4.5V to 28V Input, 8.0A Integrated MOSFET Single Synchronous Buck DC/DC Converter

BD9F800MUX-Z

General Description

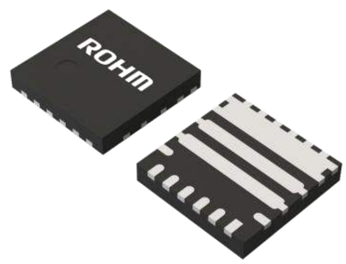
BD9F800MUX-Z is a synchronous buck DC/DC converter with built-in low on-resistance power MOSFETs. It is capable of providing current of up to 8 A. External phase compensation circuit is not necessary for it is a constant on-time control DC/DC converter with high speed response.

Key Specifications

- Input Voltage Range: 4.5V to 28 V
- Output Voltage Setting Range: 0.765V to 13.5V
- Output Current: 8 A (Max)
- Switching Frequency: 300kHz or 600kHz (Typ)
- High Side MOSFET On-Resistance: 23 m Ω (Typ)
- Low Side MOSFET On-Resistance: 11 m Ω (Typ)
- Shutdown Current: 2 μA (Typ)

Package

Package	W (Typ) × D (Typ) × H (Max)
VQFN11X3535A	3.50mm × 3.50mm × 0.60mm



VQFN11X3535A

Features

- Synchronous Single DC/DC Converter
- Constant On-time Control
- Over Current Protection
- Short Circuit Protection
- Thermal Shutdown Protection
- Under Voltage Lockout Protection
- Power Good Output
- VQFN11X3535A Package

Applications

- Step-down Power Supply for DSPs, Microprocessors, etc.
- Set-top Box
- LCD TVs
- DVD / Blu-ray Player / Recorder
- Entertainment Devices

Typical Application Circuit

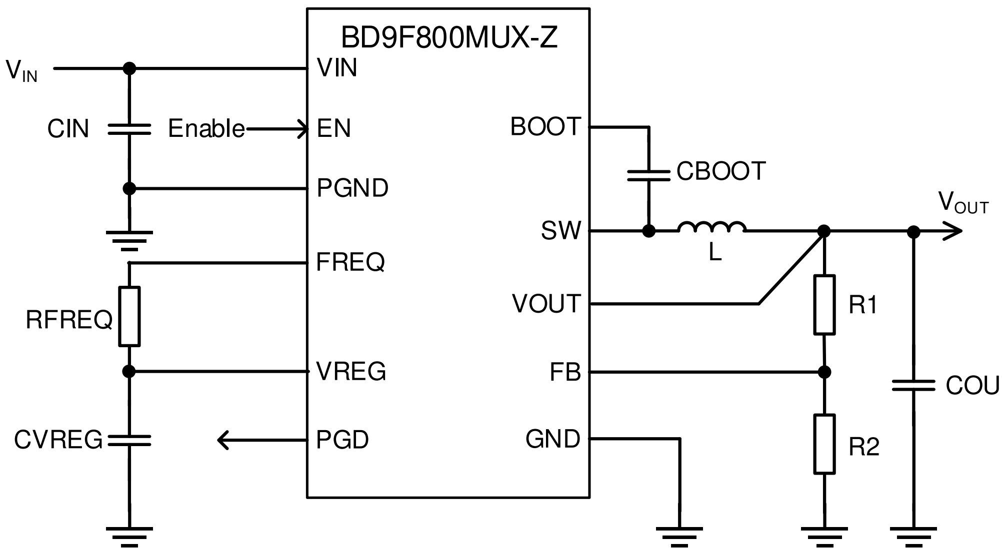


Figure 1. Typical Application Circuit

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

Pin Configuration

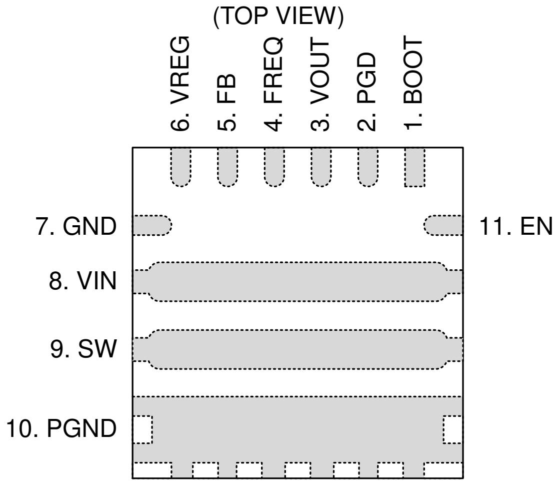


Figure 2. Pin Configuration

Pin Descriptions

Terminal No.	Symbol	Function
1	BOOT	Bootstrap terminal. Connect a ceramic capacitor of 0.1µF between BOOT and SW terminal. The voltage of this capacitor is the gate drive voltage of the High-Side MOSFET.
2	PGD	Power Good terminal. It is necessary to connect a pull-up resistor due to an open drain output. See page 19 for how to specify the resistance. When the FB terminal voltage is within ±7% of 0.765V (Typ), the internal Nch MOSFET turns off and the output turns High.
3	VOUT	Output voltage sense terminal. Connect a 10Ω resistor in series when output voltage setting is more than 3.3V.
4	FREQ	Switching frequency setting terminal. Switching frequency is set to 300kHz when this terminal is set to Low (0.8V or lower). Setting this terminal to High (2.2V or higher) will make switching frequency set to 600kHz. This terminal needs to be pulled down to ground or pulled up to VREG by 10kΩ.
5	FB	An inverting input node for the error amplifier and main comparator. To calculate for the resistance value of the output voltage setting, refer to page 39.
6	VREG	Internal power supply voltage terminal. A voltage of 5.25V (Typ) is outputted if there is more than 2.3V for EN terminal. Connect a ceramic capacitor of 2.2µF to ground.
7	GND	Ground terminal for the control circuit.
8	VIN	Power supply terminal for the switching regulator. Connecting 20µF(10µF×2) and 0.1µF ceramic capacitor to ground is recommended.
9	SW	Switch terminal. The SW terminal is connected to the source of the High-Side MOSFET and drain of the Low-Side MOSFET. Connect a bootstrap capacitor of 0.1µF between BOOT and SW terminal. Also, connect an inductor considering the direct current superimposition characteristic.
10	PGND	Ground terminal for the output stage of the switching regulator.
11	EN	Enable terminal. Turning this terminal signal Low (0.7V or lower) forces the device to enter in shutdown mode. Turning this terminal signal High (2.3V or higher) enables the device. This terminal must be properly terminated.

Block Diagram

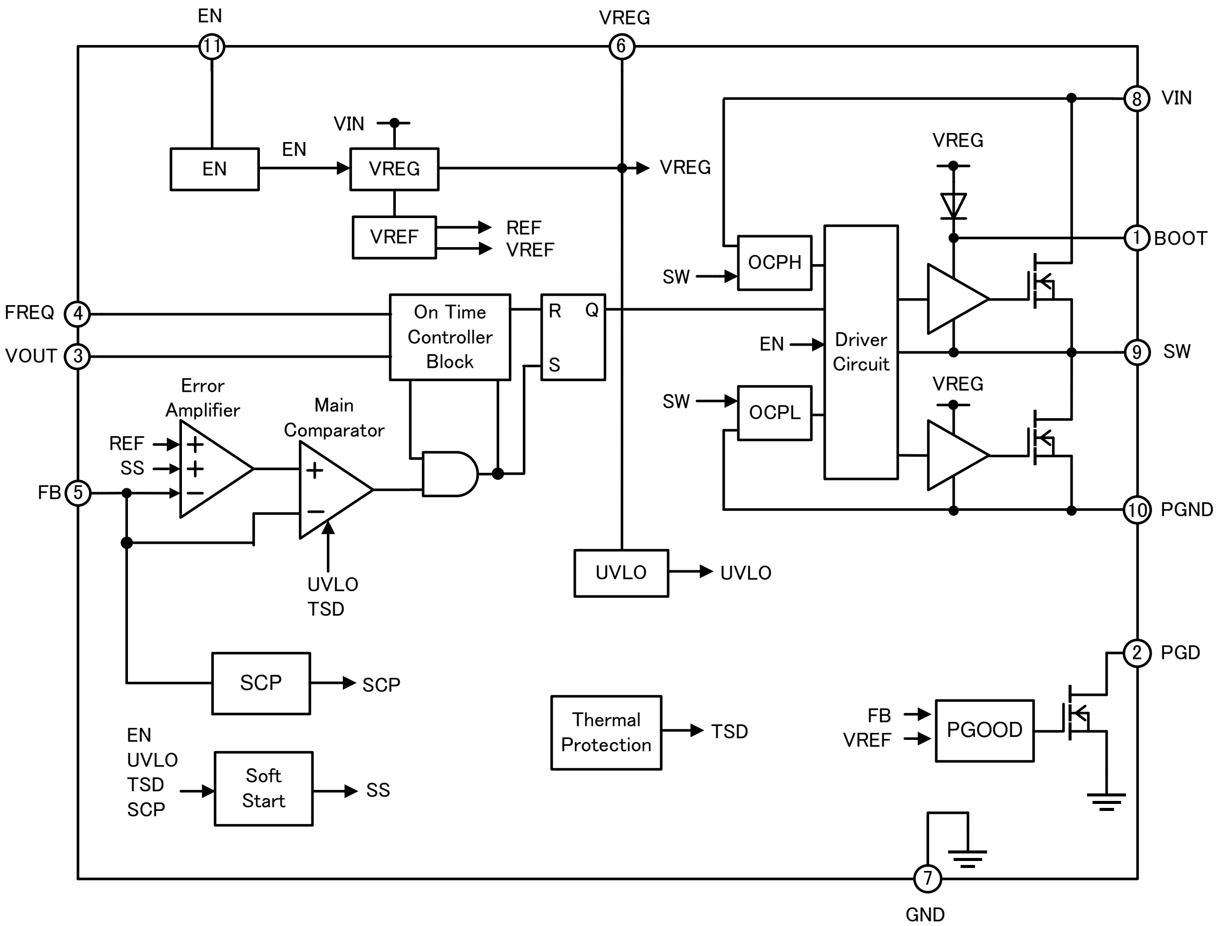


Figure 3. Block Diagram

Description of Blocks

- EN
  The device will shut down when EN falls to 0.7V (Max) or lower. When EN reaches 2.3V (Min), the internal circuit is activated and the device starts up.

- VREG
  The VREG block generates the internal power supply.

- VREF
  The VREF block generates the internal reference voltage.

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

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

- ON Time Controller Block
  This block generates ON Time. The desired ON Time is generated when Main Comparator output becomes High. ON Time is adjusted to restrict frequency change even with Input / Output voltage change.

- 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 typically.

- PGOOD
  When the FB terminal voltage reaches within ±7% of 0.765V(Typ), the built-in open drain output Nch MOSFET turns off and the output goes high.

- Driver Circuit
  This block is a DC/DC driver. A signal from ON Time Controller Block is applied to drive the MOSFETs.

- UVLO
  UVLO is a protection circuit that prevents low voltage malfunction. It prevents malfunction of the internal circuit from sudden rise and fall of power supply voltage. When VIN voltage is higher than 4.2V (Typ), UVLO is released and the soft-start circuit will be started. This threshold voltage has a hysteresis of 400mV (Typ). When VIN voltage is less than 3.8V (Typ), the device will shut down.

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

- SCP
  After the soft start is completed and when the FB terminal voltage has fallen below 0.38V (Typ) for 250µs (Typ), the SCP stops the operation for 8ms (Typ) and subsequently initiates restart.

- OCPH
  When inductor current exceeds the current limit threshold value while High-Side MOSFET is ON, the High-Side MOSFET will turn OFF.

- OCPL
  The OCP function limits the current flowing through the Low-Side MOSFET for every switching period. If the inductor current exceeds the source current limit threshold value I_{OCP} while Low-Side MOSFET is ON, the Low-Side MOSFET remains ON even with FB voltage is lower than the REF voltage. The Low-Side MOSFET keeps ON until inductor current becomes lower than I_{OCP} and High-Side MOSFET will turn ON. The Low-Side MOSFET will turn OFF when inductor current exceeds the sink current limit threshold value while Low-Side MOSFET is ON.

Absolute Maximum Ratings (Ta = 25°C)

Parameter	Symbol	Rating	Unit
Input Voltage	V_{IN}	-0.3 to +30	V
Voltage from GND to BOOT	V_{BOOT}	-0.3 to +35	V
Voltage from SW to BOOT	V_{BOOT} - V_{SW}	-0.3 to +7	V
SW Terminal Voltage	V_{SW}	-0.3 to V_{IN} + 0.3	V
FB Terminal Voltage	V_{FB}	-0.3 to V_{VREG}	V
VREG Terminal Voltage	V_{VREG}	-0.3 to +6	V
FREQ Terminal Voltage	V_{FREQ}	-0.3 to +7	V
VOUT Terminal Voltage	V_{VOUT}	-0.3 to +20	V
PGD Terminal Voltage	V_{PGD}	-0.3 to +35	V
EN Terminal Voltage	V_{EN}	-0.3 to +30	V
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, increase the board size and copper area to prevent exceeding the maximum junction temperature rating.

Thermal Resistance*(Note 1)*

Parameter	Symbol	Thermal Resistance (Typ)		Unit
		1s*(Note 3)*	2s2p*(Note 4)*	
VQFN11X3535A				
Junction to Ambient	θ_{JA}	232.1	48.0	°C/W
Junction to Top Characterization Parameter*(Note 2)*	Ψ_{JT}	44.2	8.2	°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 a PCB board based on JESD51-3.

Layer Number of Measurement Board	Material	Board Size
Single	FR-4	114.3mm x 76.2mm x 1.57mmt

Top	
Copper Pattern	Thickness
Footprints and Traces	70µm

(Note 4) Using a PCB board based on JESD51-7.

Layer Number of Measurement Board	Material	Board Size	Thermal Via*(Note 5)*	
			Pitch	Diameter
4 Layers	FR-4	114.3mm x 76.2mm x 1.6mmt	1.20mm	Φ0.30mm

Top		2 Internal Layers		Bottom	
Copper Pattern	Thickness	Copper Pattern	Thickness	Copper Pattern	Thickness
Footprints and Traces	70µm	74.2mm x 74.2mm	35µm	74.2mm x 74.2mm	70µm

(Note 5) This thermal via connects with the copper pattern of all layers.

Recommended Operating Conditions

Parameter	Symbol	Min	Typ	Max	Unit
Input Voltage	V_{IN}	4.5	12	28	V
Operating Temperature Range	Topr	-40	-	+85 (Note 1)	°C
Output Current	I_{OUT}	0	-	8	A
Output Voltage Range	V_{RANGE}	0.765 (Note 2)	-	13.5 (Note 3)	V

(Note 1) Tj must be lower than 150°C under actual operating environment. Life time is derated at junction temperature greater than125°C.
(Note 2) Please use under the condition of $V_{OUT} \geq V_{IN} \times 0.033$ [V] (300kHz), $V_{OUT} \geq V_{IN} \times 0.067$ [V] (600kHz).
(Note 3) Please use under the condition of $V_{OUT} \leq V_{IN} \times 0.87 - 0.12 \times I_{OUT}$ [V](300kHz), $V_{OUT} \leq V_{IN} \times 0.77 - 0.13 \times I_{OUT}$ [V](600kHz).
(Refer to the page 39 for how to calculate the output voltage setting.)

Electrical Characteristics (Ta = 25°C, V_{IN} = 12V, V_{EN} = 3V, FREQ=L unless otherwise specified)

Parameter	Symbol	Min	Typ	Max	Unit	Conditions
Shutdown Current	I_{SD}	-	2	15	µA	V_{EN}=GND
Operating Circuit Current	I_{VIN}	-	0.85	1.6	mA	I_{OUT}=0mA when no switching
EN Low Voltage	V_{ENL}	-	-	0.7	V	
EN High Voltage	V_{ENH}	2.3	-	V_{IN}	V	
EN Input Current	I_{EN}	-	2.5	10	µA	V_{EN}=3V
FREQ Low Voltage	V_{FREQL}	-	-	0.8	V	
FREQ High Voltage	V_{FREQH}	2.2	-	V_{VREG}	V	
FREQ Input Current	I_{FREQ}	-	1.5	5	µA	V_{FREQ}=3V
VREG Shutdown Voltage	V_{VREG_SD}	-	-	0.1	V	V_{EN}=GND
VREG Output Voltage	V_{VREG}	5	5.25	5.5	V	
VREG Output Current	I_{REG}	-	10	-	mA	
UVLO Threshold Voltage	V_{UVLO}	3.9	4.2	4.5	V	VIN:Sweep up
UVLO Hysteresis Voltage	V_{UVLO_HYS}	200	400	600	mV	
FB Terminal Voltage	V_{FB}	0.757	0.765	0.773	V	V_{IN}=12V, V_{OUT}=1.0V
FB Input Bias Current	I_{FB}	-	-	1	µA	
Soft Start Time	t_{SS}	0.5	1	2	ms	
On Time1	t_{ON1}	-	277	-	ns	V_{IN}=12V, V_{OUT}=1.0V, FREQ=L
On Time2	t_{ON2}	-	150	-	ns	V_{IN}=12V, V_{OUT}=1.0V, FREQ=H
Minimum Off Time	t_{MINOFF}	-	250	-	ns	
High Side FET ON Resistance	R_{ONH}	-	23	-	mΩ	
Low Side FET ON Resistance	R_{ONL}	-	11	-	mΩ	
Current Limit Threshold	I_{OCP}	-	11.5	-	A	(Note 4)
Power Good Falling (Fault) Voltage	V_{PGDFF}	87	90	93	%	FB falling
Power Good Rising (Good) Voltage	V_{PGDRG}	90	93	96	%	FB rising
Power Good Rising (Fault) Voltage	V_{PGDRF}	107	110	113	%	FB rising
Power Good Falling (Good) Voltage	V_{PGDFG}	104	107	110	%	FB falling
Power Good Output Leakage Current	I_{LKPGD}	-	0	5	µA	PGD= 5V
Power Good ON Resistance	R_{PGD}	-	500	1000	Ω	
Hiccup Threshold Voltage	V_{HCP}	0.26	0.38	0.5	V	FB Terminal
Hiccup Delay Time	t_{HCPDLY}	-	250	-	µs	

(Note 4) No tested on outgoing inspection.

Typical Performance Curves

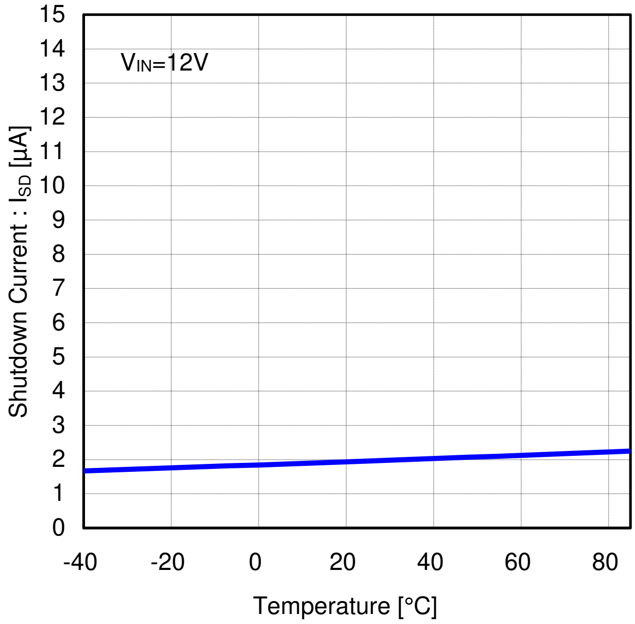


Figure 4. Shutdown Current vs Temperature

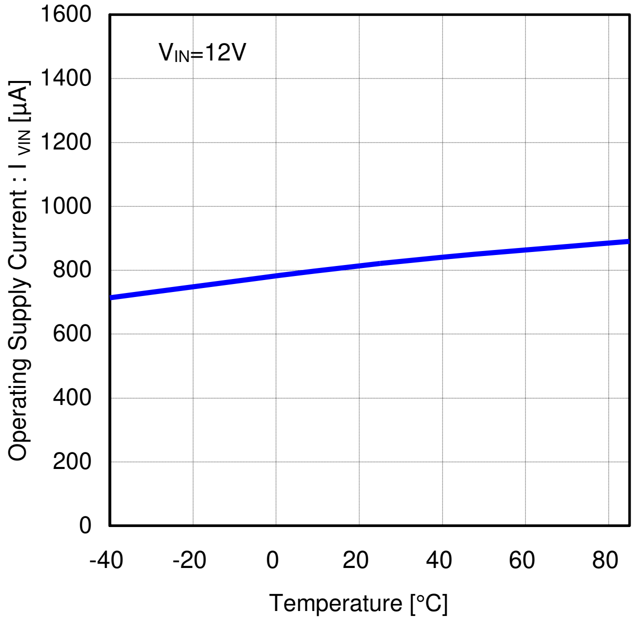


Figure 5. Operating Supply Current vs Temperature

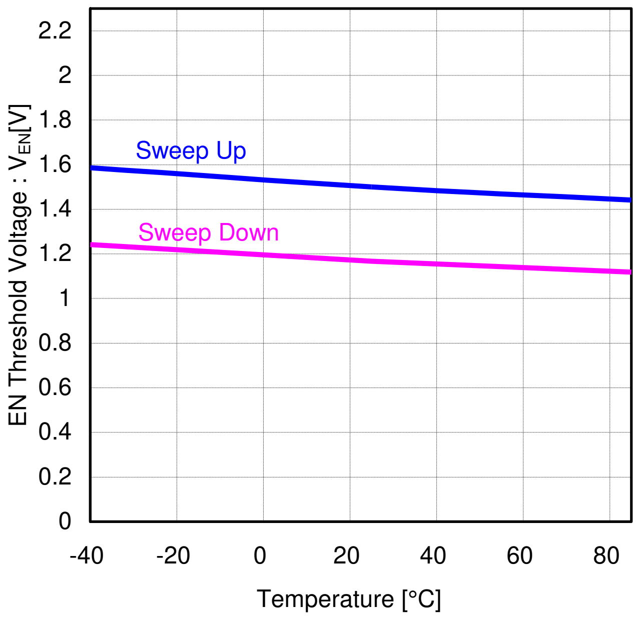


Figure 6. EN Threshold Voltage vs Temperature

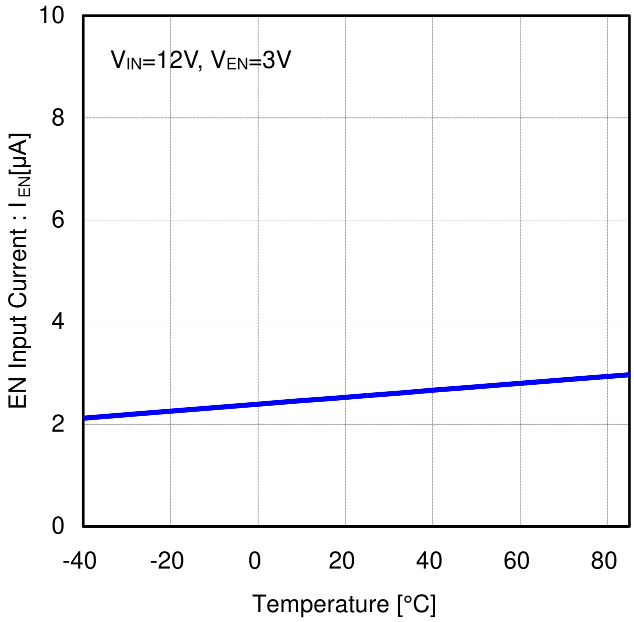


Figure 7. EN Input Current vs Temperature

Typical Performance Curves - continued

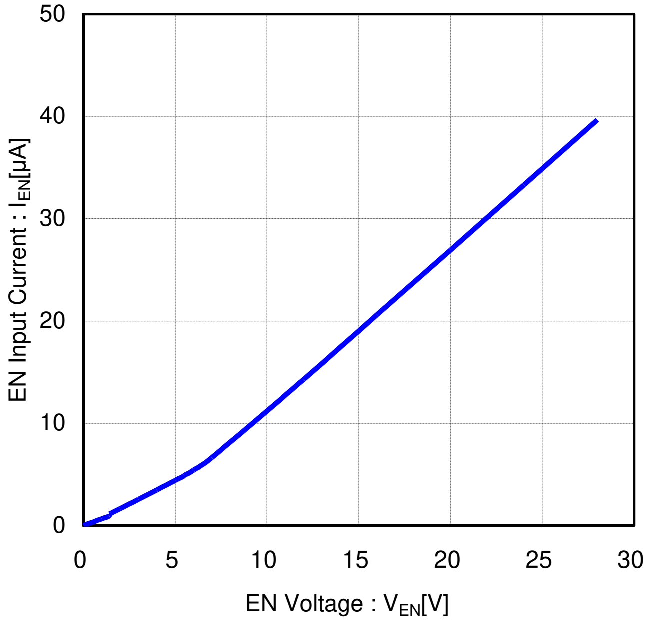


Figure 8. EN Input Current vs EN Voltage

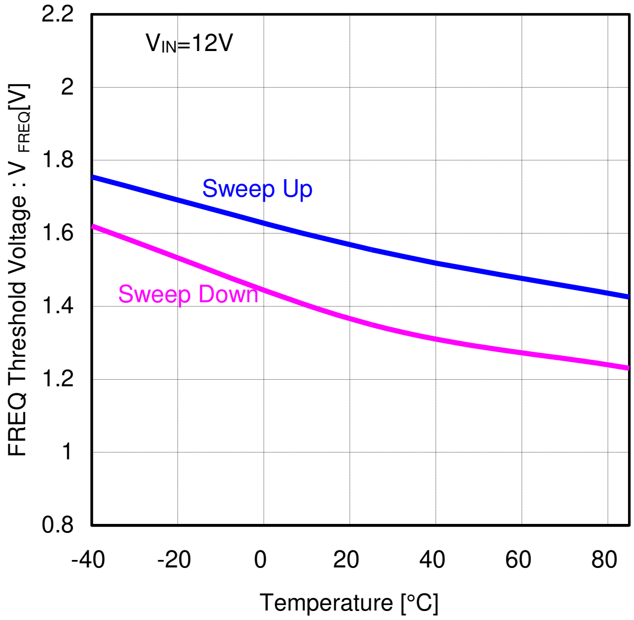


Figure 9. FREQ Threshold Voltage vs Temperature

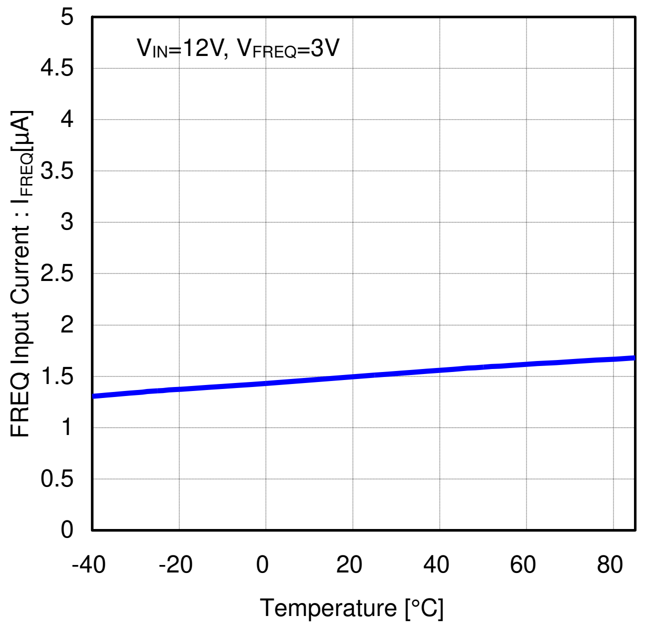


Figure 10. FREQ Input Current vs Temperature

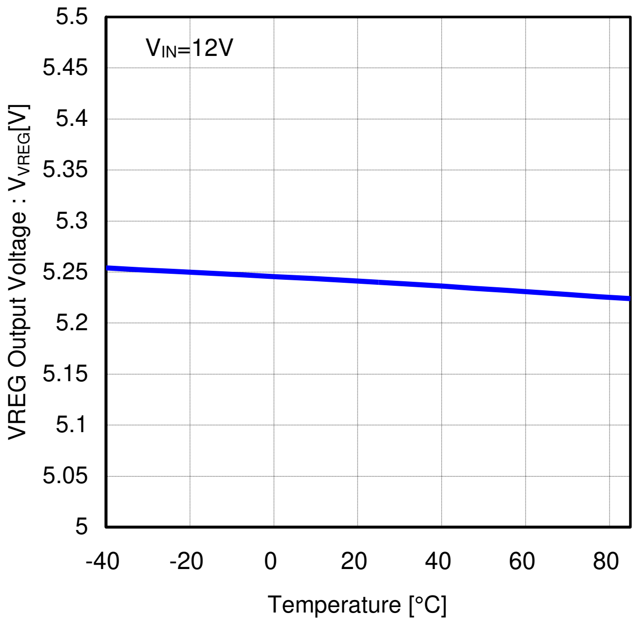


Figure 11. VREG Output Voltage vs Temperature

Typical Performance Curves - continued

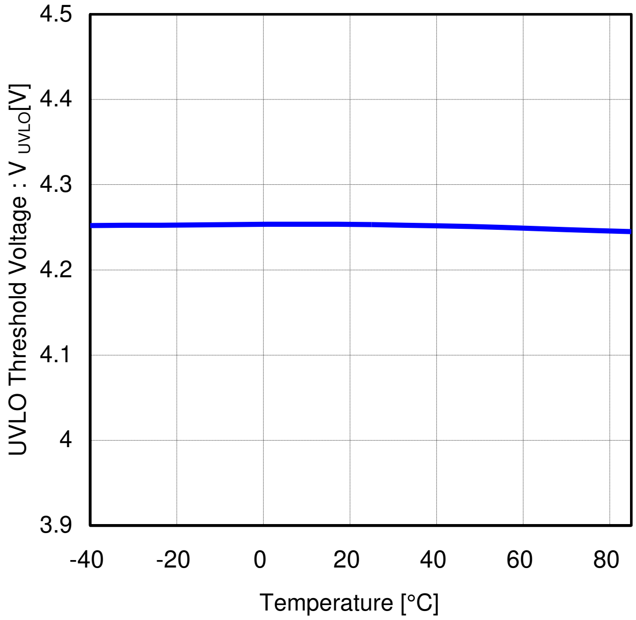


Figure 12. UVLO Threshold Voltage vs Temperature

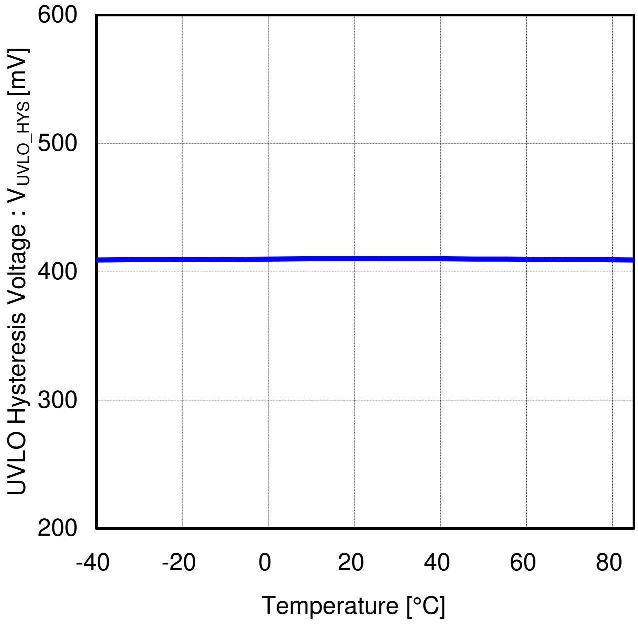


Figure 13. UVLO Hysteresis Voltage vs Temperature

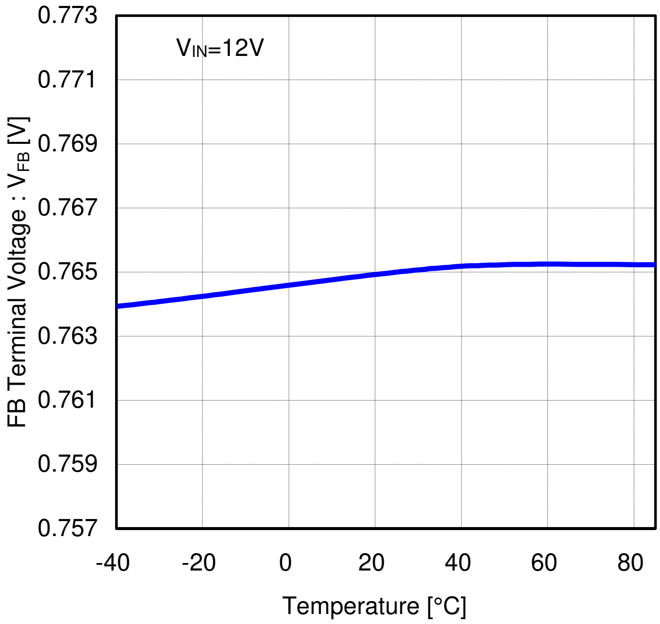


Figure 14. FB Terminal Voltage vs Temperature

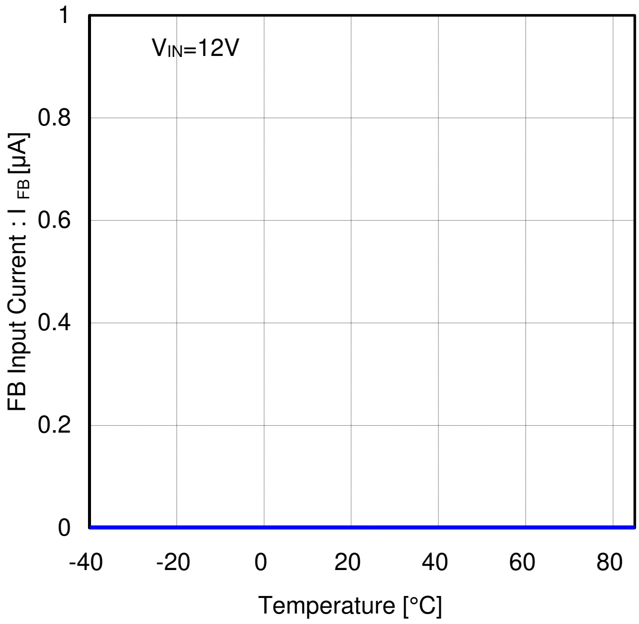


Figure 15. FB Input Current vs Temperature

Typical Performance Curves - continued

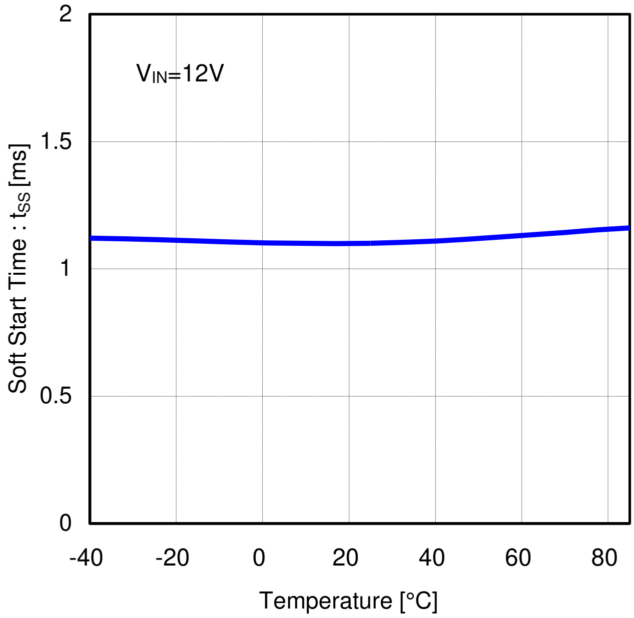


Figure 16. Soft Start Time vs Temperature

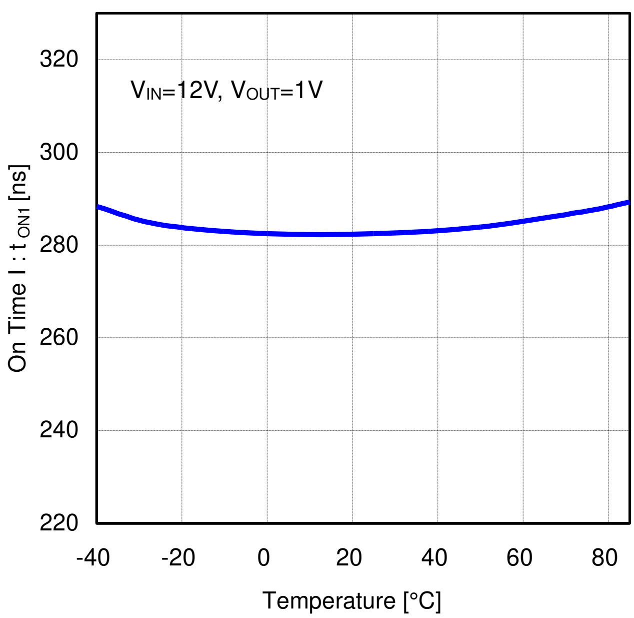


Figure 17. On Time 1 vs Temperature

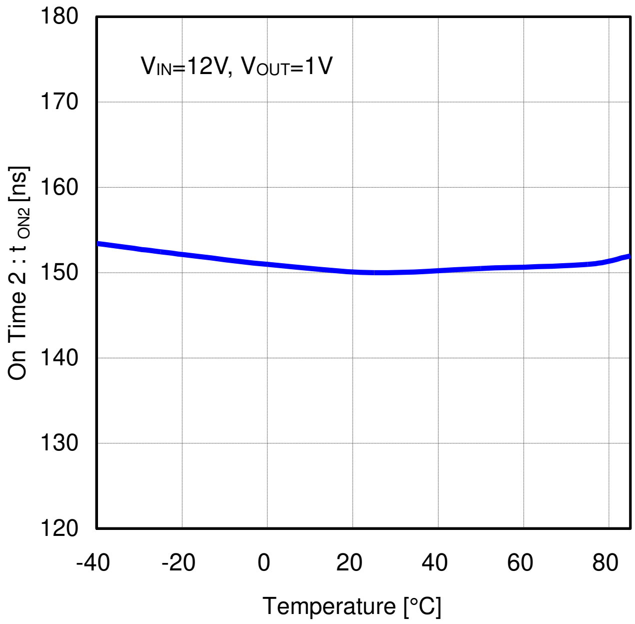


Figure 18. On Time 2 vs Temperature

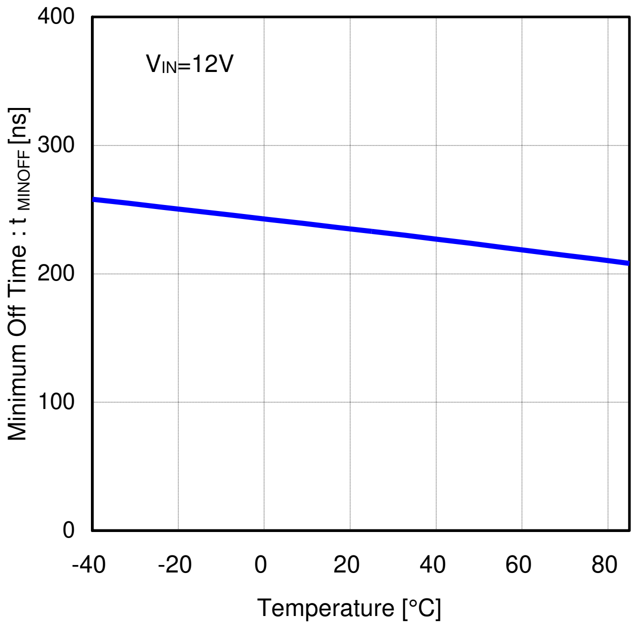


Figure 19. Minimum Off Time vs Temperature

Typical Performance Curves - continued

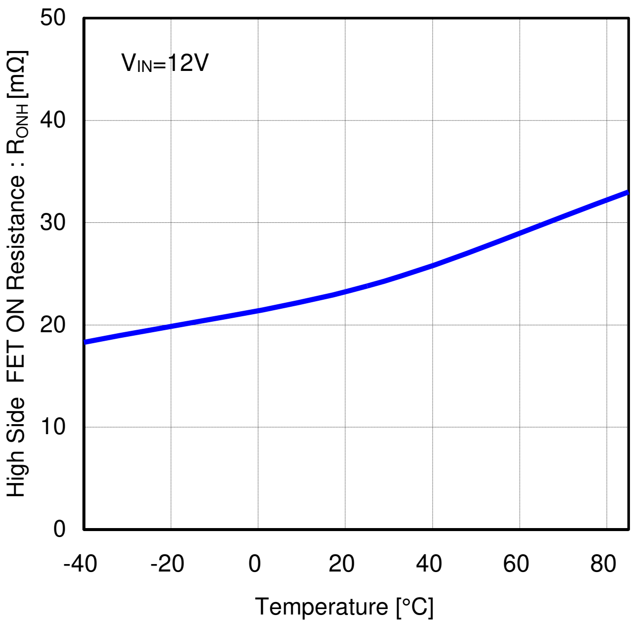


Figure 20. High Side FET ON Resistance vs Temperature

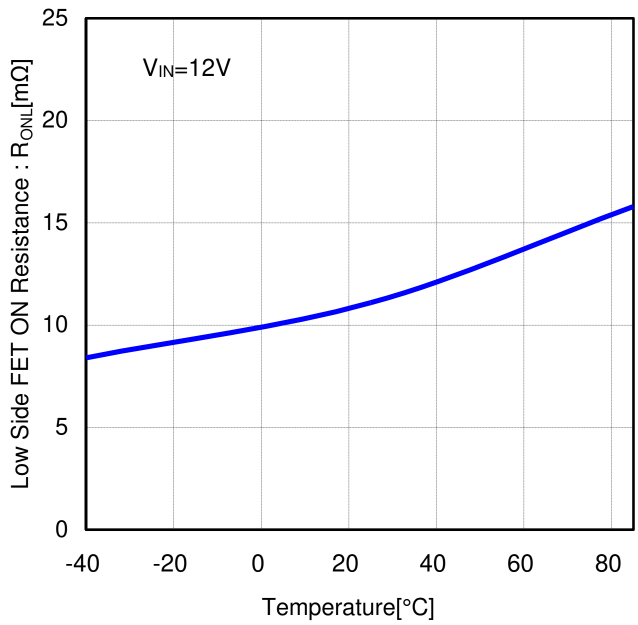


Figure 21. Low Side FET ON Resistance vs Temperature

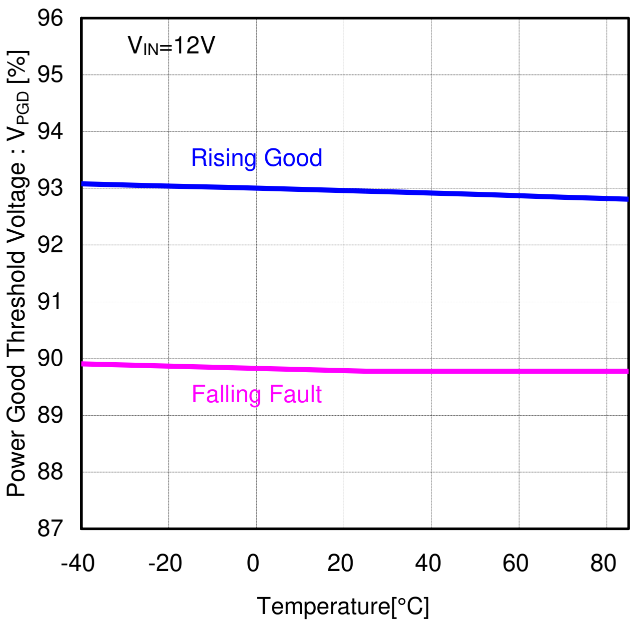


Figure 22. Power Good Threshold Voltage vs Temperature

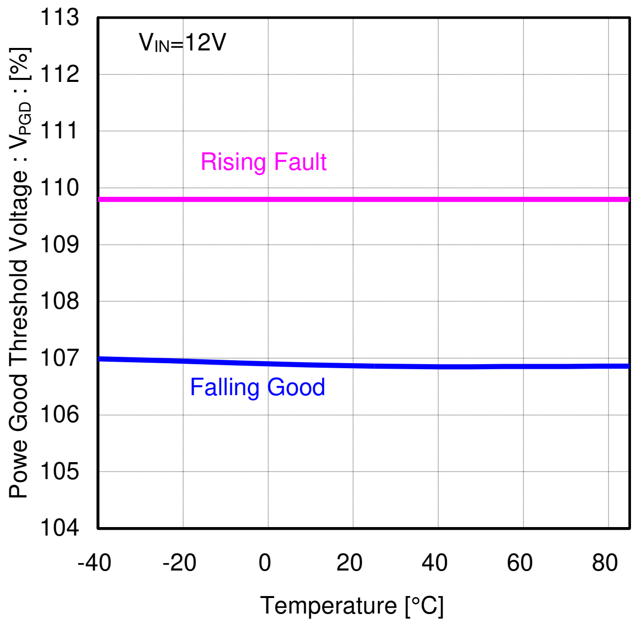


Figure 23. Power Good Threshold Voltage vs Temperature

Typical Performance Curves - continued

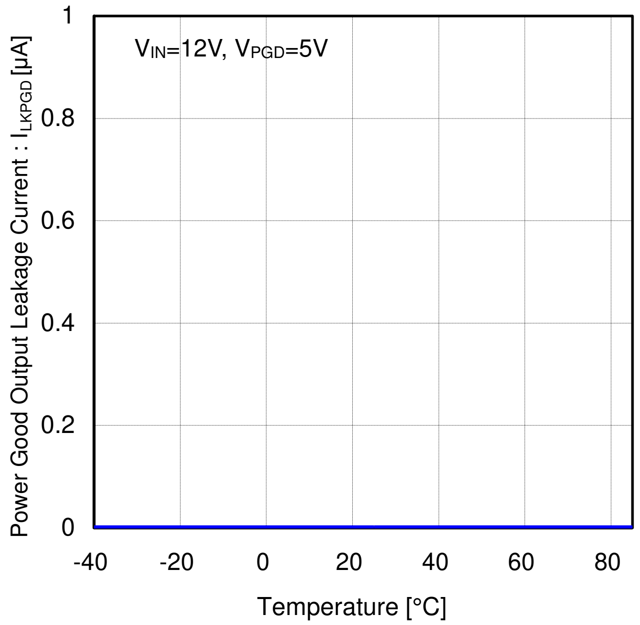


Figure 24. Power Good Output Leakage Current vs Temperature

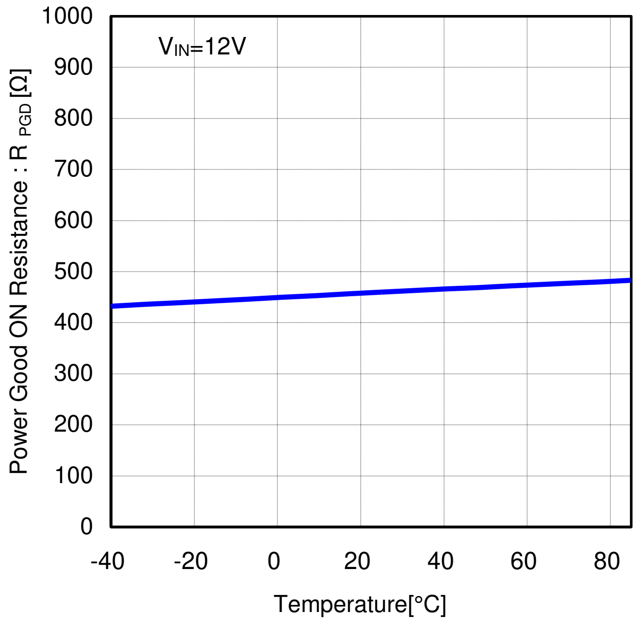


Figure 25. Power Good ON Resistance vs Temperature

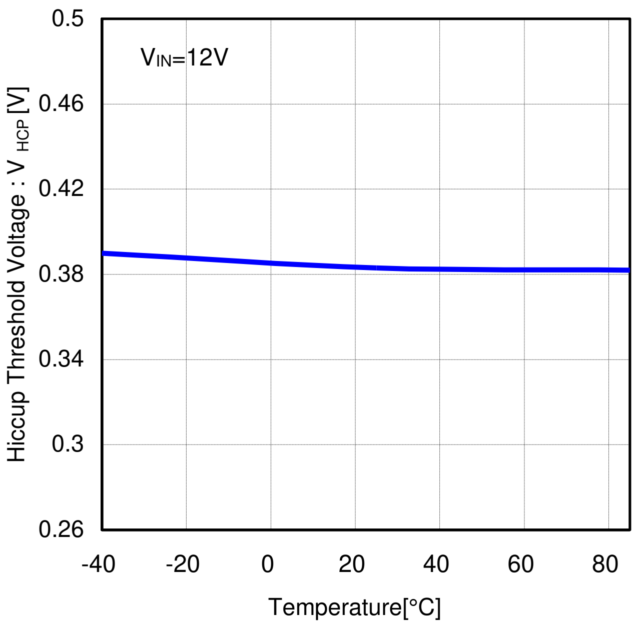


Figure 26. Hiccup Threshold Voltage vs Temperature

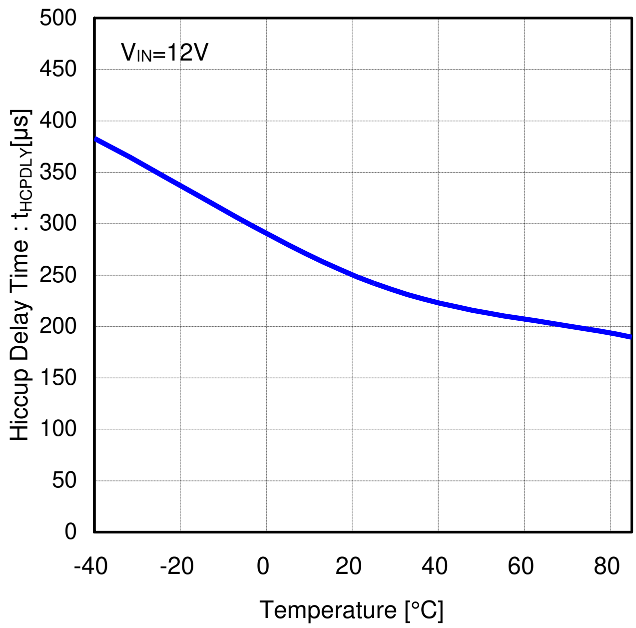


Figure 27. Hiccup Delay Time vs Temperature

Typical Performance Curves - continued

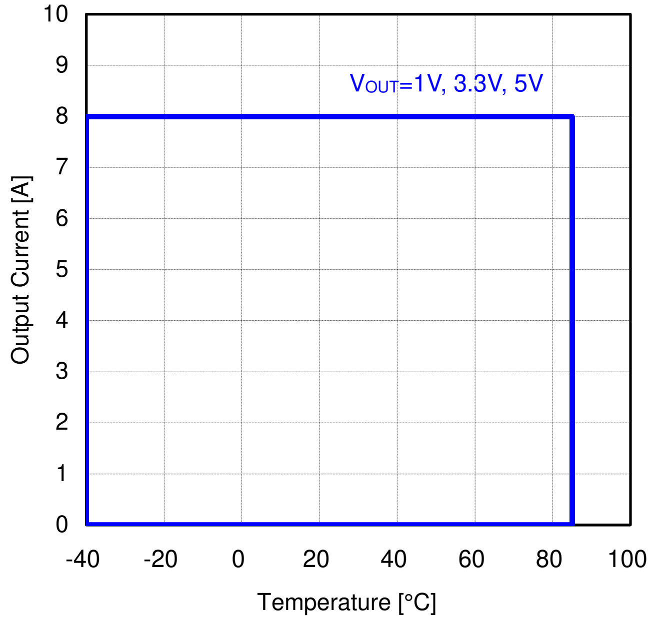


Figure 28. Operational Range
V_{IN}=12V, FREQ=L(300kHz), (Tj<150°C)
(Measured on FR-4 board 85 mm x 85 mm,
Copper Thickness: Top and Bottom 70µm, 2 Internal Layers 35µm)

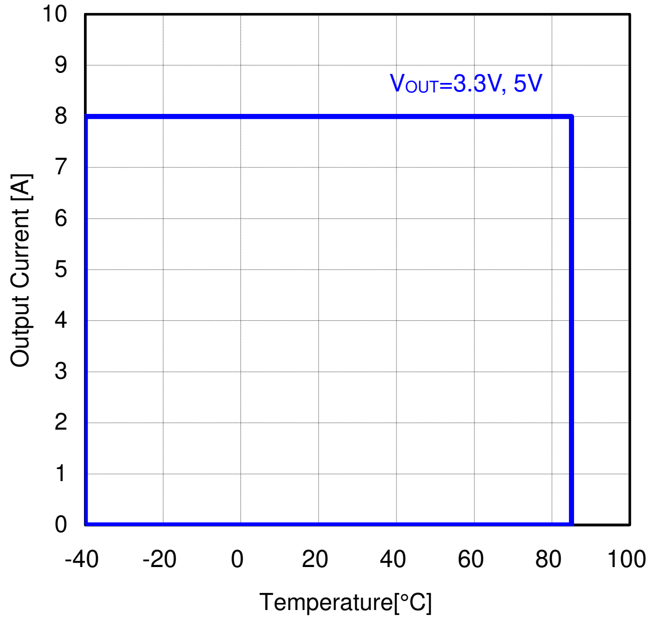


Figure 29. Operational Range
V_{IN}=24V, FREQ=L(300kHz), (Tj<150°C)
(Measured on FR-4 board 85 mm x 85 mm,
Copper Thickness: Top and Bottom 70µm, 2 Internal Layers 35µm)

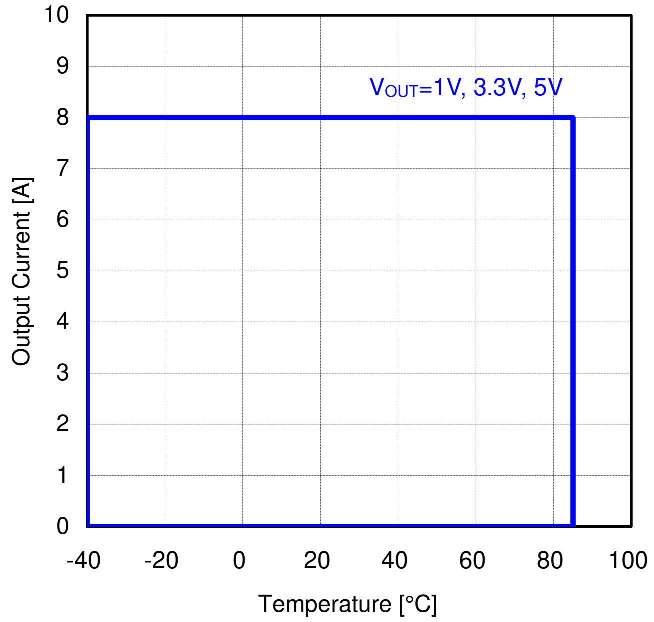


Figure 30. Operational Range
V_{IN}=12V, FREQ=H(600kHz), (Tj<150°C)
(Measured on FR-4 board 85 mm x 85 mm,
Copper Thickness: Top and Bottom 70µm, 2 Internal Layers 35µm)

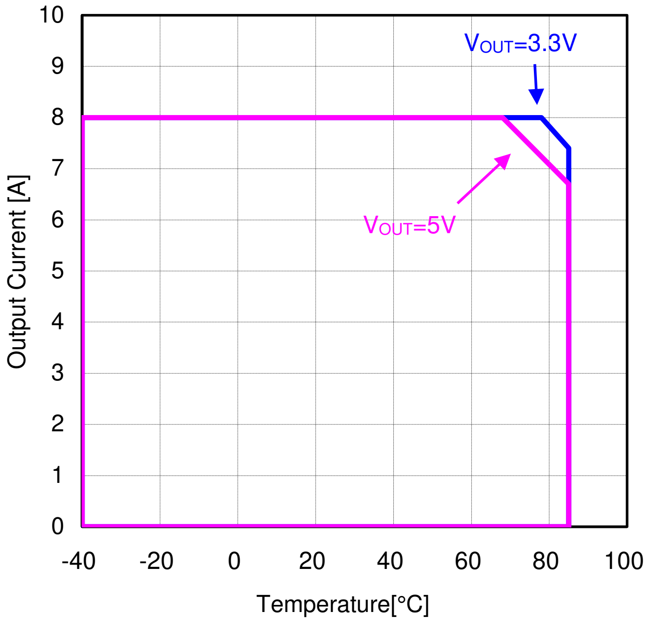


Figure 31. Operational Range
V_{IN}=24V, FREQ=H(600kHz), (Tj<150°C)
(Measured on FR-4 board 85 mm x 85 mm,
Copper Thickness: Top and Bottom 70µm, 2 Internal Layers 35µm)

Typical Performance Curves - continued

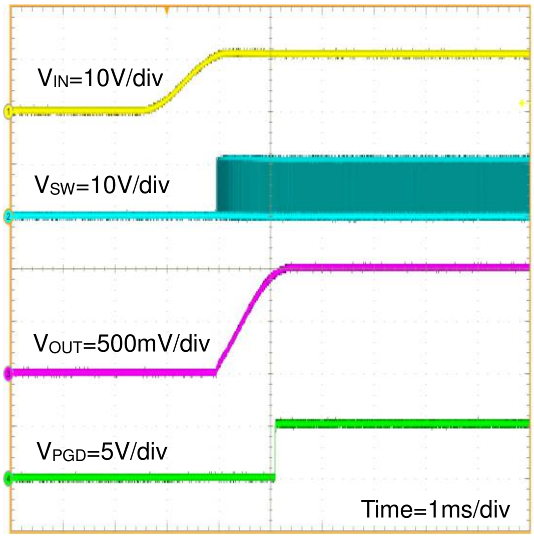


Figure 32. Start-up Waveform（V_{IN}=V_{EN}）
(V_{IN}=12V, V_{OUT}=1V, FREQ=L(300kHz), R_{LOAD}=0.125Ω)

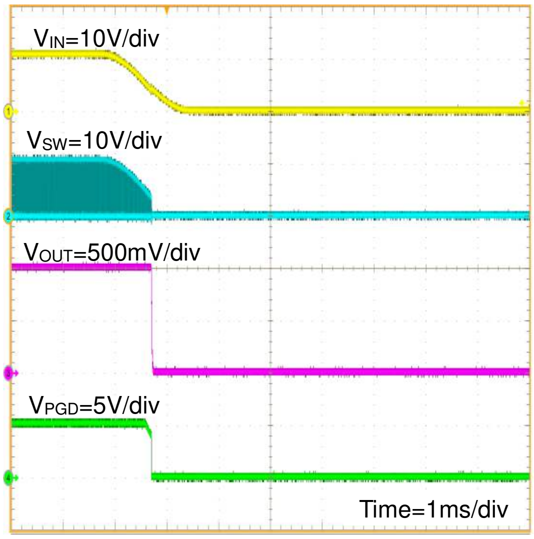


Figure 33. Shutdown Waveform（V_{IN}=V_{EN}）
(V_{IN}=12V, V_{OUT}=1V, FREQ=L(300kHz), R_{LOAD}=0.125Ω)

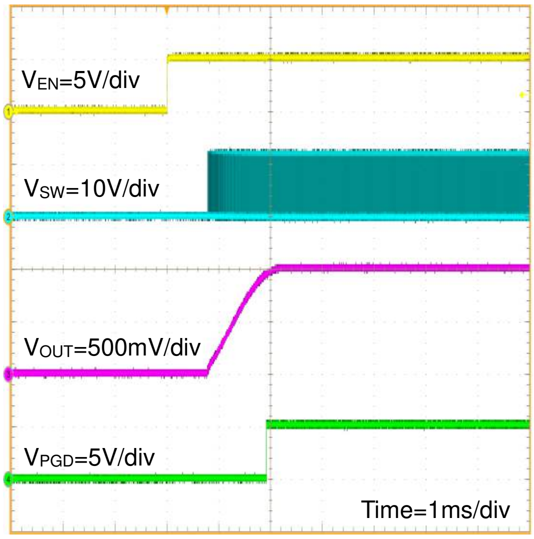


Figure 34. Start-up Waveform（V_{EN}=0V to 5V）
(V_{IN}=12V, V_{OUT}=1V, FREQ=L(300kHz), R_{LOAD}=0.125Ω)

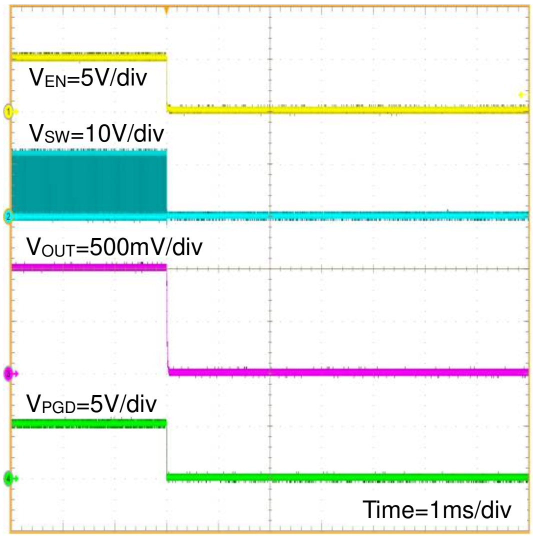


Figure 35. Shutdown Waveform（V_{EN}=5V to 0V）
(V_{IN}=12V, V_{OUT}=1V, FREQ=L(300kHz), R_{LOAD}=0.125Ω)

Typical Performance Curves - continued

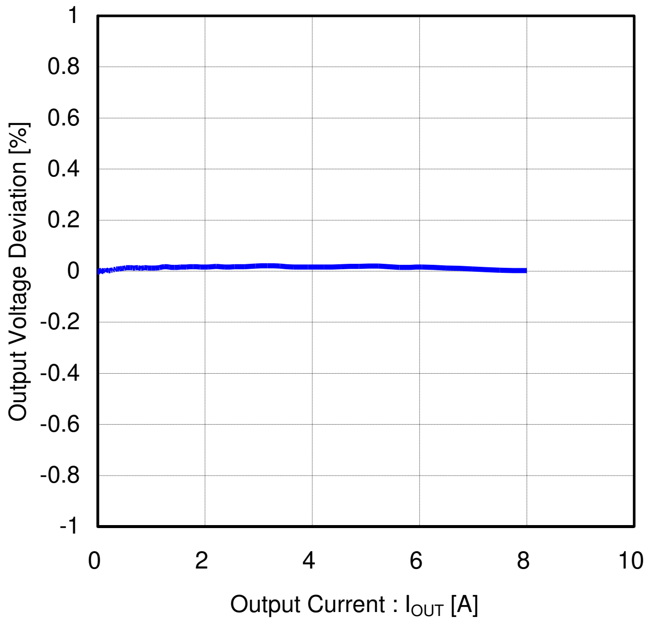


Figure 36. Load Regulation
(V_{IN}=12V, V_{OUT}=1V, FREQ=L(300kHz))

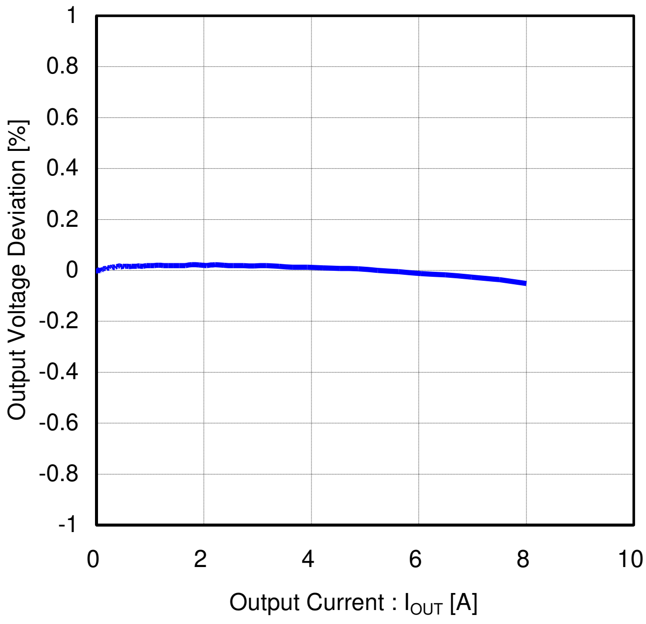


Figure 37. Load Regulation
(V_{IN}=12V, V_{OUT}=1V, FREQ=H(600kHz))

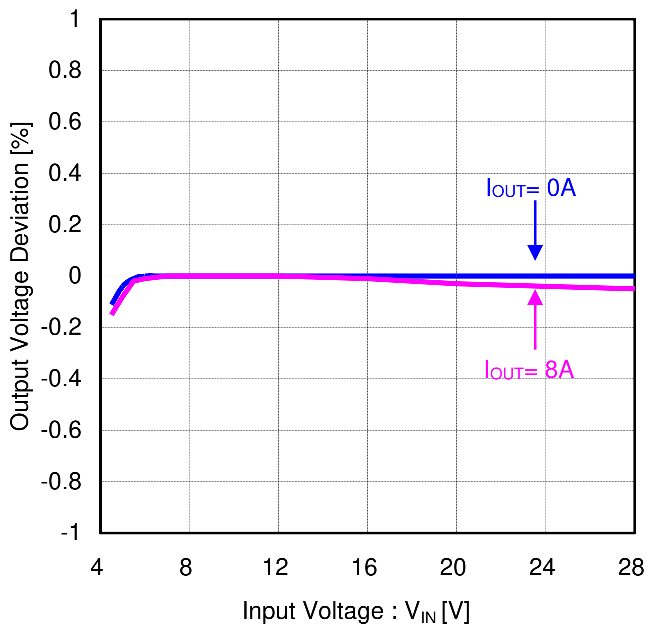


Figure 38. Line Regulation
(V_{IN}=12V, V_{OUT}=1V, FREQ=L(300kHz))

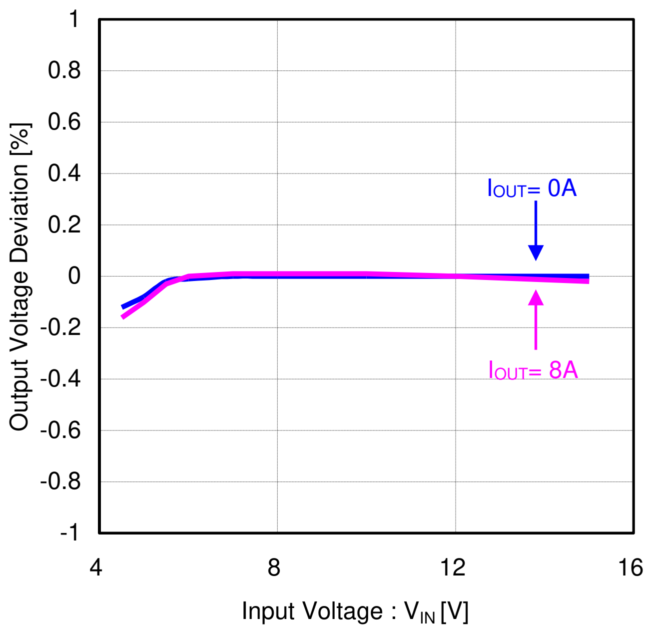


Figure 39. Line Regulation
(V_{IN}=12V, V_{OUT}=1V, FREQ=H(600kHz))

Typical Performance Curves - continued

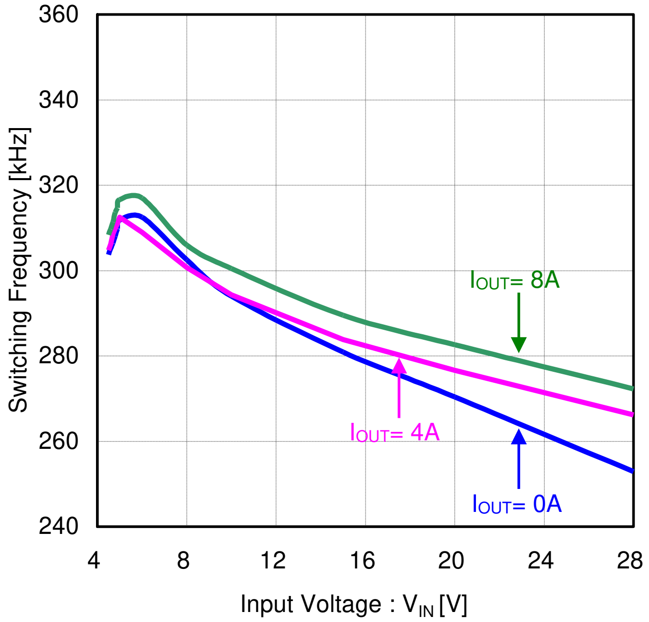


Figure 40. Switching Frequency vs Input Voltage (V_{OUT}=1V, FREQ=L(300kHz))

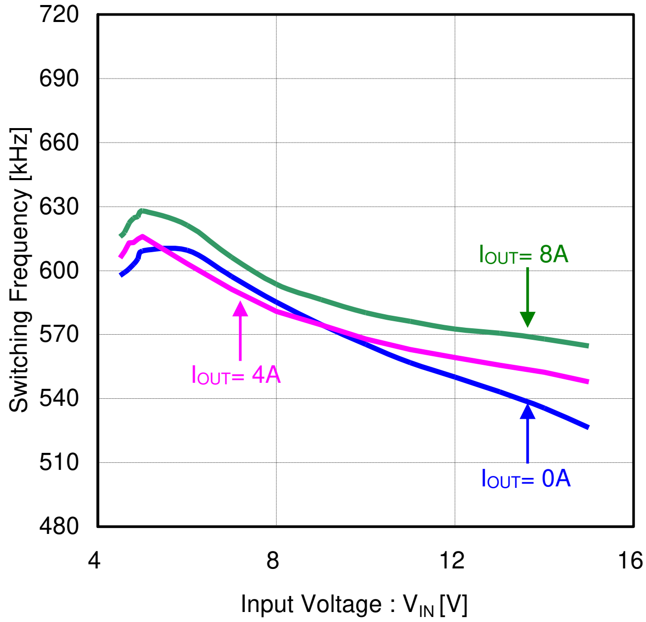


Figure 41. Switching Frequency vs Input Voltage (V_{OUT}=1V, FREQ=H(600kHz))

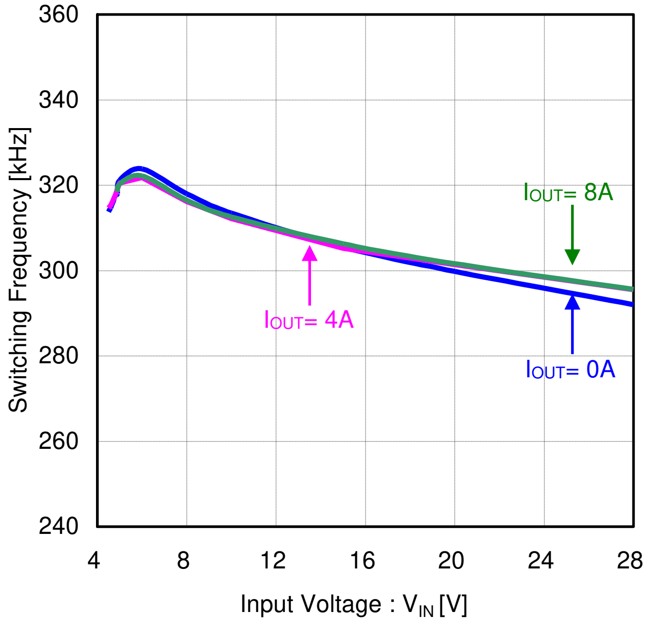


Figure 42. Switching Frequency vs Input Voltage (V_{OUT}=3.3V, FREQ=L(300kHz))

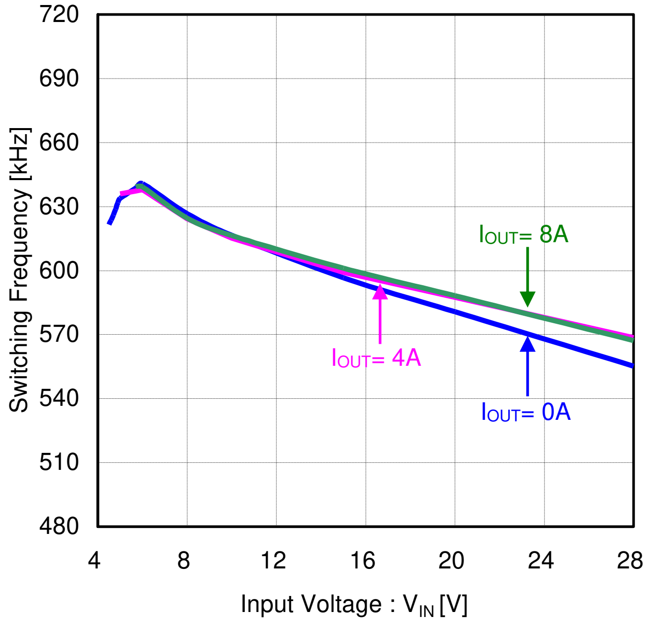


Figure 43. Switching Frequency vs Input Voltage (V_{OUT}=3.3V, FREQ=H(600kHz))

Typical Performance Curves - continued

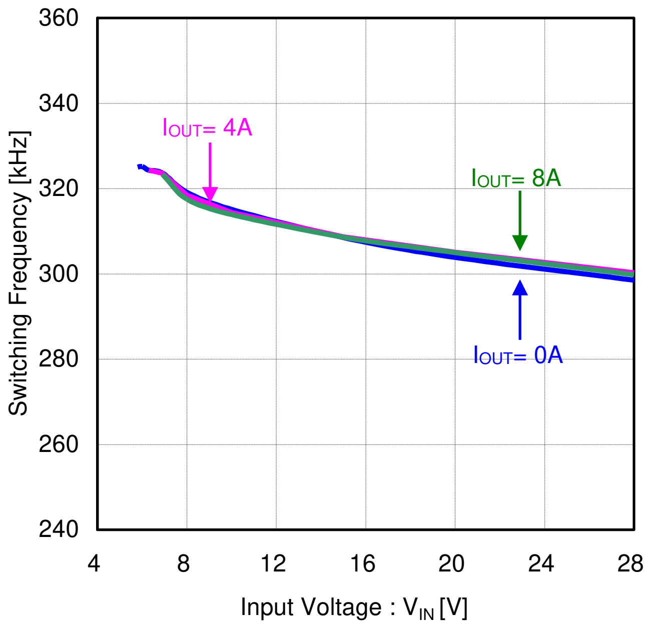


Figure 44. Switching Frequency vs Input Voltage
(V_{OUT}=5V, FREQ=L(300kHz))

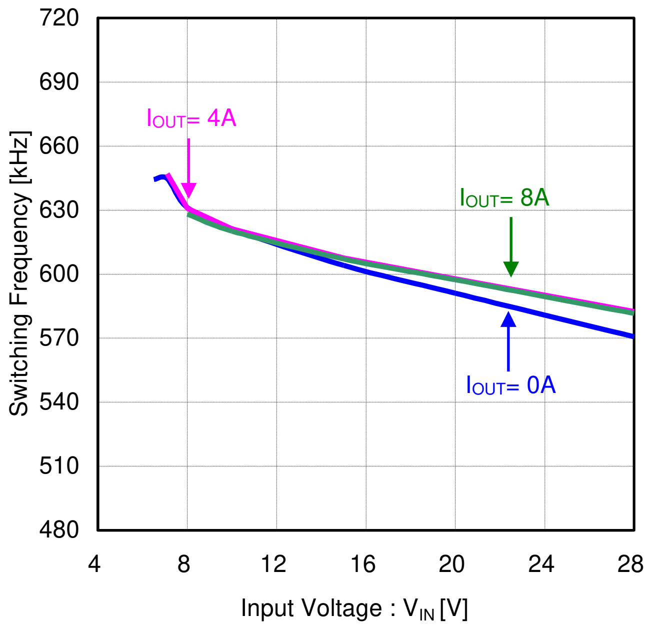


Figure 45. Switching Frequency vs Input Voltage
(V_{OUT}=5V, FREQ=H(600kHz))

Function Explanations

1. Basic Operation

(1) Constant On Time Control

BD9F800MUX-Z is a single synchronous buck switching regulator employing a constant on-time control system.
It controls the on-time by using the duty ratio of V_{OUT} /V_{IN} inside device so that a switching frequency becomes 300 kHz or 600 kHz. Therefore it runs with the frequency of 300 kHz or 600 kHz under the constant on-time decided with V_{OUT} / V_{IN}.

(2) Enable Control

The device shutdown can be controlled by the voltage applied to the EN terminal. When V_{EN} reaches 2.3 V(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 100 µs or longer. Startup by EN must be at the same time or after the input of power supply voltage.

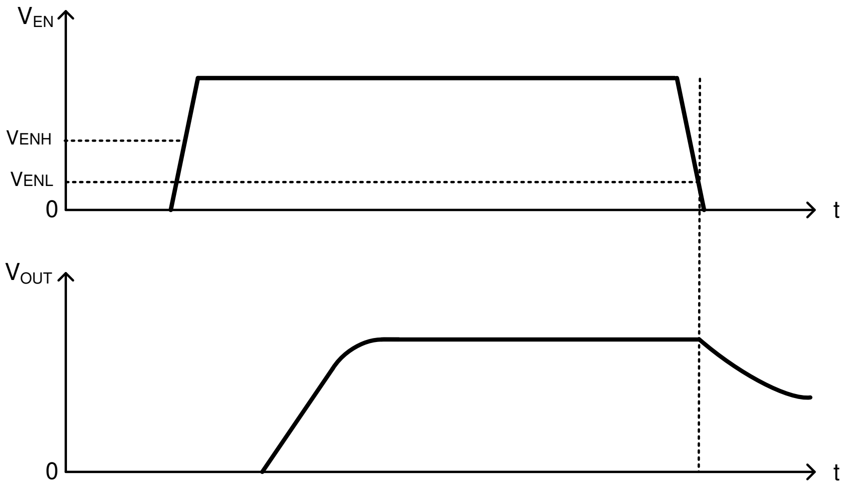


Figure 46. Start Up and Shut Down with Enable

(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).

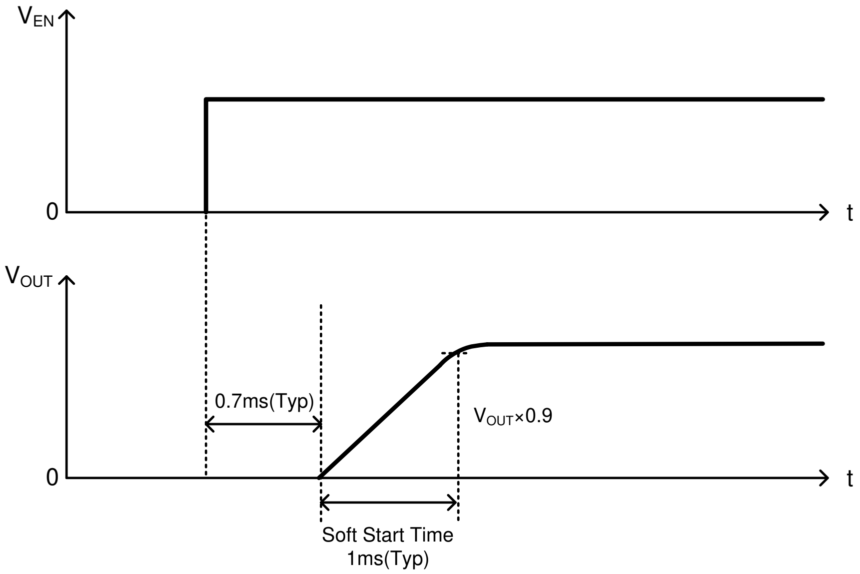


Figure 47. Soft Start Timing Chart

(4) Power Good Output

When the output voltage reaches within ±7% (Typ) of the set voltage, the open drain Nch MOSFET internally connected to the PGD terminal turns off and the PGD terminal goes into Hi-Z state. When the output voltage goes beyond ±10% (Typ) of the set voltage, the open drain Nch MOSFET turns on and PGD terminal turns Low by a 500Ω (Typ) pull-down resistor. Connecting a pull up resistor of about 20kΩ to 100kΩ is recommended.

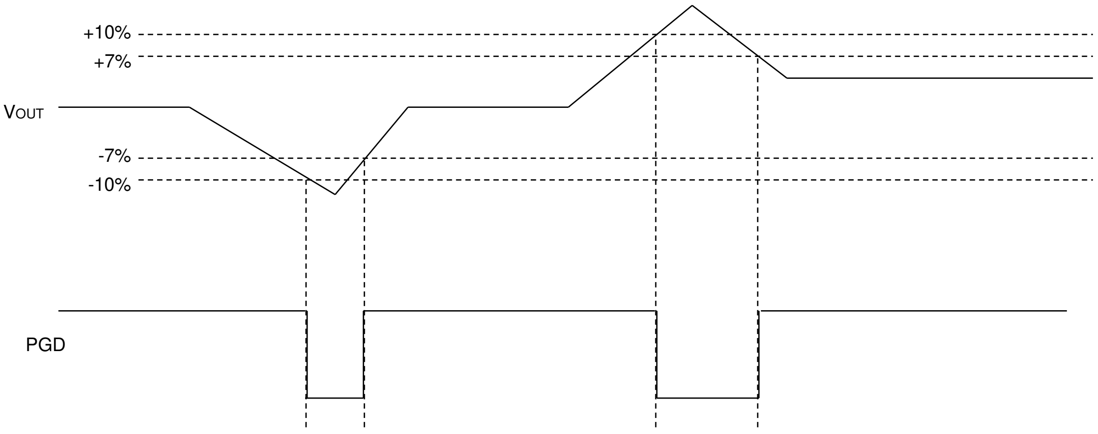


Figure 48. PGD Timing Chart

2. Protective Functions

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, Short Circuit Protection (OCPL, SCP)

Over current protection function limits the current flowing through the Low-Side MOSFET for every switching period. If the inductor current exceeds the source current limit threshold value I_{OCP} 11.5A(Typ) while Low-Side MOSFET is ON, the Low-Side MOSFET remains ON even with FB voltage is lower than the REF voltage. The Low-Side MOSFET keeps ON until inductor current becomes lower than I_{OCP} and High-Side MOSFET will turn ON. As a result both frequency and duty fluctuates and output voltage may decrease.
In a case where output decreases because of OCP, output may rise after OCP is released due to the action at high speed load response.
When the FB voltage falls below 0.38V(Typ) and its state continues for 250µs(Typ), the operation stops and restart in hiccup mode after 8 ms(Typ).

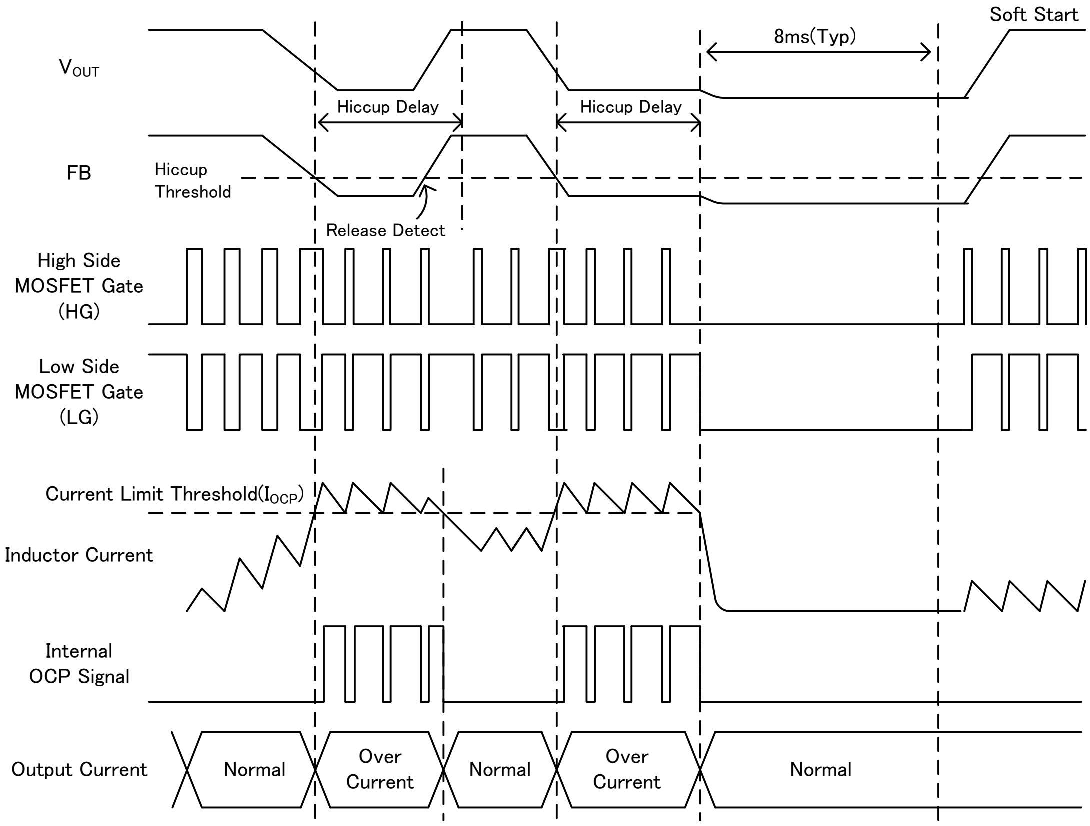


Figure 49. Over current protection timing chart

(2) Low Side Sink Over Current Protection (RCP)

When inductor current exceeds the sink current limit threshold value of 3.5A(Typ) while Low-Side MOSFET is ON, the Low-Side MOSFET will turn OFF.

(3) High Side Over Current Protection (OCPH)

When inductor current exceeds the current limit threshold value of 15.5A(Typ) while High-Side MOSFET is ON, the High-Side MOSFET will turn OFF.

(4) Under Voltage Lockout Protection (UVLO)

The operation enters standby when the VIN terminal voltage is 3.8 V (Typ) or lower.
The operation starts when the VIN terminal voltage is 4.2 V (Typ) or higher.

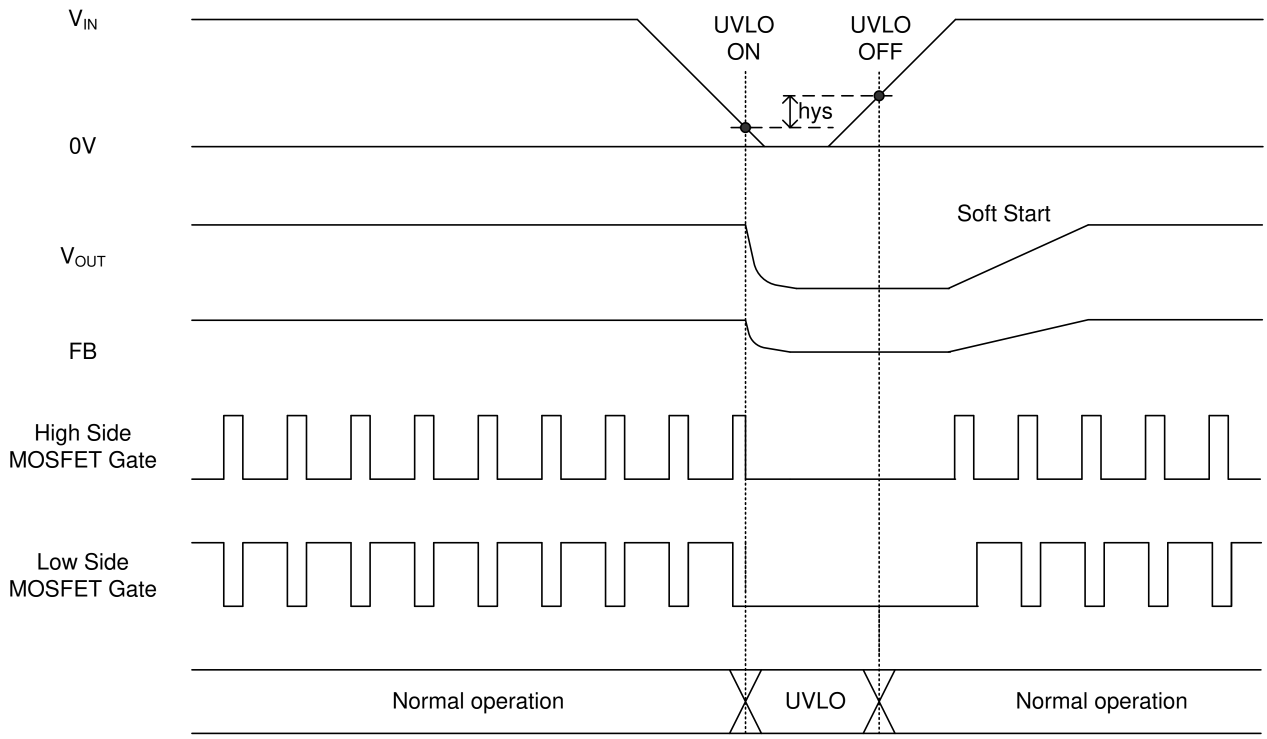


Figure 50. UVLO Timing Chart

(5) Thermal Shutdown Function

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

When thermal shut down circuit operates, the device will shut down and re-start in hiccup mode after 8ms(Typ).

Application Example (V_{OUT}=1V, F_{OSC}=300kHz)

Parameter	Symbol	Value
Input Voltage	V_{IN}	12 V
Output Voltage	V_{OUT}	1 V
Switching Frequency	F_{OSC}	300kHz(Typ)
Maximum Output Current	I_{OMAX}	8A

Caution: Tj must be lower than 150°C under actual operating environment.

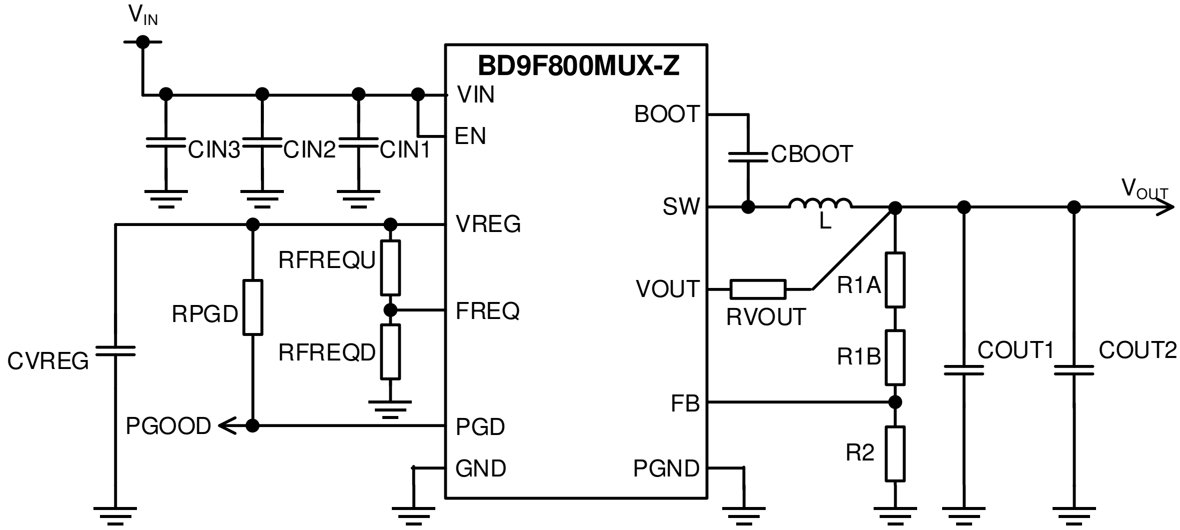


Figure 51. Application Circuit

Table 1. Recommended Component Values

Part No.	Value	Company	Part Name
R1A	0 Ω	ROHM	MCR01MZPJ000
R1B	6.8 kΩ	ROHM	MCR01MZPD6801
R2	22 kΩ	ROHM	MCR01MZPD2202
RPGD	100 kΩ	ROHM	MCR01MZPJ104
RFREQU	-	-	-
RFREQD	10 kΩ	ROHM	MCR01MZPJ103
RVOUT	0 Ω	ROHM	MCR01MZPJ000
CIN1 (Note 1)	0.1 µF	Murata	GRM155R61H104ME14
CIN2 (Note 2)	10 µF	Murata	GRM32ER61H106MA12
CIN3 (Note 2)	10 µF	Murata	GRM32ER61H106MA12
COUT1 (Note 3)	47 µF	Murata	GRM31CR60J476ME19
COUT2 (Note 3)	22 µF	Murata	GRM21BR60J226ME39
CBOOT (Note 4)	0.1 µF	Murata	GRM152R61A104ME19
CVREG (Note 5)	2.2 µF	Murata	GRM188R61A225KE34
L	2.2µH	Murata	FDVE1040-H-2R2M

(Note 1) In order to reduce the influence of high frequency noise, connect a 0.1µF ceramic capacitor as close as possible to the VIN pin and the PGND pin if needed.
(Note 2) 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 10µF(300kHz).
(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 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) For the capacitance of CVREG capacitor, take temperature characteristics, DC bias characteristics, etc. into consideration to set minimum value to no less than 1µF.

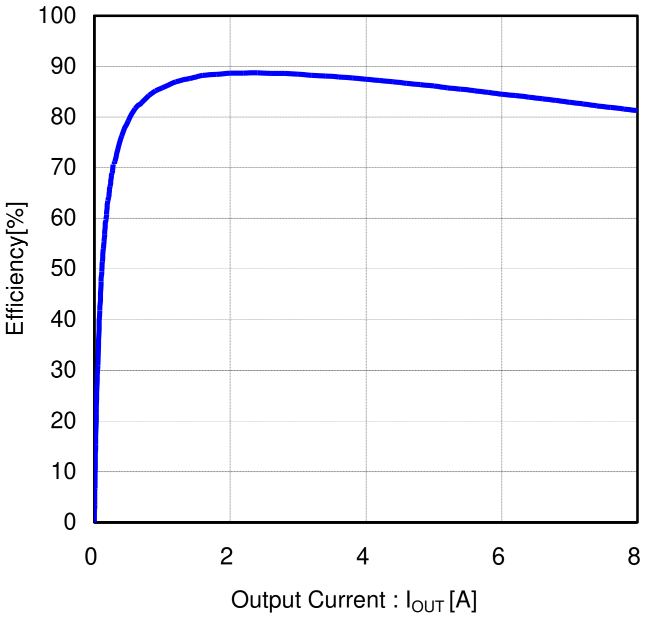


Figure 52. Efficiency vs Output Current
(V_{IN}=12V, V_{OUT}=1V, FREQ=L(300kHz))

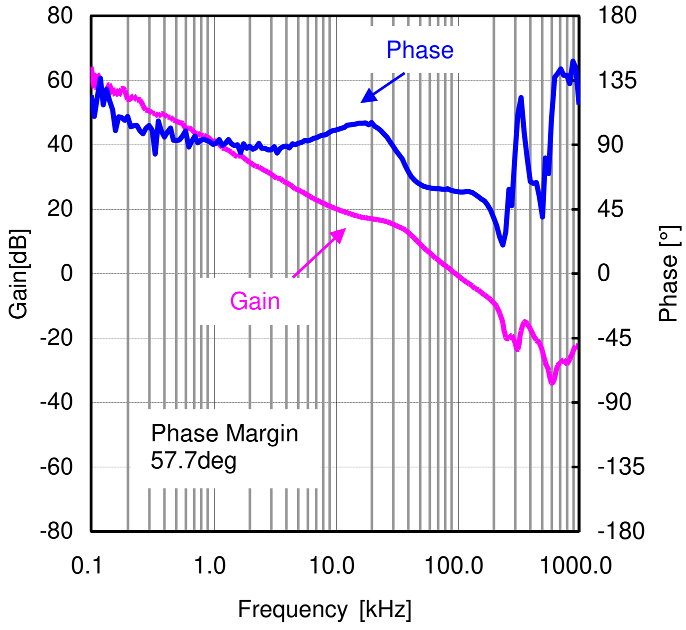


Figure 53. Loop Response I_{OUT}=8A
(V_{IN}=12V, V_{OUT}=1V, FREQ=L(300kHz))

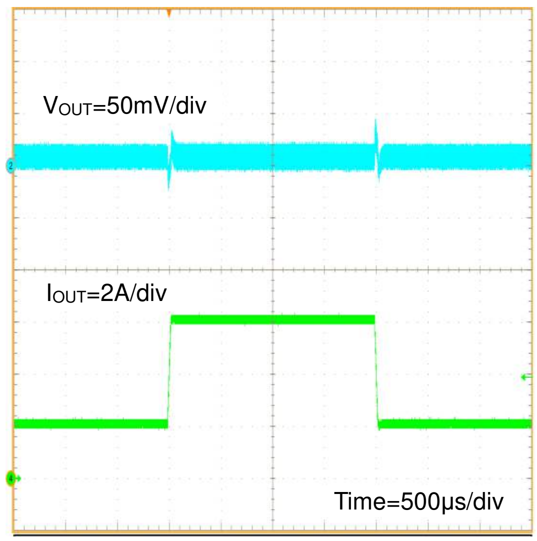


Figure 54. Load Transient Response I_{OUT}=2A - 6A
(V_{IN}=12V, V_{OUT}=1V, FREQ=L(300kHz))

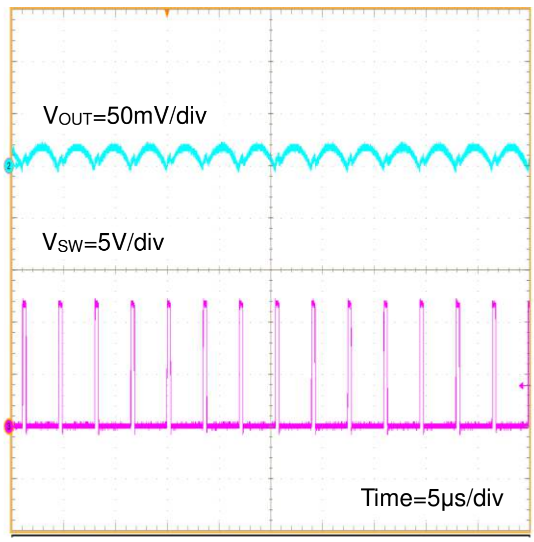


Figure 55. V_{OUT} Ripple I_{OUT}=8A
(V_{IN}=12V, V_{OUT}=1V, FREQ=L(300kHz))

Application Example (V_{OUT}=1V, F_{OSC}=600kHz)

Parameter	Symbol	Value
Input Voltage	V_{IN}	12 V
Output Voltage	V_{OUT}	1 V
Switching Frequency	F_{OSC}	600kHz(Typ)
Maximum Output Current	I_{OMAX}	8A

Caution: Tj must be lower than 150°C under actual operating environment.

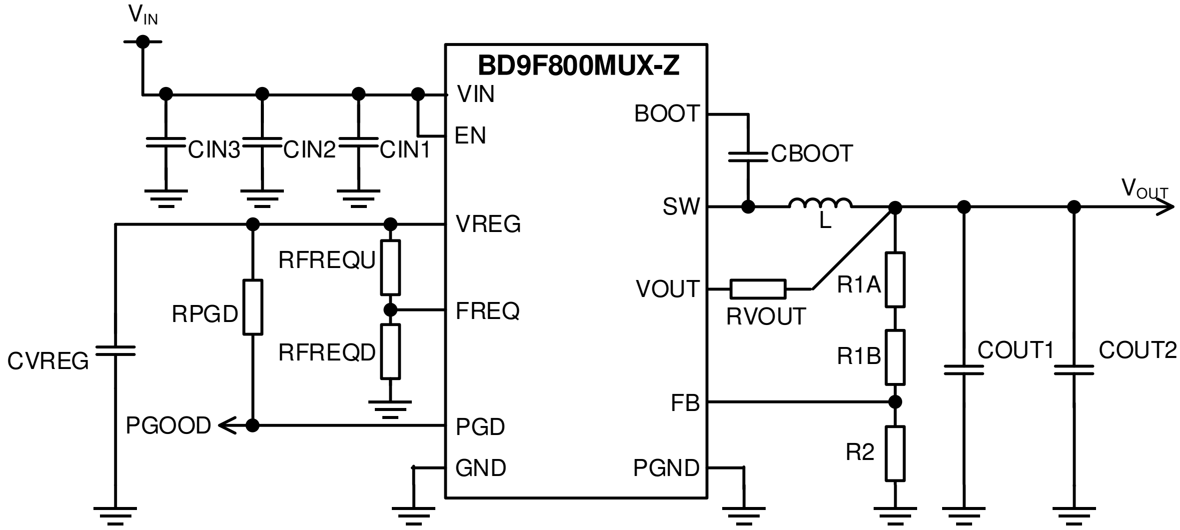


Figure 56. Application Circuit

Table 2. Recommended Component Values

Part No.	Value	Company	Part Name
R1A	0 Ω	ROHM	MCR01MZPJ000
R1B	6.8 kΩ	ROHM	MCR01MZPD6801
R2	22 kΩ	ROHM	MCR01MZPD2202
RPGD	100 kΩ	ROHM	MCR01MZPJ104
RFREQU	10 kΩ	ROHM	MCR01MZPJ103
RFREQD	-	-	-
RVOUT	0 Ω	ROHM	MCR01MZPJ000
CIN1 (Note 1)	0.1 µF	Murata	GRM155R61H104ME14
CIN2 (Note 2)	10 µF	Murata	GRM32ER61H106MA12
CIN3 (Note 2)	10 µF	Murata	GRM32ER61H106MA12
COUT1 (Note 3)	47 µF	Murata	GRM31CR60J476ME19
COUT2 (Note 3)	-	-	-
CBOOT (Note 4)	0.1 µF	Murata	GRM152R61A104ME19
CVREG (Note 5)	2.2 µF	Murata	GRM188R61A225KE34
L	1.0µH	Murata	FDUE1040D-H-1R0M

(Note 1) In order to reduce the influence of high frequency noise, connect a 0.1µF ceramic capacitor as close as possible to the VIN pin and the PGND pin if needed.
(Note 2) 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 6µF(600kHz).
(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 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) For the capacitance of CVREG capacitor, take temperature characteristics, DC bias characteristics, etc. into consideration to set minimum value to no less than 1µF.

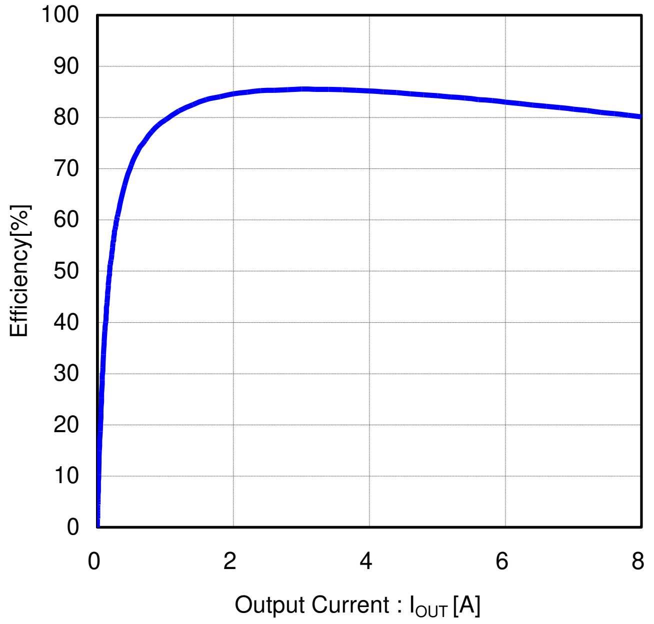


Figure 57. Efficiency vs Output Current
(V_{IN}=12V, V_{OUT}=1V, FREQ=H(600kHz))

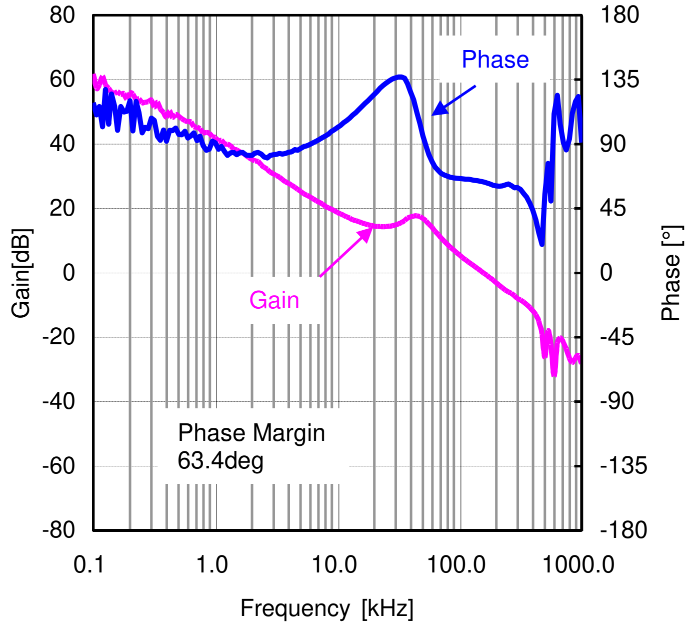


Figure 58. Loop Response I_{OUT}=8A
(V_{IN}=12V, V_{OUT}=1V, FREQ=H(600kHz))

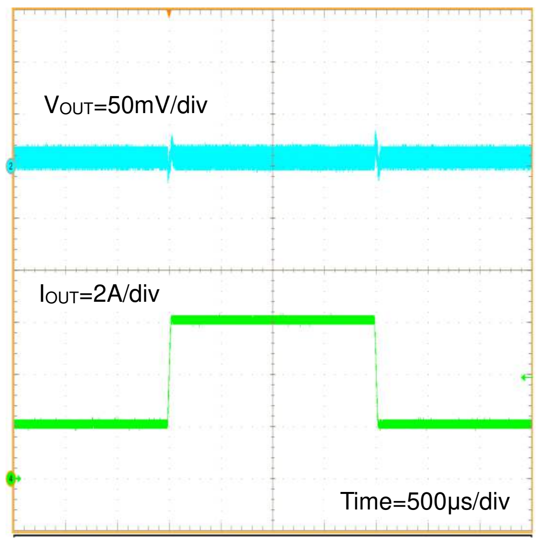


Figure 59. Load Transient Response I_{OUT}=2A - 6A
(V_{IN}=12V, V_{OUT}=1V, FREQ=H(600kHz))

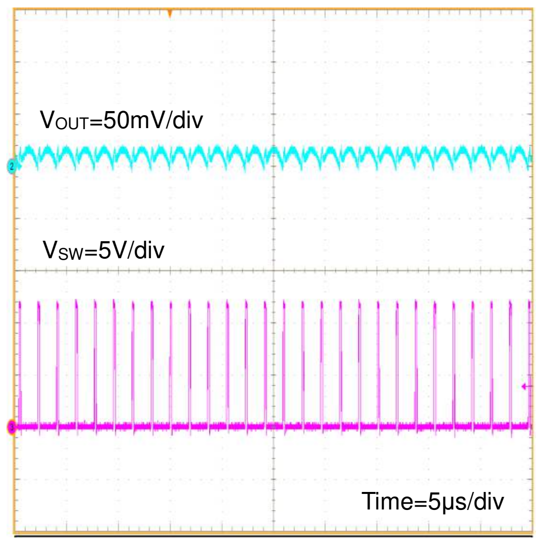


Figure 60. V_{OUT} Ripple I_{OUT}=8A
(V_{IN}=12V, V_{OUT}=1V, FREQ=H(600kHz))

Application Example (V_{OUT}=1.2V, F_{OSC}=300kHz)

Parameter	Symbol	Value
Input Voltage	V_{IN}	12 V
Output Voltage	V_{OUT}	1.2 V
Switching Frequency	F_{OSC}	300kHz(Typ)
Maximum Output Current	I_{OMAX}	8A

Caution: Tj must be lower than 150°C under actual operating environment.

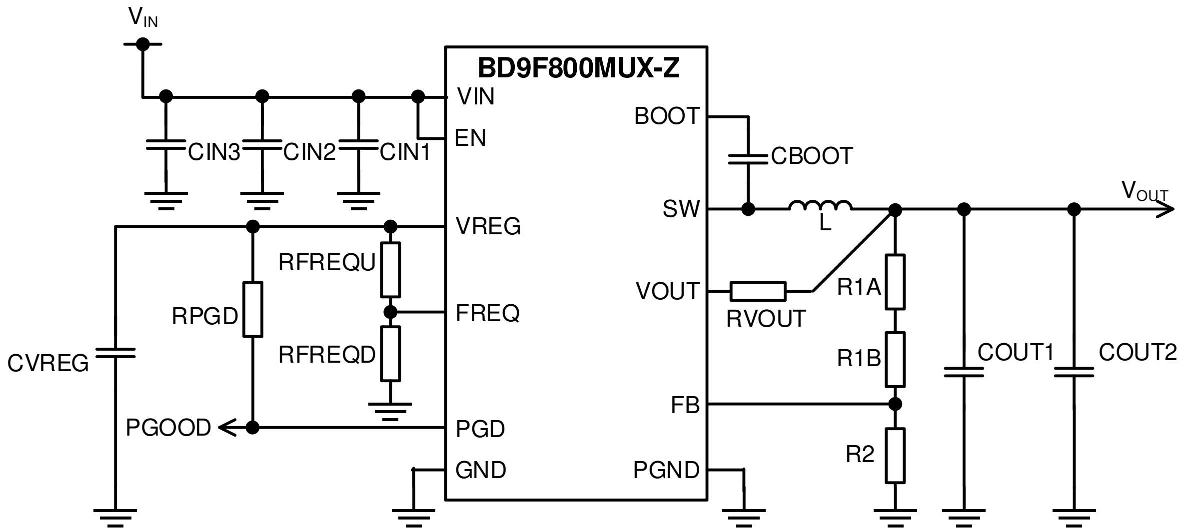


Figure 61. Application Circuit

Table 3. Recommended Component Values

Part No.	Value	Company	Part Name
R1A	0 Ω	ROHM	MCR01MZPJ000
R1B	6.8 kΩ	ROHM	MCR01MZPD6801
R2	12 kΩ	ROHM	MCR01MZPD1202
RPGD	100 kΩ	ROHM	MCR01MZPJ104
RFREQU	-	-	-
RFREQD	10 kΩ	ROHM	MCR01MZPJ103
RVOUT	0 Ω	ROHM	MCR01MZPJ000
CIN1 (Note 1)	0.1 μF	Murata	GRM155R61H104ME14
CIN2 (Note 2)	10 μF	Murata	GRM32ER61H106MA12
CIN3 (Note 2)	10 μF	Murata	GRM32ER61H106MA12
COUT1 (Note 3)	47 μF	Murata	GRM31CR60J476ME19
COUT2 (Note 3)	22 μF	Murata	GRM21BR60J226ME39
CBOOT (Note 4)	0.1 μF	Murata	GRM152R61A104ME19
CVREG (Note 5)	2.2 μF	Murata	GRM188R61A225KE34
L	2.2μH	Murata	FDVE1040-H-2R2M

(Note 1) In order to reduce the influence of high frequency noise, connect a 0.1μF ceramic capacitor as close as possible to the VIN pin and the PGND pin if needed.
(Note 2) 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 10μF(300kHz).
(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 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) For the capacitance of CVREG capacitor, take temperature characteristics, DC bias characteristics, etc. into consideration to set minimum value to no less than 1μF.

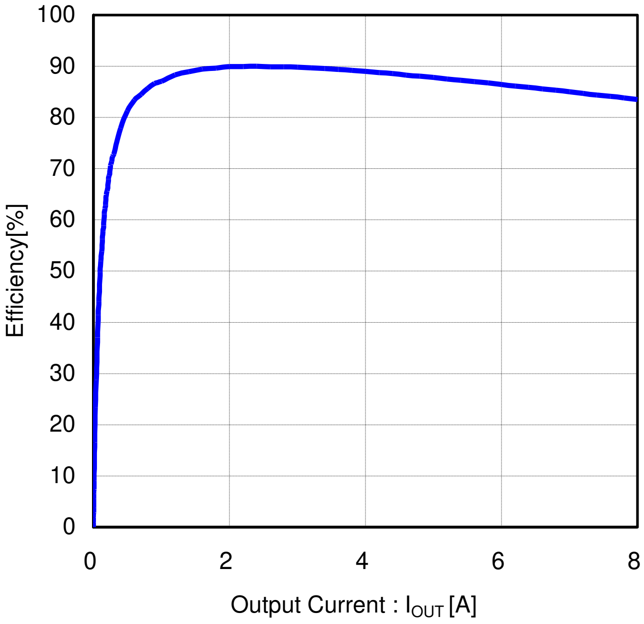


Figure 62. Efficiency vs Output Current
(V_{IN}=12V, V_{OUT}=1.2V, FREQ=L(300kHz))

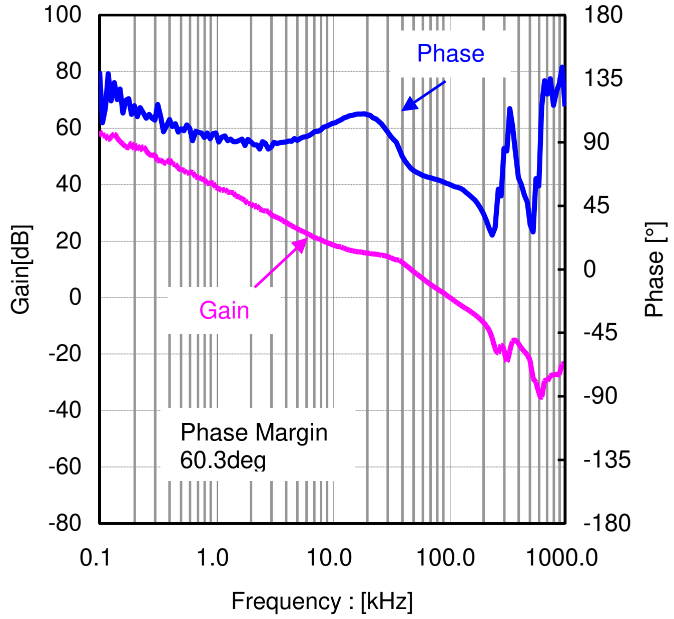


Figure 63. Loop Response I_{OUT}=8A
(V_{IN}=12V, V_{OUT}=1.2V, FREQ=L(300kHz))

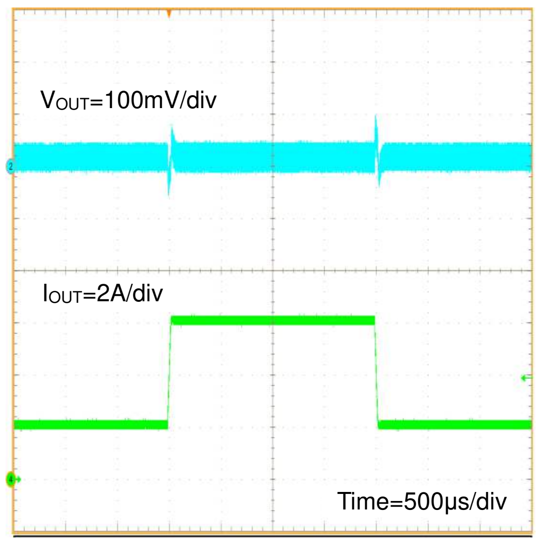


Figure 64. Load Transient Response I_{OUT}=2A - 6A
(V_{IN}=12V, V_{OUT}=1.2V, FREQ=L(300kHz))

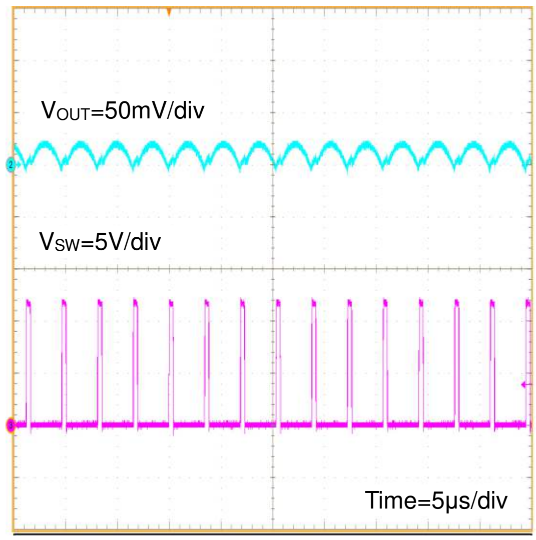


Figure 65. V_{OUT} Ripple I_{OUT}=8A
(V_{IN}=12V, V_{OUT}=1.2V, FREQ=L(300kHz))

Application Example (V_{OUT}=1.2V, F_{OSC}=600kHz)

Parameter	Symbol	Value
Input Voltage	V_{IN}	12 V
Output Voltage	V_{OUT}	1.2 V
Switching Frequency	F_{OSC}	600kHz(Typ)
Maximum Output Current	I_{OMAX}	8A

Caution: Tj must be lower than 150°C under actual operating environment.

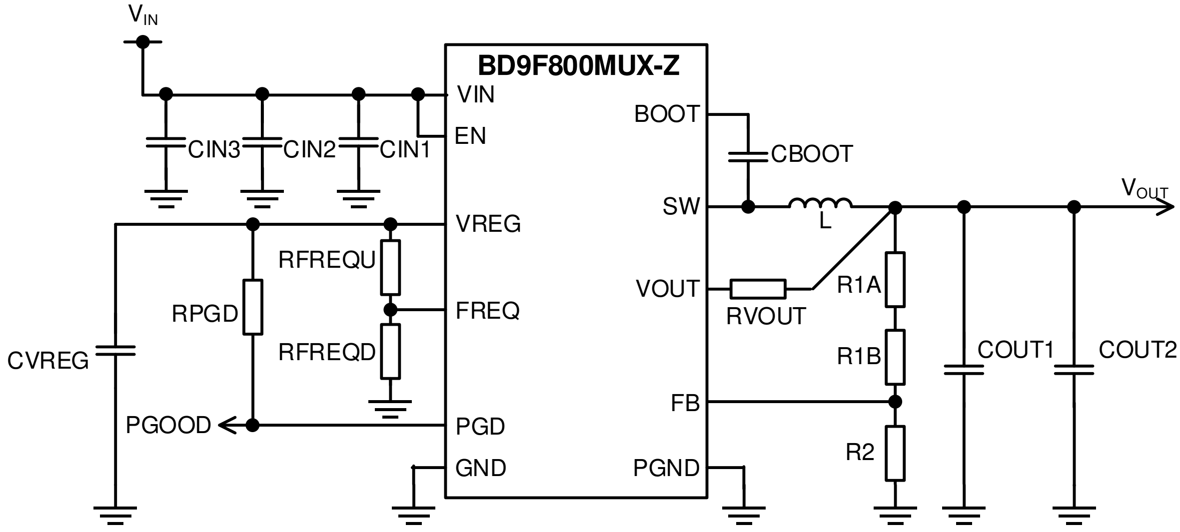


Figure 66. Application Circuit

Table 4. Recommended Component Values

Part No.	Value	Company	Part Name
R1A	0 Ω	ROHM	MCR01MZPJ000
R1B	6.8 kΩ	ROHM	MCR01MZPD6801
R2	12 kΩ	ROHM	MCR01MZPD1202
RPGD	100 kΩ	ROHM	MCR01MZPJ104
RFREQU	10 kΩ	ROHM	MCR01MZPJ103
RFREQD	-	-	-
RVOUT	0 Ω	ROHM	MCR01MZPJ000
CIN1 (Note 1)	0.1 µF	Murata	GRM155R61H104ME14
CIN2 (Note 2)	10 µF	Murata	GRM32ER61H106MA12
CIN3 (Note 2)	10 µF	Murata	GRM32ER61H106MA12
COUT1 (Note 3)	47 µF	Murata	GRM31CR60J476ME19
COUT2 (Note 3)	-	-	-
CBOOT (Note 4)	0.1 µF	Murata	GRM152R61A104ME19
CVREG (Note 5)	2.2 µF	Murata	GRM188R61A225KE34
L	1.0µH	Murata	FDUE1040D-H-1R0M

(Note 1) In order to reduce the influence of high frequency noise, connect a 0.1µF ceramic capacitor as close as possible to the VIN pin and the PGND pin if needed.

(Note 2) 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 6µF(600kHz).

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

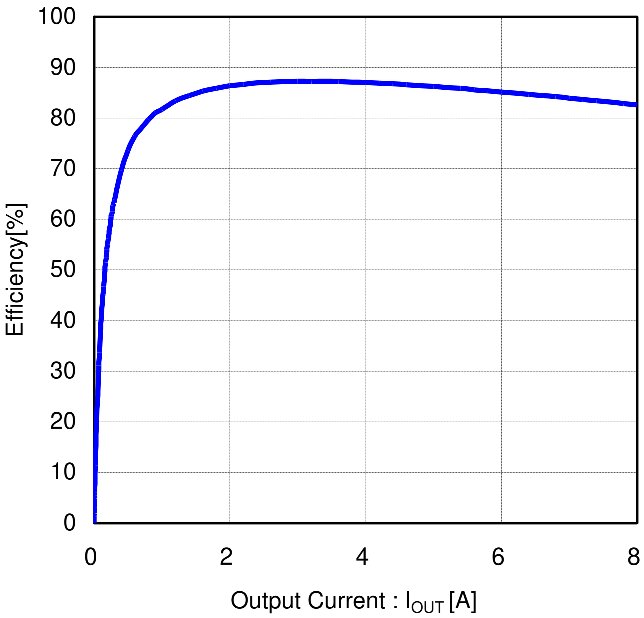


Figure 67. Efficiency vs Output Current
(V_{IN}=12V, V_{OUT}=1.2V, FREQ=H(600kHz))

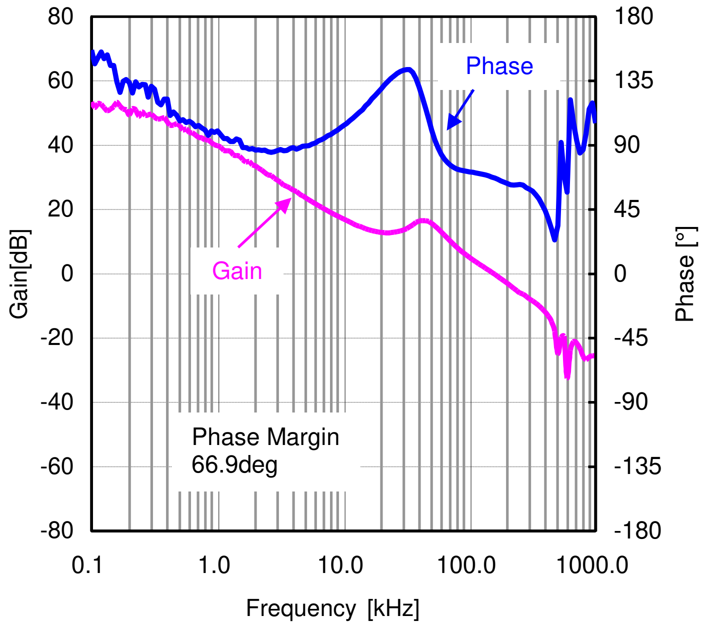


Figure 68. Loop Response I_{OUT}=8A
(V_{IN}=12V, V_{OUT}=1.2V, FREQ=H(600kHz))

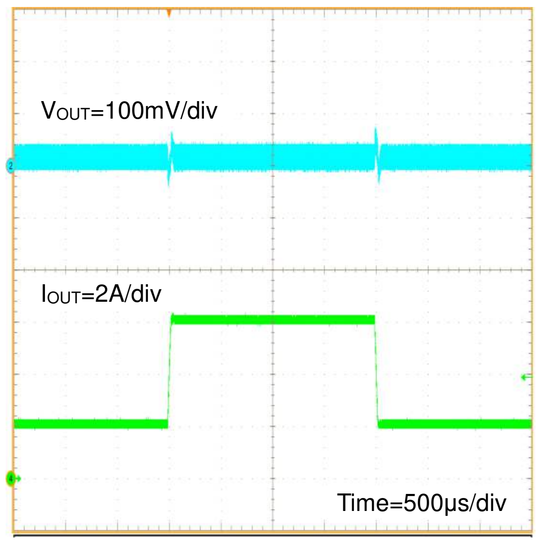


Figure 69. Load Transient Response I_{OUT}=2A - 6A
(V_{IN}=12V, V_{OUT}=1.2V, FREQ=H(600kHz))

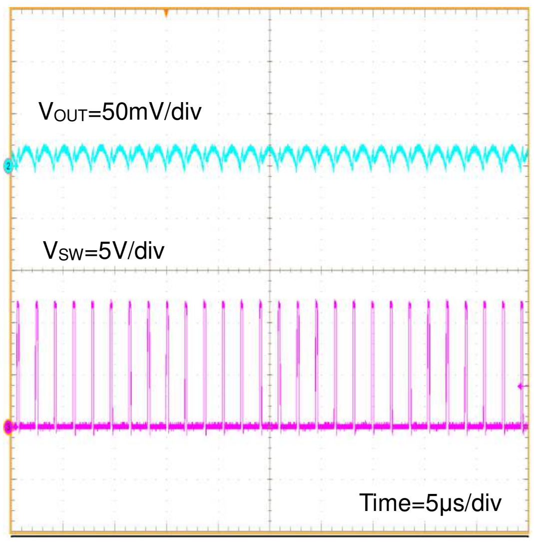


Figure 70. V_{OUT} Ripple I_{OUT}=8A
(V_{IN}=12V, V_{OUT}=1.2V, FREQ=H(600kHz))

Application Example (V_{OUT}=3.3V, F_{OSC}=300kHz)

Parameter	Symbol	Value
Input Voltage	V_{IN}	12 V
Output Voltage	V_{OUT}	3.3 V
Switching Frequency	F_{OSC}	300kHz(Typ)
Maximum Output Current	I_{OMAX}	8A

Caution: Tj must be lower than 150°C under actual operating environment.

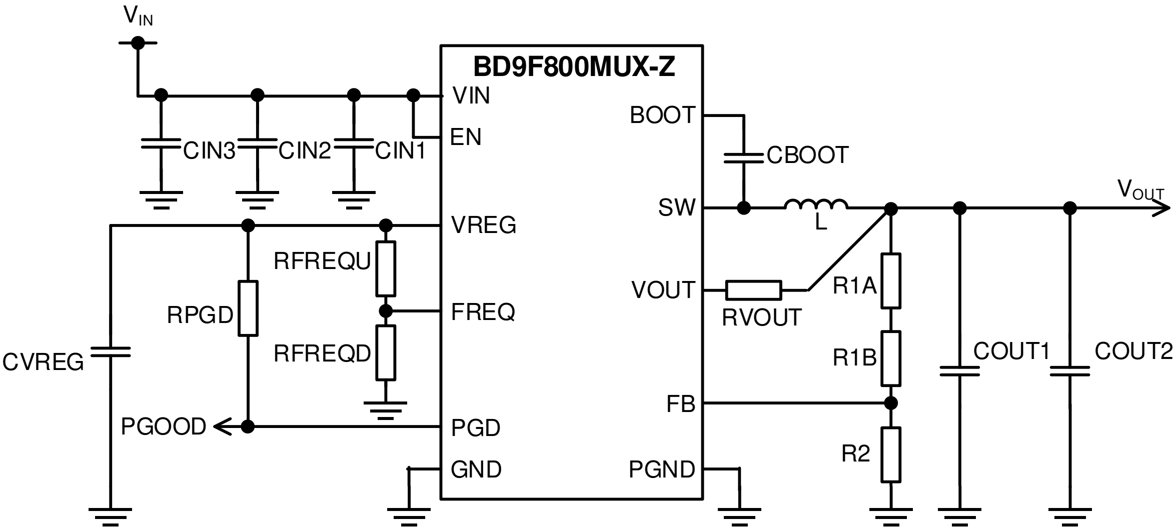


Figure 71. Application Circuit

Table 5. Recommended Component Values

Part No.	Value	Company	Part Name
R1A	5.1 kΩ	ROHM	MCR01MZPD5101
R1B	68 kΩ	ROHM	MCR01MZPD6802
R2	22 kΩ	ROHM	MCR01MZPD2202
RPGD	100 kΩ	ROHM	MCR01MZPJ104
RFREQU	-	-	-
RFREQD	10 kΩ	ROHM	MCR01MZPJ103
RVOUT	0 Ω	ROHM	MCR01MZPJ000
CIN1 (Note 1)	0.1 μF	Murata	GRM155R61H104ME14
CIN2 (Note 2)	10 μF	Murata	GRM32ER61H106MA12
CIN3 (Note 2)	10 μFV	Murata	GRM32ER61H106MA12
COUT1 (Note 3)	47 μF	Murata	GRM32ER61A476ME20
COUT2 (Note 3)	22 μF	Murata	GRM31CR61A226ME19
CBOOT (Note 4)	0.1 μF	Murata	GRM152R61A104ME19
CVREG (Note 5)	2.2 μF	Murata	GRM188R61A225KE34
L	3.3μH	Murata	FDVE1040-H-3R3M

(Note 1) In order to reduce the influence of high frequency noise, connect a 0.1μF ceramic capacitor as close as possible to the VIN pin and the PGND pin if needed.

(Note 2) 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 10μF(300kHz).

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

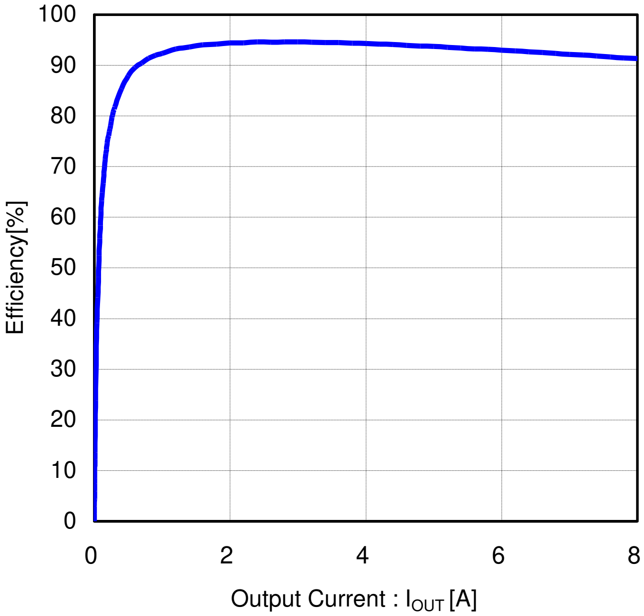


Figure 72. Efficiency vs Output Current
(V_{IN}=12V, V_{OUT}=3.3V, FREQ=L(300kHz))

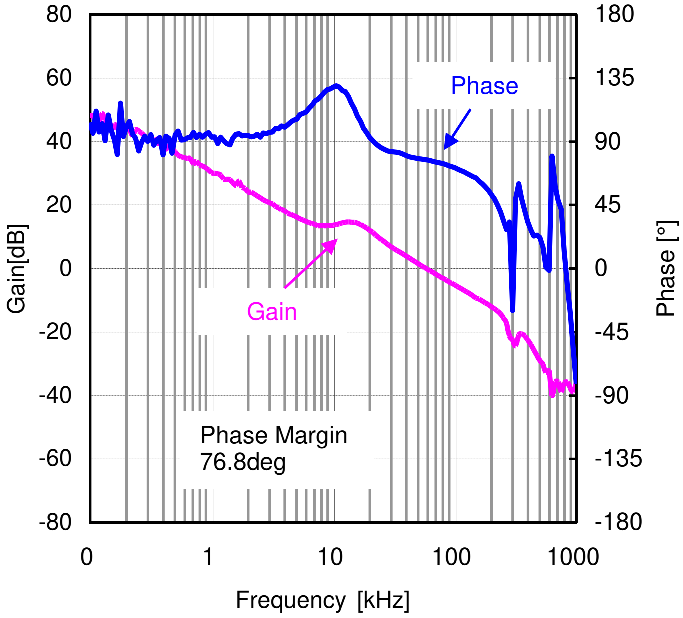


Figure 73. Loop Response I_{OUT}=8A
(V_{IN}=12V, V_{OUT}=3.3V, FREQ=L(300kHz))

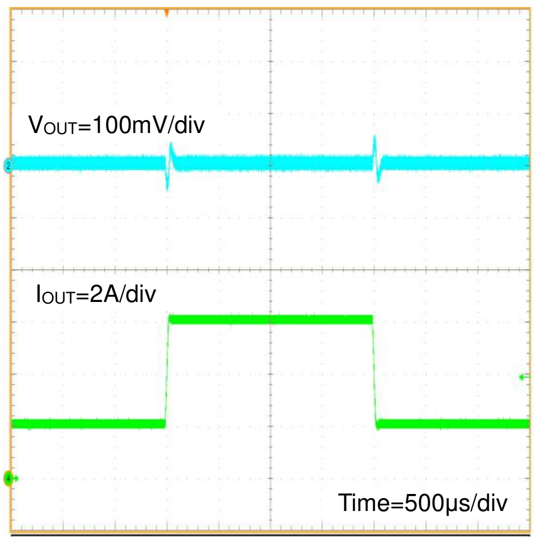


Figure 74. Load Transient Response I_{OUT}=2A - 6A
(V_{IN}=12V, V_{OUT}=3.3V, FREQ=L(300kHz))

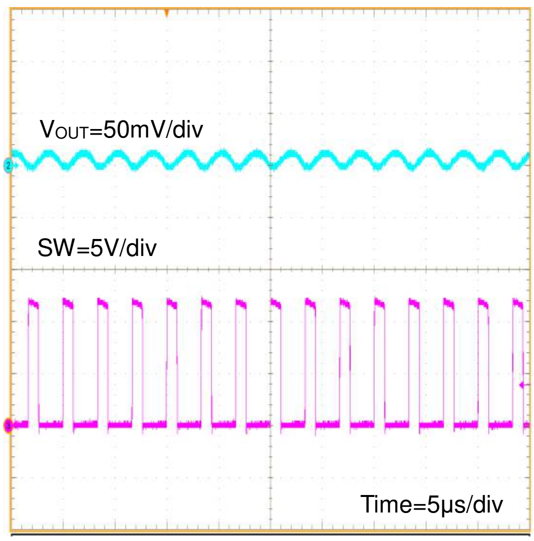


Figure 75. V_{OUT} Ripple I_{OUT}=8A
(V_{IN}=12V, V_{OUT}=3.3V, FREQ=L(300kHz))

Application Example (V_{OUT}=3.3V, F_{OSC}=600kHz)

Parameter	Symbol	Value
Input Voltage	V_{IN}	12 V
Output Voltage	V_{OUT}	3.3 V
Switching Frequency	F_{OSC}	600kHz(Typ)
Maximum Output Current	I_{OMAX}	8A

Caution: Tj must be lower than 150°C under actual operating environment.

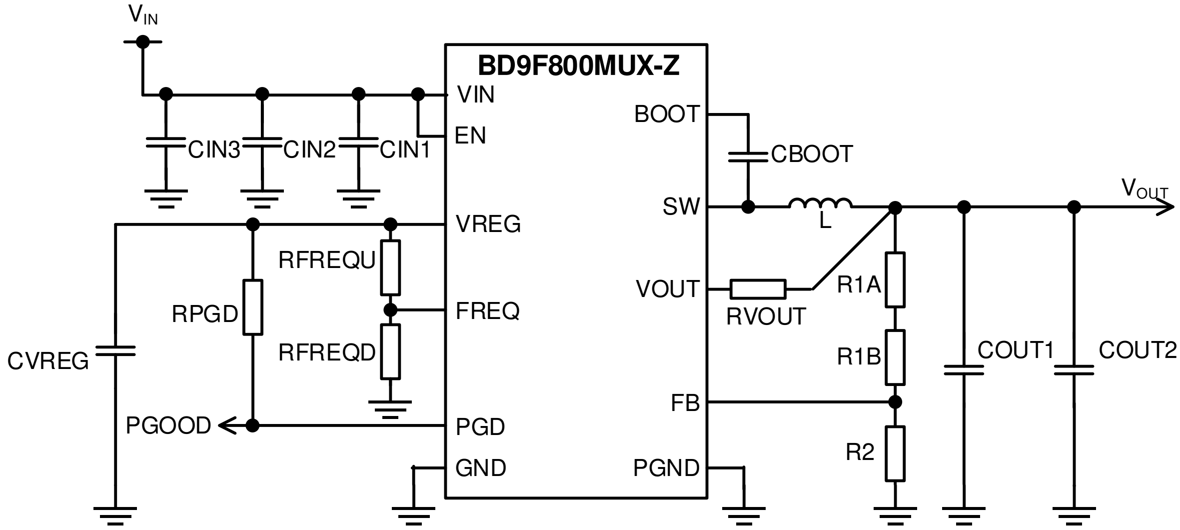


Figure 76. Application Circuit

Table 6. Recommended Component Values

Part No.	Value	Company	Part Name
R1A	5.1 kΩ	ROHM	MCR01MZPD5101
R1B	68 kΩ	ROHM	MCR01MZPD6802
R2	22 kΩ	ROHM	MCR01MZPD2202
RPGD	100 kΩ	ROHM	MCR01MZPJ104
RFREQU	10 kΩ	ROHM	MCR01MZPJ103
RFREQD	-	-	-
RVOUT	0 Ω	ROHM	MCR01MZPJ000
CIN1(Note 1)	0.1 μF	Murata	GRM155R61H104ME14
CIN2(Note 2)	10 μF	Murata	GRM32ER61H106MA12
CIN3(Note 2)	10 μF	Murata	GRM32ER61H106MA12
COUT1(Note 3)	47 μF	Murata	GRM32ER61A476ME20
COUT2(Note 3)	-	-	-
CBOOT(Note 4)	0.1 μF	Murata	GRM152R61A104ME19
CVREG(Note 5)	2.2 μF	Murata	GRM188R61A225KE34
L	1.5μH	Murata	FDVE1040-H-1R5M

(Note 1) In order to reduce the influence of high frequency noise, connect a 0.1μF ceramic capacitor as close as possible to the VIN pin and the PGND pin if needed.
(Note 2) 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 6μF(600kHz).
(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 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) For the capacitance of CVREG capacitor, take temperature characteristics, DC bias characteristics, etc. into consideration to set minimum value to no less than 1μF.

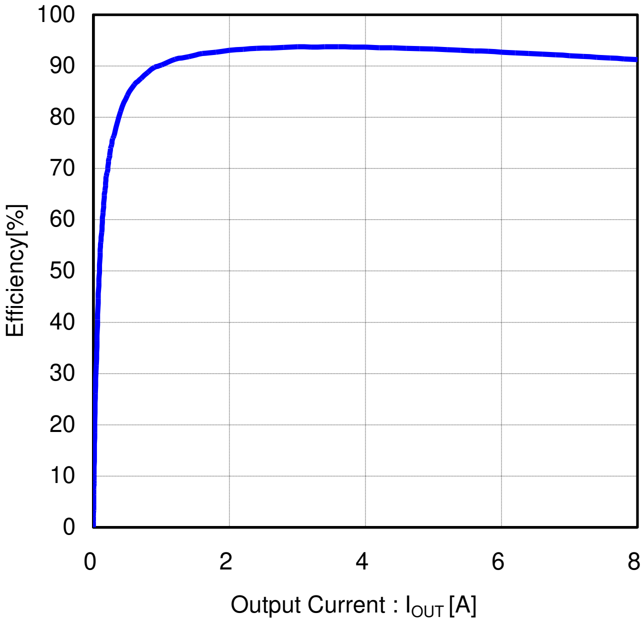


Figure 77. Efficiency vs Output Current
(V_{IN}=12V, V_{OUT}=3.3V, FREQ=H(600kHz))

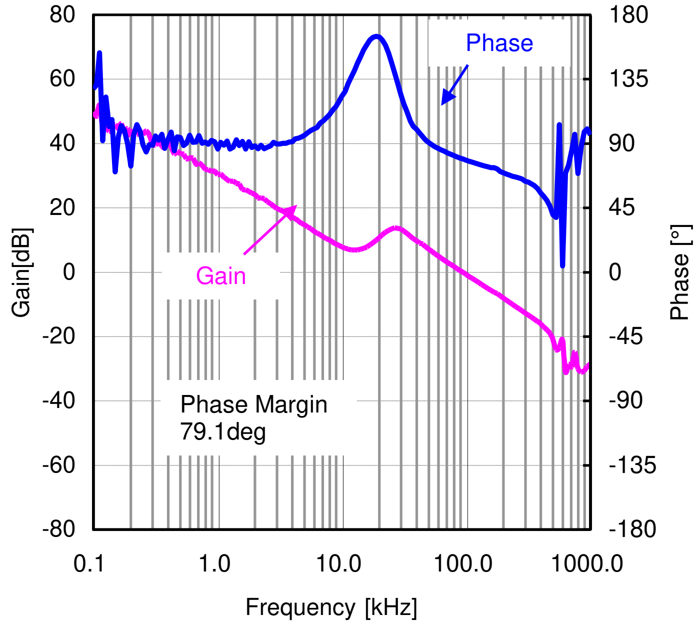


Figure 78. Loop Response I_{OUT}=8A
(V_{IN}=12V, V_{OUT}=3.3V, FREQ=H(600kHz))

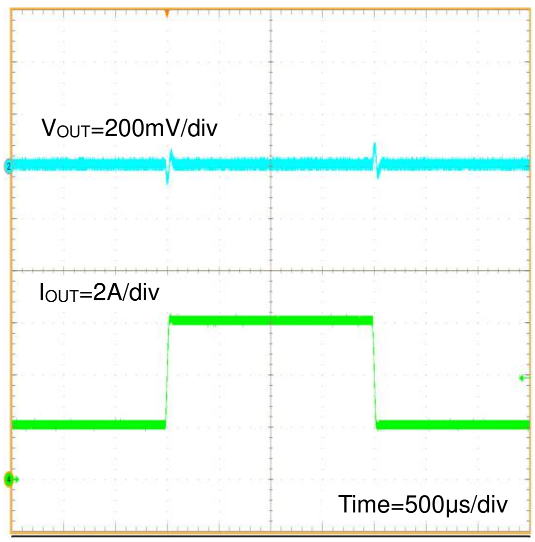


Figure 79. Load Transient Response I_{OUT}=2A - 6A
(V_{IN}=12V, V_{OUT}=3.3V, FREQ=H(600kHz))

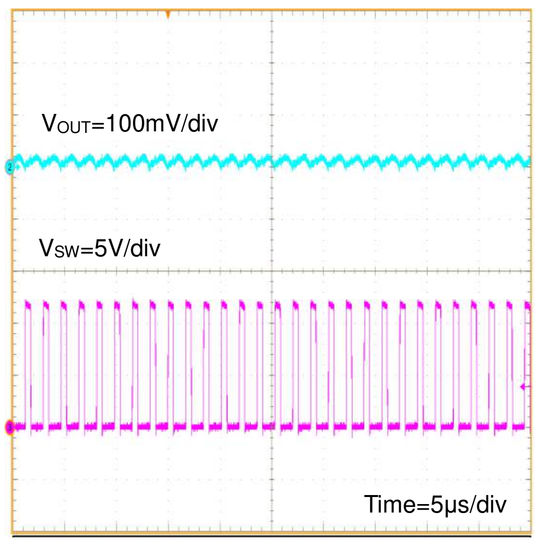


Figure 80. V_{OUT} Ripple I_{OUT}=8A
(V_{IN}=12V, V_{OUT}=3.3V, FREQ=H(600kHz))

Application Example (V_{OUT}=5V, F_{OSC}=300kHz)

Parameter	Symbol	Value
Input Voltage	V_{IN}	12 V
Output Voltage	V_{OUT}	5 V
Switching Frequency	F_{OSC}	300kHz(Typ)
Maximum Output Current	I_{OMAX}	8A

Caution: Tj must be lower than 150°C under actual operating environment.

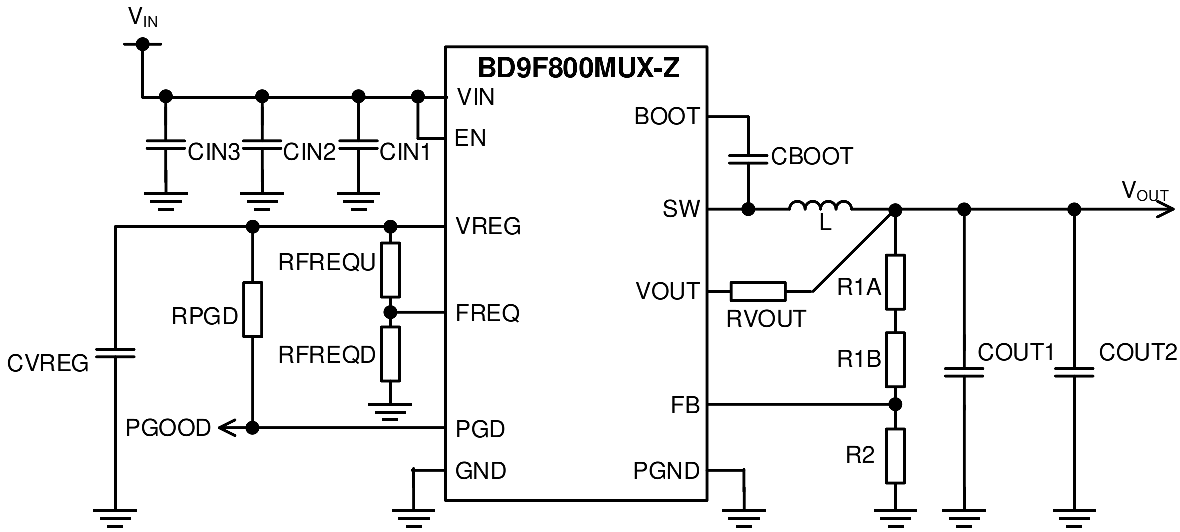


Figure 81. Application Circuit

Table 7. Recommended Component Values

Part No.	Value	Company	Part Name
R1A	8.2k Ω	ROHM	MCR01MZPD8201
R1B	47 kΩ	ROHM	MCR01MZPD4702
R2	10 kΩ	ROHM	MCR01MZPD1002
RPGD	100 kΩ	ROHM	MCR01MZPJ104
RFREQU	-	-	-
RFREQD	10 kΩ	ROHM	MCR01MZPJ103
RVOUT	10 Ω	ROHM	MCR01MZPJ100
CIN1(Note 1)	0.1 µF	Murata	GRM155R61H104ME14
CIN2(Note 2)	10 µF	Murata	GRM32ER61H106MA12
CIN3(Note 2)	10 µF	Murata	GRM32ER61H106MA12
COUT1(Note 3)	47 µF	Murata	GRM32ER61A476ME20
COUT2(Note 3)	22 µF	Murata	GRM31CR61A226ME19
CBOOT(Note 4)	0.1 µF	Murata	GRM152R61A104ME19
CVREG(Note 5)	2.2 µF	Murata	GRM188R61A225KE34
L	4.7µH	Murata	FDVE1040-H-4R7M

(Note 1) In order to reduce the influence of high frequency noise, connect a 0.1µF ceramic capacitor as close as possible to the VIN pin and the PGND pin if needed.
(Note 2) 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 10µF(300kHz).
(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 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) For the capacitance of CVREG capacitor, take temperature characteristics, DC bias characteristics, etc. into consideration to set minimum value to no less than 1µF.

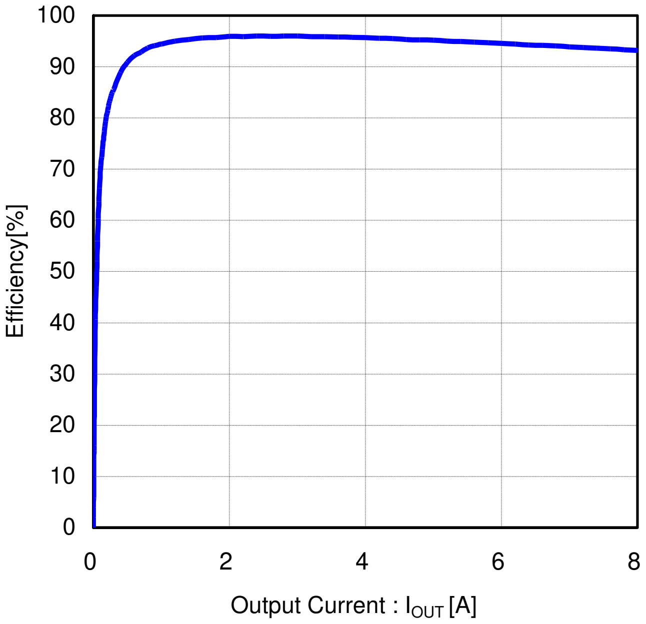


Figure 82. Efficiency vs Output Current
(V_{IN}=12V, V_{OUT}=5V, FREQ=L(300kHz))

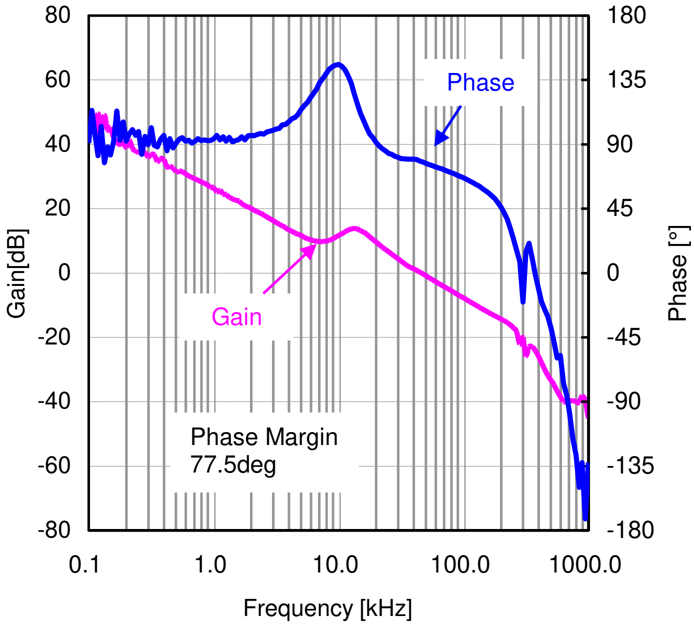


Figure 83. Loop Response I_{OUT}=8A
(V_{IN}=12V, V_{OUT}=5V, FREQ=L(300kHz))

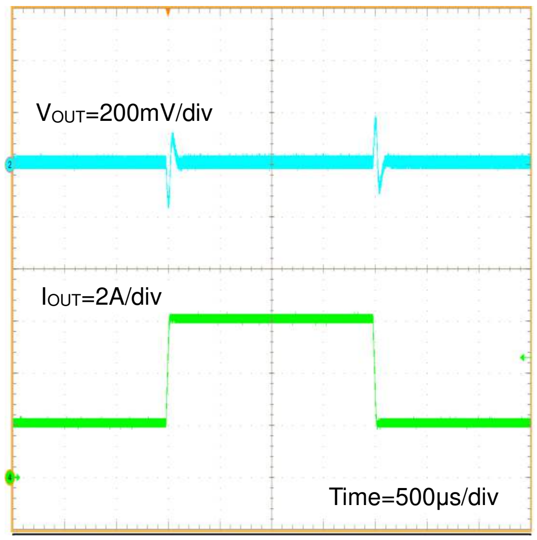


Figure 84. Load Transient Response I_{OUT}=2A - 6A
(V_{IN}=12V, V_{OUT}=5V, FREQ=L(300kHz))

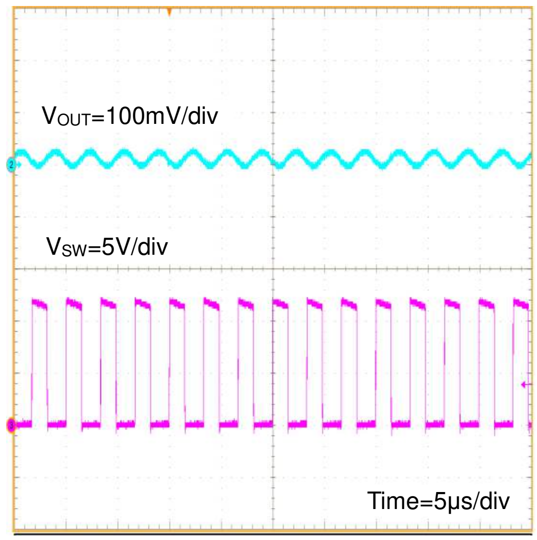


Figure 85. V_{OUT} Ripple I_{OUT}=8A
(V_{IN}=12V, V_{OUT}=5V, FREQ=L(300kHz))

Application Example (V_{OUT}=5V, F_{OSC}=600kHz)

s

Parameter	Symbol	Value
Input Voltage	V_{IN}	12 V
Output Voltage	V_{OUT}	5 V
Switching Frequency	F_{OSC}	600kHz(Typ)
Maximum Output Current	I_{OMAX}	8A

Caution: Tj must be lower than 150°C under actual operating environment.

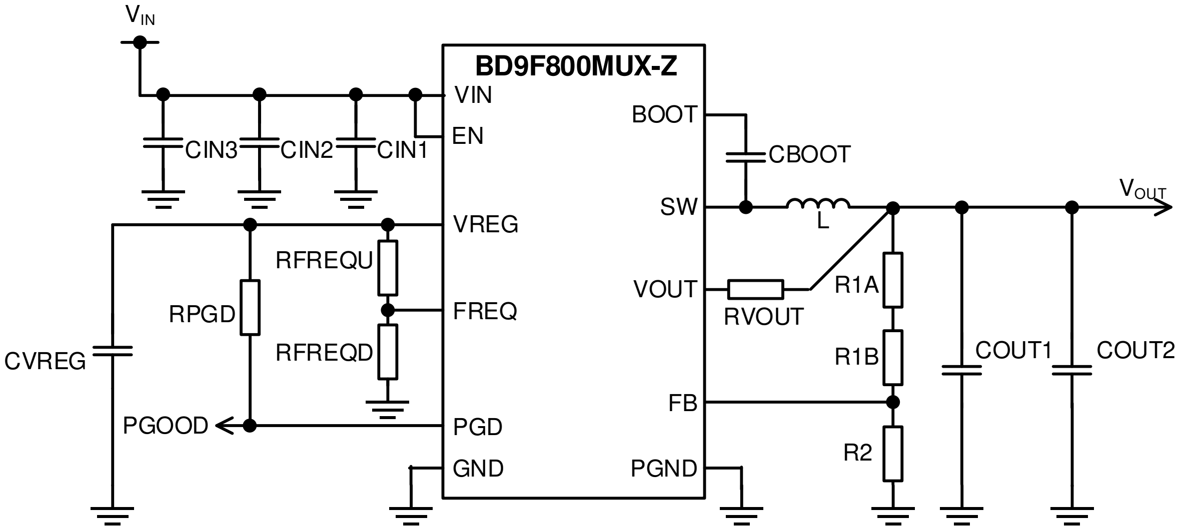


Figure 86. Application Circuit

Table 8. Recommended Component Values

Part No.	Value	Company	Part Name
R1A	8.2k Ω	ROHM	MCR01MZPD8201
R1B	47 kΩ	ROHM	MCR01MZPD4702
R2	10 kΩ	ROHM	MCR01MZPD1002
RPGD	100 kΩ	ROHM	MCR01MZPJ104
RFREQU	10 kΩ	ROHM	MCR01MZPJ103
RFREQD	-	-	-
RVOUT	10 Ω	ROHM	MCR01MZPJ100
CIN1(Note 1)	0.1 µF	Murata	GRM155R61H104ME14
CIN2(Note 2)	10 µF	Murata	GRM32ER61H106MA12
CIN3(Note 2)	10 µF	Murata	GRM32ER61H106MA12
COUT1(Note 3)	47 µF	Murata	GRM32ER61A476ME20
COUT2(Note 3)	-	-	-
CBOOT(Note 4)	0.1 µF	Murata	GRM152R61A104ME19
CVREG(Note 5)	2.2 µF	Murata	GRM188R61A225KE34
L	2.2µH	Murata	FDVE1040-H-2R2M

(Note 1) In order to reduce the influence of high frequency noise, connect a 0.1µF ceramic capacitor as close as possible to the VIN pin and the PGND pin if needed.
(Note 2) 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 6µF(600kHz).
(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 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) For the capacitance of CVREG capacitor, take temperature characteristics, DC bias characteristics, etc. into consideration to set minimum value to no less than 1µF.

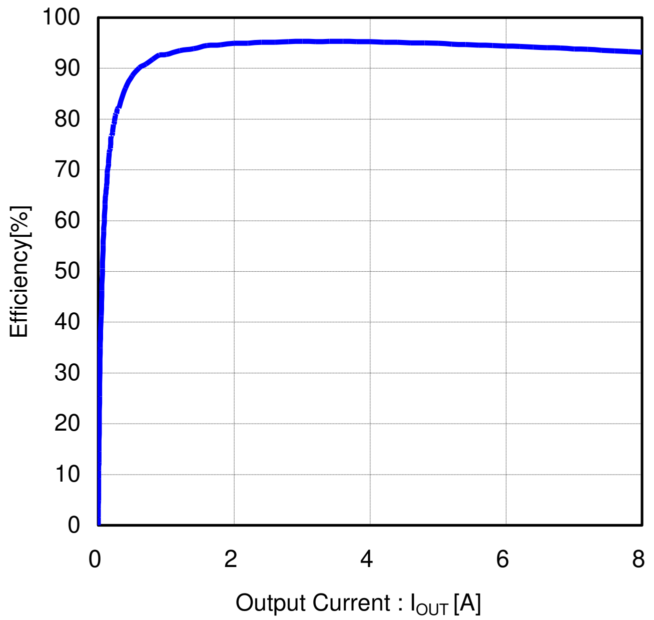


Figure 87. Efficiency vs Output Current
(V_{IN}=12V, V_{OUT}=5V, FREQ=H(600kHz))

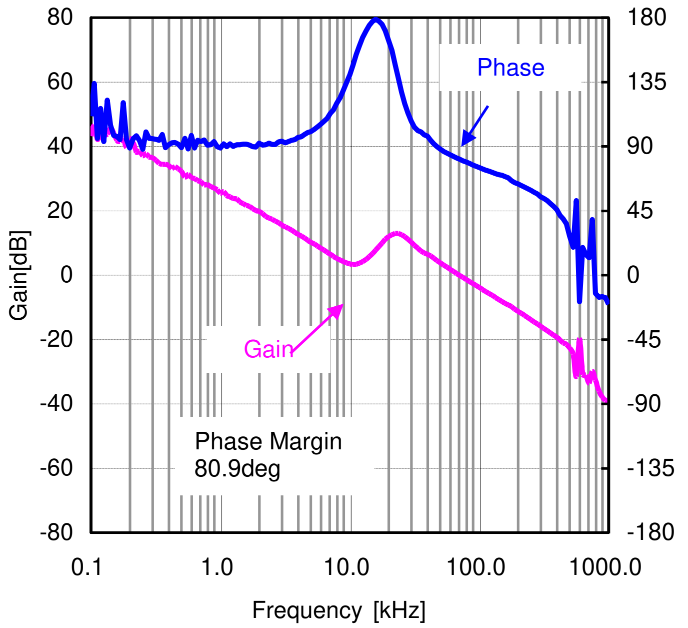


Figure 88. Loop Response I_{OUT}=8A
(V_{IN}=12V, V_{OUT}=5V, FREQ=H(600kHz))

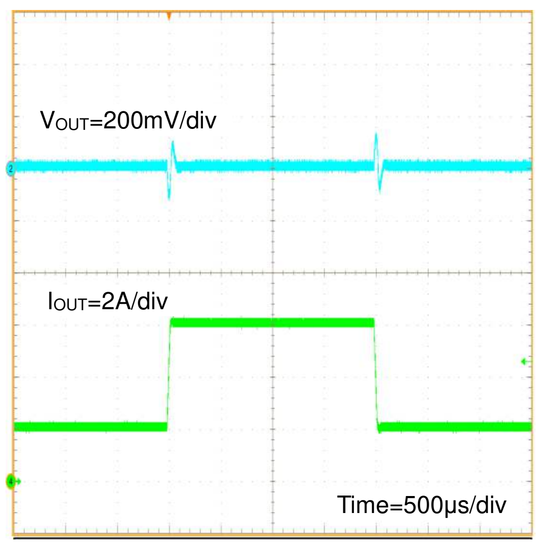


Figure 89. Load Transient Response I_{OUT}=2A - 6A
(V_{IN}=12V, V_{OUT}=5V, FREQ=H(600kHz))

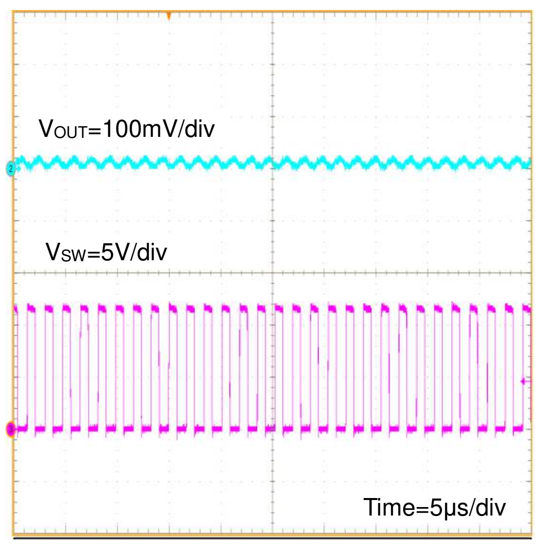


Figure 90. V_{OUT} Ripple I_{OUT}=8A
(V_{IN}=12V, V_{OUT}=5V, FREQ=H(600kHz))

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. The recommended inductance value is listed in Table 9.

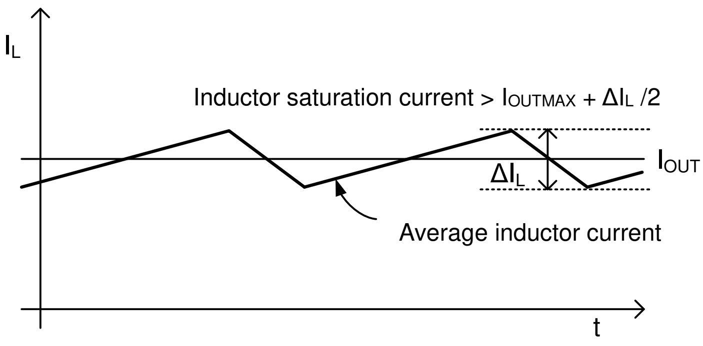


Figure 91. Waveform of current through inductor

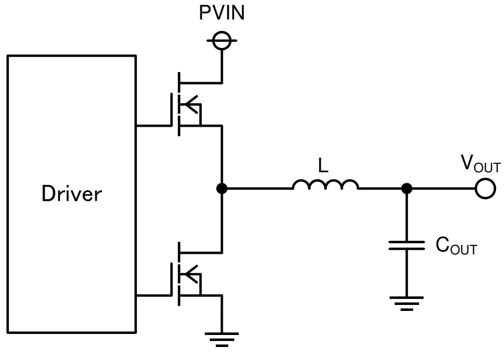


Figure 92. Output LC filter circuit

Inductor ripple current ΔI_L can be represented by the following equation.

$$\Delta I_L = V_{OUT} \times (V_{IN} - V_{OUT}) \times \frac{1}{V_{IN} \times f_{SW} \times L} = 1528 \,[\mathrm{mA}]$$

Where:
V_{IN} = 12V
V_{OUT} = 1.0V
L = 1.0µH
f_{sw} = 600kHz

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.

Table 9. Recommended inductance value

Frequency	Output Voltage				
	1.0V	1.2V	3.3V	5.0V	12V
300kHz	2.2µH	2.2µH	3.3µH	4.7µH	5.6µH
600kHz	1.0µH	1.0µH	1.5µH	2.2µH	3.3µH

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.

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

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 66µF to 100µF(300kHz), or 44µF to 100µF(600kHz).

* 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.

$$\text{Maximum starting inductor bottom ripple current } I_{LSTART} < \text{Current Limit Threshold } 8.5\,[\mathrm{A}]\,(\text{Min})$$

Maximum starting inductor bottom 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.

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

* 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.

2. Output Voltage Setting
The output voltage value can be set by the feedback resistance ratio. Please use resisters of about 1kΩ to 100kΩ.

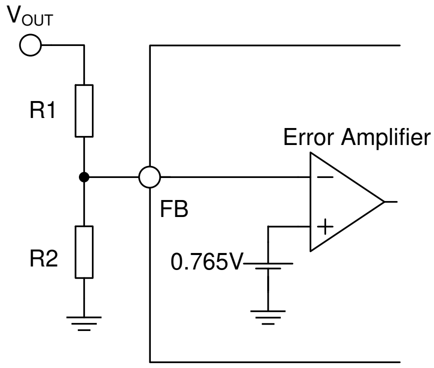


Figure 93. Feedback Resistor Circuit

$$V_{OUT} = \frac{R1 + R2}{R2} \times 0.765 [V]$$

$$R2 = \frac{0.765}{V_{OUT} - 0.765} \times R1 [\Omega]$$

$$0.765 [V] \leq V_{OUT} \leq 13.5 [V]$$

BD9F800MUX-Z operates under the condition which satisfies the following equation.

$$V_{IN} \times 0.033 [V] \leq V_{OUT} \leq V_{IN} \times 0.87 - 0.12 \times I_{OUT} [V] (300kHz)$$

$$V_{IN} \times 0.067 [V] \leq V_{OUT} \leq V_{IN} \times 0.77 - 0.13 \times I_{OUT} [V] (600kHz)$$

3. Input Capacitor
Use a ceramic capacitor. It is more effective by placing it near VIN and PGND terminals. In using capacitor, please consider temperature and DC bias characteristics. For normal setting, it is recommended to connect two 10µF and 0.1µF capacitors. Input ripple voltage can be reduced further by using larger values. Also, considering temperature and DC bias characteristics, do not use capacity less than 10µF(300kHz), 6µF(600kHz). In order to reduce the influence of high frequency noise, place 0.1µF ceramic capacitor close to VIN terminal and PGND terminal as much as possible.

4. VREG Capacitor
Connect a 2.2µF ceramic capacitor between VREG terminal and GND terminal. For the capacitance of VREG capacitor, take temperature characteristics, DC bias characteristics, etc. into consideration to set minimum value to no less than 1µF. Place VREG capacitor close to VREG terminal and GND terminal as much as possible.

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. Place bootstrap capacitor close to BOOT terminal and SW terminal as much as possible.

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 94-a to 94-c show the current path in a buck converter circuit. The Loop1 in Figure 94-a is a current path when H-side Switch is ON and L-side Switch is OFF, the Loop2 in Figure 94-b is when H-side Switch is OFF and L-side Switch is ON. The thick line in Figure 94-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".

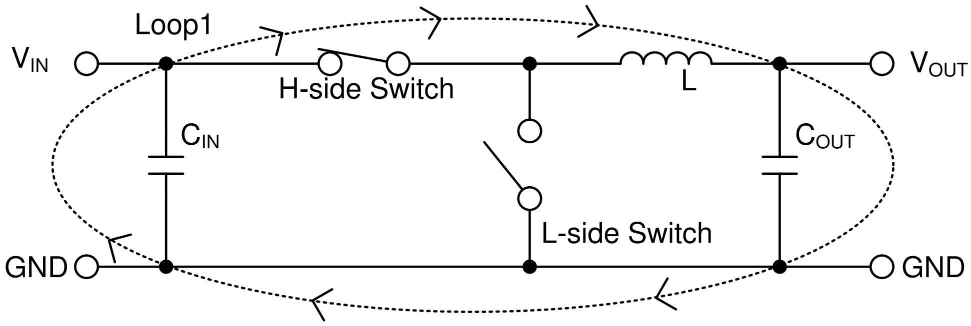


Figure 94-a. Current path when H-side Switch = ON, L-side switch = OFF

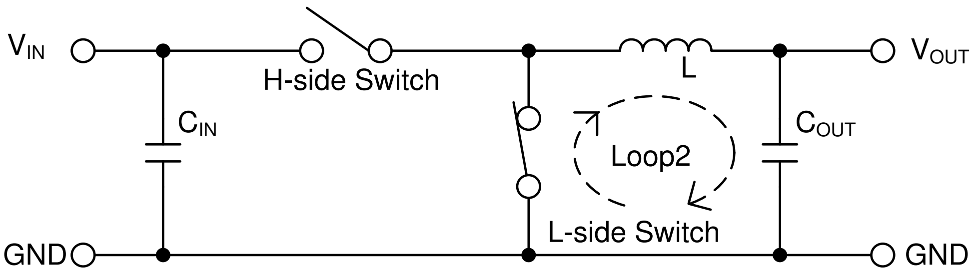


Figure 94-b. Current path when H-side Switch = OFF, L-side switch = ON

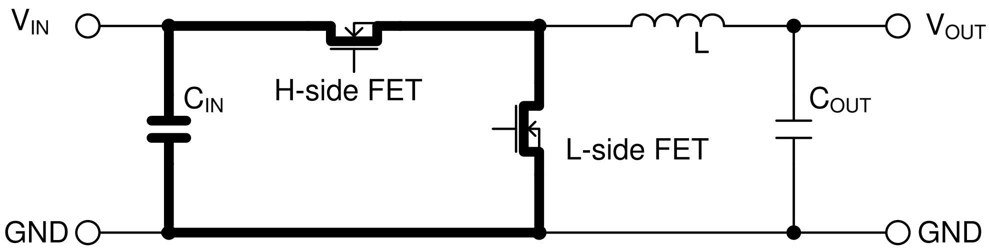


Figure 94-c. Difference of current and critical area in layout

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 VIN terminal and PGND terminal.
- If there is any unused area on the PCB, provide a copper foil plane for the ground node to assist heat dissipation from the IC and the surrounding components.
- 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 GND to PGND that are close to the output capacitor. It can avoid harmonic noise.

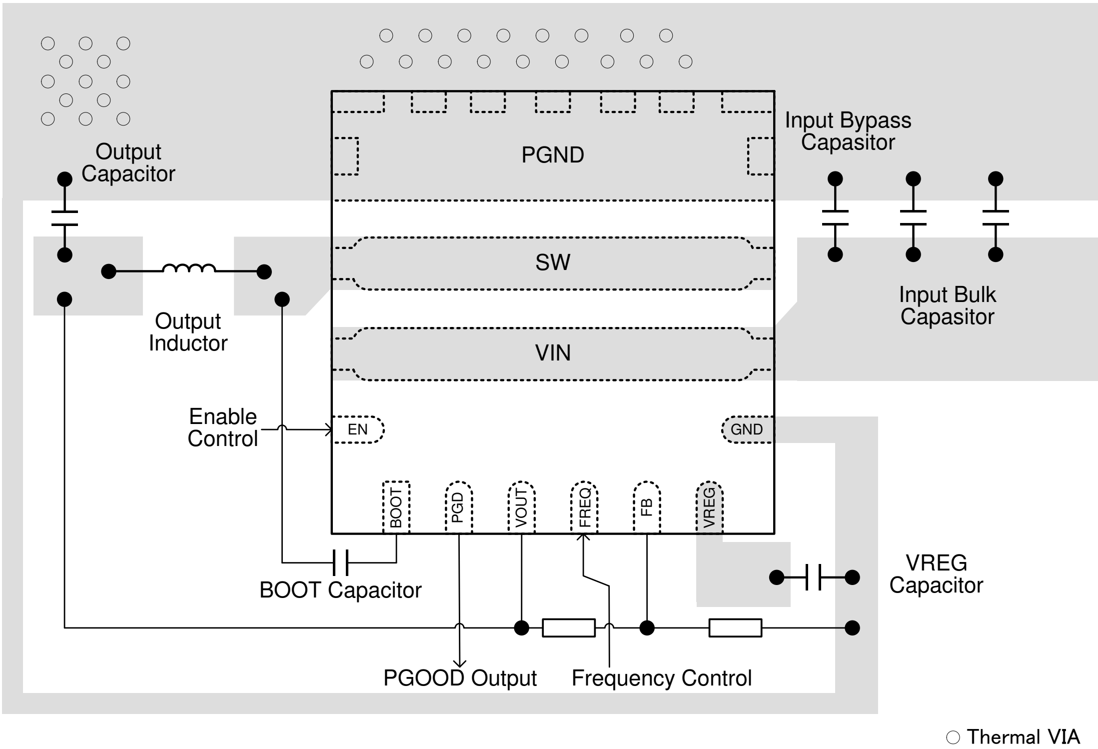
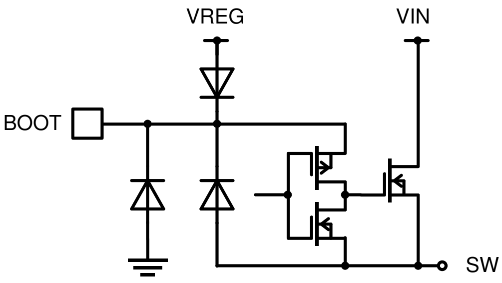


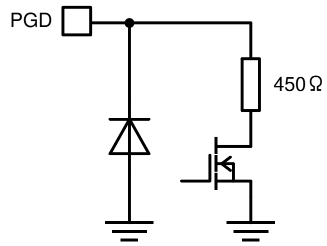
Figure 95. Example of PCB Layout (TOP VIEW)

I/O Equivalent Circuit

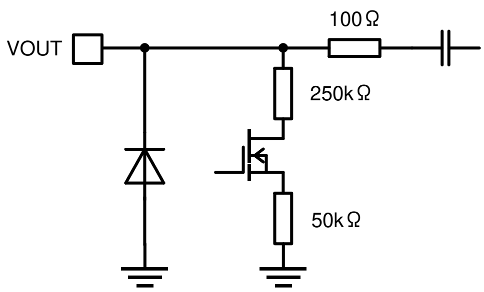
1. BOOT



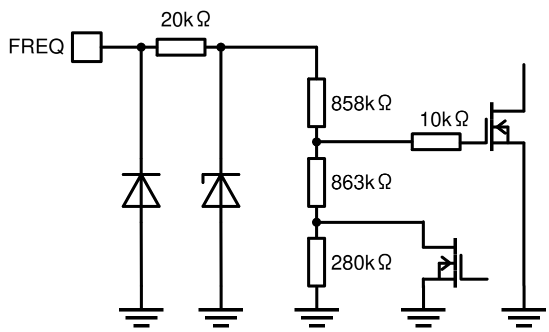
2. PGD



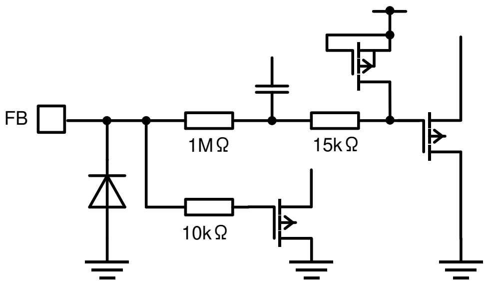
3. VOUT



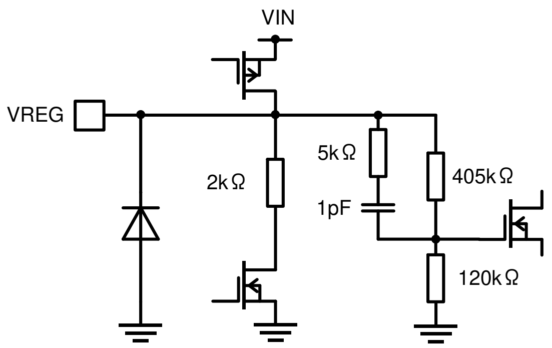
4. FREQ



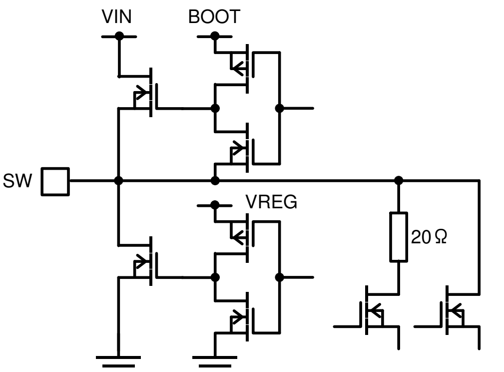
5. FB



6. VREG



9. SW



11. EN

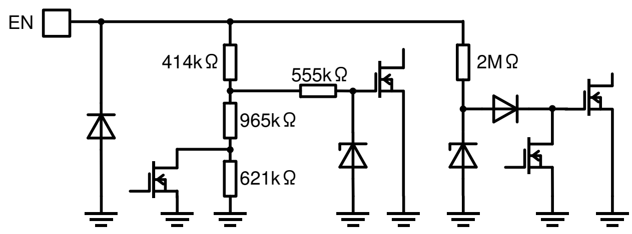


Figure 96. I/O equivalence circuit

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. 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.

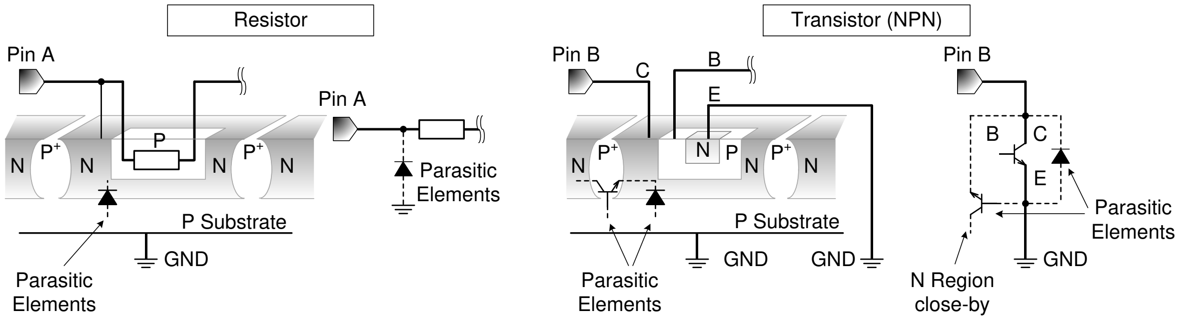


Figure 97. Example of monolithic IC structure

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 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.

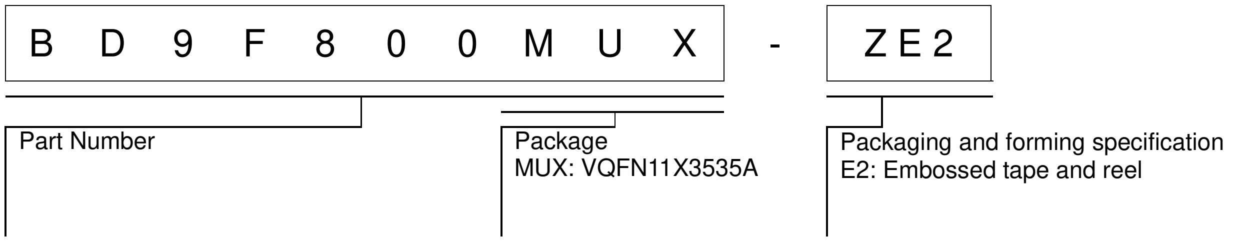
15. Over Current Protection Circuit (OCP)

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.

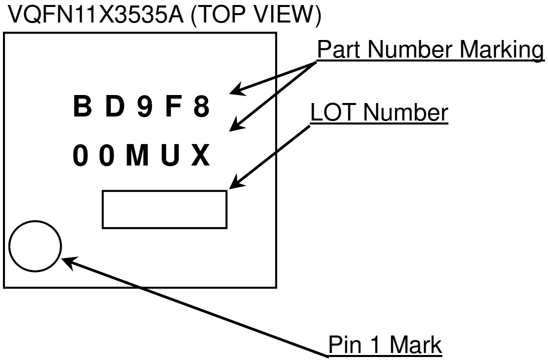
16. Disturbance Light

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

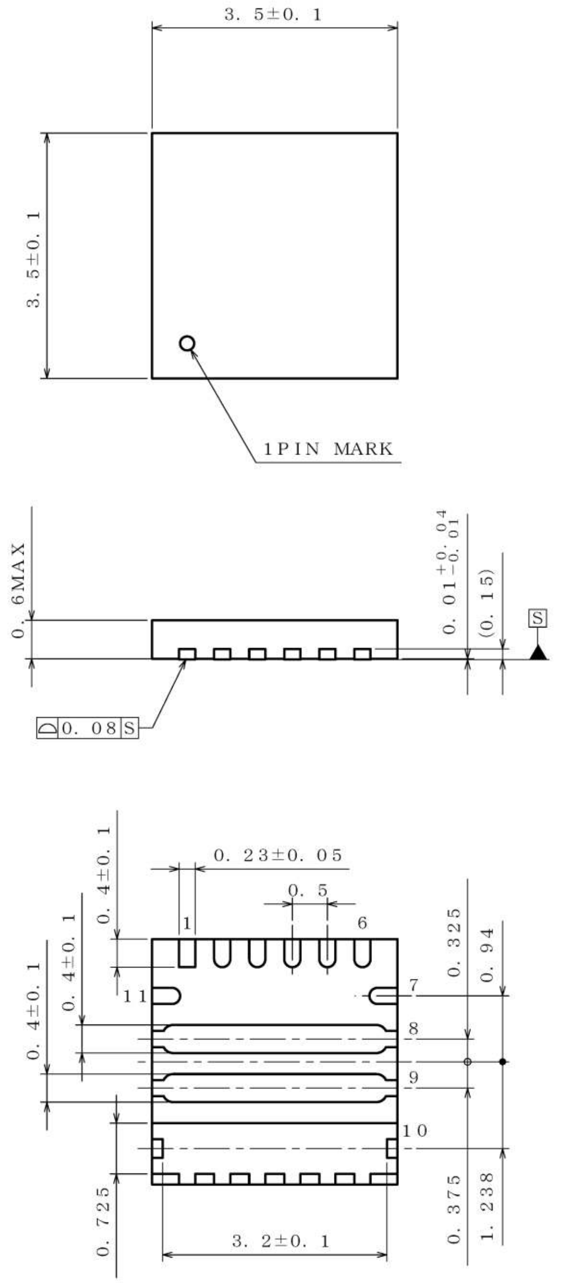


Marking Diagram



Physical Dimension and Packing Information

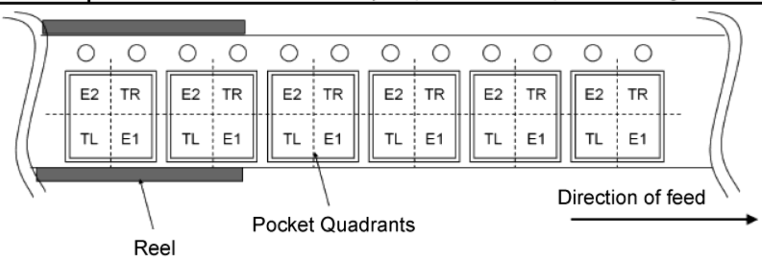
Package Name	VQFN11X3535A



(UNIT : mm)
PKG : VQFN11X3535A
Drawing No. EX378−5001

< Tape and Reel Information >

Tape	Embossed carrier tape
Quantity	2500pcs
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
31.Jul.2017	001	Created
19.Mar.2018	002	Revised Tape Quantity
27.Dec.2018	003	Revised Part Number

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(Note1) Medical Equipment Classification of the Specific Applications

JAPAN	USA	EU	CHINA
CLASSⅢ	CLASSⅢ	CLASSⅡb	CLASSⅢ
CLASSⅣ		CLASSⅢ	

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   [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.

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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.

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