SPICE Modeling Report

4.5 V to 28 V Input, 2.0 A Integrated MOSFET Single Synchronous Buck DC/DC Converter BD9E202FP4-Z

General Description

In this report, the characteristics that can be confirmed by the simulation using the SPICE model of the regulator IC BD9E202FP4-Z will be described.

Simulation Environment

- Circuit Simulator : PSpice / Cadence Design System, Inc.
- Version Information : 17.4-2019
- OS Information : Windows 10 64-bit Edition

File Information

- Library File Name : BD9E202FP4-Z_PSPICE.lib
- Symbol File Name : BD9E202FP4-Z_PSPICE.olb
- Subcircuit and Symbol

Table 1 Correspondence Table

Product Name	Subcircuit	Symbol
BD9E202FP4-Z	BD9E202FP4 (Model for Transient Analysis)	BD9E202FP4-Z
		BD9E202FP4-Z_CAD (Note2)
	BD9E202FP4_AVE (Note1) (Model for AC Analysis)	BD9E202FP4-Z_AVE (Note3)
		BD9E202FP4-Z_AVE_CAD (Note2) (Note3)

(Note 1) BD9E202FP4_AVE is the spice macro model for Frequency Characteristic (AC simulation). Refer to Page 11 to 13 for simulation detail.
(Note 2) Symbol with _CAD at the end of the name conform to IEC60617, and were designed so that signals flow from left to right.
(Note 3) Pin information for BD9E202FP4_AVE is same like Table 2.

Caution

- These model characteristics are specifically at Ta = 25 °C. Thus, the simulation result with temperature variances may significantly differ from the result with the one done at actual application board (actual measurement).
- The simulation result and characteristics described in this report may differ depending on the board design. It is recommended to perform the measurement on the actual board to verify the result.
- The values from the simulation results are not guaranteed. Use these results as a guide for your design.
- Actual measurement was done using a specific sample, thus the measured data is just as a reference.

BD9E202FP4-Z Spice Model

■ Pin Information

Figure 1 is for simulation, and Figure 2 is the actual IC pin layout.

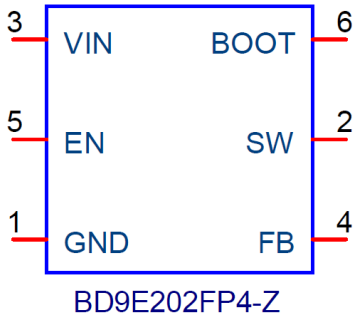


Figure 1 Symbol of BD9E202FP4-Z

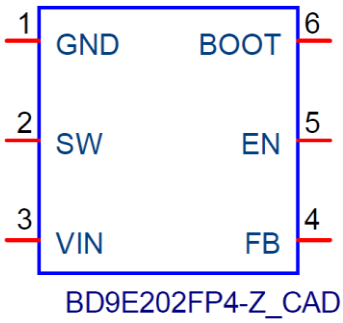


Figure 2 Symbol of BD9E202FP4-Z_CAD

Table 2 Subcircuit Pin Table

Pin No.	Pin Name	Pin No.	Pin Name
1.	GND	4.	FB
2.	SW	5.	EN
3.	VIN	6.	BOOT

■ Model Parameter

Table 3 Model Parameter Table

Parameter	Default Value	Description
BD9E202FP4		
-	-	-
BD9E202FP4_AVE		
l	10u	Set the inductor value connected to SW pin.
v_vo	3.3	On Duty parameter for the Numerator.
v_vin	12	On Duty parameter for the Denominator. On Duty is given as { v_vo / v_vin }.

Verifiable Characteristics

Electrical Characteristics (vs. Datasheet)

Table 4 Electrical Characteristics Comparison

(Unless otherwise specified Ta = 25 °C, V_{IN} = 12 V, V_{EN} = 3 V)

Parameter	Modeled *(Note1)*	Design Value		Unit	Error	Condition
		Datasheet	SPICE			
Input Supply						
Shutdown Current	Yes	4	4	µA	0%	V_{EN} = 0 V
Operating Quiescent Current	Yes	95	95	µA	0%	I_{OUT} = 0 A, No switching
UVLO Threshold Voltage	Yes	3.9	3.9	V	0%	V_{IN} falling
UVLO Hysteresis Voltage	Yes	350	350	mV	0%	
Enable						
EN Threshold Voltage High	Yes	1.21	1.21	V	0%	V_{EN} rising
EN Threshold Voltage Low	Yes	1.19	1.19	V	0%	V_{EN} falling
EN Input Current	Yes	0.7	0.7	µA	0%	V_{EN} = 1 V
EN Input Hysteresis Current	Yes	1.50	1.50	µA	0%	$I_{VEN=2V} - I_{VEN=1V}$
Reference Voltage, Error Amplifier, Soft Start						
FB Threshold Voltage	Yes	0.596	0.596	V	0%	
FB Input Current	Yes	< 100	< 100	nA	-	V_{FB} = 0.7 V
Soft Start Time	Yes	5.0	5.0	ms	0%	
SW (MOSFET)						
Switching Frequency	Yes	500	500	kHz	0%	
Maximum Duty Ratio	Yes	> 80	> 80	%	-	
High Side FET ON Resistance	Yes	185	185	mΩ	0%	
Low Side FET ON Resistance	Yes	98	98	mΩ	0%	
Protection						
High Side Over Current Limit	Yes	3.2	3.2	A	0%	No switching

(Note 1) Yes: Model available (supported), No: Model not available" (not supported).

Characteristics in SPICE (vs. Measured Waveform)
1. Output Ripple Voltage (V_{IN} = 12 V, V_{OUT} = 3.3 V, I_{OUT} = 2 A)

Simulation Setting
Type: Transient
Run Time: 12 ms
(Maximum Step Size: 10 ns)

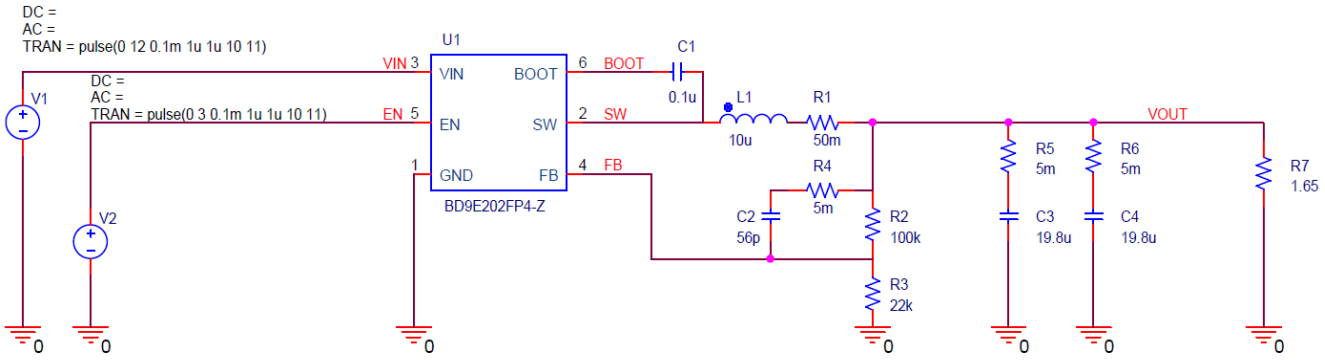
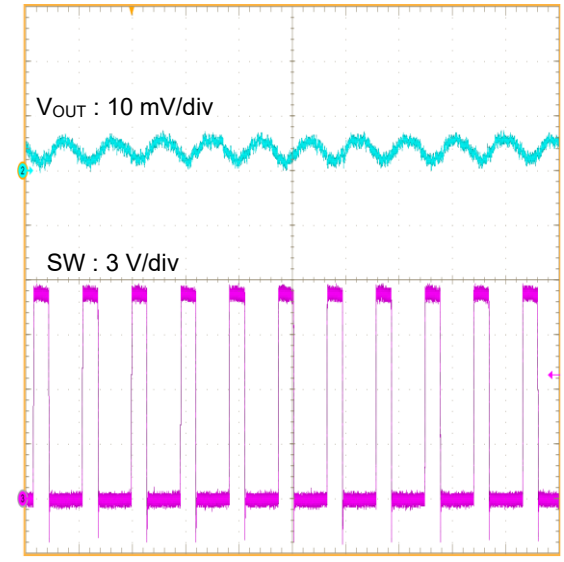
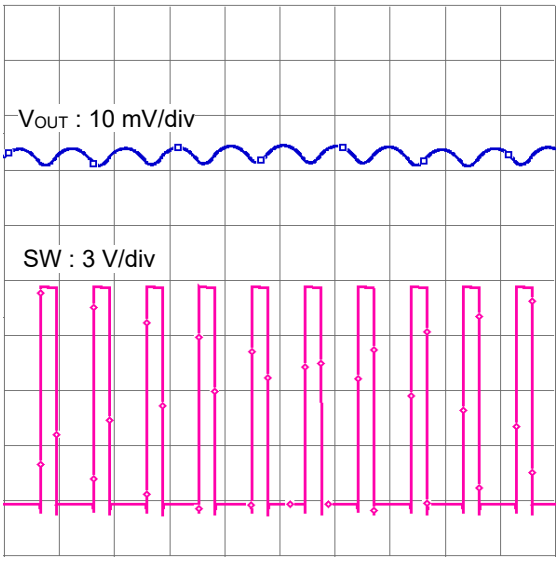


Figure 3.
Simulation Schematic 1



Time = 2 µs/div

Figure 4.
Output Ripple Voltage
(V_{IN} = 12 V, V_{OUT} = 3.3 V, I_{OUT} = 2 A)
(Measured Waveform)



Time = 2 µs/div

Figure 5.
Output Ripple Voltage
(V_{IN} = 12 V, V_{OUT} = 3.3 V, I_{OUT} = 2 A)
(SPICE Simulation)

Table 5 Characteristics Comparison

Parameter	Measured Result (Note1) (Note2)	SPICE Simulation Result	Unit	Error	Condition
Output Ripple Voltage	1.6	1.6	mV	0 %	V_{IN} = 12 V, V_{OUT} = 3.3 V, I_{OUT} = 2 A

(Note 1) The above data is based on a specific sample and it is not a guaranteed value.
(Note 2) These characteristics depend on some dynamic characteristics of external components, input signal speed, PCB pattern and mounting condition of each on-board parts.

2. Output Ripple Voltage (V_{IN} = 12 V, V_{OUT} = 5 V, I_{OUT} = 2 A)

Simulation Setting
Type: Transient
Run Time: 12 ms
(Maximum Step Size: 10 ns)

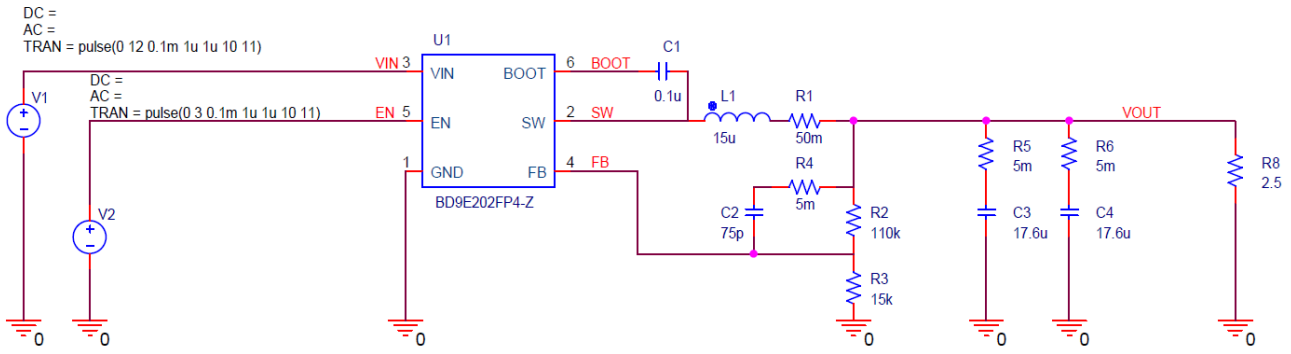


Figure 6.
Simulation Schematic 2

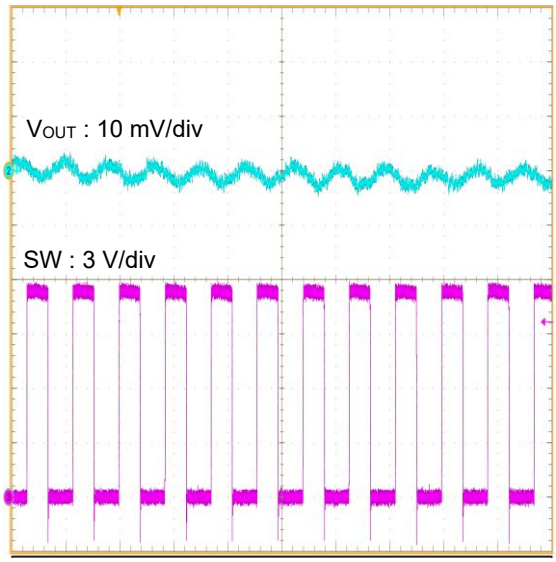


Figure 7.
Output Ripple Voltage
(V_{IN} = 12 V, V_{OUT} = 5 V, I_{OUT} = 2 A)
(Measured Waveform)

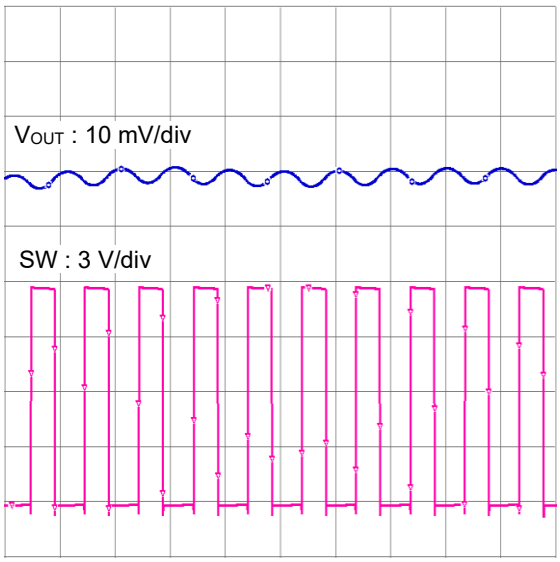


Figure 8.
Output Ripple Voltage
(V_{IN} = 12 V, V_{OUT} = 5 V, I_{OUT} = 2 A)
(SPICE Simulation)

Table 6 Characteristics Comparison

Parameter	Measured Result (Note1) (Note2)	SPICE Simulation Result	Unit	Error	Condition
Output Ripple Voltage	1.5	1.4	mV	-6.7 %	V_{IN} = 12 V, V_{OUT} = 5 V, I_{OUT} = 2 A

(Note 1) The above data is based on a specific sample and it is not a guaranteed value.
(Note 2) These characteristics depend on some dynamic characteristics of external components, input signal speed, PCB pattern and mounting condition of each on-board parts.

3. Output Ripple Voltage (V_{IN} = 24 V, V_{OUT} = 12 V, I_{OUT} = 2 A)

Simulation Setting
Type: Transient
Run Time: 12 ms
(Maximum Step Size: 10 ns)

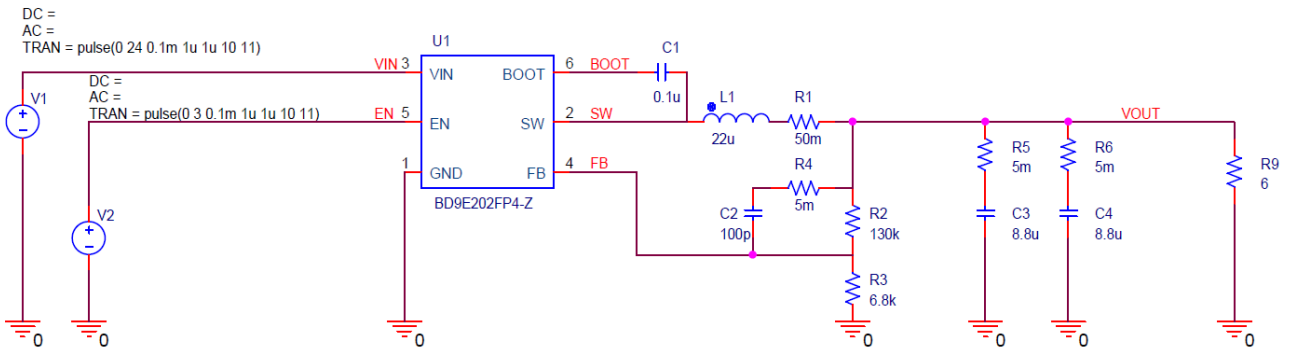


Figure 9.
Simulation Schematic 3

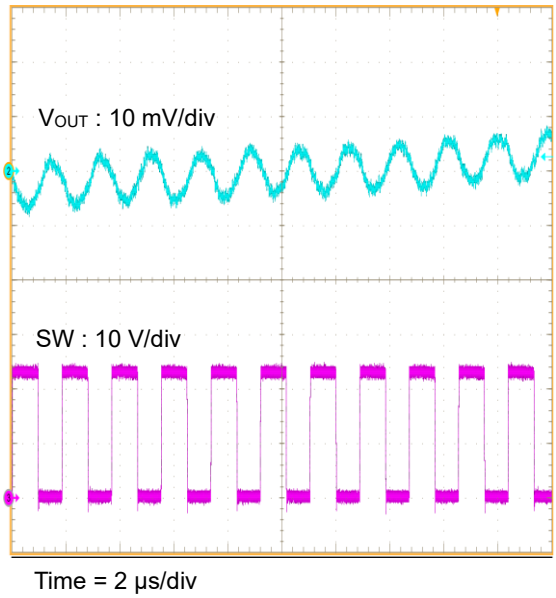


Figure 10.
Output Ripple Voltage
(V_{IN} = 24 V, V_{OUT} = 12 V, I_{OUT} = 2 A)
(Measured Waveform)

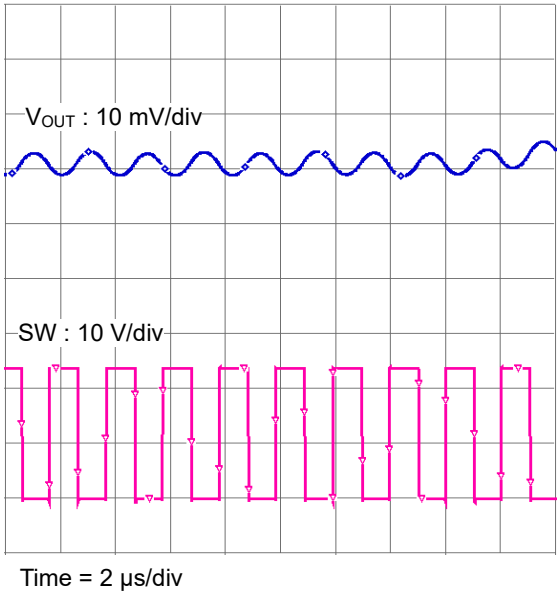


Figure 11.
Output Ripple Voltage
(V_{IN} = 24 V, V_{OUT} = 12 V, I_{OUT} = 2 A)
(SPICE Simulation)

Table 7 Characteristics Comparison

Parameter	Measured Result (Note1) (Note2)	SPICE Simulation Result	Unit	Error	Condition
Output Ripple Voltage	4.0	3.5	mV	-12.5 %	V_{IN} = 24 V, V_{OUT} = 12 V, I_{OUT} = 2 A

(Note 1) The above data is based on a specific sample and it is not a guaranteed value.
(Note 2) These characteristics depend on some dynamic characteristics of external components, input signal speed, PCB pattern and mounting condition of each on-board parts.

4. Load Response (V_{IN} = 12 V, V_{OUT} = 3.3 V, I_{OUT} = 0.5 A to 1.5 A)

Simulation Setting
Type: Transient
Run Time: 12 ms
(Maximum Step Size: 10 ns)

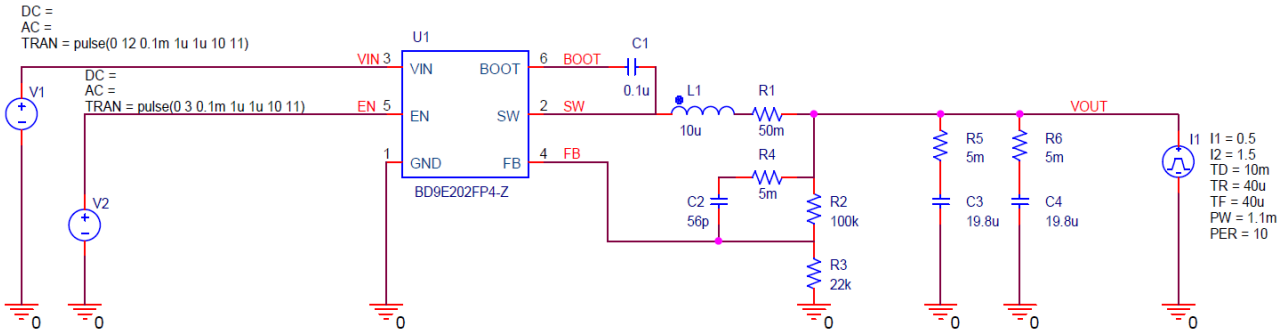


Figure 12.
Simulation Schematic 4

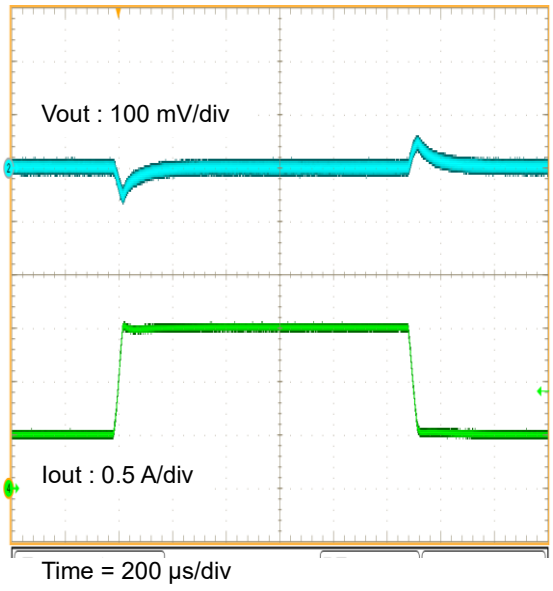


Figure 13.
Load Response
(V_{IN} = 12 V, V_{OUT} = 3.3 V, I_{OUT} = 0.5 A to 1.5 A)
(Measured Waveform)

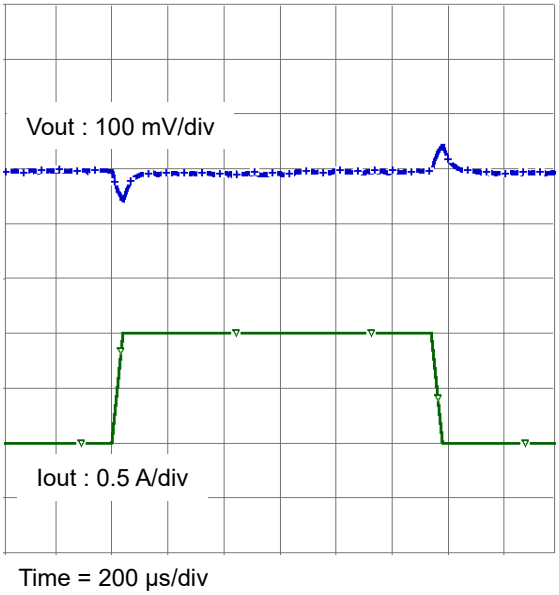


Figure 14.
Load Response
(V_{IN} = 12 V, V_{OUT} = 3.3 V, I_{OUT} = 0.5 A to 1.5 A)
(SPICE Simulation)

Table 8 Characteristics Comparison

Parameter	Measured Result (Note1) (Note2)	SPICE Simulation Result	Unit	Error	Condition
Overshoot	40	51	mV	27.5 %	V_{IN} = 12 V, V_{OUT} = 3.3 V, I_{OUT} = 0.5 A to 1.5 A
Undershoot	40	49	mV	22.5 %	

(Note 1) The above data is based on a specific sample and it is not a guaranteed value.
(Note 2) These characteristics depend on some dynamic characteristics of external components, input signal speed, PCB pattern and mounting condition of each on-board parts.

5. Load Response (V_{IN} = 12 V, V_{OUT} = 5 V, I_{OUT} = 0.5 A to 1.5 A)

Simulation Setting
Type: Transient
Run Time: 12 ms
(Maximum Step Size: 10 ns)

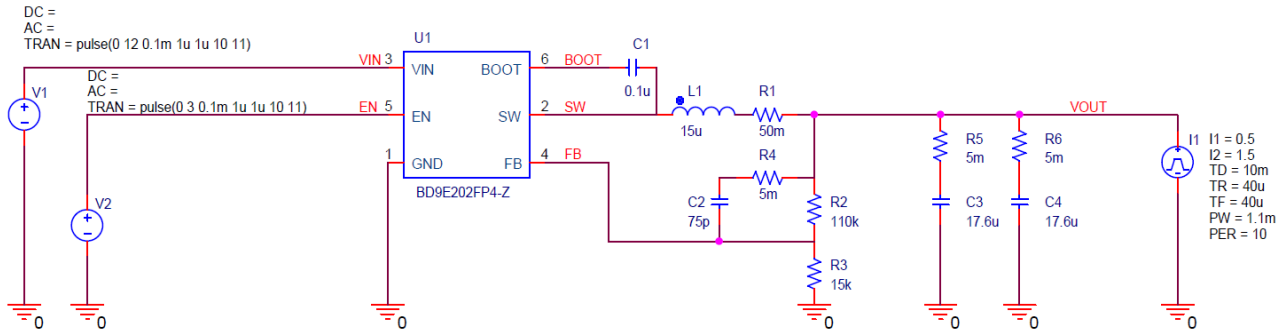


Figure 15.
Simulation Schematic 5

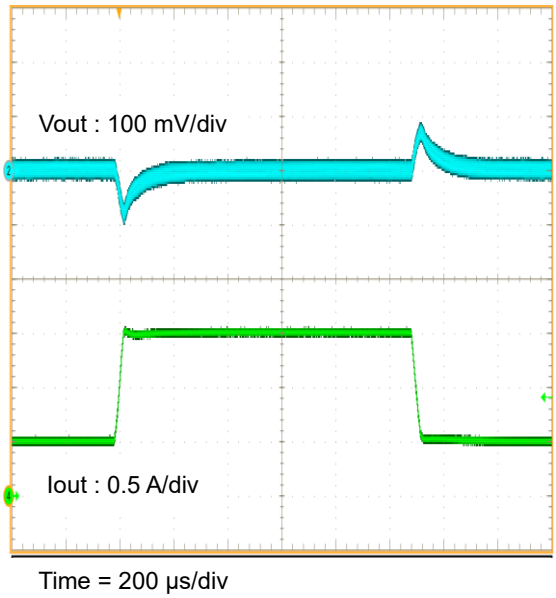


Figure 16.
Load Response
(V_{IN} = 12 V, V_{OUT} = 5 V, I_{OUT} = 0.5 A to 1.5 A)
(Measured Waveform)

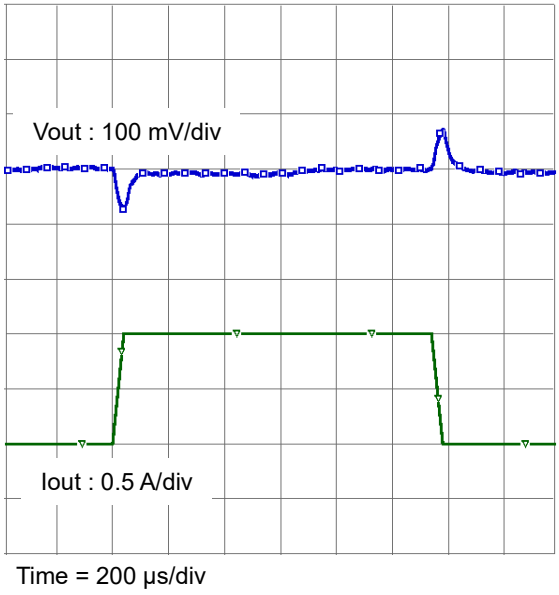


Figure 17.
Load Response
(V_{IN} = 12 V, V_{OUT} = 5 V, I_{OUT} = 0.5 A to 1.5 A)
(SPICE Simulation)

Table 9 Characteristics Comparison

Parameter	Measured Result (Note1) (Note2)	SPICE Simulation Result	Unit	Error	Condition
Overshoot	88	70.5	mV	-19.9 %	V_{IN} = 12 V, V_{OUT} = 5 V, I_{OUT} = 0.5 A to 1.5 A
Undershoot	85	78	mV	-8.2 %	

(Note 1) The above data is based on a specific sample and it is not a guaranteed value.
(Note 2) These characteristics depend on some dynamic characteristics of external components, input signal speed, PCB pattern and mounting condition of each on-board parts.

6. Load Response (V_{IN} = 24 V, V_{OUT} = 12 V, I_{OUT} = 0.5 A to 1.5 A)

Simulation Setting
Type: Transient
Run Time: 12 ms
(Maximum Step Size: 10 ns)

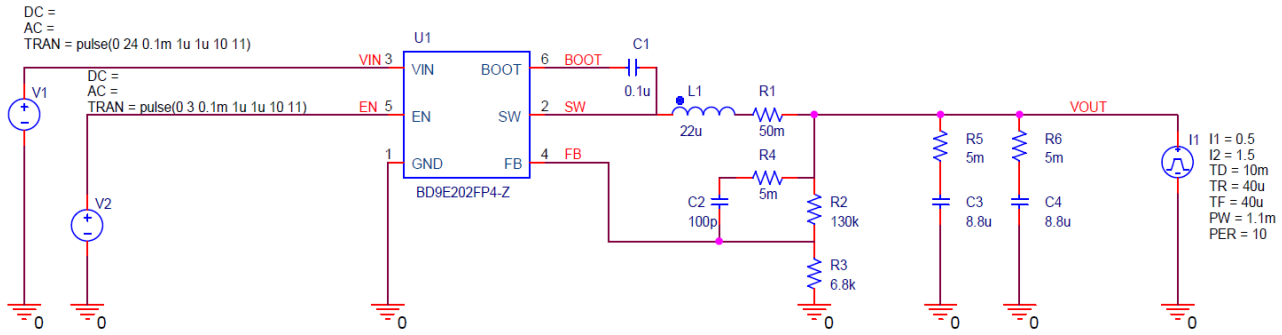


Figure 18.
Simulation Schematic 6

Figure 19.
Load Response
(V_{IN} = 24 V, V_{OUT} = 12 V, I_{OUT} = 0.5 A to 1.5 A)
(Measured Waveform)

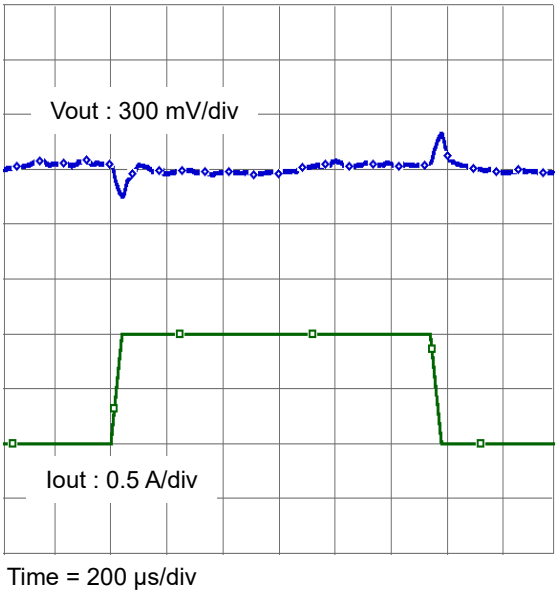


Figure 20.
Load Response
(V_{IN} = 24 V, V_{OUT} = 12 V, I_{OUT} = 0.5 A to 1.5 A)
(SPICE Simulation)

Table 10 Characteristics Comparison

Parameter	Measured Result (Note1) (Note2)	SPICE Simulation Result	Unit	Error	Condition
Overshoot	210	170	mV	-19.0 %	V_{IN} = 24 V, V_{OUT} = 12 V, I_{OUT} = 0.5 A to 1.5 A
Undershoot	230	169	mV	-26.5 %	

(Note 1) The above data is based on a specific sample and it is not a guaranteed value.
(Note 2) These characteristics depend on some dynamic characteristics of external components, input signal speed, PCB pattern and mounting condition of each on-board parts.

7. Frequency Characteristics (V_{IN} = 12 V, V_{OUT} = 3.3 V, I_{OUT} = 2 A)

Simulation Setting
Type: AC
Frequency Range:
1 kHz to 1 MHz
(Points/Decade: 20)

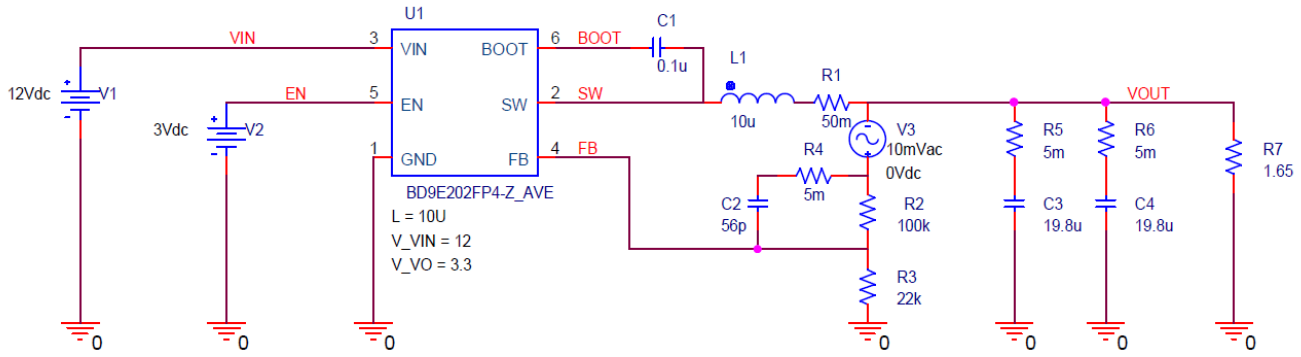


Figure 21.
Simulation Schematic 7

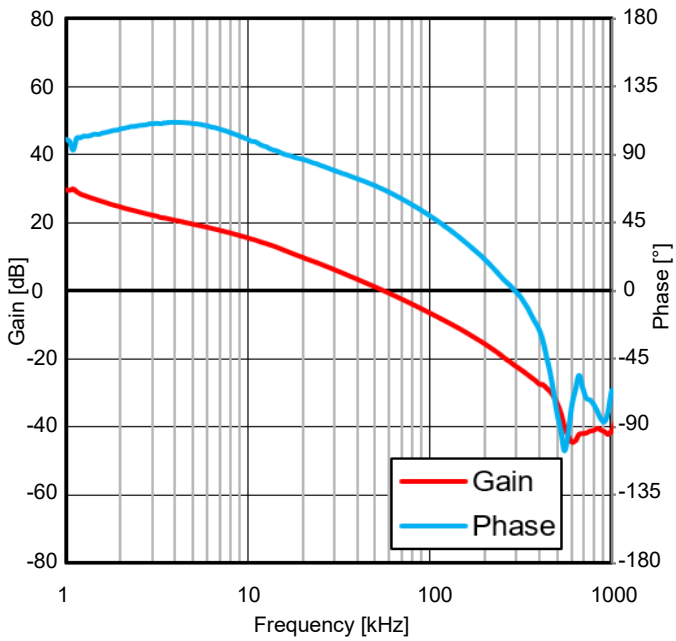


Figure 22.
Frequency Characteristics
(V_{IN} = 12 V, V_{OUT} = 3.3 V, I_{OUT} = 2 A)
(Measured Waveform)

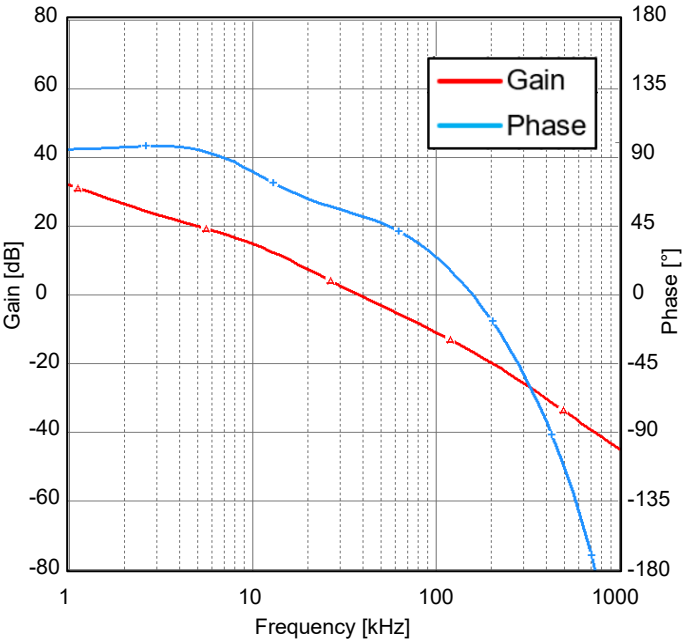


Figure 23.
Frequency Characteristics
(V_{IN} = 12 V, V_{OUT} = 3.3 V, I_{OUT} = 2 A)
(SPICE Simulation)

Table 11 Characteristics Comparison

Parameter	Measured Result (Note1) (Note2)	SPICE Simulation Result	Unit	Error	Condition
Phase Margin	65.8	52.3	degree	-20.5 %	V_{IN} = 12 V, V_{OUT} = 3.3 V, I_{OUT} = 2 A
Crossover Frequency	57.5	37.7	kHz	-34.4 %	

(Note 1) The above data is based on a specific sample and it is not a guaranteed value.
(Note 2) These characteristics depend on some dynamic characteristics of external components, input signal speed, PCB pattern and mounting condition of each on-board parts.

8. Frequency Characteristics (V_{IN} = 12 V, V_{OUT} = 5 V, I_{OUT} = 2 A)

Simulation Setting
Type: AC
Frequency Range:
1 kHz to 1 MHz
(Points/Decade: 20)

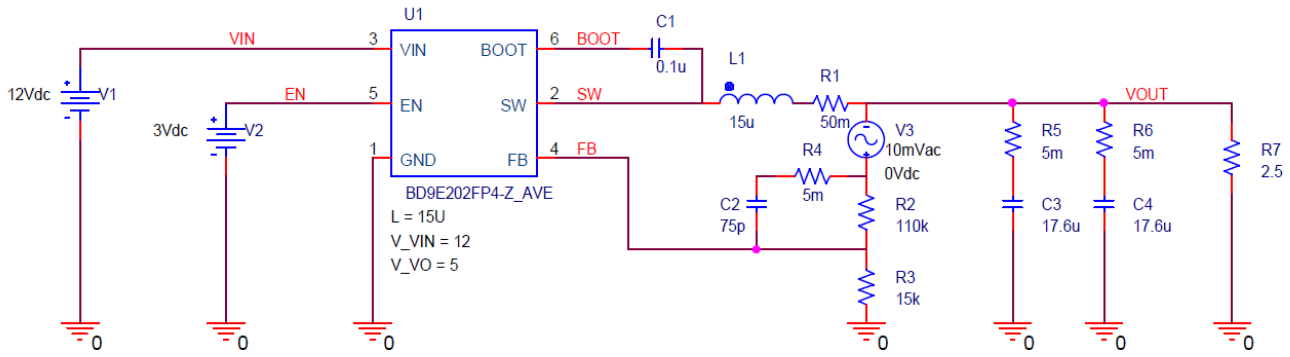


Figure 24.
Simulation Schematic 8

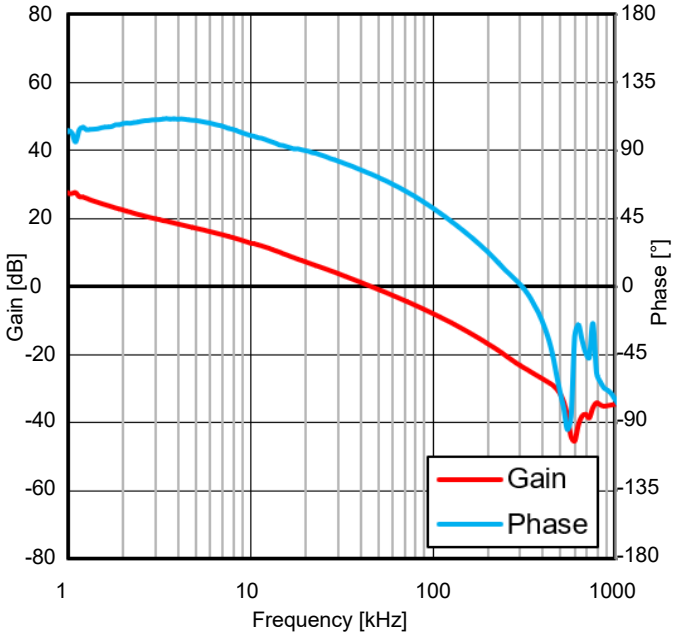


Figure 25.
Frequency Characteristics
(V_{IN} = 12 V, V_{OUT} = 5 V, I_{OUT} = 2 A)
(Measured Waveform)

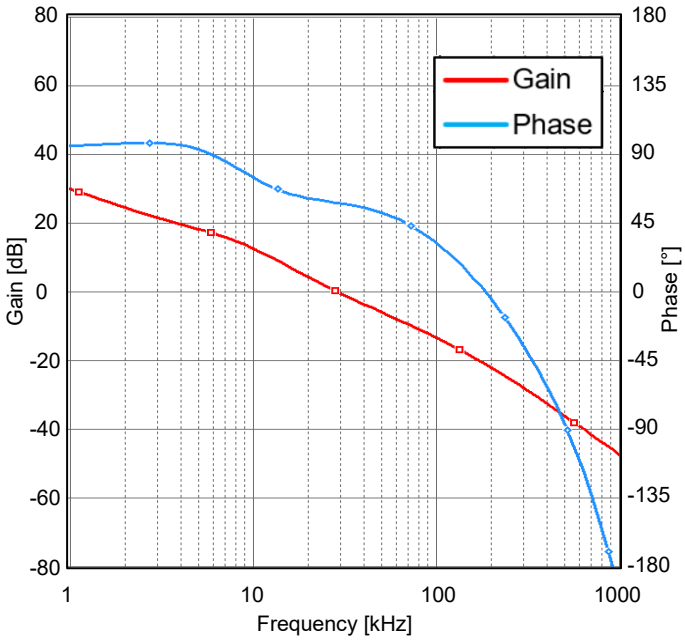


Figure 26.
Frequency Characteristics
(V_{IN} = 12 V, V_{OUT} = 5 V, I_{OUT} = 2 A)
(SPICE Simulation)

Table 12 Characteristics Comparison

Parameter	Measured Result (Note1) (Note2)	SPICE Simulation Result	Unit	Error	Condition
Phase Margin	74.1	58.3	degree	-21.3 %	V_{IN} = 12 V, V_{OUT} = 5 V, I_{OUT} = 2 A
Crossover Frequency	45.7	29.2	kHz	-36.1 %	

(Note 1) The above data is based on a specific sample and it is not a guaranteed value.
(Note 2) These characteristics depend on some dynamic characteristics of external components, input signal speed, PCB pattern and mounting condition of each on-board parts.

9. Frequency Characteristics (V_{IN} = 24 V, V_{OUT} = 12 V, I_{OUT} = 2 A)

Simulation Setting
Type: AC
Frequency Range:
1 kHz to 1 MHz
(Points/Decade: 20)

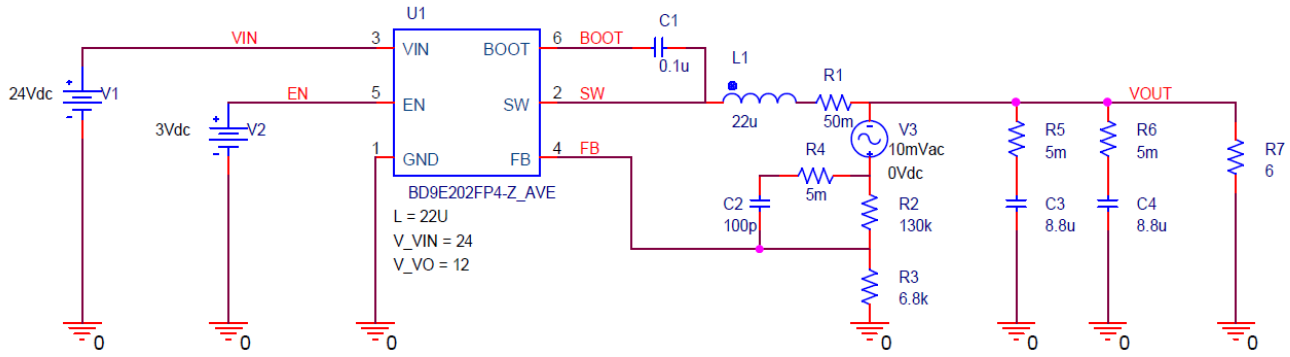


Figure 27.
Simulation Schematic 9

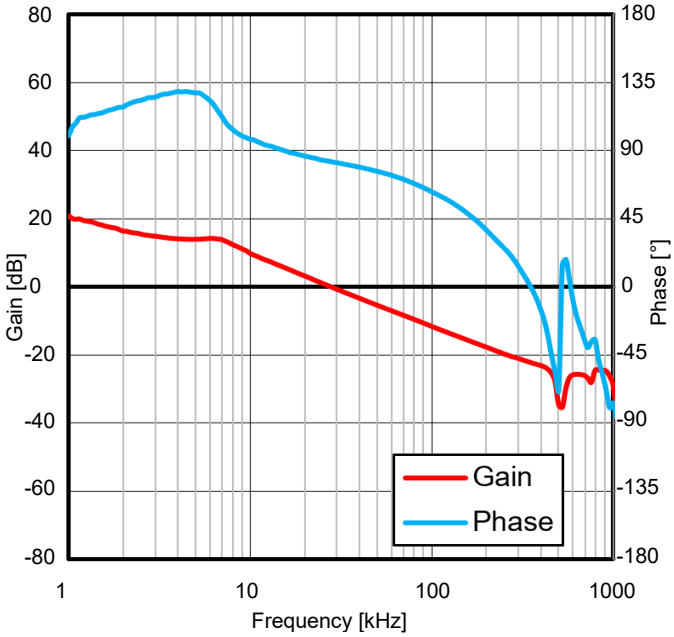


Figure 28.
Frequency Characteristics
(V_{IN} = 24 V, V_{OUT} = 12 V, I_{OUT} = 2 A)
(Measured Waveform)

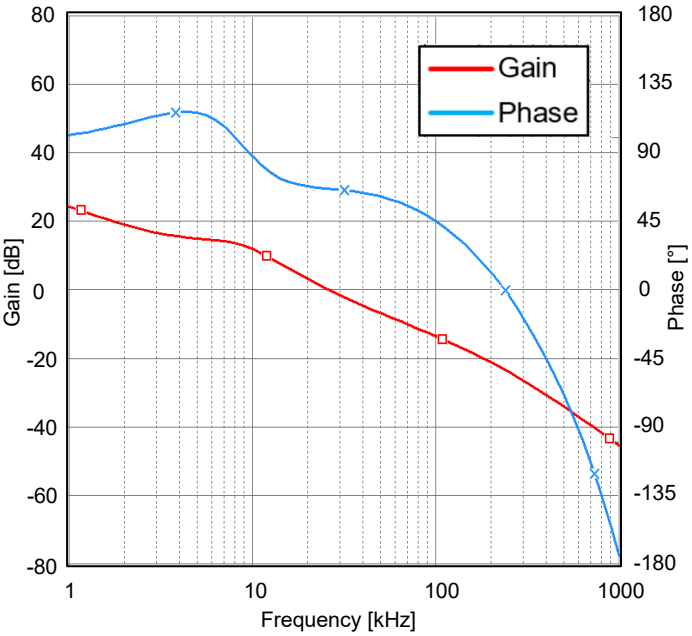


Figure 29.
Frequency Characteristics
(V_{IN} = 24 V, V_{OUT} = 12 V, I_{OUT} = 2 A)
(SPICE Simulation)

Table 13 Characteristics Comparison

Parameter	Measured Result (Note1) (Note2)	SPICE Simulation Result	Unit	Error	Condition
Phase Margin	82.8	66.6	degree	-19.6 %	V_{IN} = 24 V, V_{OUT} = 12 V, I_{OUT} = 2 A
Crossover Frequency	27.5	26.0	kHz	-5.5 %	

(Note 1) The above data is based on a specific sample and it is not a guaranteed value.
(Note 2) These characteristics depend on some dynamic characteristics of external components, input signal speed, PCB pattern and mounting condition of each on-board parts.

Revision History

Date	Revision	Changes
Apr. 2023	001	New Release

Notes

1) The information contained herein is subject to change without notice.

2) Before you use our Products, please contact our sales representative and verify the latest specifications :

3) Although ROHM is continuously working to improve product reliability and quality, semiconductors can break down and malfunction due to various factors.
Therefore, in order to prevent personal injury or fire arising from failure, please take safety measures such as complying with the derating characteristics, implementing redundant and fire prevention designs, and utilizing backups and fail-safe procedures. ROHM shall have no responsibility for any damages arising out of the use of our Poducts beyond the rating specified by ROHM.

4) Examples of application circuits, circuit constants and any other information contained herein are provided only to illustrate the standard usage and operations of the Products. The peripheral conditions must be taken into account when designing circuits for mass production.

5) The technical information specified herein is intended only to show the typical functions of and examples of application circuits for the Products. ROHM does not grant you, explicitly or implicitly, any license to use or exercise intellectual property or other rights held by ROHM or any other parties. ROHM shall have no responsibility whatsoever for any dispute arising out of the use of such technical information.

6) The Products specified in this document are not designed to be radiation tolerant.

7) For use of our Products in applications requiring a high degree of reliability (as exemplified below), please contact and consult with a ROHM representative : transportation equipment (i.e. cars, ships, trains), primary communication equipment, traffic lights, fire/crime prevention, safety equipment, medical systems, servers, solar cells, and power transmission systems.

8) Do not use our Products in applications requiring extremely high reliability, such as aerospace equipment, nuclear power control systems, and submarine repeaters.

9) ROHM shall have no responsibility for any damages or injury arising from non-compliance with the recommended usage conditions and specifications contained herein.

10) ROHM has used reasonable care to ensure the accuracy of the information contained in this document. However, ROHM does not warrants that such information is error-free, and ROHM shall have no responsibility for any damages arising from any inaccuracy or misprint of such information.

11) Please use the Products in accordance with any applicable environmental laws and regulations, such as the RoHS Directive. For more details, including RoHS compatibility, please contact a ROHM sales office. ROHM shall have no responsibility for any damages or losses resulting non-compliance with any applicable laws or regulations.

12) When providing our Products and technologies contained in this document to other countries, you must abide by the procedures and provisions stipulated in all applicable export laws and regulations, including without limitation the US Export Administration Regulations and the Foreign Exchange and Foreign Trade Act.

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ROHM SEMICONDUCTOR

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