2.7V to 5.5V Input, 3.0A Integrated MOSFET Single Synchronous Buck DC/DC Converter

BD9B333GWZ

General Description

BD9B333GWZ is a synchronous buck DC/DC converter with built-in low on-resistance power MOSFETs. This IC, which is capable of providing current up to 3A, features fast transient response by employing constant on-time control system. It offers high oscillating frequency at low inductance. With its original constant on-time control method which operates low consumption at light load, this product is ideal for equipment and devices that demand minimal standby power consumption.
BD9B333GWZ achieves the high power density and offer a small footprint on the PCB by employing small CSP package.

Features

- Single Synchronous Buck DC/DC Converter
- Constant On-time Control Suitable to Deep-SLLM
- Over Current Protection
- Short Circuit Protection
- Over Voltage Protection
- Thermal Shutdown Protection
- Under Voltage Lockout Protection
- Adjustable Soft Start
- Power Good Output
- UCSP35L1 Package (Resin Coating)

Applications

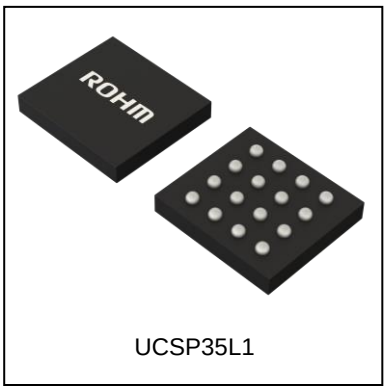
- Step-down Power Supply for DSPs, FPGAs, Microprocessors, etc.
- Laptop PCs/Tablet PCs/Servers
- LCD TVs
- Storage Devices (HDDs/SSDs)
- Printers, OA Equipment
- Distributed Power Supplies, Secondary Power Supplies

Key Specifications

- Input Voltage Range: 2.7V to 5.5V
- Output Voltage Range: 0.6 V to V_{IN} x 0.8 V
- Output Current: 3A (Max)
- Switching Frequency: 1.3MHz (Typ)
- High-Side MOSFET ON Resistance: 23mΩ (Typ)
- Low-Side MOSFET ON Resistance: 23mΩ (Typ)
- Standby Current: 0μA (Typ)

Package

	W (Typ) x D (Typ) x H (Max)
UCSP35L1	1.98mm x 1.80mm x 0.40mm



UCSP35L1

Typical Application Circuit

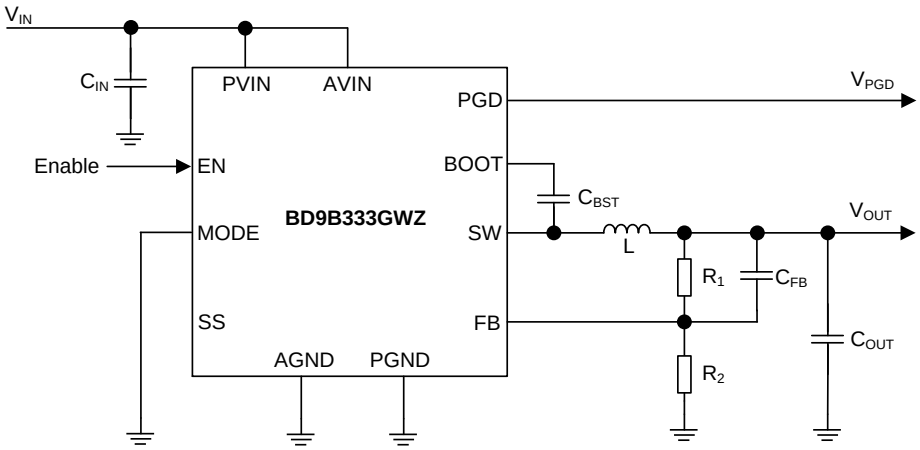


Figure 1. Application Circuit (MODE=L)

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

Pin Configuration

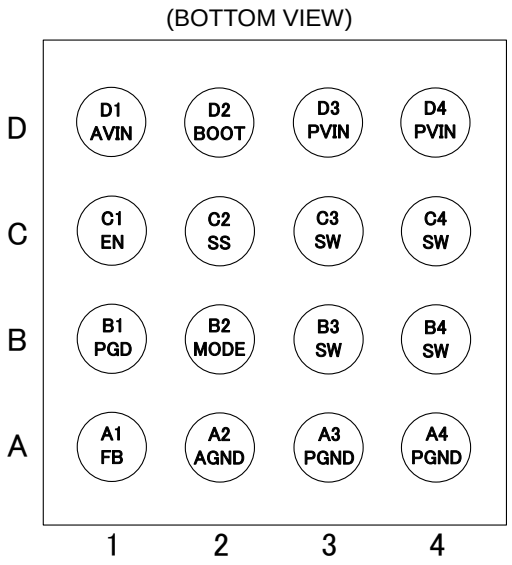


Figure 2. Pin Configuration

Pin Descriptions

Pin No.	Pin Name	Function
A1	FB	An inverting input node for the error amplifier and main comparator. See page 31 for how to calculate the resistance of the output voltage setting.
A2	AGND	Ground terminal for the control circuit.
A3, A4	PGND	Ground terminals for the output stage of the switching regulator.
B1	PGD	Power Good terminal. A pull-up resistor is needed due to an open drain output. See page 17 for how to specify the resistance. When the FB terminal voltage reaches more than 90% of 0.6V (Typ), the internal Nch MOSFET turns off and the output turns High.
B2	MODE	Terminal for setting switching control mode. Connecting this terminal to AVIN forces the device to operate in the fixed frequency PWM mode. Connecting this terminal to ground enables the Deep-SLLM control and the mode is automatically switched between the Deep-SLLM control and fixed frequency PWM mode. Please fix this terminal to AVIN or ground. Do not change the control mode during operation.
B3, B4 C3, C4	SW	Switch terminals. These terminals are connected to the source of the High-Side MOSFET and drain of the Low-Side MOSFET. Connect a bootstrap capacitor of 0.1µF between these terminals and BOOT terminal. In addition, connect an inductor considering the direct current superimposition characteristic.
C1	EN	Enable terminal. Turning this terminal signal Low (0.5V or less) forces the device to enter the shutdown mode. Turning this terminal signal High (1.5V or more) enables the device. This terminal must be properly terminated.
C2	SS	Terminal for setting the soft start time. Rising time of output voltage is 1ms (Typ) when SS terminal is open. A capacitor connected to the SS terminal makes rising time more than 1ms. See page 32 for how to calculate the capacitance.
D1	AVIN	Terminal for supplying power to the control circuit of the switching regulator. This terminal is connected to PVIN.
D2	BOOT	Terminal for bootstrap. Connect a bootstrap capacitor of 0.1µF between this terminal and SW terminals. The voltage of this terminal is the gate drive voltage of the High-Side MOSFET.
D3, D4	PVIN	Power supply terminals for the switching regulator. These terminals supply power to the output stage of the switching regulator. Connecting a 22µF ceramic capacitor is recommended.

Block Diagram

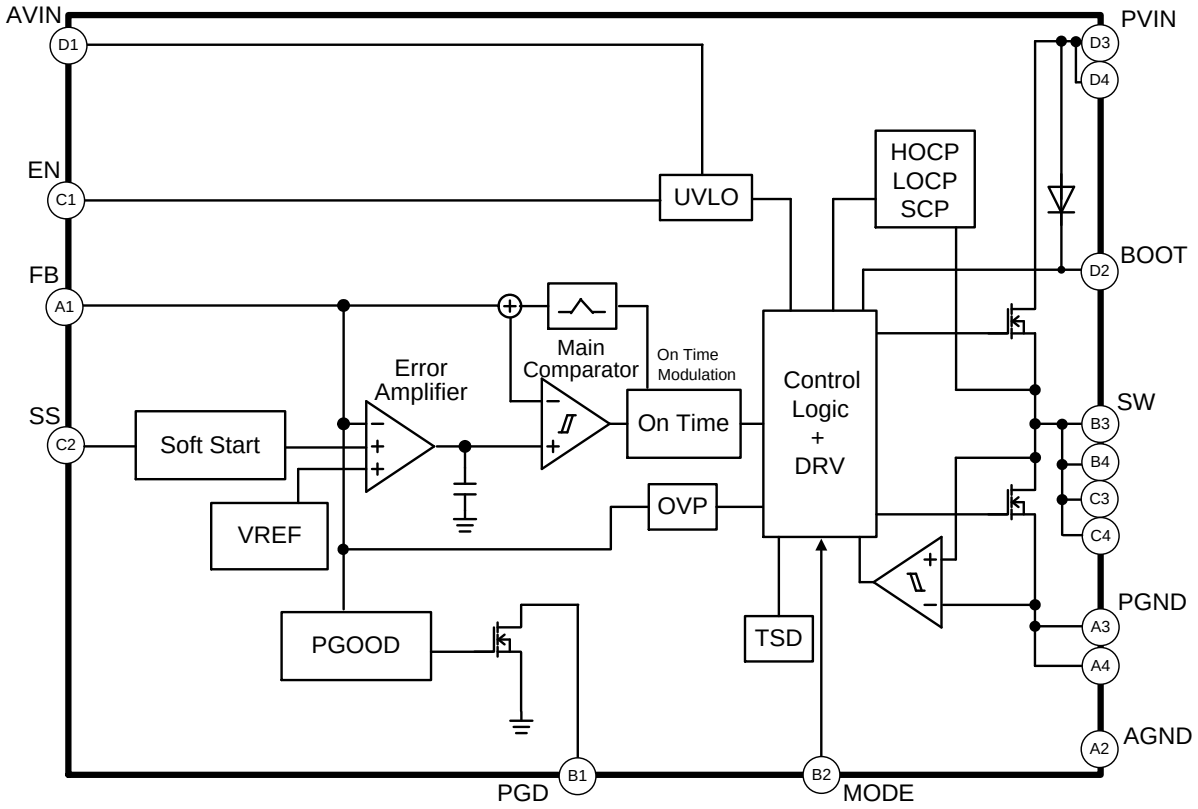


Figure 3. Block Diagram

Description of Blocks

1. VREF
   The VREF block generates the internal reference voltage.

2. UVLO
   The UVLO block is for under voltage lockout protection. It will shut down the IC when AVIN falls to 2.45 V (Typ) or less. The threshold voltage has a hysteresis of 100mV (Typ).

3. TSD
   The TSD block is for thermal protection. The thermal protection circuit shuts down the device when the internal temperature of IC rises to 175°C (Typ) or more. Thermal protection circuit resets when the temperature falls. The circuit has a hysteresis of 25°C (Typ).

4. Soft Start
   The Soft Start circuit slows down the rise of output voltage during start-up and controls the current, which allows the prevention of output voltage overshoot and inrush current. The internal soft start time is set to 1ms (Typ) when the SS terminal is open. A capacitor connected to the SS terminal makes the rising time more than 1ms.

5. Error Amplifier
   Error Amplifier adjusts Main Comparator input voltage to make the internal reference voltage equal to FB terminal voltage.

6. Main Comparator
   Main comparator compares Error Amplifier output voltage and FB terminal voltage. When FB terminal voltage becomes lower than Error Amplifier output voltage, it outputs High and reports to the On Time block that the output voltage has dropped below the control voltage.

7. On Time
   This is a block which generates On Time. Designed On Time is generated when Main Comparator output becomes High. On Time is adjusted to restrict frequency change even with Input and Output voltage change.

8. Control Logic + DRV
   This block is a DC/DC driver. A signal from On Time block is applied to drive the MOSFETs.

9. PGOOD
   When the output voltage reaches 90% (Typ) or more of the voltage setting, the open drain Nch MOSFET, internally connected to the PGD terminal, turns off and the PGD terminal turns to Hi-Z condition. When the output voltage falls 85% (Typ) or less of the voltage setting, the open drain Nch MOSFET turns on and PGD terminal pulls down with 100Ω (Typ).

10. HOCP/LOCP/SCP
    After soft start is completed and in condition where output voltage is below 85% (Typ) of the voltage setting, this block counts the number of times of which current flowing in High-Side MOSFET or Low-Side MOSFET reaches over current limit. When 512 times is counted, it stops operation for 3ms (Typ) and re-operates. Counting is reset when output voltage is above 90% (Typ) of voltage setting or when IC re-operates by EN, UVLO, SCP function.

11. OVP
    The over voltage protection function (OVP) compares FB terminal voltage with the internal reference voltage. When the FB terminal voltage exceeds 0.72V (Typ), it turns the output MOSFETs off. The output voltage returns with hysteresis after the output voltage drops to normal operation level.

Absolute Maximum Ratings (Ta = 25°C)

Parameter	Symbol	Rating	Unit
Input Voltage	V_{PVIN}, V_{AVIN}	-0.3 to +7	V
EN Terminal Voltage	V_{EN}	-0.3 to +7	V
MODE Terminal Voltage	V_{MODE}	-0.3 to +7	V
Voltage from GND to BOOT	V_{BOOT}	-0.3 to +14	V
Voltage from SW to BOOT	ΔV_{BOOT}	-0.3 to +7	V
FB Terminal Voltage	V_{FB}	-0.3 to +7	V
SW Terminal Voltage	V_{SW}	-0.3 to V_{PVIN} + 0.3	V
Output Current	I_{OUT}	3.5	A
Maximum Junction Temperature	Tjmax	150	°C
Storage Temperature Range	Tstg	-55 to +150	°C

Caution 1: *Operating the IC over the absolute maximum ratings may damage the IC. The damage can either be a short circuit between pins or an open circuit between pins and the internal circuitry. Therefore, it is important to consider circuit protection measures, such as adding a fuse, in case the IC is operated over the absolute maximum ratings.*

Caution 2: *Should by any chance the maximum junction temperature rating be exceeded the rise in temperature of the chip may result in deterioration of the properties of the chip. In case of exceeding this absolute maximum rating, design a PCB boards with thermal resistance taken into consideration by increasing board size and copper area so as not to exceed the maximum junction temperature rating.*

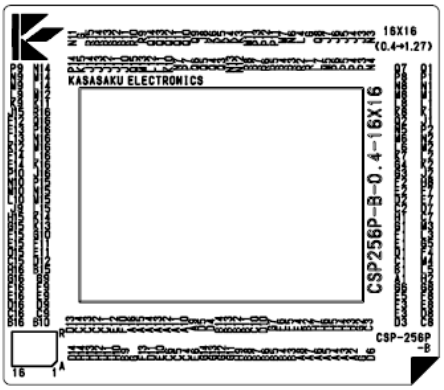
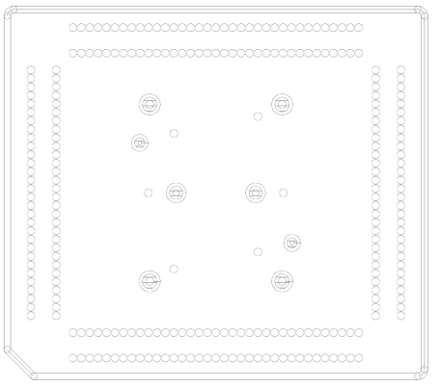
Thermal Resistance*(Note 1)*

Parameter	Symbol	Thermal Resistance (Typ)*(Note 3)*	Unit
UCSP35L1			
Junction to Ambient	θ_{JA}	153.8	°C/W
Junction to Top Characterization Parameter*(Note 2)*	Ψ_{JT}	1.6	°C/W

(Note 1) Based on JESD51-2A (Still-Air).

(Note 2) The thermal characterization parameter to report the difference between junction temperature and the temperature at the top center of the outside surface of the component package.

(Note 3) Using the specified PCB board.

		Evaluation board
Layout of Board for Measurement		 Top Layer (Top View)  Bottom Layer (Bottom View)
Board Material		Glass epoxy resin (9 layers)
Board Size		62 mm x 54 mm x 1.6 mmt
Wiring Rate	Top layer	Metal (GND) wiring rate: Approx. 81.6%
	Bottom layer	Metal (GND) wiring rate: Approx. 82.3%
Copper Foil Thickness		Outer layer L1,L9 : 27µm Inner layer L8 : 27µm, L2~L7 : 18µm
Through Hole		Diameter 0.1mm x 256 holes Diameter 0.6mm x 266 holes

Recommended Operating Conditions

Parameter	Symbol	Min	Typ	Max	Unit
Input Voltage	V_{PVIN}, V_{AVIN}	2.7	-	5.5	V
Operating Temperature Range	Topr	-40	-	+85	°C
Output Current	I_{OUT}	0	-	3	A
Output Voltage Range	V_{RANGE}	0.6	-	V_{PVIN} × 0.8	V

Electrical Characteristics (Unless otherwise specified Ta = 25°C, V_{PVIN} = V_{AVIN} = 5V, V_{EN} = 5V, V_{MODE} = GND)

Parameter	Symbol	Min	Typ	Max	Unit	Conditions
Input Supply						
Standby Supply Current	I_{STB}	-	0	10	µA	V_{EN} = GND
Operating Supply Current	I_{CC}	-	50	75	µA	I_{OUT} = 0mA Non switching
UVLO Detection Threshold Voltage	V_{UVLO1}	2.350	2.450	2.550	V	V_{AVIN} falling
UVLO Release Threshold Voltage	V_{UVLO2}	2.425	2.550	2.700	V	V_{AVIN} rising
UVLO Hysteresis	$V_{UVLOHYS}$	50	100	200	mV	
Enable						
EN Input High Level Voltage	V_{ENH}	1.5	-	V_{AVIN}	V	
EN Input Low Level Voltage	V_{ENL}	GND	-	0.5	V	
EN Input Current	I_{EN}	-	3	6	µA	V_{EN} = 5V
Reference Voltage, Error Amplifier						
FB Terminal Voltage	V_{FB}	0.591	0.600	0.609	V	
FB Input Current	I_{FB}	-	-	1	µA	V_{FB} = 0.6V
Internal Soft Start Time	t_{SS}	0.5	1.0	2.0	ms	SS terminal is open.
Soft Start Terminal Current	I_{SS}	0.5	1.2	1.8	µA	
Control						
MODE Input High Level Voltage	V_{MODEH}	V_{AVIN} - 0.3	-	V_{AVIN}	V	
MODE Input Low Level Voltage	V_{MODEL}	GND	-	0.3	V	
On Time	t_{ONT}	140	185	230	ns	V_{OUT} = 1.2V, V_{MODE} = V_{AVIN}
Power Good						
Power Good Rising Threshold	V_{PGDH}	85	90	95	%	V_{FB} rising
Power Good Falling Threshold	V_{PGDL}	80	85	90	%	V_{FB} falling
PGD Output Leakage Current	I_{LKPGD}	-	0	1	µA	V_{PGD} = 5V
Power Good On Resistance	R_{PGD}	-	100	200	Ω	
Power Good Low Level Voltage	V_{PGDVL}	-	0.1	0.2	V	I_{PGD} = 1mA
SW						
High Side FET On Resistance	R_{ONH}	-	23	50	mΩ	V_{BOOT} - V_{SW} = 5V
Low Side FET On Resistance	R_{ONL}	-	23	50	mΩ	
High Side Output Leakage Current	I_{LH}	-	0	10	µA	No switching
Low Side Output Leakage Current	I_{LL}	-	0	10	µA	No switching

Typical Performance Curves

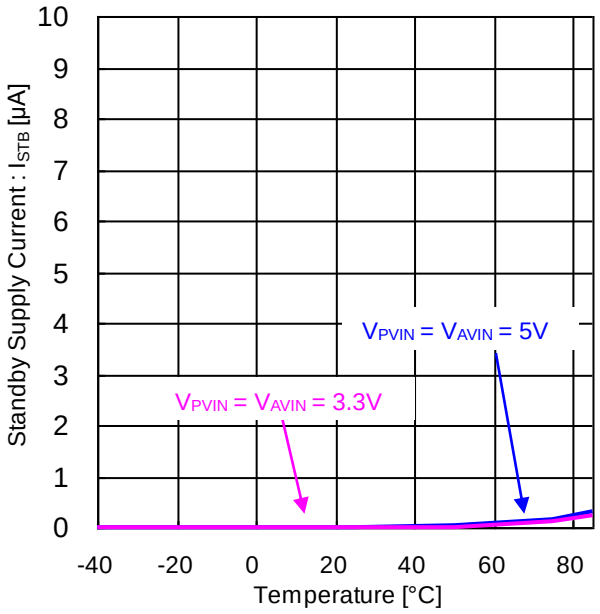


Figure 4. Standby Supply Current vs Temperature

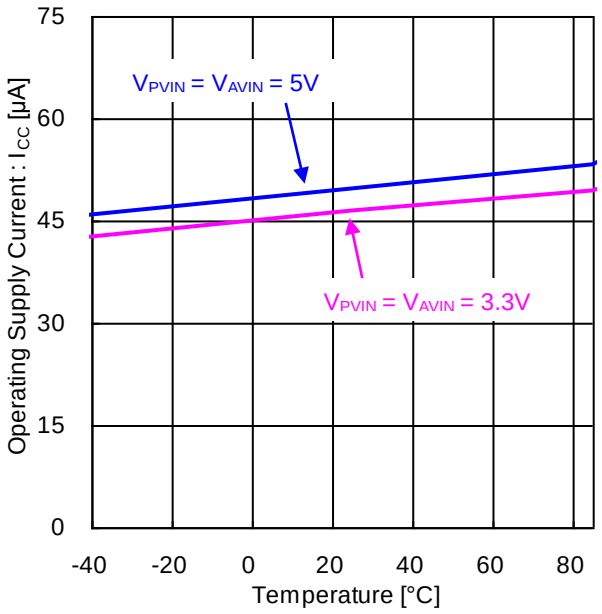


Figure 5. Operating Supply Current vs Temperature

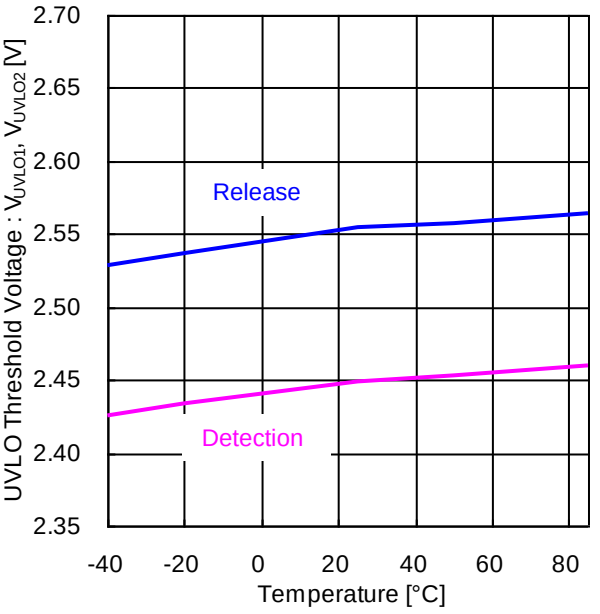


Figure 6. UVLO Threshold Voltage vs Temperature

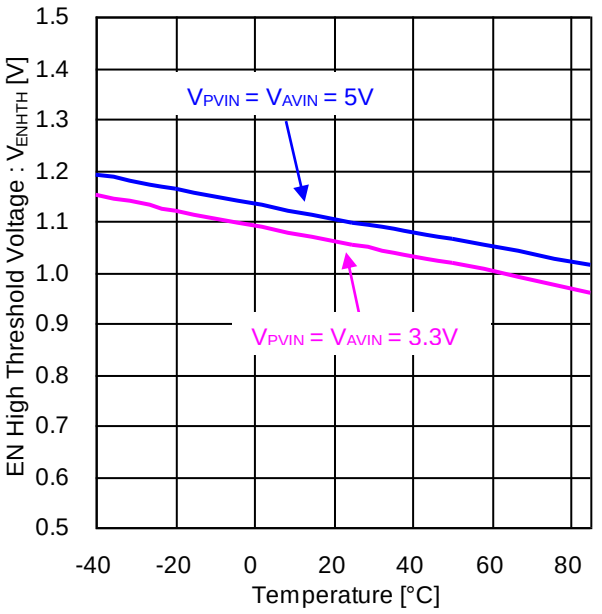


Figure 7. EN High Threshold Voltage vs Temperature (V_{EN} Sweep Up)

Typical Performance Curves - continued

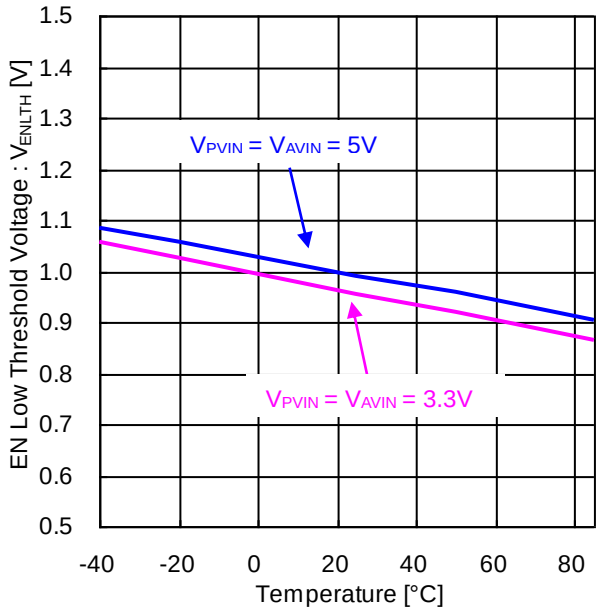


Figure 8. EN Low Threshold Voltage vs Temperature
(V_{EN} Sweep Down)

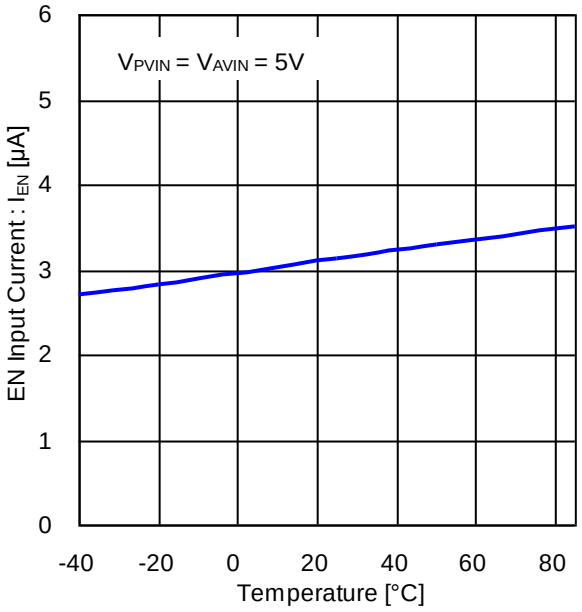


Figure 9. EN Input Current vs Temperature
(V_{EN} = 5V)

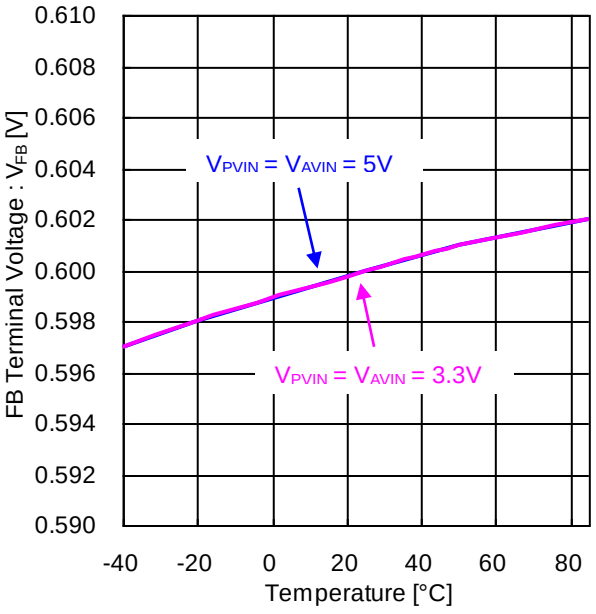


Figure 10. FB Terminal Voltage vs Temperature

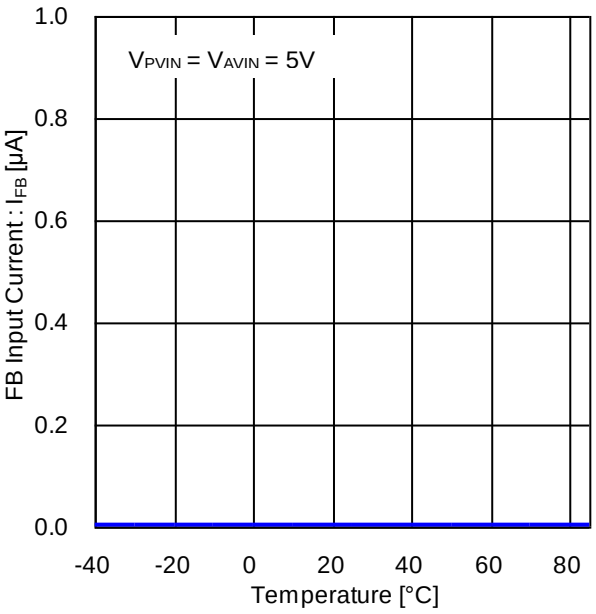


Figure 11. FB Input Current vs Temperature
(V_{FB} = 0.6V)

Typical Performance Curves - continued

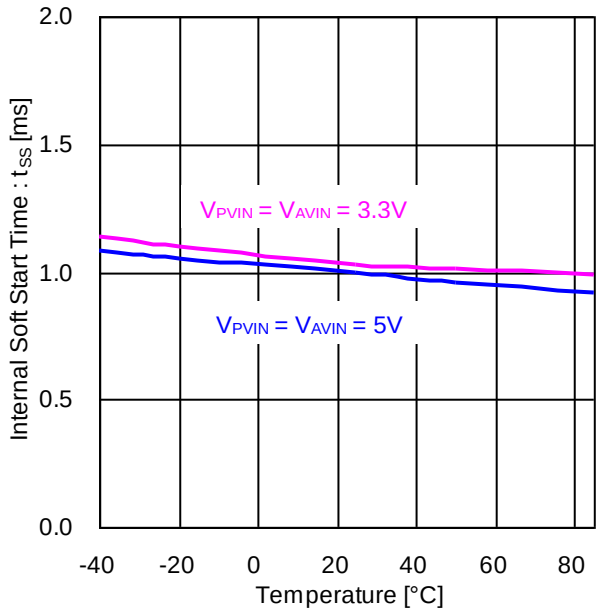


Figure 12. Internal Soft Start Time vs Temperature (C_{SS} = OPEN)

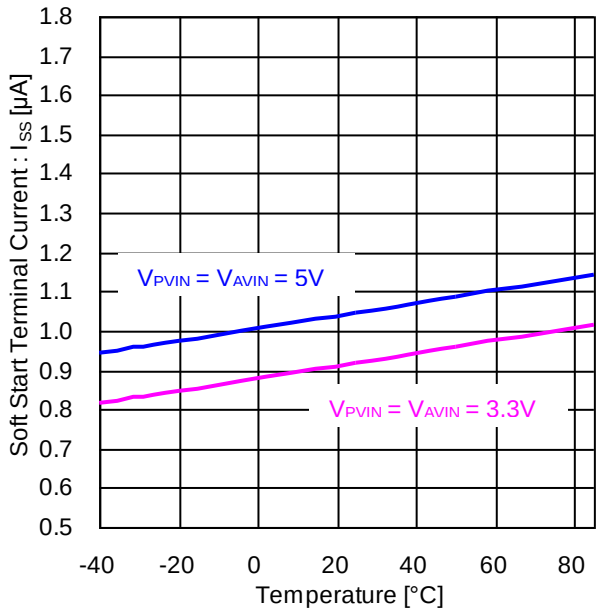


Figure 13. Soft Start Terminal Current vs Temperature

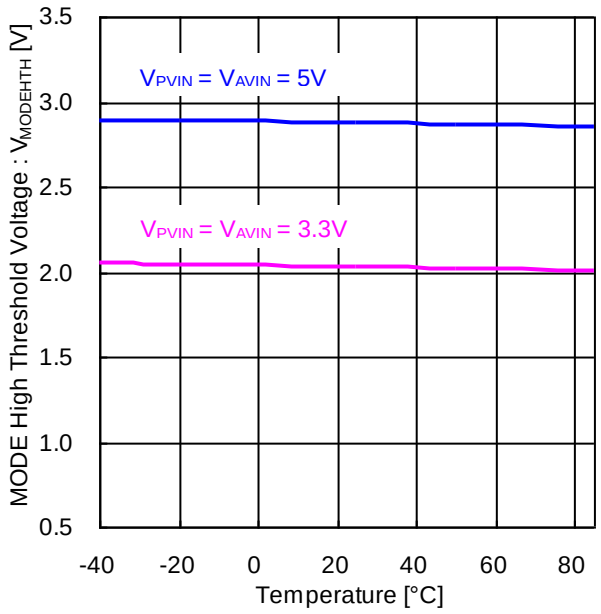


Figure 14. MODE High Threshold Voltage vs Temperature

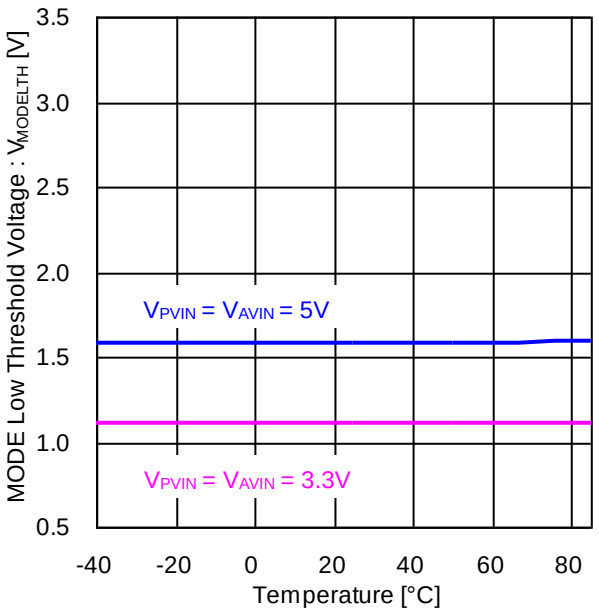


Figure 15. MODE Low Threshold Voltage vs Temperature

Typical Performance Curves - continued

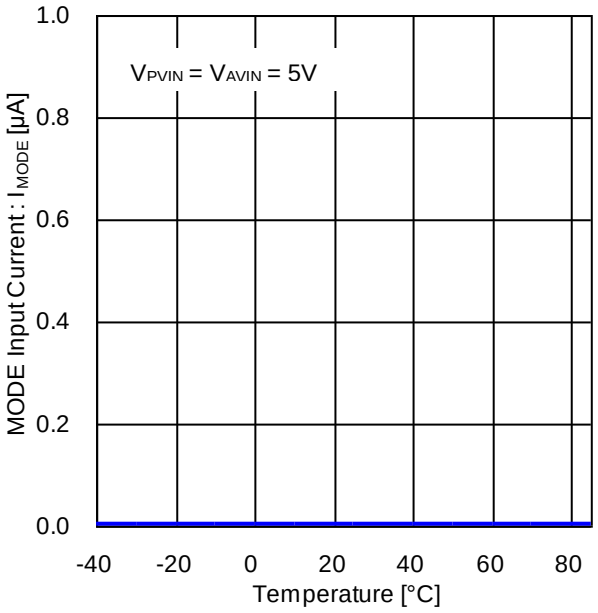


Figure 16. MODE Input Current vs Temperature
(V_{MODE} = 5V)

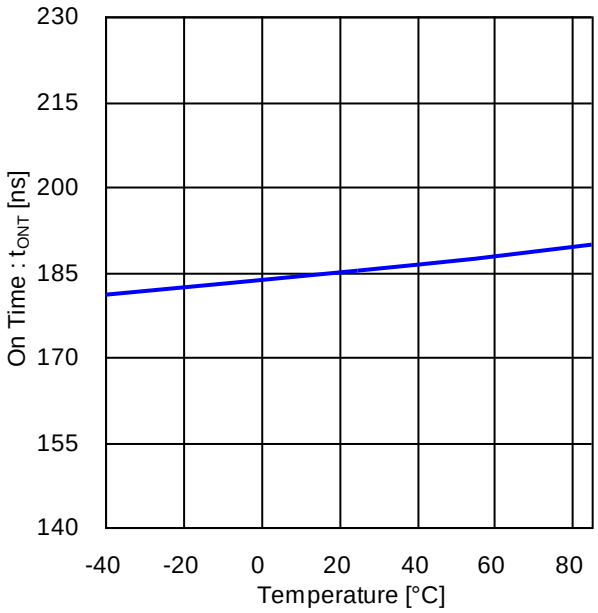


Figure 17. On Time vs Temperature
(V_{PVIN} = V_{AVIN} = 5V, V_{OUT} = 1.2V, V_{MODE} = V_{AVIN})

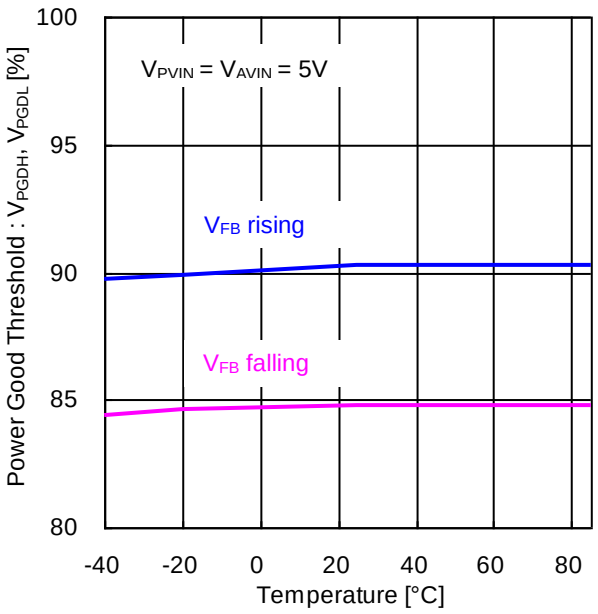


Figure 18. Power Good Threshold vs Temperature

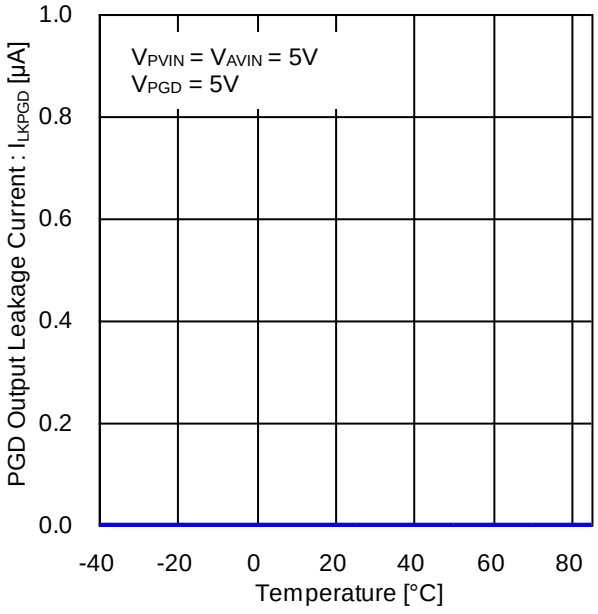


Figure 19. PGD Output Leakage Current vs Temperature

Typical Performance Curves - continued

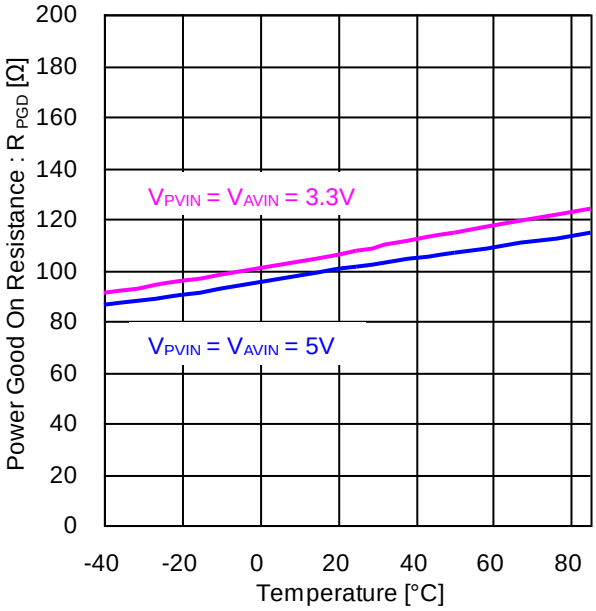


Figure 20. Power Good On Resistance vs Temperature

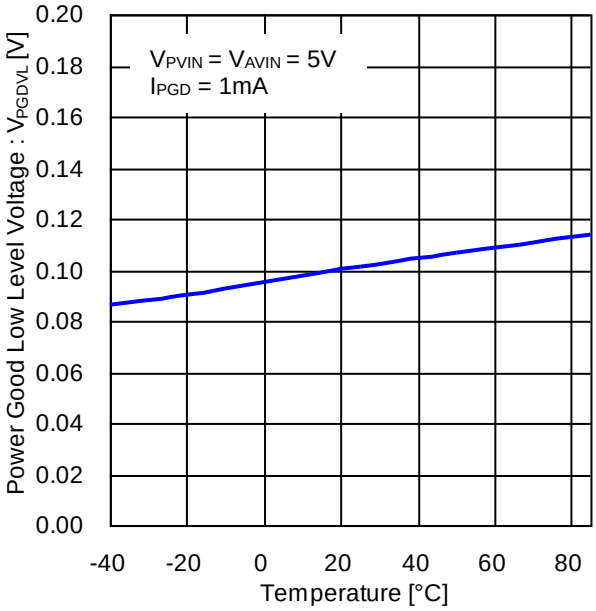


Figure 21. Power Good Low Level Voltage vs Temperature

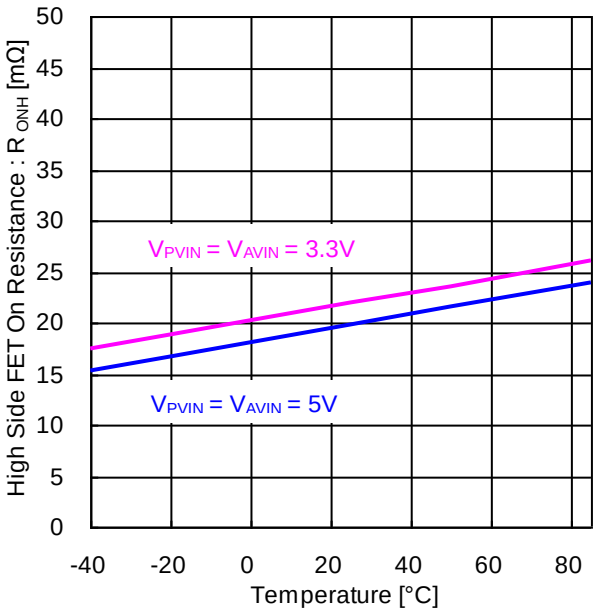


Figure 22. High Side FET On Resistance vs Temperature

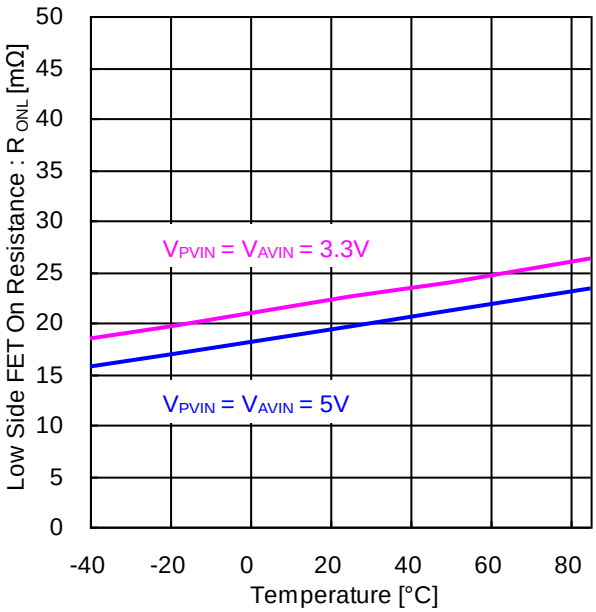


Figure 23. Low Side FET On Resistance vs Temperature

Typical Performance Curves - continued

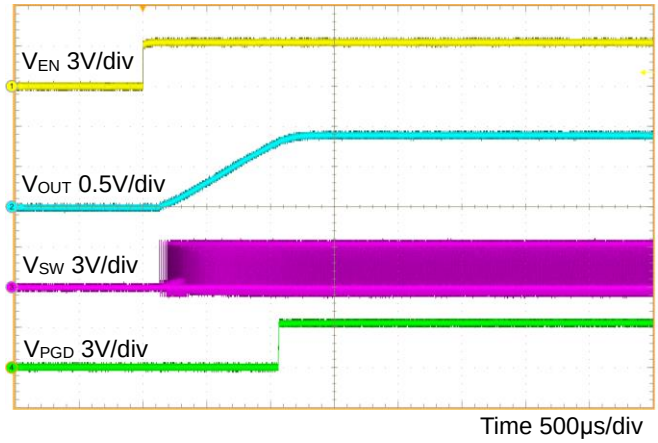


Figure 24. Start-up Waveform (V_{EN} = 0V to 3.3V)
(V_{PVIN} = V_{AVIN} = 3.3V, V_{OUT} = 0.9V, V_{MODE} = 0V, R_{LOAD} = 1Ω, C_{SS} = OPEN)

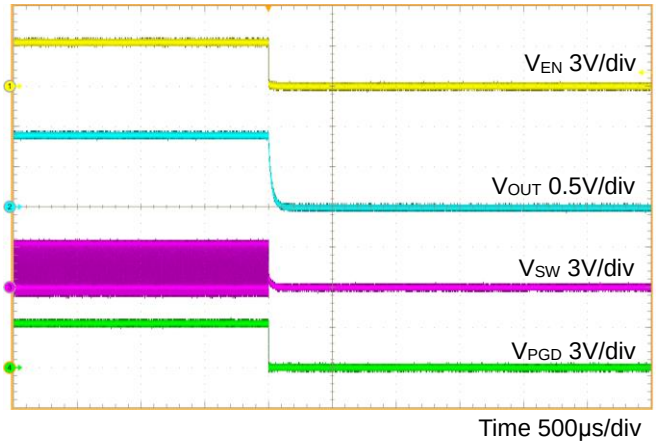


Figure 25. Shutdown Waveform (V_{EN} = 3.3V to 0V)
(V_{PVIN} = V_{AVIN} = 3.3V, V_{OUT} = 0.9V, V_{MODE} = 0V, R_{LOAD} = 1Ω, C_{SS} = OPEN)

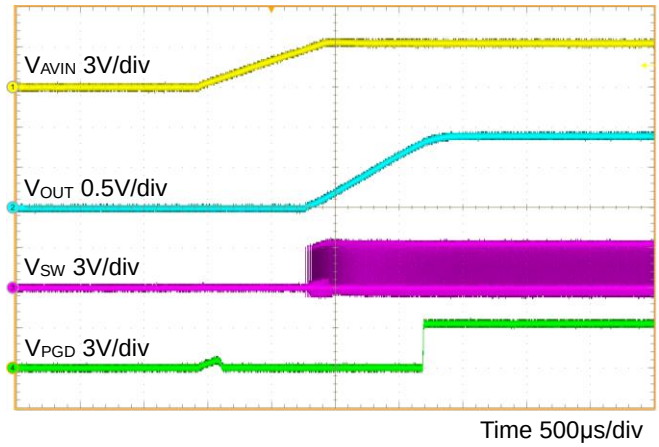


Figure 26. Start-up Waveform (V_{PVIN} = V_{AVIN} = V_{EN})
(V_{PVIN} = V_{AVIN} = 3.3V, V_{OUT} = 0.9V, V_{MODE} = 0V, R_{LOAD} = 1Ω, C_{SS} = OPEN)

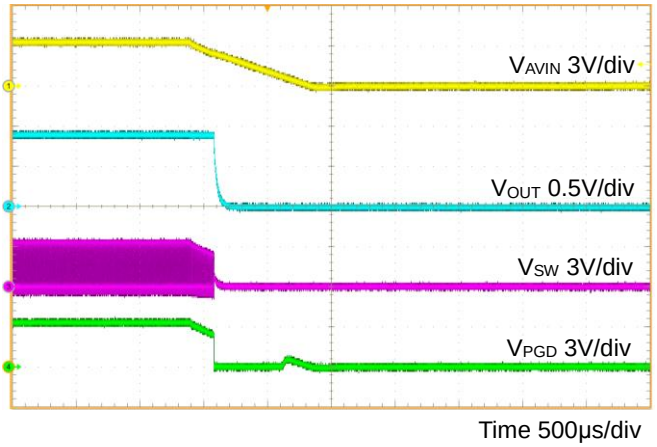


Figure 27. Shutdown Waveform (V_{PVIN} = V_{AVIN} = V_{EN})
(V_{PVIN} = V_{AVIN} = 3.3V, V_{OUT} = 0.9V, V_{MODE} = 0V, R_{LOAD} = 1Ω, C_{SS} = OPEN)

Typical Performance Curves - continued

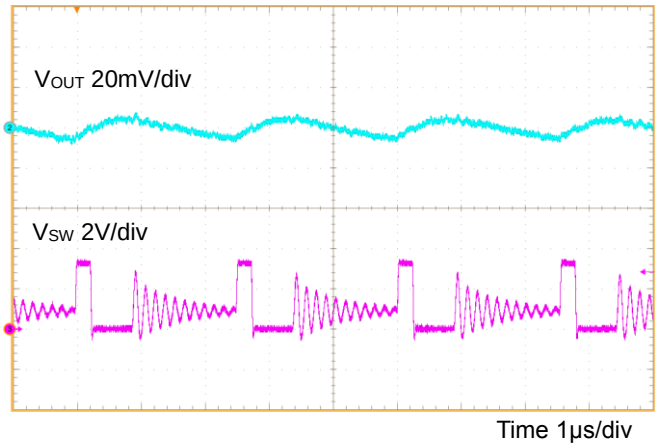


Figure 28. Switching Waveform
(V_{PVIN} = V_{AVIN} = 3.3V, V_{OUT} = 0.9V, V_{MODE} = 0V, I_{OUT} = 0.1A)

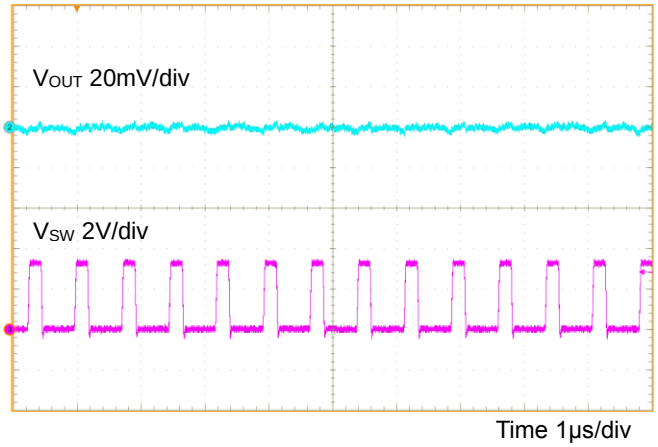


Figure 29. Switching Waveform
(V_{PVIN} = V_{AVIN} = 3.3V, V_{OUT} = 0.9V, V_{MODE} = 3.3V, I_{OUT} = 0.1A)

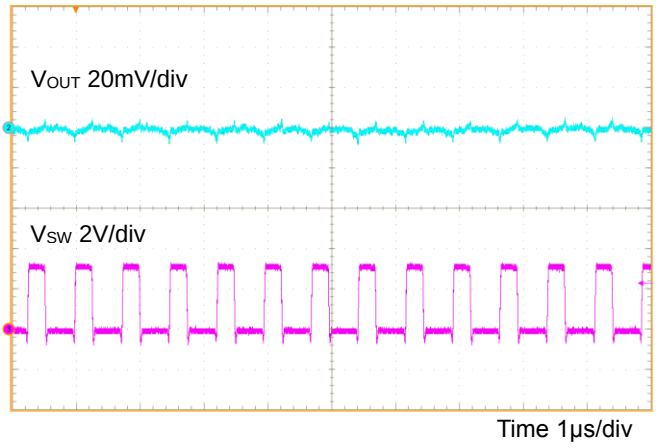


Figure 30. Switching Waveform
(V_{PVIN} = V_{AVIN} = 3.3V, V_{OUT} = 0.9V, V_{MODE} = 0V, I_{OUT} = 3A)

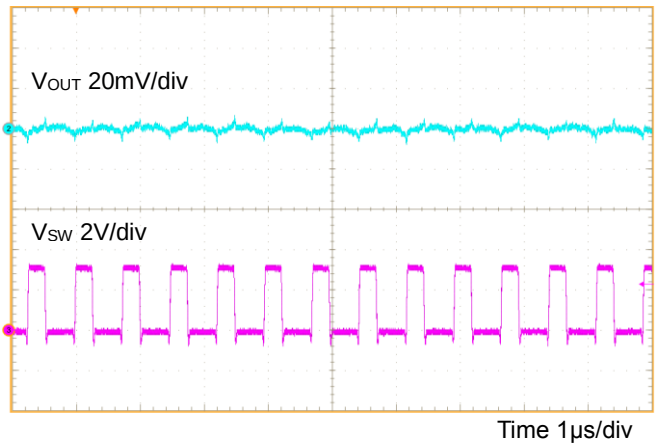


Figure 31. Switching Waveform
(V_{PVIN} = V_{AVIN} = 3.3V, V_{OUT} = 0.9V, V_{MODE} = 3.3V, I_{OUT} = 3A)

Typical Performance Curves - continued

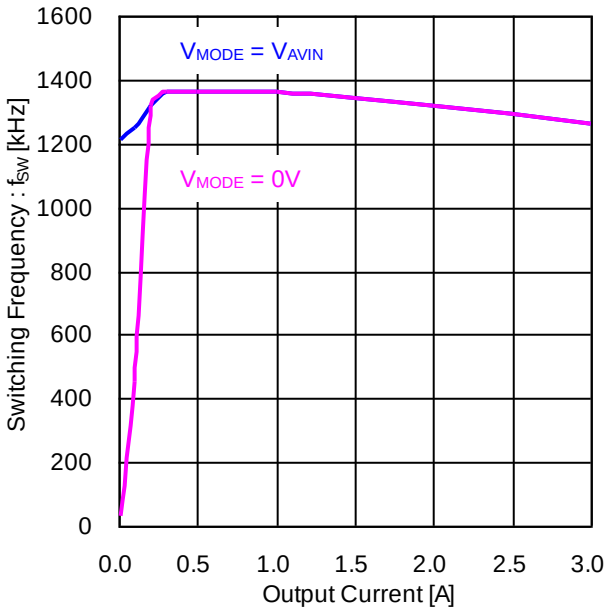


Figure 32. Switching Frequency vs Output Current
(V_{PVIN} = V_{AVIN} = 3.3V, V_{OUT} = 0.9V)

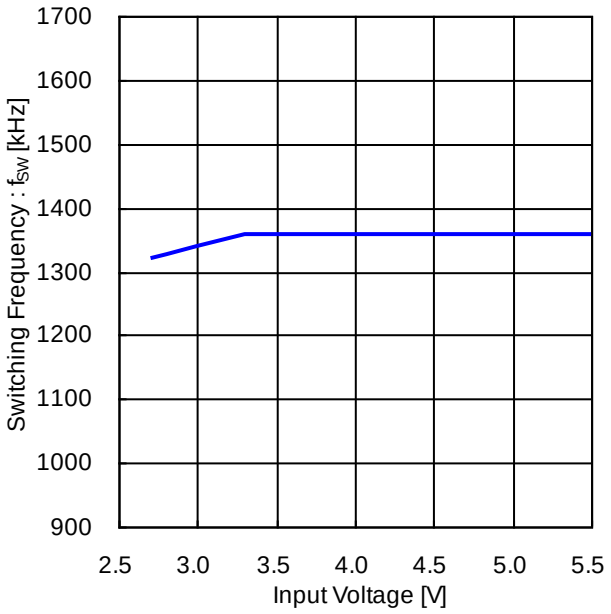


Figure 33. Switching Frequency vs Input Voltage
(V_{OUT} = 0.9V, V_{MODE} = 0V, I_{OUT} = 1A)

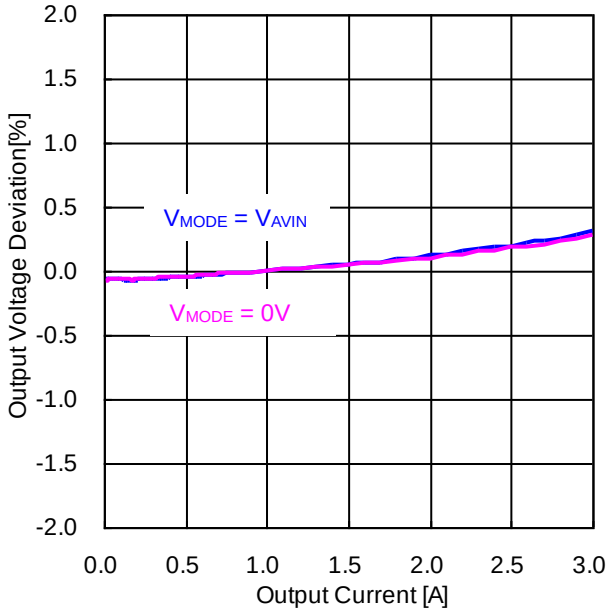


Figure 34. Load Regulation
(V_{PVIN} = V_{AVIN} = 3.3V, V_{OUT} = 0.9V)

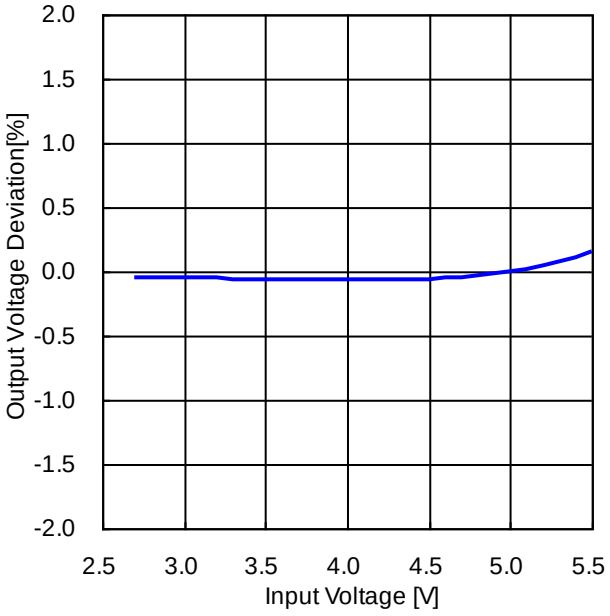


Figure 35. Line Regulation
(V_{OUT} = 0.9V, V_{MODE} = 0V, I_{OUT} = 1A)

Typical Performance Curves - continued

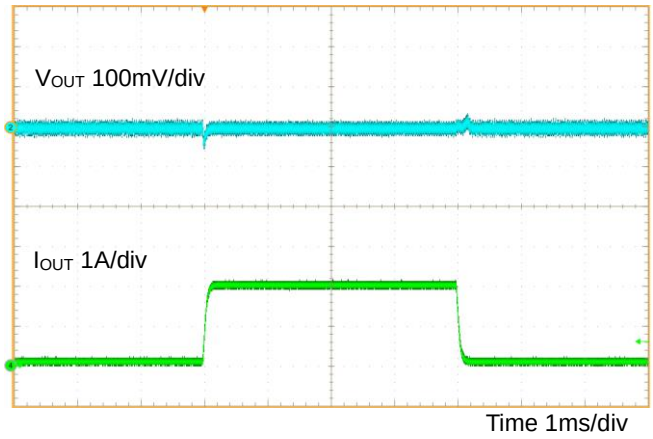


Figure 36. Load Transient Response I_{OUT} = 0.1A - 2A
(V_{PVIN}=V_{AVIN}=3.3V, V_{OUT}=0.9V, V_{MODE}=0V, C_{OUT}=22µF)

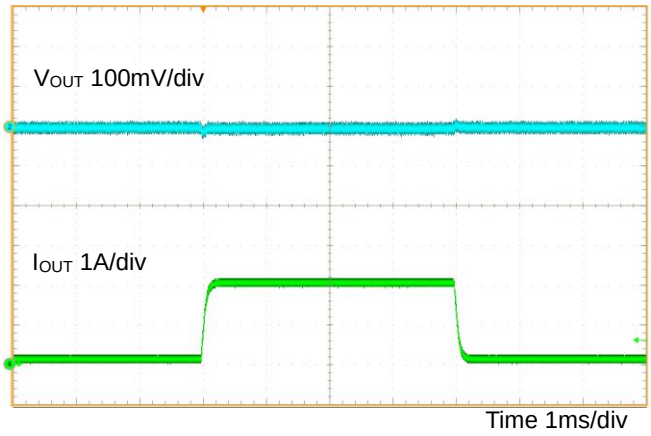


Figure 37. Load Transient Response I_{OUT} = 0.1A - 2A
(V_{PVIN}=V_{AVIN}=3.3V, V_{OUT}=0.9V, V_{MODE}=V_{AVIN}, C_{OUT}=22µF)

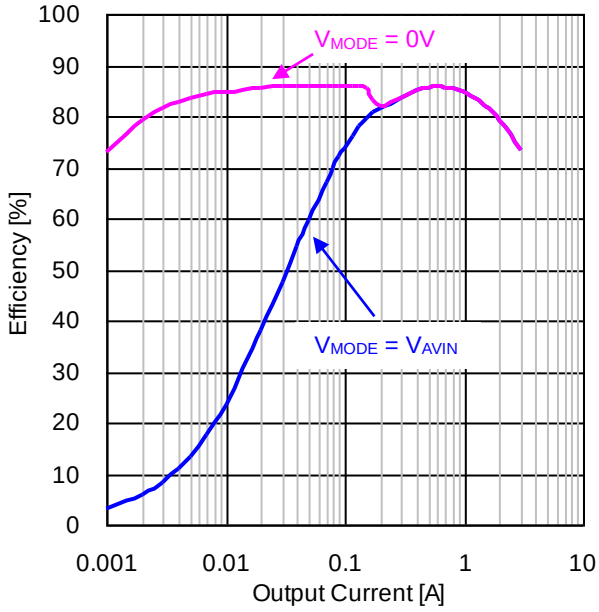


Figure 38. Efficiency vs Output Current
(V_{PVIN}=V_{AVIN}=3.3V, V_{OUT}=0.9V, L=1.0µH)

Function Explanations

1. Basic Operation

(1) DC/DC Converter Operation

BD9B333GWZ is a synchronous rectifying step-down switching regulator that achieves faster load transient response by employing constant on-time control system. It utilizes switching operation in PWM (Pulse Width Modulation) mode for heavier load, while it utilizes Deep-SLLM (Simple Light Load Mode) control for lighter load to improve efficiency.

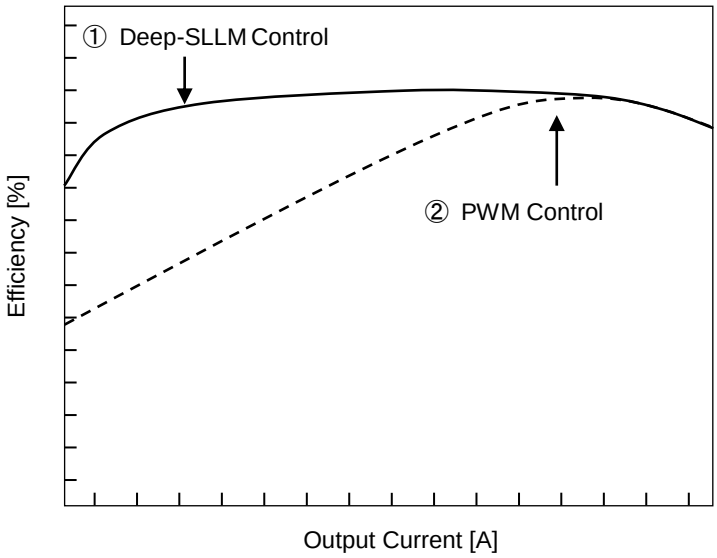


Figure 39. Efficiency (Deep-SLLM Control and PWM Control)

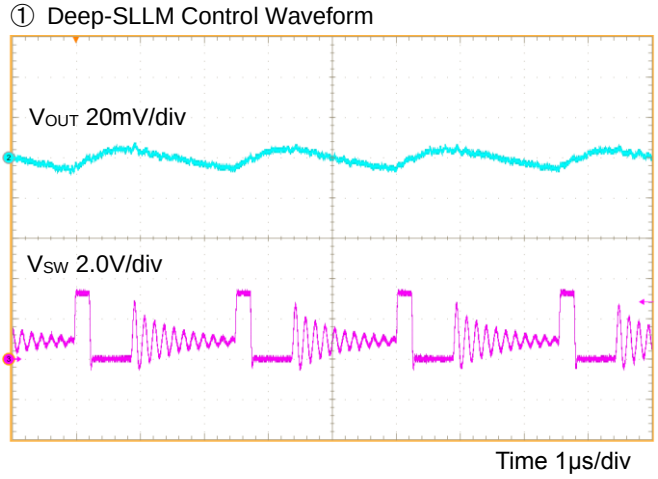


Figure 40. Switching Waveform at Deep-SLLM Control
(V_{PVIN} = V_{AVIN} = 3.3V, V_{OUT} = 0.9V, I_{OUT} = 0.1A)

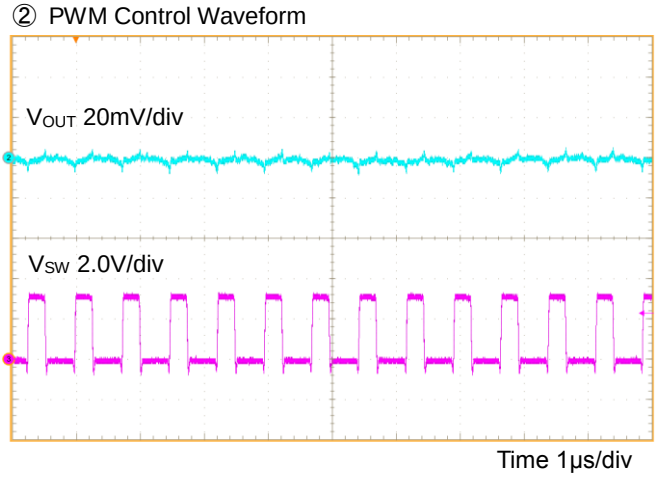


Figure 41. Switching Waveform at PWM Control
(V_{PVIN} = V_{AVIN} = 3.3V, V_{OUT} = 0.9V, I_{OUT} = 3A)

(2) Enable Control

The shutdown can be controlled by the voltage applied to the EN terminal. When V_{EN} reaches 1.5V (Min), the internal circuit is activated and the device starts up. To enable shutdown control with the EN terminal, the shutdown interval (Low level interval of EN) must be set to 100µs or more. Startup by EN must be at the same time or after the input of power supply voltage.

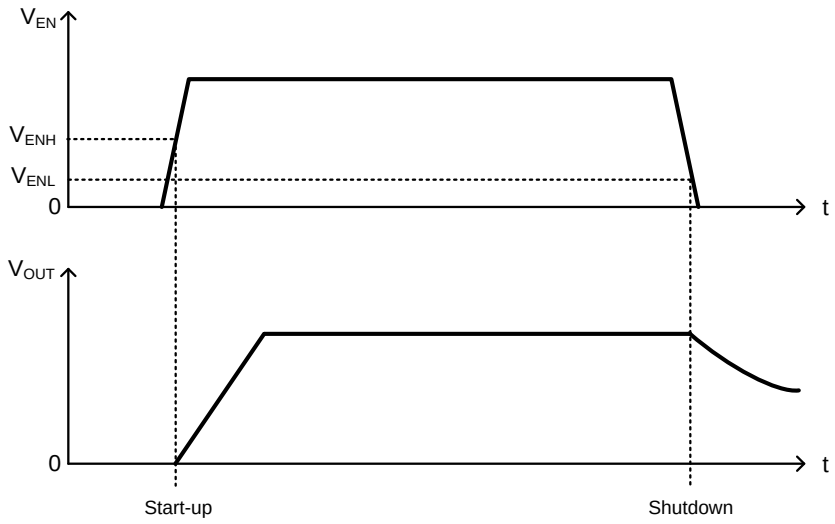


Figure 42. Start-up and Shutdown with Enable

(3) Soft Start

When EN terminal is turned High, Soft Start operates and output voltage gradually rises. With the Soft Start Function, over shoot of output voltage and rush current can be prevented. Rising time of output voltage is 1ms (Typ) when SS terminal is open. A capacitor connected to SS terminal makes rising time more than 1ms. Please refer to Page 32 for the method of setting rising time.

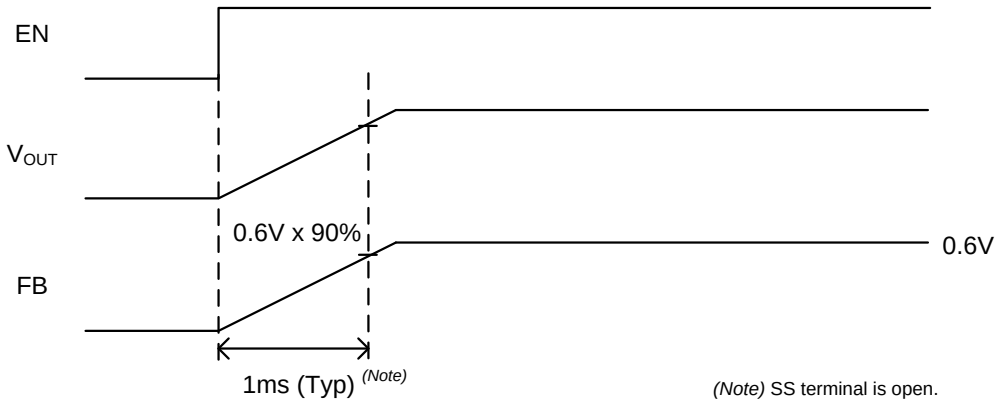


Figure 43. Soft Start Timing Chart

(4) Power Good

When the output voltage reaches to 90% (Typ) or more of the voltage setting, the open drain Nch MOSFET, internally connected to the PGD terminal, turns off and the PGD terminal turns to Hi-Z condition. When the output voltage falls to 85% (Typ) or less of the voltage setting, the open drain Nch MOSFET turns on and PGD terminal pulls down with 100Ω (Typ). Connecting a pull up resistor (10kΩ to 100kΩ) is recommended.

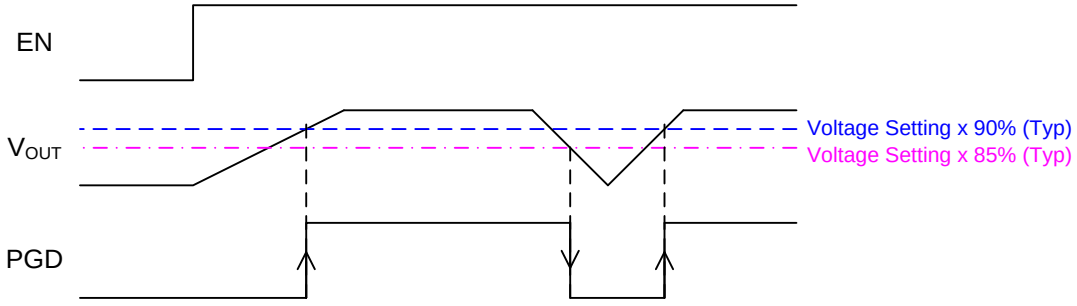


Figure 44. Power Good Timing Chart

2. Protection

The protective circuits are intended for prevention of damage caused by unexpected accidents. Do not use them for continuous protective operation.

(1) Over Current Protection (OCP) / Short Circuit Protection (SCP)

Setting value of Low Side OCP is 5.1A (Typ). Setting value of High Side OCP is 7.1A (Typ). When OCP is triggered, over current protection is realized by restricting On / Off Duty of current flowing in upper and lower MOSFET by each switching cycle. Also, if Over current protection operates 512 cycles in a condition where FB terminal voltage reaches below 85% of internal reference voltage (PGD = L), Short Circuit protection (SCP) operates and stops switching for 3ms (Typ) before it initiates restart. However, during startup, Short circuit protection will not operate even if the IC is still in the SCP condition. Do not to exceed the maximum junction temperature rating during OCP and SCP operation.

Table 1. Over Current Protection / Short Circuit Protection Function

EN terminal	PGD	Startup	Over Current Protection	Short Circuit Protection
More than 1.5V	L	During start-up	Valid	Invalid
		Completed start-up	Valid	Valid
	H	*	Valid	Invalid
Less than 0.5V	L	Shutdown	Invalid	Invalid

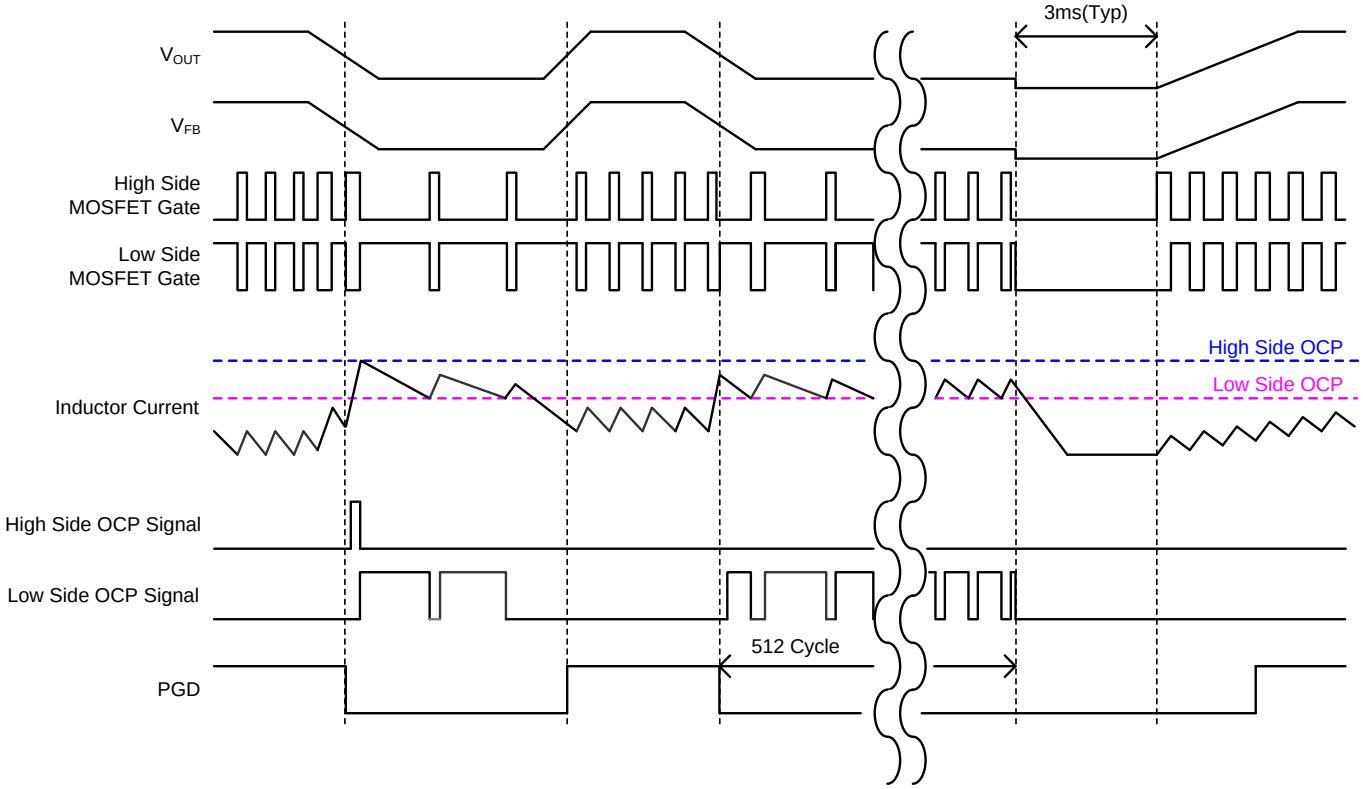


Figure 45. Short Circuit Protection (SCP) Timing Chart

(2) Under Voltage Lockout Protection (UVLO)

The Under Voltage Lockout Protection circuit monitors the AVIN terminal voltage. The operation enters standby when the AVIN terminal voltage is 2.45V (Typ) or less. The operation starts when the AVIN terminal voltage is 2.55V (Typ) or more.

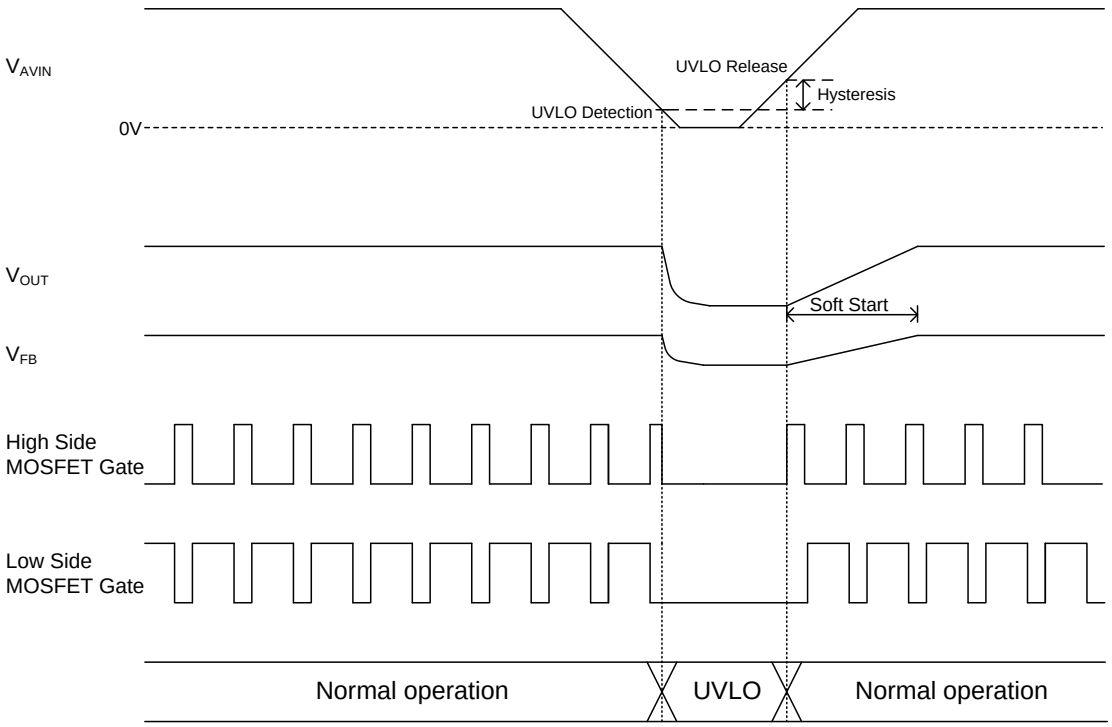


Figure 46. UVLO Timing Chart

(3) Thermal Shutdown (TSD)

When the chip temperature exceeds Tj=175°C (Typ), the DC/DC converter output is stopped. Thermal protection circuit resets and the output voltage returns to the normal operation level when the temperature falls. The circuit has a hysteresis of 25°C (Typ). The thermal shutdown circuit is intended for shutting down the IC from thermal runaway in an abnormal state with the temperature exceeding Tjmax=150°C. It is not meant to protect or guarantee the reliability of the application. Do not use this function of the circuit for application protection design.

(4) Over Voltage Protection (OVP)

The over voltage protection (OVP) compares the FB terminal voltage with the internal reference voltage. When the FB terminal voltage exceeds 0.72V (Typ), it turns the output MOSFETs off. The output voltage returns to normal operation level with hysteresis after the output voltage drops.

Application Example (V_{OUT} = 0.9V)

Parameter	Symbol	Value
Input Voltage	V_{IN}	5V
Output Voltage	V_{OUT}	0.9V
Switching Frequency	f_{SW}	1.3MHz (Typ)
Maximum Output Current	I_{OUTMAX}	3A
Operating Temperature Range	Topr	-40°C to +85°C

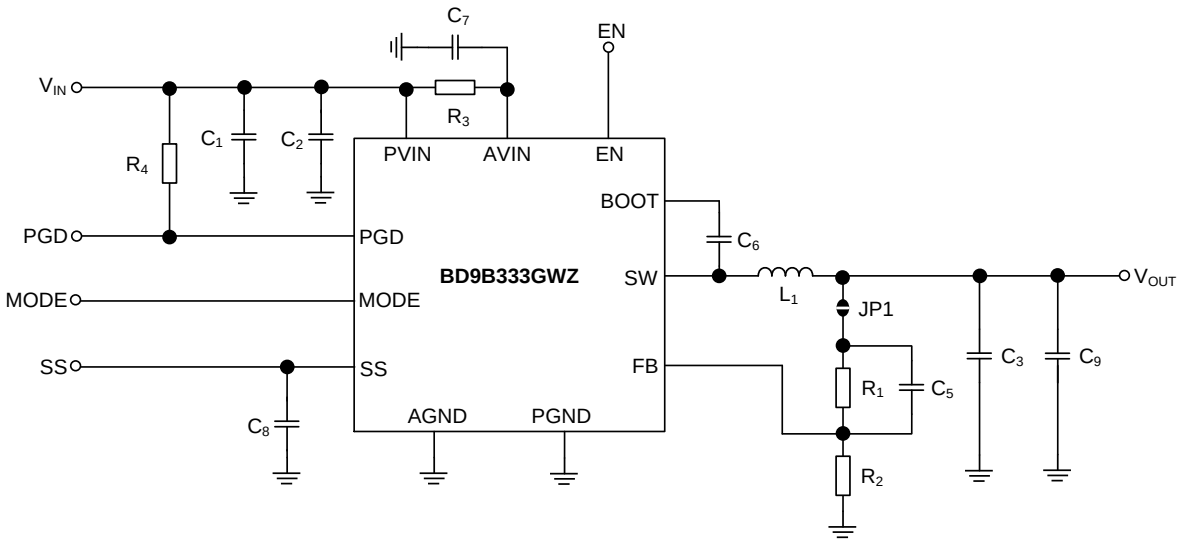


Figure 47. Application Circuit

Table 2. Recommended Component Values

Part No.	Value	Company	Part Name	Size (mm)
L_1	1.0µH	Murata	DFE252012F-1R0M	2520
C_1 *(Note 1)*	22µF	Murata	GRM21BR61A226ME44	2012
C_2 *(Note 2)*	-	-	-	-
C_3 *(Note 3)*	22µF	Murata	GRM188R60G226MEA0	1608
C_5	100pF	Murata	GRM15 series	1005
C_6 *(Note 4)*	0.1µF	Murata	GRM155R61A104MA01	1005
C_7 *(Note 5)*	-	-	-	
C_8	-	-	-	
C_9	-	-	-	
R_1	100kΩ	ROHM	MCR01MZPD1003	1005
R_2	200kΩ	ROHM	MCR01MZPD2003	1005
R_3 *(Note 5)*	Short	-	-	-
R_4	100kΩ	ROHM	MCR01MZPD1003	1005
JP1 *(Note 6)*	Short	-	-	-

(Note 1) For the capacitance of input capacitor, take temperature characteristics, DC bias characteristics, etc. into consideration to set to a minimum value of no less than 8µF.

(Note 2) In order to reduce the influence of high frequency noise, connect a 0.1µF ceramic capacitor as close as possible to the PVIN pin and the PGND pin if needed.

(Note 3) In case capacitance value fluctuates due to temperature characteristics, DC bias characteristics, etc. of the output capacitor, loop response characteristics may change. Please confirm on the actual equipment. When selecting a capacitor, confirm the characteristics of the capacitor in its datasheet. A ceramic capacitor of 22µF to 47µF is recommended for the output capacitor.

(Note 4) For the capacitance of bootstrap capacitor, take temperature characteristics, DC bias characteristics, etc. into consideration to set minimum value to no less than 0.047µF.

(Note 5) AVIN is connected to PVIN by using R_3 resistor pattern. By adding R_3=100Ω and C_7=1000pF between the PVIN pin and the AVIN pin as the low pass filter, Load Regulation and Line Regulation can be improved. Please add the low pass filter after confirming on actual equipment if needed.

(Note 6) JP1 is an option, used for feedback's frequency response measurement. By inserting a resistor at JP1, it is possible to measure the frequency response (phase margin) using a FRA. However, the resistor will not be used in actual application, please use this resistor pattern in short-circuit mode.

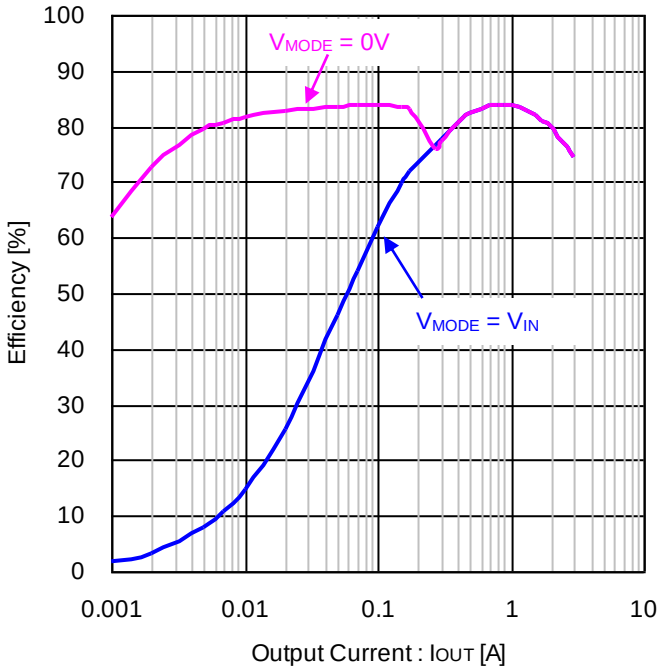


Figure 48. Efficiency vs Output Current
(V_{IN} = 5V, V_{OUT} = 0.9V, L = 1.0µH)

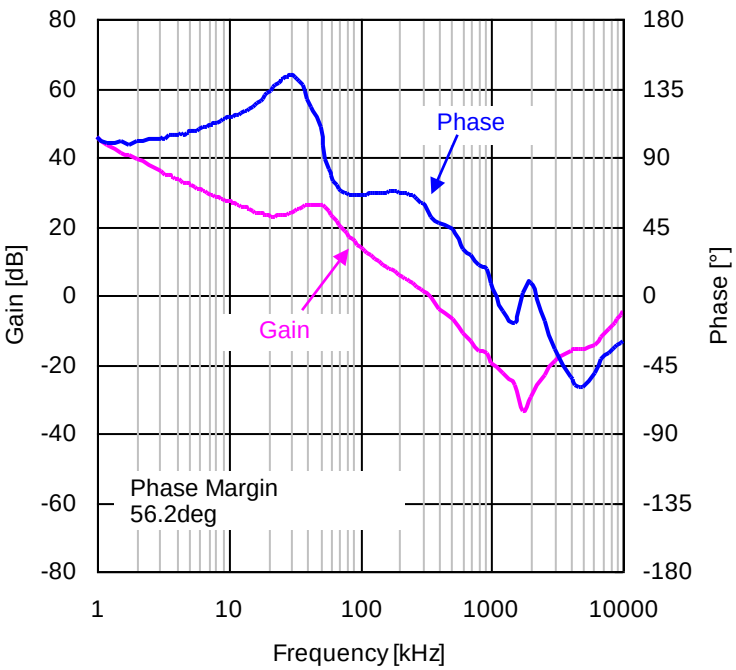


Figure 49. Closed Loop Response I_{OUT} = 1A
(V_{IN} = 5V, V_{OUT} = 0.9V, L = 1.0µH, C_{OUT} = 22µF)

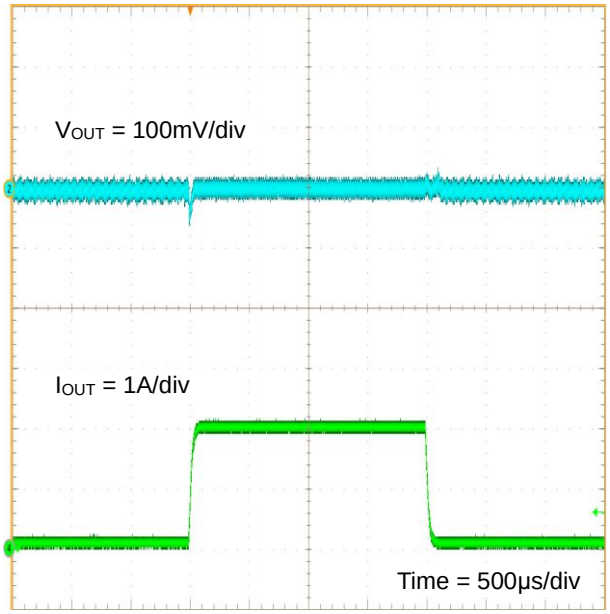


Figure 50. Load Transient Response
I_{OUT} = 0.1A – 2.0A
(V_{IN} = 5V, V_{OUT} = 0.9V, L = 1.0µH, C_{OUT} = 22µF)

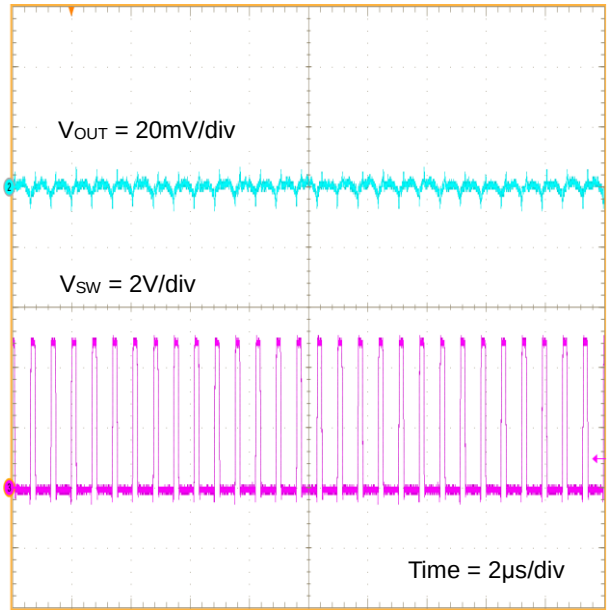


Figure 51. V_{OUT} Ripple I_{OUT} = 3A
(V_{IN} = 5V, V_{OUT} = 0.9V, L = 1.0µH, C_{OUT} = 22µF)

Application Example (V_{OUT} = 1.0V)

Parameter	Symbol	Value
Input Voltage	V_{IN}	5V
Output Voltage	V_{OUT}	1.0V
Switching Frequency	f_{SW}	1.3MHz (Typ)
Maximum Output Current	I_{OUTMAX}	3A
Operating Temperature Range	Topr	-40°C to +85°C

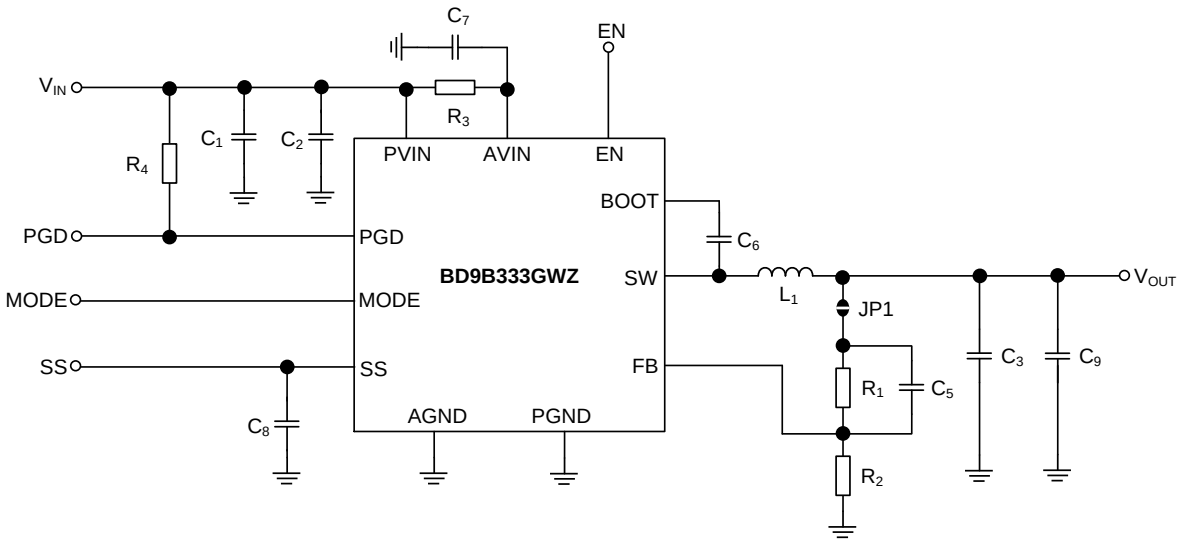


Figure 52. Application Circuit

Table 3. Recommended Component Values

Part No.	Value	Company	Part Name	Size (mm)
L_1	1.0µH	Murata	DFE252012F-1R0M	2520
C_1 *(Note 1)*	22µF	Murata	GRM21BR61A226ME44	2012
C_2 *(Note 2)*	-	-	-	-
C_3 *(Note 3)*	22µF	Murata	GRM188R60G226MEA0	1608
C_5	100pF	Murata	GRM15 series	1005
C_6 *(Note 4)*	0.1µF	Murata	GRM155R61A104MA01	1005
C_7 *(Note 5)*	-	-	-	
C_8	-	-	-	
C_9	-	-	-	
R_1	100kΩ	ROHM	MCR01MZPD1003	1005
R_2	150kΩ	ROHM	MCR01MZPD1503	1005
R_3 *(Note 5)*	Short	-	-	-
R_4	100kΩ	ROHM	MCR01MZPD1003	1005
JP1 *(Note 6)*	Short	-	-	-

(Note 1) For the capacitance of input capacitor, take temperature characteristics, DC bias characteristics, etc. into consideration to set to a minimum value of no less than 8µF.

(Note 2) In order to reduce the influence of high frequency noise, connect a 0.1µF ceramic capacitor as close as possible to the PVIN pin and the PGND pin if needed.

(Note 3) In case capacitance value fluctuates due to temperature characteristics, DC bias characteristics, etc. of the output capacitor, loop response characteristics may change. Please confirm on the actual equipment. When selecting a capacitor, confirm the characteristics of the capacitor in its datasheet. A ceramic capacitor of 22µF to 47µF is recommended for the output capacitor.

(Note 4) For the capacitance of bootstrap capacitor, take temperature characteristics, DC bias characteristics, etc. into consideration to set minimum value to no less than 0.047µF.

(Note 5) AVIN is connected to PVIN by using R_3 resistor pattern. By adding R_3=100Ω and C_7=1000pF between the PVIN pin and the AVIN pin as the low pass filter, Load Regulation and Line Regulation can be improved. Please add the low pass filter after confirming on actual equipment if needed.

(Note 6) JP1 is an option, used for feedback's frequency response measurement. By inserting a resistor at JP1, it is possible to measure the frequency response (phase margin) using a FRA. However, the resistor will not be used in actual application, please use this resistor pattern in short-circuit mode.

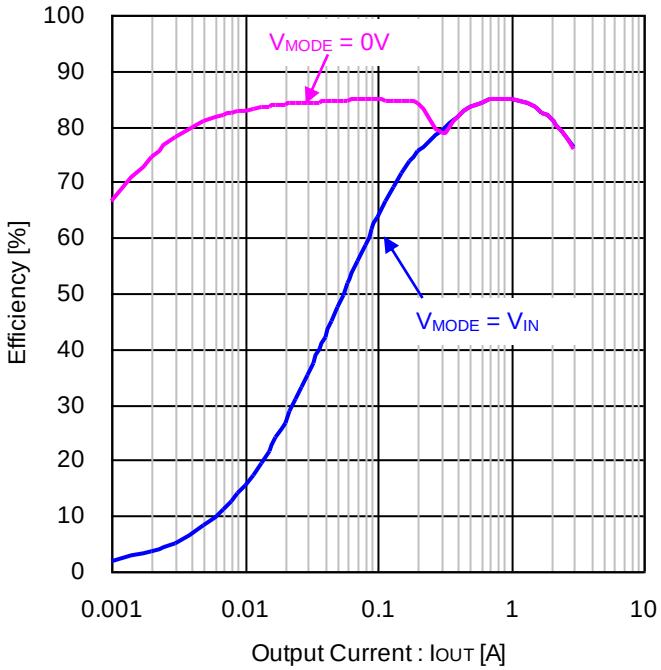


Figure 53. Efficiency vs Output Current
(V_{IN} = 5V, V_{OUT} = 1.0V, L = 1.0µH)

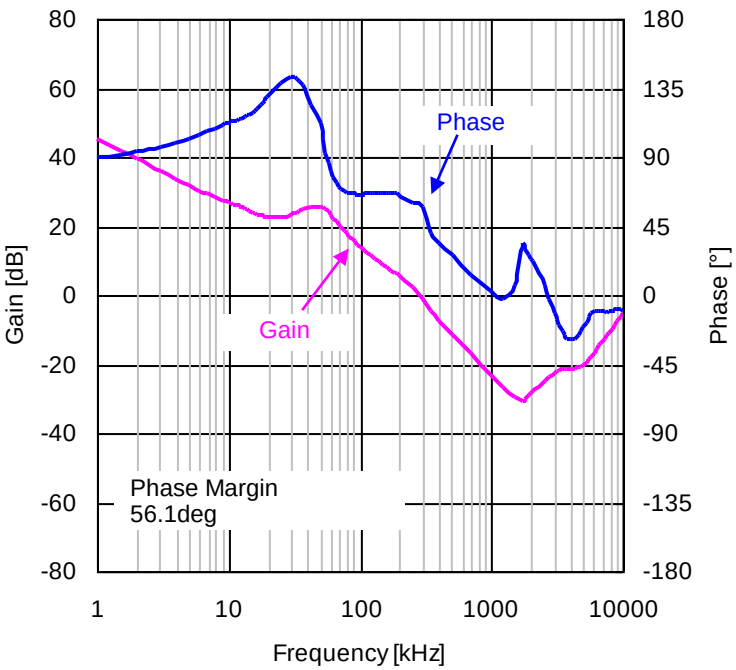


Figure 54. Closed Loop Response I_{OUT} = 1A
(V_{IN} = 5V, V_{OUT} = 1.0V, L = 1.0µH, C_{OUT} = 22µF)

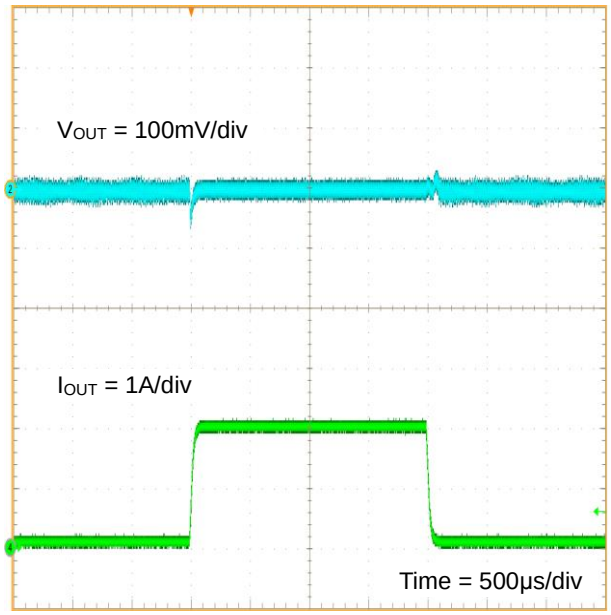


Figure 55. Load Transient Response
I_{OUT} = 0.1A – 2.0A
(V_{IN} = 5V, V_{OUT} = 1.0V, L = 1.0µH, C_{OUT} = 22µF)

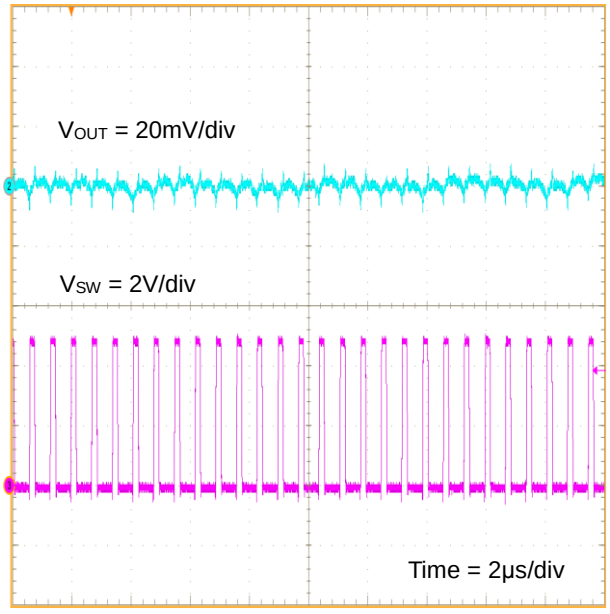


Figure 56. V_{OUT} Ripple I_{OUT} = 3A
(V_{IN} = 5V, V_{OUT} = 1.0V, L = 1.0µH, C_{OUT} = 22µF)

Application Example (V_{OUT} = 1.2V)

Parameter	Symbol	Value
Input Voltage	V_{IN}	5V
Output Voltage	V_{OUT}	1.2V
Switching Frequency	f_{SW}	1.3MHz (Typ)
Maximum Output Current	I_{OUTMAX}	3A
Operating Temperature Range	Topr	-40°C to +85°C

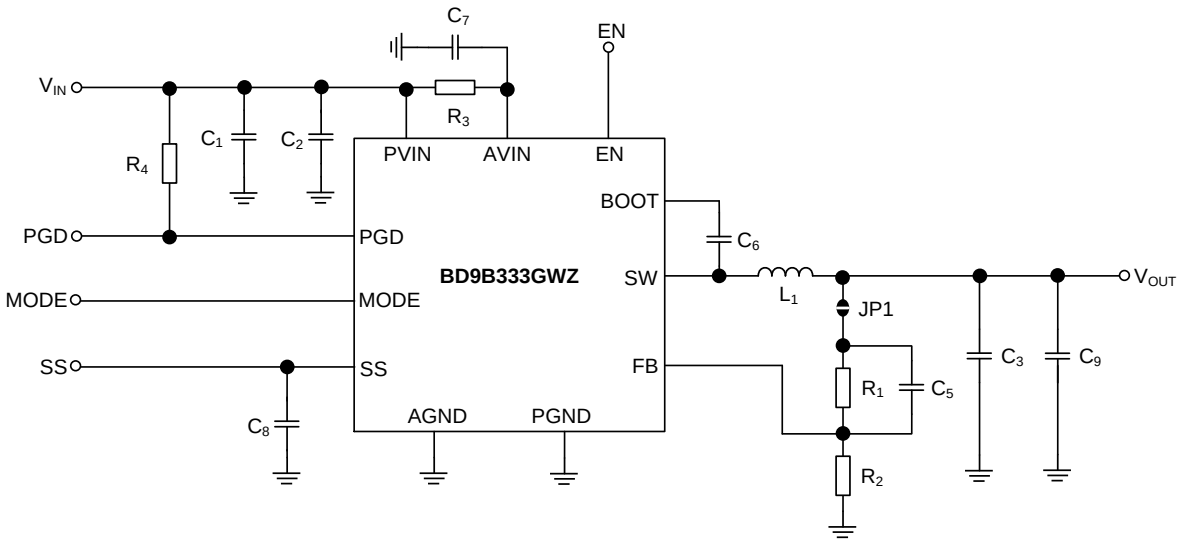


Figure 57. Application Circuit

Table 4. Recommended Component Values

Part No.	Value	Company	Part Name	Size (mm)
L_1	1.0µH	Murata	DFE252012F-1R0M	2520
C_1 *(Note 1)*	22µF	Murata	GRM21BR61A226ME44	2012
C_2 *(Note 2)*	-	-	-	-
C_3 *(Note 3)*	22µF	Murata	GRM188R60G226MEA0	1608
C_5	100pF	Murata	GRM15 series	1005
C_6 *(Note 4)*	0.1µF	Murata	GRM155R61A104MA01	1005
C_7 *(Note 5)*	-	-	-	
C_8	-	-	-	
C_9	-	-	-	
R_1	150kΩ	ROHM	MCR01MZPD1503	1005
R_2	150kΩ	ROHM	MCR01MZPD1503	1005
R_3 *(Note 5)*	Short	-	-	-
R_4	100kΩ	ROHM	MCR01MZPD1003	1005
JP1 *(Note 6)*	Short	-	-	-

(Note 1) For the capacitance of input capacitor, take temperature characteristics, DC bias characteristics, etc. into consideration to set to a minimum value of no less than 8µF.

(Note 2) In order to reduce the influence of high frequency noise, connect a 0.1µF ceramic capacitor as close as possible to the PVIN pin and the PGND pin if needed.

(Note 3) In case capacitance value fluctuates due to temperature characteristics, DC bias characteristics, etc. of the output capacitor, loop response characteristics may change. Please confirm on the actual equipment. When selecting a capacitor, confirm the characteristics of the capacitor in its datasheet. A ceramic capacitor of 22µF to 47µF is recommended for the output capacitor.

(Note 4) For the capacitance of bootstrap capacitor, take temperature characteristics, DC bias characteristics, etc. into consideration to set minimum value to no less than 0.047µF.

(Note 5) AVIN is connected to PVIN by using R_3 resistor pattern. By adding R_3=100Ω and C_7=1000pF between the PVIN pin and the AVIN pin as the low pass filter, Load Regulation and Line Regulation can be improved. Please add the low pass filter after confirming on actual equipment if needed.

(Note 6) JP1 is an option, used for feedback's frequency response measurement. By inserting a resistor at JP1, it is possible to measure the frequency response (phase margin) using a FRA. However, the resistor will not be used in actual application, please use this resistor pattern in short-circuit mode.

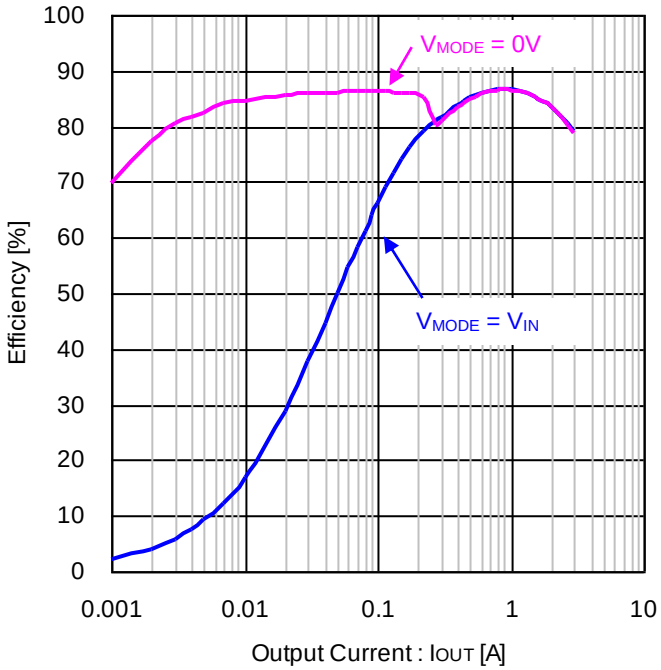


Figure 58. Efficiency vs Output Current
(V_{IN} = 5V, V_{OUT} = 1.2V, L = 1.0µH)

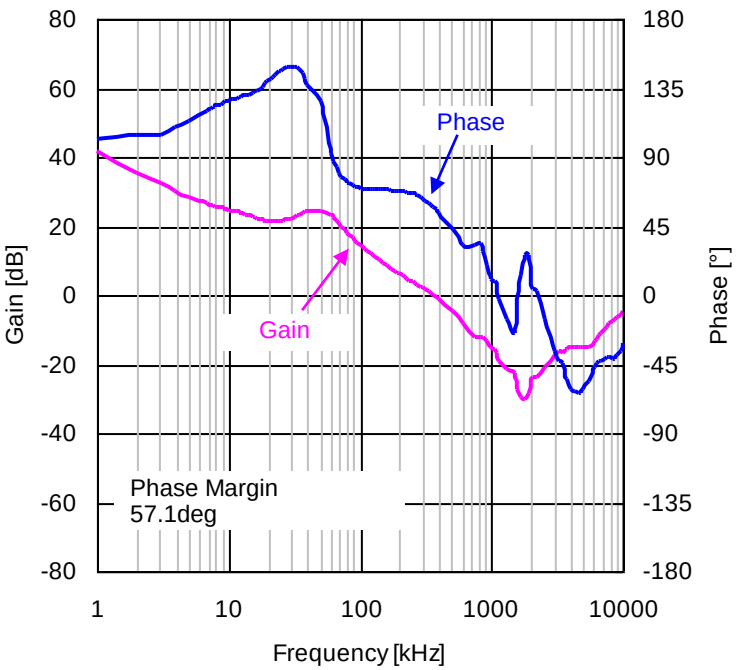


Figure 59. Closed Loop Response I_{OUT} = 1A
(V_{IN} = 5V, V_{OUT} = 1.2V, L = 1.0µH, C_{OUT} = 22µF)

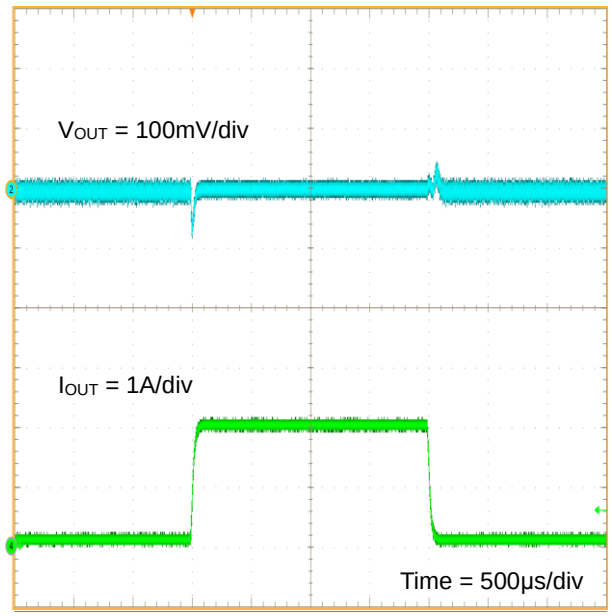


Figure 60. Load Transient Response
I_{OUT} = 0.1A – 2.0A
(V_{IN} = 5V, V_{OUT} = 1.2V, L = 1.0µH, C_{OUT} = 22µF)

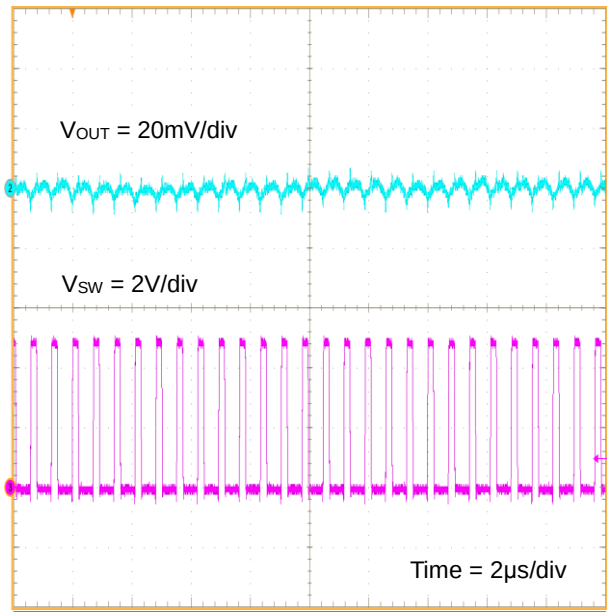


Figure 61. V_{OUT} Ripple I_{OUT} = 3A
(V_{IN} = 5V, V_{OUT} = 1.2V, L = 1.0µH, C_{OUT} = 22µF)

Application Example (V_{OUT} = 1.8V)

Parameter	Symbol	Value
Input Voltage	V_{IN}	5V
Output Voltage	V_{OUT}	1.8V
Switching Frequency	f_{SW}	1.3MHz (Typ)
Maximum Output Current	I_{OUTMAX}	3A
Operating Temperature Range	Topr	-40°C to +85°C

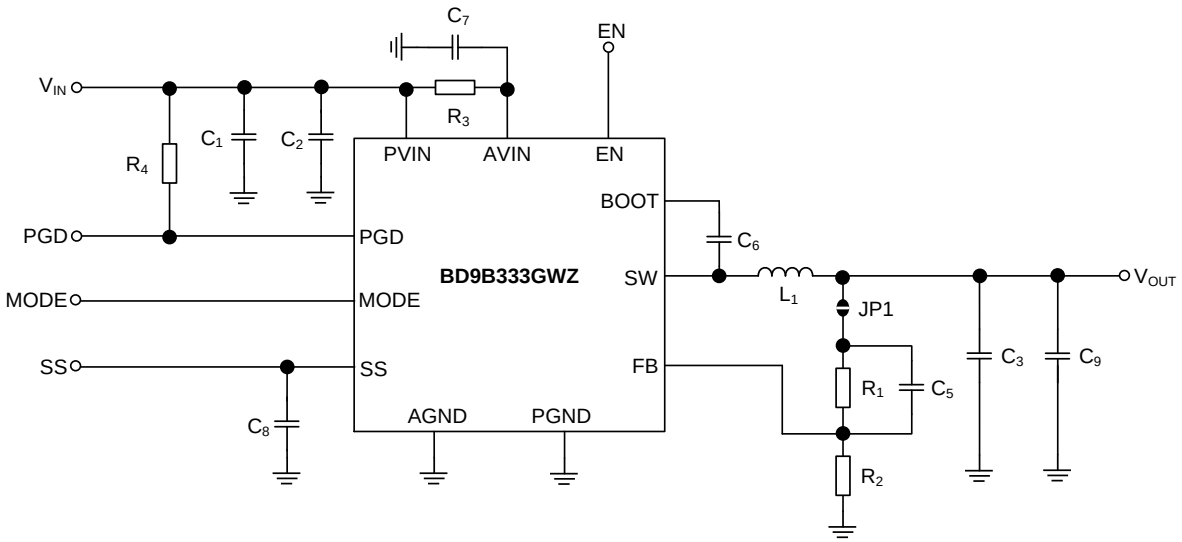


Figure 62. Application Circuit

Table 5. Recommended Component Values

Part No.	Value	Company	Part Name	Size (mm)
L_1	1.0µH	Murata	DFE252012F-1R0M	2520
C_1 *(Note 1)*	22µF	Murata	GRM21BR61A226ME44	2012
C_2 *(Note 2)*	-	-	-	-
C_3 *(Note 3)*	22µF	Murata	GRM188R60G226MEA0	1608
C_5	120pF	Murata	GRM15 series	1005
C_6 *(Note 4)*	0.1µF	Murata	GRM155R61A104MA01	1005
C_7 *(Note 5)*	-	-	-	
C_8	-	-	-	
C_9	-	-	-	
R_1	200kΩ	ROHM	MCR01MZPD2003	1005
R_2	100kΩ	ROHM	MCR01MZPD1003	1005
R_3 *(Note 5)*	Short	-	-	-
R_4	100kΩ	ROHM	MCR01MZPD1003	1005
JP1 *(Note 6)*	Short	-	-	-

(Note 1) For the capacitance of input capacitor, take temperature characteristics, DC bias characteristics, etc. into consideration to set to a minimum value of no less than 8µF.

(Note 2) In order to reduce the influence of high frequency noise, connect a 0.1µF ceramic capacitor as close as possible to the PVIN pin and the PGND pin if needed.

(Note 3) In case capacitance value fluctuates due to temperature characteristics, DC bias characteristics, etc. of the output capacitor, loop response characteristics may change. Please confirm on the actual equipment. When selecting a capacitor, confirm the characteristics of the capacitor in its datasheet. A ceramic capacitor of 22µF to 47µF is recommended for the output capacitor.

(Note 4) For the capacitance of bootstrap capacitor, take temperature characteristics, DC bias characteristics, etc. into consideration to set minimum value to no less than 0.047µF.

(Note 5) AVIN is connected to PVIN by using R_3 resistor pattern. By adding R_3=100Ω and C_7=1000pF between the PVIN pin and the AVIN pin as the low pass filter, Load Regulation and Line Regulation can be improved. Please add the low pass filter after confirming on actual equipment if needed.

(Note 6) JP1 is an option, used for feedback's frequency response measurement. By inserting a resistor at JP1, it is possible to measure the frequency response (phase margin) using a FRA. However, the resistor will not be used in actual application, please use this resistor pattern in short-circuit mode.

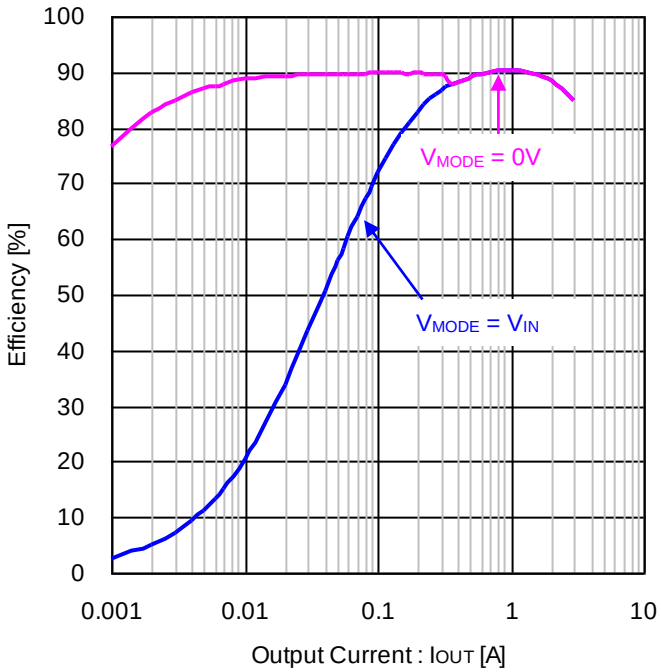


Figure 63. Efficiency vs Output Current
(V_{IN} = 5V, V_{OUT} = 1.8V, L = 1.0µH)

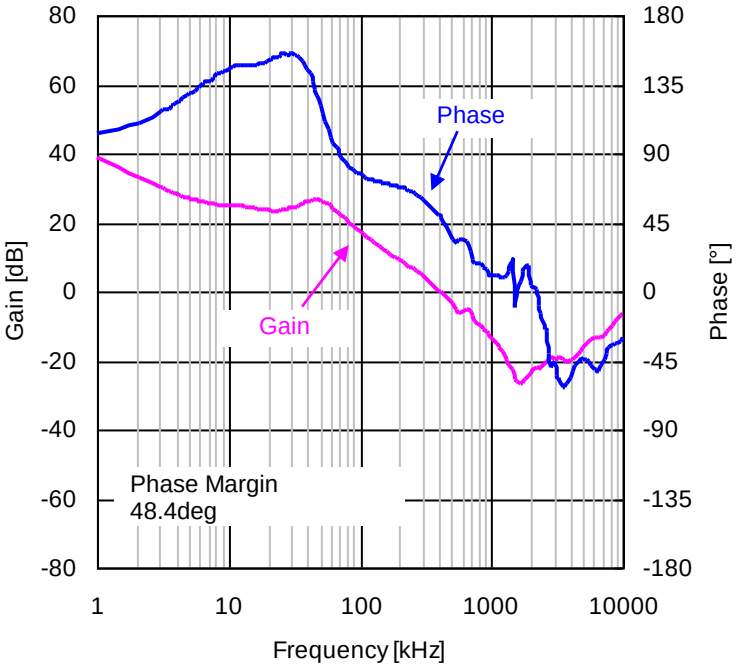


Figure 64. Closed Loop Response I_{OUT} = 1A
(V_{IN} = 5V, V_{OUT} = 1.8V, L = 1.0µH, C_{OUT} = 22µF)

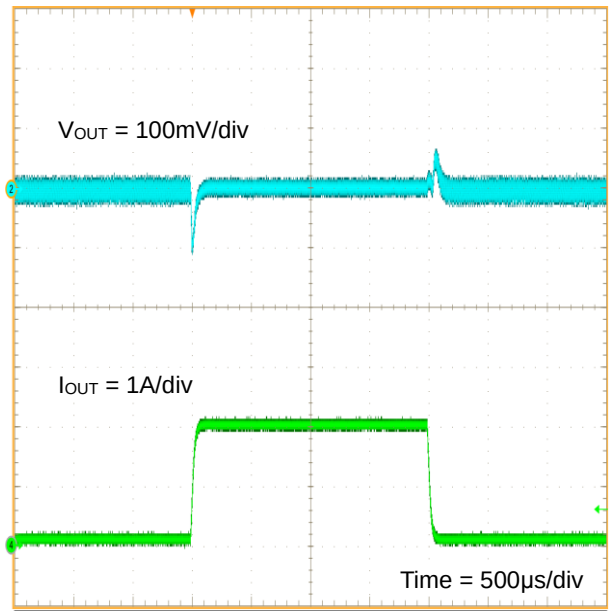


Figure 65. Load Transient Response
I_{OUT} = 0.1A – 2.0A
(V_{IN} = 5V, V_{OUT} = 1.8V, L = 1.0µH, C_{OUT} = 22µF)

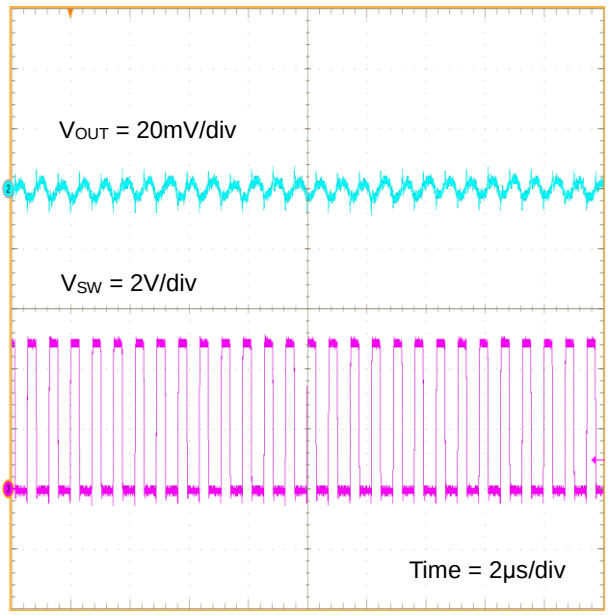


Figure 66. V_{OUT} Ripple I_{OUT} = 3A
(V_{IN} = 5V, V_{OUT} = 1.8V, L = 1.0µH, C_{OUT} = 22µF)

Application Example (V_{OUT} = 3.3V)

Parameter	Symbol	Value
Input Voltage	V_{IN}	5V
Output Voltage	V_{OUT}	3.3V
Switching Frequency	f_{SW}	1.3MHz (Typ)
Maximum Output Current	I_{OUTMAX}	3A
Operating Temperature Range	Topr	-40°C to +85°C

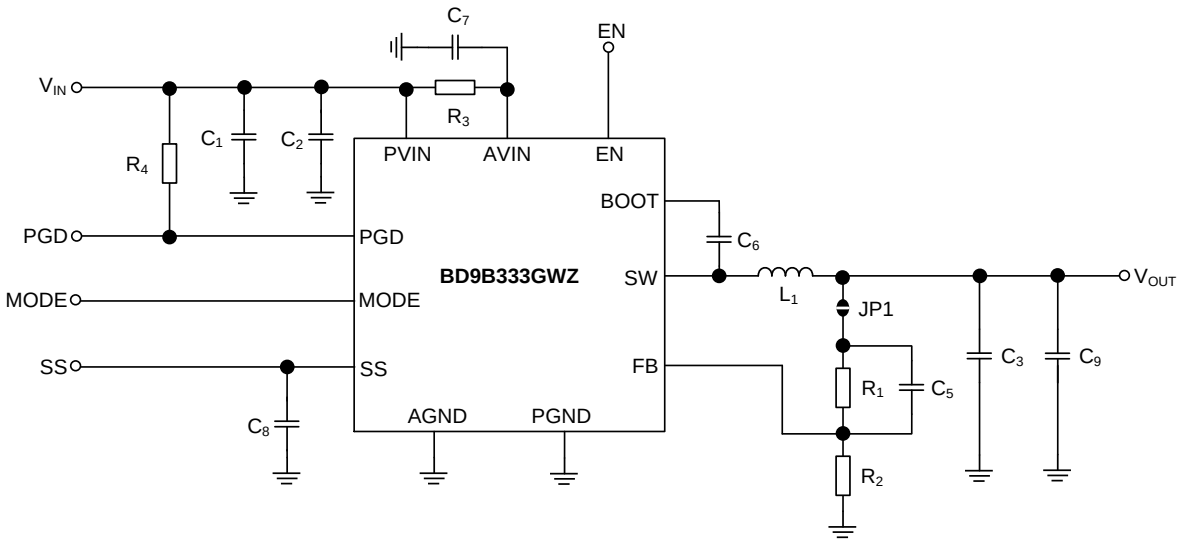


Figure 67. Application Circuit

Table 6. Recommended Component Values

Part No.	Value	Company	Part Name	Size (mm)
L_1	1.5µH	Murata	DFE322512F-1R5M	3225
C_1 *(Note 1)*	22µF	Murata	GRM21BR61A226ME44	2012
C_2 *(Note 2)*	-	-	-	-
C_3 *(Note 3)*	22µF	Murata	GRM188R61A226ME15	1608
C_5	120pF	Murata	GRM15 series	1005
C_6 *(Note 4)*	0.1µF	Murata	GRM155R61A104MA01	1005
C_7 *(Note 5)*	-	-	-	
C_8	-	-	-	
C_9	-	-	-	
R_1	150kΩ	ROHM	MCR01MZPD1503	1005
R_2	33kΩ	ROHM	MCR01MZPD3302	1005
R_3 *(Note 5)*	Short	-	-	-
R_4	100kΩ	ROHM	MCR01MZPD1003	1005
JP1 *(Note 6)*	Short	-	-	-

(Note 1) For the capacitance of input capacitor, take temperature characteristics, DC bias characteristics, etc. into consideration to set to a minimum value of no less than 8µF.

(Note 2) In order to reduce the influence of high frequency noise, connect a 0.1µF ceramic capacitor as close as possible to the PVIN pin and the PGND pin if needed.

(Note 3) In case capacitance value fluctuates due to temperature characteristics, DC bias characteristics, etc. of the output capacitor, loop response characteristics may change. Please confirm on the actual equipment. When selecting a capacitor, confirm the characteristics of the capacitor in its datasheet. A ceramic capacitor of 22µF to 47µF is recommended for the output capacitor.

(Note 4) For the capacitance of bootstrap capacitor, take temperature characteristics, DC bias characteristics, etc. into consideration to set minimum value to no less than 0.047µF.

(Note 5) AVIN is connected to PVIN by using R_3 resistor pattern. By adding R_3=100Ω and C_7=1000pF between the PVIN pin and the AVIN pin as the low pass filter, Load Regulation and Line Regulation can be improved. Please add the low pass filter after confirming on actual equipment if needed.

(Note 6) JP1 is an option, used for feedback's frequency response measurement. By inserting a resistor at JP1, it is possible to measure the frequency response (phase margin) using a FRA. However, the resistor will not be used in actual application, please use this resistor pattern in short-circuit mode.

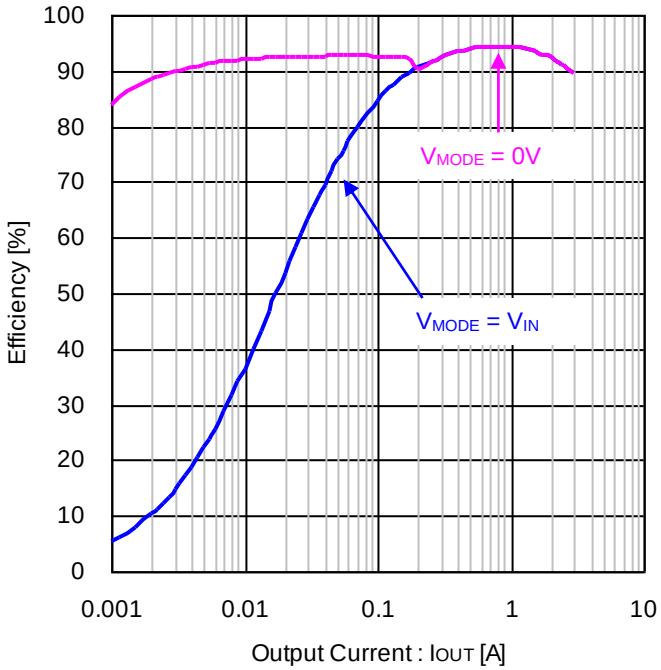


Figure 68. Efficiency vs Output Current
(V_{IN} = 5V, V_{OUT} = 3.3V, L = 1.5µH)

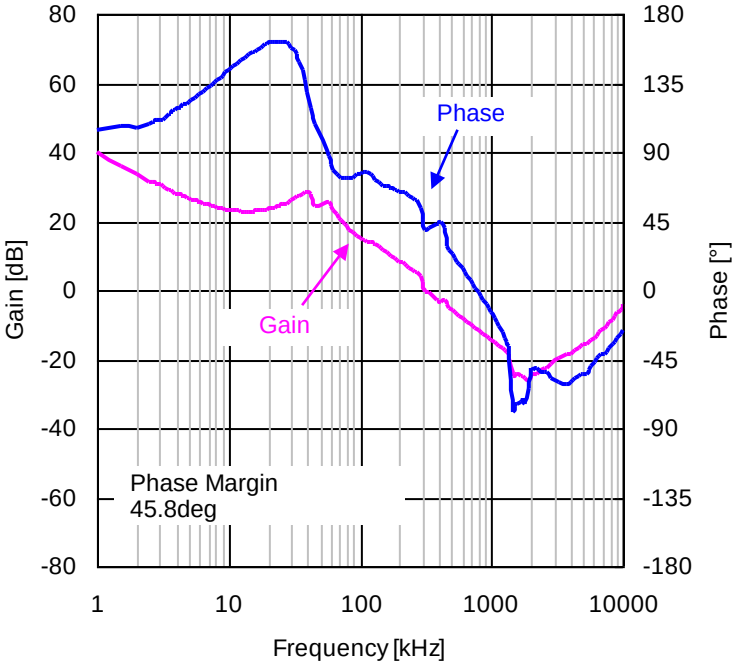


Figure 69. Closed Loop Response I_{OUT} = 1A
(V_{IN} = 5V, V_{OUT} = 3.3V, L = 1.5µH, C_{OUT} = 22µF)

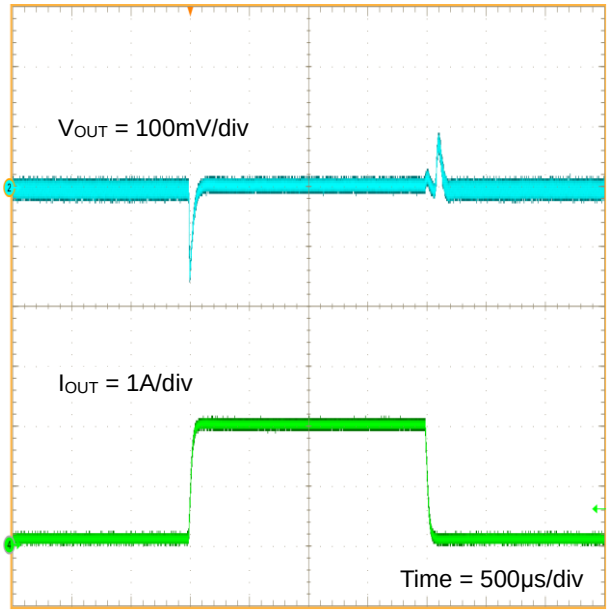


Figure 70. Load Transient Response
I_{OUT} = 0.1A – 2.0A
(V_{IN} = 5V, V_{OUT} = 3.3V, L = 1.5µH, C_{OUT} = 22µF)

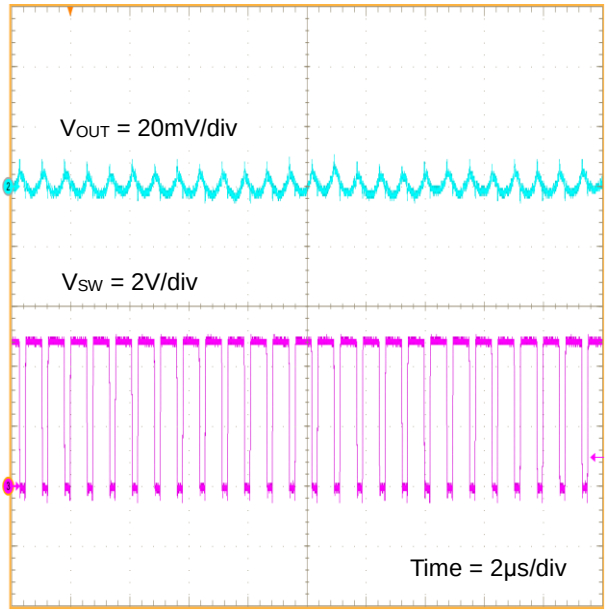


Figure 71. V_{OUT} Ripple I_{OUT} = 3A
(V_{IN} = 5V, V_{OUT} = 3.3V, L = 1.5µH, C_{OUT} = 22µF)

Selection of Components Externally Connected

About the application except the recommendation, please contact us.

1. Output LC Filter

In order to supply a continuous current to the load, the DC/DC converter requires an LC filter for smoothing the output voltage. Use inductors of value from 0.47µH to 1.5µH.

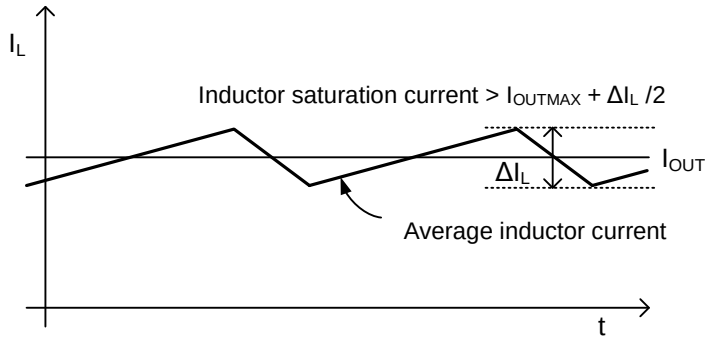


Figure 72. Waveform of current through inductor

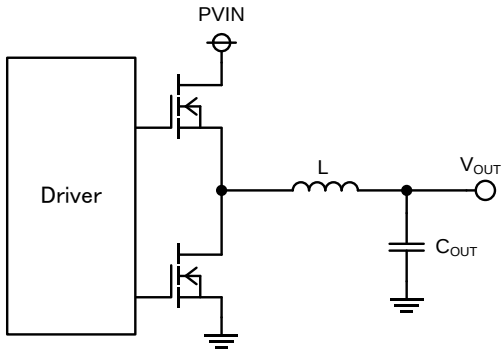


Figure 73. Output LC filter circuit

Inductor ripple current ΔI_L

$$\Delta I_L = V_{OUT} \times (V_{IN} - V_{OUT}) \times \frac{1}{V_{IN} \times f_{SW} \times L} = 702 \text{ [mA]}$$

Where:
V_{IN} = 5V
V_{OUT} = 1.2V
L = 1.0µH
fsw = 1.3MHz

The saturation current of the inductor must be larger than the sum of the maximum output current and 1/2 of the inductor ripple current ΔI_L.

The output capacitor C_{OUT} affects the output ripple voltage characteristics. The output capacitor C_{OUT} must satisfy the required ripple voltage characteristics.

The output ripple voltage can be represented by the following equation.

$$\Delta V_{RPL} = \Delta I_L \times (R_{ESR} + \frac{1}{8 \times C_{OUT} \times f_{SW}}) \text{[V]}$$

Where:
R_{ESR} is the Equivalent Series Resistance (ESR) of the output capacitor.

* The capacitor rating must allow a sufficient margin with respect to the output voltage.
  The output ripple voltage is decreased with a smaller R_{ESR}.
  Considering temperature and DC bias characteristics, please use ceramic capacitor of about 22µF to 47µF.

* Be careful of total capacitance value, when additional capacitor C_{LOAD} is connected in addition to output capacitor C_{OUT}.
  Use maximum additional capacitor C_{LOAD} (Max) which satisfies the following condition.

$$Maximum\ starting\ inductor\ bottom\ ripple\ current\ I_{LSTART} < Low\ side\ OCP\ 3.3\text{[A]}\ (Min)$$

Maximum starting inductor ripple current I_{LSTART} can be expressed using the following equation.

$$I_{LSTART} = Maximum\ starting\ output\ current(I_{OSS}) + Charge\ current\ to\ output\ capacitor(I_{CAP}) - \frac{\Delta I_L}{2}$$

Charge current to output capacitor I_{CAP} can be expressed using the following equation.

$$I_{CAP} = \frac{(C_{OUT} + C_{LOAD}) \times V_{OUT}}{t_{SS}} [A]$$

For example, given V_{IN} = 5V, V_{OUT} = 1.2V, L = 1.0µH, switching frequency f_{SW} = 0.98MHz (Min), Output capacitor C_{OUT} = 22µF, Soft Start time t_{SS} = 0.5ms (Min), and load current during soft start I_{OSS} = 3A, maximum C_{LOAD} can be computed using the following equation.

$$C_{LOAD}(max) < \frac{(3.3 - I_{OSS} + \Delta I_L/2) \times t_{SS}}{V_{OUT}} - C_{OUT} = 296.9 [\mu F]$$

* C_{LOAD} has an effect on the stability of the DC/DC converter.
To ensure the stability of the DC/DC converter, make sure that a sufficient phase margin is provided.

If the value of C_{LOAD} is large, and cannot meet the above equation, adjust the value of the capacitor C_{SS} to meet the condition below.

$$C_{LOAD}(max) < \frac{(3.3 - I_{OSS} + \Delta I_L/2) \times V_{FB}}{V_{OUT} \times I_{SS}} \times C_{SS} - C_{OUT}$$

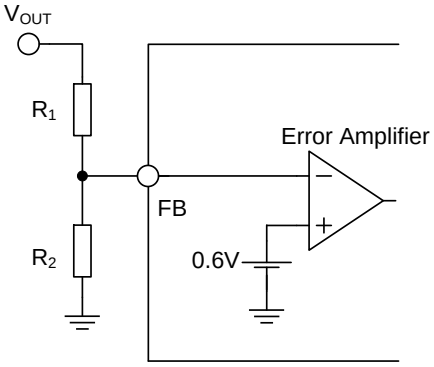
(Refer to the following items “3.Soft Start Setting” about the equation of soft start time t_{SS} and the capacitor C_{SS}.)

For example, given V_{IN} = 5V, V_{OUT} = 1.2V, L = 1.0µH, load current during soft start I_{OSS} = 3A, switching frequency fsw = 1.62MHz (Max), Output capacitor C_{OUT} = 22µF, V_{FB} = 0.609V (Max), I_{SS} = 1.8µA (Max), with C_{LOAD} = 470µF, capacitor C_{SS} is computed as follows.

$$C_{SS} > \frac{V_{OUT} \times I_{SS}}{(3.3 - I_{OSS} + \Delta I_L/2) \times V_{FB}} \times (C_{LOAD} + C_{OUT}) = 3001 [pF]$$

2. Output Voltage Setting

The output voltage value can be set by the feedback resistance ratio.
For stable operation, use feedback resistance R_1 more than 20kΩ.



$$V_{OUT} = \frac{R_1 + R_2}{R_2} \times 0.6 [V]$$

$$0.6 [V] \leq V_{OUT} \leq (V_{PVIN} \times 0.8) [V]$$

Figure 74. Feedback Resistor Circuit

3. Soft Start Setting

Turning the EN terminal signal High activates the soft start function. This makes output voltage to rise gradually while controlling current at start-up. This prevents output voltage overshoot and inrush current. The rise time depends on the value of the capacitor connected to the SS terminal. Please use less than 0.01µF capacitor value.

$$t_{SS} = (C_{SS} \times V_{FB}) / I_{SS}$$

Where:

t_{SS} is the Soft Start Time

C_{SS} is the Capacitor connected to SS terminal

V_{FB} is the FB Terminal Voltage (0.6V (Typ))

I_{SS} is the Soft Start Terminal Current (1.2µA (Typ))

With C_{SS} = 5600pF,

$$t_{SS} = (5600[\text{pF}] \times 0.6[\text{V}]) / 1.2[\mu\text{A}]$$
$$= 2.8[\text{msec}]$$

Rising time of output voltage is 1ms (Typ) by turning the EN terminal signal High with the SS terminal open (no capacitor connected).

4. FB Capacitor

Generally, in fixed ON time control, sufficient ripple voltage in FB voltage is needed to operate main comparator stably. Regarding this IC, by injecting ripple voltage to FB voltage inside IC, it is designed to correspond to low ESR output capacitor. Please set the FB capacitor (C_{FB}) within the range of the following expression to inject an appropriate ripple.

$$\frac{V_{OUT} \times (1 - \frac{V_{OUT}}{V_{IN}})}{f_{SW} \times 9.0 \times 10^{3}} < C_{FB} < \frac{V_{OUT} \times (1 - \frac{V_{OUT}}{V_{IN}})}{f_{SW} \times 3.3 \times 10^{3}} \ [\text{F}]$$

Where:

V_{IN} is the Input Voltage [V]

V_{OUT} is the Output Voltage [V]

f_{SW} is the Switching Frequency [Hz]

5. Bootstrap Capacitor

Connect a 0.1µF ceramic capacitor between SW terminal and BOOT terminal. For the capacitance of bootstrap capacitor, take temperature characteristics, DC bias characteristics, etc. into consideration to set minimum value to no less than 0.047µF.

PCB Layout Design

PCB layout design for DC/DC converter power supply IC is as important as the circuit design. Appropriate layout can avoid various problems caused by power supply circuit. Figure 75-a to 75-c show the current path in a buck converter circuit. The Loop1 in Figure 75-a is a current path when H-side switch is ON and L-side switch is OFF, the Loop2 in Figure 75-b is when H-side switch is OFF and L-side switch is ON. The thick line in Figure 75-c shows the difference between Loop1 and Loop2. The current in thick line changes sharply each time the switching element H-side and L-side switch change from OFF to ON, and vice versa. These sharp changes induce several harmonics in the waveform. Therefore, the loop area of thick line that is consisted by input capacitor and IC should be as small as possible to minimize noise. For more detail, refer to application note of switching regulator series “PCB Layout Techniques of Buck Converter”.

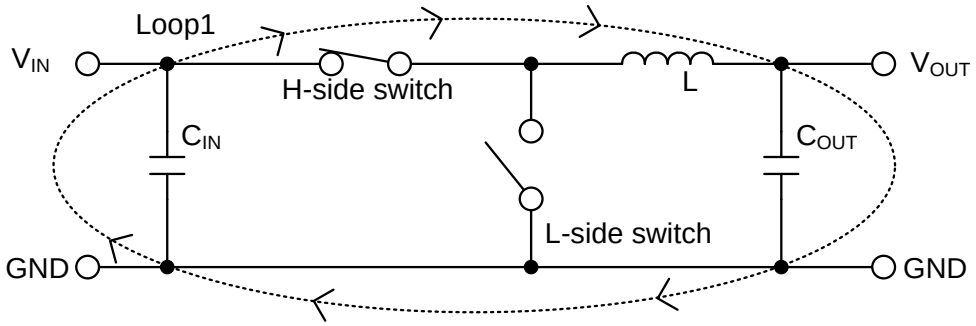


Figure 75-a. Current path when H-side switch = ON, L-side switch = OFF

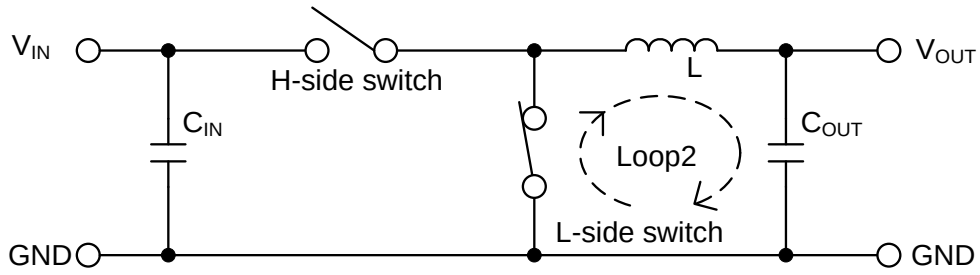


Figure 75-b. Current path when H-side switch = OFF, L-side switch = ON

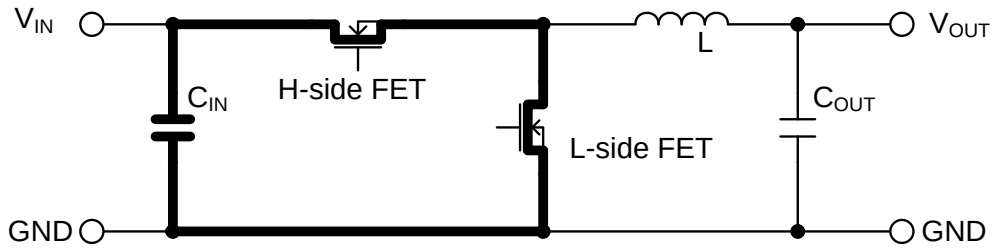


Figure 75-c. Difference of current and critical area in layout

PCB Layout Design - continued

When designing the PCB layout, please pay extra attention to the following points:

- Place input capacitor on the same PCB surface as the IC and as close as possible to the IC's PVIN terminal.
- Switching nodes should be traced as thick and short as possible to the inductor, because they may induce the noise to the other nodes due to AC coupling.
- Please keep the lines connected to FB away from the SW node as far as possible.
- Please place output capacitor away from input capacitor to avoid harmonics noise from the input.
- Please connect AGND to PGND that are close to the output capacitor. It can avoid harmonic noise.

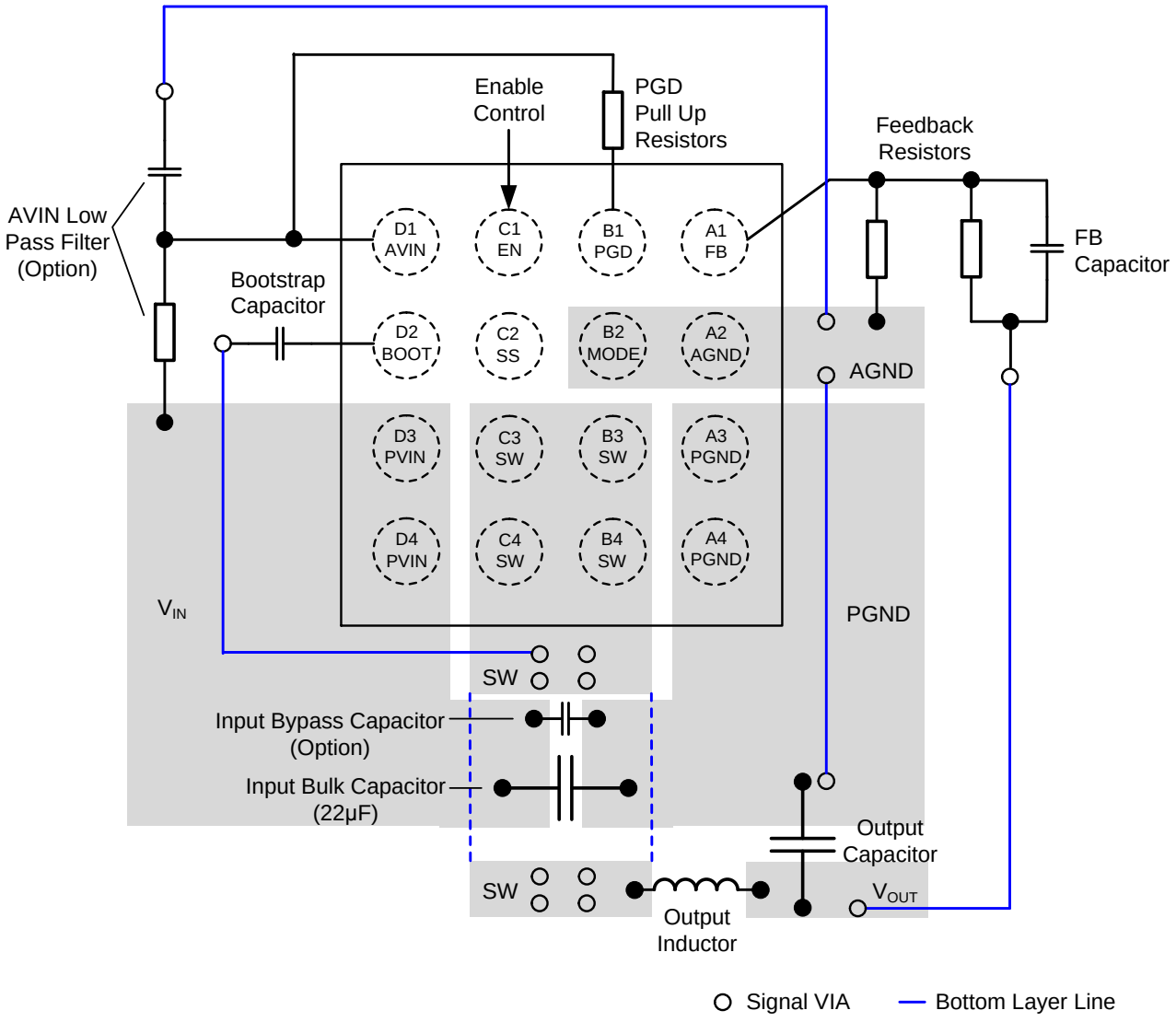


Figure 76. Example of PCB Layout (TOP VIEW)

I/O Equivalence Circuits

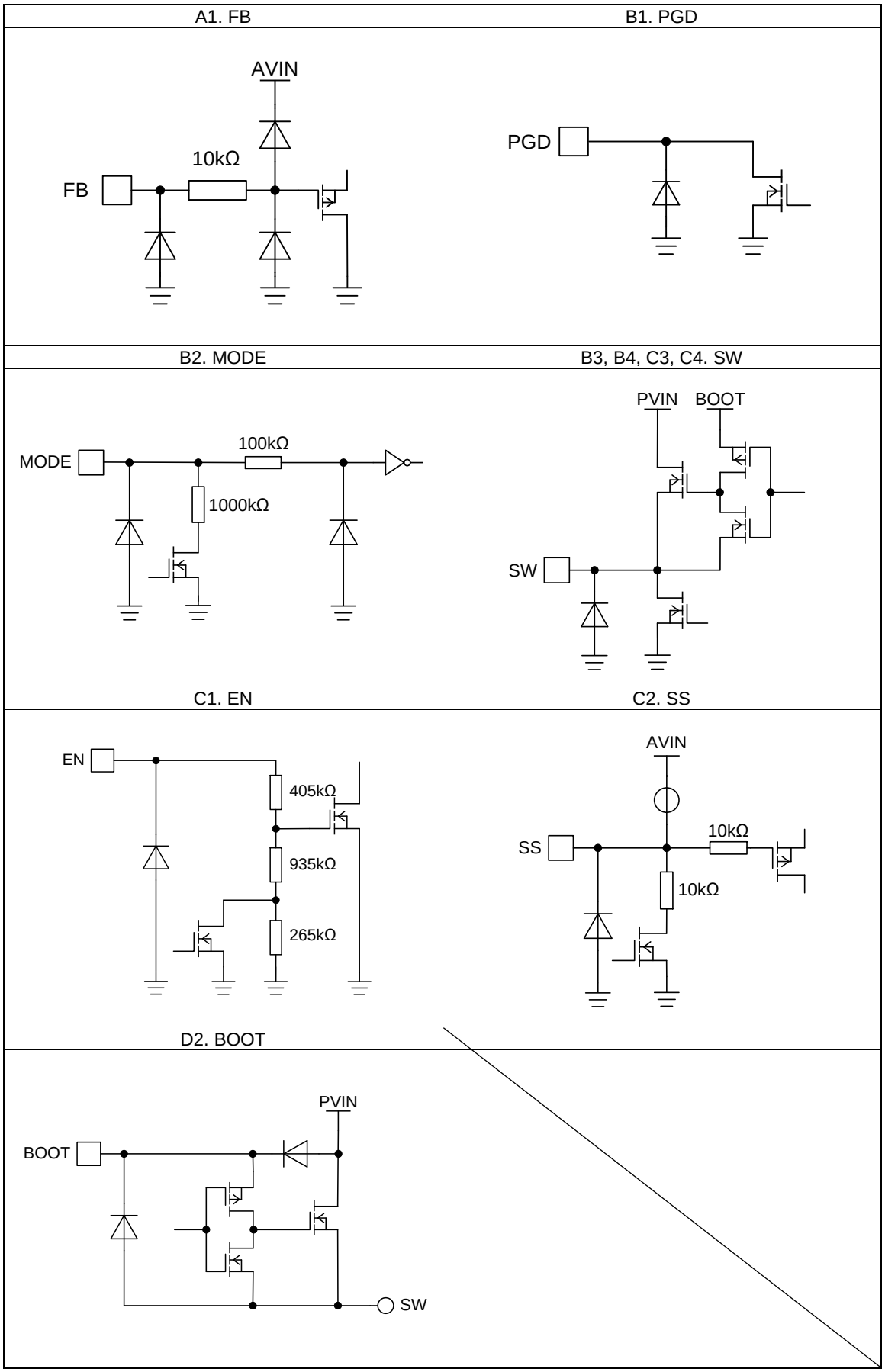


Figure 77. I/O Equivalence Circuits

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. Separate the ground and supply lines of the digital and analog blocks to prevent noise in the ground and supply lines of the digital block from affecting the analog block. 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. However, pins that drive inductive loads (e.g. motor driver outputs, DC-DC converter outputs) may inevitably go below ground due to back EMF or electromotive force. In such cases, the user should make sure that such voltages going below ground will not cause the IC and the system to malfunction by examining carefully all relevant factors and conditions such as motor characteristics, supply voltage, operating frequency and PCB wiring to name a few.

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. **Operation Under Strong Electromagnetic Field**
   Operating the IC in the presence of a strong electromagnetic field may cause the IC to malfunction.

8. **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.

9. **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.

10. **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

11. 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.

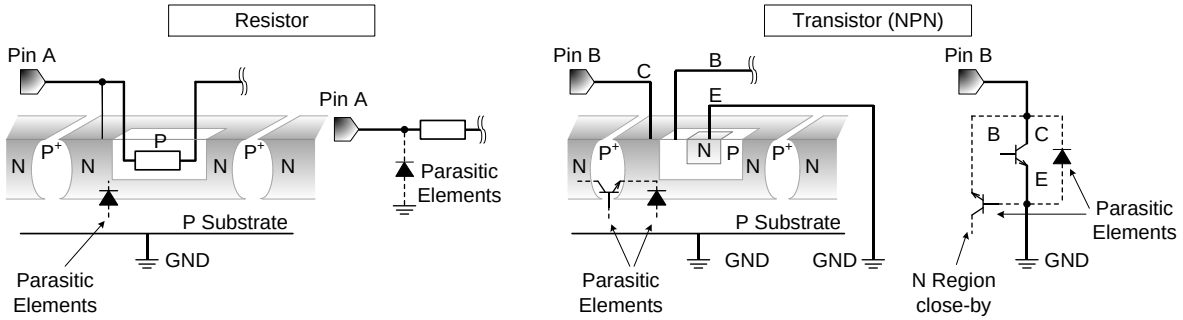


Figure 78. Example of monolithic IC structure

12. 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.

13. Area of Safe Operation (ASO)

Operate the IC such that the output voltage, output current, and the maximum junction temperature rating are all within the Area of Safe Operation (ASO).

14. 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 all 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.

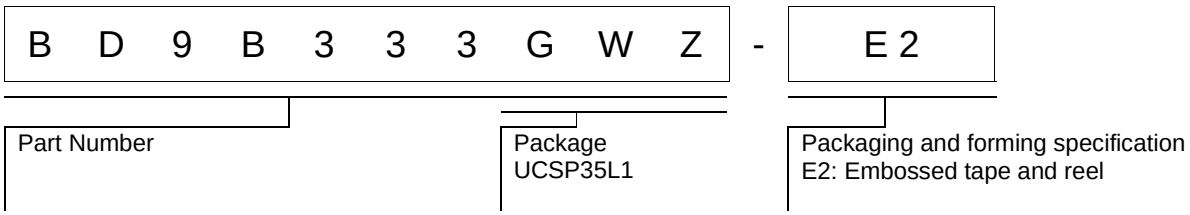
15. Over Current Protection Circuit (OCP)

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.

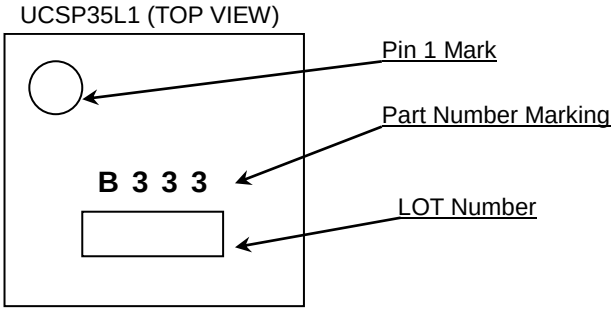
16. Disturbance Light

In a device where a portion of silicon is exposed to light such as in a WL-CSP and chip products, IC characteristics may be affected due to photoelectric effect. For this reason, it is recommended to come up with countermeasures that will prevent the chip from being exposed to light.

Ordering Information

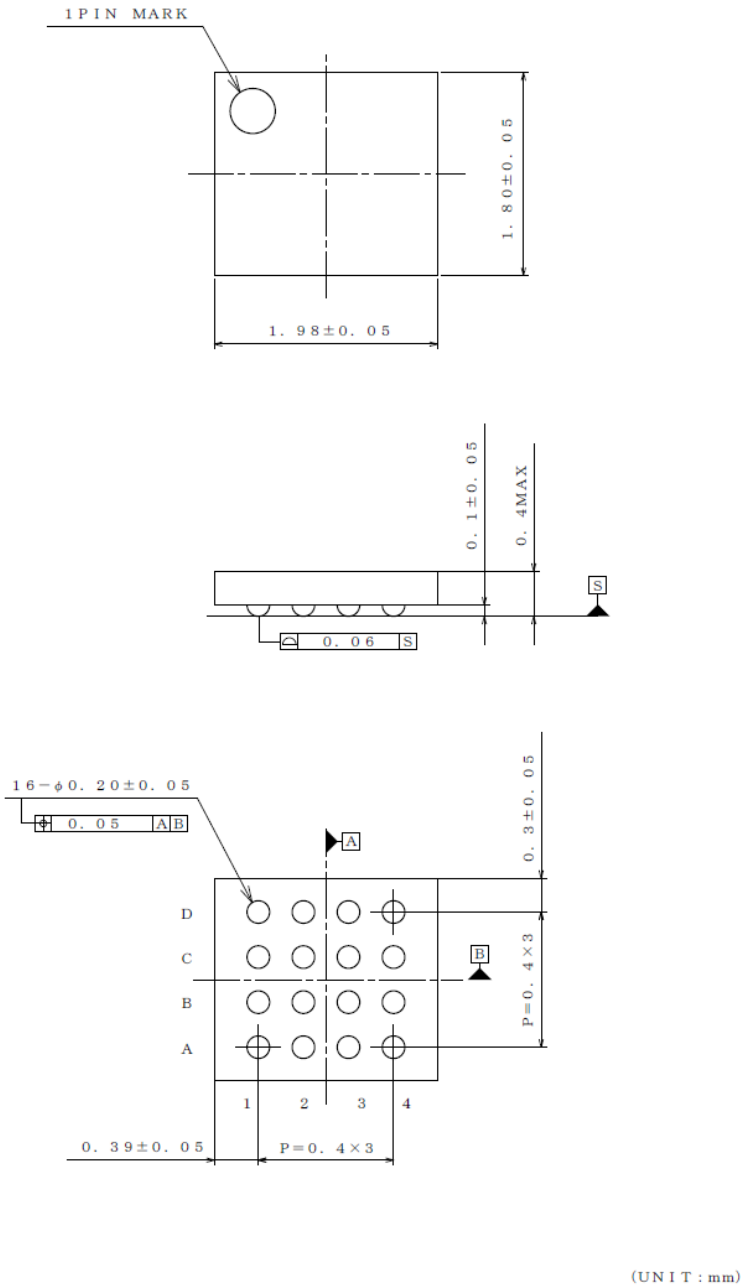


Marking Diagram



Physical Dimension and Packing Information

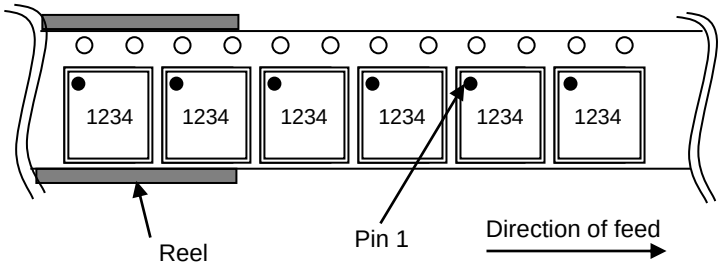
Package Name (Product Name)	UCSP35L1 (BD9B333GWZ)



(UNIT : mm)

< Tape and Reel Information >

Tape	Embossed carrier tape
Quantity	3000pcs
Direction of feed	E2 The direction is the pin 1 of product is at the upper left when you hold reel on the left hand and you pull out the tape on the right hand



Revision History

Date	Revision	Changes
16.Jun.2017	001	New Release

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JAPAN	USA	EU	CHINA
CLASSⅢ	CLASSⅢ	CLASSⅡb	CLASSⅢ
CLASSⅣ		CLASSⅢ	

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   [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 (even if you use no-clean type fluxes, cleaning residue of flux is recommended); 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.

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.

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