SPICE Modeling Report

4.5 V to 42 V Input Voltage Range 3.5 A Output Current Integrated FET 1ch Buck Converter BD9G401EFJ

General Description

In this report, the characteristics that can be confirmed by the simulation using the SPICE model of the regulator IC BD9G401EFJ 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 : BD9G401EFJ.lib
- Symbol File Name : BD9G401EFJ.olb
- Subcircuit and Symbol

Table 1 Correspondence Table

Product Name	Subcircuit	Symbol
BD9G401EFJ	BD9G401EFJ (Model for Transient Analysis)	BD9G401EFJ
	BD9G401EFJ_AVE (Note1) (Model for AC Analysis)	BD9G401EFJ_AVE (Note2)

(Note 1) BD9G401EFJ_AVE is the spice macro model for Frequency Characteristic (AC simulation). Refer to P10-12 for simulation detail.
(Note 2) Pin information for BD9G401EFJ_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.

BD9G401EFJ Spice Model

■ Pin Information

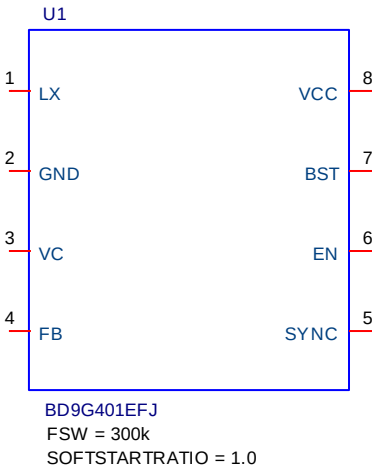

Figure 1 Symbol of BD9G401EFJ

Table 2 Subcircuit Pin Table

Pin No.	Pin Name	Pin No.	Pin Name
1.	LX	5.	SYNC
2.	GND	6.	EN
3.	VC	7.	BST
4.	FB	8.	VCC

■ Model Parameter

Table 3 Model Parameter Table

Parameter	Default Value	Description
BD9G401EFJ		
fsw (Note1)	300k	Set the external CLK frequency (250 kHz to 500 kHz). (This parameter influences soft start time and OCP turn off time.)
softstartratio (Note1)	1.0	Set the soft start ratio (0.1 to 1.0). It is possible to be short soft start Time by changing this parameter.
BD9G401EFJ_AVE		
l	22u	Set the inductor value connected to SW pin.
v_vo	5	On Duty parameter for the Numerator.
v_vin	12	On Duty parameter for the Denominator. On Duty is given as { v_vo / v_vin }.
fsw	300k	Set the external CLK frequency (250 kHz to 500 kHz).

(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, V_{IN} = 12 V, V_{EN} = 3 V)

Parameter	Modeled *(Note1)*	Design Value		Unit	Error	Condition
		Datasheet	SPICE			
Circuit Current						
Standby Current	Yes	0	0	μA	0 %	V_{EN} = 0 V
Operating Current	Yes	1.2	1.2	mA	0 %	V_{FB} = 1.2 V
Under Voltage Lock Out (UVLO)						
Detect Voltage	Yes	4.00	4.00	V	0 %	VCC down sweep
Hysteresis Width	Yes	200	200	mV	0 %	
Oscillator						
Oscillating Frequency	Yes	300	300	kHz	0 %	
Max Duty Cycle	Yes	97.0	97.0	%	0 %	V_{SYNC} = 0 V
Error Amp						
FB Threshold Voltage	Yes	0.800	0.800	V	0 %	Ta = 25° C
Input Bias Current	Yes	0	0	μA	0 %	V_{FB} = 3.0 V
FB Leak Current	Yes	0	0	μA	0 %	V_{FB} = 0 V
Soft Start Time	Yes	8.0	8.0	ms	0 %	V_{SYNC} = 0 V
Output						
LX NMOS ON Resistance	Yes	140	140	mΩ	0 %	
LX Precharge NMOS ON Resistance	Yes	10	10	Ω	0 %	
Over Current Detect	Yes	6	6	A	0 %	
CTL						
EN Terminal Internal REG ON-Threshold	Yes	-	0.8	V	-	IC on or off threshold
EN Terminal IC Output on Threshold	Yes	1.80	1.80	V	0 %	
EN Terminal Source Current	Yes	10.0	10.0	μA	0 %	V_{EN} = 3 V
SYNC						
SYNC Terminal Control High Threshold Voltage	Yes	-	2.0	V	-	
SYNC Terminal Control Low Threshold Voltage	Yes	-	1.6	V	-	
SYNC Terminal Input Current	Yes	12	12	μA	0 %	V_{SYNC} = 3 V

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

Characteristic in SPICE (vs. Measured Waveform)
1. Output Ripple Voltage (V_{IN} = 12 V, V_{OUT} = 5 V)

Simulation Setting
Type: Transient
Run Time: 15 ms
(Maximum Step Size: 10 ns)

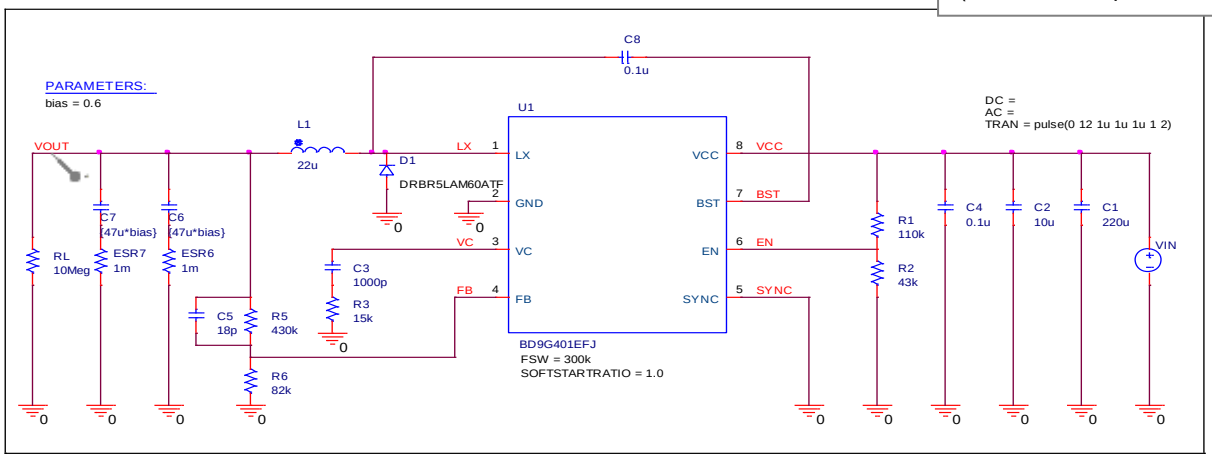

Figure 2.
Simulation Schematic 1

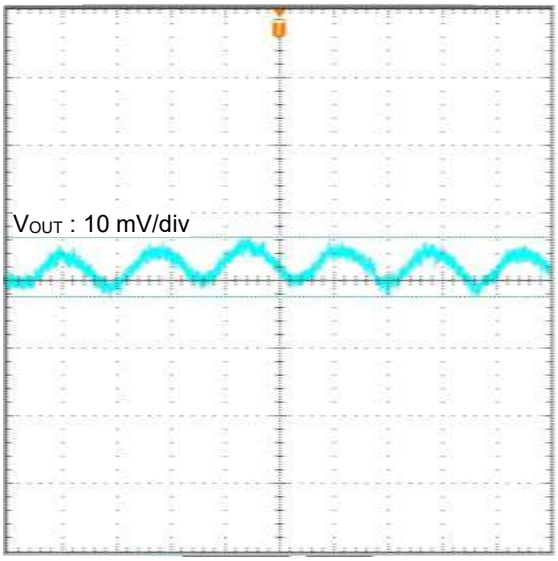

Figure 3.
Output Ripple Voltage (VIN = 12 V, VOUT = 5 V)
(Measured Waveform)

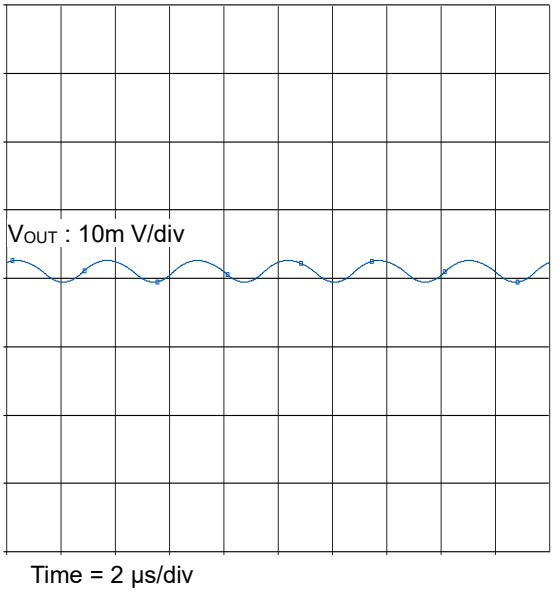

Figure 4.
Output Ripple Voltage (VIN = 12 V, VOUT = 5 V)
(SPICE Simulation)

Table 5 Characteristics Comparison

Parameter	Measured Result (Note1)(Note2)	SPICE Simulation Result	Unit	Error	Condition
Output Ripple Voltage	4	3.2	mV	-20.0 %	V_{IN} = 12 V, V_{OUT} = 5 V, I_{OUT} = 0 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. Switching Frequency (V_{IN} = 12 V, V_{OUT} = 5 V)

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

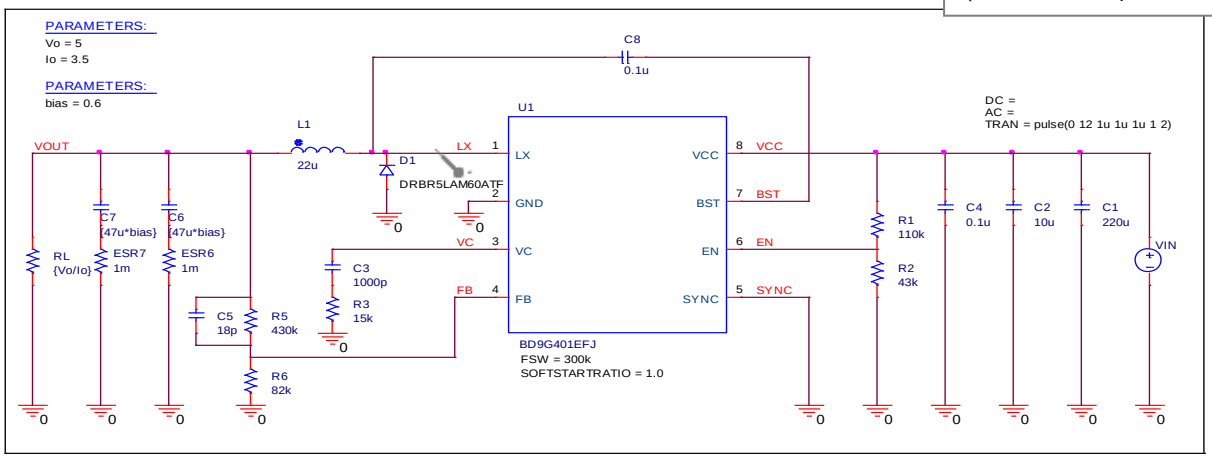

Figure 5.
Simulation Schematic 2

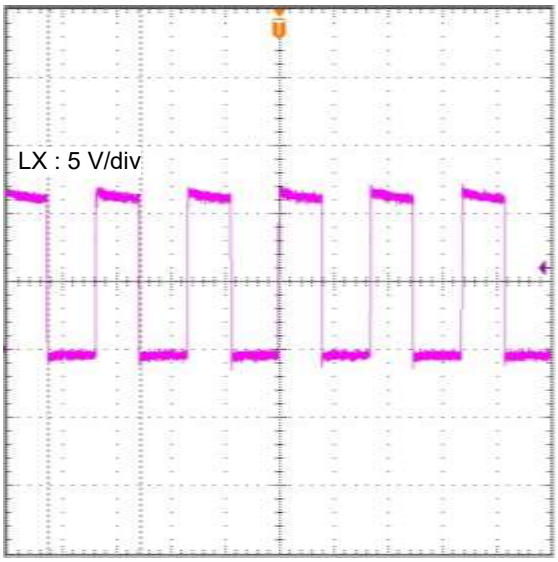

Figure 6.
Switching Frequency (VIN = 12 V, VOUT = 5 V)
(Measured Waveform)

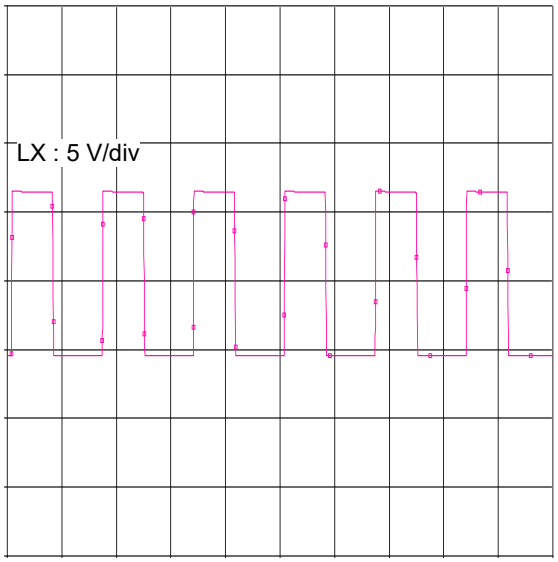

Figure 7.
Switching Frequency (VIN = 12 V, VOUT = 5 V)
(SPICE Simulation)

Table 6 Characteristics Comparison

Parameter	Measured Result (Note1)(Note2)	SPICE Simulation Result	Unit	Error	Condition
Switching Frequency	300	300	kHz	0.0 %	V_{IN} = 12 V, V_{OUT} = 5 V, I_{OUT} = 3 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. Load Regulation (V_{IN} = 12 V, V_{OUT} = 5 V)

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

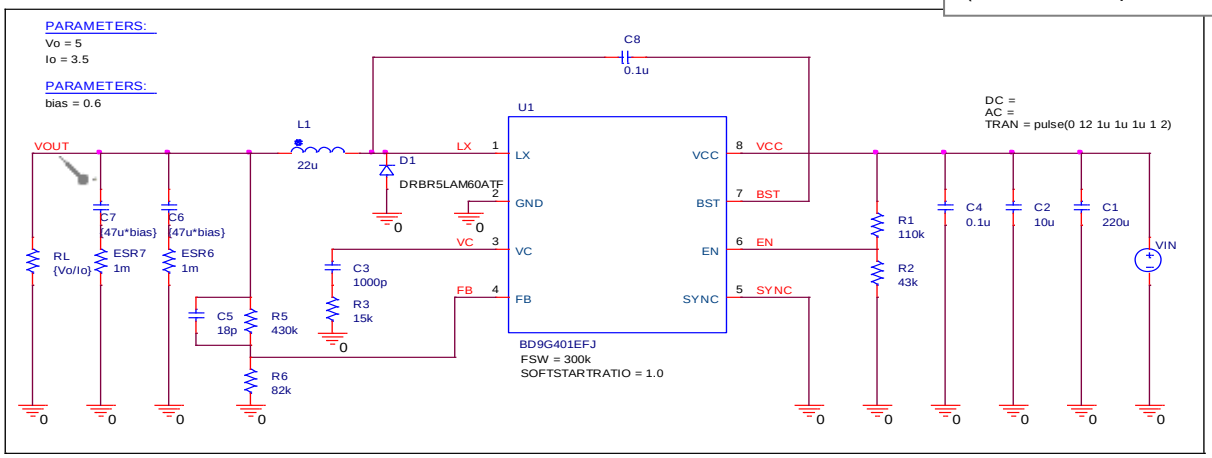

Figure 8.
Simulation Schematic 3

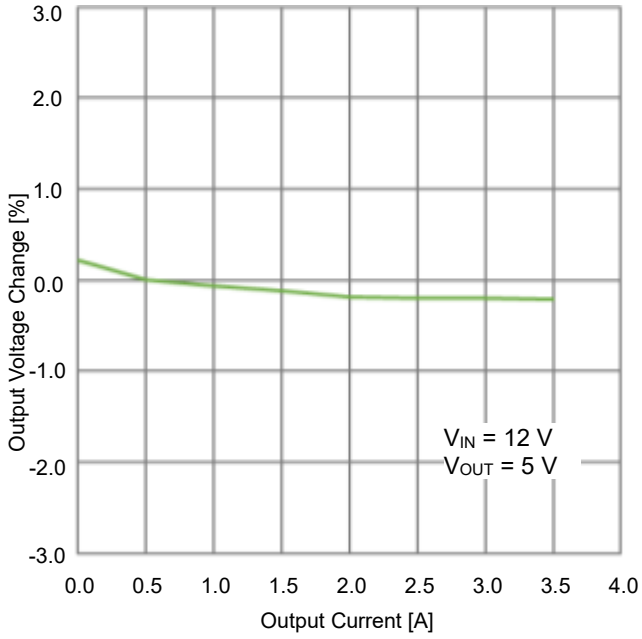

Figure 9.
Load Regulation (VIN = 12 V, VOUT = 5 V)
(Measured Waveform)

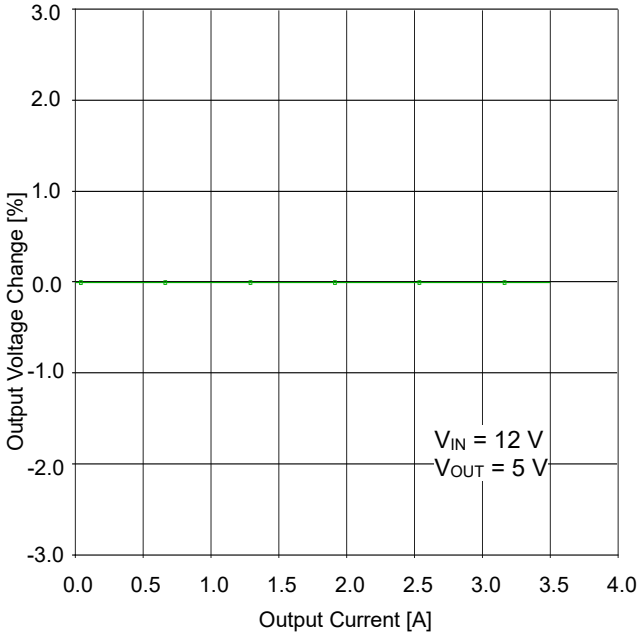

Figure 10.
Load Regulation (VIN = 12 V, VOUT = 5 V)
(SPICE Simulation)

Table 7 Characteristics Comparison

Parameter	Measured Result (Note1)(Note2)	SPICE Simulation Result	Unit	Error	Condition
Output Voltage Deviation	0.3	0	%	0.3 %	V_{IN} = 12 V, V_{OUT} = 5 V, I_{OUT} = 0 A to 3.5 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.

4. Load Response (V_{IN} = 12 V, V_{OUT} = 5 V, I_{OUT} = 0.875 A to 2.625 A)

Simulation Setting
Type: Transient
Run Time:11 ms
(Maximum Step Size: 10 ns)

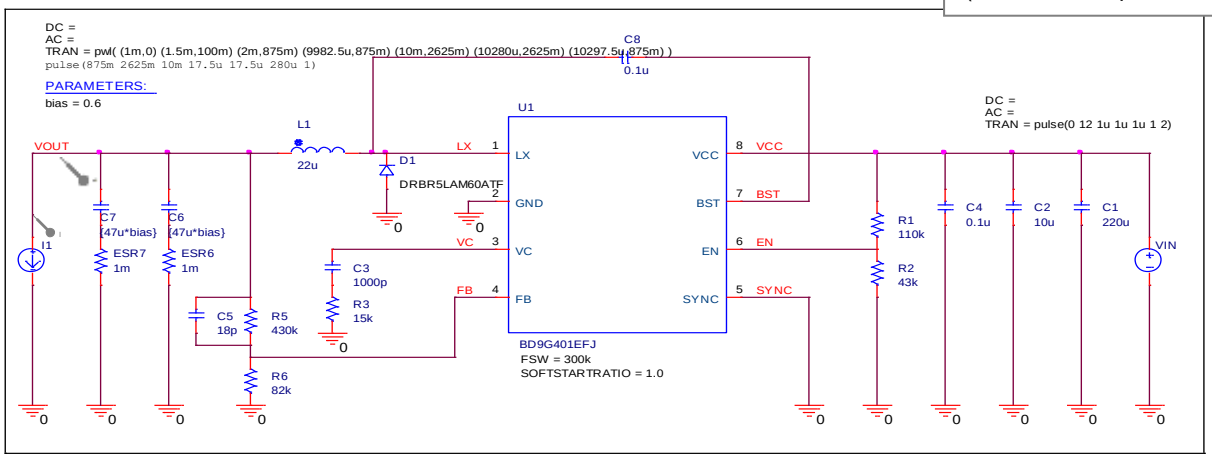

Figure 11.
Simulation Schematic 4

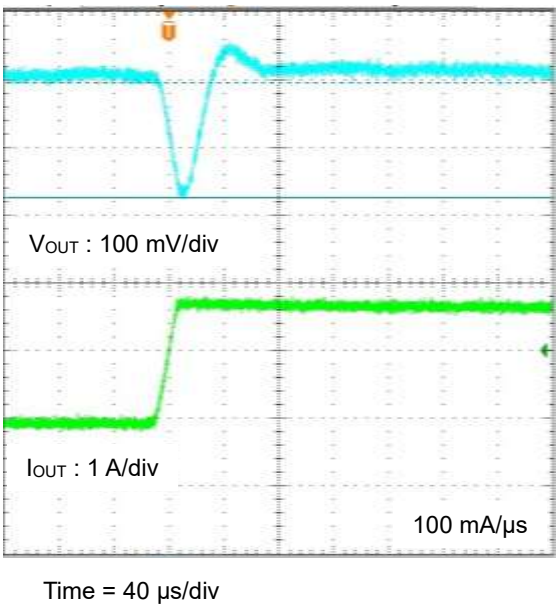

Figure 12.
Load Response (VIN = 12 V, VOUT = 5 V, IOUT = 0.875 A to 2.625 A)
(Measured Waveform)

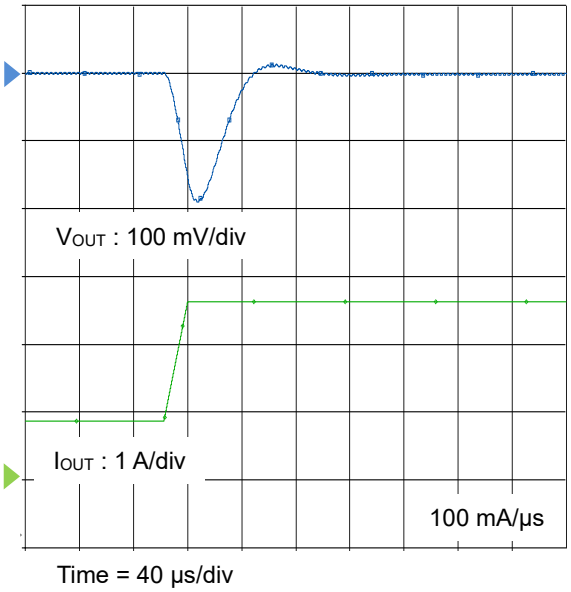

Figure 13.
Load Response (VIN = 12 V, VOUT = 5 V, IOUT = 0.875 A to 2.625 A)
(SPICE Simulation)

Table 8 Characteristics Comparison

Parameter	Measured Result (Note1)(Note2)	SPICE Simulation Result	Unit	Error	Condition
Undershoot	180	205.6	mV	14.2 %	V_{IN} = 12 V, V_{OUT} = 5 V

(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} = 2.625 A to 0.875 A)

Simulation Setting
Type: Transient
Run Time: 11 ms
(Maximum Step Size: 10 ns)

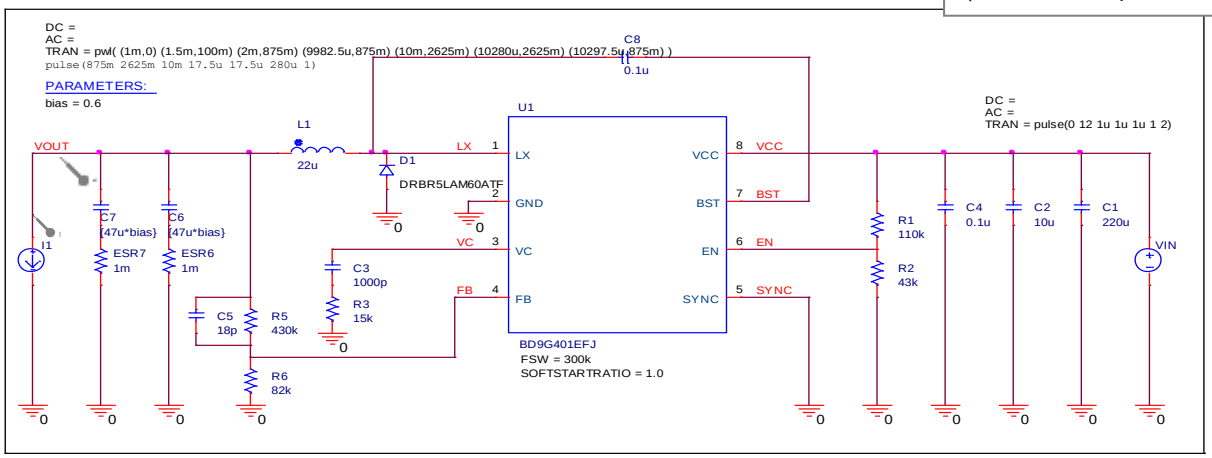

Figure 14.
Simulation Schematic 5

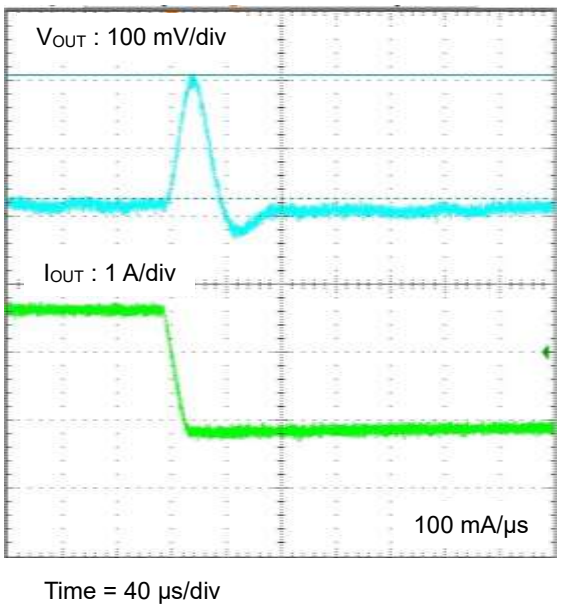

Figure 15.
Load Response (VIN = 12 V, VOUT = 5 V, IOUT = 2.625 A to 0.875 A)
(Measured Waveform)

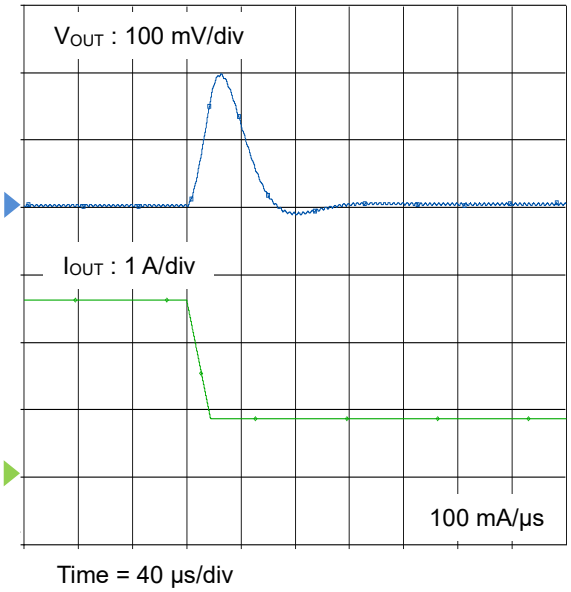

Figure 16.
Load Response (VIN = 12 V, VOUT = 5 V, IOUT = 2.625 A to 0.875 A)
(SPICE Simulation)

Table 9 Characteristics Comparison

Parameter	Measured Result (Note1)(Note2)	SPICE Simulation Result	Unit	Error	Condition
Overshoot	190	177.9	mV	-6.4 %	V_{IN} = 12 V, V_{OUT} = 5 V

(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. Frequency Characteristic (V_{IN} = 12 V, V_{OUT} = 5 V, I_{OUT} = 3.5 A)

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

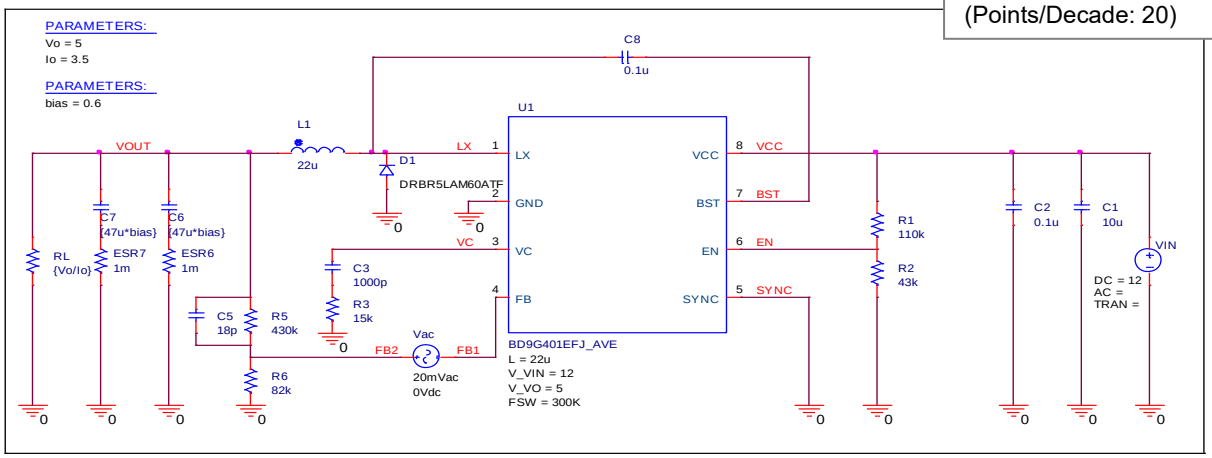

Figure 17.
Simulation Schematic 6

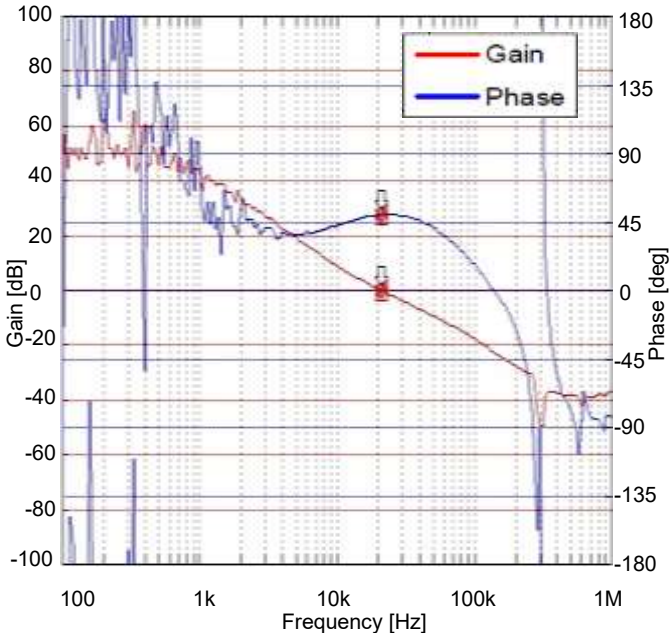

Figure 18.
Frequency Characteristic (VIN = 12 V, VOUT = 5 V, IOUT = 3.5 A)
(Measured Waveform)

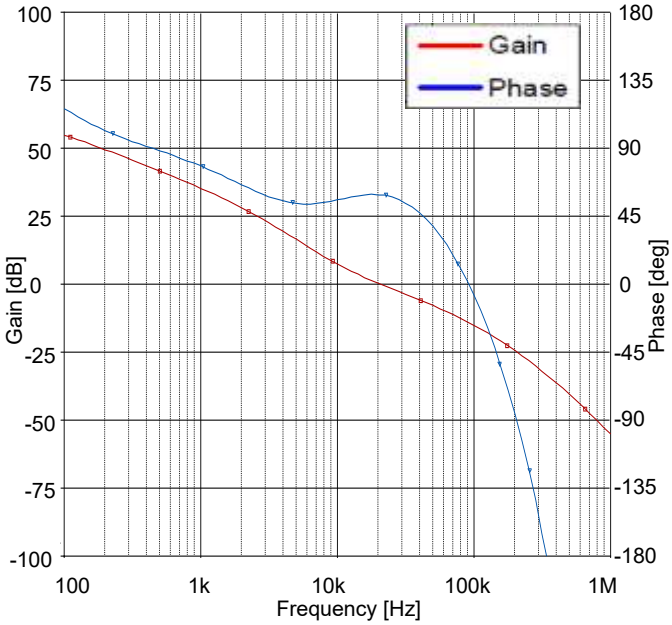

Figure 19.
Frequency Characteristic (VIN = 12 V, VOUT = 5 V, IOUT = 3.5 A)
(SPICE Simulation)

Table 10 Characteristics Comparison

Parameter	Measured Result (Note1)(Note2)	SPICE Simulation Result	Unit	Error	Condition
Phase Margin	49.6	59.2	degree	19.4 %	V_{IN} = 12 V, V_{OUT} = 5 V
Crossover Frequency	20.9	20.4	kHz	-2.4 %	

(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.

7. Frequency Characteristic (V_{IN} = 36 V, V_{OUT} = 24 V, I_{OUT} = 3.5 A)

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

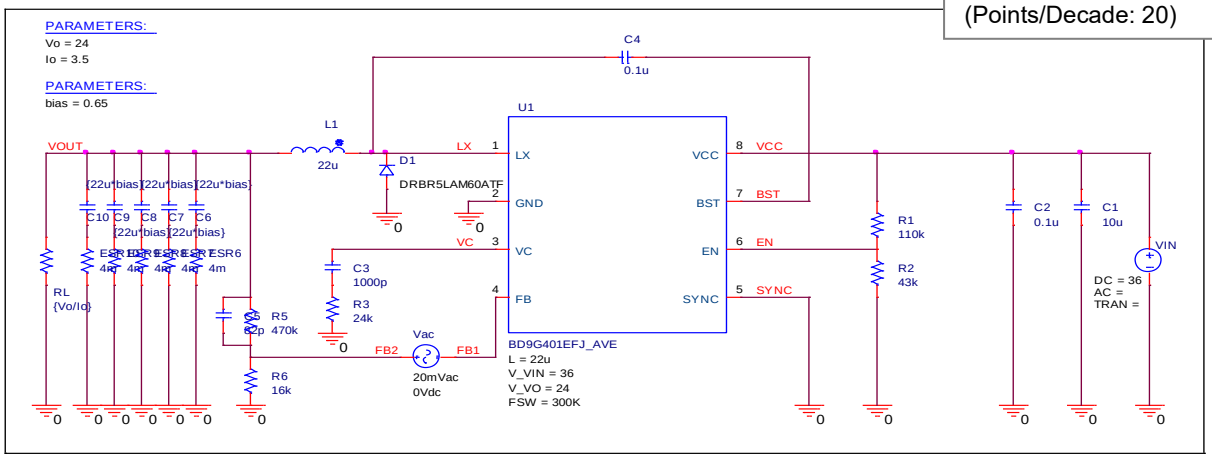

Figure 20.
Simulation Schematic 7

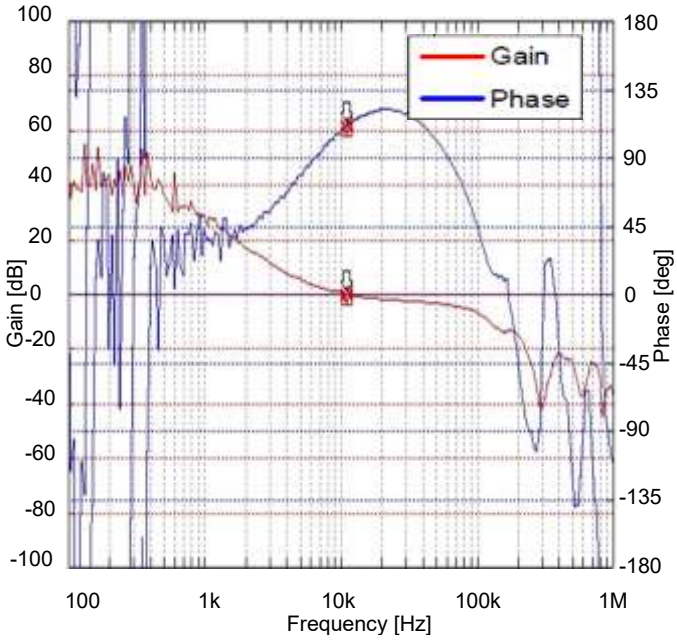

Figure 21.
Frequency Characteristic (VIN = 36 V, VOUT = 24 V, IOUT = 3.5 A)
(Measured Waveform)

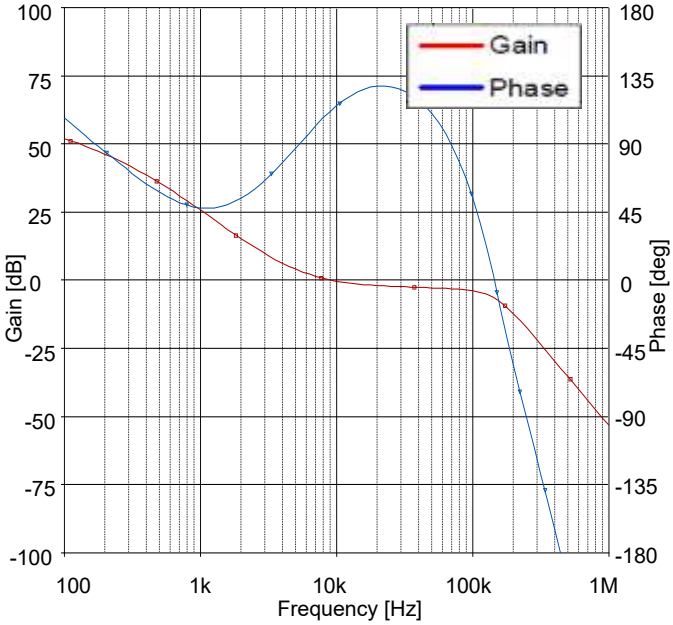

Figure 22.
Frequency Characteristic (VIN = 36 V, VOUT = 24 V, IOUT = 3.5 A)
(SPICE Simulation)

Table 11 Characteristics Comparison

Parameter	Measured Result (Note1)(Note2)	SPICE Simulation Result	Unit	Error	Condition
Phase Margin	110.6	112.6	degree	1.8 %	V_{IN} = 36 V, V_{OUT} = 24 V
Crossover Frequency	11	9.3	kHz	-15.5 %	

(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
Sep.2021	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.

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