN, COUT, M1 and RS 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 components R_FB1 and R_FB2 close to IC as possible. The trace should be kept away from the power loops and shielded with a ground trace to prevent any noise coupling.

- 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 to the COMP pin as close as possible, no matter the compensation is RC, C_C1 or C_C2.

![Figure 4. Derating Curve of Maximum Power Dissipation](image)

![Figure 5. PCB Layout Guide](image)
Outline Dimension

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Dimensions In Millimeters</th>
<th>Dimensions In Inches</th>
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<tr>
<td></td>
<td>Min.</td>
<td>Max.</td>
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<tr>
<td>A</td>
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<td>0.800</td>
</tr>
<tr>
<td>A1</td>
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<tr>
<td>A3</td>
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<td>0.250</td>
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<tr>
<td>D</td>
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<td>3.050</td>
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<tr>
<td>Option1</td>
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</tr>
<tr>
<td>Option2</td>
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<td>2.070</td>
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<tr>
<td>E</td>
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<tr>
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<tr>
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<td></td>
</tr>
<tr>
<td>L</td>
<td>0.350</td>
<td>0.450</td>
</tr>
</tbody>
</table>

W-Type 12L DFN 3x3 Package

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