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 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

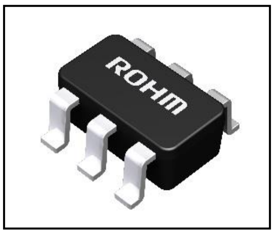
- High and Wide Input Voltage Range (VCC=6V to 42V)
- 45V/800mΩ Internal Power Nch-FET
- 1.5MHz Fixed Operating High Frequency
- Built-in Reference Voltage 0.75V±1.5% circuit
- Built-in Phase Compensation circuit
- Internal Over Current protection, Under Voltage Lock Out, Thermal shutdown
- Stand-by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

Key Specifications

- Input Voltage: 6V to 42 V
- 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

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



SSOP6

Applications

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

Typical Application Circuits

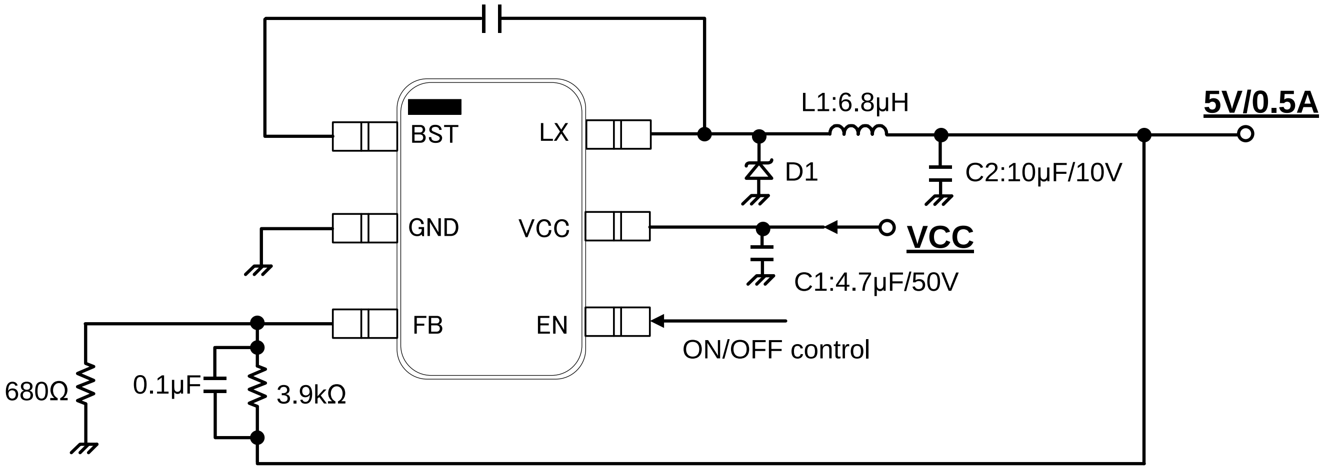


Figure 1. Typical Application Circuit

〇Product structure : Silicon integrated circuit 〇This product has no designed protection against radioactive rays

Pin Configuration

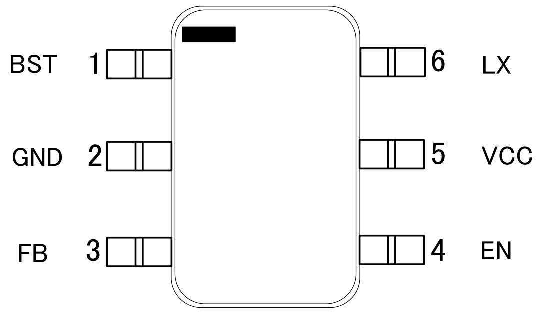


Figure 2. Pin Configuration (TOP VIEW)

Pin Description

Pin No.	Pin Name	Description
1	BST	The pin is power supply for floating Power Nch-FET driver. Connected 15000pF between this pin and LX pin for bootstrap operation.
2	GND	Ground.
3	FB	Voltage feedback pin. This pin is error-amplifier input, the DCDC is set 0.75V at this pin with feed-back operation.
4	EN	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.
5	VCC	Input supply. It should be connected as near as possible to the bypass capacitor. It should be increased impedance by thick PCB pattern.
6	LX	Power Nch-FET switching node pin. It should be connected as near as possible to the Schottky barrier diode, and inductor.

Block Diagram

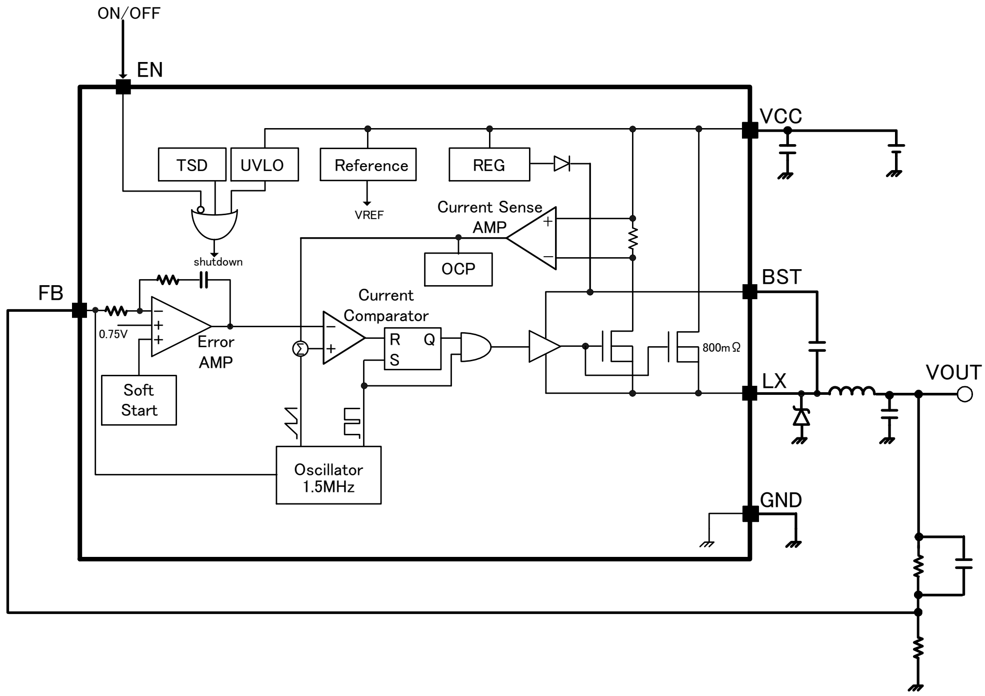


Figure 3. Block Diagram

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 current to error-amp, oscillator, 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 converter, 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 ERROR AMPs' 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 input 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

Item	Symbol	Ratings	Unit
VCC to GND	VCC	45	V
BST to GND	VBST	50	V
Maximum rating current	Imax	1.0	A
BST to LX	ΔVBST	7	V
EN to GND	VEN	45	V
LX to GND	VLX	45	V
FB to GND	VFB	7	V
Power Dissipation	Pd	0.675(*1)	W
Operating Temperature	Topr	-40 to +105	°C
Storage Temperature	Tstg	-55 to +150	°C
Junction Temperature	Tjmax	150(*2)	°C

(*1) During mounting of 70mm x 70mm x 1.6mmt 1layer board. Reduce by 5.4mW for every 1°C increase. (25°C or more)
(*2) 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

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

Parameter		Symbol	Limit			Unit	Condition
			Min	Typ	Max		
Circuit Current							
Stand-by Current		Ist	-	0	5	μA	VEN=0V
Operating Current		Icc	-	0.7	1.2	mA	FB=1.2V
Under Voltage Lock Out (UVLO)							
Detect Threshold Voltage		Vuv	5.1	5.4	5.7	V	
Hysteresis width		Vuvhy	-	200	300	mV	
Oscillator							
Switching Frequency		Fosc	1.3	1.5	1.7	MHz	
Max Duty Cycle		Dmax	85	-	-	%	
Error AMP							
FB Pin Threshold Voltage		VFBN	0.739	0.750	0.761	V	Ta=25°C
		VFBA	0.735	0.750	0.765	V	Ta=-25°C to 105°C
FB Pin Input Current		IFB	-100	0	100	nA	VFB=2.0V
Soft-Start Time		Tsoft	1.2	4.0	-	ms	
Current Comparator							
Trans-conductance		G_{CS}	-	3	-	A/V	
Output							
High-side Nch-FET ON Resistance		RonH	-	800	-	mΩ	
Min ON Time		Tmin	-	100	-	ns	
OCP Detect Current		Iocp	0.85	1.2	-	A	
CTL							
EN Threshold Voltage	ON	VENON	2.0	-	VCC	V	
	OFF	VENOFF	-0.3	-	0.8	V	
EN Input Current		IEN	2.7	5.5	11	μA	VEN=3V

Operating Ratings

Item	Symbol	Ratings			Unit
		Min	Typ	Max	
Input Voltage	VCC	6	-	42	V
Output Voltage	VOUT	1.0(*3)	-	VCC x 0.7(*4)	V
Output Current	IOUT	-	-	500	mA

(*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 charging current (normal mode)

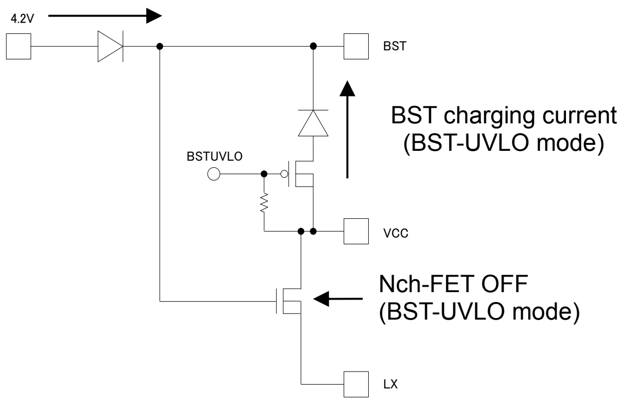


Figure 4. BST-UVLO equivalent circuit

*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.

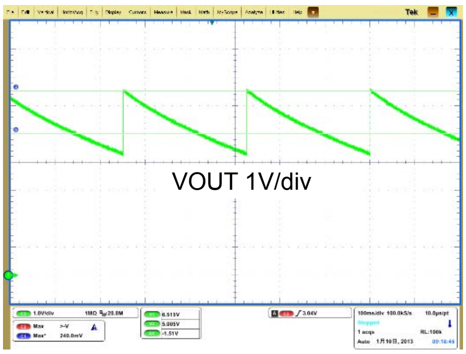
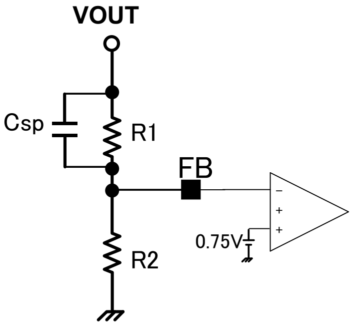


Figure 5. Low voltage and light load,
BST-UVLO operation waveform
VOUT=5V VCC=7V IOUT=0mA

1. BST-UVLO detection → Nch-FET is turned OFF
↓
2. VOUT, LX are discharged
→Error AMP output is raised
↓
3. The voltage between BST-LX is secured enough
→BST-UVLO release
↓
4. In order to carry out a start of operation with Max duty cycle, an output leaps up.
↓
5. The voltage between BST-LX is insufficient.

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).



$$VOUT = \frac{(R1+R2)}{R2} \times 0.75\ V \qquad (1)$$

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.

$$R1 + R2 \leq VOUT \times 10^3 \quad \cdot\cdot\cdot (2)$$

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 so does the transient response speed. Consequently, output fluctuation gets suppressed.
The feed-forward capacitor Csp should use the value near the following formulas.

$$Csp = \frac{4.7k}{R1} \times 0.15 \quad [uF] \quad \cdot\cdot\cdot (3)$$

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 VOUTmax = (VCC - RonH x Imax) x 0.85.
It should be used in range VOUTmax = VCC x 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.

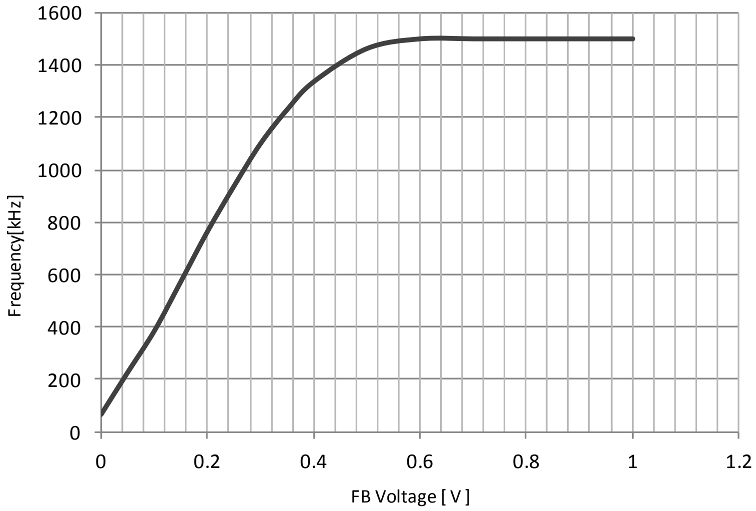


Figure 7. FB voltage -frequency Characteristics

When the output and GND are shorted the FB voltage becomes 0V, so the IC can limit the input current by the frequency getting lowered to about 150kHz(Typ).
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 frequency 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, so please check the using condition and refer the typical application start-up waveform (P.11, P14).

Typical Performance Characteristics
(Unless otherwise specified, Ta=25°C, VCC=12V, VOUT=5V, EN=3V)

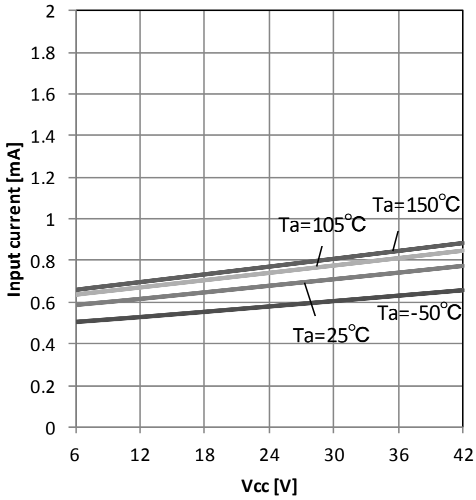


Figure 8. Operating Current - Input Voltage

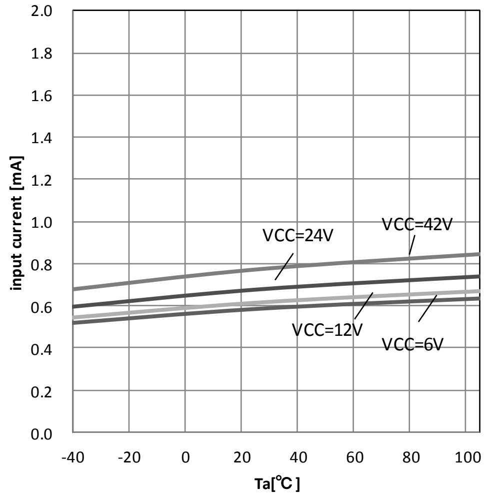


Figure 9. Operating Current - Temperature

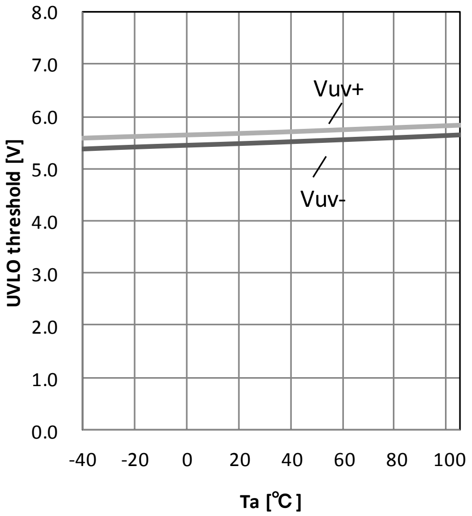


Figure 10. UVLO Threshold - Temperature

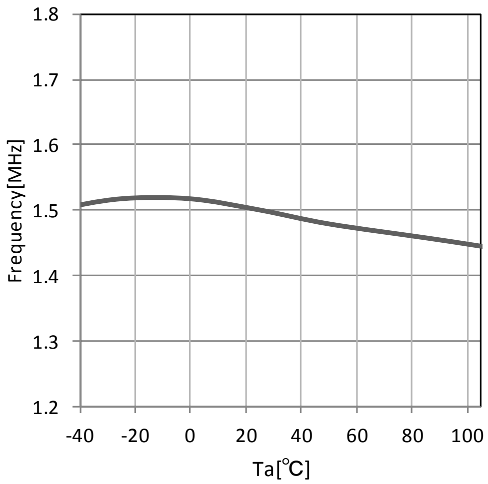


Figure 11. Oscillation frequency - Temperature

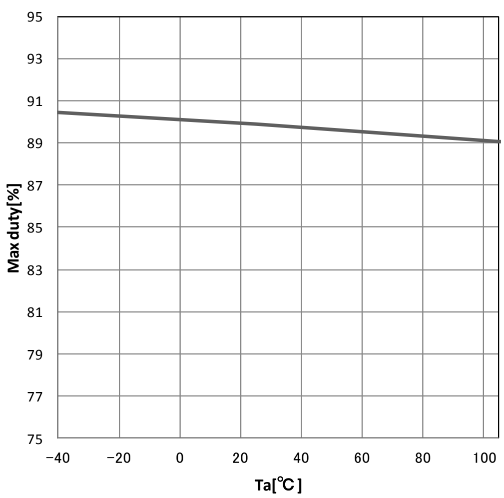


Figure 12. Max Duty - Temperature

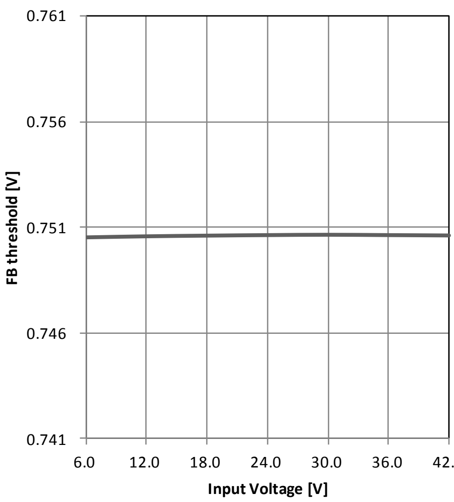


Figure 13. FB Pin Reference Voltage – Input Voltage

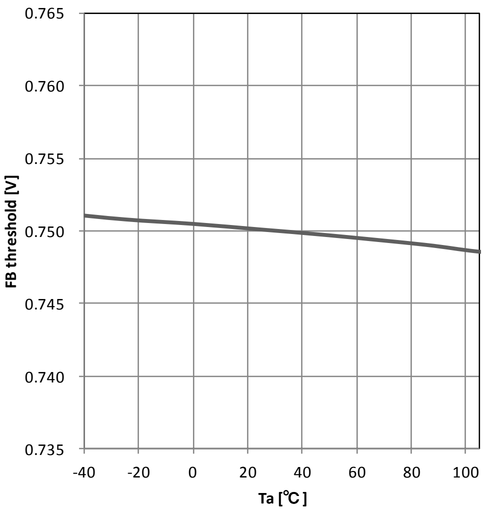


Figure 14. FB Threshold - Temperature

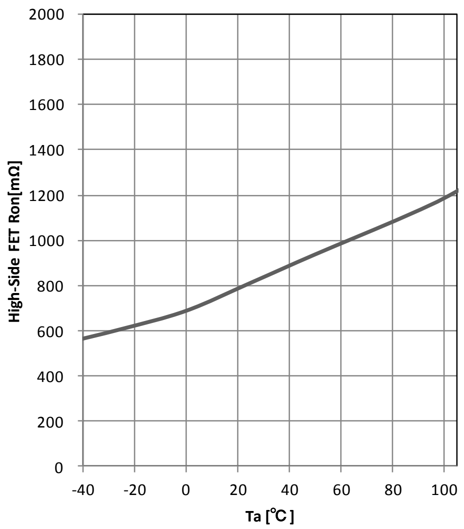


Figure 15. High-side Nch-FET ON Resistance - Temperature

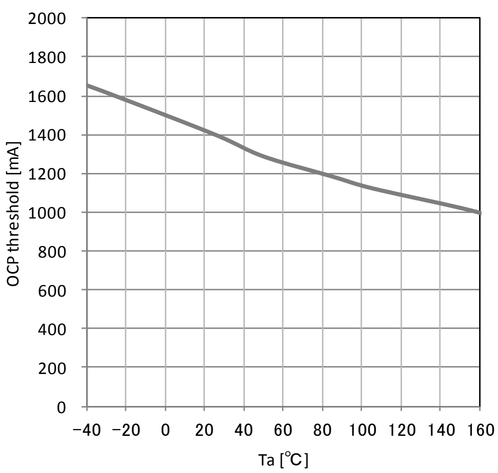


Figure 16. OCP threshold- Temperature

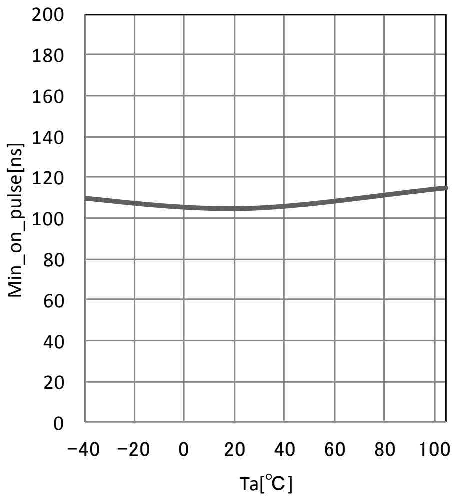


Figure 17. Min ON Time - Temperature

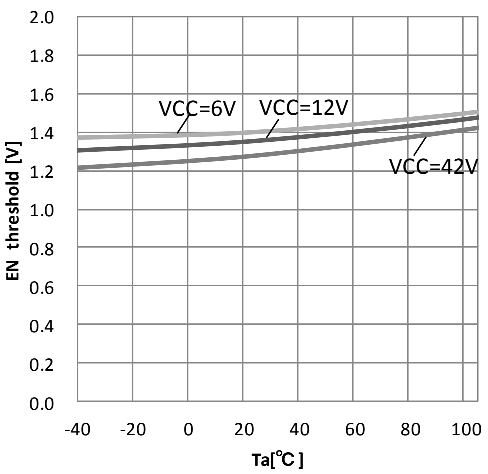


Figure 18. EN Threshold Voltage - Temperature

Reference Characteristics of typical Application Circuits

1. VOUT=5V, IOUT=0.5A

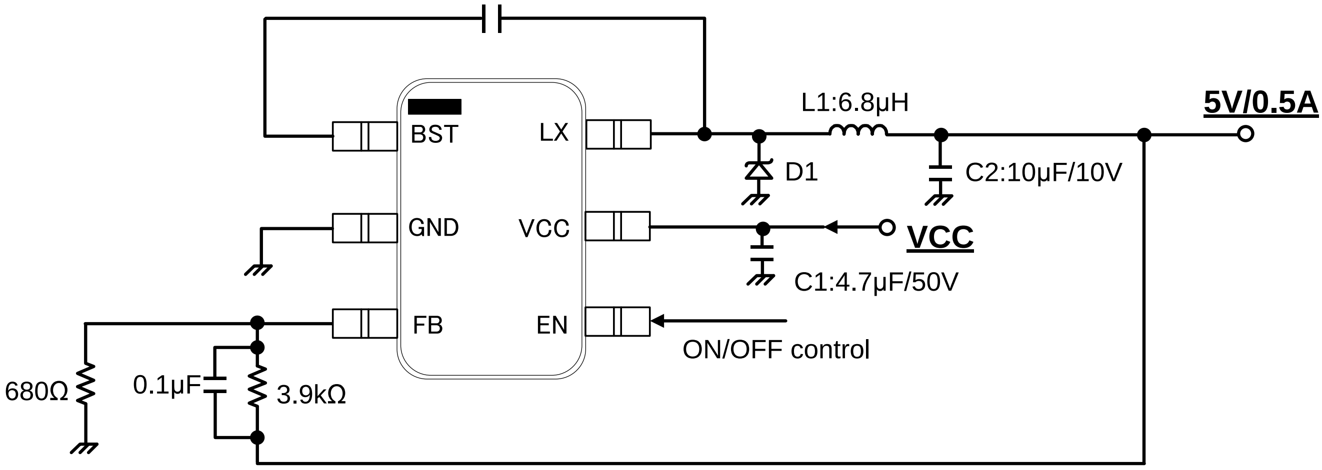


Figure 19. Typical Application Circuit (VOUT=5V)

Parts	L1	:	Murata TAIYO YUDEN	DEM4518C 1235AS-H-6R8M LSXND4040TKL6R8MDG	6.8µH 6.8µH
	C1	:	Murata	GRM32EB31H475KA87	4.7µF/50V
	C2	:	Murata	GRM31CB11A106KA01	10µF/10V
	D1	:	ROHM	RBR2MM60B	

Recommended parts are selected from those products and information available at the time this data sheet (Rev.010) was released. If supply conditions change and parts are not available, use similar parts

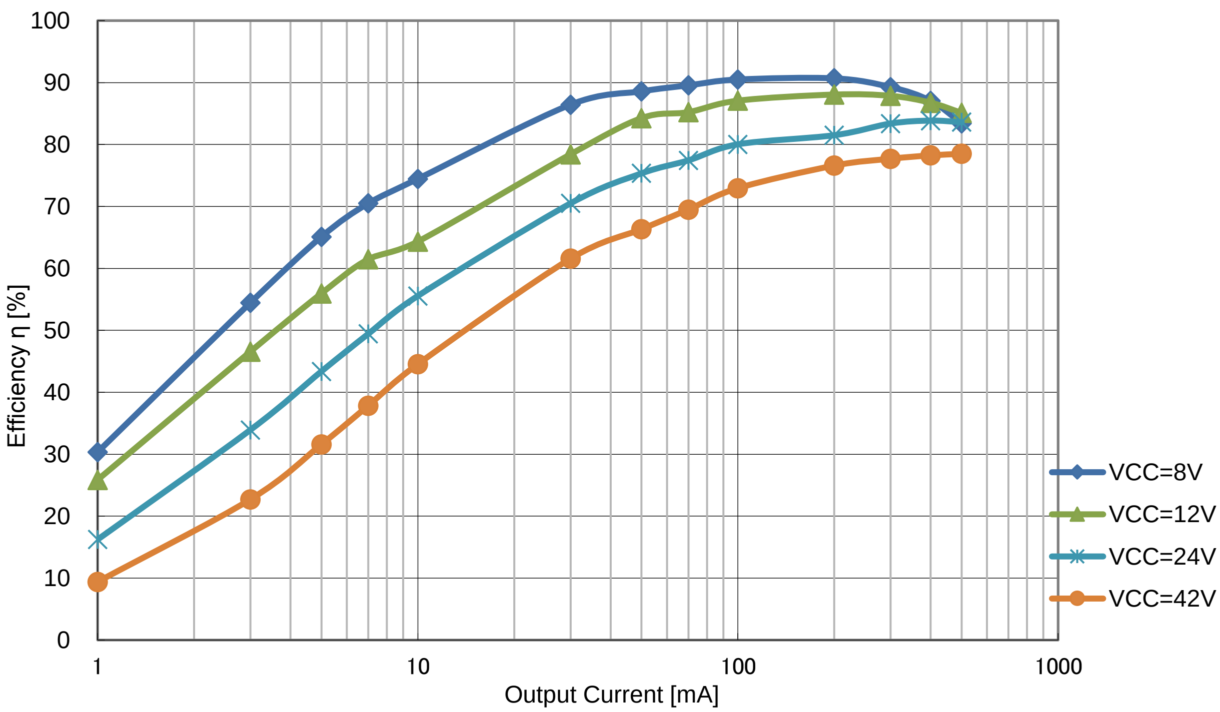


Figure 20. Power Conversion Efficiency - Output Current VOUT=5V

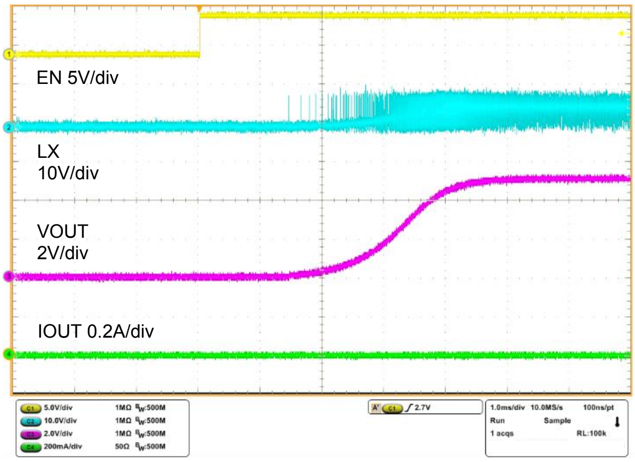


Figure 21. Start-up Characteristics
VCC=8V, IOUT=0mA, VOUT=5V

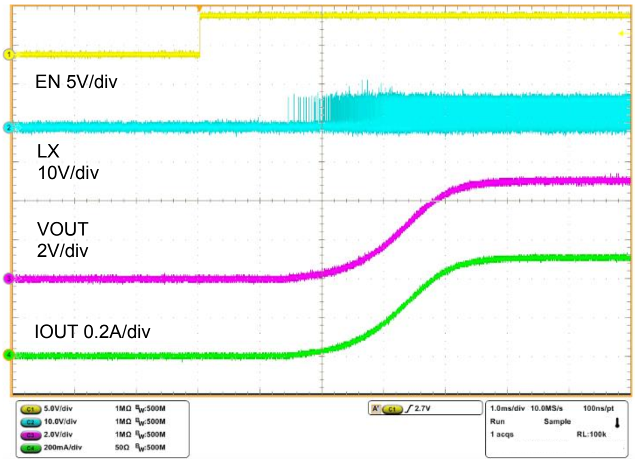


Figure 22. Start-up Characteristics
VCC=8V, IOUT=500mA, VOUT=5V

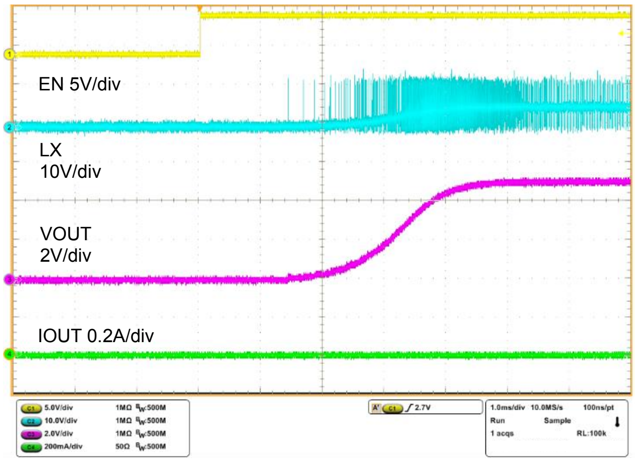


Figure 23. Start-up Characteristics
VCC=12V, IOUT=0mA, VOUT=5V

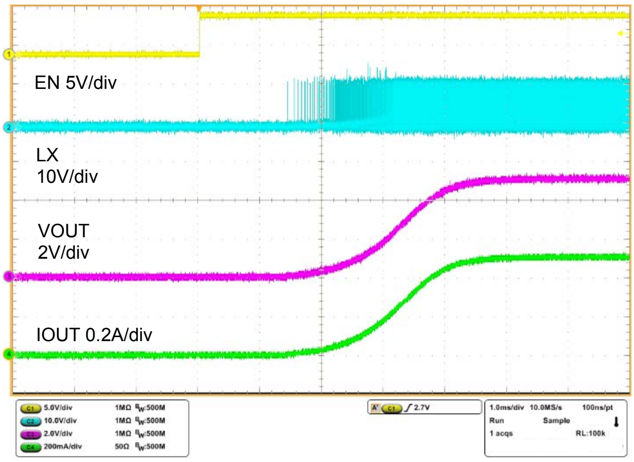


Figure 24. Start-up Characteristics
VCC=12V, IOUT=500mA, VOUT=5V

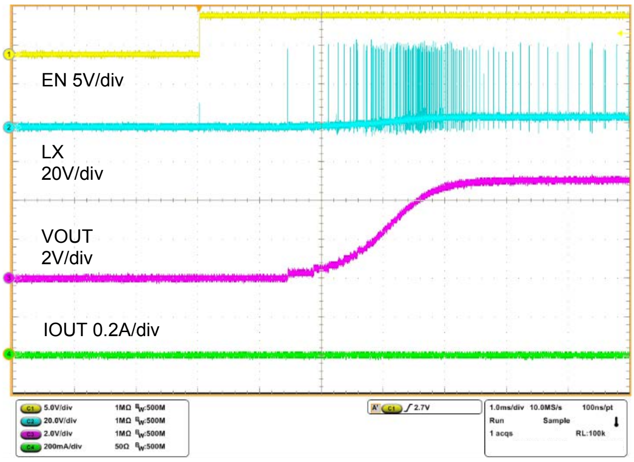


Figure 25. Start-up Characteristics
VCC=42V, IOUT=0mA, VOUT=5V

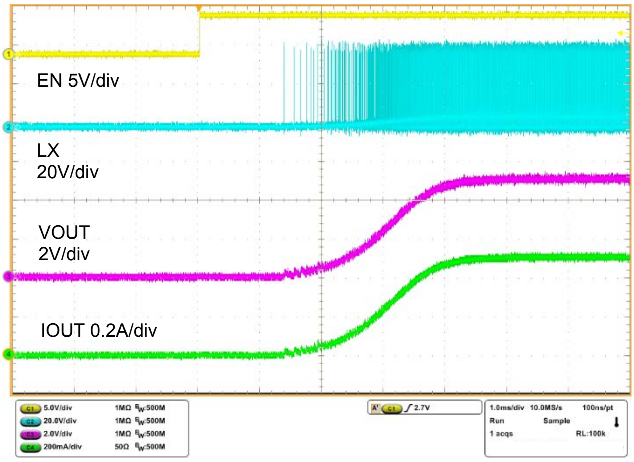


Figure 26. Start-up Characteristics
VCC=42V, IOUT=500mA, VOUT=5V

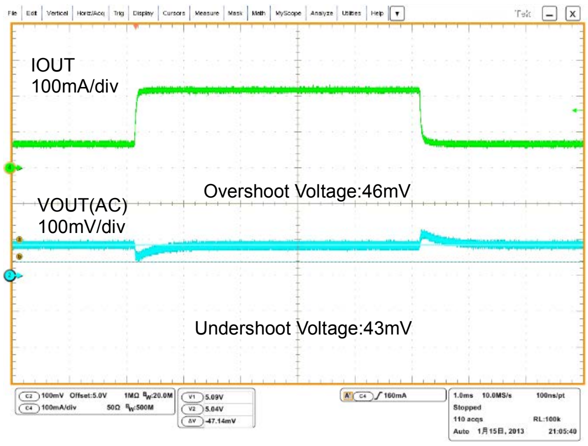


Figure 27. Load Response
IOUT=50mA<->200mA, VOUT=5V

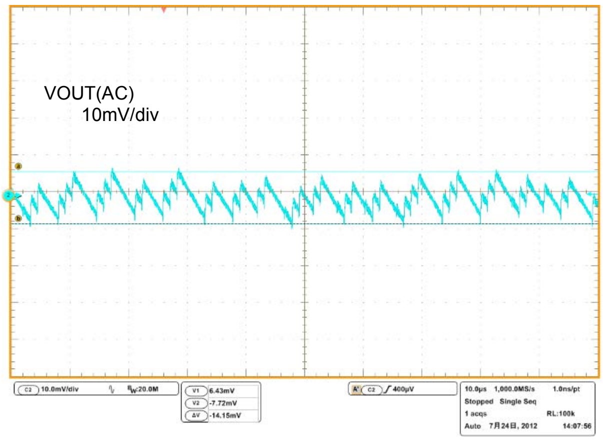


Figure 28. VOUT Ripple
IOUT=20mA, VOUT=5V

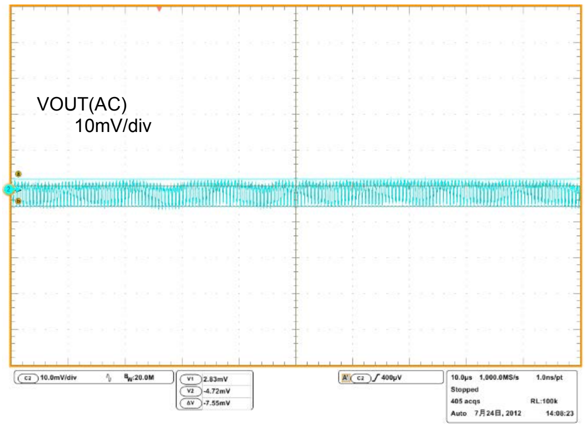


Figure 29. VOUT Ripple
IOUT=200mA, VOUT=5V

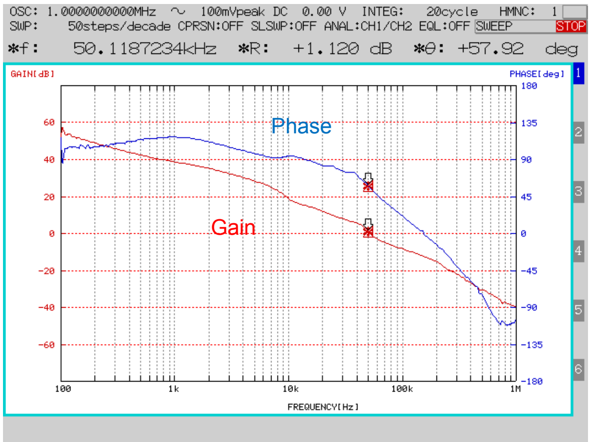


Figure 30. Frequency Response
IOUT=100mA, VOUT=5V

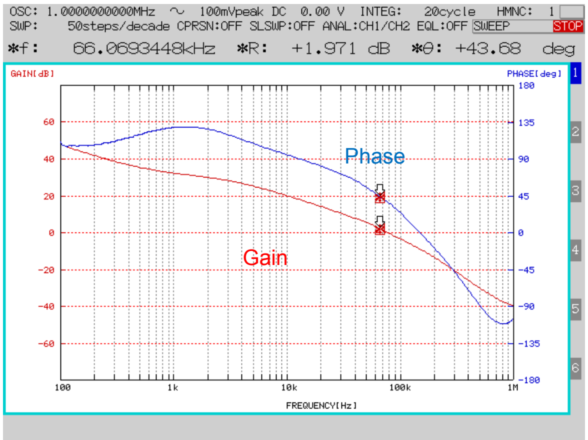


Figure 31. Frequency Response
IOUT=500mA, VOUT=5V

2. VOUT=12V, IOUT=0.5A

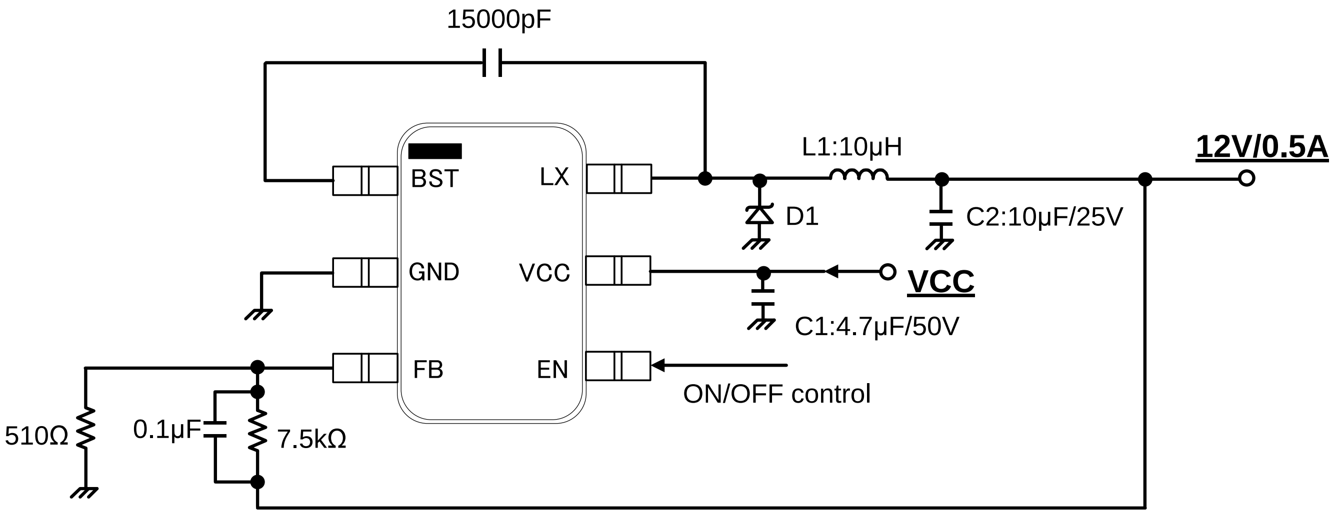
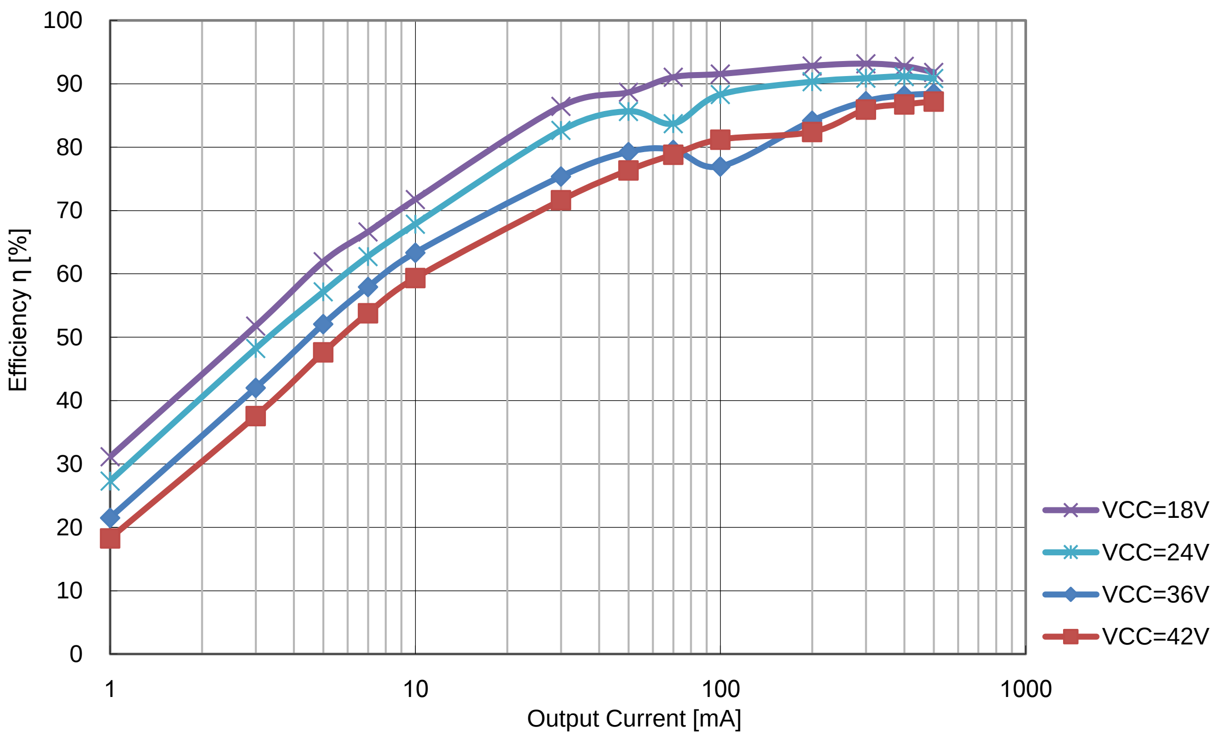


Figure 32. Typical Application Circuit (VOUT=12V)

Parts	L1	:	Murata TAIYO YUDEN	DEM4518C 1235AS-H-100M LSXND4040TKL100MDG	10μH 10μH
	C1	:	Murata	GRM32EB31H475KA87	4.7μF/50V
	C2	:	Murata	GRM319B31E106KA12	10μF/25V
	D1	:	ROHM	RBR2MM60B	

Recommended parts are selected from those products and information available at the time this data sheet (Rev.010) was released. If supply conditions change and parts are not available, use similar parts.



*The efficiency falls when the switching waveform is turning from intermittent mode to continuous mode

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

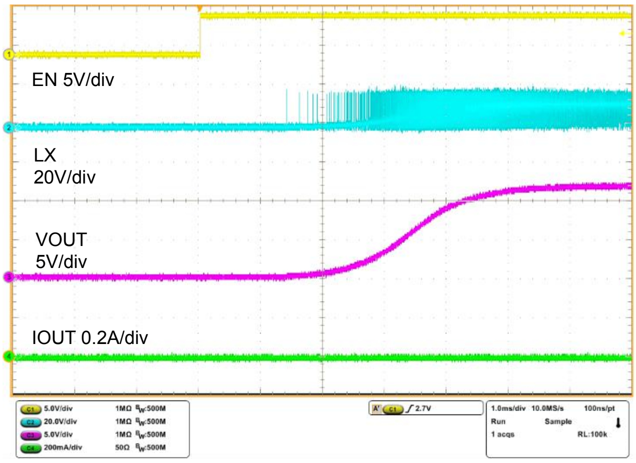


Figure 34. Start-up Characteristics
VCC=18V, IOUT=0mA, VOUT=12V

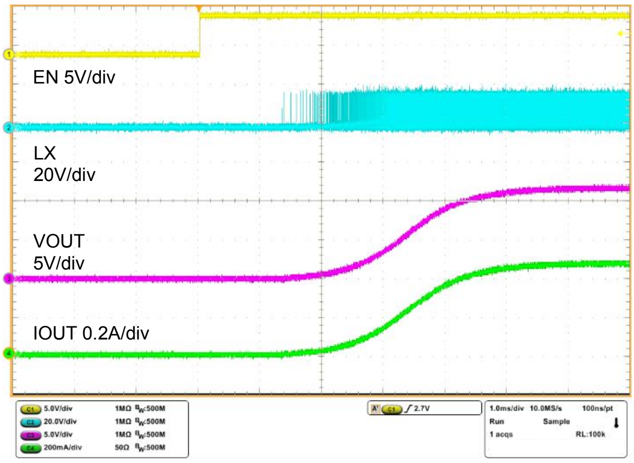


Figure 35. Start-up Characteristics
VCC=18V, IOUT=500mA, VOUT=12V

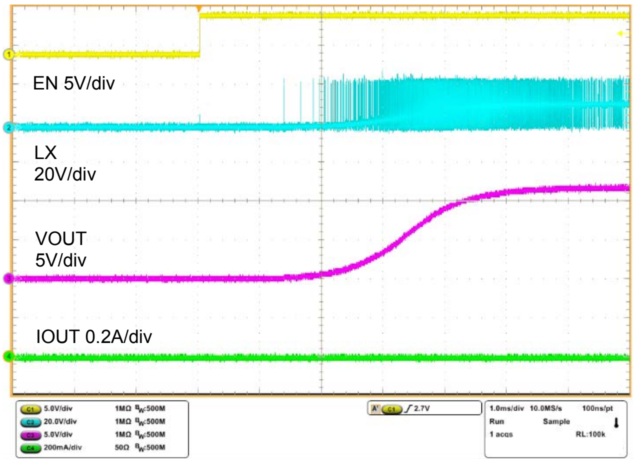


Figure 36. Start-up Characteristics
VCC=24V, IOUT=0mA, VOUT=12V

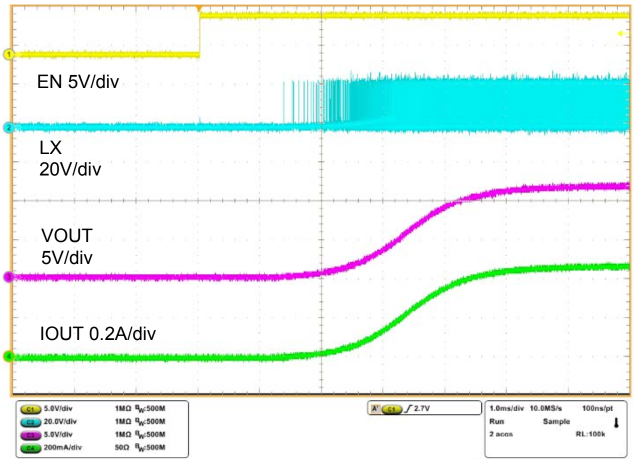


Figure 37. Start-up Characteristics
VCC=24V, IOUT=500mA, VOUT=12V

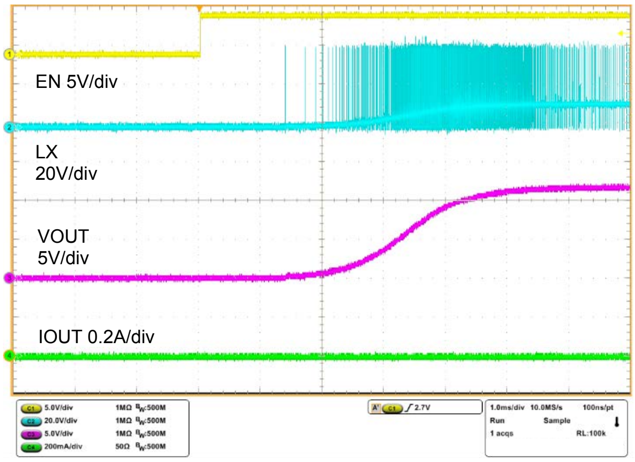


Figure 38. Start-up Characteristics
VCC=42V, IOUT=0mA, VOUT=12V

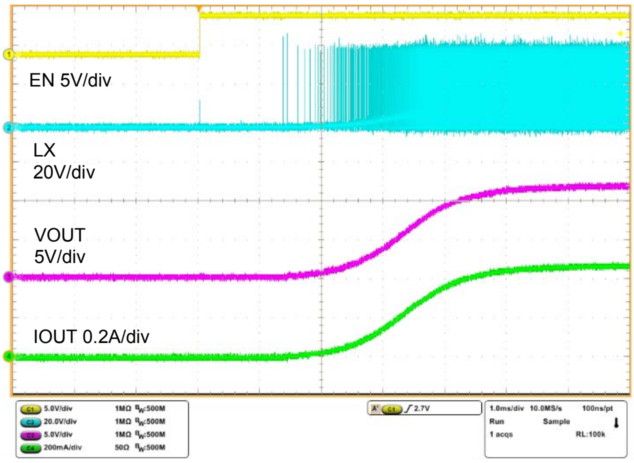


Figure 39. Start-up Characteristics
VCC=42V, IOUT=500mA, VOUT=12V

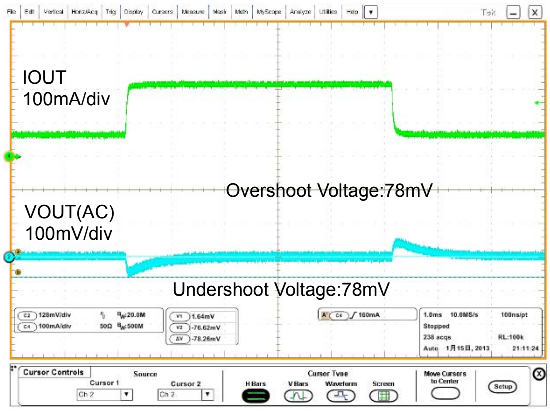


Figure 40. Load Response
IOUT=50mA<->200mA, VOUT=12V

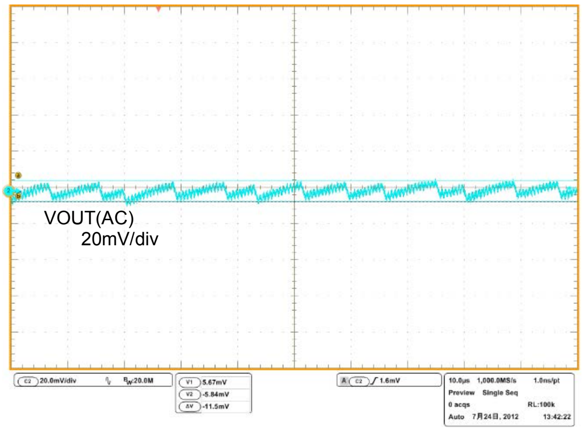


Figure 41. VOUT Ripple
IOUT=50mA, VOUT=12V

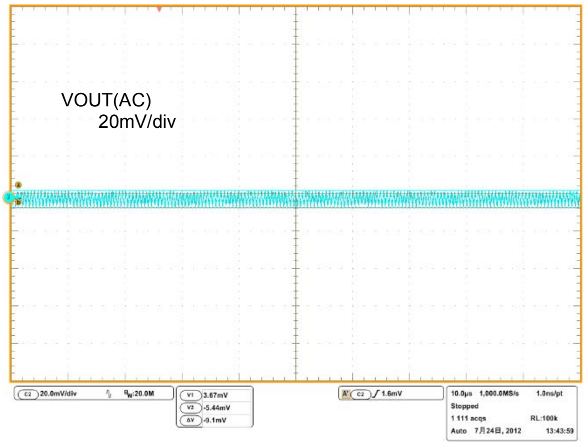


Figure 42. VOUT Ripple
IOUT=200mA, VOUT=12V

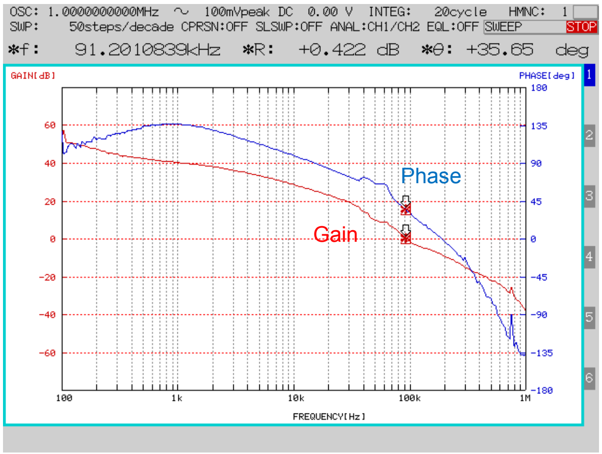


Figure 43. Frequency Response
IOUT=100mA, VOUT=12V

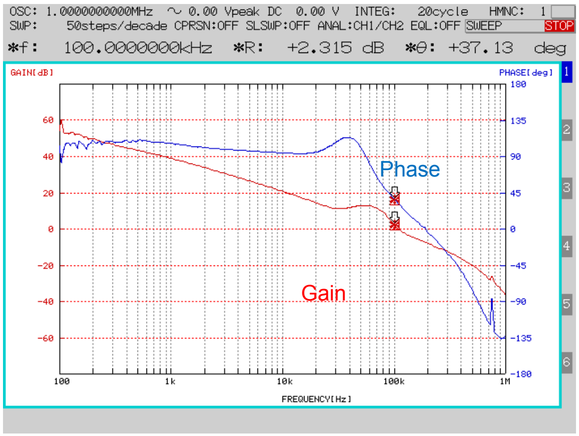


Figure 44. Frequency Response
IOUT=500mA, VOUT=12V

Application Components Selection Method

(1) Inductors
Something of the shield type that fulfills the current rating (Current value Ipeak 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 small for as big as the L value of inductor or as high as the Switching Frequency.

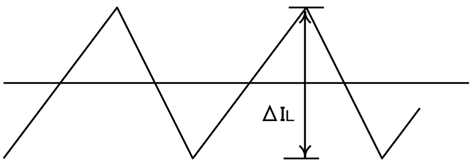


Figure 45. Inductor Current

$$I_{peak} = I_{OUT} + \Delta I_L/2 \text{ [A]} \quad (4)$$

$$\Delta I_L = \frac{V_{CC} - V_{OUT}}{L} \times \frac{V_{OUT}}{V_{CC}} \times \frac{1}{f} \text{ [A]} \quad (5)$$

(ΔIL: Output Ripple Current, f: Switching Frequency)
In the BD9G101G, it is recommended the below series of 4.7μH to 15μH inductance value. (If supply conditions change and parts are not available, use similar parts.)

Recommended Inductor **Murata DEM4518C Series**
TAIYO YUDEN LSXND4040 Series

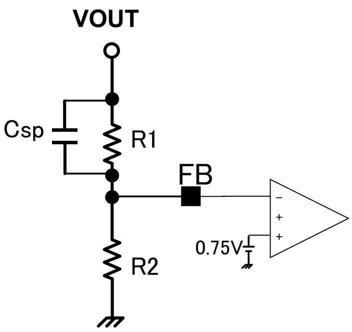
(2) Input Capacitor
In order to reduce input ripple, mount ceramic capacitor of low ESR near the VCC pin.
In the BD9G101G, it is recommended 4.7μF or more ceramic capacitor value. In case of using the electrolytic capacitor, mount about 1μF ceramic capacitor in parallel in order to prevent oscillation

(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.

$$V_{pp} = \Delta I_L \times \frac{1}{2\pi \times f \times C_o} + \Delta I_L \times R_{ESR} \quad \text{[V]} \quad (6)$$

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).



$$V_{OUT} = \frac{(R1+R2)}{R2} \times 0.75 \text{ V} \quad (7)$$

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 R1+R2 is satisfied the following formulas.

$$R1 + R2 \leq VOUT \times 10^3 \quad \cdot\cdot\cdot (8)$$

(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.

$$Csp = \frac{4.7k}{R1} \times 0.15 \qquad [\mu F] \qquad \cdot\cdot\cdot (9)$$

(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.

Cautions on PCB layout

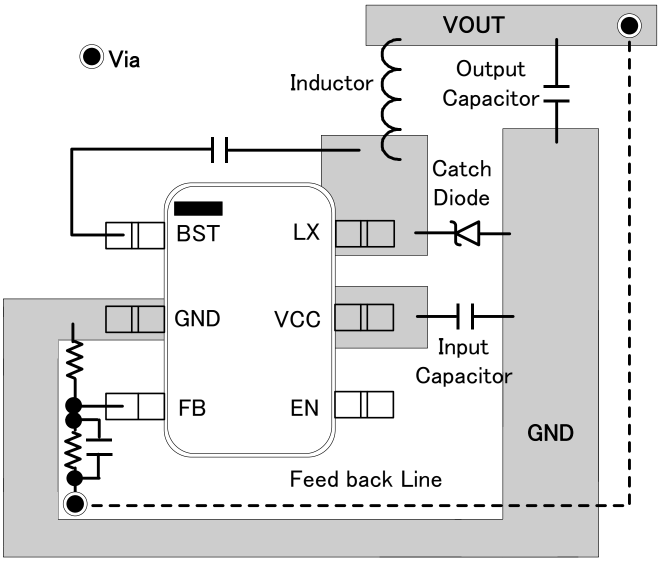


Figure 47. Reference PCB layout

PCB layout is a critical portion of good power supply design. Some paths that conduct fast current / voltage change may cause noises and degrade the power supplying performance due to leakage flux or interaction with parasitic capacitance. To help reducing these problems, the VCC pin should be bypassed to ground with a low ESR ceramic capacitor. Also, the large current is generated especially on the following 2 loops; Bypass input capacitor -> Inductor -> Output capacitor or Catch diode -> Inductor -> Output capacitor. Therefore, the distance between the output capacitor and the catch diode, or the distance between the output capacitor and the bypass input capacitor on the GND pattern should be as short as possible.

The input bypass capacitor, the catch diode and the inductor should be located as close to the IC as possible. Please keep GND line on the top layer to avoid GND level fluctuation caused by external connection.

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.

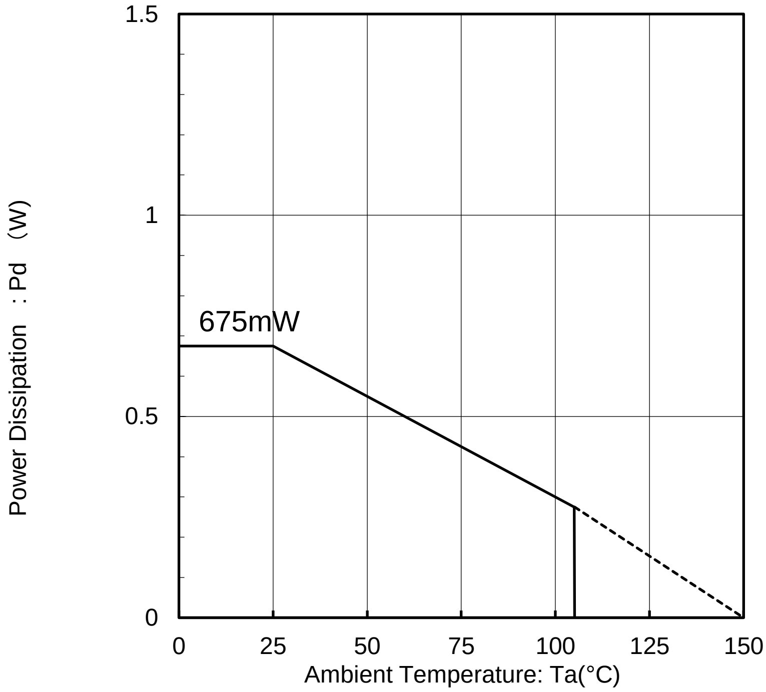


Figure 48. Power Dissipation (70mm x 70mm x 1.6mmt 1layer PCB)

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 = $IOUT^2$ x RonH x VOUT/VCC
2) Switching loss : Psw = 2.5 x 10^{-9} x VCC x IOUT × 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

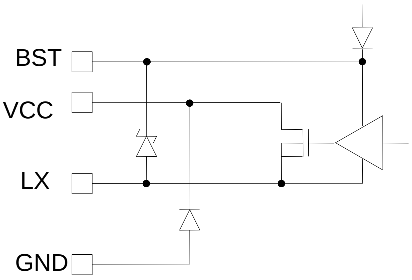
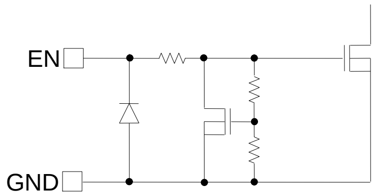
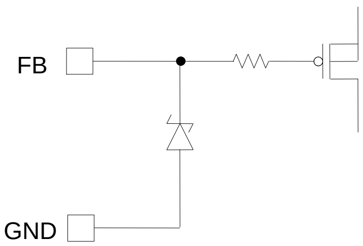
Pin. No	Pin Name	Pin Equivalent Circuit	Pin. No	Pin Name	Pin Equivalent Circuit
6 2 1 5	LX GND BST VCC		4	EN	
3	FB				

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.

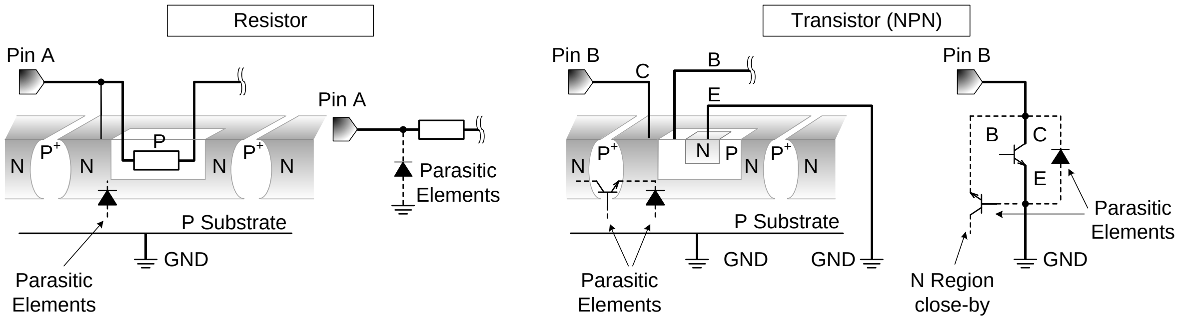


Figure50. Example of monolithic IC structure

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

B	D	9	G	1	0	1	G	-	TR

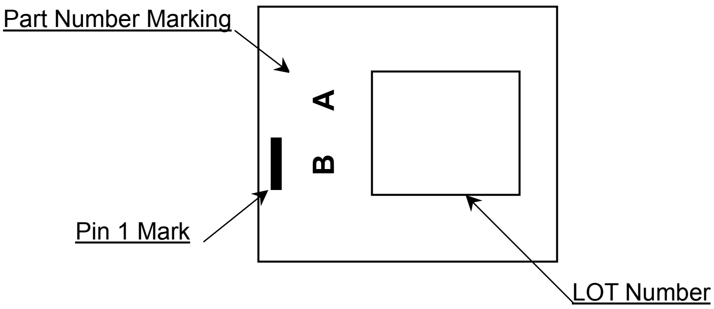
Part Number

Package
G: SSOP6

Packaging and forming specification
TR: Embossed tape and reel

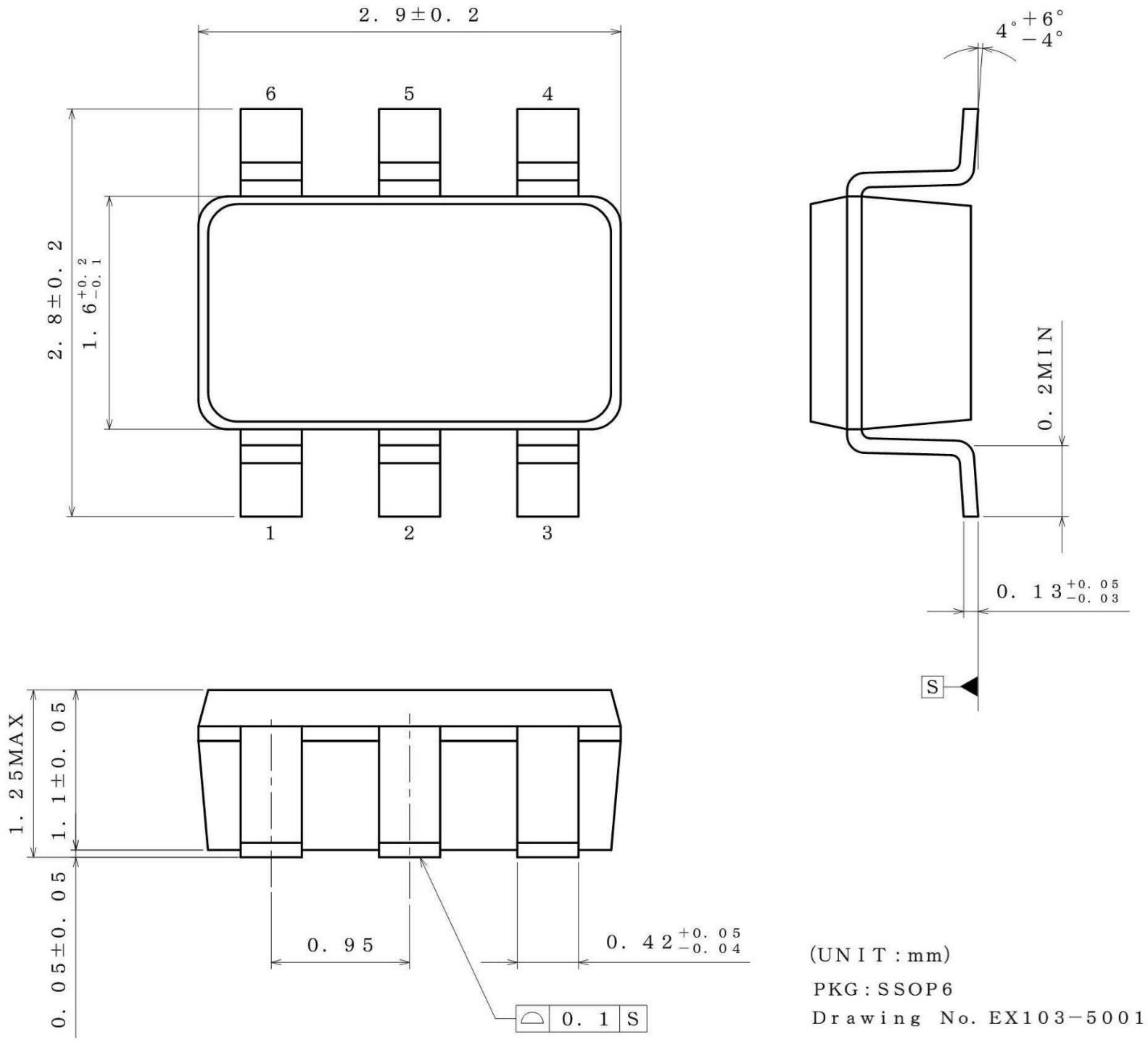
Marking Diagram

SSOP6(TOP VIEW)



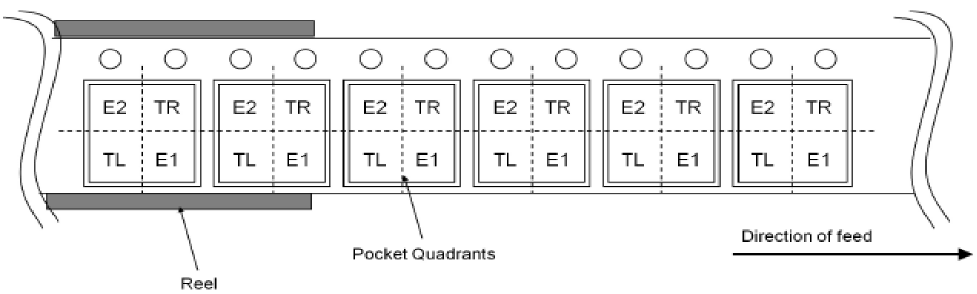
Physical Dimension and Packing Information

Package Name	SSOP6



<Tape and Reel information>

Tape	Embossed carrier tape
Quantity	3000pcs
Direction of feed	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)



Revision History

Date	Revision	Changes
21.Aug.2012	001	New Release
04.Feb.2013	002	P5~6: Adding of output voltage range P1, 10, 13: Change of typical application circuit P12, 15: Change of typical performance characteristic
22.Mar.2013	003	P16: Added description of input capacitor
04.Mar.2014	004	P10, 13: Correction of application parts
13.Jan.2015	005	P19: Correction of erroneous power dissipation estimate
16.Feb.2015	006	P23: Correction of ordering part number format
26.Jun.2017	007	P17: Correction of erroneous feed-forward capacitor formula
11.Dec.2018	008	P1: Deletion of car application in use application P11, 14: Correction of characteristics in typical application Review sentences over all pages
03.Dec.2021	009	P1 Changed the text on the lower-right of the footer. P3 1. Reference: Partly changed the description. P3 4. Soft Start: Partly changed the description: "DC/DC comparator"->"DC/DC convertor". P3 5. ERROR AMP: Partly changed the description. P3 10. OCP: Partly changed the description: "the over current"->"the input current" P4 Partly changed the description int the first foot note of Absolute Maximum Ratings: "70x70x1.6t mm"->"70mm x 70mm x 1.6mmt" P6 1.2 Feed-forward capacitor Csp: Partly changed the description. P7 Changed the description of Figure 7. P7 Start-up Characteristics: Partly changed the description. P10 Figure 20　Changed the format of the graph. P12 Figure 28, Figure 29 Changed the label on VOUT: "VOUT:offset 5V"-> "VOUT(AC)" P13 Figure 33　Changed the format of the graph. P15 Figure 41, Figure 42 Fixed the label of VOUT:"VOUT:offset 12V"->" VOUT(AC)" P16 (1)Inductor: Fixed the model name of the recommended inductor (TOKO DE4518C Series -> TOKO DEM4518C Series) P18 Cautions on PCB Layout: Partly changed the description.
28.Dec.2022	010	P2 Fixed some typos. P4 Fixed some typos. P10 Changed the company name: TOKO DEM4518C 1235AS-H-6R8M→Murata DEM4518C 1235AS-H-6R8M P10 Changed the part number of recommended product: NR4018T680M→LSXND4040TKL6R8MDG P10 Changed the part number of recommended product: Rohm RB060M-60→ROHM RBR2MM60B P10 Added note on recommended products: Recommended parts are selected from those products and information available at the time this data sheet (Rev.010) was released. If supply conditions change and parts are not available, use similar parts. P13 Changed the company name: TOKO DEM4518C 1235AS-H-100M→Murata DEM4518C 1235AS-H-100M P13 Changed the part number of recommended product: NR4018T100M→LSXND4040TKL100MDG P13 Changed the part number of recommended product: Rohm RB060M-60→ROHM RBR2MM60B P13 Added note on recommended products: Recommended parts are selected from those products and information available at the time this data sheet (Rev.010) was released. If supply conditions change and parts are not available, use similar parts. P16 Changed the company name: TOKO DEM4518C Series→Murata DEM4518C Series P16 Changed the part number of recommended product: NR4018 Series→LSXND4040 Series P16 Added note on recommended products: (If supply conditions change and parts are not available, use similar parts.) P17 Fixed some typos.

Notice

Precaution on using ROHM Products

1. Our Products are designed and manufactured for application in ordinary electronic equipment (such as AV equipment, OA equipment, telecommunication equipment, home electronic appliances, amusement equipment, etc.). If you intend to use our Products in devices requiring extremely high reliability (such as medical equipment (Note 1), transport equipment, traffic equipment, aircraft/spacecraft, nuclear power controllers, fuel controllers, car equipment including car accessories, safety devices, 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

JAPAN	USA	EU	CHINA
CLASSⅢ	CLASSⅢ	CLASSⅡb	CLASSⅢ
CLASSⅣ		CLASSⅢ	

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

3. Our Products are designed and manufactured for use under standard conditions and not under any special or extraordinary environments or conditions, as exemplified below. Accordingly, ROHM shall not be in any way responsible or liable for any damages, expenses or losses arising from the use of any ROHM's Products under any special or extraordinary environments or conditions. If you intend to use our Products under any special or extraordinary environments or conditions (as exemplified below), your independent verification and confirmation of product performance, reliability, etc, prior to use, must be necessary:
   [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 Cl_2, H_2S, NH_3, SO_2, and NO_2
   [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 Cl_2, H_2S, NH_3, SO_2, and NO_2
   [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.

Precaution for Product Label

A two-dimensional barcode printed on ROHM Products label is for ROHM's internal use only.

Precaution for Disposition

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

Precaution for Foreign Exchange and Foreign Trade act

Since concerned goods might be fallen under listed items of export control prescribed by Foreign exchange and Foreign trade act, please consult with ROHM in case of export.

Precaution Regarding Intellectual Property Rights

1. All information and data including but not limited to application example contained in this document is for reference only. ROHM does not warrant that foregoing information or data will not infringe any intellectual property rights or any other rights of any third party regarding such information or data.
2. ROHM shall not have any obligations where the claims, actions or demands arising from the combination of the Products with other articles such as components, circuits, systems or external equipment (including software).
3. No license, expressly or implied, is granted hereby under any intellectual property rights or other rights of ROHM or any third parties with respect to the Products or the information contained in this document. Provided, however, that ROHM will not assert its intellectual property rights or other rights against you or your customers to the extent necessary to manufacture or sell products containing the Products, subject to the terms and conditions herein.

Other Precaution

1. This document may not be reprinted or reproduced, in whole or in part, without prior written consent of ROHM.
2. The Products may not be disassembled, converted, modified, reproduced or otherwise changed without prior written consent of ROHM.
3. In no event shall you use in any way whatsoever the Products and the related technical information contained in the Products or this document for any military purposes, including but not limited to, the development of mass-destruction weapons.
4. The proper names of companies or products described in this document are trademarks or registered trademarks of ROHM, its affiliated companies or third parties.

General Precaution

1. Before you use our Products, you are requested to carefully read this document and fully understand its contents. ROHM shall not be in any way responsible or liable for failure, malfunction or accident arising from the use of any ROHM's Products against warning, caution or note contained in this document.

2. All information contained in this document is current as of the issuing date and subject to change without any prior notice. Before purchasing or using ROHM's Products, please confirm the latest information with a ROHM sales representative.

3. The information contained in this document is provided on an “as is” basis and ROHM does not warrant that all information contained in this document is accurate and/or error-free. ROHM shall not be in any way responsible or liable for any damages, expenses or losses incurred by you or third parties resulting from inaccuracy or errors of or concerning such information.