2.7 V to 5.5 V Input, 2 A Integrated MOSFET Single Synchronous Buck DC/DC Converter

BD9A201FP4-LBZ

General Description

This is the product guarantees long time support in Industrial market.
BD9A201FP4-LBZ is a synchronous buck DC/DC converter with built-in low on-resistance power MOSFETs. It is a current mode control DC/DC converter and features high-speed transient response. Phase compensation can also be set easily. Power Good function makes it possible for system to control sequence.

Key Specifications

■Input Voltage Range:	2.7 V to 5.5 V
■Output Voltage Range:	0.8 V to V_{IN} x 0.7 V
■Output Current:	2 A (Max)
■Switching Frequency:	1000 kHz (Typ)
■ High-side FET ON Resistance:	50 mΩ (Typ)
■ Low-side FET ON Resistance:	50 mΩ (Typ)
■ Shutdown Current:	0 µA (Typ)

Package

Package	W (Typ) x D (Typ) x H (Max)
TSOT23-8L	2.8 mm x 2.92 mm x 0.95 mm

TSOT23-8L

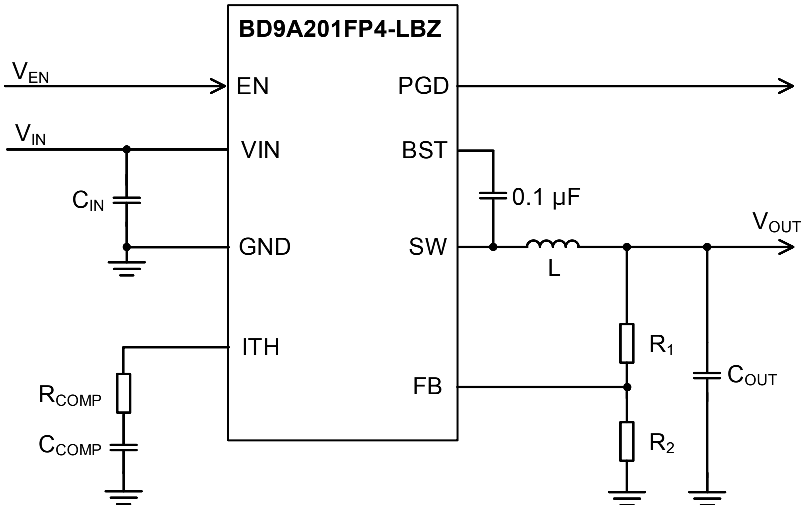
Features

- Long Time Support Product for Industrial Applications
- Single Synchronous Buck DC/DC Converter
- Constant PWM Mode Control
- Power Good Function
- Over Voltage Protection (OVP)
- Over Current Protection (OCP)
- Short Circuit Protection (SCP)
- Thermal Shutdown Protection (TSD)
- Under Voltage Lockout Protection (UVLO)
- TSOT23-8L Package

Applications

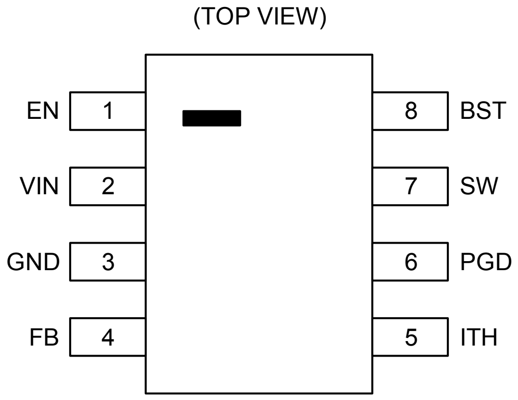
- Industrial Equipment
- Products for Industrial Equipment such as NC Machine Tools
- Secondary Power Supply and Adapter Equipment
- Communication Infrastructure Equipment

Typical Application Circuit



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

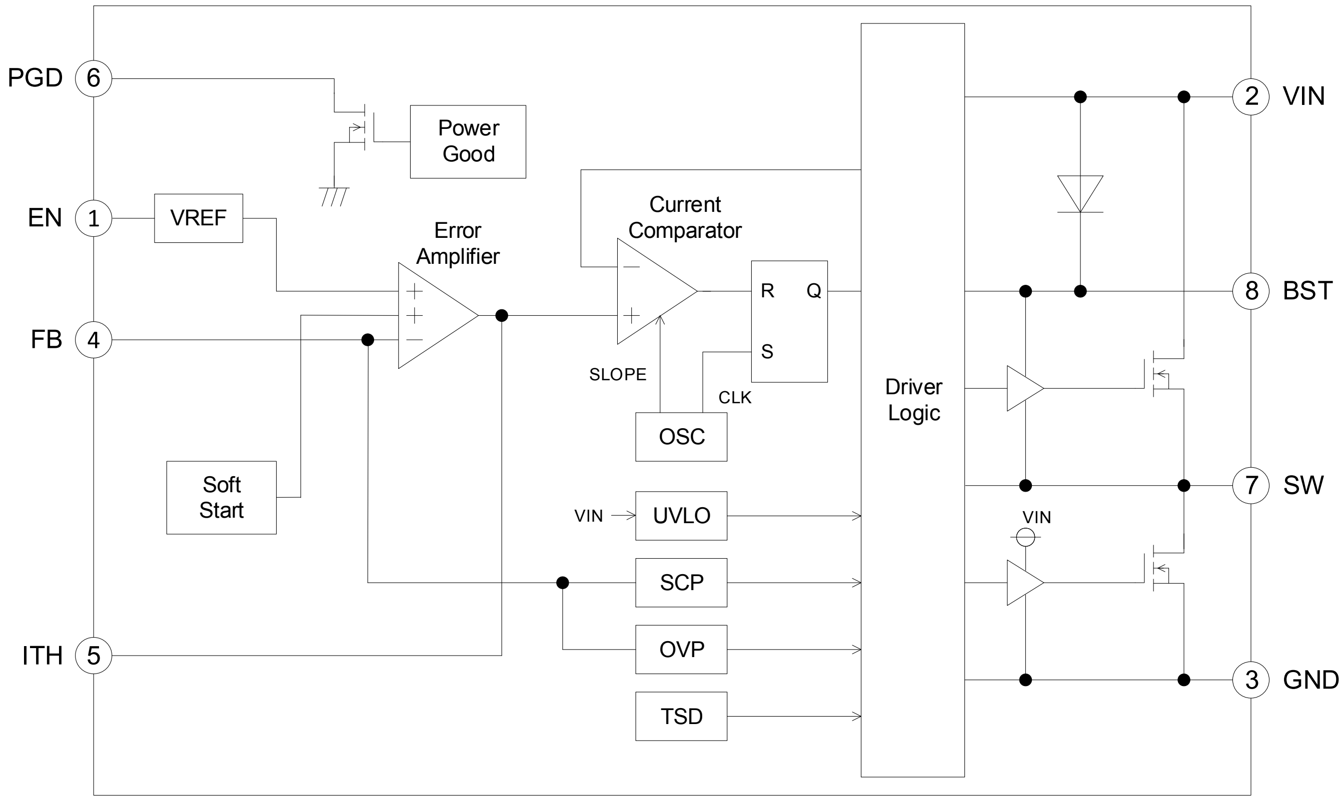
Pin Configuration



Pin Descriptions

Pin No.	Pin Name	Function
1	EN	Enable pin. The device starts up with setting V_{EN} to 2.0 V (Min) or more. The device enters the shutdown mode with setting V_{EN} to 0.8 V (Max) or less.
2	VIN	Power supply pin. Connecting 0.1 µF (Typ) and 10 µF (Typ) ceramic capacitors is recommended. The detail of a selection is described in Selection of Components Externally Connected 1. Input Capacitor.
3	GND	Ground pin.
4	FB	Output voltage feedback pin. See Selection of Components Externally Connected 3. Output Voltage Setting for the output voltage setting.
5	ITH	Output pin of the Error Amplifier and input of the Current Comparator. See Selection of Components Externally Connected 4. Phase Compensation Components for the phase compensation setting.
6	PGD	Power good pin. This pin is an open drain output that requires a pull-up resistor. See Function Explanations (3) Power Good for setting the resistance. If not used, this pin can be left floating or connected to the ground.
7	SW	Switch pin. This pin is connected to the source of the High-side FET and the drain of the Low-side FET. Connect a bootstrap capacitor of 0.1 µF between this pin and the BST pin. In addition, connect an inductor considering the direct current superimposition characteristic.
8	BST	Pin for bootstrap. Connect a bootstrap capacitor of 0.1 µF between this pin and the SW pin. The voltage of this pin is the gate drive voltage of the High-side FET.

Block Diagram



Description of Blocks

1. VREF
   This block generates the internal reference voltage.

2. UVLO
   The UVLO block is for under voltage lockout protection. The device is shutdown when input voltage (V_{IN}) falls to 2.45 V (Typ) or less. The threshold voltage has the 100 mV (Typ) hysteresis.

3. SCP
   This block is for short circuit protection. After soft start is completed, if the FB voltage of output falls to 0.4 V (Typ) or less and remain in that state for 1 ms (Typ), the device is shutdown for 16 ms (Typ) and re-operates.

4. OVP
   This block is for output over voltage protection. When the FB voltage V_{FB} exceeds V_{FBTH} x 110 % (Typ) or more, the output MOSFETs are off to prevent the increase in the output voltage. After the V_{FB} falls V_{FBTH} x 107 % (Typ) or less, the device is returned to normal operation condition. Switching operation restarts after V_{FB} or less V_{FBTH} (Typ).

5. TSD
   The TSD block is for thermal protection. The device is shutdown when the junction temperature Tj reaches to 175 °C (Typ) or more. The device is automatically restored to normal operation with a hysteresis of 25 °C (Typ) when the Tj goes down.

6. 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 1 ms (Typ).

7. Error Amplifier
   The block is an error amplifier and its inputs are the internal reference voltage and the FB voltage. Phase compensation can be set by connecting a resistor and a capacitor to the ITH pin.

8. Current Comparator
   The Current Comparator block compares the output voltage of the Error Amplifier and the Slope signal to determine the switching duty.

9. Driver Logic
   This block controls switching operation and various protection functions.

10. OSC
    This block generates the oscillating frequency.

11. Power Good
    This block is for power good function. When the output voltage reaches within ±7 % (Typ) of the setting voltage, the built-in open drain Nch MOSFET connected to the PGD pin is turned off and the PGD pin becomes Hi-Z (High impedance). When the output voltage reaches outside ±10 % (Typ) of the setting voltage, the open drain Nch MOSFET is turned on.

Absolute Maximum Ratings (Ta = 25 °C)

Parameter	Symbol	Rating	Unit
Input Voltage	V_{IN}	-0.3 to +7	V
SW Voltage	V_{SW}	-0.3 to V_{IN} + 0.3	V
SW Voltage (10 ns pulse width)	V_{SWAC}	-3 to V_{IN} + 0.3	V
Voltage from GND to BST	V_{BST}	-0.3 to +14	V
Voltage from SW to BST	$\Delta V_{BST\text{-}SW}$	-0.3 to +7	V
FB Voltage	V_{FB}	-0.3 to +7	V
ITH Voltage	V_{ITH}	-0.3 to +7	V
EN Voltage	V_{EN}	-0.3 to V_{IN}	V
PGD Voltage	V_{PGD}	-0.3 to +7	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, design a PCB 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)		Unit
		1s *(Note 3)*	2s2p *(Note 4)*	
TSOT23-8L				
Junction to Ambient	θ_{JA}	185.4	85.4	°C/W
Junction to Top Characterization Parameter *(Note 2)*	Ψ_{JT}	31.0	26.0	°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.
(Note 4) Using a PCB board based on JESD51-5, 7.

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

Top	
Copper Pattern	Thickness
Footprints and Traces	70 µm

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

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

(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}	2.7	-	5.5	V
Operating Temperature *(Note 1)*	Topr	-40	-	+85	°C
Output Current *(Note 1)*	I_{OUT}	0	-	2	A
Output Voltage Setting *(Note 2)*	V_{OUT}	0.8	-	V_{IN} x 0.7	V

(Note 1) Tj must be 125 °C or less under the actual operating environment. Life time is derated at junction temperature greater or than 125 °C.
(Note 2) Use under the condition of $V_{OUT} \geq V_{IN} \times 0.1$ [V].

Electrical Characteristics (Unless otherwise specified Ta = 25 °C, V_{IN} = 5 V, V_{EN} = 5 V)

Parameter	Symbol	Min	Typ	Max	Unit	Conditions
Input Supply						
Shutdown Current	I_{STBY}	-	0	10	μA	V_{EN} = 0 V
Operating Circuit Current	I_{OPR}	-	350	500	μA	I_{OUT} = 0 A No switching
UVLO Detection Threshold Voltage	V_{UVLO1}	2.350	2.450	2.550	V	V_{IN} falling
UVLO Release Threshold Voltage	V_{UVLO2}	2.425	2.550	2.700	V	V_{IN} rising
Enable						
EN Threshold Voltage High	V_{ENH}	2.0	-	V_{IN}	V	
EN Threshold Voltage Low	V_{ENL}	GND	-	0.8	V	
EN Input Current	I_{EN}	-	5	10	μA	
Power Good						
Falling (Fault) Voltage	V_{PGDFF}	V_{FBTH} x 0.87	V_{FBTH} x 0.90	V_{FBTH} x 0.93	V	V_{FB} Falling
Rising (Good) Voltage	V_{PGDRG}	V_{FBTH} x 0.90	V_{FBTH} x 0.93	V_{FBTH} x 0.96	V	V_{FB} Rising
Rising (Fault) Voltage	V_{PGDRF}	V_{FBTH} x 1.07	V_{FBTH} x 1.10	V_{FBTH} x 1.13	V	V_{FB} Rising
Falling (Good) Voltage	V_{PGDFG}	V_{FBTH} x 1.04	V_{FBTH} x 1.07	V_{FBTH} x 1.10	V	V_{FB} Falling
PGD Output Leakage Current	I_{LKPGD}	-	0	5	μA	V_{PGD} = 5 V
PGD FET ON Resistance	R_{PGD}	-	100	200	Ω	
PGD Low Level Voltage	P_{GDVL}	-	0.1	0.2	V	I_{PGD} = 1 mA
Reference Voltage, Error Amplifier, Soft Start						
FB Threshold Voltage	V_{FBTH}	0.792	0.800	0.808	V	
FB Input Current	I_{FB}	-	-	1	μA	V_{FB} = 0.8 V
ITH Source Current	I_{ITHSO}	10	20	40	μA	V_{FB} = 0.7 V
ITH Sink Current	I_{ITHSI}	10	20	40	μA	V_{FB} = 0.9 V
Soft Start Time	t_{SS}	0.5	1.0	2.0	ms	
SW (MOSFET)						
Switching Frequency	f_{OSC}	800	1000	1200	kHz	
Max Duty	D_{MAX}	70	-	-	%	
High-side FET ON Resistance	R_{ONH}	-	50	100	mΩ	$\Delta V_{BST\text{-}SW}$ = 5 V
Low-side FET ON Resistance	R_{ONL}	-	50	100	mΩ	
Protection						
Short Circuit Protection Detection	V_{SCP}	0.28	0.40	0.52	V	

Typical Performance Curves

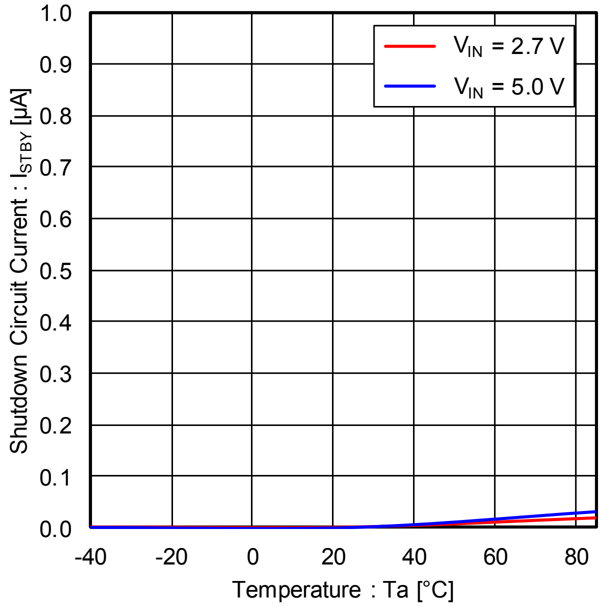


Figure 1. Shutdown Current vs Temperature

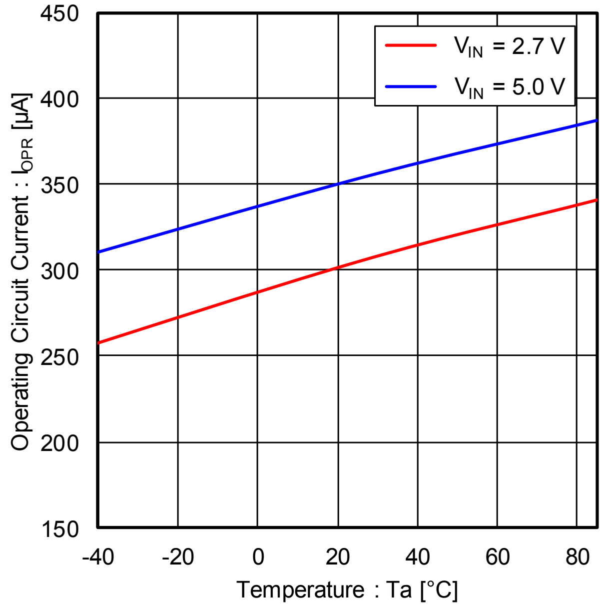


Figure 2. Operating Circuit Current vs Temperature

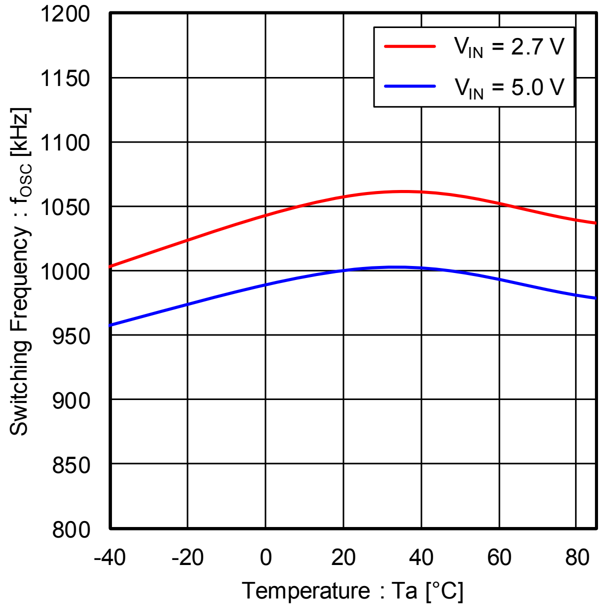


Figure 3. Switching Frequency vs Temperature

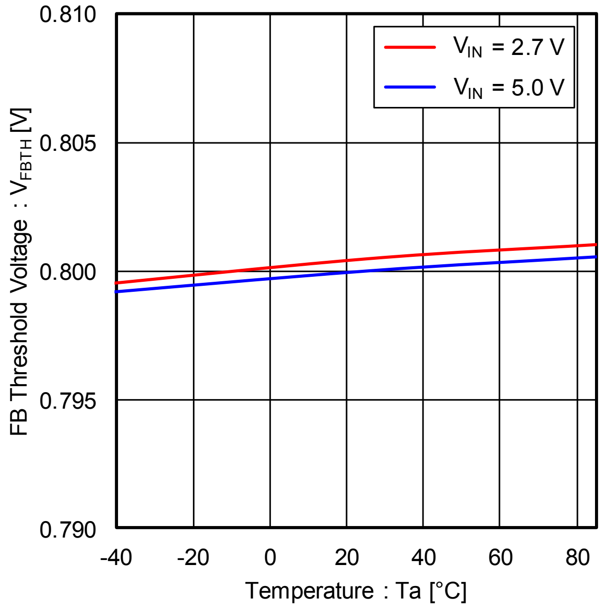


Figure 4. FB Threshold Voltage vs Temperature

Typical Performance Curves – continued

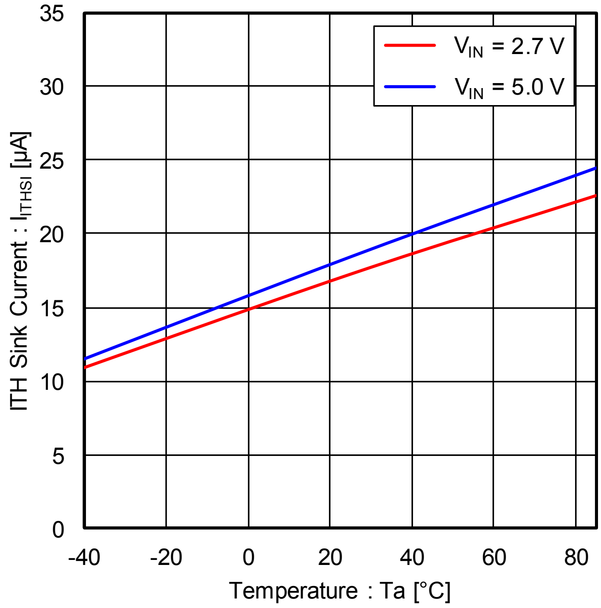


Figure 5. ITH Sink Current vs Temperature

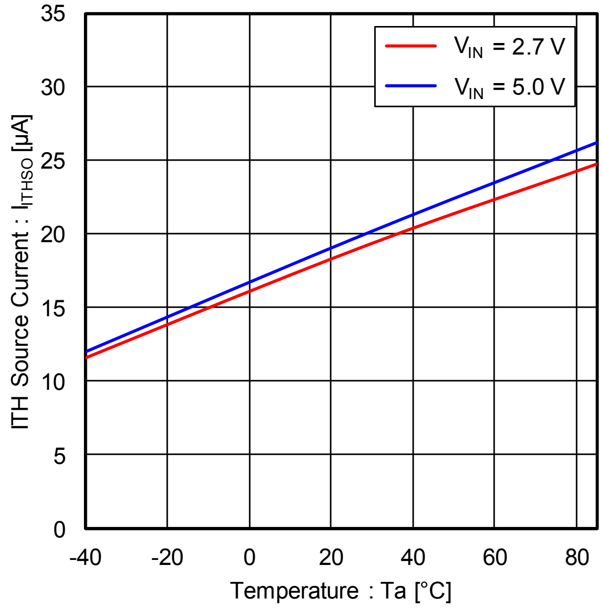


Figure 6. ITH Source Current vs Temperature

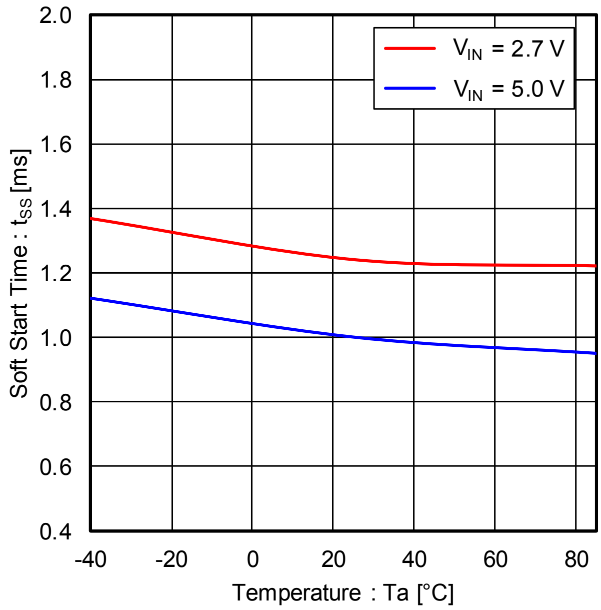


Figure 7. Soft Start Time vs Temperature

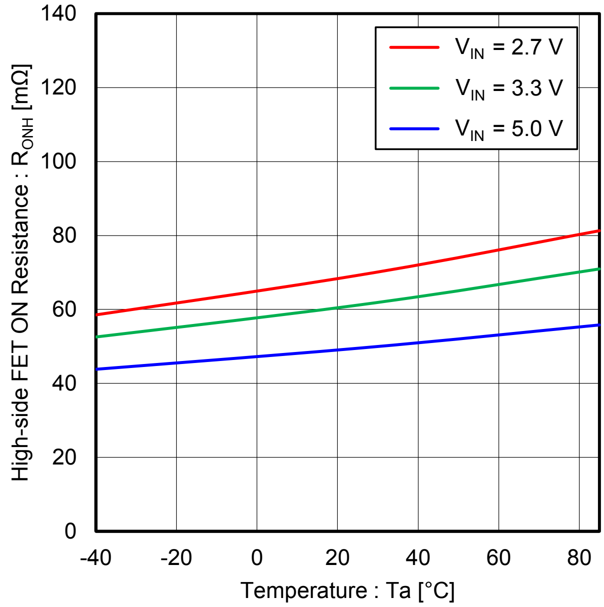


Figure 8. High-side FET ON Resistance vs Temperature

Typical Performance Curves – continued

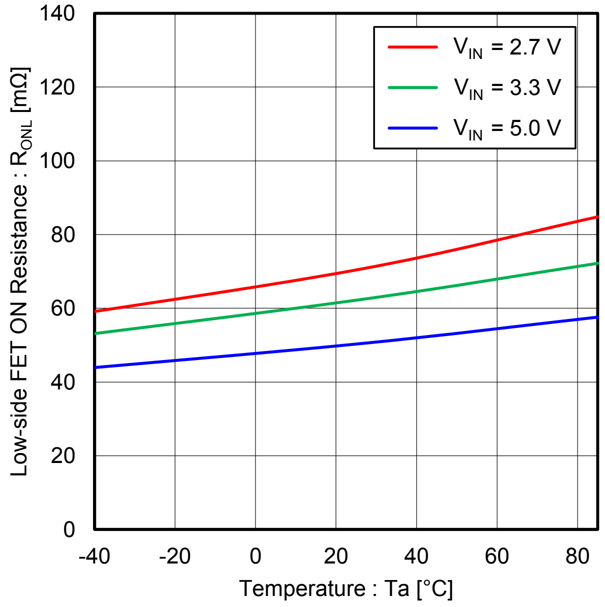


Figure 9. Low-side FET ON Resistance vs Temperature

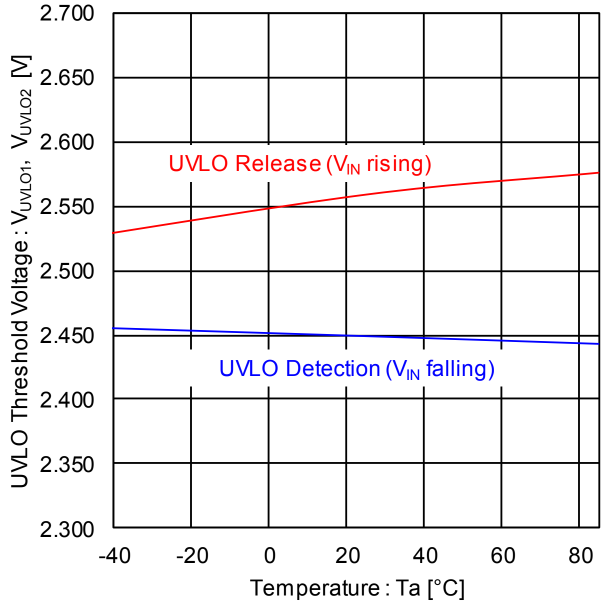


Figure 10. UVLO Threshold Voltage vs Temperature

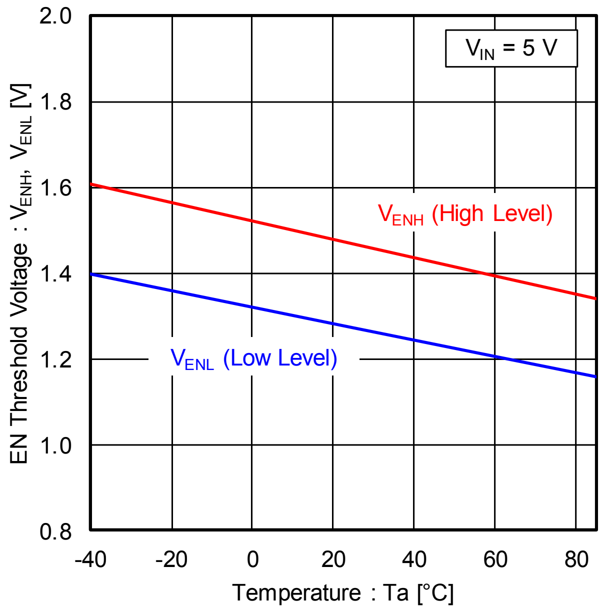


Figure 11. EN Threshold Voltage vs Temperature

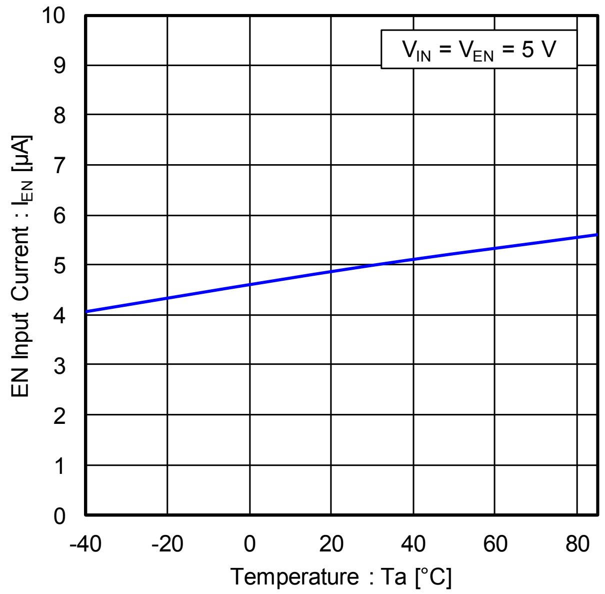


Figure 12. EN Input Current vs Temperature

Typical Performance Curves – continued

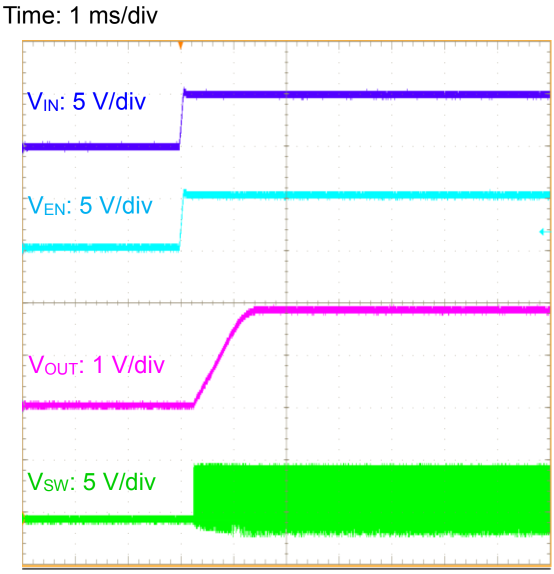


Figure 13. Start-up at R_{LOAD} = 0.9 Ω
(V_{EN} = V_{IN}, V_{IN} = 5 V, V_{OUT} = 1.8 V)

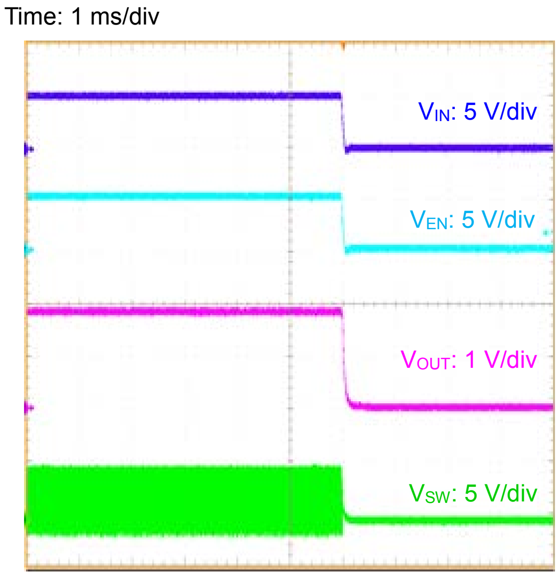


Figure 14. Shutdown at R_{LOAD} = 0.9 Ω
(V_{EN} = V_{IN}, V_{IN} = 5 V, V_{OUT} = 1.8 V)

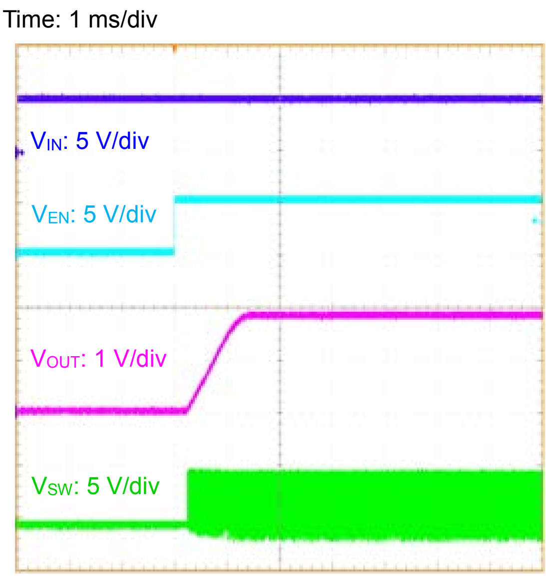


Figure 15. Start-up at R_{LOAD} = 0.9 Ω
(V_{EN} = 0 V to 5 V, V_{IN} = 5 V, V_{OUT} = 1.8 V)

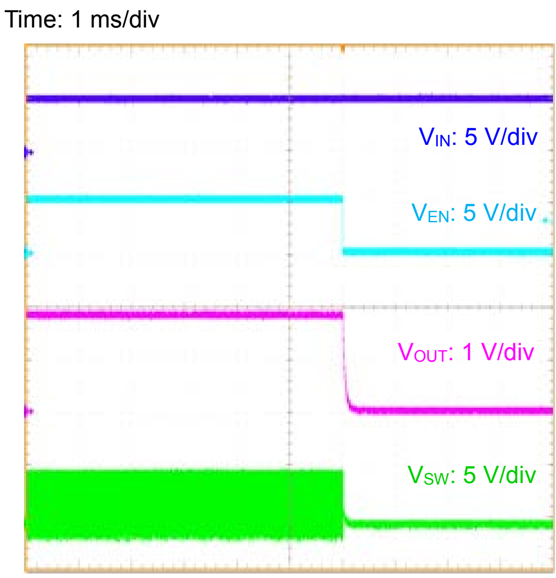


Figure 16. Shutdown at R_{LOAD} = 0.9 Ω
(V_{EN} = 5 V to 0 V, V_{IN} = 5 V, V_{OUT} = 1.8 V)

Typical Performance Curves – continued

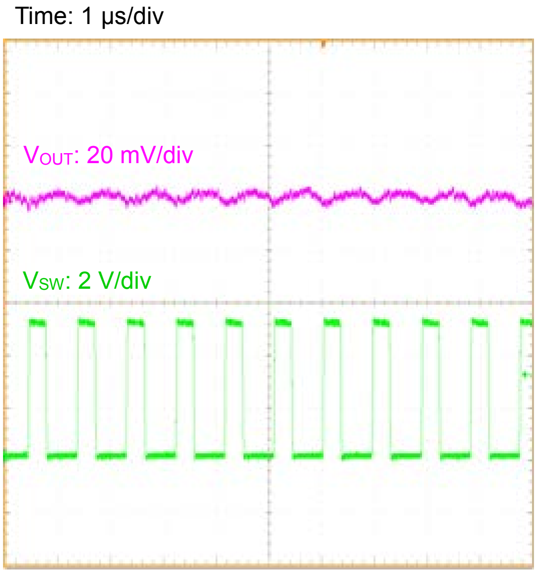


Figure 17. Output Voltage Ripple
(V_{IN} = 5 V, V_{OUT} = 1.8 V, I_{OUT} = 0 A)

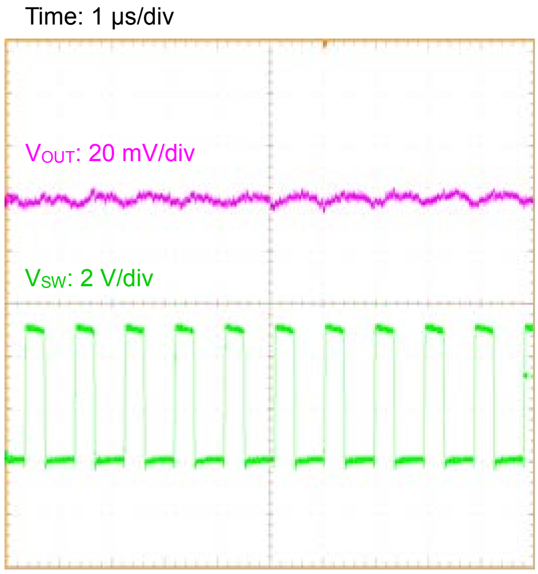


Figure 18. Output Voltage Ripple
(V_{IN} = 5 V, V_{OUT} = 1.8 V, I_{OUT} = 2 A)

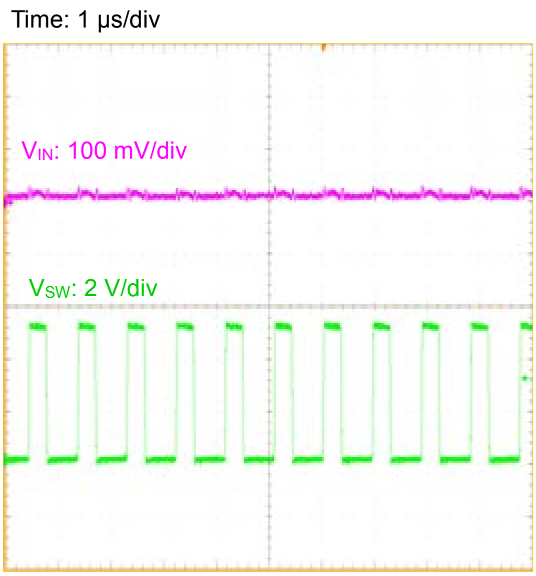


Figure 19. Input Voltage Ripple
(V_{IN} = 5 V, V_{OUT} = 1.8 V, I_{OUT} = 0 A)

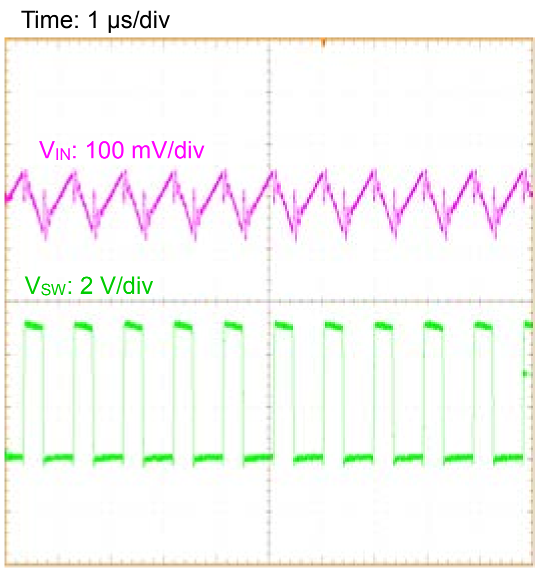


Figure 20. Input Voltage Ripple
(V_{IN} = 5 V, V_{OUT} = 1.8 V, I_{OUT} = 2 A)

Function Explanations

1. Basic Operation

(1) Enable Control

The startup and shutdown can be controlled by the EN voltage V_{EN}. When V_{EN} becomes 2.0 V (Min) or more, the internal circuit is activated and the device starts up. When V_{EN} becomes 0.8 V (Max) or less, the device is shutdown. In this shutdown mode, the High-side FET and the Low-side FET are turned off. The start-up with V_{EN} must be at the same time of the input voltage V_{IN} (V_{IN} = V_{EN}) or after supplying V_{IN}.

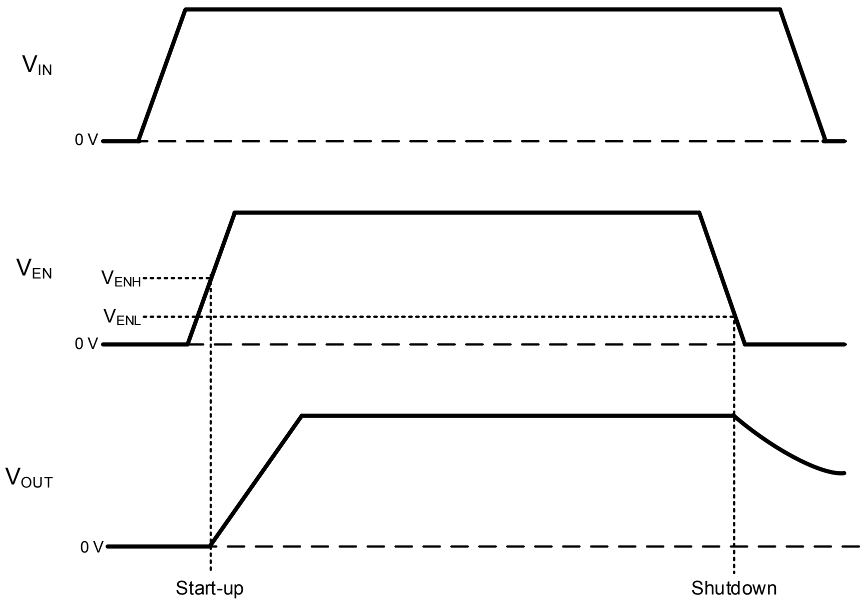


Figure 21. Start-up and Shutdown with Enable Control Timing Chart

(2) Soft Start

When V_{EN} goes high, soft start function operates and output voltage gradually rises. This soft start function can prevent overshoot of the output voltage and excessive inrush current. The soft start time t_{SS} is 1 ms (Typ).

(3) Power Good

When the output voltage reaches within ±7 % (Typ) of the setting voltage, the built-in open drain Nch MOSFET connected to the PGD pin is turned off and the PGD pin becomes Hi-Z (High impedance). When the output voltage reaches outside ±10 % (Typ) of the setting voltage, the open drain Nch MOSFET is turned on. It is recommended to connect a pull-up resistor of 10 kΩ to 100 kΩ.

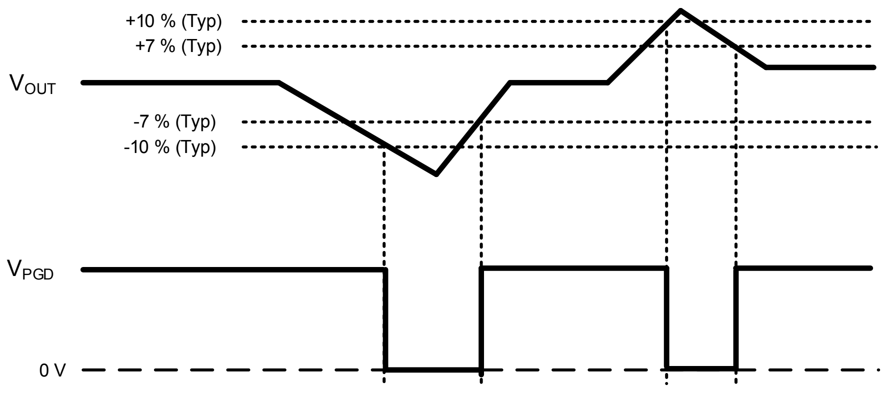


Figure 22. Power Good Timing Chart

Function Explanations – continued

2. Protection

The protection circuits are intended for prevention of damage caused by unexpected accidents. Do not use the continuous protection.

(1) Short Circuit Protection (SCP)

The Short Circuit Protection block compares the FB voltage V_{FB} with the internal reference voltage. When the V_{FB} has fallen to 0.4 V (Typ) or less and remained there for 1 ms (Typ), SCP stops the operation for 16 ms (Typ) and subsequently initiates a restart. SCP does not operate during the soft start even if the device is in the SCP condition. Do not to exceed maximum junction temperature rating (Tjmax = 150 °C) during OCP and SCP operation.

Table 1. The Operating Condition of SCP

VEN	VFB	Start-up	SCP
≥ 2.0 V (Min)	≤ 0.4 V (Typ)	During Soft Start	Disable
	> 0.4 V (Typ)		Disable
	≤ 0.4 V (Typ)	Complete Soft Start	Enable
	> 0.4 V (Typ)		Disable
≤ 0.8 V (Max)	-	Shutdown	Disable

(2) Over Current Protection (OCP)

The Over Current Protection function operates by limiting the current that flows through High-side FET at each cycle of the switching frequency. Over current limit is 6.0 A (Typ).

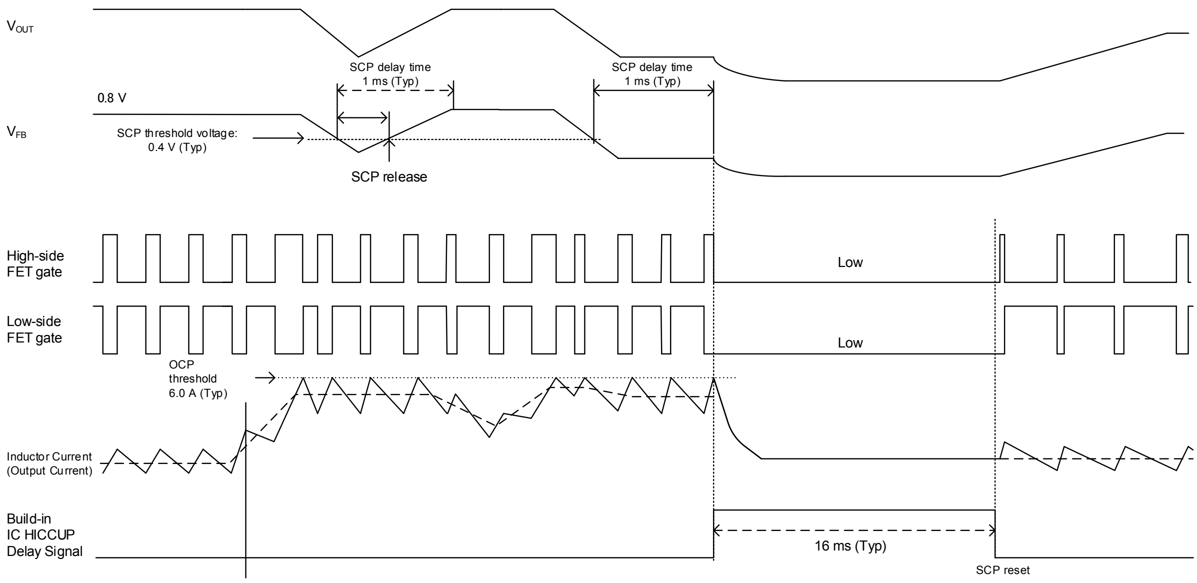


Figure 23. OCP and SCP Timing Chart

2. Protection – continued

(3) Under Voltage Lockout Protection (UVLO)

When input voltage V_{IN} falls to 2.45 V (Typ) or less, the device is shutdown. When V_{IN} becomes 2.55 V (Typ) or more, the device starts up. The hysteresis is 100 mV (Typ).

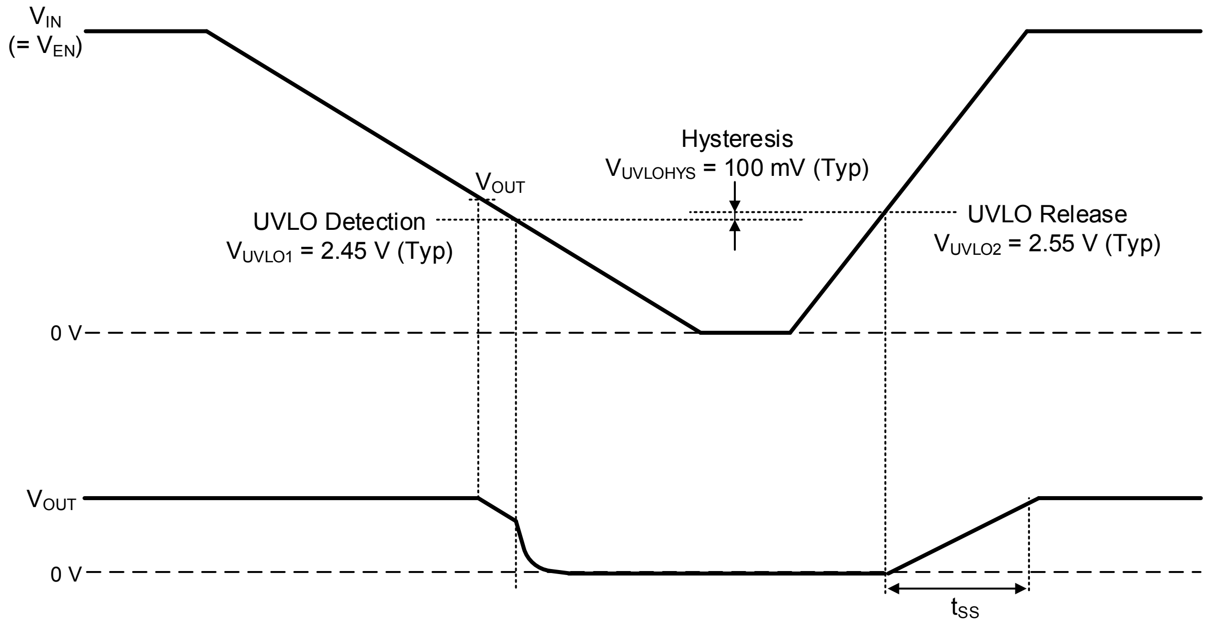


Figure 24. UVLO Timing Chart

(4) Thermal Shutdown Protection (TSD)

Thermal shutdown circuit prevents heat damage to the IC. The device should always operate within the IC's maximum junction temperature rating (Tjmax = 150 °C). However, if it continues exceeding the rating and the junction temperature Tj rises to 175 °C (Typ), the TSD circuit is activated and it turns the output MOSFETs off. When the Tj falls below the TSD threshold, the circuits are automatically restored to normal operation. The TSD threshold has a hysteresis of 25 °C (Typ). Note that the TSD circuit operates in a situation that exceeds the absolute maximum ratings. 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.

(5) Over Voltage Protection (OVP)

When the FB voltage V_{FB} exceeds V_{FBTH} x 110 % (Typ) or more, the output MOSFETs are off to prevent the increase in the output voltage. After the V_{FB} falls V_{FBTH} x 107 % (Typ) or less, the output MOSFETs are returned to normal operation condition.

Application Examples

1. V_{IN} = 5 V, V_{OUT} = 1.8 V

Table 2. Specification of Application

Parameter	Symbol	Specification Value
Input Voltage	V_{IN}	5 V (Typ)
Output Voltage	V_{OUT}	1.8 V (Typ)
Maximum Output Current	I_{OUTMAX}	2 A
Temperature	Ta	25 °C

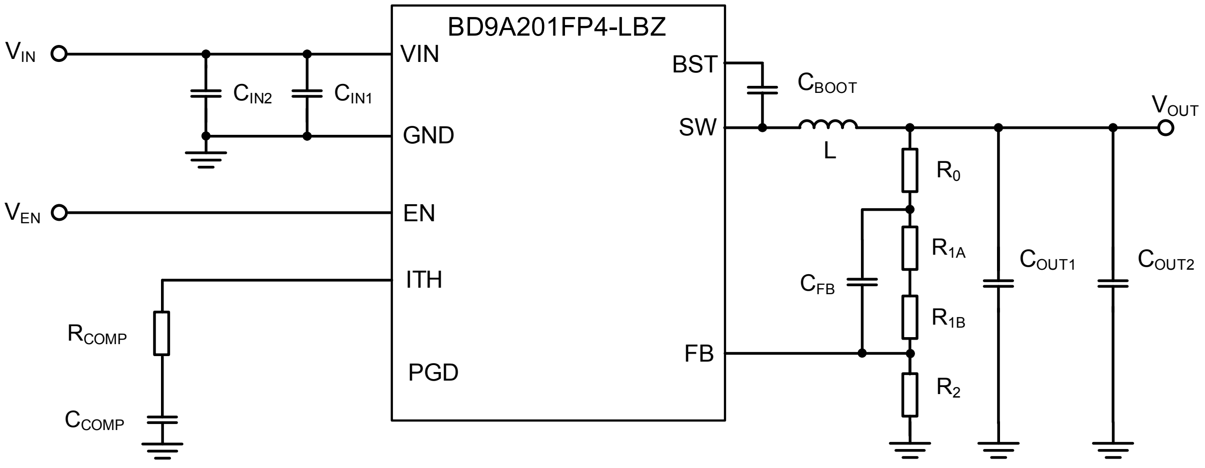


Figure 25. Application Circuit

Table 3. Recommended Component Values

Part No.	Value	Part Name	Size Code (mm)	Manufacturer
L	1.5 µH	FDSD0420-H-1R5M	4040	Murata
C_{IN1} *(Note 1)*	0.1 µF (50 V, X5R, ±15 %)	GRM155R61H104KE14	1005	Murata
C_{IN2} *(Note 2)*	22 µF (10 V, X5R, ±20 %)	GRM21BR61A226ME51	2012	Murata
C_{BOOT} *(Note 3)*	0.1 µF (50 V, X5R, ±15 %)	GRM155R61H104KE14	1005	Murata
C_{OUT1} *(Note 4)*	47 µF (10 V, X5R, ±20 %)	GRM21BR61A476ME15	2012	Murata
C_{OUT2}	-	-	-	-
C_{FB}	-	-	-	-
C_{COMP}	2.7 nF (50 V, C0G, ±5 %)	GRM1555C1H272JE01	1005	Murata
R_{COMP}	9.1 kΩ (1 %, 1/16 W)	MCR01MZPF9101	1005	ROHM
R_{1A}	Short	-	-	-
R_{1B}	30 kΩ (1 %, 1/16 W)	MCR01MZPF3002	1005	ROHM
R_2	24 kΩ (1 %, 1/16 W)	MCR01MZPF2402	1005	ROHM
R_0 *(Note 5)*	Short	-	-	-

(Note 1) In order to reduce the influence of high frequency noise, connect a 0.1 µF ceramic capacitor C_{IN1} as close as possible to the VIN pin and the GND pin.
(Note 2) For the input capacitor C_{IN2}, take temperature characteristics, DC bias characteristics, etc. into consideration to set to the actual capacitance of no less than 3 µF.
(Note 3) For the bootstrap capacitor C_{BOOT}, take temperature characteristics, DC bias characteristics, etc. into consideration to set to the actual capacitance of no less than 0.022 µF.
(Note 4) In case of changing the actual capacitance value due to temperature characteristics, DC bias characteristics, etc. of the output capacitor C_{OUT1} and C_{OUT2}, the loop response characteristics may change. Confirm with the actual application.
(Note 5) R_0 is an option, used for feedback's frequency response measurement. By inserting a resistor at R_0, it is possible to measure the frequency response (phase margin) using a FRA. However, the resistor is not used in actual application, use this resistor pattern in short-circuit mode.

1. V_{IN} = 5 V, V_{OUT} = 1.8 V – continued

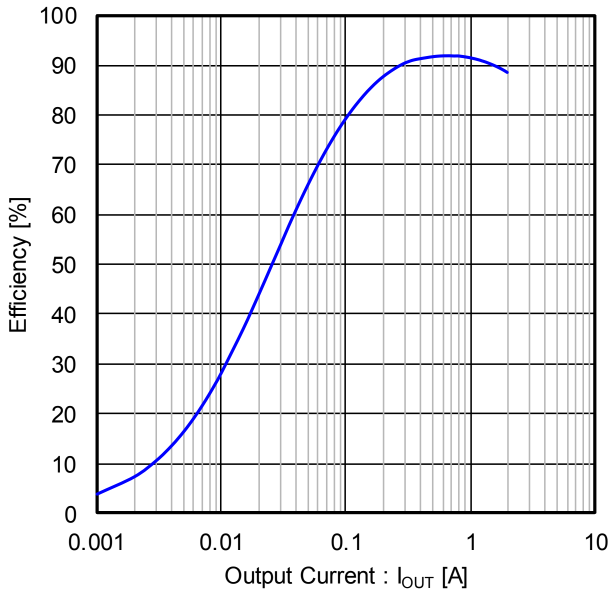


Figure 26. Efficiency vs Output Current

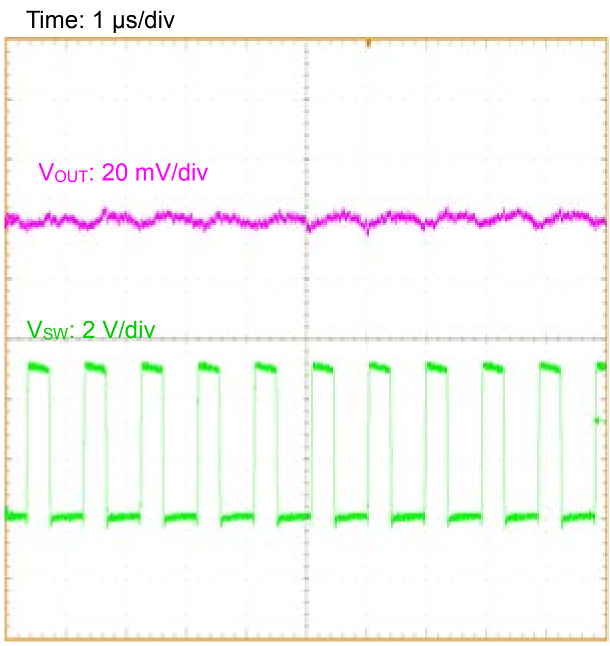


Figure 27. Output Ripple Voltage (I_{OUT} = 2 A)

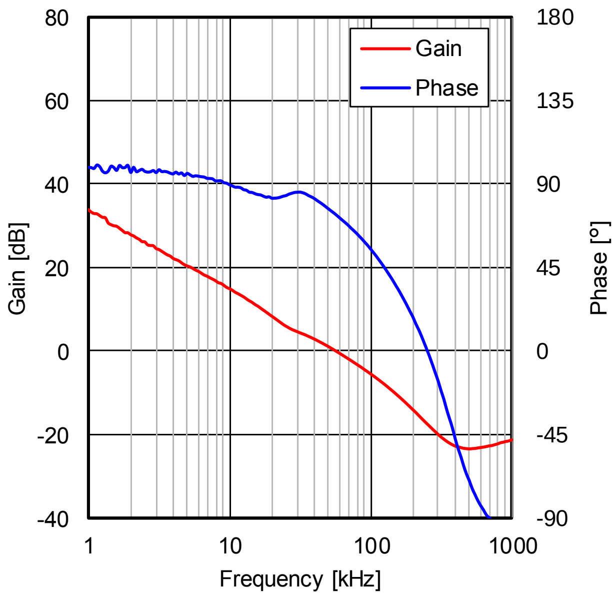


Figure 28. Frequency Characteristics (I_{OUT} = 1 A)

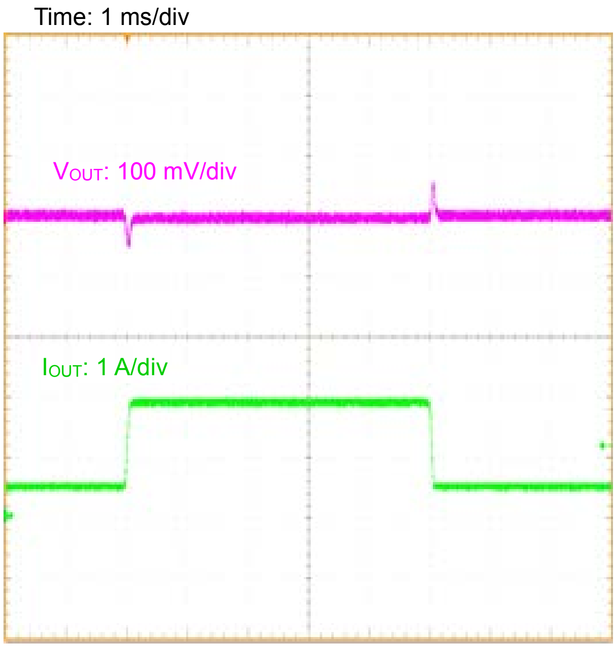


Figure 29. Load Transient Response
(I_{OUT} = 0.5 A to 2.0 A)

Application Examples – continued

2. V_{IN} = 5 V, V_{OUT} = 1.5 V

Table 4. Specification of Application

Parameter	Symbol	Specification Value
Input Voltage	V_{IN}	5 V (Typ)
Output Voltage	V_{OUT}	1.5 V (Typ)
Maximum Output Current	I_{OUTMAX}	2 A
Temperature	Ta	25 °C

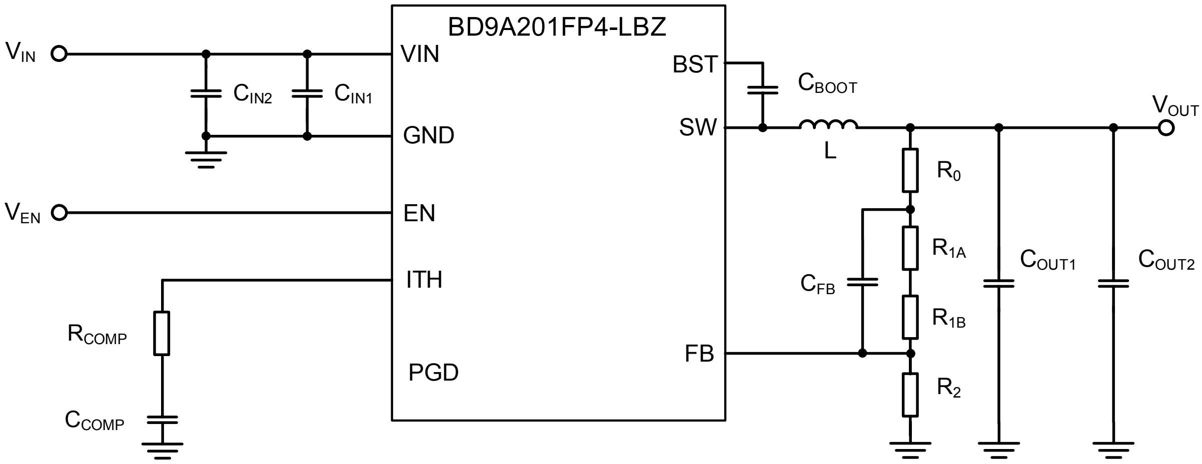


Figure 30. Application Circuit

Table 5. Recommended Component Values

Part No.	Value	Part Name	Size Code (mm)	Manufacturer
L	1.5 µH	FDSD0420-H-1R5M	4040	Murata
C_{IN1} *(Note 1)*	0.1 µF (50 V, X5R, ±15 %)	GRM155R61H104KE14	1005	Murata
C_{IN2} *(Note 2)*	22 µF (10 V, X5R, ±20 %)	GRM21BR61A226ME51	2012	Murata
C_{BOOT} *(Note 3)*	0.1 µF (50 V, X5R, ±15 %)	GRM155R61H104KE14	1005	Murata
C_{OUT1} *(Note 4)*	47 µF (10 V, X5R, ±20 %)	GRM21BR61A476ME15	2012	Murata
C_{OUT2}	-	-	-	-
C_{FB}	-	-	-	-
C_{COMP}	2.7 nF (50 V, C0G, ±5 %)	GRM1555C1H272JE01	1005	Murata
R_{COMP}	9.1 kΩ (1 %, 1/16 W)	MCR01MZPF9101	1005	ROHM
R_{1A}	Short	-	-	-
R_{1B}	16 kΩ (1 %, 1/16 W)	MCR01MZPF1602	1005	ROHM
R_2	18 kΩ (1 %, 1/16 W)	MCR01MZPF1802	1005	ROHM
R_0 *(Note 5)*	Short	-	-	-

(Note 1) In order to reduce the influence of high frequency noise, connect a 0.1 µF ceramic capacitor C_{IN1} as close as possible to the VIN pin and the GND pin.
(Note 2) For the input capacitor C_{IN2}, take temperature characteristics, DC bias characteristics, etc. into consideration to set to the actual capacitance of no less than 3 µF.
(Note 3) For the bootstrap capacitor C_{BOOT}, take temperature characteristics, DC bias characteristics, etc. into consideration to set to the actual capacitance of no less than 0.022 µF.
(Note 4) In case of changing the actual capacitance value due to temperature characteristics, DC bias characteristics, etc. of the output capacitor C_{OUT1} and C_{OUT2}, the loop response characteristics may change. Confirm with the actual application.
(Note 5) R_0 is an option, used for feedback's frequency response measurement. By inserting a resistor at R_0, it is possible to measure the frequency response (phase margin) using a FRA. However, the resistor is not used in actual application, use this resistor pattern in short-circuit mode.

2. V_{IN} = 5 V, V_{OUT} = 1.5 V – continued

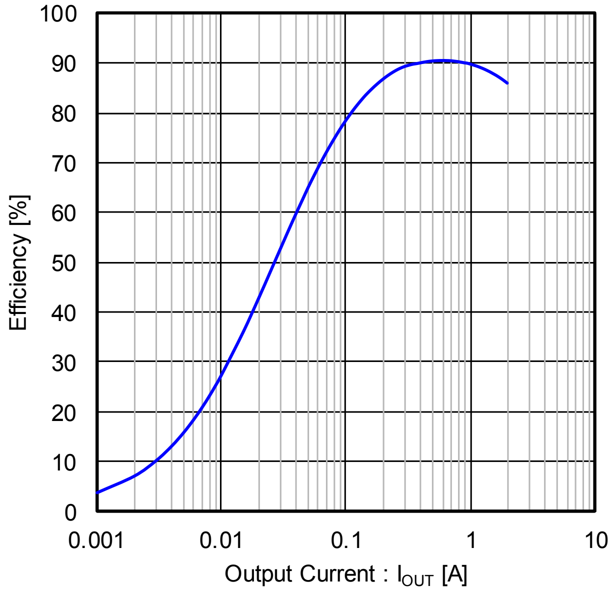


Figure 31. Efficiency vs Output Current

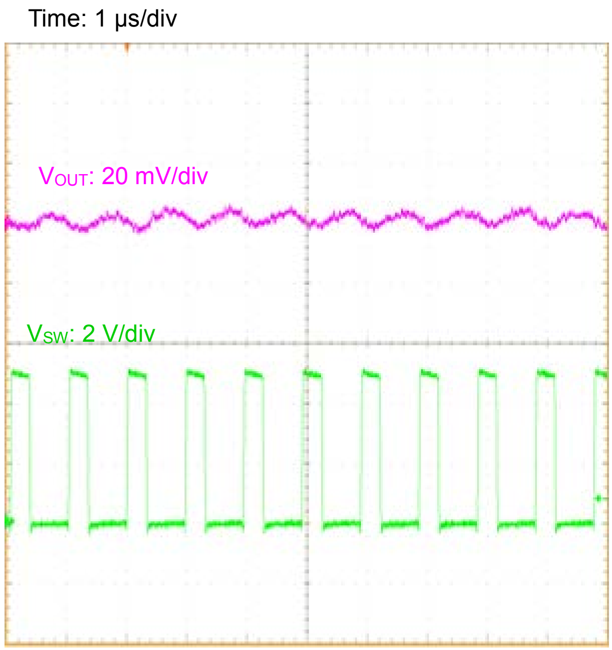


Figure 32. Output Ripple Voltage (I_{OUT} = 2 A)

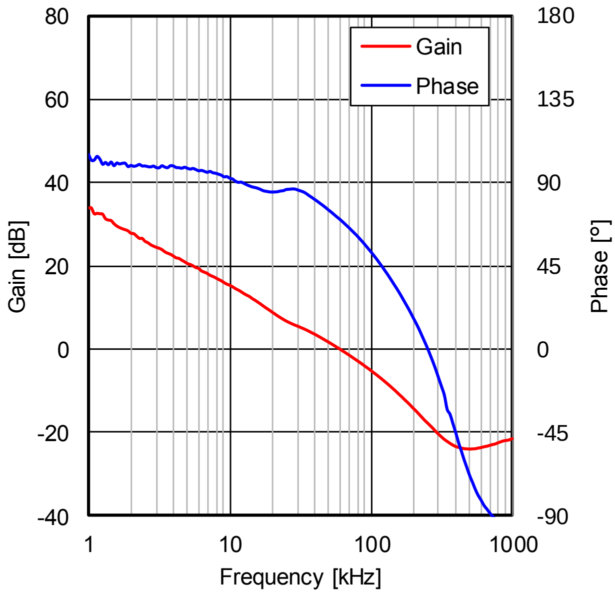


Figure 33. Frequency Characteristics (I_{OUT} = 1 A)

Figure 34. Load Transient Response
(I_{OUT} = 0.5 A to 2.0 A)

Application Examples – continued

3. V_{IN} = 5 V, V_{OUT} = 1.2 V

Table 6. Specification of Application

Parameter	Symbol	Specification Value
Input Voltage	V_{IN}	5 V (Typ)
Output Voltage	V_{OUT}	1.2 V (Typ)
Maximum Output Current	I_{OUTMAX}	2 A
Temperature	Ta	25 °C

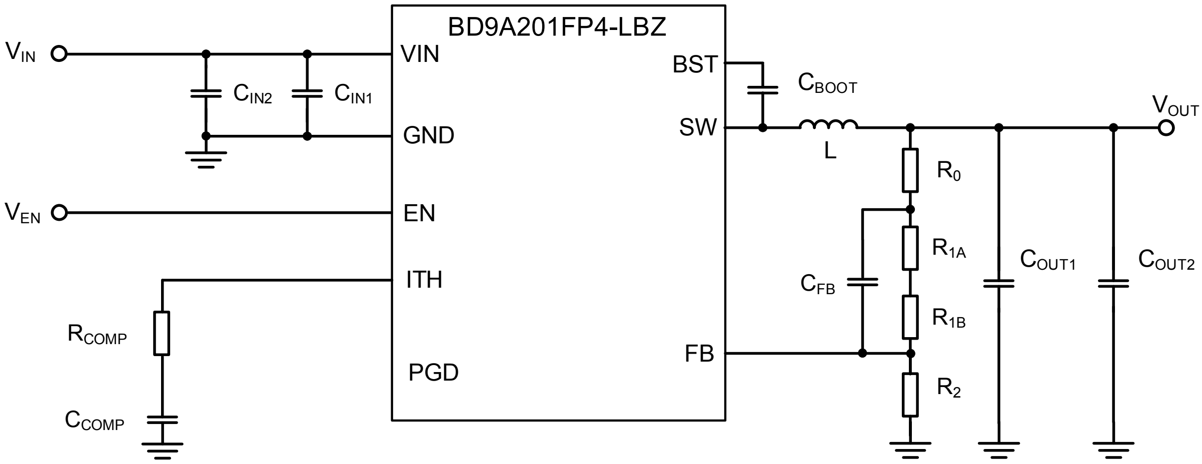


Figure 35. Application Circuit

Table 7. Recommended Component Values

Part No.	Value	Part Name	Size Code (mm)	Manufacturer
L	1.5 µH	FDSD0420-H-1R5M	4040	Murata
C_{IN1} *(Note 1)*	0.1 µF (50 V, X5R, ±15 %)	GRM155R61H104KE14	1005	Murata
C_{IN2} *(Note 2)*	22 µF (10 V, X5R, ±20 %)	GRM21BR61A226ME51	2012	Murata
C_{BOOT} *(Note 3)*	0.1 µF (50 V, X5R, ±15 %)	GRM155R61H104KE14	1005	Murata
C_{OUT1} *(Note 4)*	47 µF (10 V, X5R, ±20 %)	GRM21BR61A476ME15	2012	Murata
C_{OUT2}	-	-	-	-
C_{FB}	-	-	-	-
C_{COMP}	2.7 nF (50 V, C0G, ±5 %)	GRM1555C1H272JE01	1005	Murata
R_{COMP}	9.1 kΩ (1 %, 1/16 W)	MCR01MZPF9101	1005	ROHM
R_{1A}	Short	-	-	-
R_{1B}	10 kΩ (1 %, 1/16 W)	MCR01MZPF1002	1005	ROHM
R_2	20 kΩ (1 %, 1/16 W)	MCR01MZPF2002	1005	ROHM
R_0 *(Note 5)*	Short	-	-	-

(Note 1) In order to reduce the influence of high frequency noise, connect a 0.1 µF ceramic capacitor C_{IN1} as close as possible to the VIN pin and the GND pin.
(Note 2) For the input capacitor C_{IN2}, take temperature characteristics, DC bias characteristics, etc. into consideration to set to the actual capacitance of no less than 3 µF.
(Note 3) For the bootstrap capacitor C_{BOOT}, take temperature characteristics, DC bias characteristics, etc. into consideration to set to the actual capacitance of no less than 0.022 µF.
(Note 4) In case of changing the actual capacitance value due to temperature characteristics, DC bias characteristics, etc. of the output capacitor C_{OUT1} and C_{OUT2}, the loop response characteristics may change. Confirm with the actual application.
(Note 5) R_0 is an option, used for feedback's frequency response measurement. By inserting a resistor at R_0, it is possible to measure the frequency response (phase margin) using a FRA. However, the resistor is not used in actual application, use this resistor pattern in short-circuit mode.

3. V_{IN} = 5 V, V_{OUT} = 1.2 V – continued

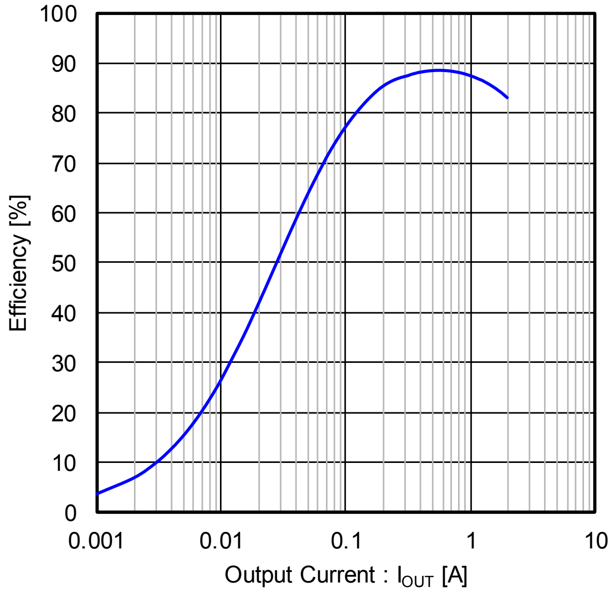


Figure 36. Efficiency vs Output Current

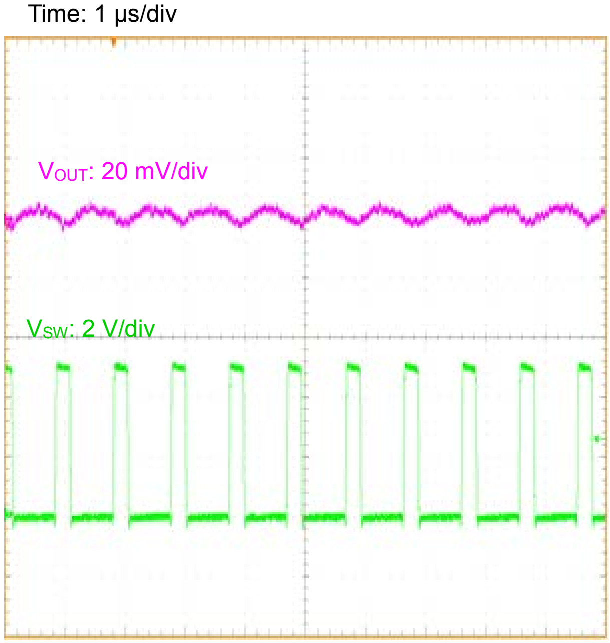


Figure 37. Output Ripple Voltage (I_{OUT} = 2 A)

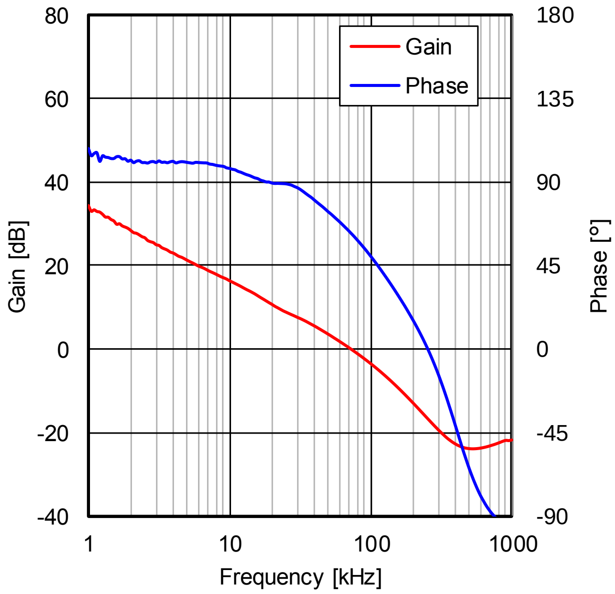


Figure 38. Frequency Characteristics (I_{OUT} = 1 A)

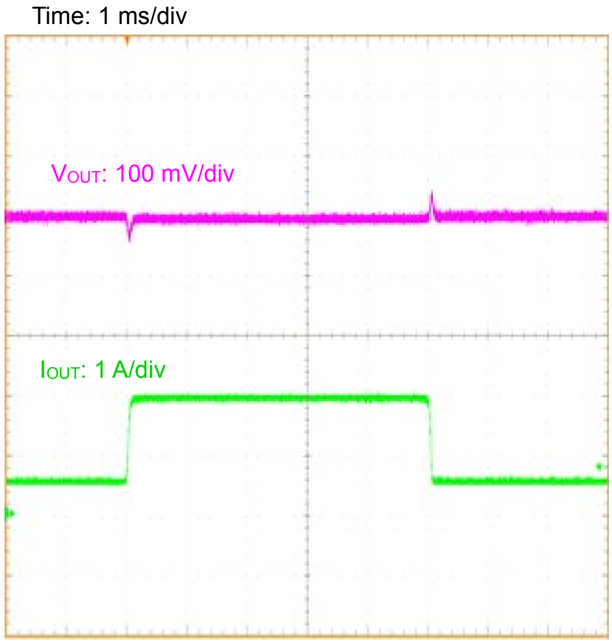


Figure 39. Load Transient Response
(I_{OUT} = 0.5 A to 2.0 A)

Selection of Components Externally Connected

Contact us if not use the recommended component values in Application Examples.

1. Input Capacitor

Use ceramic type capacitor for the input capacitor. The input capacitor is used to reduce the input ripple noise and it is effective by being placed as close as possible to the VIN pin. Set the capacitor value so that it does not fall to 3 μF considering the capacitor value variances, temperature characteristics, DC bias characteristics, aging characteristics, and etc. The PCB layout and the position of the capacitor may lead to IC malfunction. Refer to the notes on the PCB layout on PCB Layout Design when designing PCB layout. In addition, the capacitor with value 0.1 μF can be connected as close as possible to the VIN pin and the GND pin in order to reduce the high frequency noise.

2. 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.

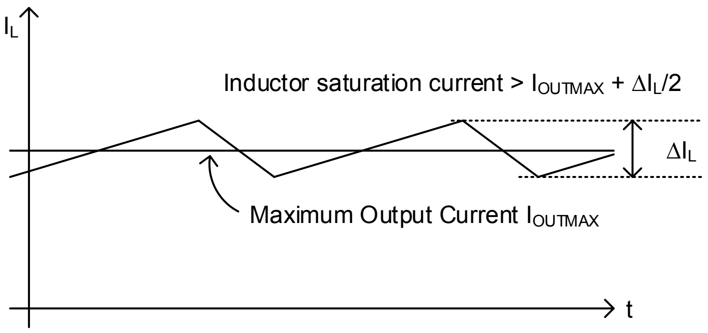


Figure 40. Waveform of Inductor Current

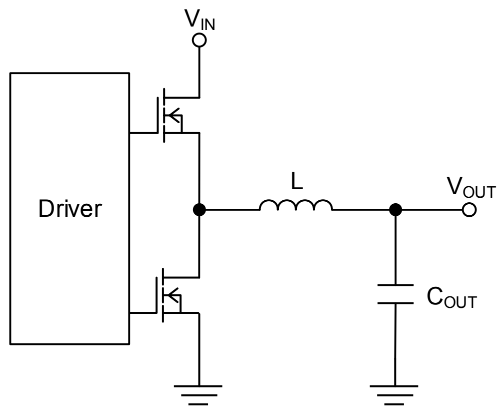


Figure 41. Output LC Filter Circuit

For example, given that V_{IN} = 5 V, V_{OUT} = 1.8 V, L = 1.5 μH, and the switching frequency f_{OSC} = 1000 kHz, Inductor current ΔI_L can be represented by the following equation.

$$\Delta I_L = V_{OUT} \times (V_{IN} - V_{OUT}) \times \frac{1}{V_{IN} \times f_{OSC} \times L} = 0.768 \text{ [A]}$$

The rated current of the inductor (Inductor saturation current) must be more than the sum of the maximum output current I_{OUTMAX} and 1/2 of the inductor ripple current ΔI_L.

Use ceramic type capacitor for the output capacitor C_{OUT}. C_{OUT} affects the output ripple voltage. Select C_{OUT} so that it must satisfy the required ripple voltage characteristics.
The output ripple voltage can be estimated by the following equation.

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

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

For example, given that C_{OUT} = 44 μF and R_{ESR} = 3 mΩ, ΔV_{RPL} can be calculated as below.

$$\Delta V_{RPL} = 0.768 \ A \times \left(3 \ m\Omega + \frac{1}{8 \times 44 \ \mu F \times 1000 \ kHz}\right) = 4.5 \text{ [mV]}$$

2. Output LC Filter – continued

In addition, the charging current I_{CAP} to the output capacitor can be represented by the following equation.

$$I_{CAP} = \frac{1}{t_{SS}} \times (C_{OUT} + C_{LOAD}) \times V_{OUT} \quad \text{[A]}$$

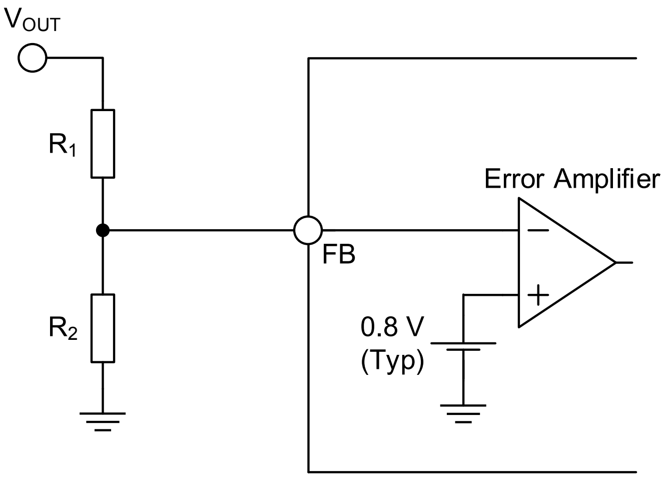
From the above formula, given that V_{IN} = 5 V, V_{OUT} = 3.3 V, L = 1.5 µH, f_{OSC} = 800 kHz (Min), C_{OUT} = 44 µF, t_{SS} = 0.5 ms (Min), and I_{OUTSS} = 2 A, C_{OUTMAX} can be calculated as below.

$$C_{OUTMAX} < \frac{t_{SS}}{V_{OUT}} \times \left(3.8 - I_{OSS} - \frac{\Delta I_L}{2}\right) - C_{OUT} = 157.9 \quad \text{[µF]}$$

If the total capacitance connected to V_{OUT} is more than C_{OUTMAX}, over current protection may be activated by the inrush current at startup and prevented to turn on the output. Confirm this on the actual application.

3. Output Voltage Setting

The output voltage can be set by the feedback resistance ratio connected to the FB pin. For recommended R_1 and R_2, use the values in Application Examples.



$$V_{OUT} = \frac{R_1+R_2}{R_2} \times 0.8 \quad \text{[V]}$$

Figure 42. Feedback Resistor Circuit

Selection of Components Externally Connected – continued

4. Phase Compensation Components

A current mode control buck DC/DC converter is two-pole, one-zero system. Two poles are formed by an error amplifier and load, and the one zero point is added by phase compensation. The phase compensation resistor R1 determines the crossover frequency f_{CRS} that the total loop gain of the DC/DC converter is 0 dB. A high value f_{CRS} provides a good load transient response characteristic but instability. Conversely, a low value f_{CRS} greatly stabilizes the characteristics but the load transient response characteristic is impaired.

(1) Selection of Phase Compensation Resistor R_{COMP}

The Phase Compensation Resistance R_{COMP} can be determined by using the following equation.

$$R_{COMP} = \frac{2 \times \pi \times V_{OUT} \times f_{CRS} \times C_{OUT}}{V_{FB} \times G_{MP} \times G_{MA}} \quad [\Omega]$$

where:
V_{OUT} is the Output Voltage
f_{CRS} is the Crossover Frequency
C_{OUT} is the Output Capacitance
V_{FB} is the Feedback Reference Voltage 0.8 V (Typ)
G_{MP} is the Current Sense Gain 13 A/V (Typ)
G_{MA} is the Error Amplifier Trans conductance 260 µA/V (Typ)

(2) Selection of Phase Compensation Capacitance C_{COMP}

For stable operations of DC/DC converter, the zero point (phase lead) to cancel the phase lag formed by loads is determined with C_{COMP}. Inserting a zero point below 1/9 of the crossover frequency often provides good characteristics.

C_{COMP} can be calculated with the following equation.

$$C_{COMP} = \frac{1}{2 \times \pi \times R_{COMP} \times f_Z} \quad [F]$$

where:
f_Z is the zero point to be inserted

(3) Loop Stability

Actually, characteristics will vary depending on PCB layout, arrangement of wiring, kinds of parts used and use conditions (temperature, etc.). Be sure to check stability and responsiveness with actual apparatus. Phase margin of at least 45° in the worst conditions is recommended. Gain Phase Analyzer or Frequency Response Analyzer FRA is used to check frequency characteristics with actual apparatus. Contact the measurement apparatus manufacturer for measurement method.

5. Bootstrap Capacitor

The bootstrap capacitor 0.1 µF is recommended. Connect the capacitor between the SW pin and the BOOT pin. For the capacitance, take temperature characteristics, DC bias characteristics, and etc. into consideration to set to the actual capacitance of no less than 0.022 µF.

PCB Layout Design

PCB layout design for DC/DC converter is very important. Appropriate layout can avoid various problems concerning power supply circuit. Figure 43-a to Figure 43-c show the current path in a buck DC/DC converter circuit. The Loop 1 in Figure 43-a is a current path when H-side switch is ON and L-side switch is OFF, the Loop 2 in Figure 43-b is when H-side switch is OFF and L-side switch is ON. The thick line in Figure 43-c shows the difference between Loop1 and Loop2. The current in thick line change sharply each time the switching element H-side and L-side switch change from OFF to ON, and vice versa. These sharp changes induce a waveform with harmonics in this loop. 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 details, refer to application note of switching regulator series "PCB Layout Techniques of Buck Converter".

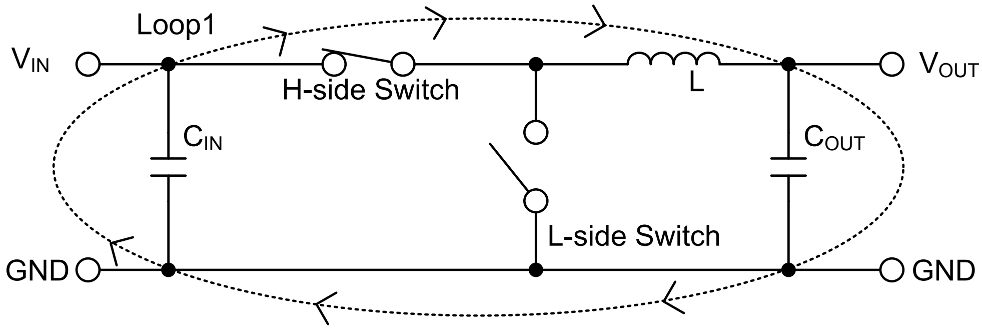


Figure 43-a. Current Path when H-side Switch = ON, L-side Switch = OFF

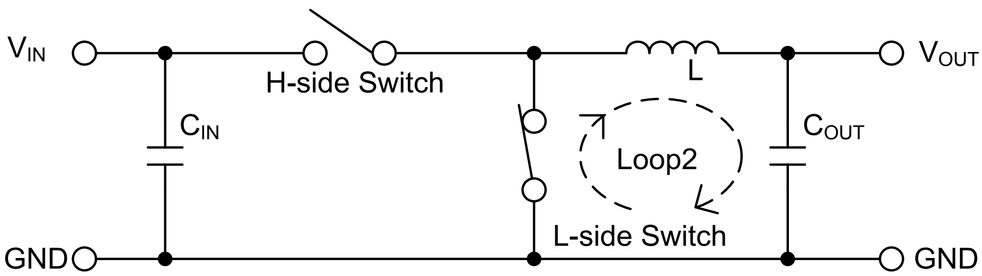


Figure 43-b. Current Path when H-side Switch = OFF, L-side Switch = ON

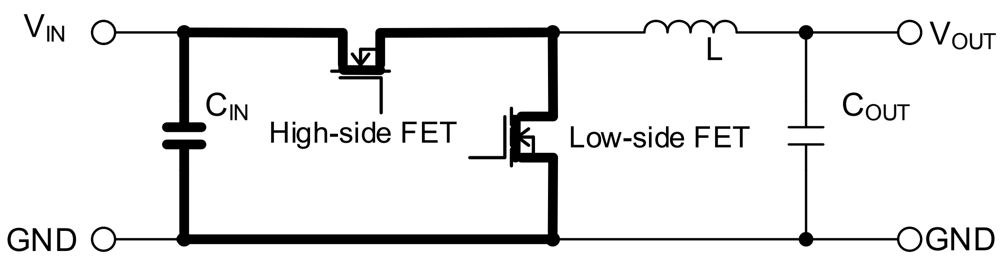


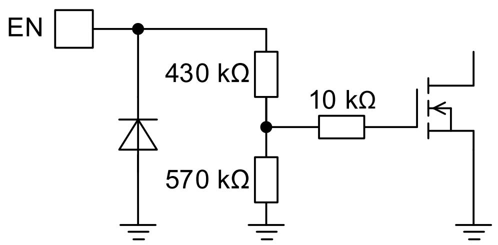
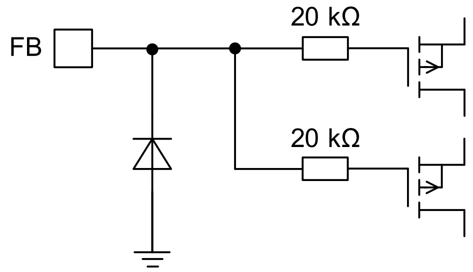
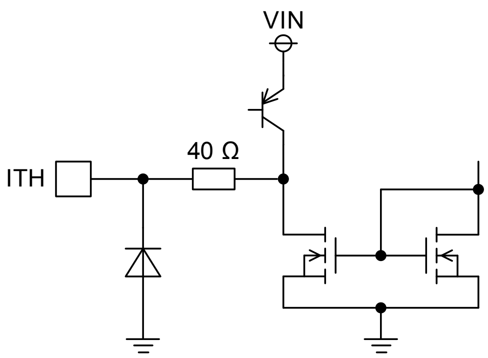
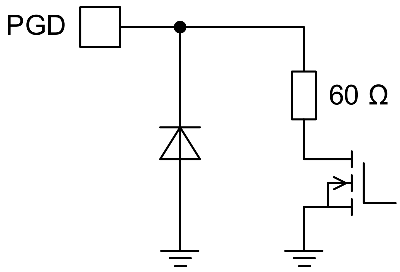
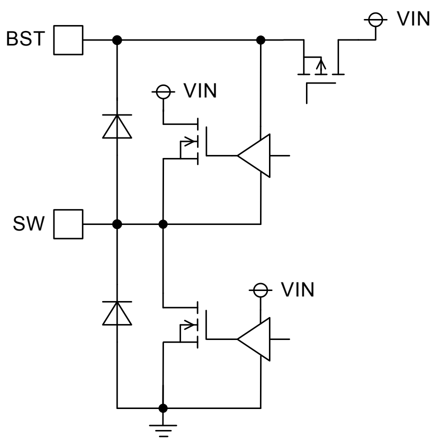
Figure 43-c. Difference of Current and Critical Area in Layout

PCB Layout Design – continued

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

- Connect the input capacitor C_{IN1} and C_{IN2} as close as possible to the VIN pin and the GND pin on the same plane as the IC.
- Switching nodes such as SW are susceptible to noise due to AC coupling with other nodes. Route the inductor pattern L as thick and as short as possible.
- The feedback line connected to the FB pin should be as far away from the SW nodes as possible.
- Place the output capacitor C_{OUT} away from input capacitor C_{IN1} and C_{IN2} to avoid harmonics noise from the input.
- Separate the reference ground and the power ground and connect them through VIA. The reference ground should be connected to the power ground that is close to the output capacitor C_{OUT}. It is because C_{OUT} has less high frequency switching noise.
- R_0 is provided for the measurement of feedback frequency characteristics (optional). By inserting a resistor into R_0, it is possible to measure the frequency characteristics of feedback (phase margin) using FRA etc. R_0 is short-circuited for normal use.

I/O Equivalence Circuits

1. EN	4. FB
	
5. ITH	**6. PGD**
	
7. SW, 8. BST	
	

Operational Notes

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

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

3. **Ground Voltage**
Ensure that no pins are at a voltage below that of the ground pin at any time, even during transient condition. 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. **Testing on Application Boards**
When testing the IC on an application board, connecting a capacitor directly to a low-impedance output pin may subject the IC to stress. Always discharge capacitors completely after each process or step. The IC's power supply should always be turned off completely before connecting or removing it from the test setup during the inspection process. To prevent damage from static discharge, ground the IC during assembly and use similar precautions during transport and storage.

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

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

Operational Notes – continued

10. Regarding the Input Pin of the IC

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

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

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

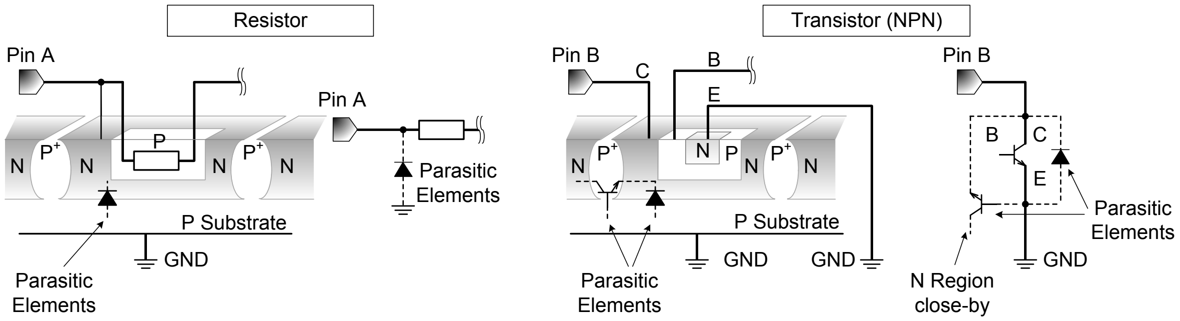


Figure 44. Example of Monolithic IC Structure

11. Ceramic Capacitor

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

12. Thermal Shutdown Circuit (TSD)

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

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

13. Over Current Protection Circuit (OCP)

This IC incorporates an integrated overcurrent protection circuit that is activated when the load is shorted. This protection circuit is effective in preventing damage due to sudden and unexpected incidents. However, the IC should not be used in applications characterized by continuous operation or transitioning of the protection circuit.

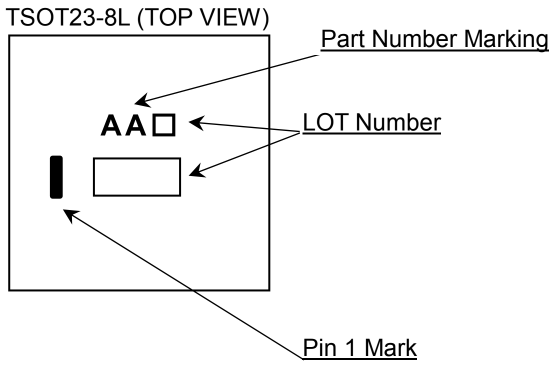
Ordering Information

B D 9 A 2 0 1 F P 4 - L B Z TL

Package
FP4-Z: TSOT23-8L

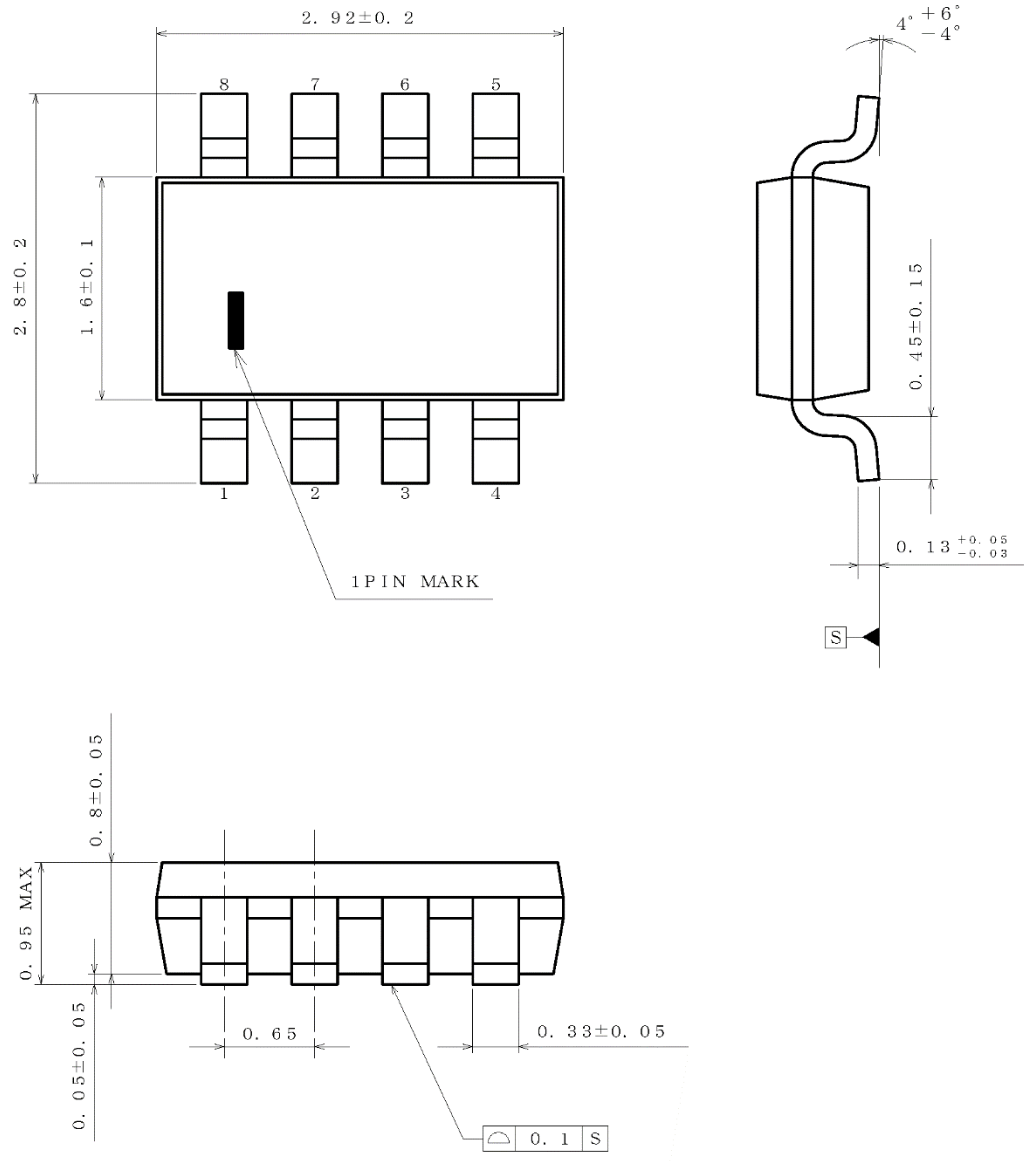
Product class
LB: for Industrial applications
Packaging and forming specification
TL: Embossed tape and reel

Marking Diagram



Physical Dimension and Packing Information

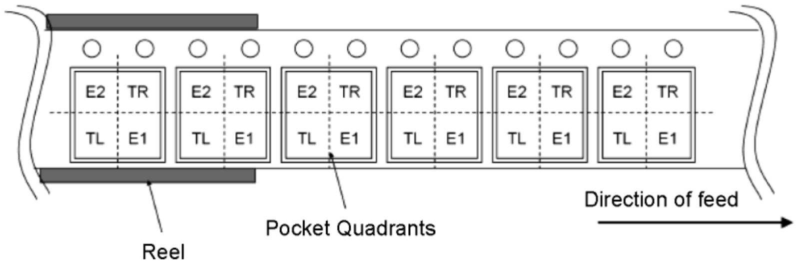
Package Name	TSOT23-8L



(UNIT : mm)
PKG : TSOT23−8L
Drawing No. EX001−0111−1

< Tape and Reel Information >

Tape	Embossed carrier tape
Quantity	3500pcs
Direction of feed	TL The direction is the pin 1 of product is at the lower left when you hold reel on the left hand and you pull out the tape on the right hand



Revision History

Date	Revision	Changes
26.Oct.2020	001	New Release

Notice

Precaution on using ROHM Products

1. If you intend to use our Products in devices requiring extremely high reliability (such as medical equipment (Note 1), aircraft/spacecraft, nuclear power controllers, etc.) and whose malfunction or failure may cause loss of human life, bodily injury or serious damage to property ("Specific Applications"), please consult with the ROHM sales representative in advance. Unless otherwise agreed in writing by ROHM in advance, ROHM shall not be in any way responsible or liable for any damages, expenses or losses incurred by you or third parties arising from the use of any ROHM's Products for Specific Applications.

(Note1) Medical Equipment Classification of the Specific Applications

JAPAN	USA	EU	CHINA
CLASSⅢ	CLASSⅢ	CLASSⅡb	CLASSⅢ
CLASSⅣ		CLASSⅢ	

2. ROHM designs and manufactures its Products subject to strict quality control system. However, semiconductor products can fail or malfunction at a certain rate. Please be sure to implement, at your own responsibilities, adequate safety measures including but not limited to fail-safe design against the physical injury, damage to any property, which a failure or malfunction of our Products may cause. The following are examples of safety measures:
   [a] Installation of protection circuits or other protective devices to improve system safety
   [b] Installation of redundant circuits to reduce the impact of single or multiple circuit failure

3. Our Products are not designed under any special or extraordinary environments or conditions, as exemplified below. Accordingly, ROHM shall not be in any way responsible or liable for any damages, expenses or losses arising from the use of any ROHM's Products under any special or extraordinary environments or conditions. If you intend to use our Products under any special or extraordinary environments or conditions (as exemplified below), your independent verification and confirmation of product performance, reliability, etc, prior to use, must be necessary:
   [a] Use of our Products in any types of liquid, including water, oils, chemicals, and organic solvents
   [b] Use of our Products outdoors or in places where the Products are exposed to direct sunlight or dust
   [c] Use of our Products in places where the Products are exposed to sea wind or corrosive gases, including Cl_2, H_2S, NH_3, SO_2, and NO_2
   [d] Use of our Products in places where the Products are exposed to static electricity or electromagnetic waves
   [e] Use of our Products in proximity to heat-producing components, plastic cords, or other flammable items
   [f] Sealing or coating our Products with resin or other coating materials
   [g] Use of our Products without cleaning residue of flux (Exclude cases where no-clean type fluxes is used. However, recommend sufficiently about the residue.); or Washing our Products by using water or water-soluble cleaning agents for cleaning residue after soldering
   [h] Use of the Products in places subject to dew condensation

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

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

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

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

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

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

Precaution for Mounting / Circuit board design

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

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

For details, please refer to ROHM Mounting specification

Precautions Regarding Application Examples and External Circuits

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

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

Precaution for Electrostatic

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

Precaution for Storage / Transportation

1. Product performance and soldered connections may deteriorate if the Products are stored in the places where:
   [a] the Products are exposed to sea winds or corrosive gases, including Cl_2, H_2S, NH_3, SO_2, and NO_2
   [b] the temperature or humidity exceeds those recommended by ROHM
   [c] the Products are exposed to direct sunshine or condensation
   [d] the Products are exposed to high Electrostatic

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

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

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

Precaution for Product Label

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

Precaution for Disposition

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

Precaution for Foreign Exchange and Foreign Trade act

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

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