SPICE Modeling Report

7 V to 76 V Input, 5 A Integrated High –Side MOSFET, Single Buck DC/DC Converter BD9G500EFJ

General Description

In this report, the characteristics that can be confirmed by the simulation using the SPICE model of the regulator IC BD9G500EFJ will be described.

Simulation Environment

- Circuit Simulator : PSpice / Cadence Design System, Inc.
- Version Information : 17.2-2016
- OS Information : Windows 10 64-bit Edition

File Information

- Library File Name : BD9G500EFJ.lib
- Symbol File Name : BD9G500EFJ.olb
- Subcircuit and Symbol

Table 1 Correspondence Table

Product Name	Subcircuit	Symbol
BD9G500EFJ	BD9G500EFJ(Note1) (Model for Transient Analysis)	BD9G500EFJ(Note3)
		BD9G500EFJ_CAD(Note2)
	BD9G500EFJ_AVE(Note1) (Model for AC Analysis)	BD9G500EFJ_AVE(Note3)
		BD9G500EFJ_AVE_CAD(Note2) (Note3)

(Note 1) BD9G500EFJ_AVE is the spice macro model for Frequency Characteristic (AC simulation). Please refer to P5-6 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) Terminal information for BD9G500EFJ_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. Please 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.

BD9G500EFJ Spice Model

■ Terminal Information

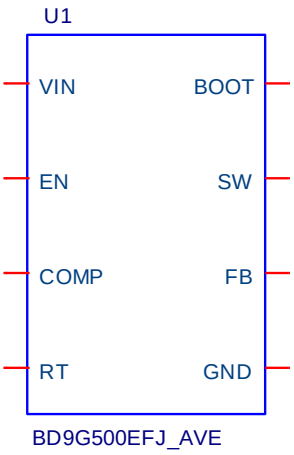

Figure 1 Symbol of BD9G500EFJ

Table 2 Pin Table

Pin No.	Pin Name	Pin No.	Pin Name
1.	VIN	5.	BOOT
2.	EN	6.	SW
3.	COMP	7.	FB
4.	RT	8.	GND

■ Model Parameter

Table 3 Model Parameter Table

Parameter	Default Value	Description
BD9G500EFJ		
param_tss(Note1)	20m	Soft start time parameter.
param_tscp(Note1)	20m	Device downtime when OCP occurs parameter.
BD9G500EFJ_AVE		
l	23µ	Please set the inductor value connected to SW terminal.
v_vo	5	On Duty parameter for the Numerator.
v_vin	48	On Duty parameter for the Denominator. On Duty is given as {v_vo/v_vin}.
Rrt	47k	Please set the RT resistance value connected to RT terminal.

(Note 1) These parameters for SPICE models only. it cannot be set on the device.
If the parameters are changed, the behavior will be different from the actual device.

Verifiable Characteristics

Electrical Characteristics (vs. Datasheet)

Table 4 Electrical Characteristics Comparison

(Unless otherwise specified Ta = 25°C, VIN = 48 V, VEN = 3 V)

Parameter	Modeled *(Note1)*	Design Value		Unit	Error	Condition
		Datasheet	SPICE			
Operating Supply Current	Yes	0.75	0.75	mA	0%	V_{FB} = 3.0 V
Shutdown Current	Yes	0	0	µA	0%	V_{EN} = 0 V
FB Threshold Voltage	Yes	1.00	1.00	V	0%	
FB Input Current	Yes	0	0	µA	0%	V_{FB} = 1.1 V
Switching Frequency Range Using RT Pin	Yes	100-650	100-650	kHz	-	
Switching Frequency Error Range	Yes	10	10	%	-	RT = 47 kΩ
High-Side MOSFET ON-Resistance	Yes	100	100	mΩ	0%	I_{SW} = -50 mA
Over Current Limit	Yes	8.0	8.0	A	0%	Without switching Open Loop
UVLO Threshold Voltage	Yes	6.4	6.4	V	0%	V_{IN} falling
UVLO Hysteresis Voltage	Yes	200	200	mV	0%	
EN High-Level Input Voltage	Yes	2.5	2.5	V	0%	
EN Low-Level Input Voltage	Yes	0.4	0.4	V	0%	
EN Input Current	Yes	2.30	2.30	µA	0%	V_{EN} = 3 V
Soft Start Time	Yes	20	20	ms	0%	

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

Characteristic in SPICE (vs. Measured Waveform)
1. Output Ripple (VOUT = 5V, IOUT = 5A)

Simulation Setting
Type: Transient
Run Time: 25msec
(Maximum Step Size: 10ns)

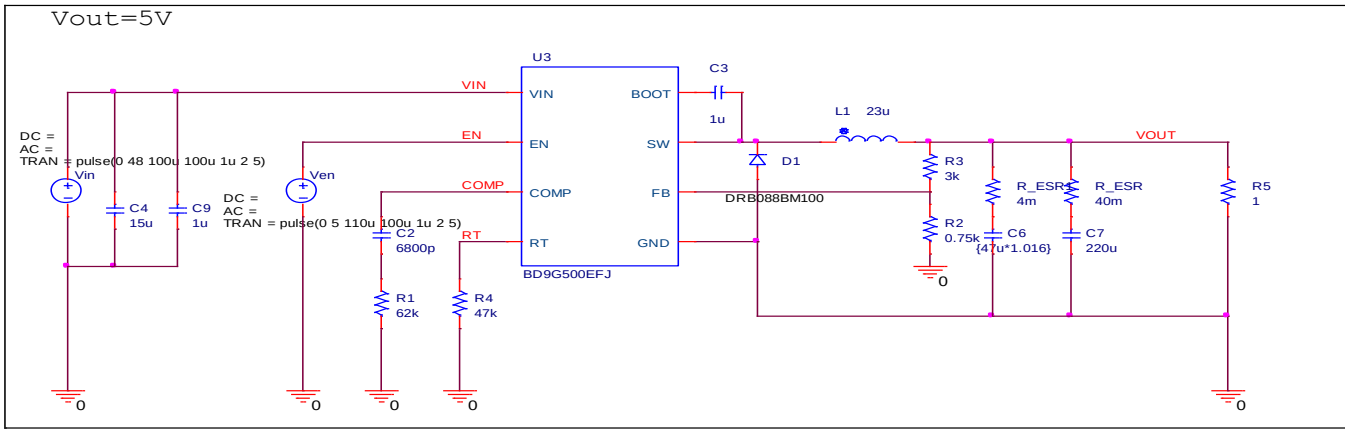

Figure 2.
Simulation Schematic 1

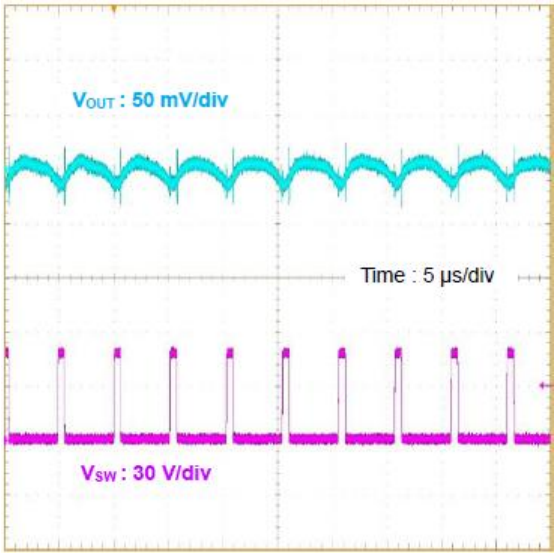

Figure 3.
Output Ripple (VOUT = 5V, IOUT = 5A)
(Measured Waveform)

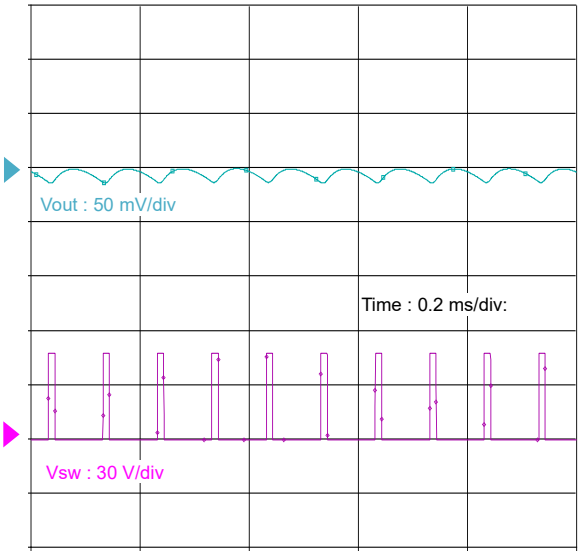

Figure 4.
Output Ripple (VOUT = 5V, IOUT = 5A)
(SPICE Simulation)

Table 5 Characteristics Comparison

Parameter	Measured Result (Note1)(Note2)	SPICE Simulation Result	Unit	Error	Condition
Output Ripple Voltage	16	13	mV	-18.8%	VIN = 48 V, VOUT = 5 V, fOSC = 200 kHz, IOUT = 5 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 (VOUT = 12V, IOUT = 5A)

Simulation Setting
Type: Transient
Run Time: 20msec
(Maximum Step Size: 10ns)

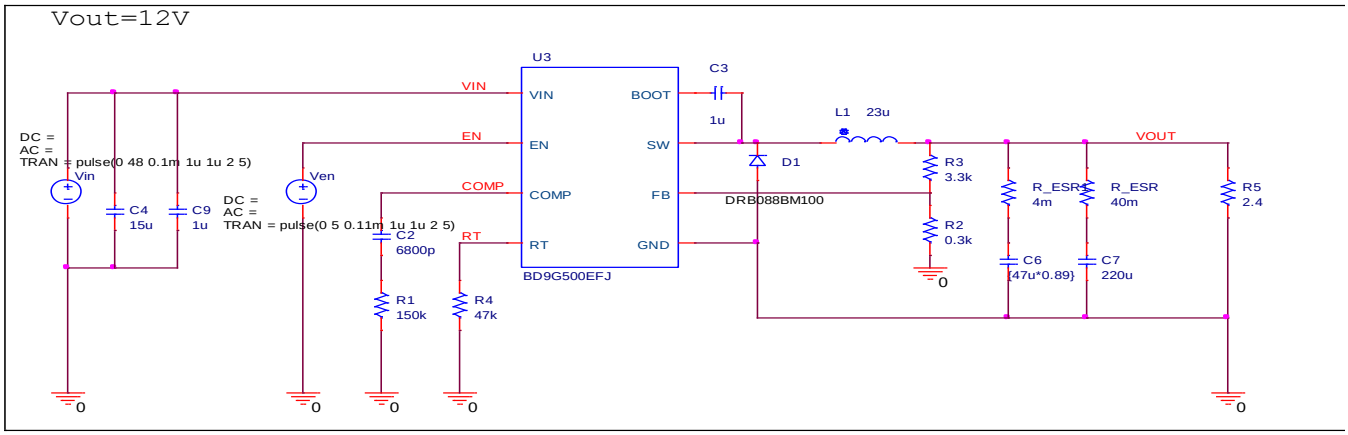

Figure 5.
Simulation Schematic 2

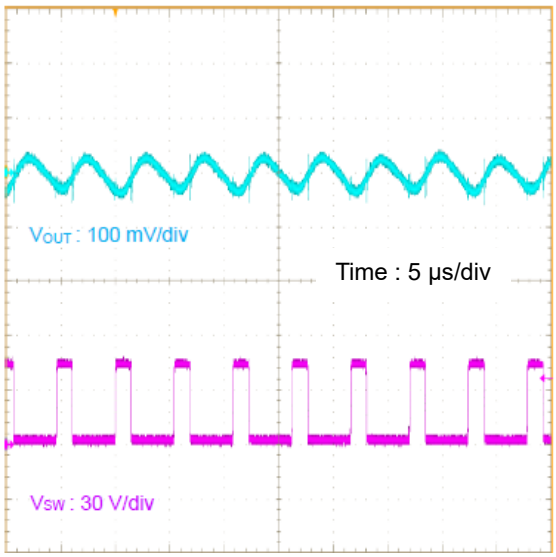

Figure 6.
Output Ripple (VOUT = 12V, IOUT = 5A)
(Measured Waveform)

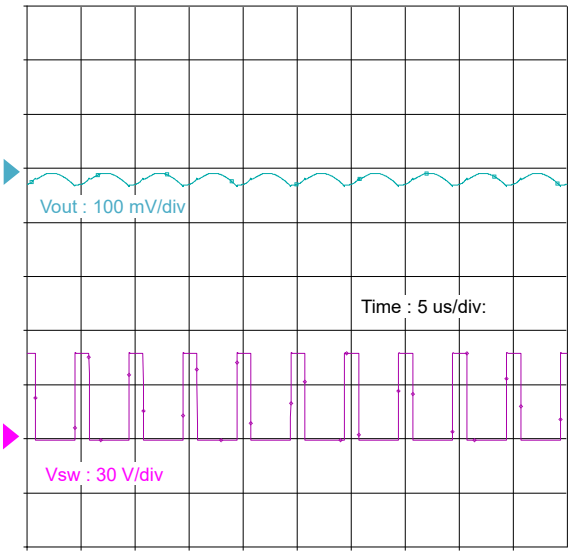

Figure 7.
Output Ripple (VOUT = 12V, IOUT = 5A)
(SPICE Simulation)

Table 6 Characteristics Comparison

Parameter	Measured Result (Note1)(Note2)	SPICE Simulation Result	Unit	Error	Condition
Output Ripple Voltage	30	25.7	mV	-14.3%	VIN = 48 V, VOUT = 12 V, fOSC = 200 kHz, IOUT = 5 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. Switching Waveform (VIN = 48V, VOUT = 5V)

Simulation Setting
Type: Transient
Run Time: 140msec
(Maximum Step Size: 100ns)

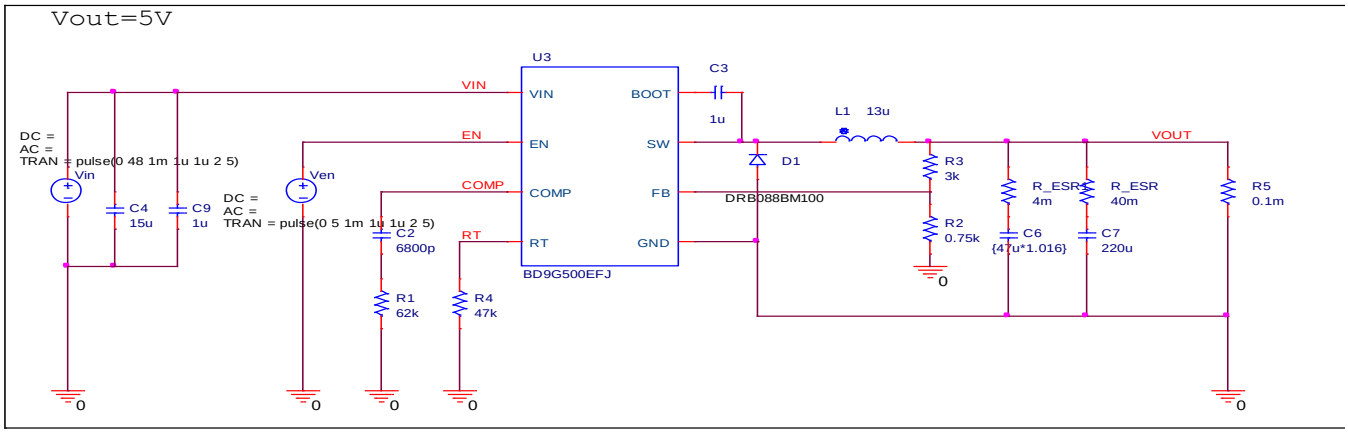

Figure 8.
Simulation Schematic 3

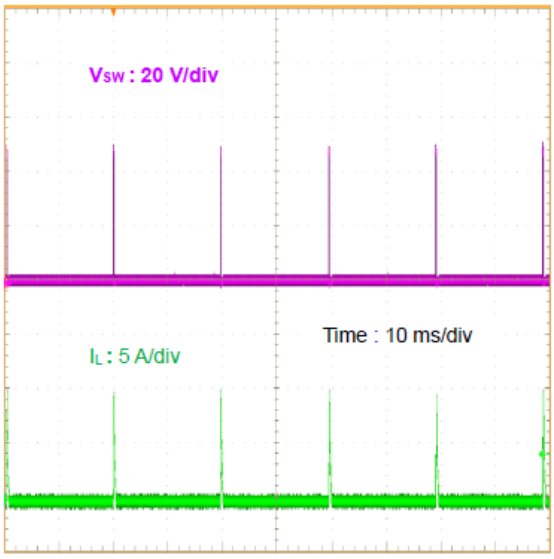

Figure 9.
Switching Waveform (VIN = 48V, VOUT = 5V)
(Measured Waveform)

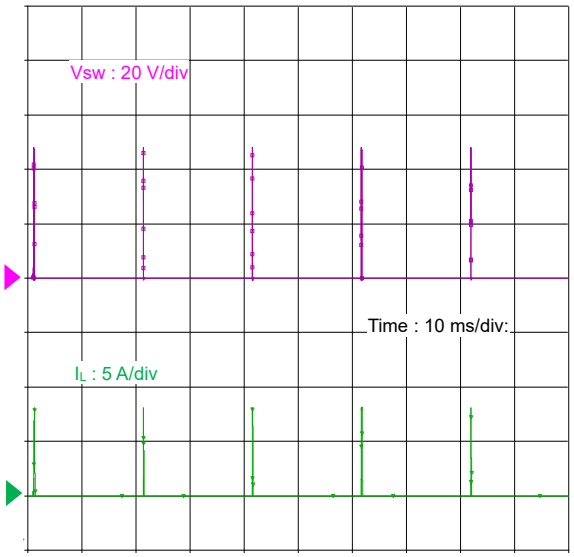

Figure 10.
Switching Waveform (VIN = 48V, VOUT = 5V)
(SPICE Simulation)

Table 7 Characteristics Comparison

Parameter	Measured Result (Note1)(Note2)	SPICE Simulation Result	Unit	Error	Condition
Output Ripple Current	9.8	8.1	mA	-17.3%	VIN = 48 V, VOUT = 5 V, fOSC = 200 kHz, VOUT short to GND

(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 (VOUT = 5V, IOUT = 1.25 A – 3.75 A)

Simulation Setting
Type: Transient
Run Time: 7msec
(Maximum Step Size: 100ns)

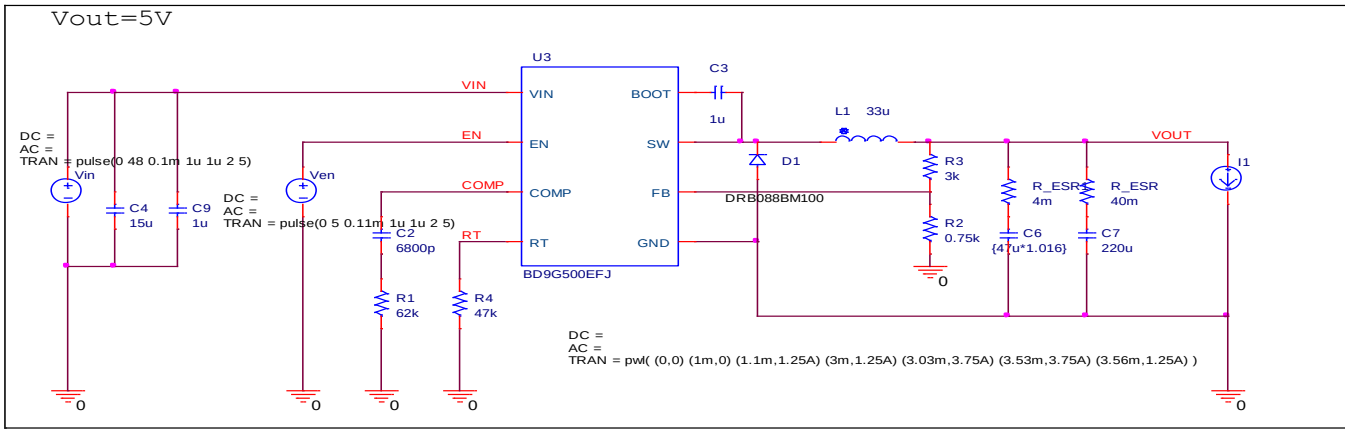

Figure 11.
Simulation Schematic 4

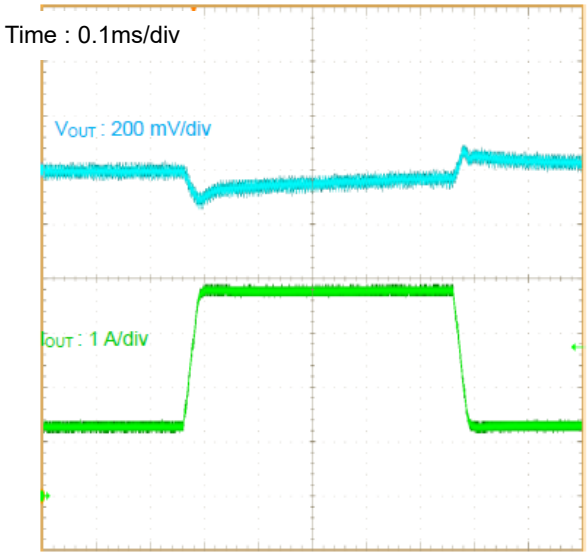

Figure 12.
Load Response (VOUT = 5V, IOUT = 1.25 A – 3.75 A)
(Measured Waveform)

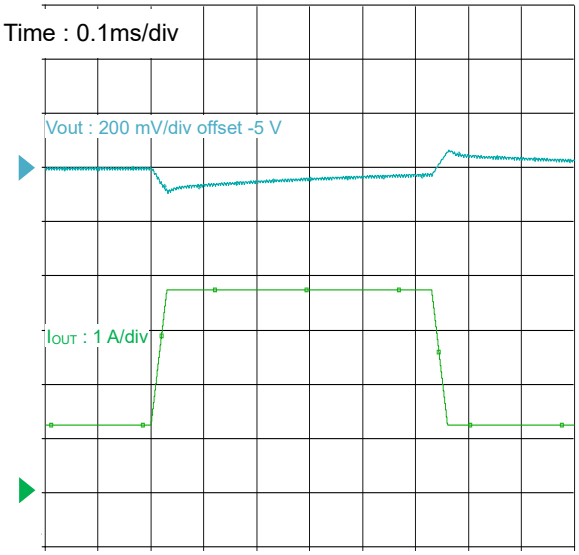

Figure 13.
Load Response (VOUT = 5V, IOUT = 1.25 A – 3.75 A)
(SPICE Simulation)

Table 8 Characteristics Comparison

Parameter	Measured Result (Note1)(Note2)	SPICE Simulation Result	Unit	Error	Condition
Overshoot	79	63.8	mV	-19.2%	IOUT = 1.25 A – 3.75 A
Undershoot	118	95.2	mV	-19.3%	

(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 (VOUT = 5V, IOUT = 0 A – 3.75 A)

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

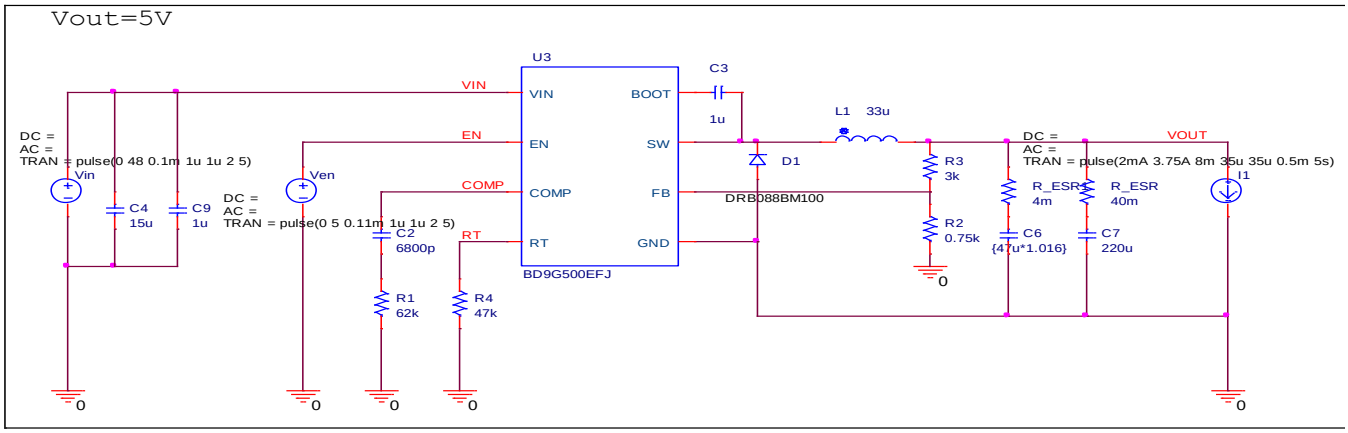

Figure 14.
Simulation Schematic 5

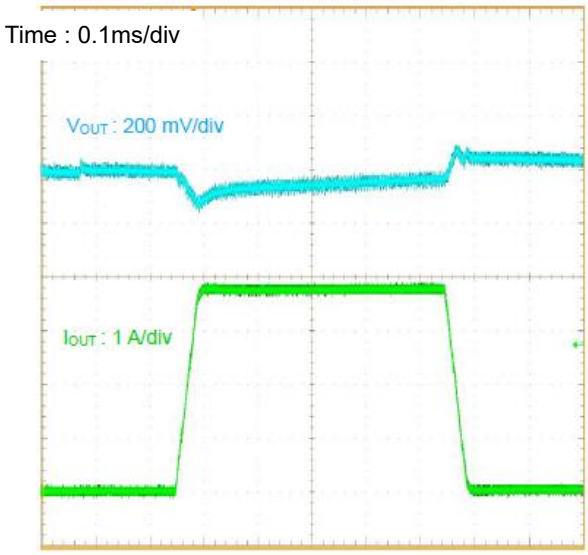

Figure 15.
Load Response (VOUT = 5V, IOUT = 0 A – 3.75 A)
(Measured Waveform)

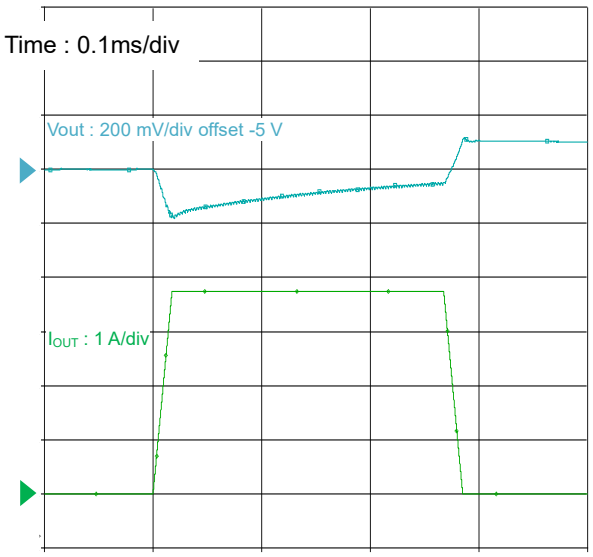

Figure 16.
Load Response (VOUT = 5V, IOUT = 0 A – 3.75 A)
(SPICE Simulation)

Table 9 Characteristics Comparison

Parameter	Measured Result (Note1)(Note2)	SPICE Simulation Result	Unit	Error	Condition
Overshoot	106	114.5	mV	8.0%	IOUT = 0 A – 3.75 A
Undershoot	176	186.3	mV	5.9%	

(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 (VOUT = 12V, IOUT = 1.25 A – 3.75 A)

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

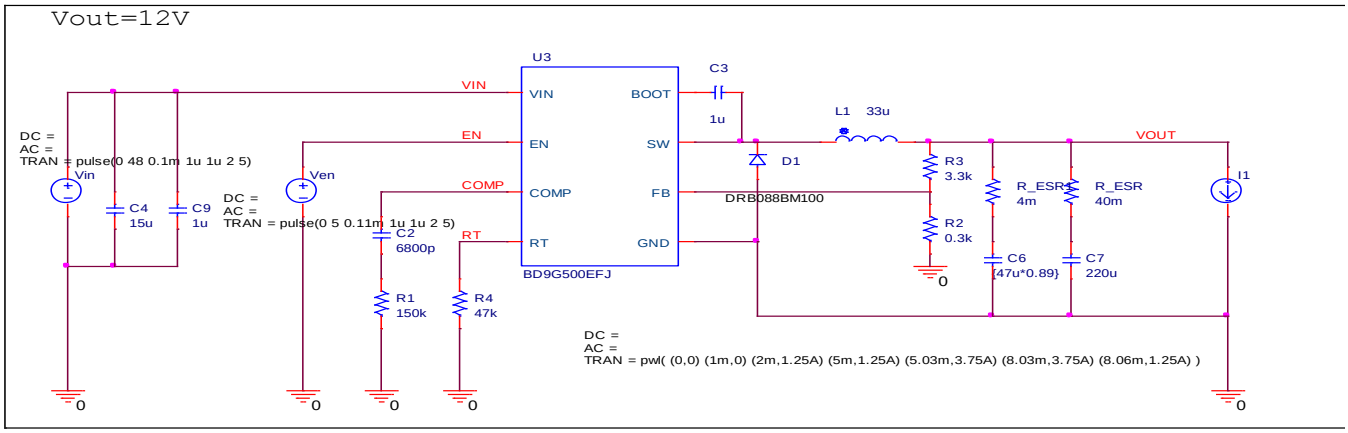

Figure 17.
Simulation Schematic 6

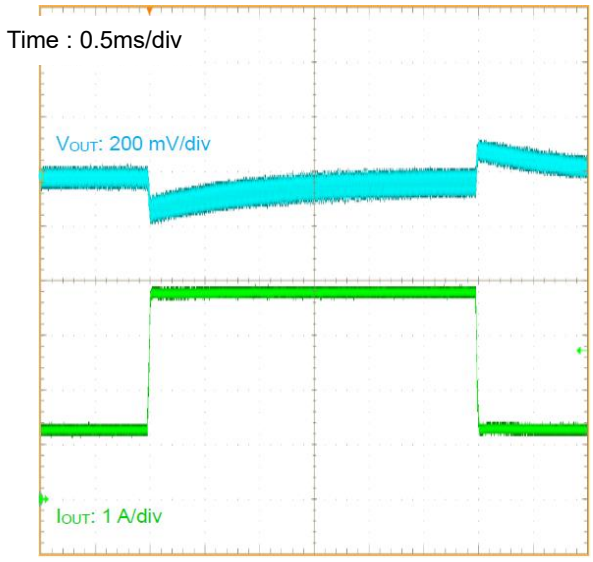

Figure 18.
Load Response (VOUT = 12V, IOUT = 1.25 A – 3.75 A)

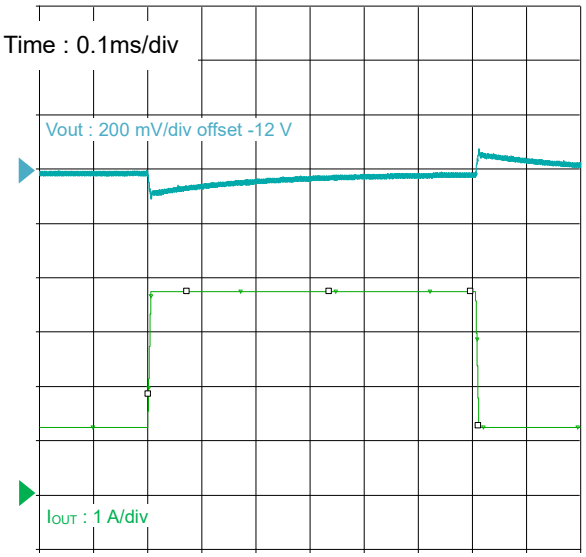

Figure 19.
Load Response (VOUT = 12V, IOUT = 1.25 A – 3.75 A)

Table 10 Characteristics Comparison

Parameter	Measured Result (Note1)(Note2)	SPICE Simulation Result	Unit	Error	Condition
Overshoot	82	72.9	mV	-11.1%	IOUT = 1.25 A – 3.75 A
Undershoot	111	111	mV	0.0%	

(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. Load Response (VOUT = 12V, IOUT = 0 A – 3.75 A)

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

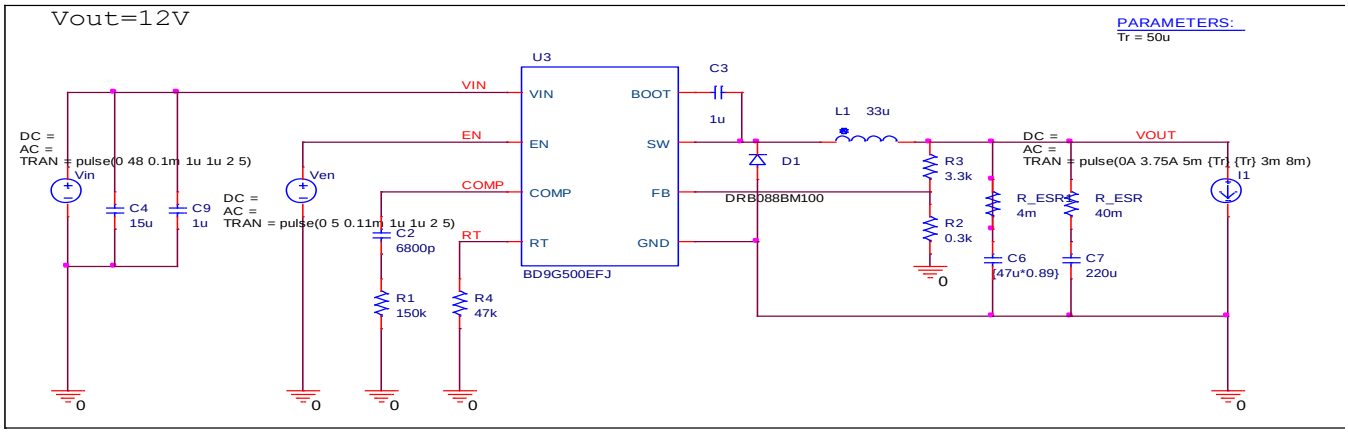

Figure 20.
Simulation Schematic 7

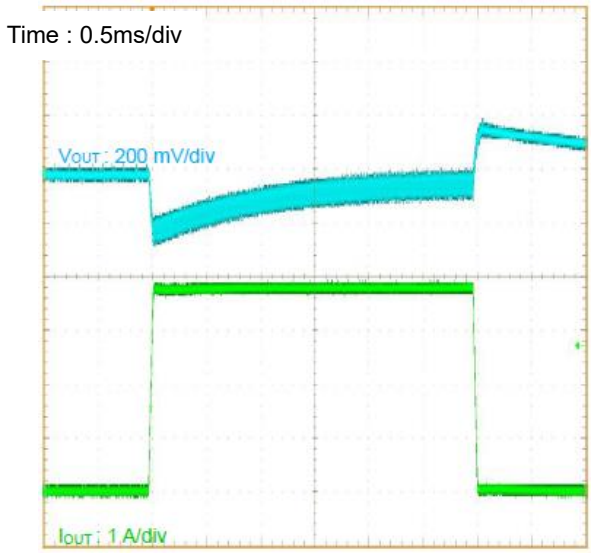

Figure 21.
Load Response (VOUT = 12V, IOUT = 0 A – 3.75 A)
(Measured Waveform)

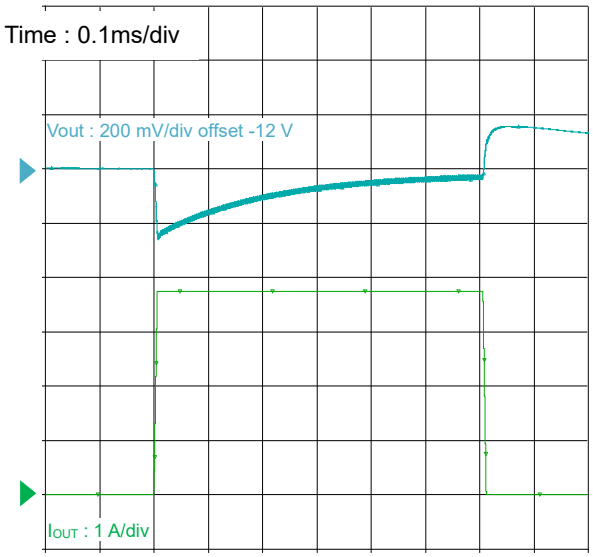

Figure 22.
Load Response (VOUT = 12V, IOUT = 0 A – 3.75 A)
(SPICE Simulation)

Table 11 Characteristics Comparison

Parameter	Measured Result (Note1)(Note2)	SPICE Simulation Result	Unit	Error	Condition
Overshoot	180	157	mV	-12.8%	IOUT = 0 A – 3.75 A
Undershoot	220	261	mV	18.6%	

(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 Characteristic (VOUT = 12V)

Simulation Setting
Type: AC
Frequency Range: 100Hz to 1MHz
(Points/Decade: 20)

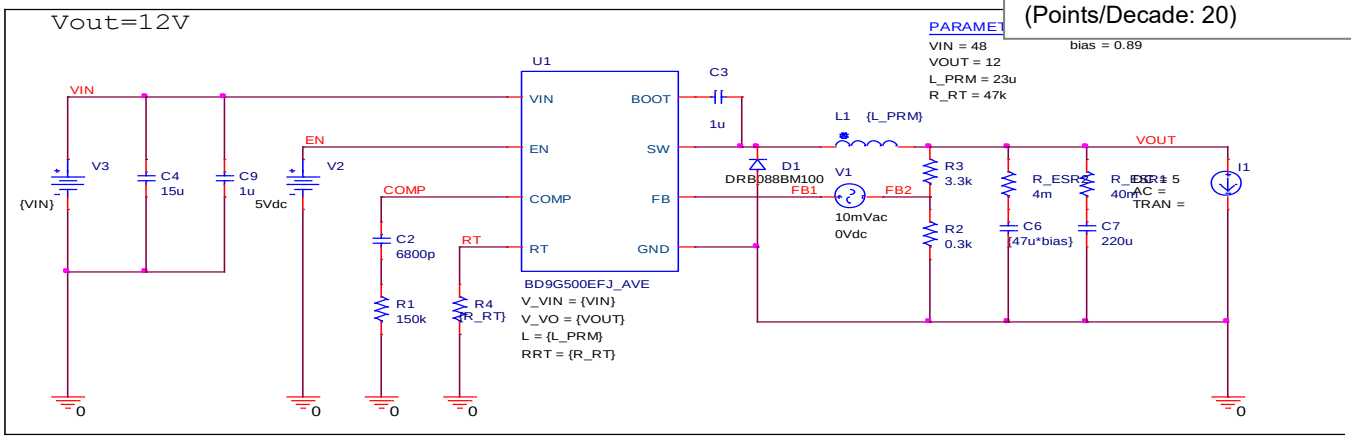

Figure 23.
Simulation Schematic 8

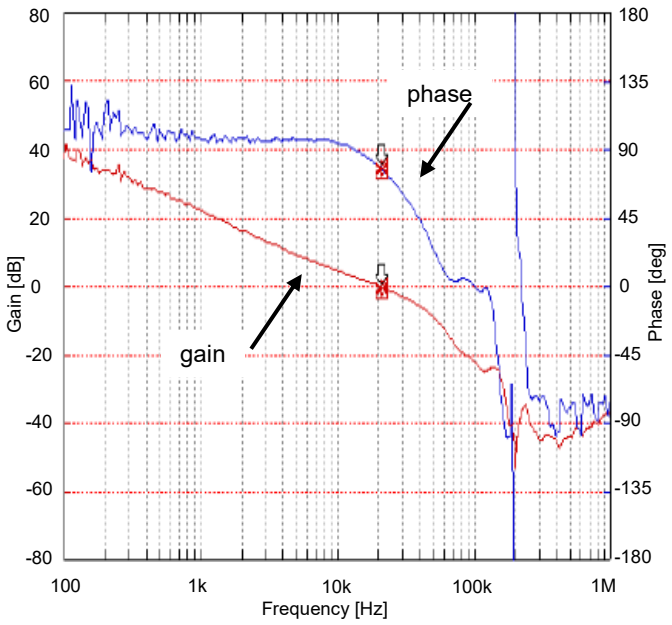

Figure 24.
Frequency Characteristic (VOUT = 12V)
(Measured Waveform)

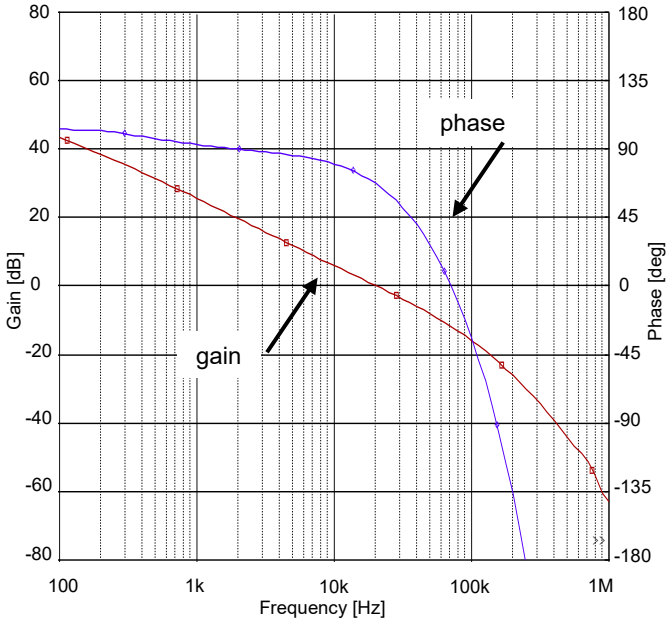

Figure 25.
Frequency Characteristic (VOUT = 12V)
(SPICE Simulation)

Table 12 Characteristics Comparison

Parameter	Measured Result (Note1)(Note2)	SPICE Simulation Result	Unit	Error	Condition
Phase Margin	66.7	67	degree	0.4%	VIN= 48V, VOUT= 12V, IOUT= 5A, L= 23µH, COUT= Ceramic 267µF
Crossover Frequency	20.5	20.4	kHz	-0.5%	

(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.

9. Frequency Characteristic (VOUT = 5.0 V)

Simulation Setting
Type: AC
Frequency Range: 100Hz to 1MHz
(Points/Decade: 20)

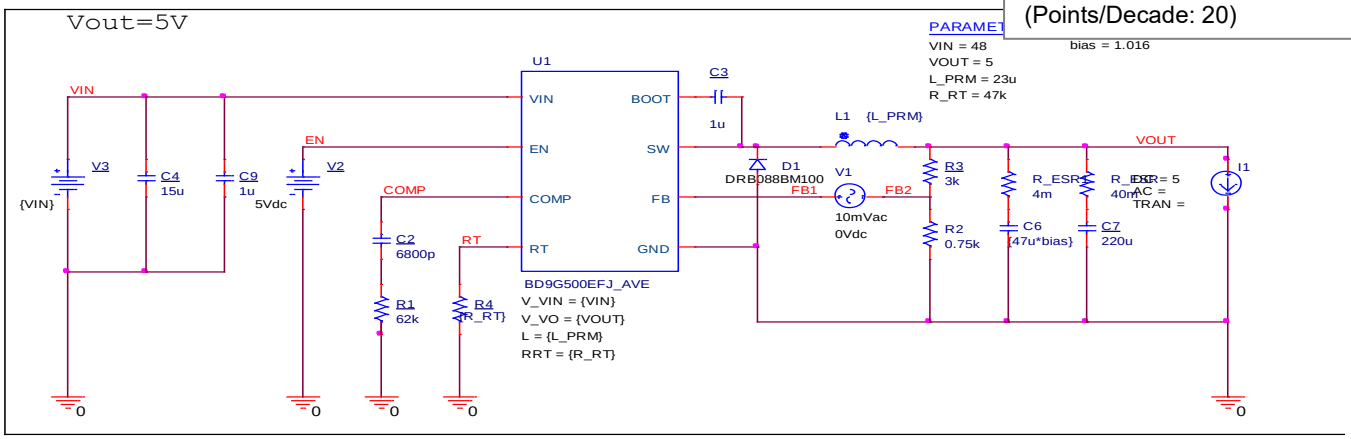

Figure 26.
Simulation Schematic 9

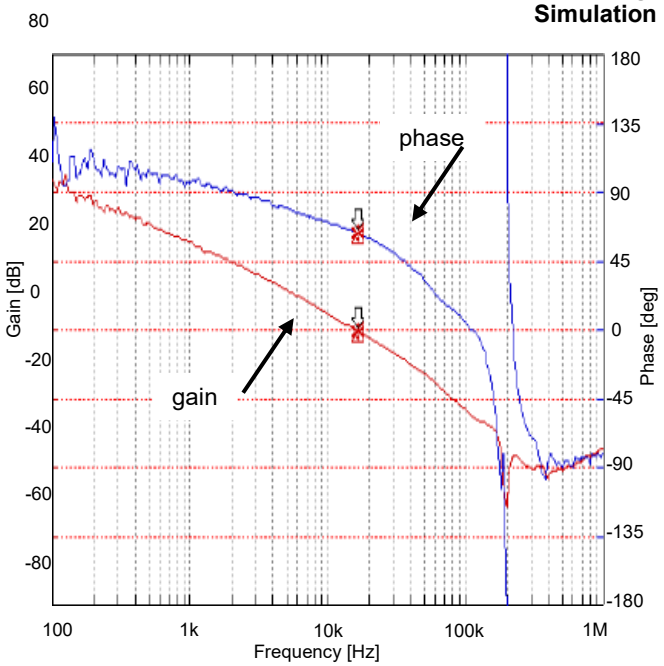

Figure 27.
Frequency Characteristic (VOUT = 5.0 V)
(Measured Waveform)

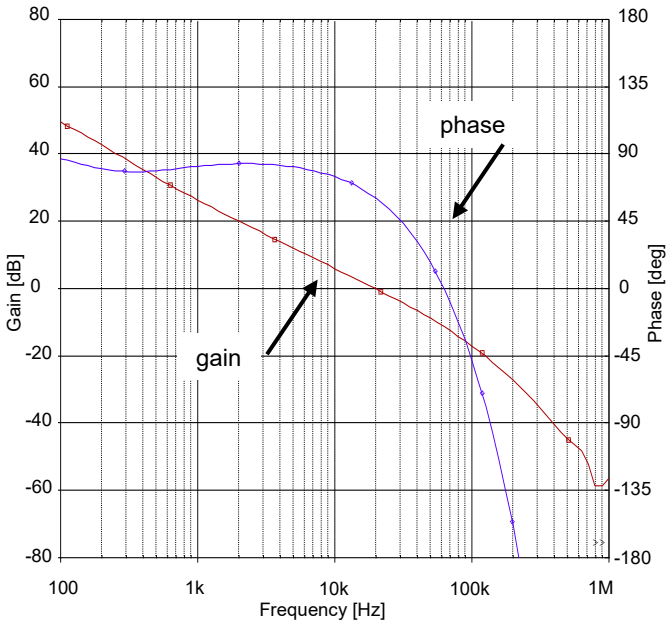

Figure 28.
Frequency Characteristic (VOUT = 5.0 V)
(SPICE Simulation)

Table 13 Characteristics Comparison

Parameter	Measured Result (Note1)(Note2)	SPICE Simulation Result	Unit	Error	Condition
Phase Margin	62.8	61.2	degree	-2.5%	VIN= 48V, VOUT= 5V, IOUT= 5A, L= 23µH, COUT= Ceramic 267µF
Crossover Frequency	16.6	19.6	kHz	18.1%	

(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.

Revision History

Date	Revision	Changes
Feb.2021	001	New Release
Apr.2021	002	Model for transient analysis has been added

Notes

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

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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.

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