

## Primary Buck DC/DC Converter

# Single Buck DC/DC Converter For Automotive BD9P209NUF-C Evaluation Board

BD9P209NUF-TSB-001 (3.0 to 36 V Input, 5.0 V, 2.0 A Output)

## Introduction

This user's guide will provide the necessary steps to operate the Evaluation Board of ROHM's BD9P209NUF-C Buck DC/DC converter. This includes the external parts, operating procedures and application data.

## Description

This Evaluation Board was developed for ROHM's single 400 kHz or 2.0 MHz buck DC/DC converter BD9P209NUF-C. BD9P209NUF-C is a current mode synchronous buck DC/DC converter with integrated POWER MOSFETs. The BD9P209NUF-C accepts a power supply input range of 3.0 V to 36 V and generates a maximum output current of 2 A. BD9P209NUF-C generates an output voltage range of 1.0 V to 9.0 V using external resistors.

## Application

- Automotive Powered Supplies
- Consumer Powered Supplies

## Recommended Operating Conditions

Table 1. Recommended Operating Conditions

Parameter	Min	Typ	Max	Units	Conditions
Input Voltage	3.0	-	36	V	Initial startup is 3.5 V or more
Output Voltage (Note1)	1.0	-	9.0	V	
Output Current Range	-	-	2.0	A	
Switching Frequency fsw2	-	400	-	kHz	FREQ_SEL = High
Switching Frequency	-	2.0	-	MHz	FREQ_SEL = Low
Maximum Efficiency	-	94.3	-	%	VIN = 12 V, VO = 5.0 V, fsw = 400kHz, Io = 0.8 A, Ta = 25 °C
Maximum Efficiency	-	92.1	-	%	VIN = 12 V, VO = 5.0 V, fsw = 2.0MHz, Io = 0.9 A, Ta = 25 °C

(Note1) Although the minimum output voltage is configurable up to 1.0 V, it may be limited by the SW min ON pulse width. For the same reason, although the maximum output voltage is configurable up to 9.0 V, it may be limited by the SW minimum OFF pulse width.

## Evaluation Board



Figure 1. Evaluation Board Top View

## Evaluation Board Schematic

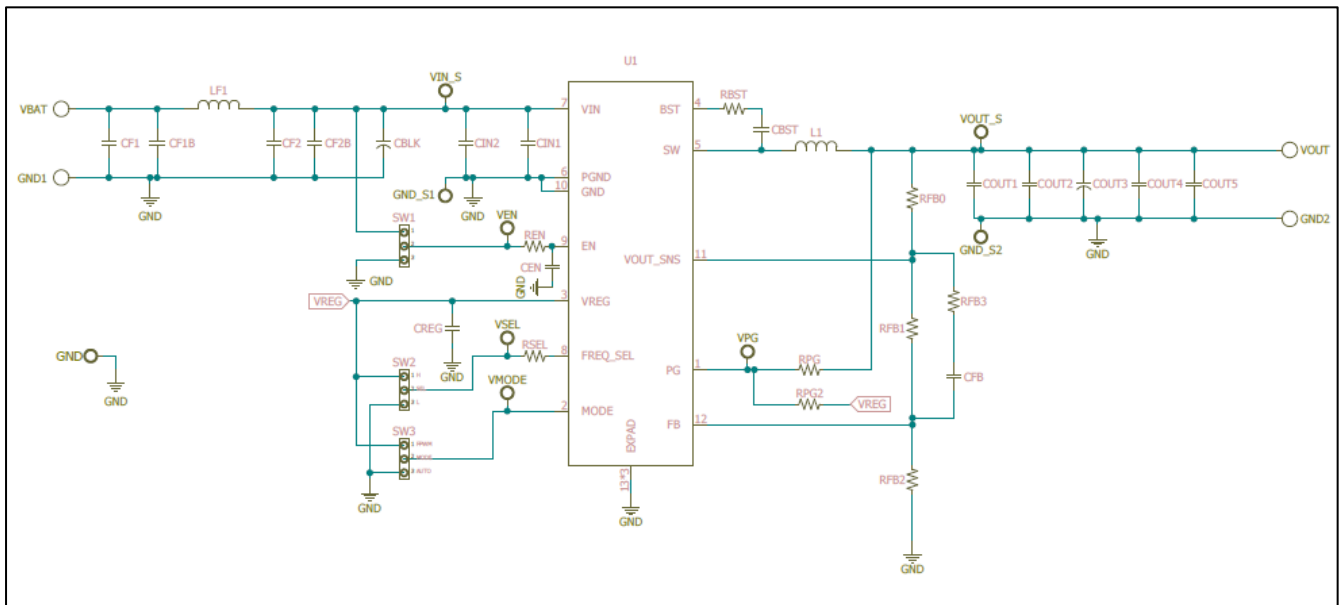


Figure 2. Circuit Diagram

## Operating Procedure

1. Turn off EN and connect the GND terminal of the power supply to the GND terminal of Evaluation Board.
2. Connect VCC pin of power supply to the VBAT pin of the Evaluation Board.
3. Connect the load to the Evaluation Board's VOUT and GND2 terminals. When using an electronic load, connect with the load turned off.
4. Connect a voltmeter to the Evaluation Board's VOUT\_S and GND\_S2 terminals.
5. Turn on the Power supply of VBAT. Turn ON the switch of EN terminal.
6. Make sure that the voltmeter is set to measure voltage.
7. Turn on the electronic load.

(Caution) This Evaluation Board does not support hot plug. Do not perform hot plug test.

(Note) If EN = High (EN short to VIN) before Power ON, the turn ON and turn OFF is controlled by VBAT only.

## Operation Mode Settings

Below is a table of BD9P209NUF-C operation modes selectable using FREQ\_SEL and MODE terminals.

Table 2. Mode Settings (Note)

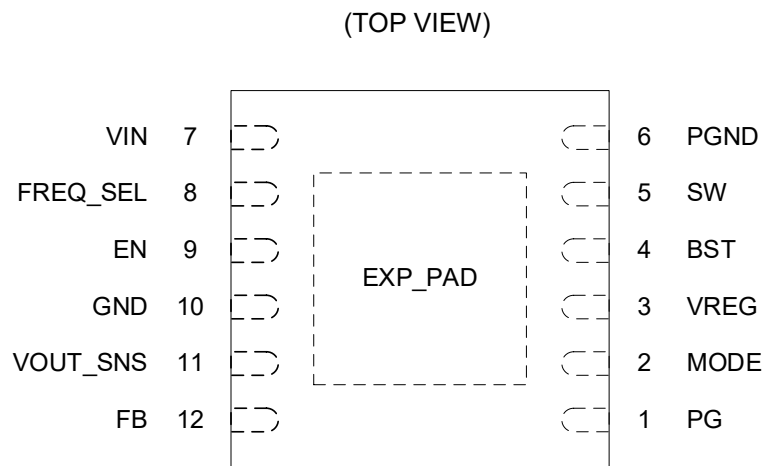
Terminal	Setting	Operation Mode	Function
FREQ_SEL	HIGH	Switching frequency selection	Switching frequency is set to 400 kHz (Typ.)
	LOW		Switching frequency is set to 2.0 MHz (Typ.)
MODE	HIGH	FPWM	Forced PWM mode
	LOW or OPEN	AUTO	Automatically switched between PWM and LLM mode.
	Apply a clock to this pin	SYNC	Activate synchronization mode

(Note) If setting is High, the terminal is shorted to VREG, and if setting is Low, the terminal is shorted to GND.

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## Pin Configuration



## Parts List (BD9P209NUF-C)

Table 3. Parts list (VOUT = 5.0 V, 2.0 MHz (FREQ\_SEL = Low))

	Part No	Value	Package	Manufacturer	Part Name(Series)
π type filter	CF1	2.2μF	3216	Murata	GCM31CR71H225K
	CF1B	2.2μF	3216	Murata	GCM31CR71H225K
	LF1	2.2μH	W6.0 x H4.5 x L6.3 mm <sup>3</sup>	TDK	CLF6045NIT-2R2N-D
	CF2	0.1μF	1005	Murata	GCM155R71H104K
	CF2B	0.1μF	1005	Murata	GCM155R71H104K
	CBLK	220μF	φ 10 mm x L10 mm	Nichicon	UWD1V221MCL1GS
Basic	CIN2	4.7μF	3225	Murata	GCM32ER71H475K
	CIN1	0.1μF	1005	Murata	GCM155R71H104K
	CREG	1μF	2012	Murata	GCM21BR71C105K
	CBST	0.1μF	1005	Murata	GCM155R71H104K
	RBST	0Ω	1608	ROHM	MCR03 Series
	RPG	10kΩ	1608	ROHM	MCR03 Series
	RPG2	Open	-	-	-
Application	L1	3.3μH	W6.0 x H4.5 x L6.3 mm <sup>3</sup>	TDK	CLF6045NIT-3R3N-D
	COUT1	22μF	3225	Murata	GCM32ER71A226K
	COUT2	Open	-	-	-
	COUT3	Open	-	-	-
	COUT4	Open	-	-	-
	COUT5	0.1μF	1005	Murata	GCM155R71H104K
	CFB	22pF	1005	Murata	GCM1555C1H220J
	RFB0	22Ω	1608	ROHM	MCR03 Series
	RFB1	68kΩ	1608	ROHM	MCR03 Series
	RFB2	13kΩ	1608	ROHM	MCR03 Series
	RFB3	1kΩ	1608	ROHM	MCR03 Series
	REN	10kΩ	1608	ROHM	MCR03 Series
	CEN	Open	-	-	-
	RSEL	0Ω	1608	ROHM	MCR03 Series

**Table 4. Parts list** (VOUT = 3.3 V, 2.0 MHz (FREQ\_SEL = Low))

	Part No	Value	Package	Manufacturer	Part Name(Series)
π type filter	CF1	2.2μF	3216	Murata	GCM31CR71H225K
	CF1B	2.2μF	3216	Murata	GCM31CR71H225K
	LF1	2.2μH	W6.0 x H4.5 x L6.3 mm <sup>3</sup>	TDK	CLF6045NIT-2R2N-D
	CF2	0.1μF	1005	Murata	GCM155R71H104K
	CF2B	0.1μF	1005	Murata	GCM155R71H104K
	CBLK	220μF	φ 10 mm x L10 mm	Nichicon	UWD1V221MCL1GS
Basic	CIN2	4.7μF	3225	Murata	GCM32ER71H475K
	CIN1	0.1μF	1005	Murata	GCM155R71H104K
	CREG	1μF	2012	Murata	GCM21BR71C105K
	CBST	0.1μF	1005	Murata	GCM155R71H104K
	RBST	0Ω	1608	ROHM	MCR03 Series
	RPG	10kΩ	1608	ROHM	MCR03 Series
	RPG2	Open	-	-	-
Application	L1	3.3μH	W6.0 x H4.5 x L6.3 mm <sup>3</sup>	TDK	CLF6045NIT-3R3N-D
	COUT1	22μF	3225	Murata	GCM32ER71A226K
	COUT2	Open	-	-	-
	COUT3	Open	-	-	-
	COUT4	Open	-	-	-
	COUT5	0.1μF	1005	Murata	GCM155R71H104K
	CFB	22pF	1005	Murata	GCM1555C1H220J
	RFB0	22Ω	1608	ROHM	MCR03 Series
	RFB1	75kΩ	1608	ROHM	MCR03 Series
	RFB2	24kΩ	1608	ROHM	MCR03 Series
	RFB3	1kΩ	1608	ROHM	MCR03 Series
	REN	10kΩ	1608	ROHM	MCR03 Series
	CEN	Open	-	-	-
RSEL	0Ω	1608	ROHM	MCR03 Series	

**Table 5. Parts list** (VOUT = 9.0 V, 2.0 MHz (FREQ\_SEL = Low))

	Part No	Value	Package	Manufacturer	Part Name(Series)
π type filter	CF1	2.2μF	3216	Murata	GCM31CR71H225K
	CF1B	2.2μF	3216	Murata	GCM31CR71H225K
	L1	2.2μH	W6.0 x H4.5 x L6.3 mm <sup>3</sup>	TDK	CLF6045NIT-2R2N-D
	CF2	0.1μF	1005	Murata	GCM155R71H104K
	CF2B	0.1μF	1005	Murata	GCM155R71H104K
	CBLK	220μF	φ 10 mm x L10 mm	Nichicon	UWD1V221MCL1GS
Basic	CIN2	4.7μF	3225	Murata	GCM32ER71H475K
	CIN1	0.1μF	1005	Murata	GCM155R71H104K
	CREG	1μF	2012	Murata	GCM21BR71C105K
	CBST	0.1μF	1005	Murata	GCM155R71H104K
	RBST	0Ω	1608	ROHM	MCR03 Series
	RPG	10kΩ	1608	ROHM	MCR03 Series
	RPG2	Open	-	-	-
Application	L1	4.7μH	W6.0 x H4.5 x L6.3 mm <sup>3</sup>	TDK	CLF6045NIT-4R7N-D
	COUT1	22μF	3225	Murata	GCM32ER71A226K
	COUT2	Open	-	-	-
	COUT3	Open	-	-	-
	COUT4	Open	-	-	-
	COUT5	0.1μF	1005	Murata	GCM155R71H104K
	CFB	22pF	1005	Murata	GCM1555C1H220J
	RFB0	22Ω	1608	ROHM	MCR03 Series
	RFB1	100kΩ+3kΩ	1608	ROHM	MCR03 Series
	RFB2	10kΩ	1608	ROHM	MCR03 Series
	RFB3	1kΩ	1608	ROHM	MCR03 Series
	REN	10kΩ	1608	ROHM	MCR03 Series
	CEN	Open	-	-	-
RSEL	0Ω	1608	ROHM	MCR03 Series	

**Table 6. Parts list** (V<sub>OUT</sub> = 5.0 V, 400 kHz (FREQ\_SEL = High))

	Part No	Value	Package	Manufacturer	Part Name(Series)
π type filter	CF1	2.2μF	3216	Murata	GCM31CR71H225K
	CF1B	2.2μF	3216	Murata	GCM31CR71H225K
	LF1	2.2μH	W6.0 x H4.5 x L6.3 mm <sup>3</sup>	TDK	CLF6045NIT-2R2N-D
	CF2	0.1μF	1005	Murata	GCM155R71H104K
	CF2B	0.1μF	1005	Murata	GCM155R71H104K
	CBLK	220μF	φ 10 mm x L10 mm	Nichicon	UWD1V221MCL1GS
Basic	CIN2	4.7μF	3225	Murata	GCM32ER71H475K
	CIN1	0.1μF	1005	Murata	GCM155R71H104K
	CREG	1μF	2012	Murata	GCM21BR71C105K
	CBST	0.1μF	1005	Murata	GCM155R71H104K
	RBST	0Ω	1608	ROHM	MCR03 Series
	RPG	10kΩ	1608	ROHM	MCR03 Series
	RPG2	Open	-	-	-
Application	L1	10μH	W7.0 x H4.5 x L7.4 mm <sup>3</sup>	TDK	CLF7045NIT-100M-D
	COUT1	22μF	3225	Murata	GCM32ER71A226K
	COUT2	22μF	3225	Murata	GCM32ER71A226K
	COUT3	Open	-	-	-
	COUT4	Open	-	-	-
	COUT5	0.1μF	1005	Murata	GCM155R71H104K
	CFB	22pF	1005	Murata	GCM1555C1H220J
	RFB0	22Ω	1608	ROHM	MCR03 Series
	RFB1	68kΩ	1608	ROHM	MCR03 Series
	RFB2	13kΩ	1608	ROHM	MCR03 Series
	RFB3	1kΩ	1608	ROHM	MCR03 Series
	REN	10kΩ	1608	ROHM	MCR03 Series
	CEN	Open	-	-	-
RSEL	0Ω	1608	ROHM	MCR03 Series	

**Table 7. Parts list** (V<sub>OUT</sub> = 3.3 V, 400 kHz (FREQ\_SEL = High))

	Part No	Value	Package	Manufacturer	Part Name(Series)
π type filter	CF1	2.2μF	3216	Murata	GCM31CR71H225K
	CF1B	2.2μF	3216	Murata	GCM31CR71H225K
	LF1	2.2μH	W6.0 x H4.5 x L6.3 mm <sup>3</sup>	TDK	CLF6045NIT-2R2N-D
	CF2	0.1μF	1005	Murata	GCM155R71H104K
	CF2B	0.1μF	1005	Murata	GCM155R71H104K
	CBLK	220μF	φ 10 mm x L10 mm	Nichicon	UWD1V221MCL1GS
Basic	CIN2	4.7μF	3225	Murata	GCM32ER71H475K
	CIN1	0.1μF	1005	Murata	GCM155R71H104K
	CREG	1μF	2012	Murata	GCM21BR71C105K
	CBST	0.1μF	1005	Murata	GCM155R71H104K
	RBST	0Ω	1608	ROHM	MCR03 Series
	RPG	10kΩ	1608	ROHM	MCR03 Series
	RPG2	Open	-	-	-
Application	L1	10μH	W7.0 x H4.5 x L7.4 mm <sup>3</sup>	TDK	CLF7045NIT-100M-D
	COUT1	22μF	3225	Murata	GCM32ER71A226K
	COUT2	22μF	3225	Murata	GCM32ER71A226K
	COUT3	22μF	3225	Murata	GCM32ER71A226K
	COUT4	Open	-	-	-
	COUT5	0.1μF	1005	Murata	GCM155R71H104K
	CFB	22pF	1005	Murata	GCM1555C1H220J
	RFB0	22Ω	1608	ROHM	MCR03 Series
	RFB1	75kΩ	1608	ROHM	MCR03 Series
	RFB2	24kΩ	1608	ROHM	MCR03 Series
	RFB3	1kΩ	1608	ROHM	MCR03 Series
	REN	10kΩ	1608	ROHM	MCR03 Series
	CEN	Open	-	-	-
RSEL	0Ω	1608	ROHM	MCR03 Series	

Table 8. Parts list (V<sub>OUT</sub> = 9.0 V, 400 kHz (FREQ\_SEL = High))

	Part No	Value	Package	Manufacturer	Part Name(Series)
π type filter	CF1	2.2μF	3216	Murata	GCM31CR71H225K
	CF1B	2.2μF	3216	Murata	GCM31CR71H225K
	LF1	2.2μH	W6.0 x H4.5 x L6.3 mm <sup>3</sup>	TDK	CLF6045NIT-2R2N-D
	CF2	0.1μF	1005	Murata	GCM155R71H104K
	CF2B	0.1μF	1005	Murata	GCM155R71H104K
	CBLK	220μF	φ 10 mm x L10 mm	Nichicon	UWD1V221MCL1GS
Basic	CIN2	4.7μF	3225	Murata	GCM32ER71H475K
	CIN1	0.1μF	1005	Murata	GCM155R71H104K
	CREG	1μF	2012	Murata	GCM21BR71C105K
	CBST	0.1μF	1005	Murata	GCM155R71H104K
	RBST	0Ω	1608	ROHM	MCR03 Series
	RPG	10kΩ	1608	ROHM	MCR03 Series
	RPG2	Open	-	-	-
Application	L1	10μH	W7.0 x H4.5 x L7.4 mm <sup>3</sup>	TDK	CLF7045NIT-100M-D
	COUT1	22μF	3225	Murata	GCM32ER71A226K
	COUT2	22μF	3225	Murata	GCM32ER71A226K
	COUT3	Open	-	-	-
	COUT4	Open	-	-	-
	COUT5	0.1μF	1005	Murata	GCM155R71H104K
	CFB	22pF	1005	Murata	GCM1555C1H220J
	RFB0	22Ω	1608	ROHM	MCR03 Series
	RFB1	100kΩ+3kΩ	1608	ROHM	MCR03 Series
	RFB2	10kΩ	1608	ROHM	MCR03 Series
	RFB3	1kΩ	1608	ROHM	MCR03 Series
	REN	10kΩ	1608	ROHM	MCR03 Series
	CEN	Open	-	-	-
	RSEL	0Ω	1608	ROHM	MCR03 Series

V <sub>OUT</sub>	FREQ_SEL	SW Frequency	Recommended C <sub>OUT</sub> Value	Minimum C <sub>OUT</sub> Value (Note1-1,2)
1 V ≤ V <sub>OUT</sub> < 3.3 V	L	2.0 MHz	$C_{OUT} \geq \frac{88}{V_{OUT}} [\mu F] (*)$	$C_{OUT\_WORST} \geq \frac{56}{V_{OUT}} [\mu F] (*)$
3.3 V ≤ V <sub>OUT</sub> < 5 V			$C_{OUT} \geq \frac{72.6}{V_{OUT}} [\mu F] (*)$	$C_{OUT\_WORST} \geq \frac{46.2}{V_{OUT}} [\mu F] (*)$
V <sub>OUT</sub> ≥ 5.0 V			$C_{OUT} \geq 22 [\mu F]$	$C_{OUT\_WORST} \geq 14 [\mu F]$
1 V ≤ V <sub>OUT</sub> < 3.3 V	H	400 kHz	$C_{OUT} \geq \frac{400}{V_{OUT}} [\mu F] (*)$	$C_{OUT\_WORST} \geq \frac{255}{V_{OUT}} [\mu F] (*)$
3.3 V ≤ V <sub>OUT</sub> < 5 V			$C_{OUT} \geq \frac{217.8}{V_{OUT}} [\mu F] (*)$	$C_{OUT\_WORST} \geq \frac{138.6}{V_{OUT}} [\mu F] (*)$
V <sub>OUT</sub> ≥ 5.0 V			$C_{OUT} \geq 44 [\mu F]$	$C_{OUT\_WORST} \geq 28 [\mu F]$

\* V<sub>OUT</sub> is the output voltage [V]

(Note 1-1) When selecting the output capacitor, ensure that the capacitance, C<sub>OUT\_WORST</sub>, of the above equation is maintained at the characteristics of DC Bias, AC Voltage, temperature, and tolerance.

(Note 1-2) If the capacitance falls below this value, oscillation may happen. When using electrolytic capacitor and conductive polymer hybrid aluminum electrolytic capacitor, please place it in addition to the ceramic capacitors with the capacity described above. The changes in the frequency characteristic are greatly affected by the type and the condition (temperature, etc.) of parts that are used, the wire routing and the layout of the PCB. Please confirm stability and responsiveness in actual application.

(Note 2) PG terminal should be pulled-up to V<sub>REG</sub> via RPG2 when the output setting is over 6.5 V because PG pin's absolute maximum rating is 7.0 V. If RPG is not pulled-up to V<sub>OUT</sub>, it can be pulled-up to V<sub>REG</sub> via RPG2 by default.

(Note 3) Please use CFB to improve the frequency characteristics.

(Note 4) If the recommended parts on tables 3 to 8 are not available anymore due to end of production, different parts will be used on the test board because the end of production parts are deprecated.

## Board Layout

Evaluation Board PCB information

Number of Layers	Material	Board Size	Copper Thickness
4	FR-4	100mm x 75mm x 1.6mm	2oz(70μm) / 1oz (35μm) / 1oz (35μm) / 2oz(70μm)

The layout is shown below.

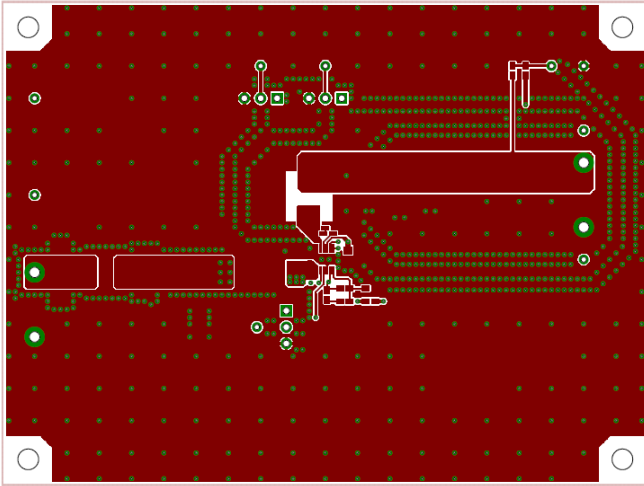


Figure 3. Top Layer Layout  
(Top View)

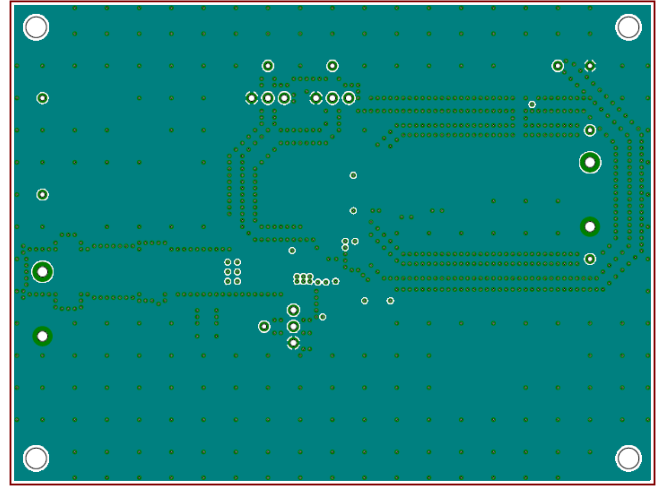


Figure 4. Middle1 Layer Layout  
(Top View)

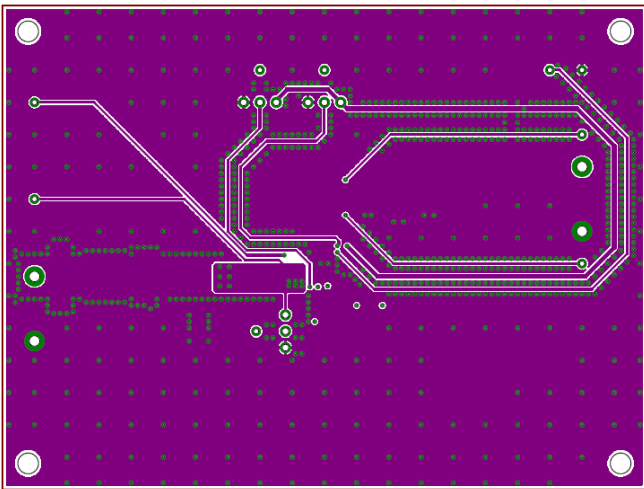


Figure 5. Middle2 Layer Layout  
(Top View)

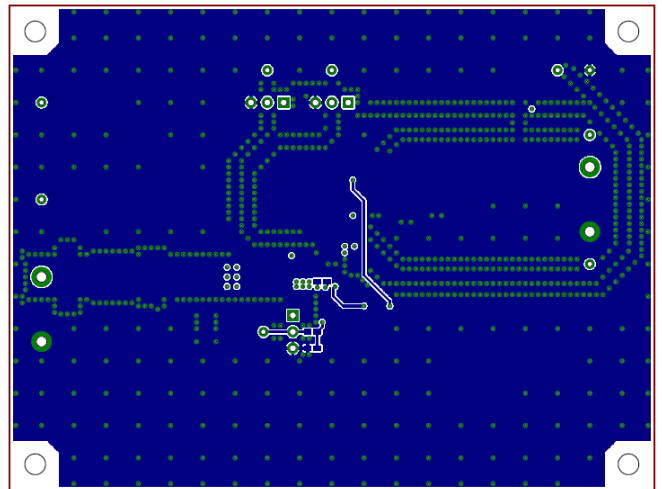


Figure 6. Bottom Layer Layout  
(Top View)

Reference Application Data

(Frequency Characteristic, VOUT = 5.0 V, FREQ\_SEL = High)

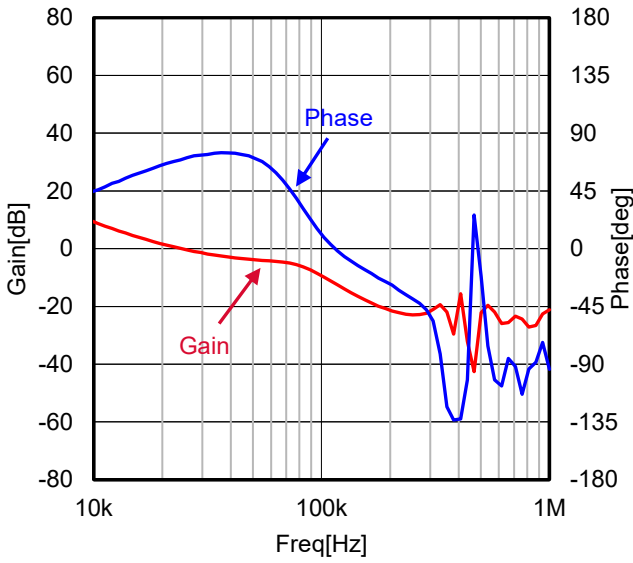


Figure 7. VIN = 8 V, IOU = 1 A

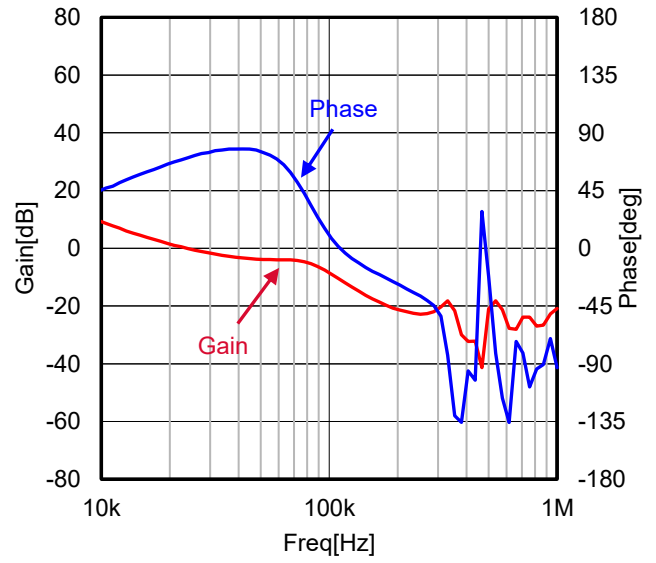


Figure 8. VIN = 8 V, IOU = 2 A

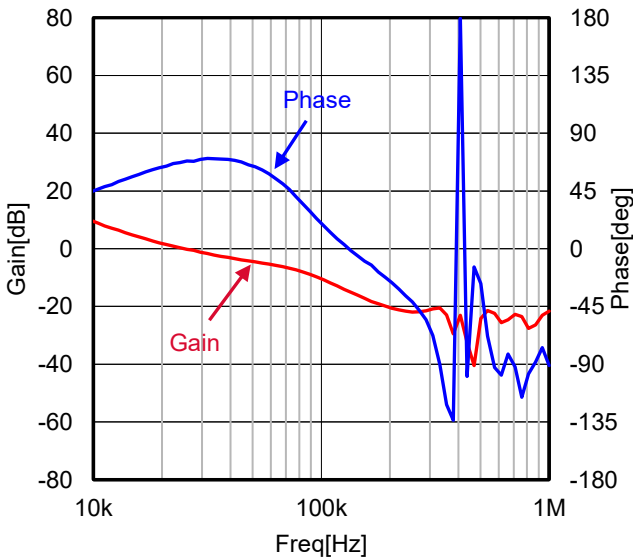


Figure 9. VIN = 12 V, IOU = 1 A

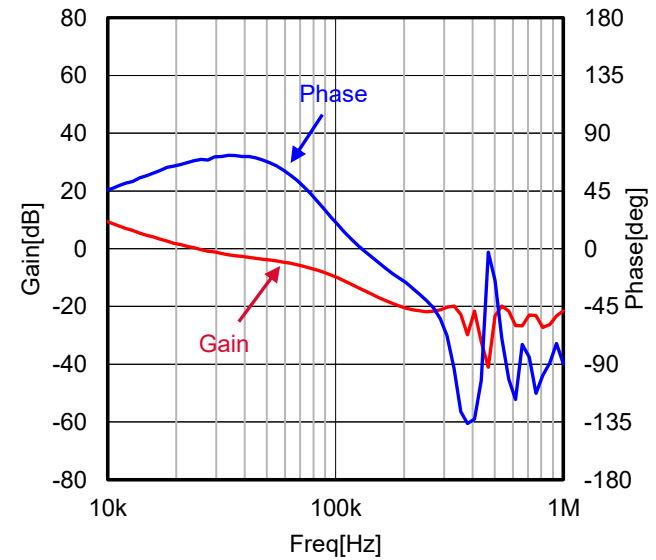


Figure 10. VIN = 12 V, IOU = 2 A

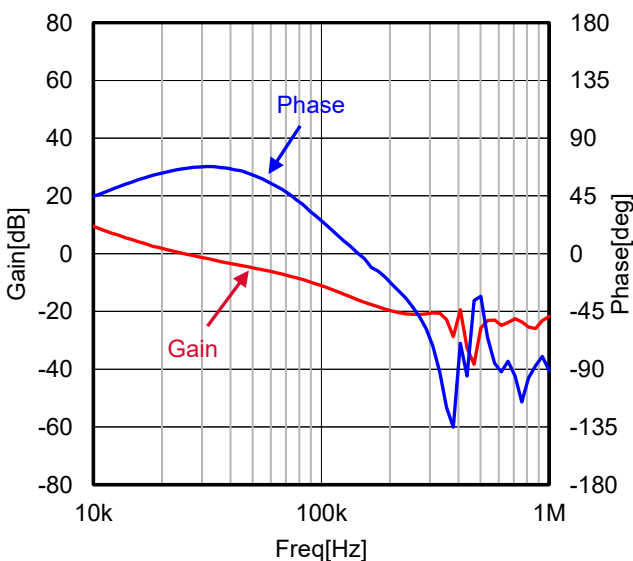


Figure 11. VIN = 18 V, IOU = 1 A

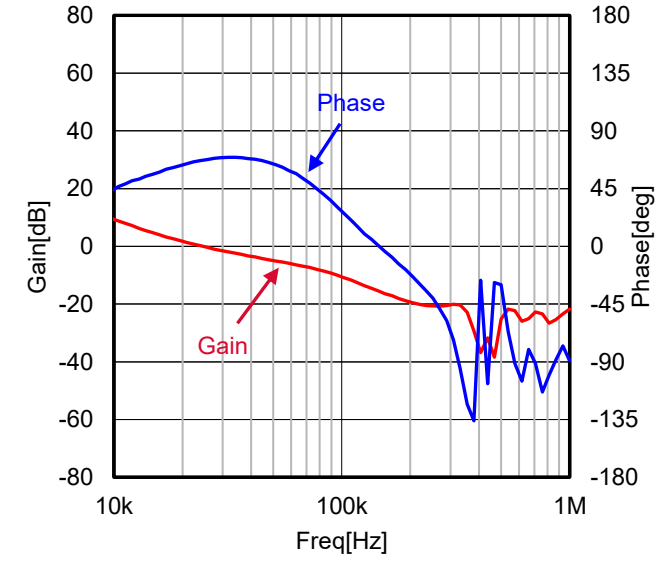


Figure 12. VIN = 18 V, IOU = 2 A

Reference Application Data - continued

(Frequency Characteristic, VOUT = 5.0 V, FREQ\_SEL = Low)

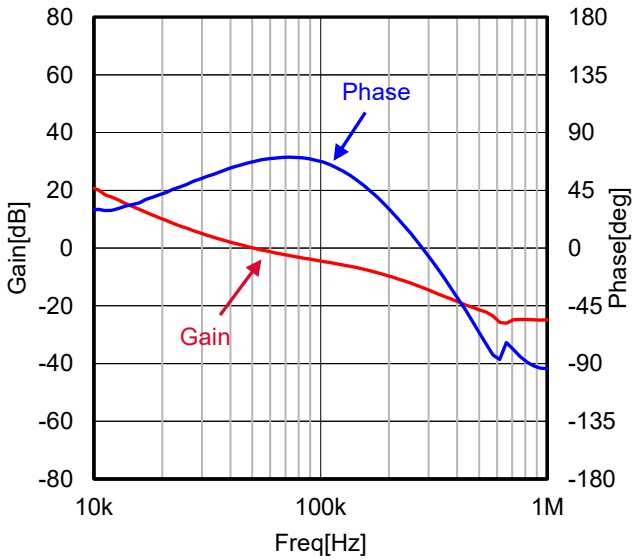


Figure 13. VIN = 8 V, IOU = 1 A

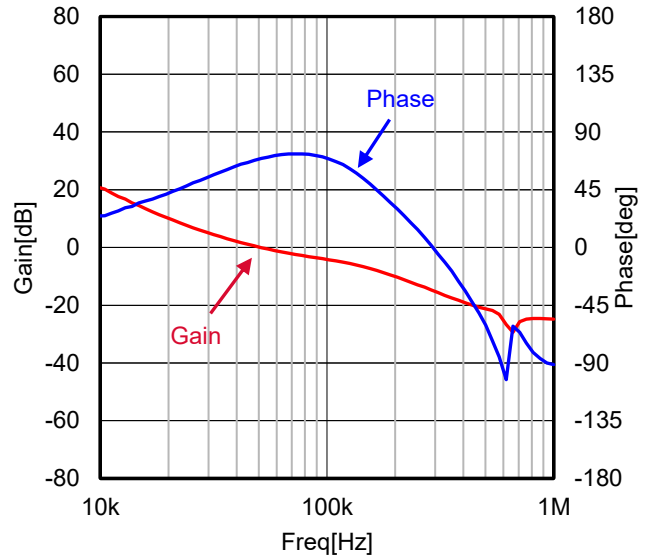


Figure 14. VIN = 8 V, IOU = 2 A

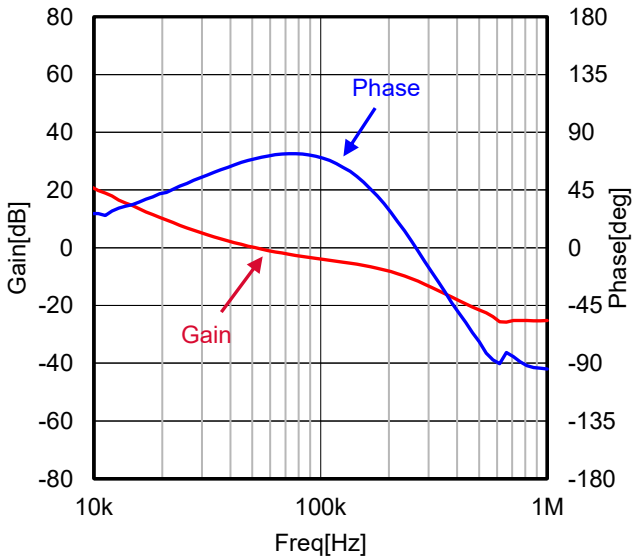


Figure 15. VIN = 12 V, IOU = 1 A

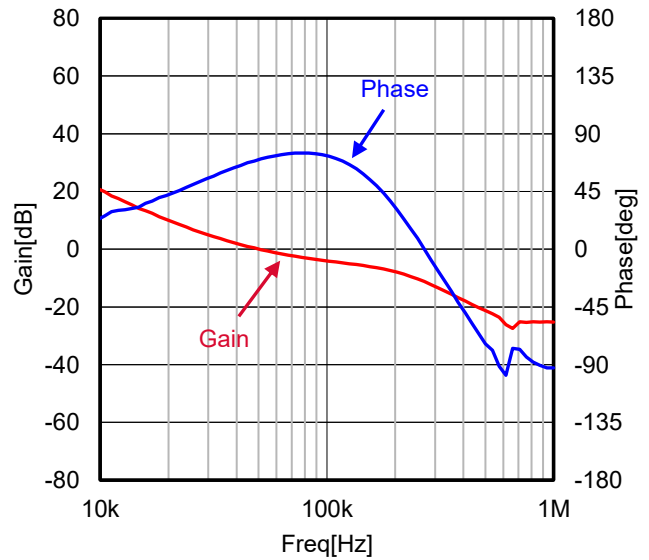


Figure 16. VIN = 12 V, IOU = 2 A

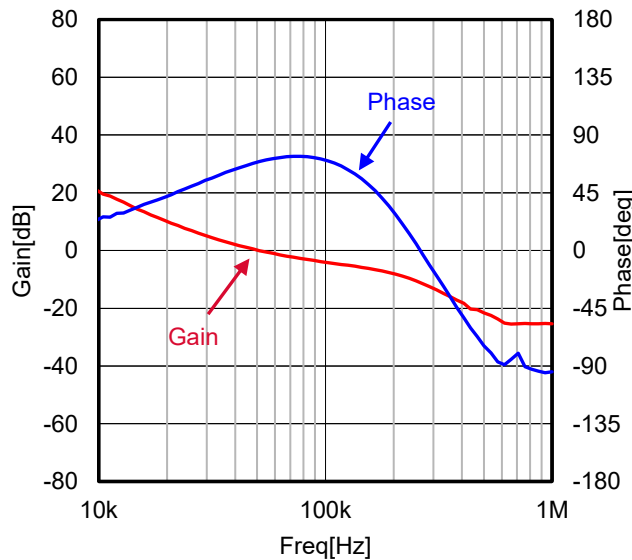


Figure 17. VIN = 18 V, IOU = 1 A

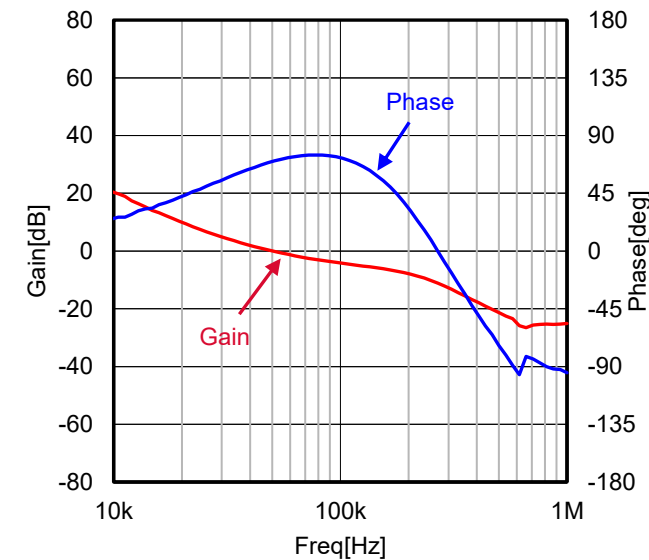


Figure 18. VIN = 18 V, IOU = 2 A

Reference Application Data - continued

(Frequency Characteristic, VOUT = 3.3 V, FREQ\_SEL = High)

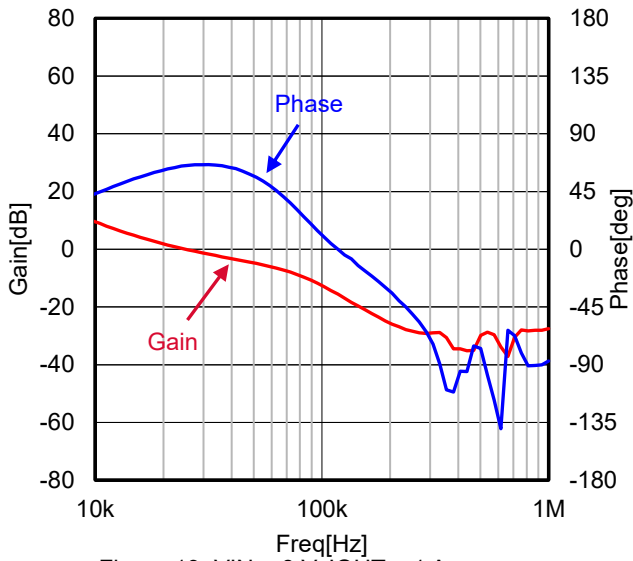


Figure 19. VIN = 8 V, IOU = 1 A

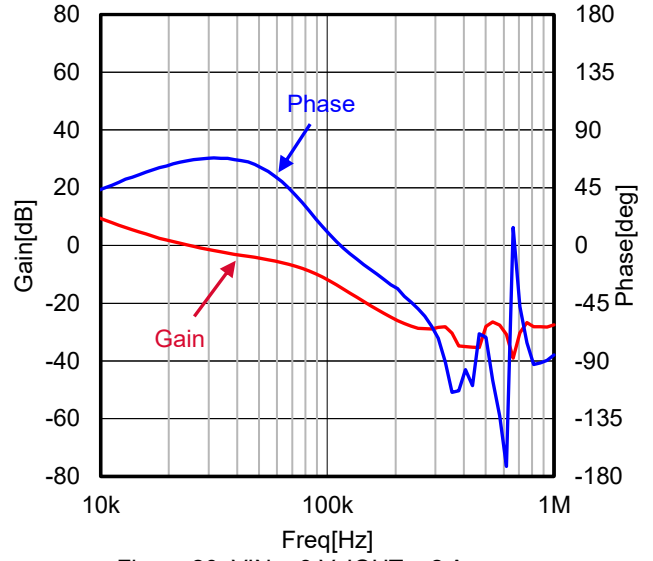


Figure 20. VIN = 8 V, IOU = 2 A

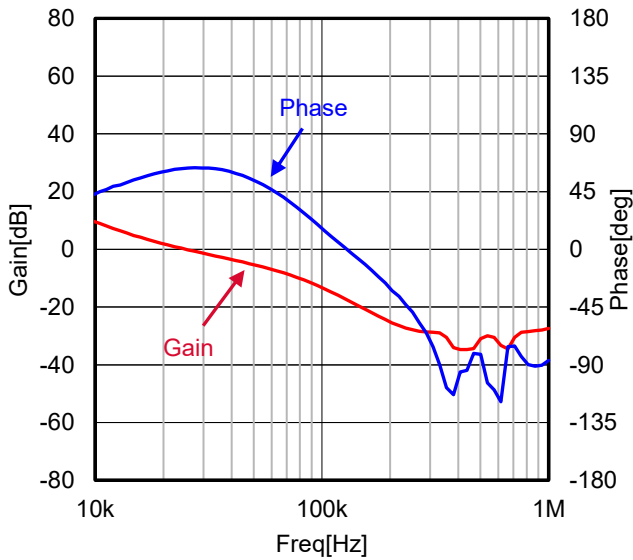


Figure 21. VIN = 12 V, IOU = 1 A

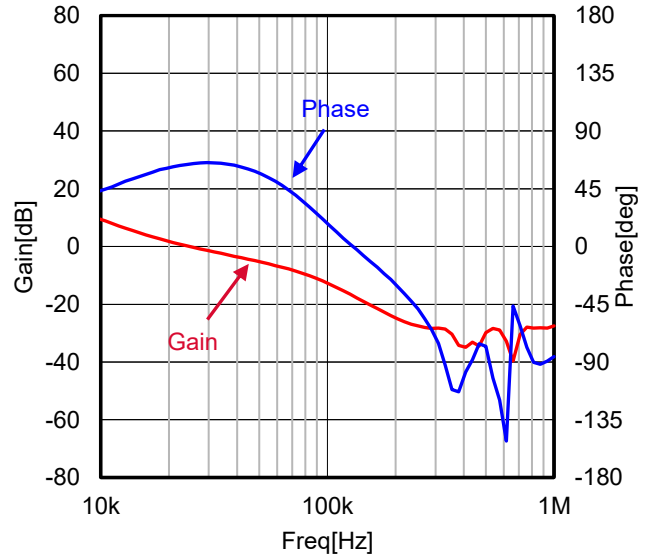


Figure 22. VIN = 12 V, IOU = 2 A

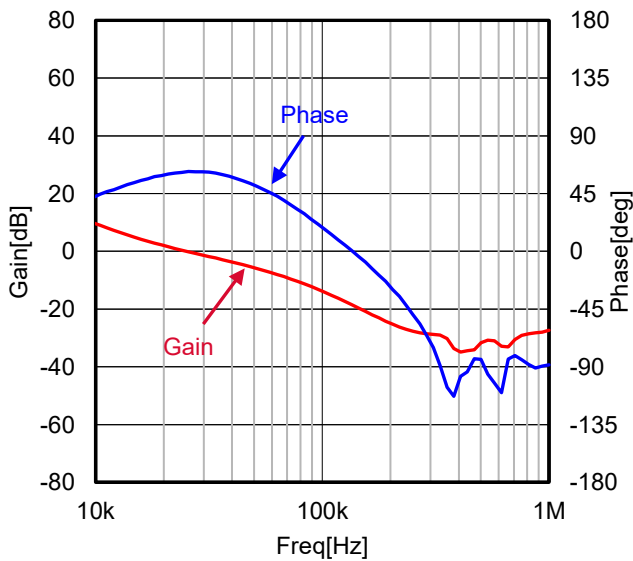


Figure 23. VIN = 18 V, IOU = 1 A

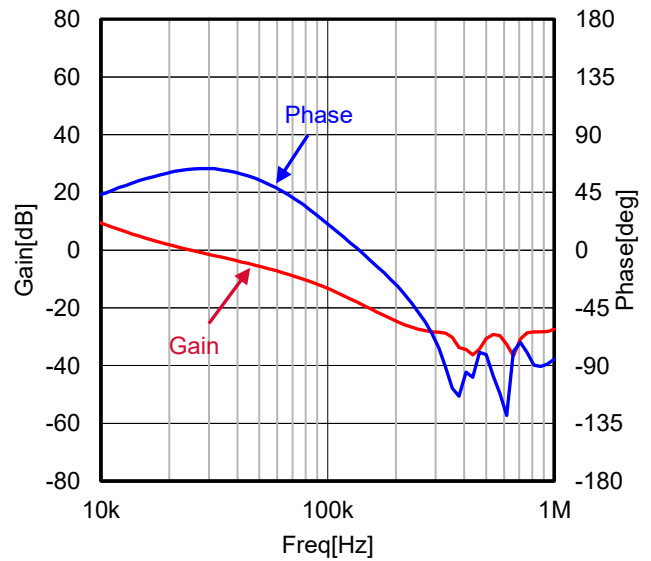


Figure 24. VIN = 18 V, IOU = 2 A

Reference Application Data - continued

(Frequency Characteristic, VOUT = 3.3 V, FREQ\_SEL = Low)

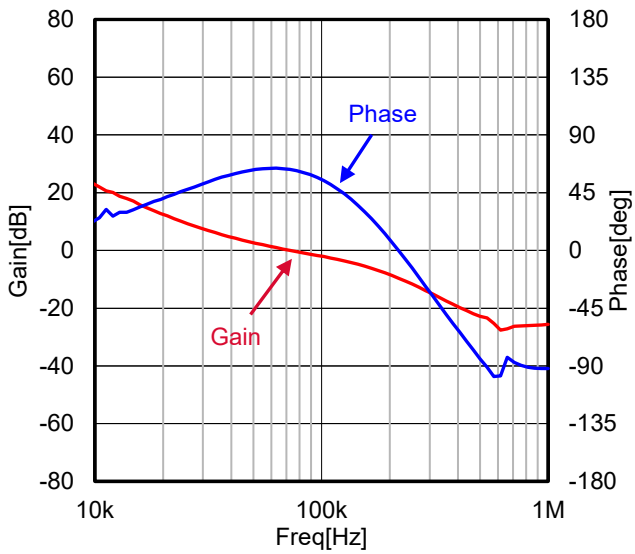


Figure 25. VIN = 8 V, IOU = 1 A

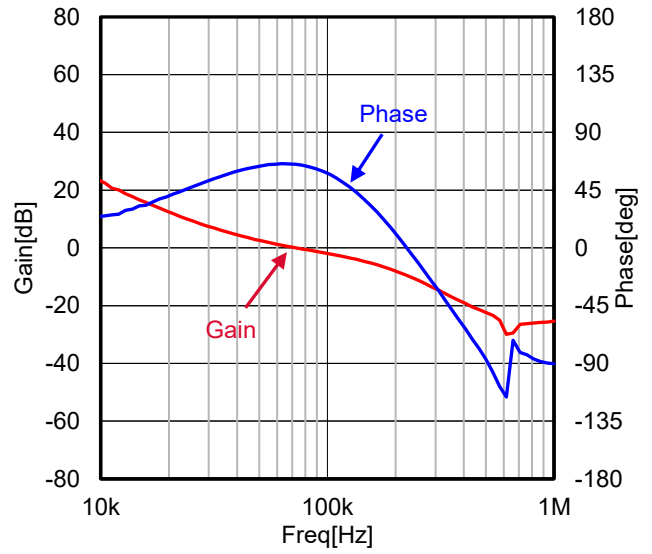


Figure 26. VIN = 8 V, IOU = 2 A

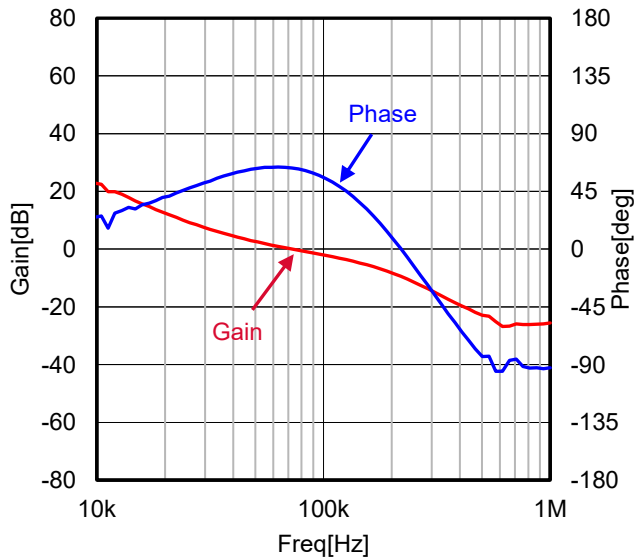


Figure 27. VIN = 12 V, IOU = 1 A

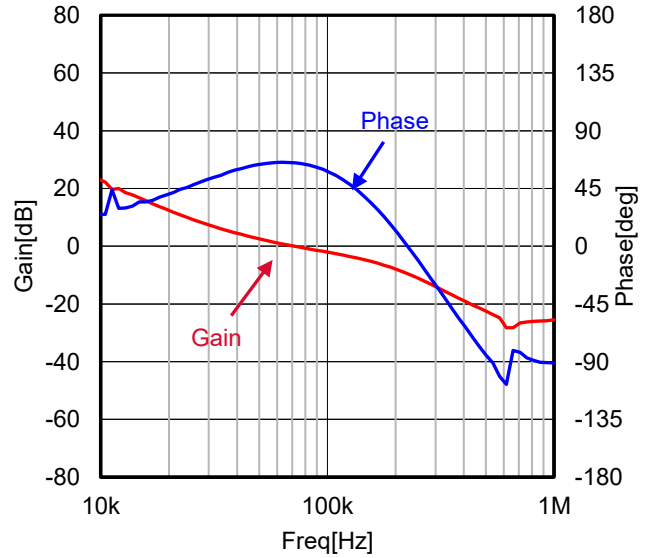


Figure 28. VIN = 12 V, IOU = 2 A

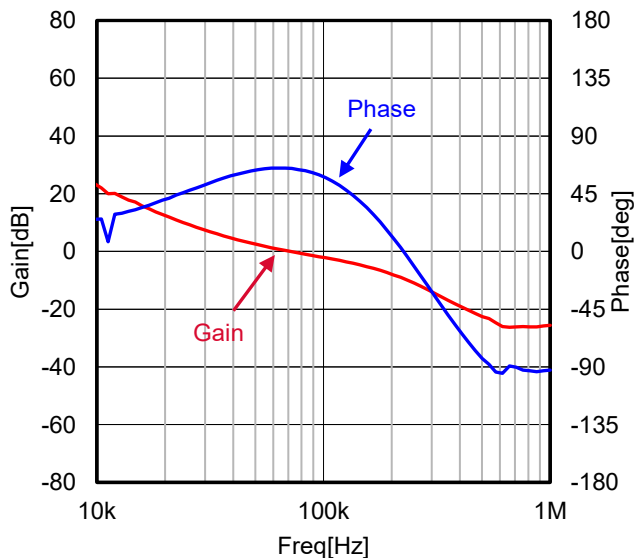


Figure 29. VIN = 18 V, IOU = 1 A

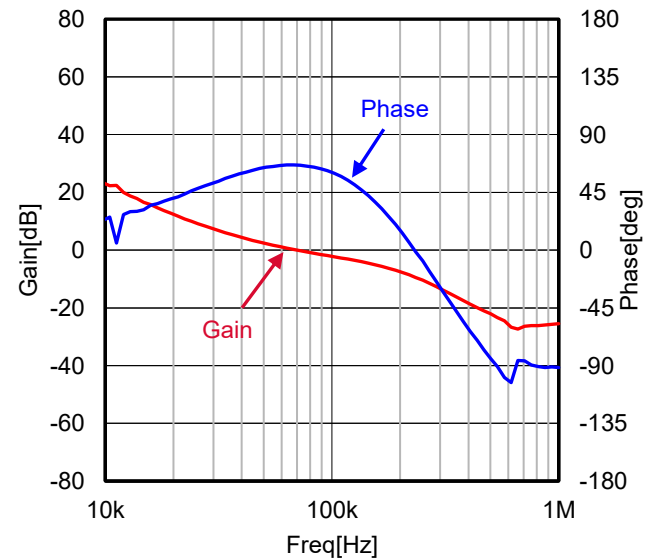


Figure 30. VIN = 18 V, IOU = 2 A

Reference Application Data - continued

(Frequency Characteristic, VOUT = 9.0 V, FREQ\_SEL = High)

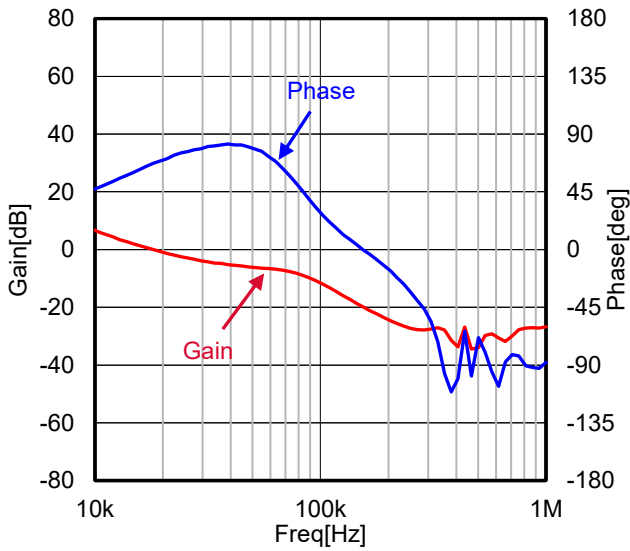


Figure 31. VIN = 16 V, IOU T = 1 A

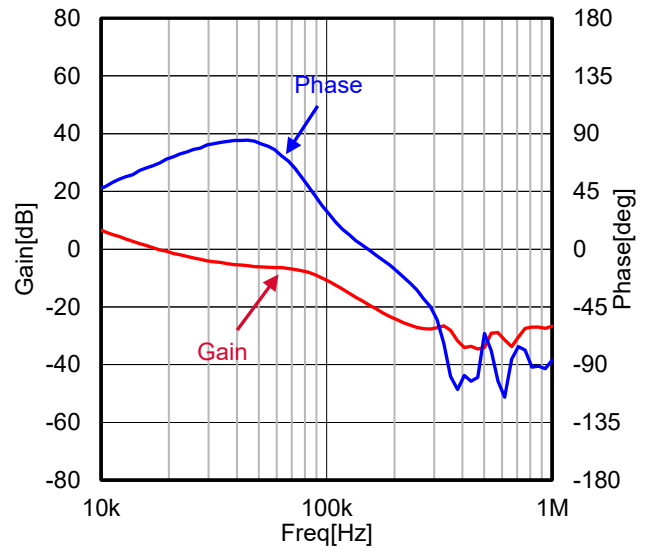


Figure 32. VIN = 16 V, IOU T = 2 A

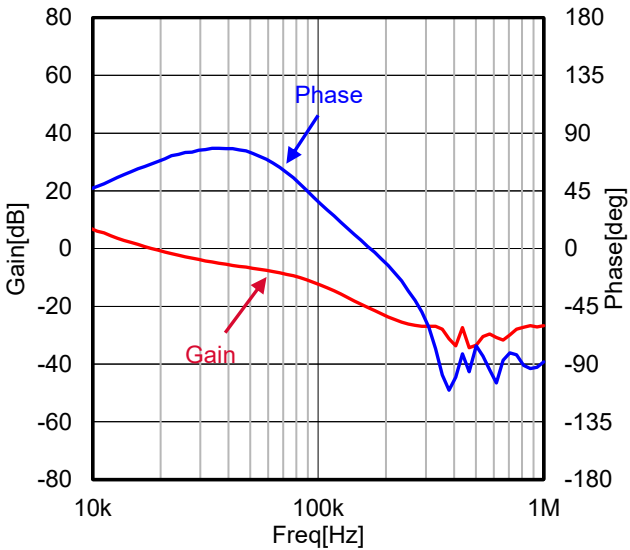


Figure 33. VIN = 24 V, IOU T = 1 A

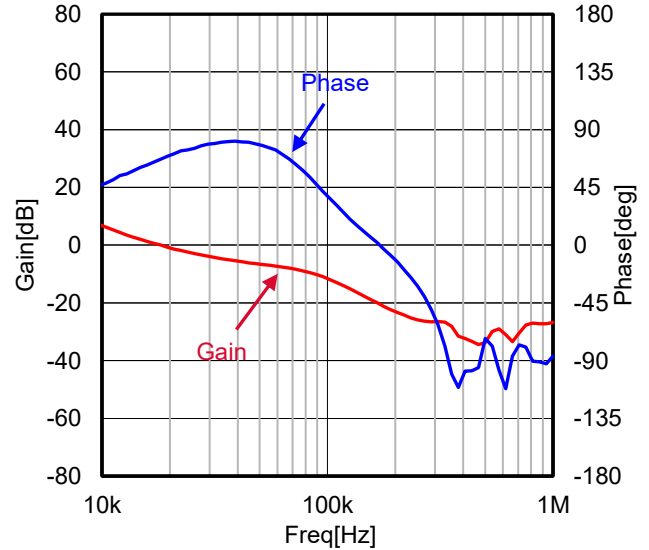


Figure 34. VIN = 24 V, IOU T = 2 A

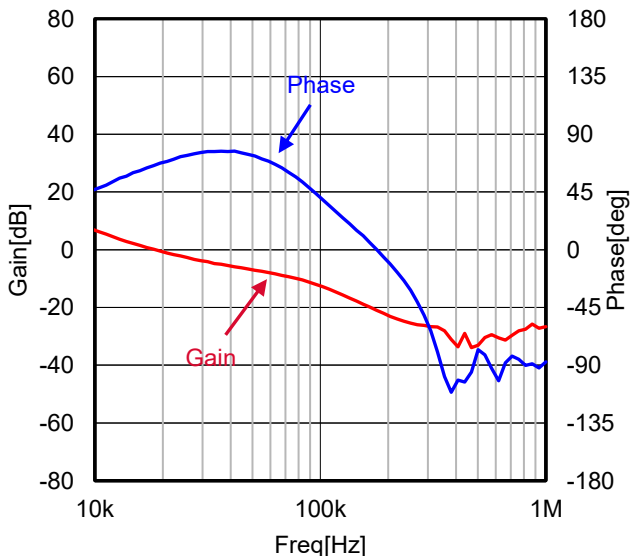


Figure 35. VIN = 32 V, IOU T = 1 A

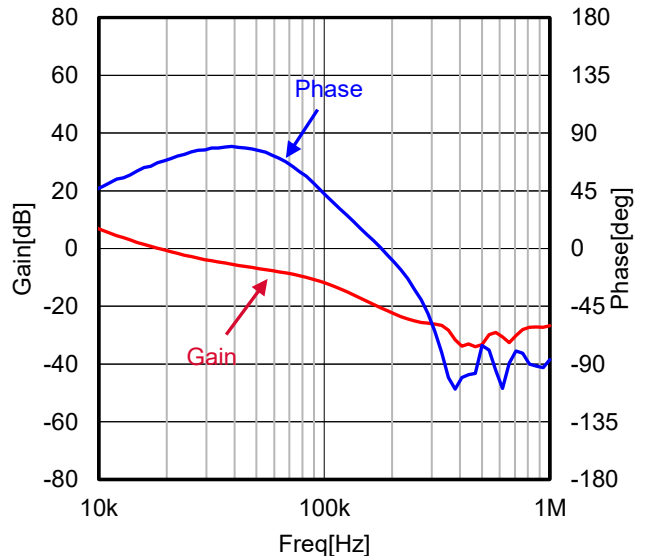


Figure 36. VIN = 32 V, IOU T = 2 A

Reference Application Data - continued

(Frequency Characteristic, VOUT = 9.0 V, FREQ\_SEL = Low)

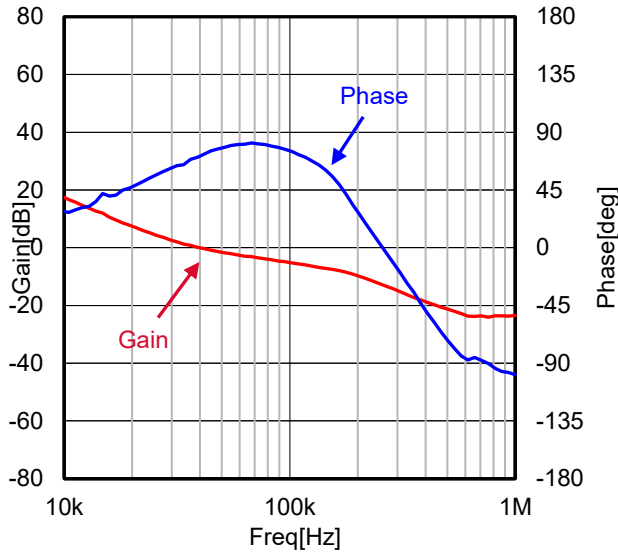


Figure 37. VIN = 16 V, IOU T = 1 A

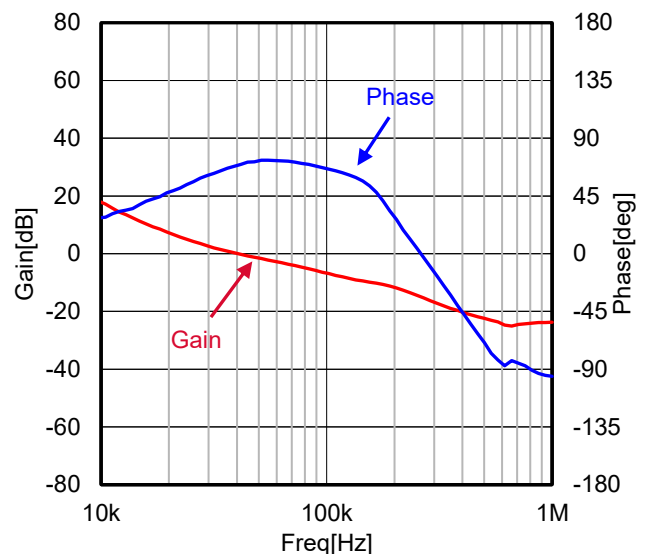


Figure 38. VIN = 16 V, IOU T = 2 A

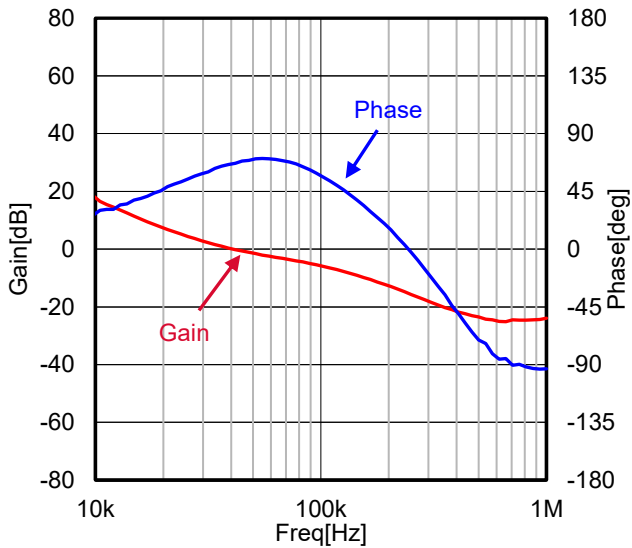


Figure 39. VIN = 24 V, IOU T = 1 A

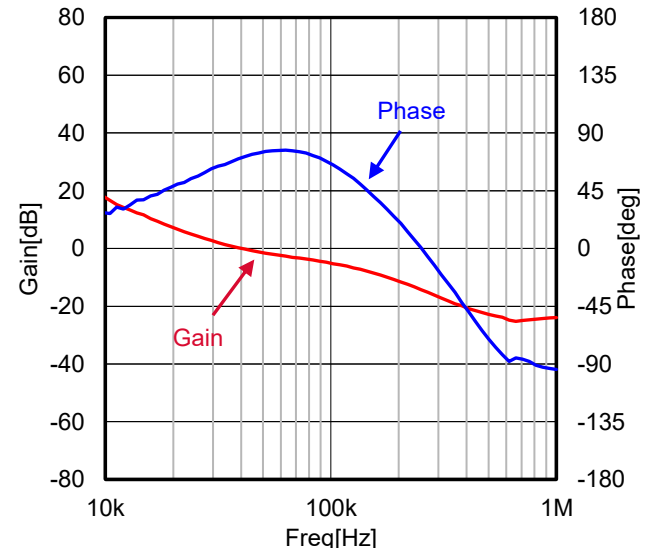


Figure 40. VIN = 24 V, IOU T = 2 A

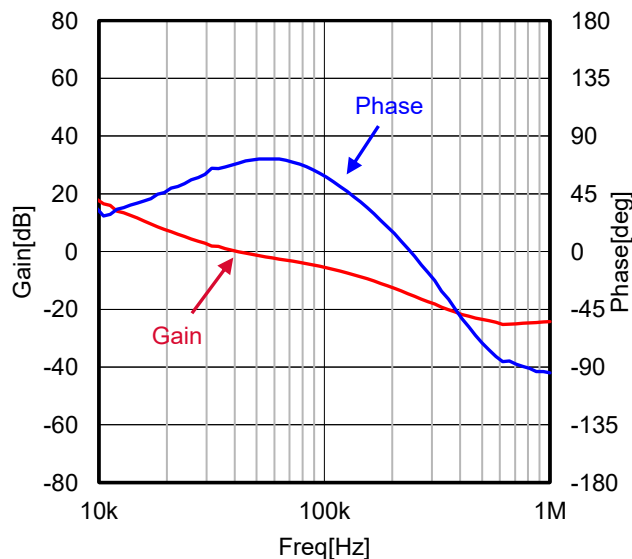


Figure 41. VIN = 32 V, IOU T = 1 A

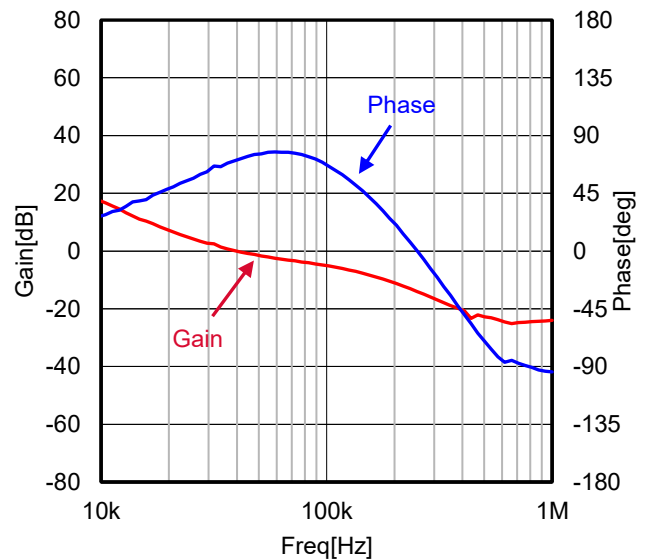


Figure 42. VIN = 32 V, IOU T = 2 A

Reference Application Data - continued

(Efficiency, VOUT = 5.0 V)

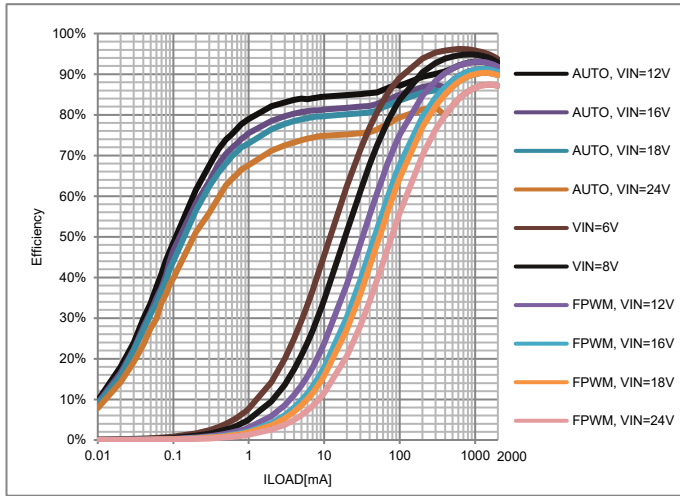


Figure 43. Efficiency (Ta = -40 °C, fsw = 2 MHz)

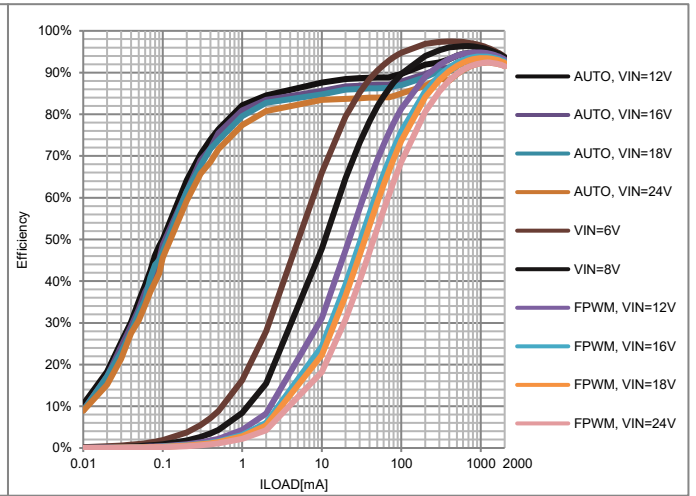


Figure 44. Efficiency (Ta = -40 °C, fsw = 400 kHz)

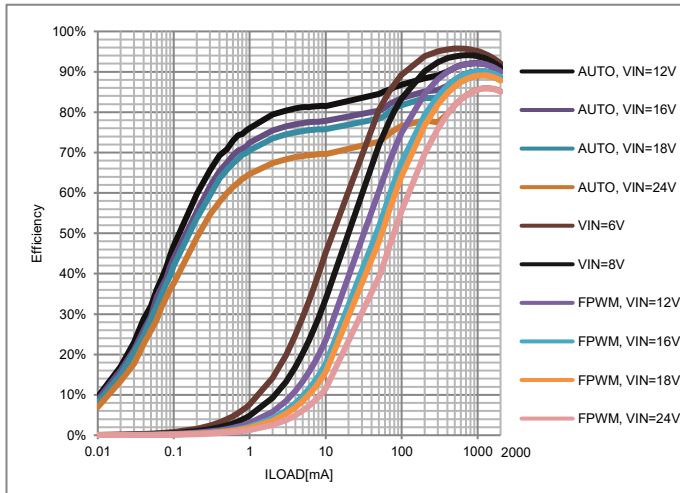


Figure 45. Efficiency (Ta = 25 °C, fsw = 2 MHz)

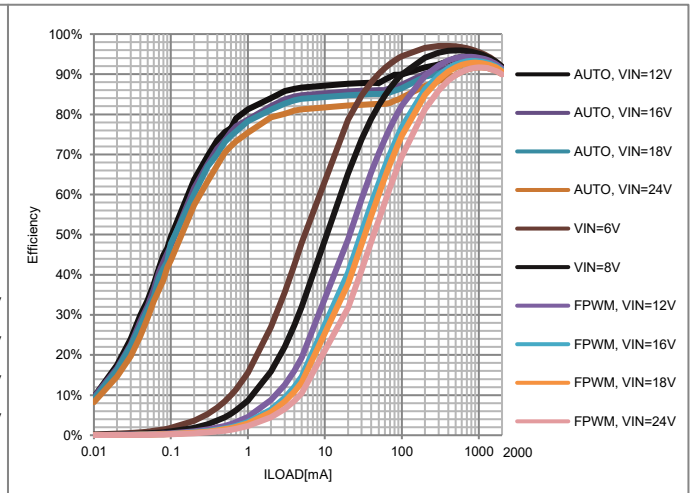


Figure 46. Efficiency (Ta = 25 °C, fsw = 400 kHz)

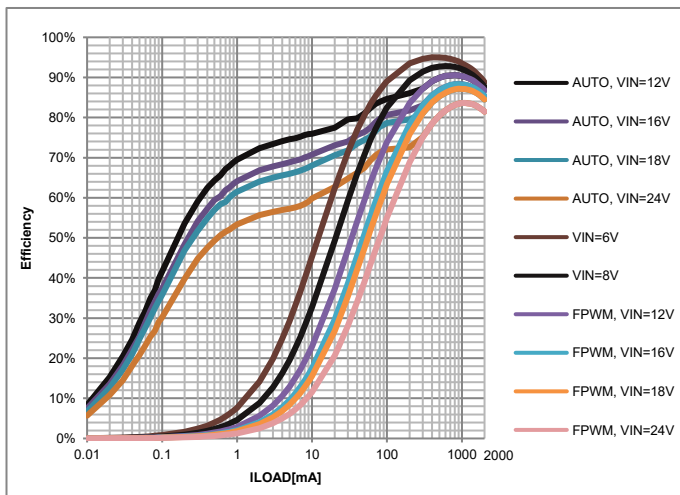


Figure 47. Efficiency (Ta = 125 °C, fsw = 2 MHz)

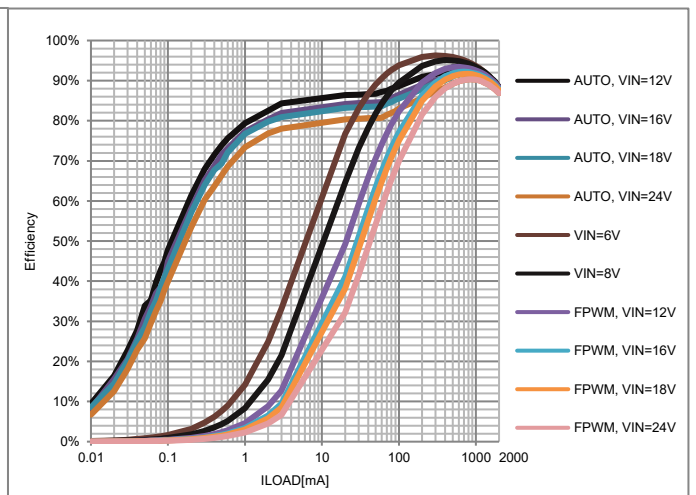


Figure 48. Efficiency (Ta = 125 °C, fsw = 400 kHz)

Reference Application Data - continued

(Efficiency, VOUT = 3.3 V)

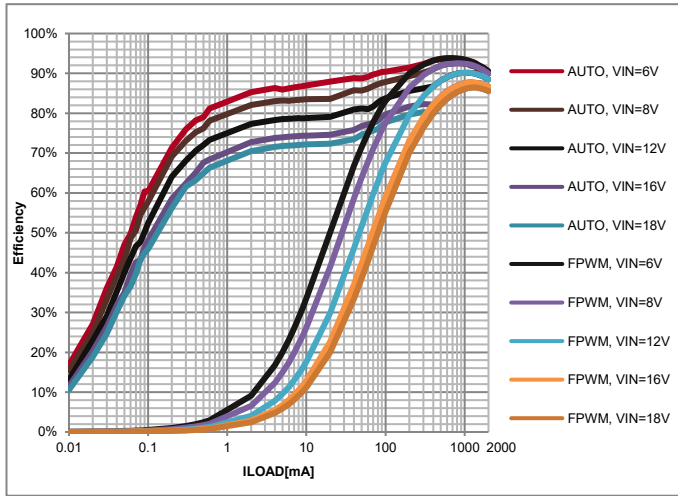


Figure 49. Efficiency (Ta = -40 °C, fsw = 2 MHz)

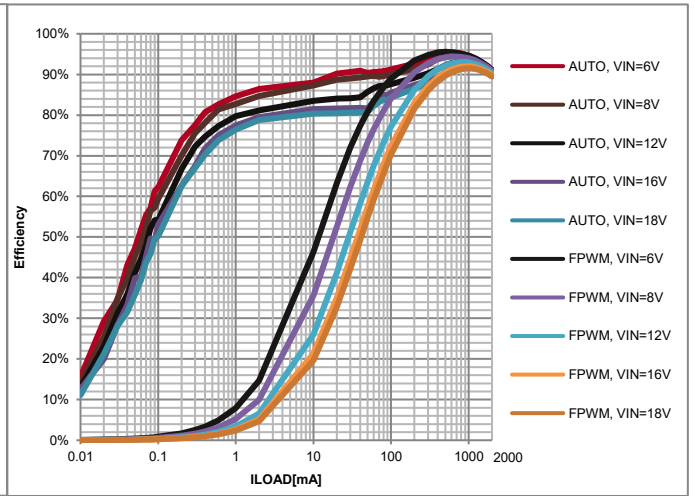


Figure 50. Efficiency (Ta = -40 °C, fsw = 400 kHz)

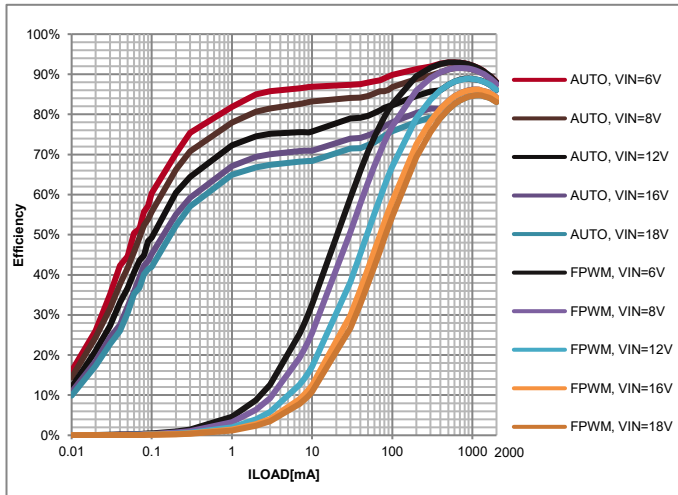


Figure 51. Efficiency (Ta = 25 °C, fsw = 2 MHz)

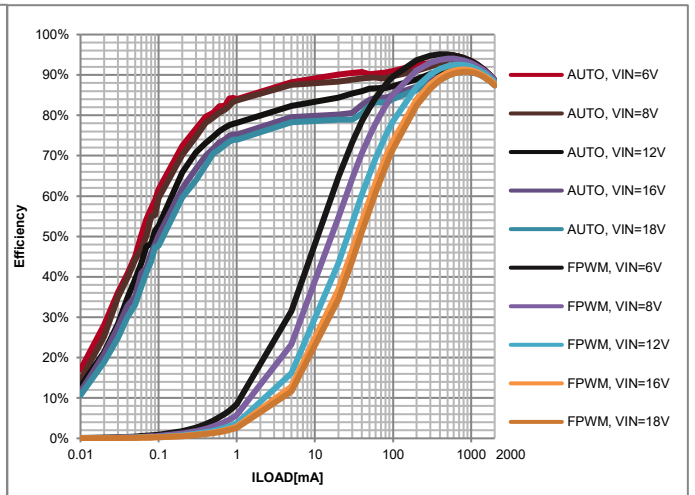


Figure 52. Efficiency (Ta = 25 °C, fsw = 400 kHz)

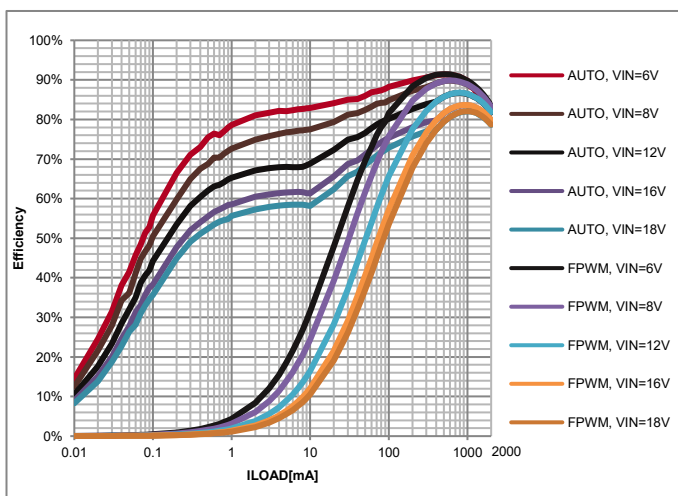


Figure 53. Efficiency (Ta = 125 °C, fsw = 2 MHz)

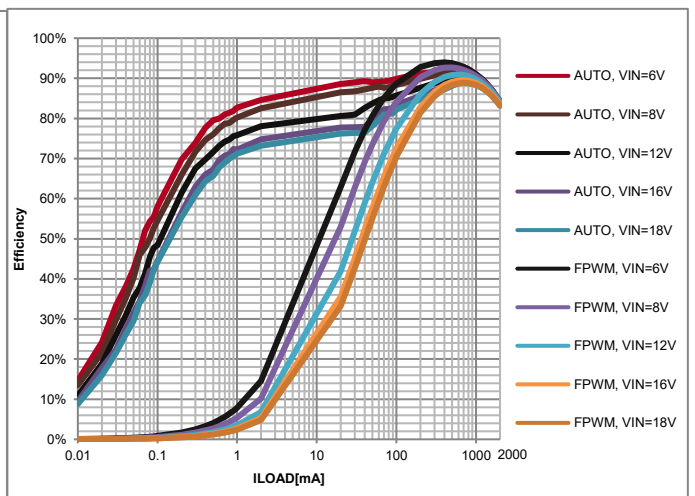


Figure 54. Efficiency (Ta = 125 °C, fsw = 400 kHz)

Reference Application Data - continued

(Efficiency, VOUT = 9.0 V)

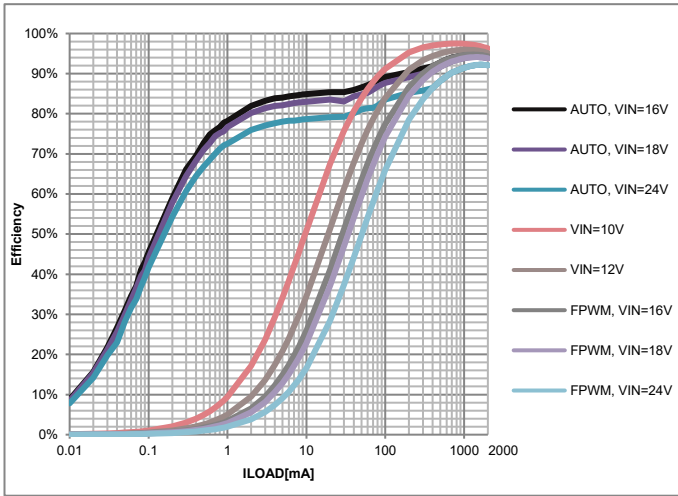


Figure 55. Efficiency (Ta = -40 °C, fsw = 2 MHz)

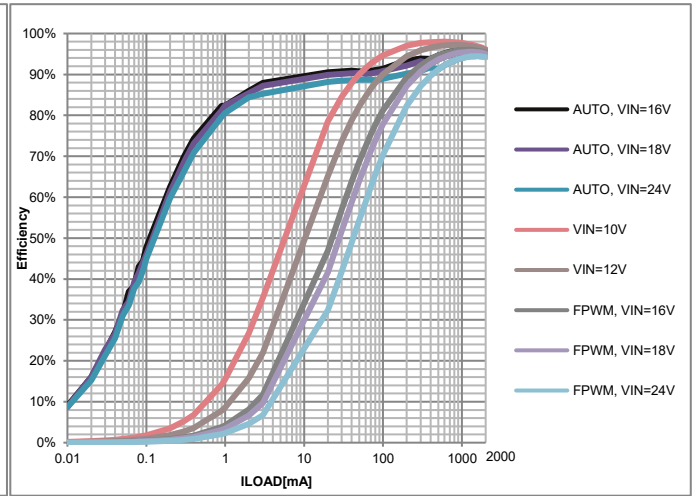


Figure 56. Efficiency (Ta = -40 °C, fsw = 400 kHz)

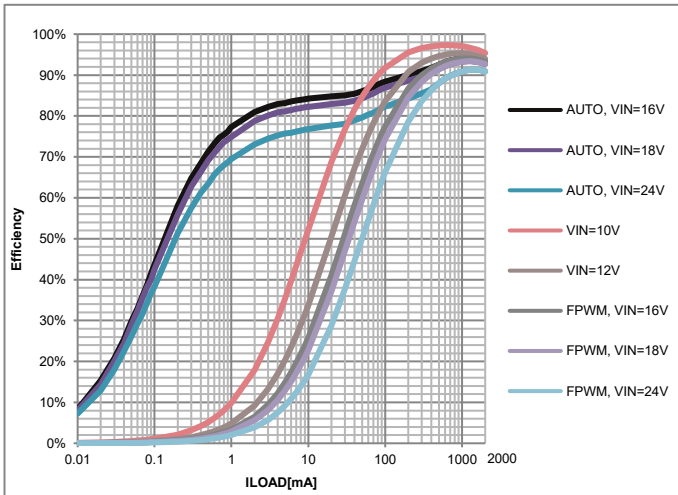


Figure 57. Efficiency (Ta = 25 °C, fsw = 2 MHz)

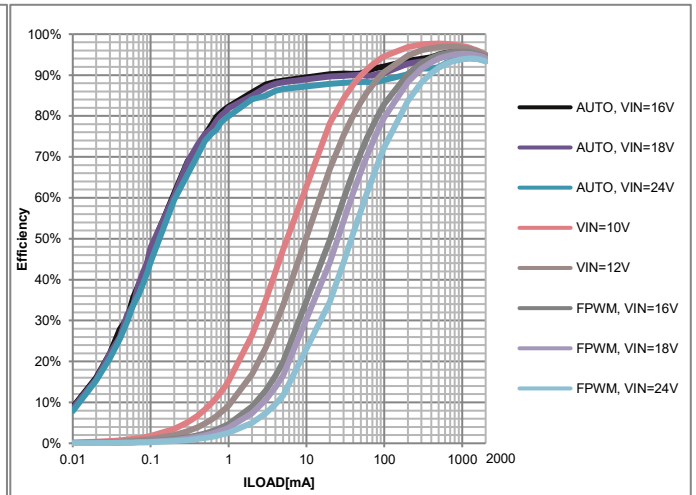


Figure 58. Efficiency (Ta = 25 °C, fsw = 400 kHz)

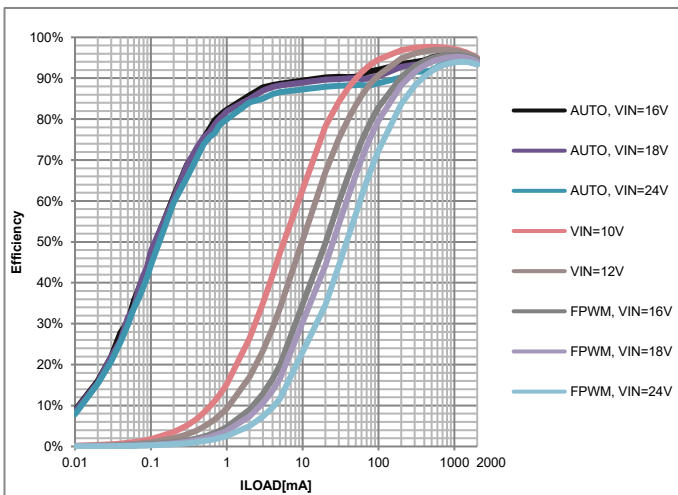


Figure 59. Efficiency (Ta = 125 °C, fsw = 2 MHz)

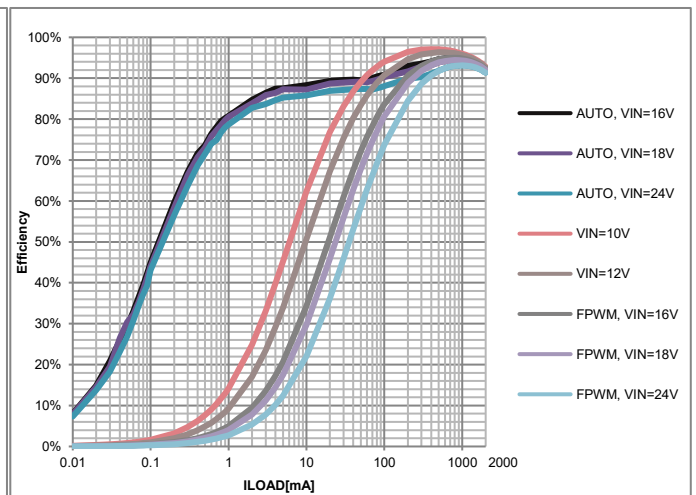


Figure 60. Efficiency (Ta = 125 °C, fsw = 400 kHz)

**Reference Application Data - continued**  
 (Switching, VOUT = 5.0 V, FREQ\_SEL = High, MODE = Low)

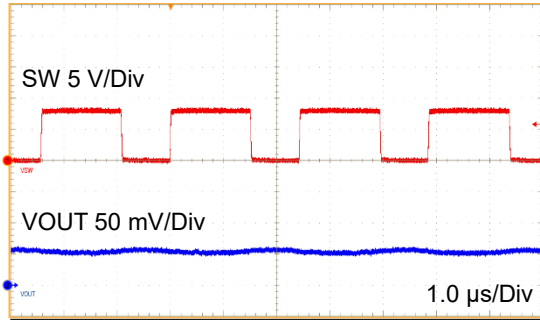


Figure 61. Switching (VIN = 8 V, IOU<sub>T</sub> = 0 A)

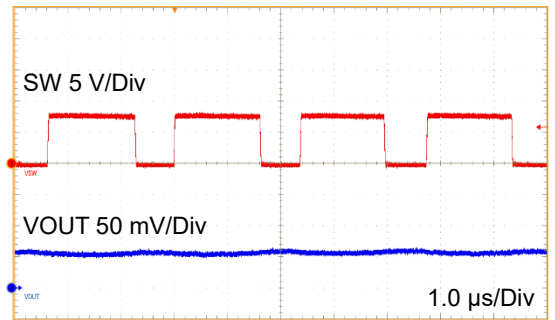


Figure 62. Switching (VIN = 8 V, IOU<sub>T</sub> = 2 A)

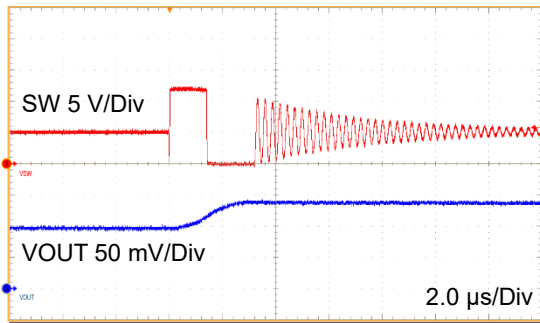


Figure 63. Switching (VIN = 12 V, IOU<sub>T</sub> = 0 A)

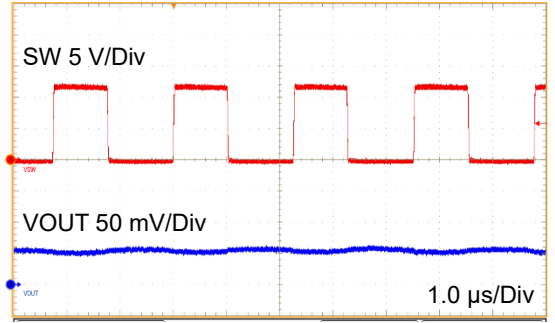


Figure 64. Switching (VIN = 12 V, IOU<sub>T</sub> = 2 A)

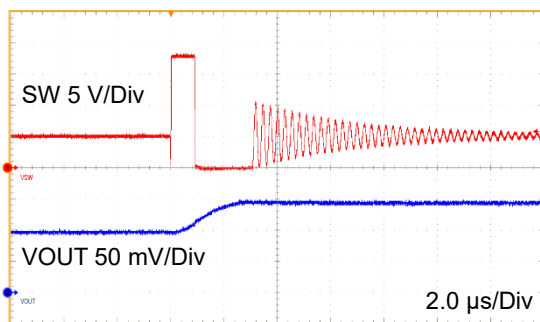


Figure 65. Switching (VIN = 18 V, IOU<sub>T</sub> = 0 A)

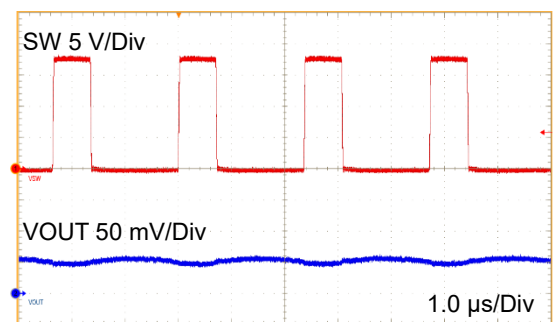


Figure 66. Switching (VIN = 18 V, IOU<sub>T</sub> = 2 A)

**Reference Application Data - continued**  
 (Switching, VOUT = 5.0 V, FREQ\_SEL = Low, MODE = Low)

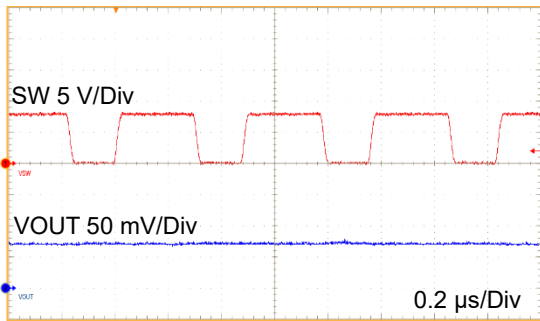


Figure 67. Switching (VIN = 8 V, IOU<sub>T</sub> = 0 A)

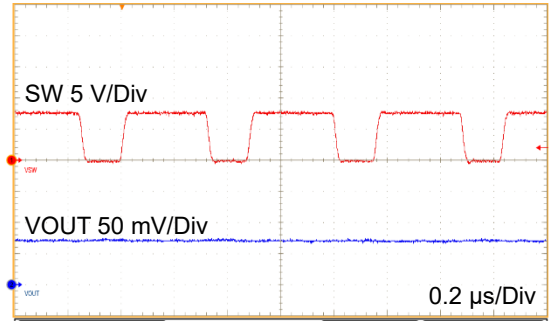


Figure 68. Switching (VIN = 8 V, IOU<sub>T</sub> = 2 A)

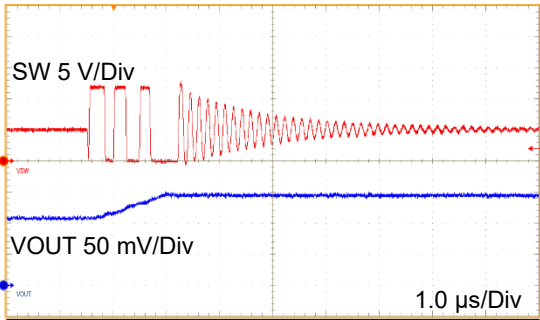


Figure 69. Switching (VIN = 12 V, IOU<sub>T</sub> = 0 A)

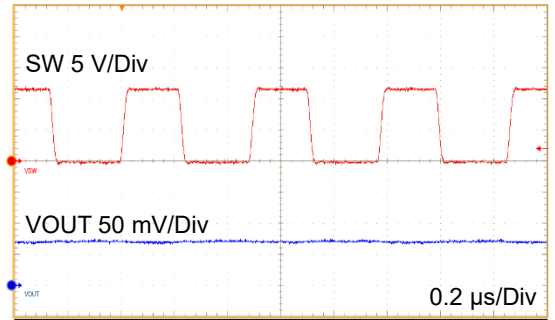


Figure 70. Switching (VIN = 12 V, IOU<sub>T</sub> = 2 A)

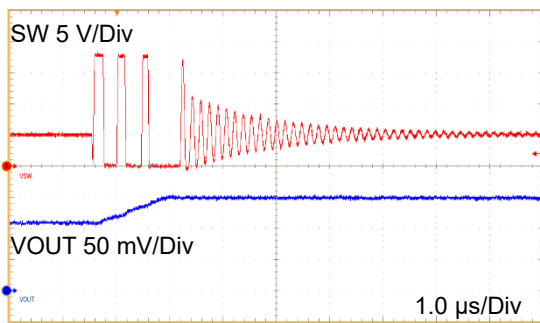


Figure 71. Switching (VIN = 18 V, IOU<sub>T</sub> = 0 A)

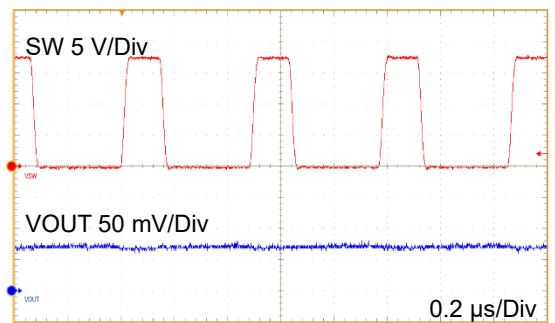


Figure 72. Switching (VIN = 18 V, IOU<sub>T</sub> = 2 A)

**Reference Application Data - continued**  
 (Switching, VOUT = 3.3 V, FREQ\_SEL = High, MODE = Low)

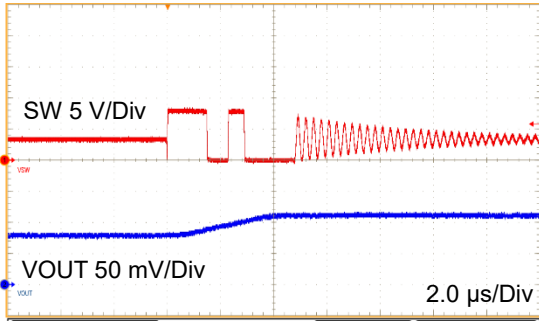


Figure 73. Switching (VIN = 8 V, IOU<sub>T</sub> = 0 A)

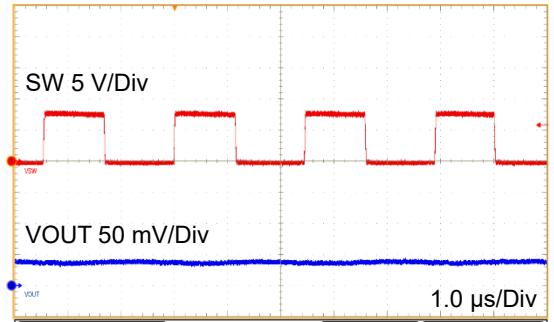


Figure 74. Switching (VIN = 8 V, IOU<sub>T</sub> = 2 A)

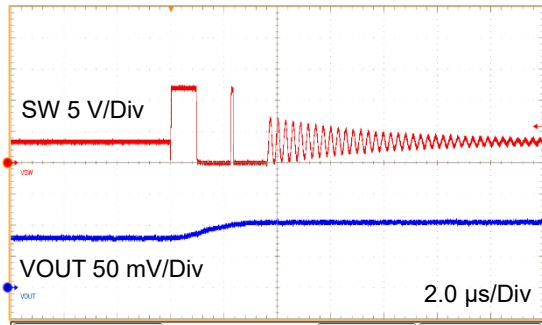


Figure 75. Switching (VIN = 12 V, IOU<sub>T</sub> = 0 A)

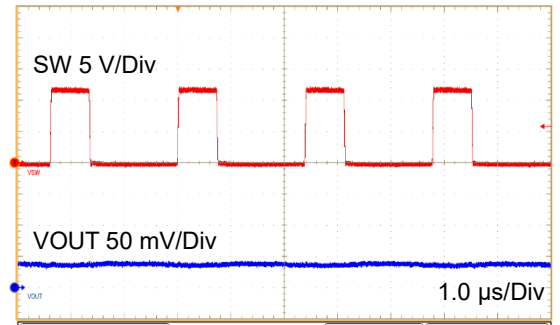


Figure 76. Switching (VIN = 12 V, IOU<sub>T</sub> = 2 A)

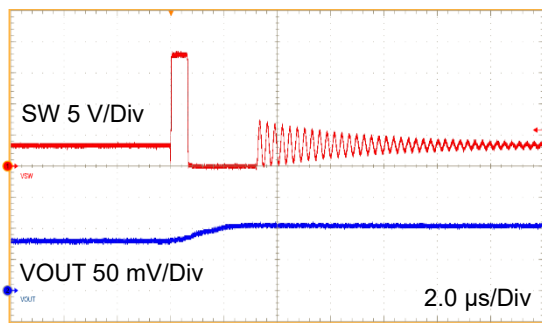


Figure 77. Switching (VIN = 18 V, IOU<sub>T</sub> = 0 A)

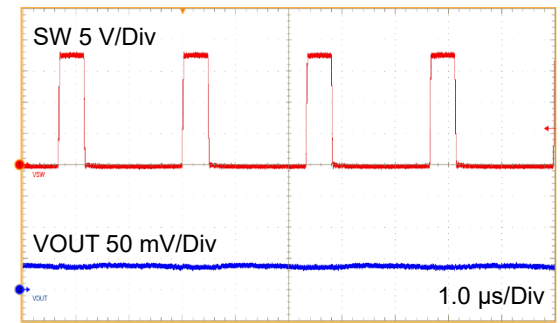


Figure 78. Switching (VIN = 18 V, IOU<sub>T</sub> = 2 A)

Reference Application Data - continued

(Switching, VOUT = 3.3 V, FREQ\_SEL = Low, MODE = Low)

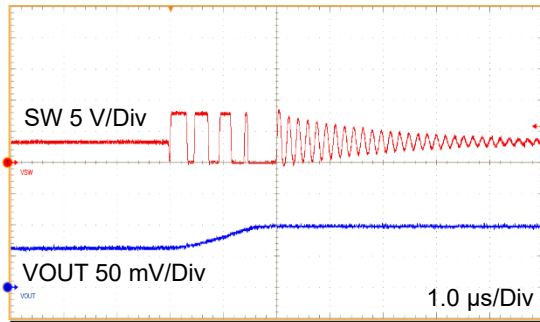


Figure 79. Switching (VIN = 8 V, IOU = 0 A)

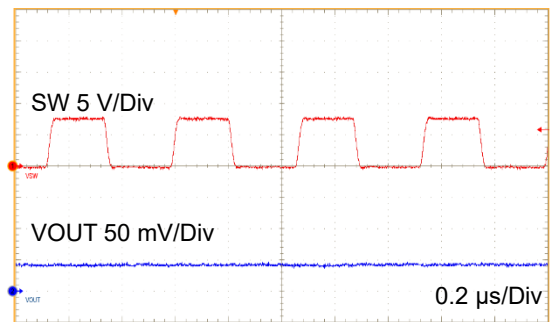


Figure 80. Switching (VIN = 8 V, IOU = 2 A)

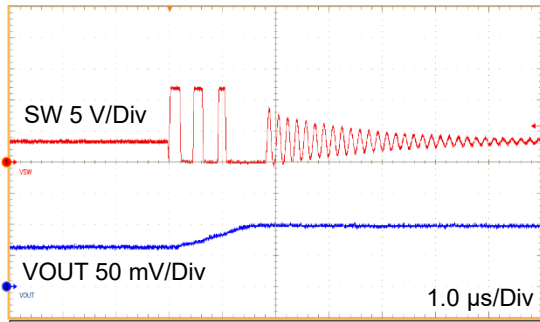


Figure 81. Switching (VIN = 12 V, IOU = 0 A)

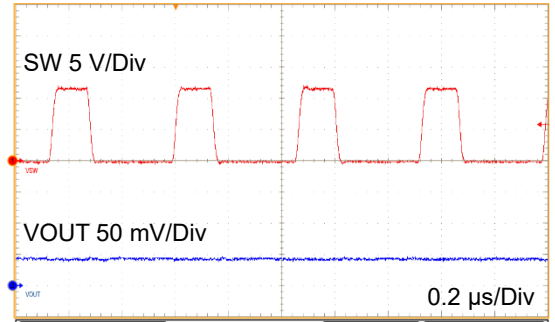


Figure 82. Switching (VIN = 12 V, IOU = 2 A)

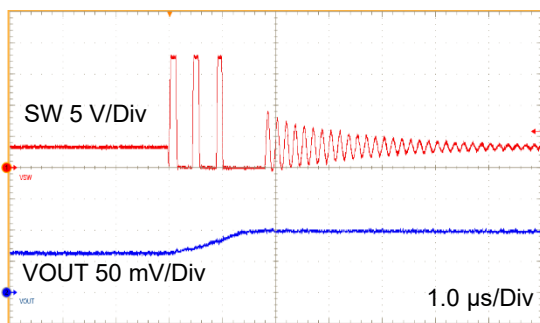


Figure 83. Switching (VIN = 18 V, IOU = 0 A)

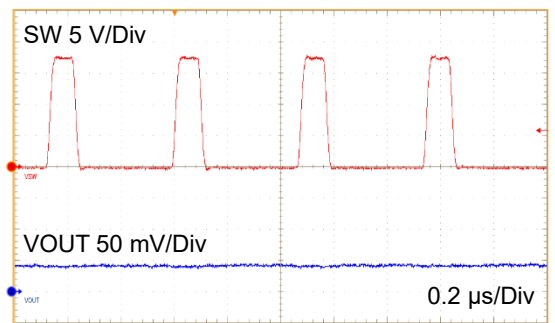


Figure 84. Switching (VIN = 18 V, IOU = 2 A)

Reference Application Data - continued

(Switching, VOUT = 9.0 V, FREQ\_SEL = High, MODE = Low)

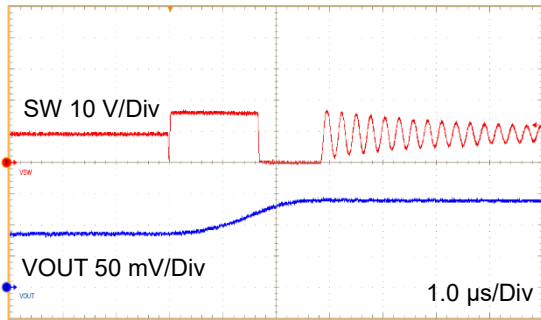


Figure 85. Switching (VIN = 16 V, IOU<sub>T</sub> = 0 A)

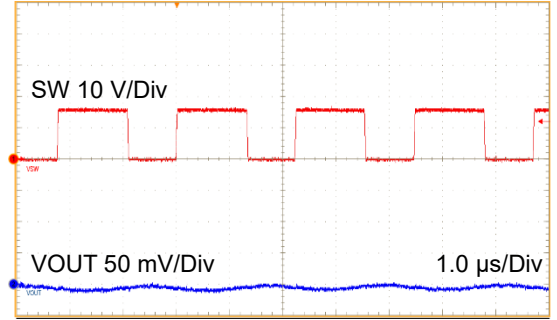


Figure 86. Switching (VIN = 16 V, IOU<sub>T</sub> = 2 A)

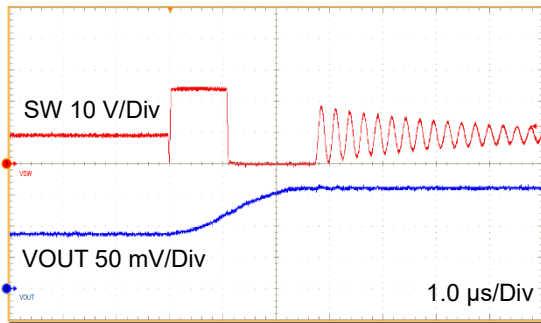


Figure 87. Switching (VIN = 24 V, IOU<sub>T</sub> = 0 A)

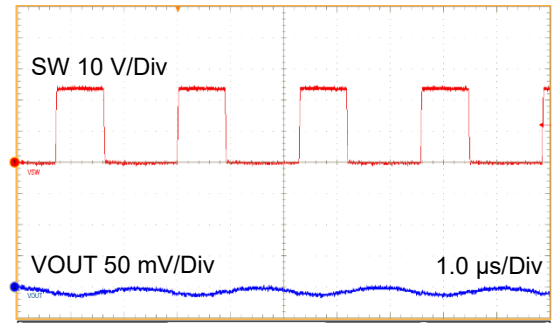


Figure 88. Switching (VIN = 24 V, IOU<sub>T</sub> = 2 A)

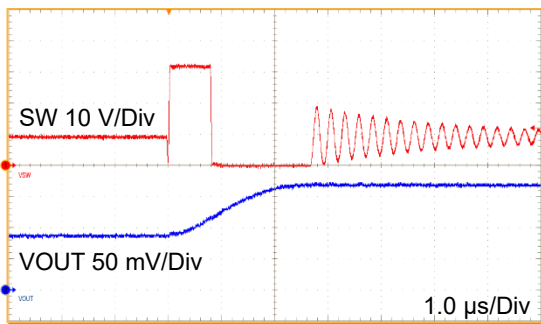


Figure 89. Switching (VIN = 32 V, IOU<sub>T</sub> = 0 A)

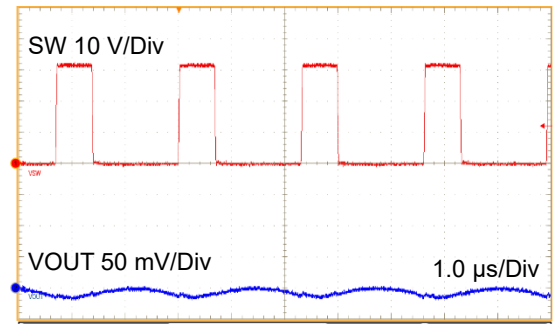


Figure 90. Switching (VIN = 32 V, IOU<sub>T</sub> = 2 A)

**Reference Application Data - continued**  
 (Switching, VOUT = 9.0 V, FREQ\_SEL = Low, MODE = Low)

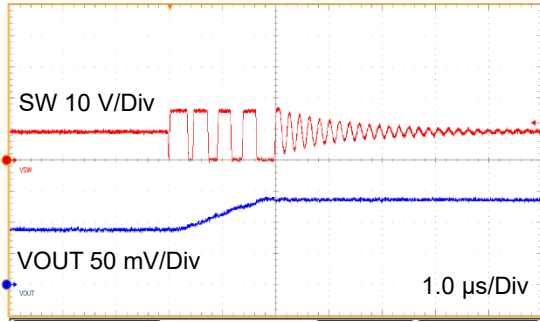


Figure 91. Switching (VIN = 16 V, IOU<sub>T</sub> = 0 A)

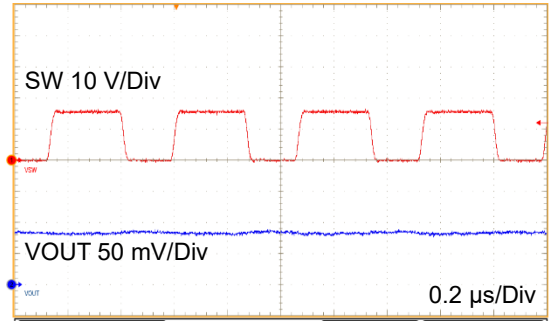


Figure 92. Switching (VIN = 16 V, IOU<sub>T</sub> = 2 A)

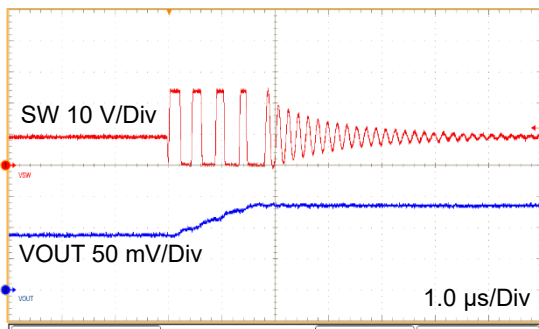


Figure 93. Switching (VIN = 24 V, IOU<sub>T</sub> = 0 A)

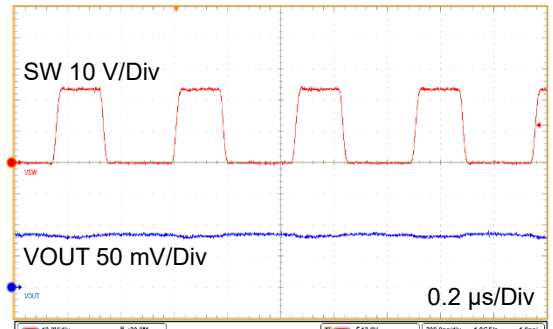


Figure 94. Switching (VIN = 24 V, IOU<sub>T</sub> = 2 A)

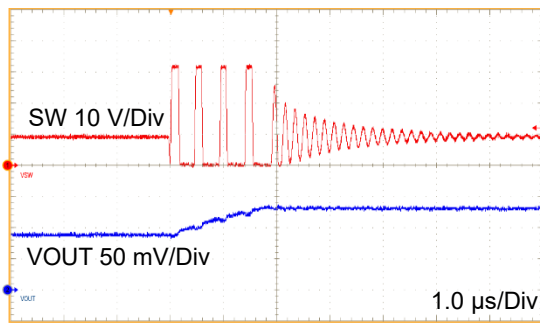


Figure 95. Switching (VIN = 32 V, IOU<sub>T</sub> = 0 A)

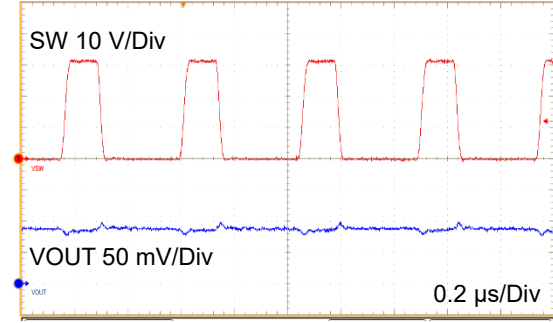


Figure 96. Switching (VIN = 32 V, IOU<sub>T</sub> = 2 A)

Reference Application Data - continued

(Load Response, VIN = 12 V, VOUT = 5.0 V)

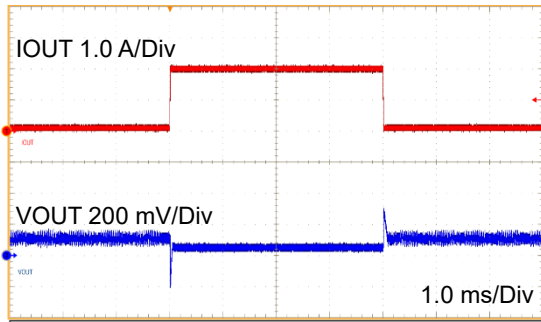


Figure 97. Load Response  
(fsw = 400 kHz, IOU<sub>T</sub> = 0.1 A to 2 A, MODE = AUTO)

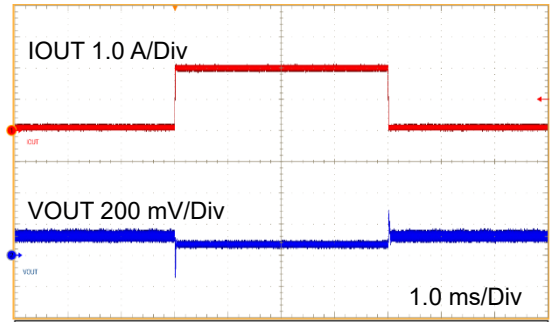


Figure 98. Load Response  
(fsw = 2 MHz, IOU<sub>T</sub> = 0.1 A to 2 A, MODE = AUTO)

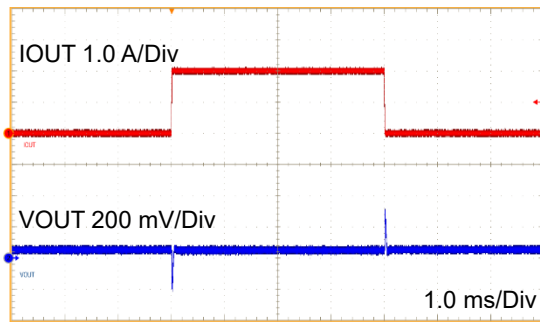


Figure 99. Load Response  
(fsw = 400 kHz, IOU<sub>T</sub> = 0 A to 2 A, MODE = FPWM)

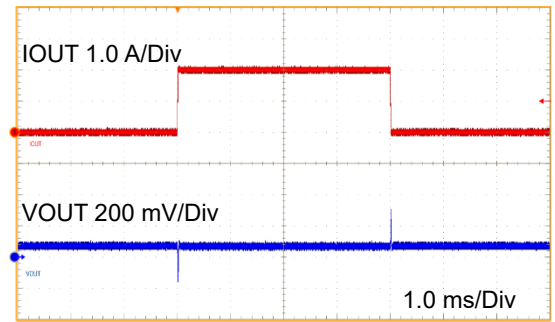


Figure 100. Load Response  
(fsw = 2 MHz, IOU<sub>T</sub> = 0 A to 2 A, MODE = FPWM)

Reference Application Data - continued

(Load Response, VIN = 12 V, VOUT = 3.3 V)

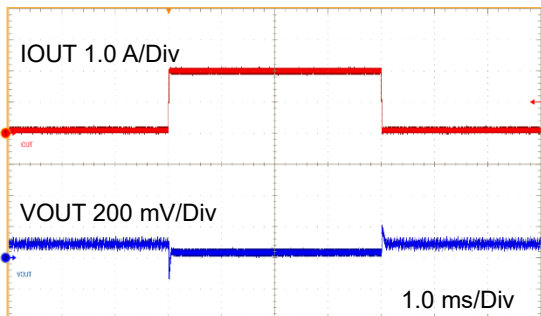


Figure 101. Load Response  
(fsw = 400 kHz, IOU<sub>T</sub> = 0.1 A to 2 A, MODE = AUTO)

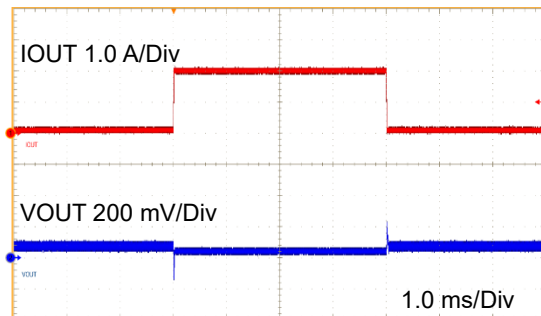


Figure 102. Load Response  
(fsw = 2 MHz, IOU<sub>T</sub> = 0.1 A to 2 A, MODE = AUTO)

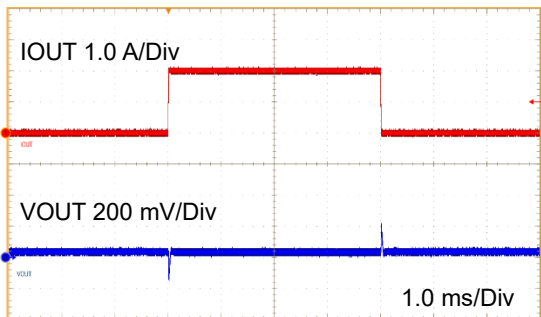


Figure 103. Load Response  
(fsw = 400 kHz, IOU<sub>T</sub> = 0 A to 2 A, MODE = FPWM)

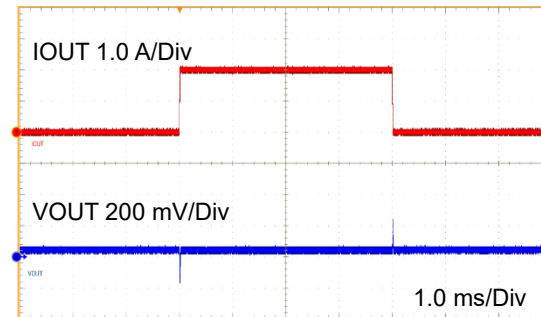


Figure 104. Load Response  
(fsw = 2 MHz, IOU<sub>T</sub> = 0 A to 2 A, MODE = FPWM)

Reference Application Data - continued

(Load Response, VIN = 24 V, VOUT = 9.0 V)

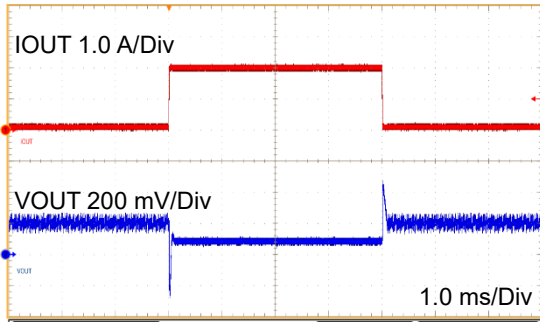


Figure 105. Load Response  
(fsw = 400 kHz, IOUT = 0.1 A to 2 A, MODE = AUTO)

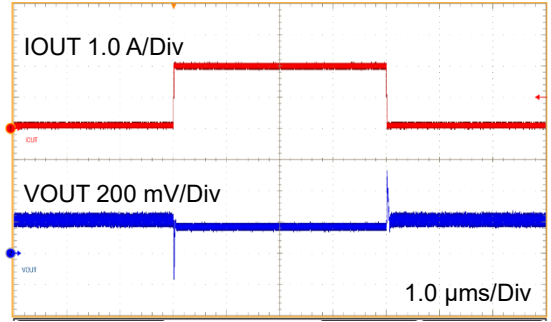


Figure 106. Load Response  
(fsw = 2 MHz, IOUT = 0.1 A to 2 A, MODE = AUTO)

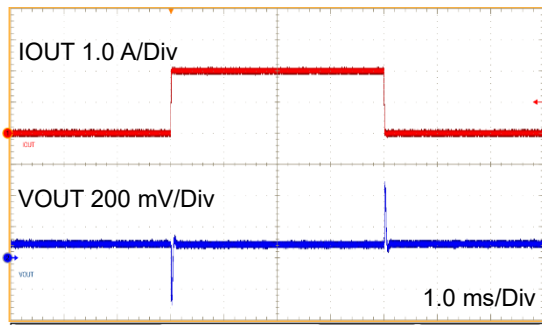


Figure 107. Load Response  
(fsw = 400 kHz, IOUT = 0 A to 2 A, MODE = FPWM)

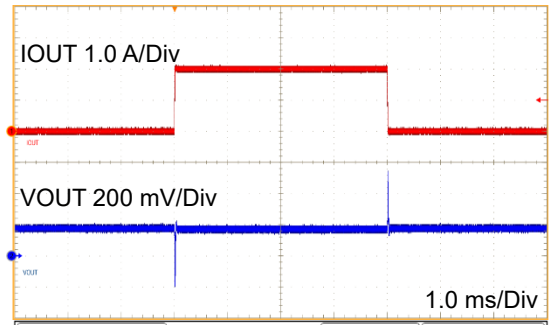


Figure 108. Load Response  
(fsw = 2 MHz, IOUT = 0 A to 2 A, MODE = FPWM)

Reference Application Data - continued

(Line Response, VOUT = 5.0 V, FREQ\_SEL = High, MODE = Low)

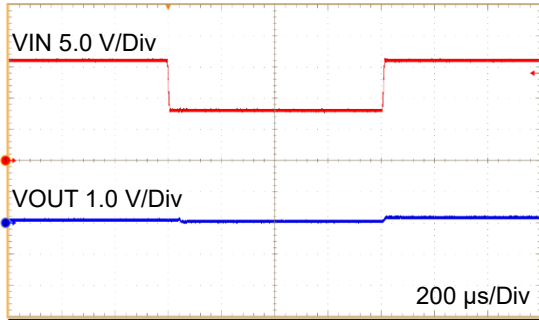


Figure 109. Line Response  
(VIN = 16 V → 8 V → 16 V, IOU<sub>T</sub> = 0 A)

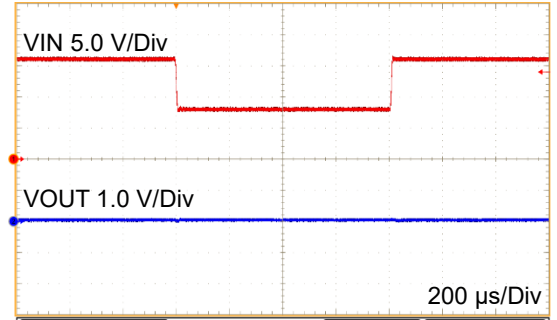


Figure 110. Line Response  
(VIN = 16 V → 8 V → 16 V, IOU<sub>T</sub> = 2 A)

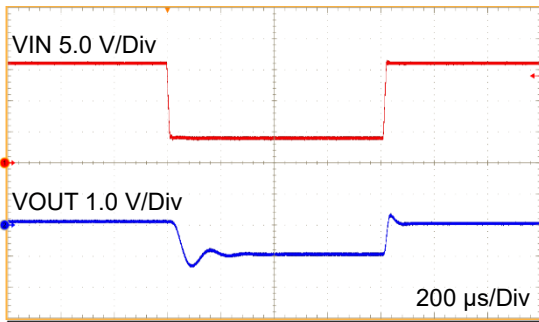


Figure 111. Line Response  
(VIN = 16 V → 4 V → 16 V, IOU<sub>T</sub> = 0 A)

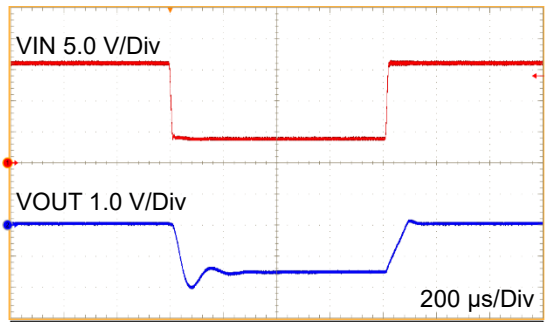


Figure 112. Line Response  
(VIN = 16 V → 4 V → 16 V, IOU<sub>T</sub> = 2 A)

Reference Application Data - continued

(Line Response, VOUT = 5.0 V, FREQ\_SEL = Low, MODE = Low)

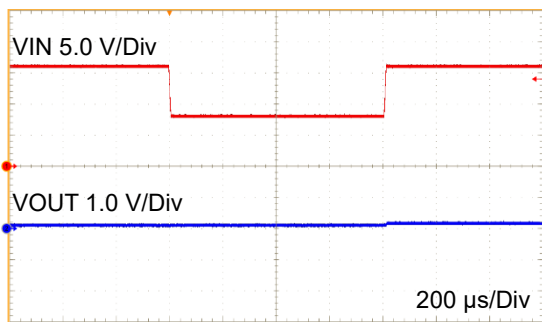


Figure 113. Line Response  
(VIN = 16 V → 8 V → 16 V, IO<sub>UT</sub> = 0 A)

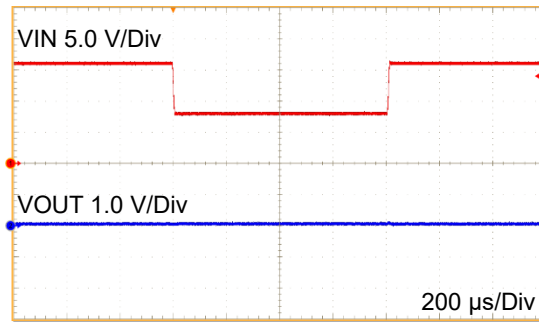


Figure 114. Line Response  
(VIN = 16 V → 8 V → 16 V, IO<sub>UT</sub> = 2 A)

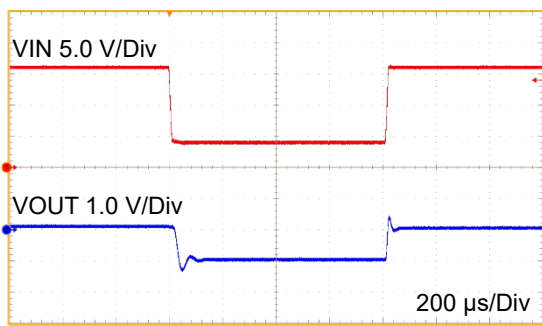


Figure 115. Line Response  
(VIN = 16 V → 4 V → 16 V, IO<sub>UT</sub> = 0 A)

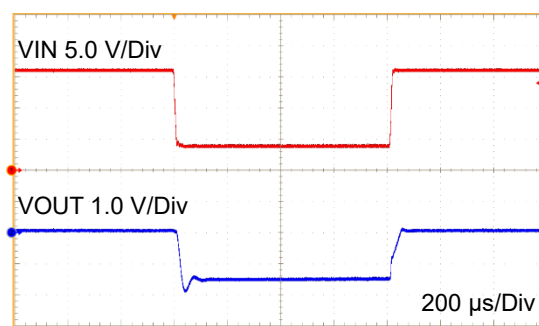


Figure 116. Line Response  
(VIN = 16 V → 4 V → 16 V, IO<sub>UT</sub> = 2 A)

Reference Application Data - continued

(Line Response, VOUT = 3.3 V, FREQ\_SEL = High, MODE = Low)

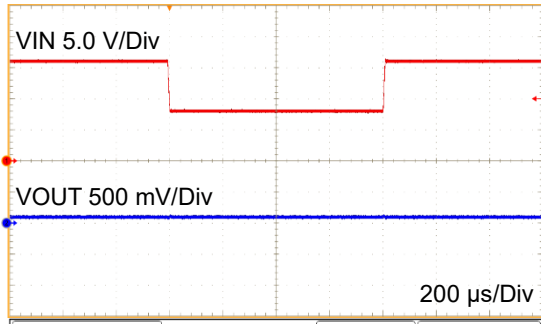


Figure 117. Line Response  
(VIN = 16 V → 8 V → 16 V, IO<sub>UT</sub> = 0 A)

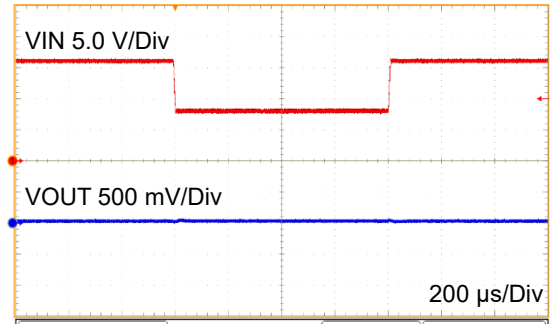


Figure 118. Line Response  
(VIN = 16 V → 8 V → 16 V, IO<sub>UT</sub> = 2 A)

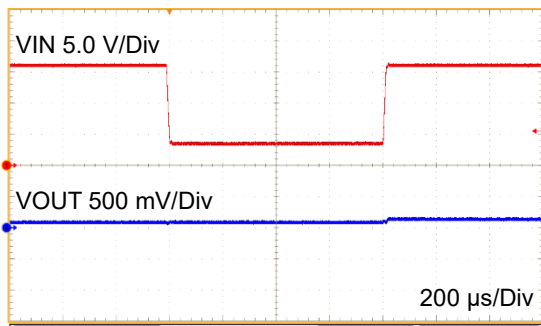


Figure 119. Line Response  
(VIN = 16 V → 3.5 V → 16 V, IO<sub>UT</sub> = 0 A)

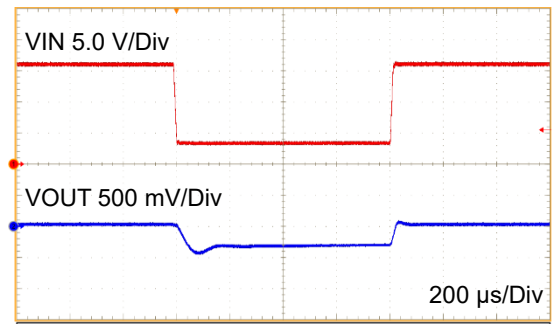


Figure 120. Line Response  
(VIN = 16 V → 3.5 V → 16 V, IO<sub>UT</sub> = 2 A)

Reference Application Data - continued

(Line Response, VOUT = 3.3 V, FREQ\_SEL = Low, MODE = Low)

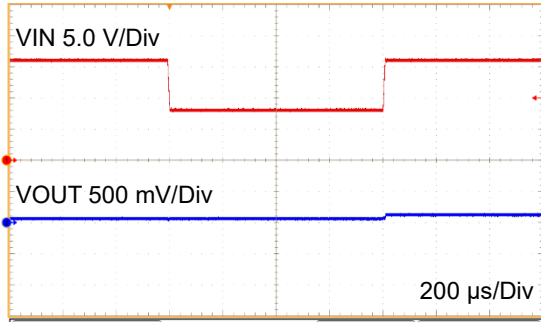


Figure 121. Line Response  
(VIN = 16 V → 8 V → 16 V, IOU = 0 A)

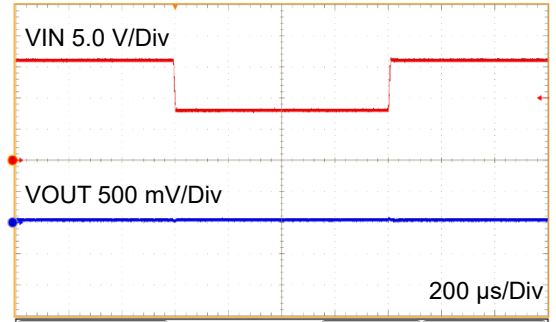


Figure 122. Line Response  
(VIN = 16 V → 8 V → 16 V, IOU = 2 A)

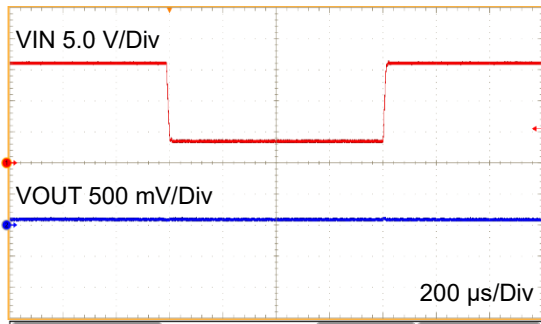


Figure 123. Line Response  
(VIN = 16 V → 3.5 V → 16 V, IOU = 0 A)

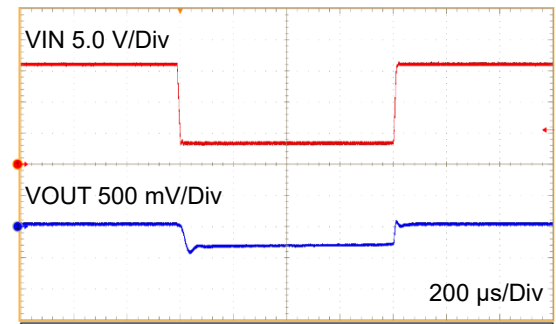


Figure 124. Line Response  
(VIN = 16 V → 3.5 V → 16 V, IOU = 2 A)

Reference Application Data - continued

(Line Response, VOUT = 9.0 V, FREQ\_SEL = High, MODE = Low)

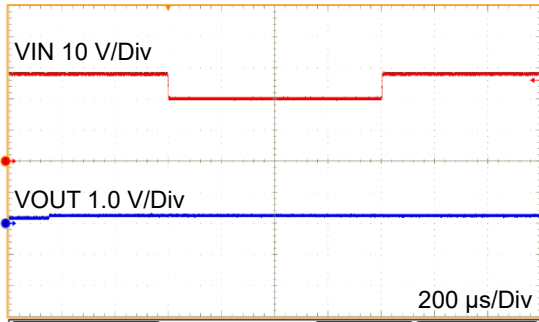


Figure 125. Line Response  
(VIN = 28 V → 20 V → 28 V, IOU<sub>T</sub> = 0 A)

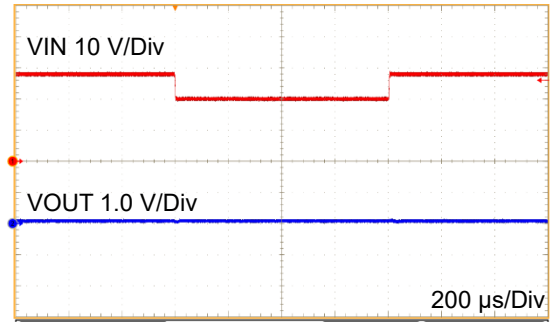


Figure 126. Line Response  
(VIN = 28 V → 20 V → 28 V, IOU<sub>T</sub> = 2 A)

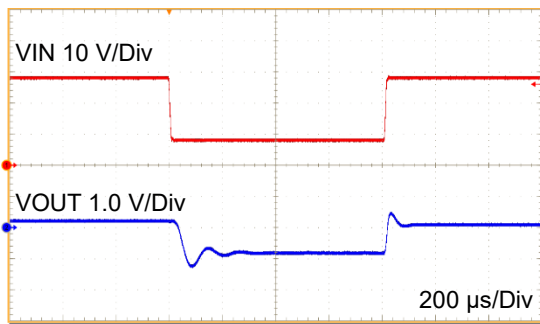


Figure 127. Line Response  
(VIN = 28 V → 8 V → 28 V, IOU<sub>T</sub> = 0 A)

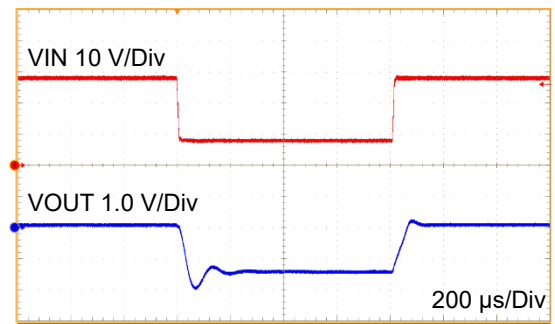


Figure 128. Line Response  
(VIN = 28 V → 8 V → 28 V, IOU<sub>T</sub> = 2 A)

Reference Application Data - continued

(Line Response, VOUT = 9.0 V, FREQ\_SEL = Low, MODE = Low)

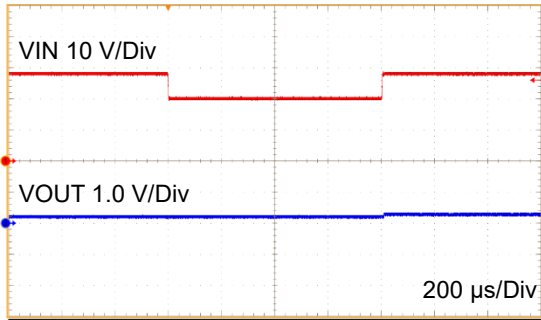


Figure 129. Line Response  
(VIN = 28 V → 20 V → 28 V, IOU = 0 A)

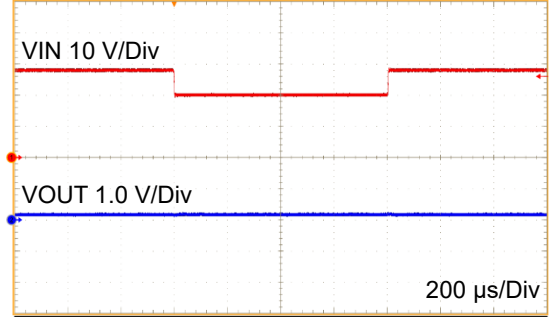


Figure 130. Line Response  
(VIN = 28 V → 20 V → 28 V, IOU = 2 A)

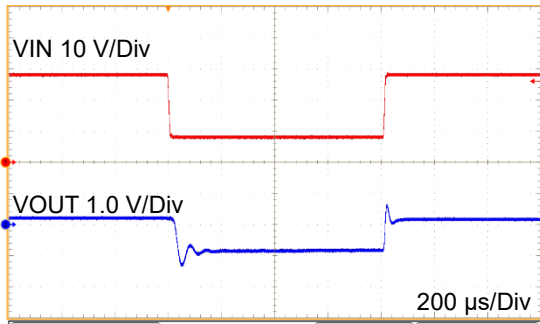


Figure 131. Line Response  
(VIN = 28 V → 8 V → 28 V, IOU = 0 A)

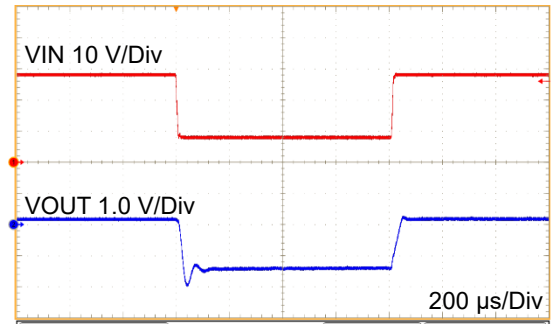


Figure 132. Line Response  
(VIN = 28 V → 8 V → 28 V, IOU = 2 A)

Reference Application Data - continued

(Mode ON/OFF Response, IOUT = 50 mA)

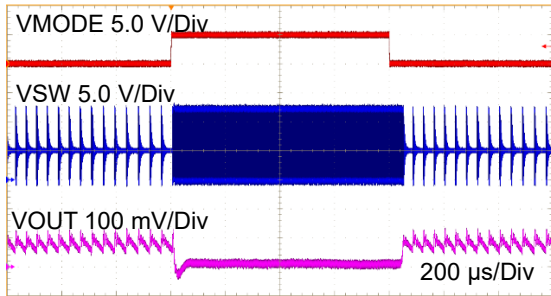


Figure 133. MODE ON/OFF Response  
(VIN = 12 V, VOUT = 5.0 V, fsw = 400 kHz)

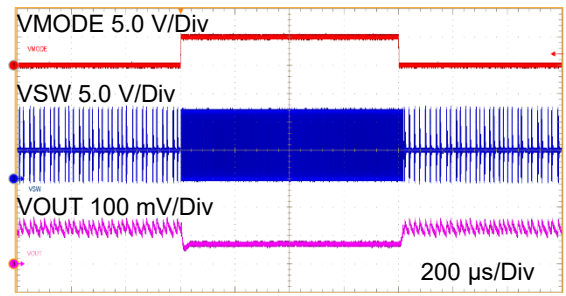


Figure 134. MODE ON/OFF Response  
(VIN = 12 V, VOUT = 5.0 V, fsw = 2 MHz)

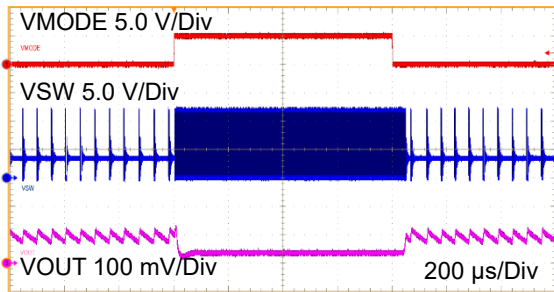


Figure 135. MODE ON/OFF Response  
(VIN = 12 V, VOUT = 3.3 V, fsw = 400 kHz)

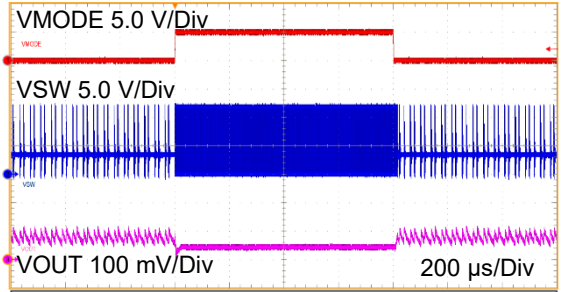


Figure 136. MODE ON/OFF Response  
(VIN = 12 V, VOUT = 3.3 V, fsw = 2 MHz)

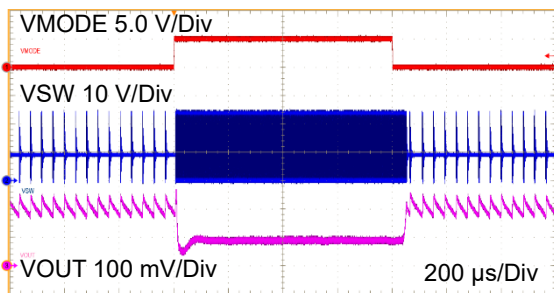


Figure 137. MODE ON/OFF Response  
(VIN = 24 V, VOUT = 9.0 V, fsw = 400 kHz)

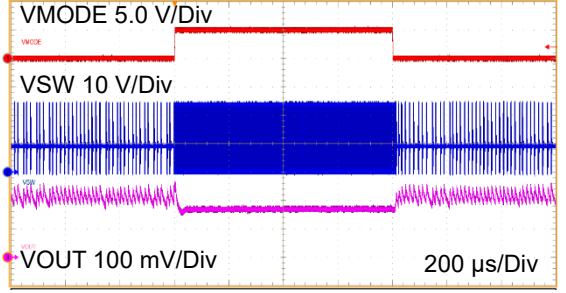


Figure 138. MODE ON/OFF Response  
(VIN = 24 V, VOUT = 9.0 V, fsw = 2 MHz)

Reference Application Data - continued

(Thermal Performance Image, IO<sub>UT</sub> = 1 A)

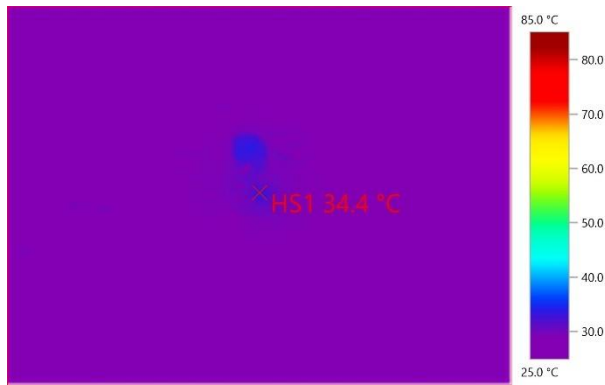


Figure 139. Thermal Performance  
(VIN = 12 V, VOUT = 5.0 V, fsw = 400 kHz)

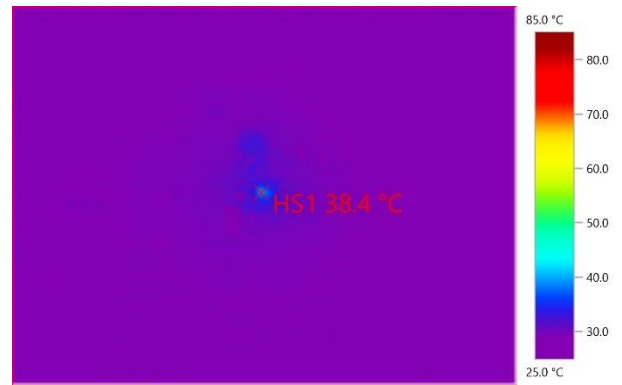


Figure 140. Thermal Performance  
(VIN = 12 V, VOUT = 5.0 V, fsw = 2 MHz)

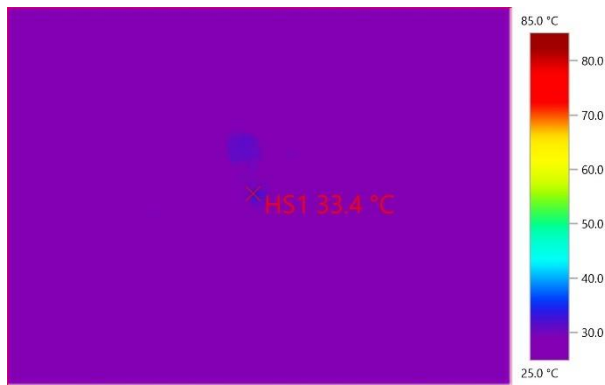


Figure 141. Thermal Performance  
(VIN = 12 V, VOUT = 3.3 V, fsw = 400 kHz)

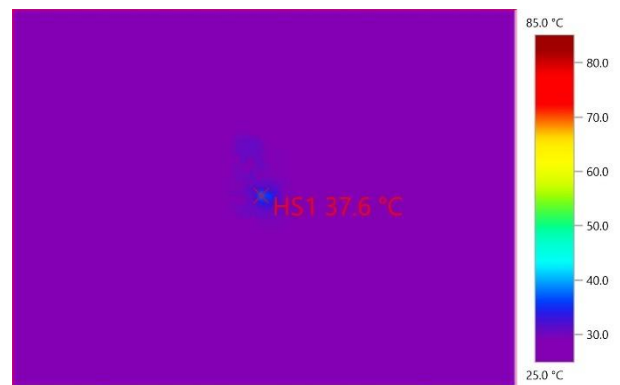


Figure 142. Thermal Performance  
(VIN = 12 V, VOUT = 3.3 V, fsw = 2 MHz)

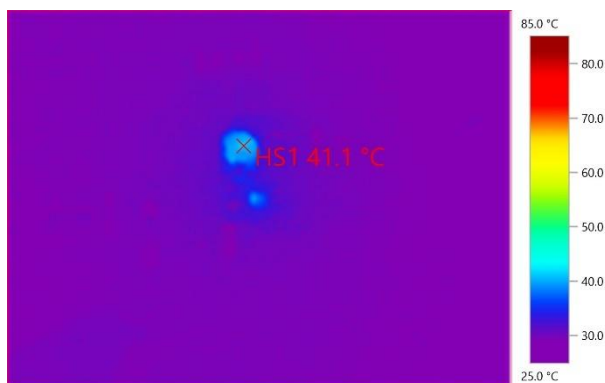


Figure 143. Thermal Performance  
(VIN = 24 V, VOUT = 9.0 V, fsw = 400 kHz)

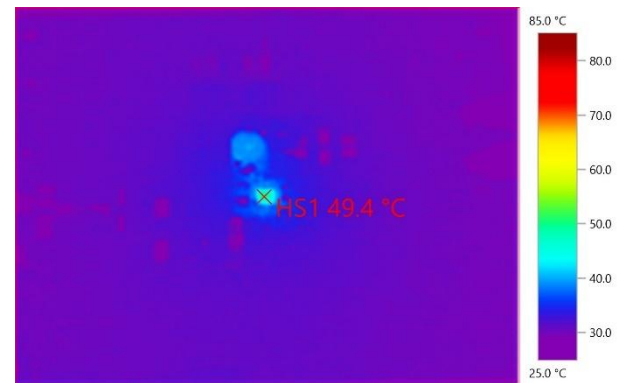


Figure 144. Thermal Performance  
(VIN = 24 V, VOUT = 9.0 V, fsw = 2 MHz)

Reference Application Data - continued

(Thermal Performance Image, IO<sub>UT</sub> = 2 A)

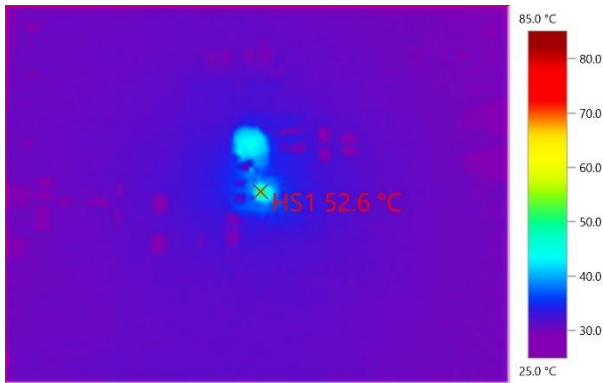


Figure 145. Thermal Performance  
(VIN = 12 V, VOUT = 5.0 V, fsw = 400 kHz)

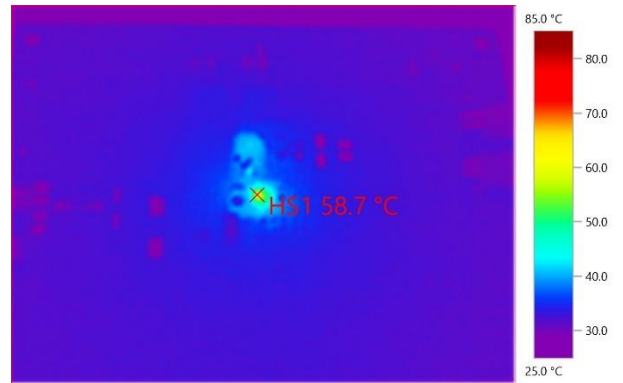


Figure 146. Thermal Performance  
(VIN = 12 V, VOUT = 5.0 V, fsw = 2 MHz)

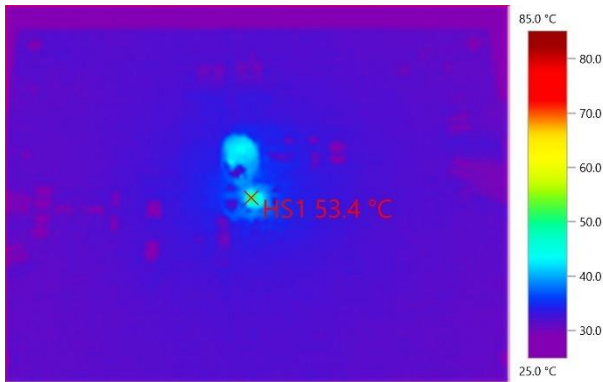


Figure 147. Thermal Performance  
(VIN = 12 V, VOUT = 3.3 V, fsw = 400 kHz)

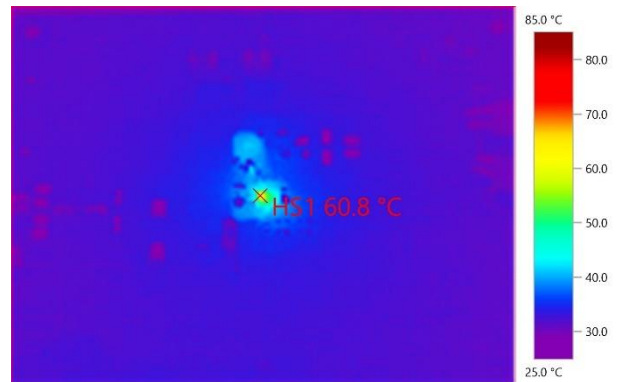


Figure 148. Thermal Performance  
(VIN = 12 V, VOUT = 3.3 V, fsw = 2 MHz)

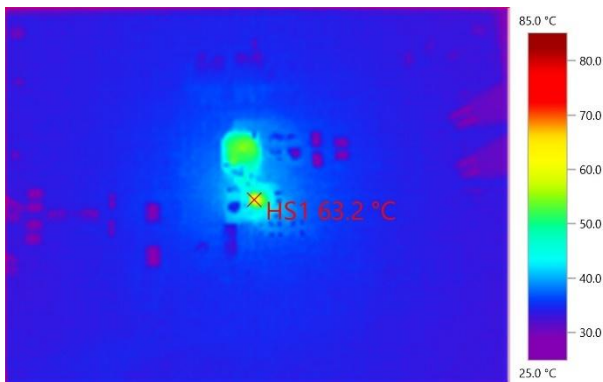


Figure 149. Thermal Performance  
(VIN = 24 V, VOUT = 9.0 V, fsw = 400 kHz)

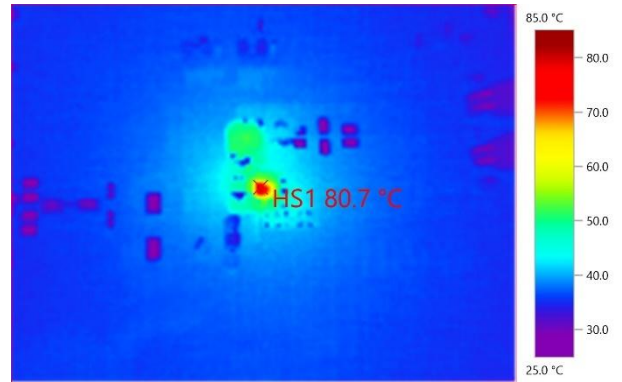


Figure 150. Thermal Performance  
(VIN = 24 V, VOUT = 9.0 V, fsw = 2 MHz)

Reference Application Data - continued

Other series application data please refer to datasheet

(EMC Test Report, VIN = 12 V, VOUT = 5.0 V, IOOUT = 2 A, fsw = 2 MHz, Ta = 25 °C)

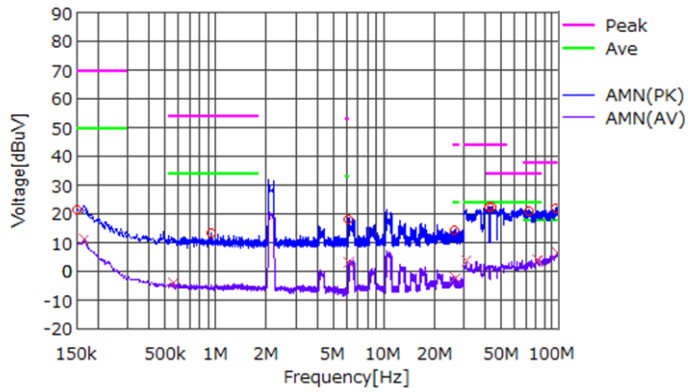


Figure 151. Conducted Emission  
(0.15 MHz ~ 108 MHz)

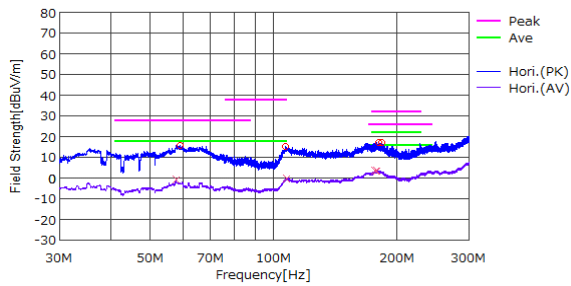


Figure 152. Radiated Noise Horizontal  
(30 MHz ~ 300 MHz)

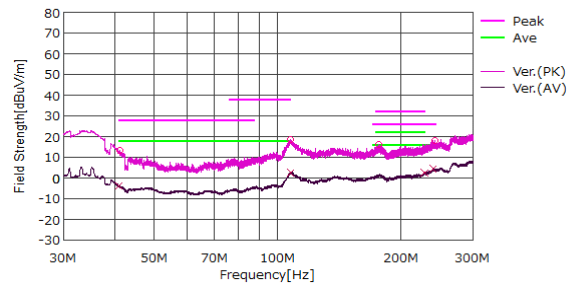


Figure 153. Radiated Noise Vertical  
(30 MHz ~ 300 MHz)

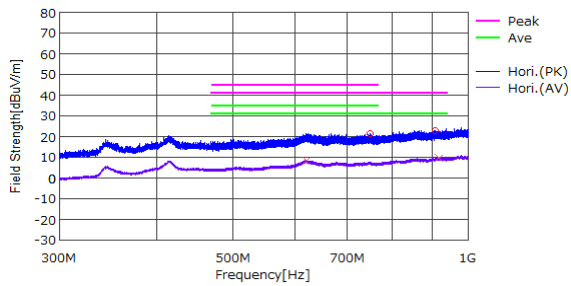


Figure 154. Radiated Noise Horizontal  
(300 MHz ~ 1000 MHz)

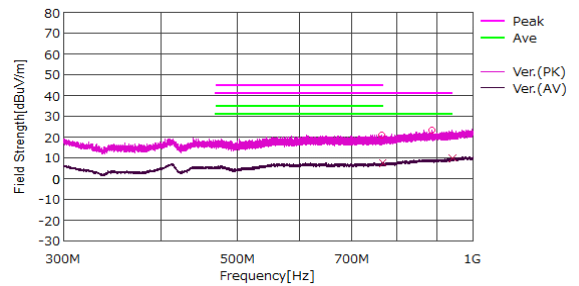


Figure 155. Radiated Noise Vertical  
(300 MHz ~ 1000 MHz)

**Revision History**

Date	Revision Number	Description
10. Oct. 2025	001	New release

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