Single-chip Type with Built-in FET Switching Regulators

Simple Step-down Switching Regulators with Built-in Power MOSFET

**BD9G101G**

**General Description**
The BD9G101G is a high voltage input 42V step-down switching regulator with integrated internal Power MOSFET. It provides maximum 0.5A output with small SSOP6 package. It is allowing the use of small inductor by high frequency operation of 1.5MHz. Also, it is implemented to downsize by incorporation of phase compensation parts with current mode.

**Features**
- High and Wide Input Voltage Range (VCC=6V to 42V)
- 45V/800mΩ Internal Power Nch-FET
- 1.5MHz Fixed Operating High Frequency
- Built-in Reference Voltage 0.75V±1.5% circuit
- Built-in Phase Compensation circuit
- Internal Over Current protection, Under Voltage Lock Out, Thermal shutdown
- Stand-by function (Ist=0µA)
- Small package SSOP6

**Key Specifications**
- **Input Voltage**: 6V to 42V
- **Reference Voltage Precision (Ta=25°C)**: ±1.5 %
  (Ta=25°C to 105°C) ±2.0 %
- **Max Output Current**: 0.5 A (Max)
- **Operating Temperature**: -40°C to +105°C
- **Max Junction Temperature**: 150°C

**Packages**
- **SSOP6**: W(Typ) x D(Typ) x H(Max)
  2.90mm x 2.80mm x 1.25mm

**Applications**
- Industrial distributed power applications
- Battery powered equipment
- OA instruments

**Typical Application Circuits**

![Typical Application Circuit](image)

**Figure 1. Typical Application Circuit**
Pin Configuration

Figure 2. Pin Configuration (TOP VIEW)

Pin Description

<table>
<thead>
<tr>
<th>Pin No.</th>
<th>Pin Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>BST</td>
<td>The pin is power supply for floating Power Nch-FET driver. Connected 15000pF between this pin and LX pin for bootstrap operation.</td>
</tr>
<tr>
<td>2</td>
<td>GND</td>
<td>Ground.</td>
</tr>
<tr>
<td>3</td>
<td>FB</td>
<td>Voltage feedback pin. This pin is error-amplifier input, the DCDC is set 0.75V at this pin with feed-back operation.</td>
</tr>
<tr>
<td>4</td>
<td>EN</td>
<td>ON/OFF pin. The IC is start-up to apply 2.0V or over. This pin has pull-down resister 550kΩ, the IC is shutdown to open or apply 0.8V or under.</td>
</tr>
<tr>
<td>5</td>
<td>VCC</td>
<td>Input supply. It should be connected as near as possible to the bypass capacitor. It should be increased impedance by thick PCB pattern.</td>
</tr>
<tr>
<td>6</td>
<td>LX</td>
<td>Power Nch-FET switching node pin. It should be connected as near as possible to the schottky barrier diode, and inductor.</td>
</tr>
</tbody>
</table>

Block Diagram

Figure 3. Block Diagram
Description of Blocks

1. Reference
   This block generates reference voltage. It starts operation by applying EN 2.0V or more.
   It provides reference voltage and error-amplifier 0.75V, oscillator, current and etc.

2. REG
   This is a gate drive voltage generator and 4.2V regulator for internal circuit power supply.

3. OSC
   It is generated rectangular wave of 1.5MHz with operation frequency of normal time.
   To protect over current from output shorted to GND, the frequency is changed depending on FB voltage by the
   Frequency fold-back function.

4. Soft Start
   This block does Soft Start to the output voltage of DC/DC comparator, and prevents in-rush current during Start-up.
   Soft Start Time depend on application start-condition because the Frequency fold-back function is built-in. The
   Frequency fold-back function changes frequency by FB voltage.

5. ERROR AMP
   This is an error-amplifier what detects output signal, and outputs PWM control signal.
   Internal reference voltage is set to 0.75V. Also, the BD9G101G has internal phase compensated element between
   input and output.

6. Current Comparator
   This is a comparator that outputs PWM signal from current feed-back signal and error-amplifier output for
   current-mode.

7. Nch-FET SW
   This is an 45V/800mΩ Power Nch-FET SW that converts inductor current of DC/DC converter.

8. UVLO
   This is a low voltage error prevention circuit.
   This prevents internal circuit error during increase of power supply voltage and during decline of power supply voltage.
   It monitors VCC pin voltage, and when VCC voltage becomes 5.4V and below, it turns OFF DC/DC converter output,
   and Soft Start circuit resets.
   Now this threshold has hysteresis of 200mV.

9. EN
   When a Voltage of 2.0V or more is applied, it turns ON. at open or 0.8V or under applied, it turns OFF.
   550kΩ (Typ) Pull-down Resistance is contained in the Pin.

10. OCP
    This is Over Current protection.
    It monitors current of high-side Nch-FET. If the current is 1.2A (Typ) or more, this function reduce duty by
    pulse-by-pulse and restrict the over current.

11. TSD
    This is circuit for preventing malfunction at high Temperature.
    When it detects an abnormal temperature Tj=175°C, it turns OFF DC/DC Converter Output. The protection circuit has
    Hysteresis (25°C). It prevents malfunction by changing near threshold.
### Absolute Maximum Ratings

<table>
<thead>
<tr>
<th>Item</th>
<th>Symbol</th>
<th>Ratings</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>VCC to GND</td>
<td>VCC</td>
<td>45</td>
<td>V</td>
</tr>
<tr>
<td>BST to GND</td>
<td>VBST</td>
<td>50</td>
<td>V</td>
</tr>
<tr>
<td>Maximum rating current</td>
<td>I&lt;sub&gt;max&lt;/sub&gt;</td>
<td>1.0</td>
<td>A</td>
</tr>
<tr>
<td>BST to LX</td>
<td>∆VBST</td>
<td>7</td>
<td>V</td>
</tr>
<tr>
<td>EN to GND</td>
<td>VEN</td>
<td>45</td>
<td>V</td>
</tr>
<tr>
<td>LX to GND</td>
<td>VLX</td>
<td>45</td>
<td>V</td>
</tr>
<tr>
<td>FB to GND</td>
<td>VFB</td>
<td>7</td>
<td>V</td>
</tr>
<tr>
<td>Power Dissipation</td>
<td>P&lt;sub&gt;d&lt;/sub&gt;</td>
<td>0.675&lt;sup&gt;(1)&lt;/sup&gt;</td>
<td>W</td>
</tr>
<tr>
<td>Operating Temperature</td>
<td>Topr</td>
<td>-40 to +105</td>
<td>°C</td>
</tr>
<tr>
<td>Storage Temperature</td>
<td>Tstg</td>
<td>-55 to +150</td>
<td>°C</td>
</tr>
<tr>
<td>Junction Temperature</td>
<td>T&lt;sub&gt;jmax&lt;/sub&gt;</td>
<td>150&lt;sup&gt;(2)&lt;/sup&gt;</td>
<td>°C</td>
</tr>
</tbody>
</table>

<sup>(1)</sup> During mounting of 70×70×1.6t mm1 layer board. Reduce by 0.4mW for every 1°C increase. (25°C or more)

<sup>(2)</sup> This is circuit for preventing malfunction at high Temperature.

When it detects an abnormal temperature T<sub>j</sub>=175°C, it turns OFF DC/DC Converter Output.

The protection circuit has Hysteresis (25°C). It prevents malfunction by changing near threshold

### Electrical Characteristics (Unless otherwise specified Ta=25°C, VCC=24V, VOUT=5V, EN=3V)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Limit</th>
<th>Unit</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circuit Current</td>
<td></td>
<td>Min</td>
<td>Typ</td>
<td>Max</td>
</tr>
<tr>
<td>Stand-by Current</td>
<td>I&lt;sub&gt;st&lt;/sub&gt;</td>
<td>-</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Operating Current</td>
<td>I&lt;sub&gt;cc&lt;/sub&gt;</td>
<td>-</td>
<td>0.7</td>
<td>1.2</td>
</tr>
<tr>
<td>Under Voltage Lock Out (UVLO)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Detect Threshold Voltage</td>
<td>V&lt;sub&gt;uv&lt;/sub&gt;</td>
<td>5.1</td>
<td>5.4</td>
<td>5.7</td>
</tr>
<tr>
<td>Hysteresis width</td>
<td>V&lt;sub&gt;uv&lt;/sub&gt;hy</td>
<td>-</td>
<td>200</td>
<td>300</td>
</tr>
<tr>
<td>Oscillator</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Switching Frequency</td>
<td>F&lt;sub&gt;osc&lt;/sub&gt;</td>
<td>1.3</td>
<td>1.5</td>
<td>1.7</td>
</tr>
<tr>
<td>Max Duty Cycle</td>
<td>D&lt;sub&gt;max&lt;/sub&gt;</td>
<td>85</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Error AMP</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FB Pin Threshold Voltage</td>
<td>V&lt;sub&gt;FBN&lt;/sub&gt;</td>
<td>0.739</td>
<td>0.750</td>
<td>0.761</td>
</tr>
<tr>
<td></td>
<td>V&lt;sub&gt;FB&lt;/sub&gt;A</td>
<td>0.735</td>
<td>0.750</td>
<td>0.765</td>
</tr>
<tr>
<td>FB Pin Input Current</td>
<td>I&lt;sub&gt;FB&lt;/sub&gt;</td>
<td>-100</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Soft-Start Time</td>
<td>T&lt;sub&gt;soft&lt;/sub&gt;</td>
<td>1.2</td>
<td>4.0</td>
<td>-</td>
</tr>
<tr>
<td>Current Comparator</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trans-conductance</td>
<td>G&lt;sub&gt;CS&lt;/sub&gt;</td>
<td>-</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>Output</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High-side Nch-FET ON Resistance</td>
<td>RonH</td>
<td>-</td>
<td>800</td>
<td>-</td>
</tr>
<tr>
<td>Min ON Time</td>
<td>T&lt;sub&gt;min&lt;/sub&gt;</td>
<td>-</td>
<td>100</td>
<td>-</td>
</tr>
<tr>
<td>OCP Detect Current</td>
<td>I&lt;sub&gt;ocp&lt;/sub&gt;</td>
<td>0.85</td>
<td>1.2</td>
<td>-</td>
</tr>
<tr>
<td>CTL</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EN Threshold Voltage</td>
<td>ON VENON</td>
<td>2.0</td>
<td>-</td>
<td>VCC</td>
</tr>
<tr>
<td></td>
<td>OFF VENOFF</td>
<td>-0.3</td>
<td>-</td>
<td>0.8</td>
</tr>
<tr>
<td>EN Input Current</td>
<td>I&lt;sub&gt;EN&lt;/sub&gt;</td>
<td>2.7</td>
<td>5.5</td>
<td>11</td>
</tr>
</tbody>
</table>
Operating Ratings

<table>
<thead>
<tr>
<th>Item</th>
<th>Symbol</th>
<th>Ratings</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Voltage</td>
<td>VCC</td>
<td>6</td>
<td>-</td>
</tr>
<tr>
<td>Output Voltage</td>
<td>VOUT</td>
<td>1.0 (3)</td>
<td>VCC x 0.7 (4)</td>
</tr>
<tr>
<td>Output Current</td>
<td>IOUT</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

(3) Restricted by Min ON Time typ 100ns.
(4) Restricted by Max duty, RonH and BST-UVLO.

Output voltage range and Output voltage setting
BD9G101G is limited the range of use by Max duty (min85%), Min ON Time (Typ 100ns), high-side Nch-FET ON resistance (RonH) and low voltage protect (BST-UVLO) for drive voltage of high-side Nch-FET between BST and LX.

1. BST-UVLO
   It is the function that secure gate voltage of Nch-FET and prevent malfunction of the IC. If the voltage between BST and LX is lower than 1.5V, Nch-FET is turned off and there is new pass to charge voltage VCC to BST. BST voltage is charged by VCC. If the voltage between BST and LX is upper than 1.8V, BST-UVLO is released. The condition that BST-UVLO is working property is VCC > (BST-UVLO + Vf) + VOUT. Therefore, maximum output voltage is restricted VCC -3V.

   ![BST-UVLO equivalent circuit](image)

   *When operation can be considered by VCC-VOUT<3V, output voltage leaps up to near input voltage by BST-UVLO operation at the time of a light load.

   The waveform of operation and a mechanism are shown.

   ![Low voltage and light load, BST-UVLO operation waveform](image)
As a measure, it is necessary to lower the order of division resistance and to put in a feed-forward capacitor between output and FB pin. The setting method of the feed-forward capacitor between output division resistance and output-FB pin is shown in below.

1.1 Output voltage setting
The internal reference voltage of error-amplifier is 0.75V. Output voltage is determined like formula (1).

$$V_{OUT} = \frac{(R1+R2)}{R2} \times 0.75 \text{V}$$

Figure 6. Voltage feedback resistance setting

However, in order to avoid the BST-UVLO operation at the time of a reduced power and light load, please set up R1+R2 is satisfied the following formulas.

$$R1 + R2 \leq V_{OUT} \times 10^3 \quad \cdots (2)$$

The example of output resistances setting: output voltage 5V R1=3.9kΩ R2=0.68kΩ output voltage 12V R1=7.5kΩ R2=0.51kΩ

1.2 Feed-forward capacitor Csp
Please mount feed-forward capacitor in parallel to output resistance R1.
In order that a feed-forward capacitor adjust the loop characteristic by adding the pair of a pole and zero to the loop characteristic. Therefore, a phase margin is improved and then transient response speed is improved.
The feed-forward capacitor Csp should use the value near the following formulas.

$$C_{sp} = \frac{4.7k \times 0.15}{R1} \quad [\mu F] \quad \cdots (3)$$

The example of a Csp setting: output voltage 5V R1=3.9kΩ R2=0.68kΩ Csp = 0.1μF or 0.22μF output voltage 12V R1=7.5kΩ R2=0.51kΩ Csp = 0.1μF

By the measures mentioned above, it is able to use it without leaping up of the output by BST-UVLO operation even in low voltage and light load of VCC-VOUT<3V.

2. Max duty, Ron
Maximum output voltage is limited by Max duty (Min85%) and Nch-FET ON resistance.
If maximum output current is Imax, VOUT drops Imax x 0.8Ω (Typ) by ON resistance. Because max duty is added to this,
VOUT is restricted casually formula $V_{OUTmax} = (V_{CC} - RonH \times Imax)$ x 0.85.
It should be used in range $V_{OUTmax} = V_{CC} \times 0.7$ when it is necessary to consider Vf drop of pulled current from diode.

3. Min ON Time
Minimum output voltage is limited by Min ON Time (Typ 100ns).
Output voltage = frequency (Typ 1.5MHz) x Nch-FET ON time x VCC
If output voltage is this formula or less, output ripple voltage is boosted by intermittent operation.
Frequency fold-back function
This IC has the frequency fold-back function to prevent from over current when the output is shorted.

The frequency fold-back has the function that the frequency is changed by FB voltage.

Figure 7 shows FB voltage vs frequency Characteristics.

When the output node is shorted, the IC narrows the frequency to about 150kHz(Typ) so that input current limiting.

This IC operates on 1.5MHz in case of normal mode, the voltage of FB is about 0.75V.

Start-up Characteristics
When the IC is starting up, it gently raises FB voltage by Soft start function and prevent rush-current. FB voltage of starting up gently raises by synchronized internal clock. Because internal clock depends on FB voltage by frequency fold-back, Soft start time become faster in accordance with rising FB voltage.

Start-up characteristics depend on application condition such as load and output capacitor. Please check the using condition and refer the typical application waveform (P.11, P14) because of the Start-up characteristics changes to the output load and the output capacitor.
Typical Performance Characteristics
(Unless otherwise specified, Ta=25°C, VCC=12V, VOUT=5V, EN=3V)

Figure 8. Operating Current - Input Voltage

Figure 9. Operating Current - Temperature

Figure 10. UVLO Threshold - Temperature

Figure 11. Oscillation frequency - Temperature

Figure 12. Max Duty - Temperature

Figure 13. FB Pin Reference Voltage – Input Voltage
Figure 14. FB Threshold - Temperature

Figure 15. High-side Nch-FET ON Resistance - Temperature

Figure 16. OCP threshold - Temperature

Figure 17. Min ON Time - Temperature

Figure 18. EN Threshold Voltage - Temperature
Reference Characteristics of typical Application Circuits
1. VOUT=5V, IOUT=0.5A

![Typical Application Circuit Diagram](image)

**Parts**
- L1: TOKO DEM4518C 1235AS-H-6R8M 6.8μH
- TAIYO YUDEN NR4018T680M 6.8μH
- C1: Murata GRM32EB31H475KA87 4.7μF/50V
- C2: Murata GRM31CB11A106KA01 10μF/10V
- D1: Rohm RB060M-60

Figure 20. Power Conversion Efficiency - Output Current VOUT=5V

Figure 19. Typical Application Circuit (VOUT=5V)
Figure 21. Start-up Characteristics
VCC=8V, IOUT=0mA, VOUT=5V

Figure 22. Start-up Characteristics
VCC=8V, IOUT=500mA, VOUT=5V

Figure 23. Start-up Characteristics
VCC=12V, IOUT=0mA, VOUT=5V

Figure 24. Start-up Characteristics
VCC=12V, IOUT=500mA, VOUT=5V

Figure 25. Start-up Characteristics
VCC=42V, IOUT=0mA, VOUT=5V

Figure 26. Start-up Characteristics
VCC=42V, IOUT=500mA, VOUT=5V
Figure 27. Load Response
IOUT=50mA<->200mA, VOUT=5V

Figure 28. VOUT Ripple
IOUT=20mA, VOUT=5V

Figure 29. VOUT Ripple
IOUT=200mA, VOUT=5V

Figure 30. Frequency Response
IOUT=100mA, VOUT=5V

Figure 31. Frequency Response
IOUT=500mA, VOUT=5V
2. VOUT=12V, IOUT=0.5A

Figure 32. Typical Application Circuit (VOUT=12V)

| Parts | L1 : TOKO DEM4518C 1235AS-H-100M 10μH |
|-------|-----------------------------------|------------------|
|       | TAIYO YUDEN NR4018T100M 10μH     |
| C1    | Murata GRM32EB31H475KA87 4.7μF/50V|
| C2    | Murata GRM319B31E106KA12 10μF/25V |
| D1    | Rohm RB060M-60                   |

Figure 33. Power Conversion Efficiency - Output Current VOUT=12V

*The efficiency falls when the switching waveform is turning from intermittent mode to continuous mode
Figure 34. Start-up Characteristics
VCC=18V, IOUT=0mA, VOUT=12V

Figure 35. Start-up Characteristics
VCC=18V, IOUT=500mA, VOUT=12V

Figure 36. Start-up Characteristics
VCC=24V, IOUT=0mA, VOUT=12V

Figure 37. Start-up Characteristics
VCC=24V, IOUT=500mA, VOUT=12V

Figure 38. Start-up Characteristics
VCC=42V, IOUT=0mA, VOUT=12V

Figure 39. Start-up Characteristics
VCC=42V, IOUT=500mA, VOUT=12V
Figure 40. Load Response
IOUT=50mA<->200mA, VOUT=12V

Figure 41. VOUT Ripple
IOUT=50mA, VOUT=12V

Figure 42. VOUT Ripple
IOUT=200mA, VOUT=12V

Figure 43. Frequency Response
IOUT=100mA, VOUT=12V

Figure 44. Frequency Response
IOUT=500mA, VOUT=12V
Application Components Selection Method

(1) Inductors
Something of the shield type that fulfills the current rating (Current value $I_{\text{peak}}$ below), with low DCR (Direct-Current Resistance component) is recommended. Value of Inductance influences Inductor Ripple Current and becomes the cause of Output Ripple. In the same way as the formula below, this Ripple Current can be made as big as the $L$ value of inductor or as high as the Switching Frequency.

\[
I_{\text{peak}} = I_{\text{OUT}} + \Delta I_L/2 \ [A]
\]  
\[\Delta I_L = \frac{V_{\text{C}} - V_{\text{OUT}}}{L} \times \frac{V_{\text{OUT}}}{V_{\text{C}}} \times \frac{1}{f} \ [A]\]  

($\Delta I_L$: Output Ripple Current, $f$: Switching Frequency)
In the BD9G101G, it is recommended the below series of 4.7μH to 15μH inductance value.

**Recommended Inductor**
- TOKO DE4518C Series
- TAIYO YUDEN NR4018 Series

(2) Input Capacitor
In order to reduce input ripple, mount ceramic capacitor of low ESR near the VCC pin.
In the BD9G101G, it is recommended the 4.7μF or more capacitor value. In case of using the electrolytic capacitor, mount about 1μF ceramic capacitor in parallel in order to prevent oscillation.

(3) Output Capacitor
In order for capacitor to be used in output to reduce output ripple, ceramic capacitor of low ESR is recommended. Also, for capacitor rating, on top of putting into consideration DC Bias characteristics, please use something whose maximum rating has sufficient margin with respect to the Output Voltage.

Output ripple voltage is calculated for using the following formula.

\[
V_{\text{pp}} = \Delta I_L \times \frac{1}{2\pi f C_0} + \Delta I_L \times R_{\text{ESR}} \ [V]
\]  

Please design in a way that it is held within Capacity Ripple Voltage.
In the BD9G101G, it is recommended a ceramic capacitor 10μF or more.

(4) Output voltage setting
The internal reference voltage of error-amplifier is 0.75V. Output voltage is determined like formula (7).

\[
V_{\text{OUT}} = \left(\frac{R_1 + R_2}{R_2}\right) \times 0.75 \ V
\]  

Figure 46. Voltage feedback resistance setting

However, in order to avoid the BST-UVLO operation at the time of a reduced power and light load, please set up $R_1 + R_2$ is satisfied the following formulas.

\[
R_1 + R_2 \leq V_{\text{OUT}} \times 10^3 \ \cdots (8)
\]
(5) Feed-forward capacitor Csp
Please mount feed-forward capacitor in parallel to output resistance R1.
In order that a feed-forward capacitor adjust the loop characteristic by adding the pair of a pole and zero to the loop characteristic. Therefore, a phase margin is improved and then transient response speed is improved.
The feed-forward capacitor Csp should use the value near the following formulas.
\[ Csp = \frac{4.7k}{R1} \times 0.15 \, [\mu F] \quad \cdots (9) \]

(6) Bootstrap Capacitor
Please connect ceramic capacitor of 15000pF between BST Pin and LX Pin to prevent a malfunction of the internal circuit of the BST pin.

(7) Diode
Select suitable schottky diode for strength voltage and input current.
Layout is a critical portion of good power supply design. There are several signals paths that conduct switching of high current or switching node of high slew rate that can interact with leakage flux or parasitic capacitance to generate noise or degrade the power supplies performance. To help reduce these problems, it should locate a low ESR ceramic capacitor as bypass capacitor near the VCC pin. Also, high current is flowed generated loop by bypass capacitor, PCB pattern of anode of catch diode. Care should be taken to minimize the current loop.

In the BD9G101G, to avoid the high frequency wave noise of high current loop, it is not connected the GND pin at the top layer and it is connected the GND pin at common line of bottom layer like Figure 47. Bypass capacitor of input, catch diode and inductor should be located as close to the IC as possible.
Power Dissipation

Figure 48 shows reducing characteristics of power dissipation measured with mount 70mm x 70mm x 1.6mmt, 1layer PCB. Junction temperature must be designed not to exceed 150°C and it should have margin design.

In actual use, it has difference of power dissipation and temperature increase by another heat source. Please examine it enough.

![Graph showing power dissipation vs. ambient temperature](image)

Figure 48. Power Dissipation (70mm x 70mm x 1.6mmt 1layer PCB)

Power Dissipation Estimate

The following formulas show how to estimate the device power dissipation under continuous mode operations. Do not use these formulas, if the device is working in the discontinuous conduction mode.

The device power dissipation includes:
1) Conduction loss : Pcon = IOUT² x RonH x VOUT/VCC
2) Switching loss : Psw = 2.5 x 10⁻⁹ x VCC x IOUT x fsw
3) Gate charge loss : Pgc = 4.88 x 10⁻⁹ x fsw
4) Current loss at non switching : Pq = 0.8 x 10⁻³ x VCC

Where:
IOUT is the output current (A), RonH is the on-resistance of the high-side Nch-FET(Ω), VOUT is the output voltage (V), VCC is the input voltage (V), fsw is the switching frequency (Hz).

Therefore

Power dissipation of IC (Pd) is the sum of above dissipation.

Pd = Pcon + Psw + Pgc + Pq

The junction temperature is as follows.

Tj = Ta + θja x Pd

Where:
Ta is the ambient temperature (°C)
Tj is the junction temperature (°C), θja is the thermal resistance of the package (°C)

Please design thermal design with enough margin so that the junction temperature is not beyond maximum Tj_max=150°C.
## I/O equivalent circuit

<table>
<thead>
<tr>
<th>Pin No</th>
<th>Pin Name</th>
<th>Pin Equivalent Circuit</th>
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<tbody>
<tr>
<td>6</td>
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<td>2</td>
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<th>Pin No</th>
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<tr>
<td>3</td>
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<th>Pin No</th>
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<th>Pin Equivalent Circuit</th>
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</thead>
<tbody>
<tr>
<td>4</td>
<td>EN</td>
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</tr>
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</table>

Figure 49. I/O equivalent circuit
Operational Notes

1. **Reverse Connection of Power Supply**
   Connecting the power supply in reverse polarity can damage the IC. Take precautions against reverse polarity when connecting the power supply, such as mounting an external diode between the power supply and the IC’s power supply pins.

2. **Power Supply Lines**
   Design the PCB layout pattern to provide low impedance supply lines. Furthermore, connect a capacitor to ground at all power supply pins. Consider the effect of temperature and aging on the capacitance value when using electrolytic capacitors.

3. **Ground Voltage**
   Ensure that no pins are at a voltage below that of the ground pin at any time, even during transient condition.

4. **Ground Wiring Pattern**
   When using both small-signal and large-current ground traces, the two ground traces should be routed separately but connected to a single ground at the reference point of the application board to avoid fluctuations in the small-signal ground caused by large currents. Also ensure that the ground traces of external components do not cause variations on the ground voltage. The ground lines must be as short and thick as possible to reduce line impedance.

5. **Recommended Operating Conditions**
   The function and operation of the IC are guaranteed within the range specified by the recommended operating conditions. The characteristic values are guaranteed only under the conditions of each item specified by the electrical characteristics.

6. **Inrush Current**
   When power is first supplied to the IC, it is possible that the internal logic may be unstable and inrush current may flow instantaneously due to the internal powering sequence and delays, especially if the IC has more than one power supply. Therefore, give special consideration to power coupling capacitance, power wiring, width of ground wiring, and routing of connections.

7. **Testing on Application Boards**
   When testing the IC on an application board, connecting a capacitor directly to a low-impedance output pin may subject the IC to stress. Always discharge capacitors completely after each process or step. The IC’s power supply should always be turned off completely before connecting or removing it from the test setup during the inspection process. To prevent damage from static discharge, ground the IC during assembly and use similar precautions during transport and storage.

8. **Inter-pin Short and Mounting Errors**
   Ensure that the direction and position are correct when mounting the IC on the PCB. Incorrect mounting may result in damaging the IC. Avoid nearby pins being shorted to each other especially to ground, power supply and output pin. Inter-pin shorts could be due to many reasons such as metal particles, water droplets (in very humid environment) and unintentional solder bridge deposited in between pins during assembly to name a few.

9. **Unused Input Pins**
   Input pins of an IC are often connected to the gate of a MOS transistor. The gate has extremely high impedance and extremely low capacitance. If left unconnected, the electric field from the outside can easily charge it. The small charge acquired in this way is enough to produce a significant effect on the conduction through the transistor and cause unexpected operation of the IC. So unless otherwise specified, unused input pins should be connected to the power supply or ground line.
Operational Notes – continued

10. Regarding the Input Pin of the IC
This monolithic IC contains P+ isolation and P substrate layers between adjacent elements in order to keep them isolated. P-N junctions are formed at the intersection of the P layers with the N layers of other elements, creating a parasitic diode or transistor. For example (refer to figure below):

When GND > Pin A and GND > Pin B, the P-N junction operates as a parasitic diode.
When GND > Pin B, the P-N junction operates as a parasitic transistor.

Parasitic diodes inevitably occur in the structure of the IC. The operation of parasitic diodes can result in mutual interference among circuits, operational faults, or physical damage. Therefore, conditions that cause these diodes to operate, such as applying a voltage lower than the GND voltage to an input pin (and thus to the P substrate) should be avoided.

![Figure 50. Example of monolithic IC structure](image)

11. Ceramic Capacitor
When using a ceramic capacitor, determine a capacitance value considering the change of capacitance with temperature and the decrease in nominal capacitance due to DC bias and others.

12. Thermal Shutdown Circuit (TSD)
This IC has a built-in thermal shutdown circuit that prevents heat damage to the IC. Normal operation should always be within the IC’s maximum junction temperature rating. If however the rating is exceeded for a continued period, the junction temperature (Tj) will rise which will activate the TSD circuit that will turn OFF power output pins. When the Tj falls below the TSD threshold, the circuits are automatically restored to normal operation.

Note that the TSD circuit operates in a situation that exceeds the absolute maximum ratings and therefore, under no circumstances, should the TSD circuit be used in a set design or for any purpose other than protecting the IC from heat damage.

13. Over Current Protection Circuit (OCP)
This IC incorporates an integrated overcurrent protection circuit that is activated when the load is shorted. This protection circuit is effective in preventing damage due to sudden and unexpected incidents. However, the IC should not be used in applications characterized by continuous operation or transitioning of the protection circuit.
Ordering part number

<table>
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<tr>
<th>B</th>
<th>D</th>
<th>9</th>
<th>G</th>
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<th>0</th>
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<td>Part Number</td>
<td>package</td>
<td>G: SSOP6</td>
<td>Packaging and forming specification</td>
<td>TR: Embossed tape and reel</td>
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Marking Diagram

SSOP6 (TOP VIEW)

Part Number Marking

Pin 1 Mark

LOT Number
Physical Dimension and Packing Information

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<tr>
<th>Package Name</th>
<th>SSOP6</th>
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</table>

![Diagram of SSOP6 Package](image)

(UNIT: mm)

PKG: SSOP6
Drawing No. EX103-5001

<Tape and Reel Information>

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<th>Tape</th>
<th>Embossed carrier tape</th>
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<tbody>
<tr>
<td>Quantity</td>
<td>3000pcs</td>
</tr>
<tr>
<td>Direction of feed</td>
<td>TR (The direction is the 1pin of product is at the upper right when you hold reel on the left hand and you pull out the tape on the right hand)</td>
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![Diagram of Tape and Reel Information](image)
## Revision History

<table>
<thead>
<tr>
<th>Date</th>
<th>Revision</th>
<th>Changes</th>
</tr>
</thead>
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<tr>
<td>04.Feb.2013</td>
<td>002</td>
<td>5–6 page : Adding of output voltage range</td>
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<tr>
<td></td>
<td></td>
<td>1, 10, 13 page : Change of typical application circuit</td>
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<tr>
<td></td>
<td></td>
<td>12, 15 page : Change of typical performance characteristic</td>
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<tr>
<td>22.Mar.2013</td>
<td>003</td>
<td>16 page : Added description of input capacitor</td>
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<tr>
<td>04.Mar.2014</td>
<td>004</td>
<td>10, 13 page : Correction of application parts</td>
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<tr>
<td>13.Jan.2015</td>
<td>005</td>
<td>19 page : Correction of erroneous power dissipation estimate</td>
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<tr>
<td>16.Feb.2015</td>
<td>006</td>
<td>23 page : Correction of ordering part number format</td>
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<tr>
<td>11.Dec.2018</td>
<td>008</td>
<td>1 page : Deletion of car application in use application</td>
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<tr>
<td></td>
<td></td>
<td>11, 14 page : Correction of characteristics in typical application</td>
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<td></td>
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<td>Review sentences over all pages</td>
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1. If you intend to use our Products in devices requiring extremely high reliability (such as medical equipment (Note 1), aircraft/spacecraft, nuclear power controllers, etc.) and whose malfunction or failure may cause loss of human life, bodily injury or serious damage to property (“Specific Applications”), please consult with the ROHM sales representative in advance. Unless otherwise agreed in writing by ROHM in advance, ROHM shall not be in any way responsible or liable for any damages, expenses or losses incurred by you or third parties arising from the use of any ROHM’s Products for Specific Applications.

(Note1) Medical Equipment Classification of the Specific Applications

<table>
<thead>
<tr>
<th>JAPAN</th>
<th>USA</th>
<th>EU</th>
<th>CHINA</th>
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<tr>
<td>CLASS III</td>
<td>CLASS III</td>
<td>CLASS II b</td>
<td>CLASS III</td>
</tr>
</tbody>
</table>

2. ROHM designs and manufactures its Products subject to strict quality control system. However, semiconductor products can fail or malfunction at a certain rate. Please be sure to implement, at your own responsibilities, adequate safety measures including but not limited to fail-safe design against the physical injury, damage to any property, which a failure or malfunction of our Products may cause. The following are examples of safety measures:

[a] Installation of protection circuits or other protective devices to improve system safety
[b] Installation of redundant circuits to reduce the impact of single or multiple circuit failure

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[a] Use of our Products in any types of liquid, including water, oils, chemicals, and organic solvents
[b] Use of our Products outdoors or in places where the Products are exposed to direct sunlight or dust
[c] Use of our Products in places where the Products are exposed to sea wind or corrosive gases, including Cl2, H2S, NH3, SO2, and NO2
[d] Use of our Products in places where the Products are exposed to static electricity or electromagnetic waves
[e] Use of our Products in proximity to heat-producing components, plastic cords, or other flammable items
[f] Sealing or coating our Products with resin or other coating materials
[g] Use of our Products without cleaning residue of flux (Exclude cases where no-clean type fluxes is used. However, recommend sufficiently about the residue.); or Washing our Products by using water or water-soluble cleaning agents for cleaning residue after soldering
[h] Use of the Products in places subject to dew condensation

4. The Products are not subject to radiation-proof design.

5. Please verify and confirm characteristics of the final or mounted products in using the Products.

6. In particular, if a transient load (a large amount of load applied in a short period of time, such as pulse, is applied, confirmation of performance characteristics after on-board mounting is strongly recommended. Avoid applying power exceeding normal rated power; exceeding the power rating under steady-state loading condition may negatively affect product performance and reliability.

7. De-rate Power Dissipation depending on ambient temperature. When used in sealed area, confirm that it is the use in the range that does not exceed the maximum junction temperature.

8. Confirm that operation temperature is within the specified range described in the product specification.

9. ROHM shall not be in any way responsible or liable for failure induced under deviant condition from what is defined in this document.

Precaution for Mounting / Circuit board design

1. When a highly active halogenous (chlorine, bromine, etc.) flux is used, the residue of flux may negatively affect product performance and reliability.

2. In principle, the reflow soldering method must be used on a surface-mount products, the flow soldering method must be used on a through hole mount products. If the flow soldering method is preferred on a surface-mount products, please consult with the ROHM representative in advance.

For details, please refer to ROHM Mounting specification
Precautions Regarding Application Examples and External Circuits

1. If change is made to the constant of an external circuit, please allow a sufficient margin considering variations of the characteristics of the Products and external components, including transient characteristics, as well as static characteristics.

2. You agree that application notes, reference designs, and associated data and information contained in this document are presented only as guidance for Products use. Therefore, in case you use such information, you are solely responsible for it and you must exercise your own independent verification and judgment in the use of such information contained in this document. ROHM shall not be in any way responsible or liable for any damages, expenses or losses incurred by you or third parties arising from the use of such information.

Precaution for Electrostatic

This Product is electrostatic sensitive product, which may be damaged due to electrostatic discharge. Please take proper caution in your manufacturing process and storage so that voltage exceeding the Products maximum rating will not be applied to Products. Please take special care under dry condition (e.g. Grounding of human body / equipment / solder iron, isolation from charged objects, setting of Ionizer, friction prevention and temperature / humidity control).

Precaution for Storage / Transportation

1. Product performance and soldered connections may deteriorate if the Products are stored in the places where:
   [a] the Products are exposed to sea winds or corrosive gases, including Cl2, H2S, NH3, SO2, and NO2
   [b] the temperature or humidity exceeds those recommended by ROHM
   [c] the Products are exposed to direct sunshine or condensation
   [d] the Products are exposed to high Electrostatic

2. Even under ROHM recommended storage condition, solderability of products out of recommended storage time period may be degraded. It is strongly recommended to confirm solderability before using Products of which storage time is exceeding the recommended storage time period.

3. Store / transport cartons in the correct direction, which is indicated on a carton with a symbol. Otherwise bent leads may occur due to excessive stress applied when dropping of a carton.

4. Use Products within the specified time after opening a humidity barrier bag. Baking is required before using Products of which storage time is exceeding the recommended storage time period.

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Precaution for Disposition

When disposing Products please dispose them properly using an authorized industry waste company.

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