Test Report: PMP23117

3.3-V, 24-A, 4-Phase Reference Design for Automotive Applications

Description

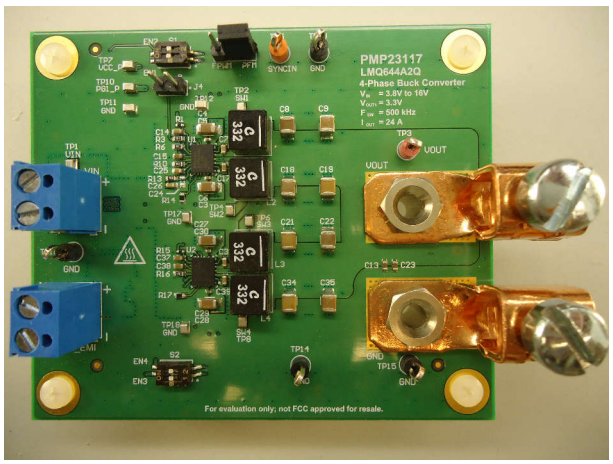
This 4-phase reference design provides 3.3-V out at 24 A from a 3.8-V to 16-V automotive power source. The circuit uses two LMQ644A2-Q1 dual-channel synchronous buck regulators operating at a nominal switching frequency of 500 kHz. Forced Pulse Width Modulation (FPWM) or Pulse Frequency Modulation (PFM) for light load operation is jumper selectable. Test points are provided for frequency synchronization, power good, and frequency response injection.

Features

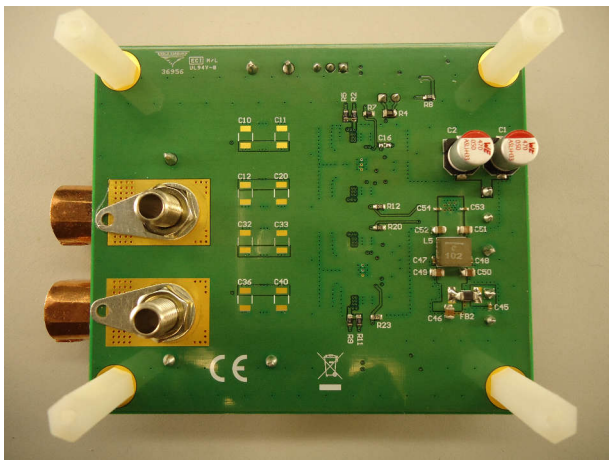
- Dual-phase integrated-switch regulators for small solution size
- Selectable FPWM or PFM operation at light load
- 3.8-V minimum input for cold cranking
- 500-kHz switching frequency for best size versus efficiency
- Spread spectrum option for low EMI
- Tested to EN 55025 class 5 conducted emissions

Applications

- Imaging radar
- Radar ECU
- ADAS domain controller
- Automotive cluster display



Top of Board



Bottom of Board

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1 Test Prerequisites

1.1 Design Requirements

Table 1-1. Design Requirements

Parameter	Specifications
Input Voltage	3.8 V to 16 V DC
Output Voltage	3.3 V
Load Current	24 A
Switching Frequency	500 kHz

1.2 Required Equipment

- DC power supply
- Electronic load
- Oscilloscope
- Current probe
- Current shunts
- Digital voltmeters
- Thermal camera

1.3 Considerations

All tests were performed at room temperature on an open bench.

1.4 Dimensions

PMP23117 Rev A was built on a six-layer board with 1-oz copper per layer. Board dimensions are 2.8 inches × 3.3 inches.

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2 Testing and Results

2.1 Efficiency Graphs

Efficiency is shown in the following figure.

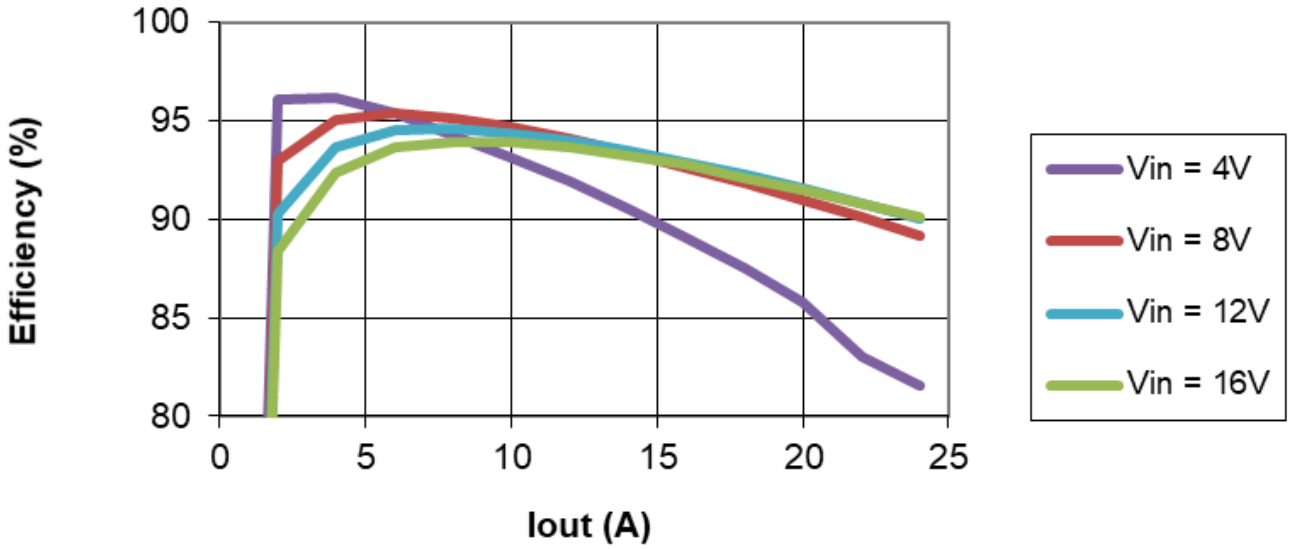

Figure 2-1. Efficiency in FPWM mode with EMI filter

2.2 Efficiency Data

Efficiency data is shown in the following tables.

V_{IN} (V)	I_{IN} (A)	V_{OUT} (V)	I_{OUT} (A)	P_{IN} (W)	P_{OUT} (W)	P_{LOSS} (W)	Efficiency (%)
3.996	0.036	3.315	0.000	0.14	0.00	0.14	0.00
3.996	1.720	3.315	1.992	6.87	6.60	0.27	96.07
3.996	3.442	3.314	3.990	13.75	13.22	0.53	96.15
3.996	5.208	3.314	5.988	20.81	19.85	0.96	95.36
3.996	7.026	3.314	7.988	28.07	26.47	1.60	94.29
3.996	8.892	3.314	9.988	35.53	33.10	2.43	93.16
3.996	10.818	3.314	11.988	43.22	39.72	3.50	91.90
3.996	12.806	3.313	13.986	51.17	46.34	4.83	90.57
3.996	14.880	3.313	15.986	59.45	52.96	6.49	89.08
3.995	17.048	3.313	17.986	68.11	59.58	8.53	87.48
3.995	19.340	3.312	20.020	77.27	66.31	10.96	85.82
3.995	21.670	3.266	22.014	86.57	71.90	14.67	83.06
3.994	22.302	3.025	24.014	89.08	72.65	16.43	81.56

V_{IN} (V)	I_{IN} (A)	V_{OUT} (V)	I_{OUT} (A)	P_{IN} (W)	P_{OUT} (W)	P_{LOSS} (W)	Efficiency (%)
7.999	0.048	3.314	0.000	0.38	0.00	0.38	0.00
7.999	0.886	3.314	1.988	7.09	6.59	0.50	92.96
7.999	1.738	3.314	3.988	13.90	13.21	0.69	95.06
7.999	2.600	3.313	5.986	20.80	19.83	0.96	95.37
7.999	3.478	3.313	7.988	27.82	26.46	1.36	95.12
7.999	4.370	3.313	9.988	34.96	33.09	1.87	94.65
7.999	5.276	3.312	11.986	42.20	39.70	2.51	94.06
7.999	6.202	3.312	13.986	49.61	46.32	3.29	93.36

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V_{IN} (V)	I_{IN} (A)	V_{OUT} (V)	I_{OUT} (A)	P_{IN} (W)	P_{OUT} (W)	P_{LOSS} (W)	Efficiency (%)
7.999	7.146	3.311	15.986	57.16	52.93	4.23	92.60
7.999	8.106	3.311	17.986	64.84	59.54	5.29	91.83
7.999	9.102	3.310	20.014	72.81	66.24	6.56	90.98
7.999	10.104	3.309	22.012	80.82	72.84	7.98	90.13
7.999	11.138	3.308	24.010	89.09	79.43	9.66	89.16

V_{IN} (V)	I_{IN} (A)	V_{OUT} (V)	I_{OUT} (A)	P_{IN} (W)	P_{OUT} (W)	P_{LOSS} (W)	Efficiency (%)
11.999	0.048	3.314	0.000	0.58	0.00	0.58	0.00
11.999	0.608	3.314	1.988	7.30	6.59	0.71	90.30
11.999	1.176	3.313	3.988	14.11	13.21	0.90	93.64
11.999	1.748	3.313	5.986	20.97	19.83	1.14	94.55
11.999	2.330	3.313	7.986	27.96	26.45	1.50	94.63
11.999	2.922	3.312	9.986	35.06	33.08	1.99	94.34
11.999	3.520	3.312	11.986	42.24	39.69	2.54	93.98
11.999	4.128	3.311	13.986	49.53	46.31	3.22	93.50
11.999	4.748	3.311	15.986	56.97	52.92	4.05	92.89
11.999	5.376	3.310	17.986	64.51	59.53	4.97	92.29
11.999	6.030	3.309	20.014	72.35	66.23	6.12	91.54
11.999	6.682	3.308	22.010	80.18	72.82	7.36	90.82
11.999	7.352	3.308	24.006	88.22	79.40	8.81	90.01

V_{IN} (V)	I_{IN} (A)	V_{OUT} (V)	I_{OUT} (A)	P_{IN} (W)	P_{OUT} (W)	P_{LOSS} (W)	Efficiency (%)
15.997	0.046	3.314	0.000	0.74	0.00	0.74	0.00
15.997	0.466	3.314	1.988	7.45	6.59	0.87	88.37
15.997	0.894	3.313	3.986	14.30	13.21	1.09	92.35
15.997	1.324	3.313	5.986	21.18	19.83	1.35	93.63
15.997	1.760	3.312	7.986	28.15	26.45	1.70	93.96
15.997	2.202	3.312	9.986	35.22	33.07	2.15	93.89
15.997	2.650	3.311	11.986	42.39	39.69	2.70	93.63
15.997	3.104	3.311	13.984	49.65	46.30	3.36	93.24
15.997	3.566	3.310	15.986	57.04	52.92	4.13	92.76
15.997	4.038	3.309	17.984	64.59	59.52	5.08	92.14
15.997	4.524	3.309	20.012	72.37	66.21	6.16	91.49
15.997	5.010	3.308	22.006	80.14	72.79	7.35	90.83
15.997	5.506	3.307	24.004	88.08	79.38	8.70	90.13

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2.3 Thermal Images

Thermal images are shown in the following figures.

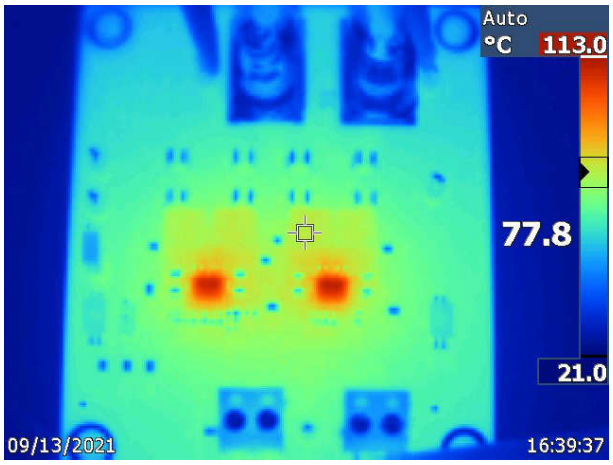

Figure 2-2. 12-V Input, 20-A Load

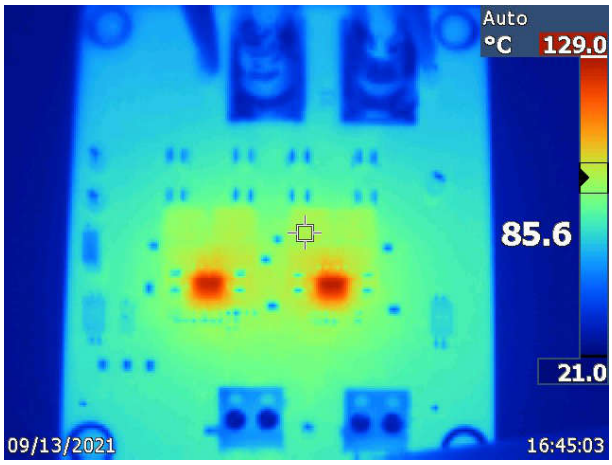

Figure 2-3. 12-V Input, 22-A Load

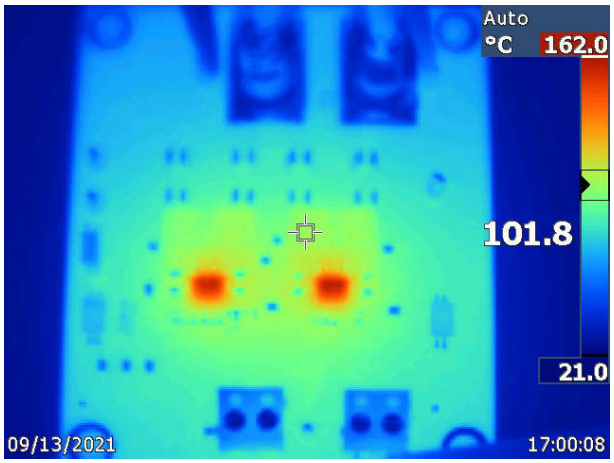

Figure 2-4. 12-V Input, 24-A Load

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2.4 Bode Plots

Bode plots are shown in the following figures.

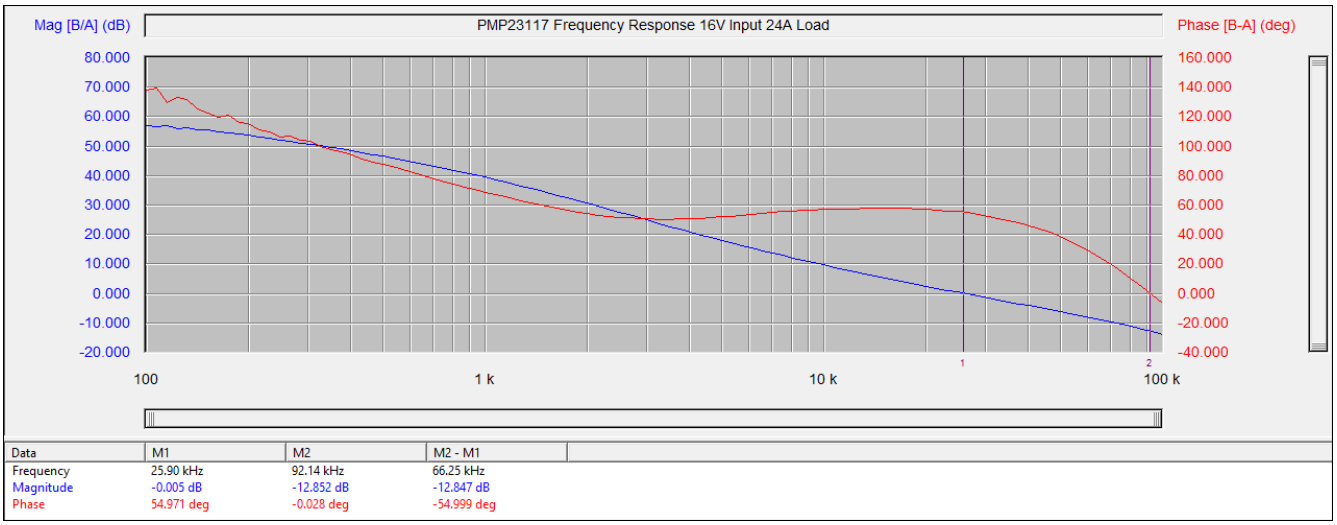

Figure 2-5. 16-V Input, 24-A Load

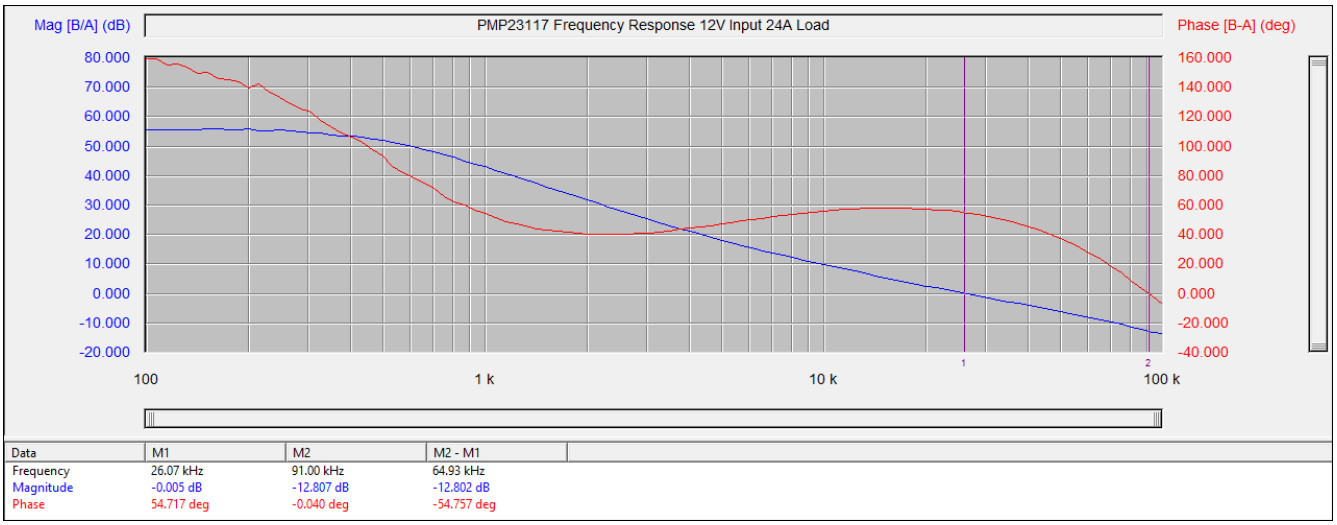

Figure 2-6. 12-V Input, 24-A Load

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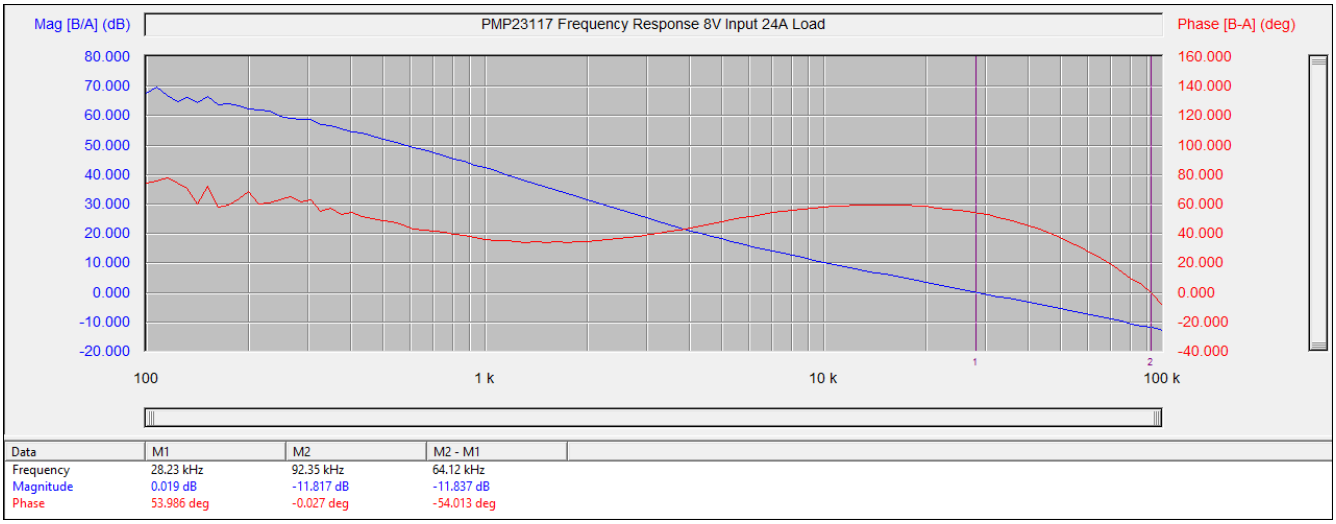

Figure 2-7. 8-V Input, 24-A Load

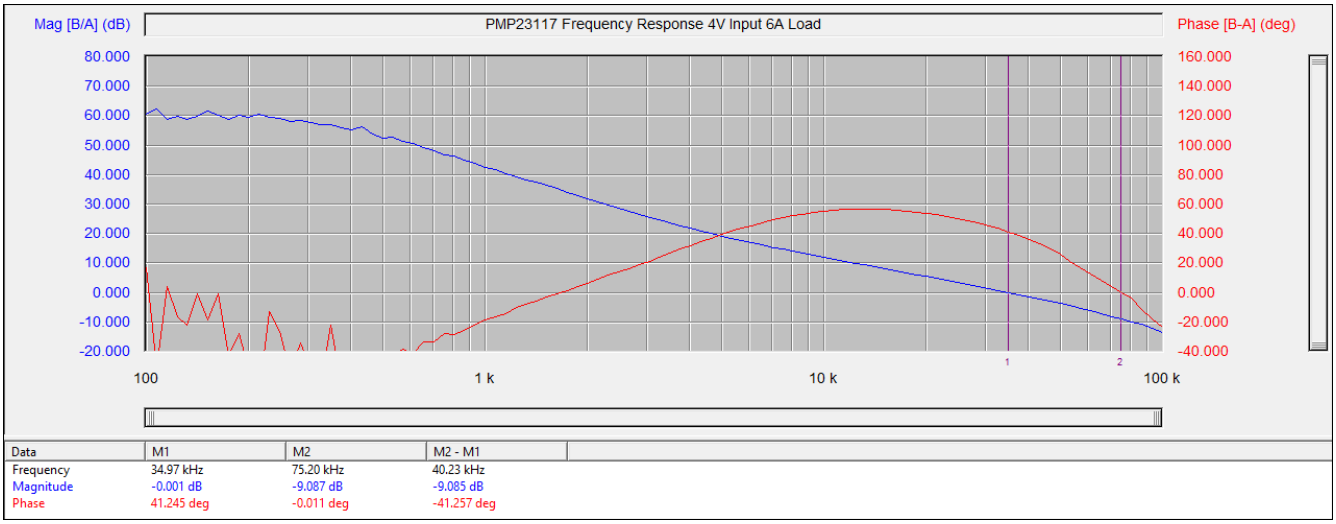

Figure 2-8. 4-V Input, 6-A Load

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2.5 EMI

EMI data is shown in the following figure.

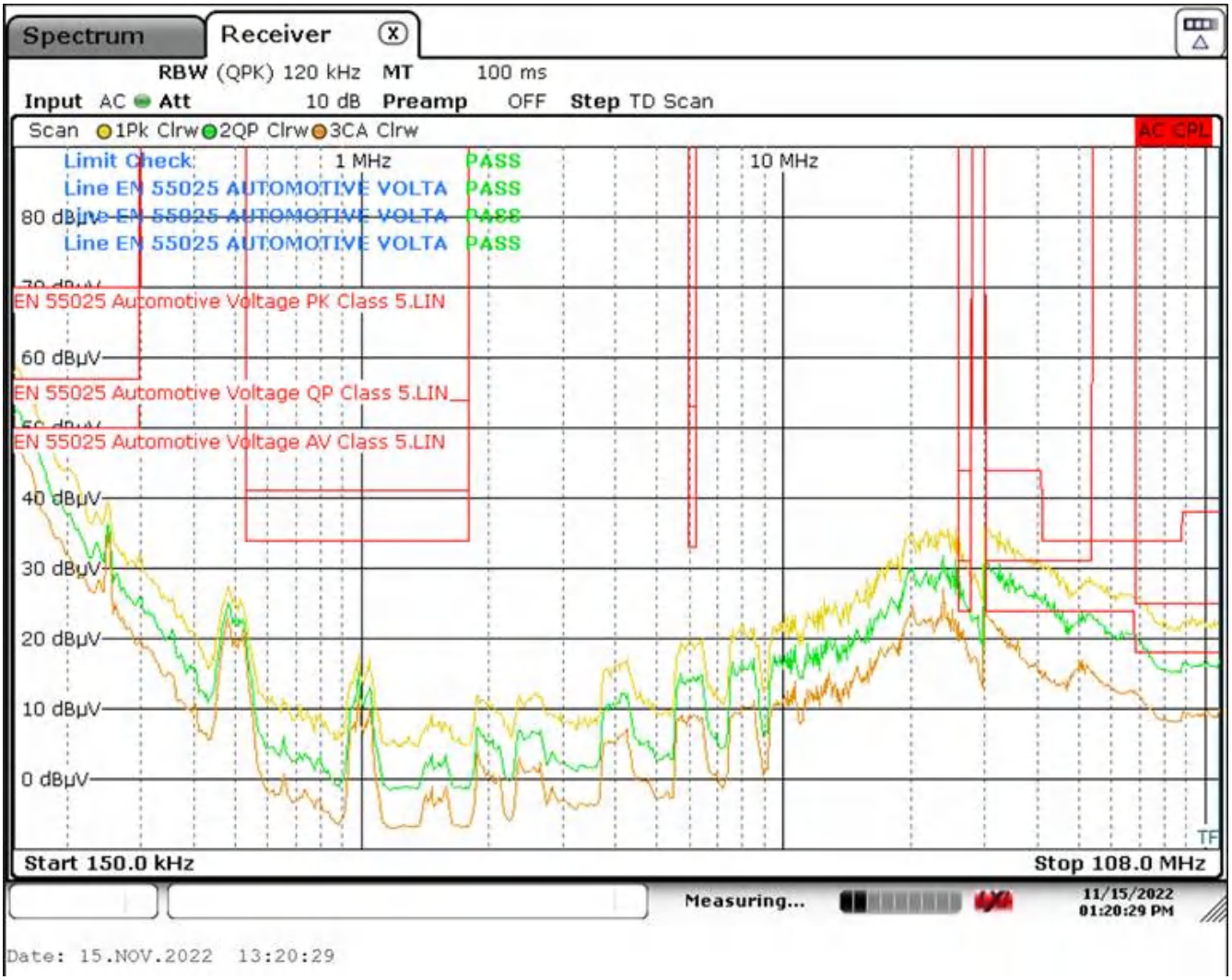

Figure 2-9. Conducted EMI

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3 Waveforms

3.1 Switching

Switching behavior is shown in the following figures.

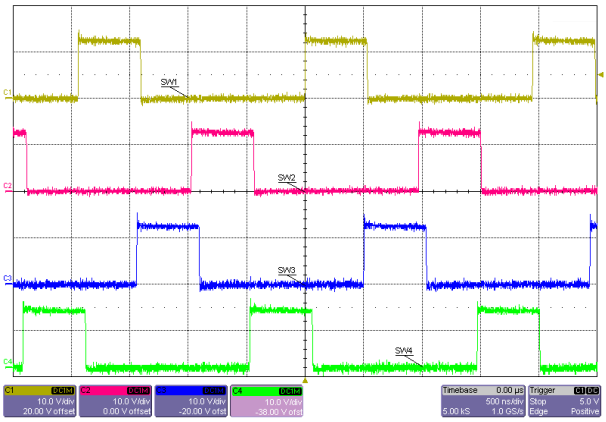

Figure 3-1. 12-V Input, 0-A Load, FPWM

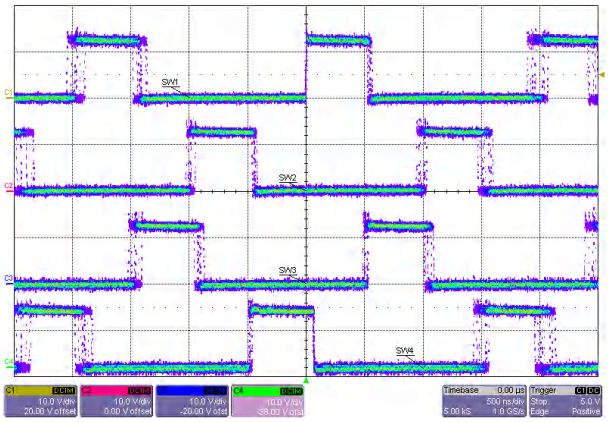

Figure 3-2. 12-V Input, 0-A Load, FPWM, Dither

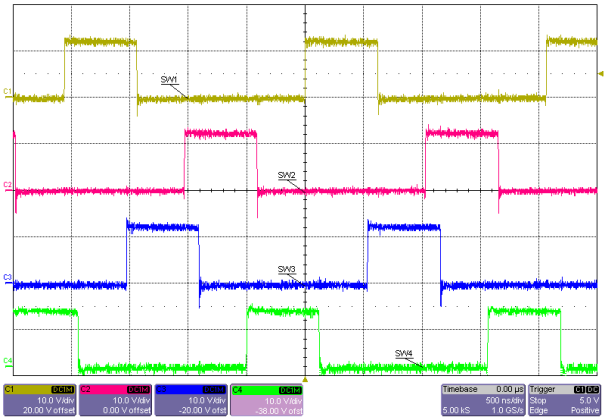

Figure 3-3. 12-V Input, 24-A Load

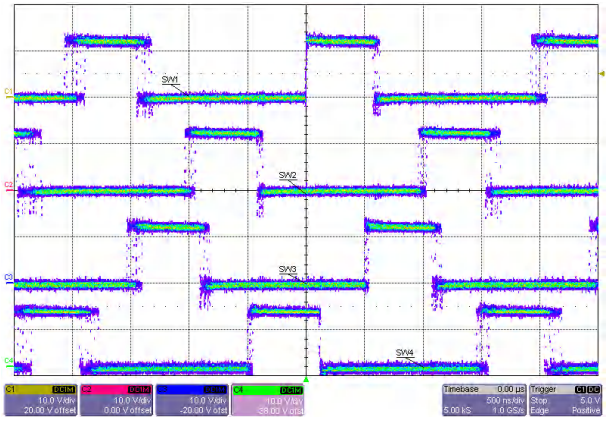

Figure 3-4. 12-V Input, 24-A Load, Dither

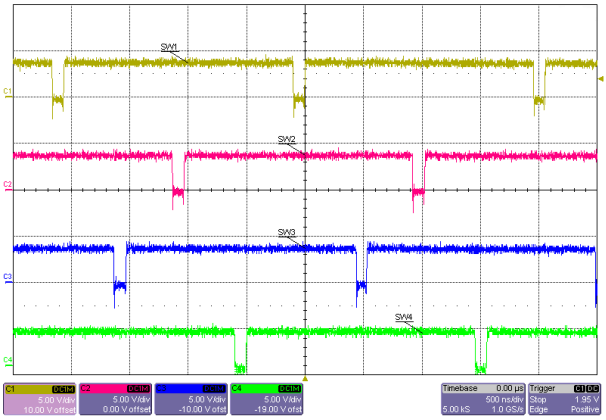

Figure 3-5. 4-V Input, 24-A Load

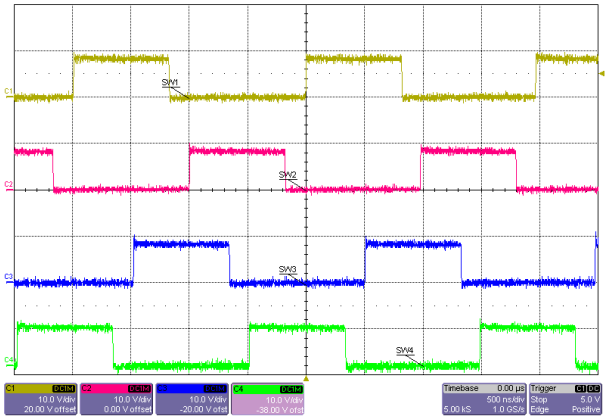

Figure 3-6. 8-V Input, 24-A Load

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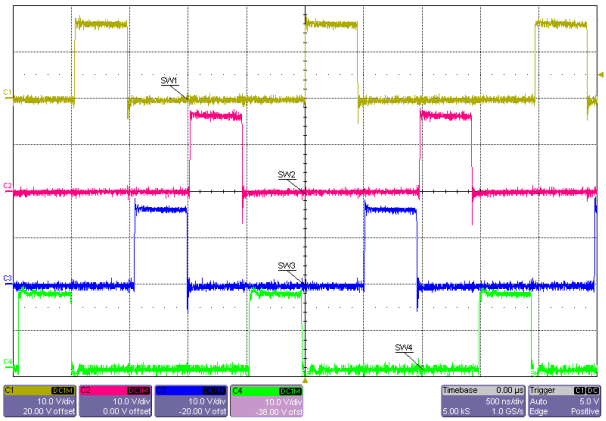

Figure 3-7. 16-V Input, 24-A Load

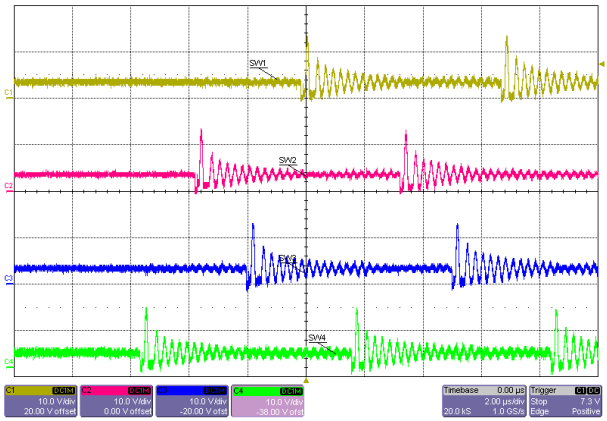

Figure 3-8. 12-V Input, 0-A Load, PFM

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3.2 Output Voltage Ripple

Output voltage ripple is shown in the following figures.

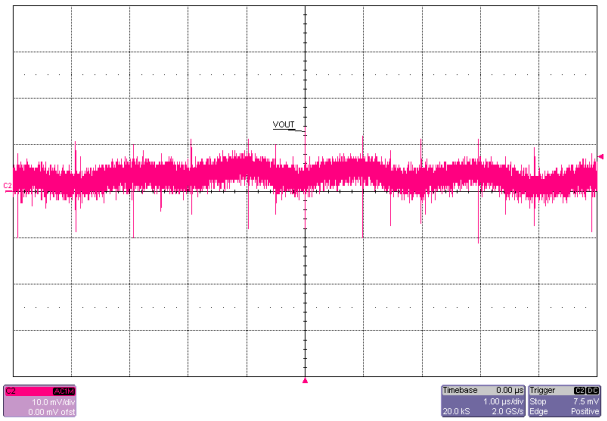

Figure 3-9. 8-V Input, 24-A Load

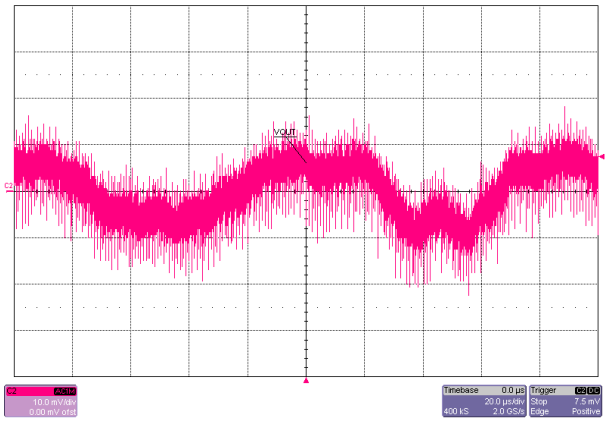

Figure 3-10. 8-V Input, 24-A Load

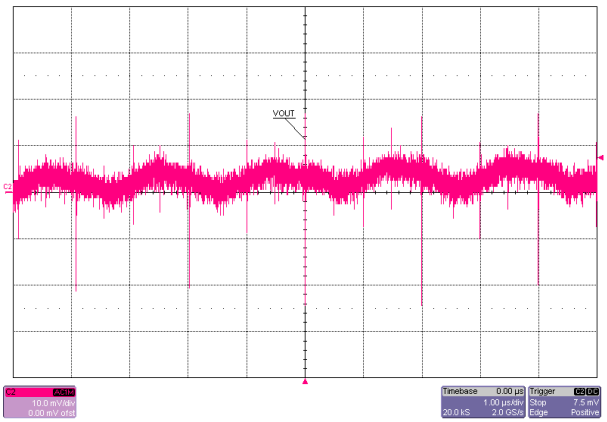

Figure 3-11. 16-V Input, 24-A Load

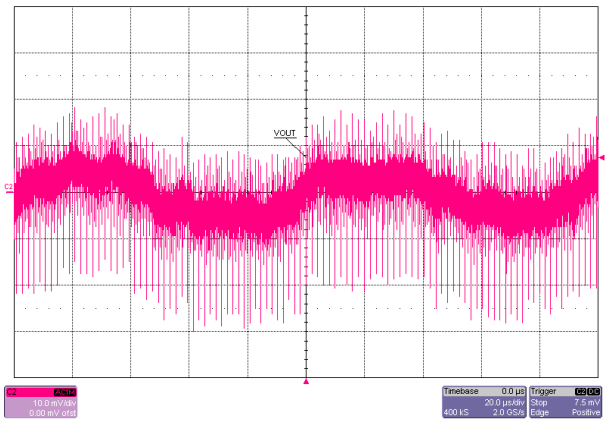

Figure 3-12. 16-V Input, 24-A Load

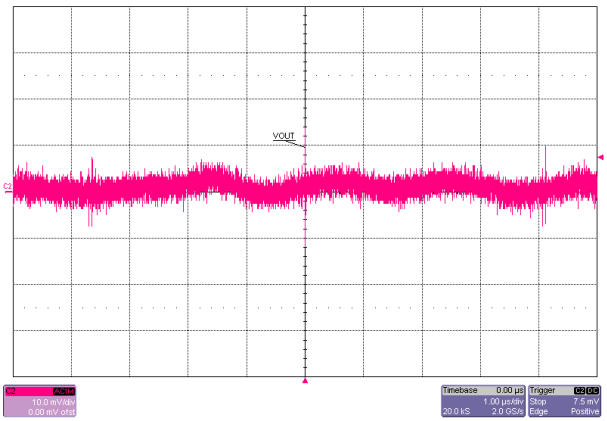

Figure 3-13. 4-V Input, 24-A Load

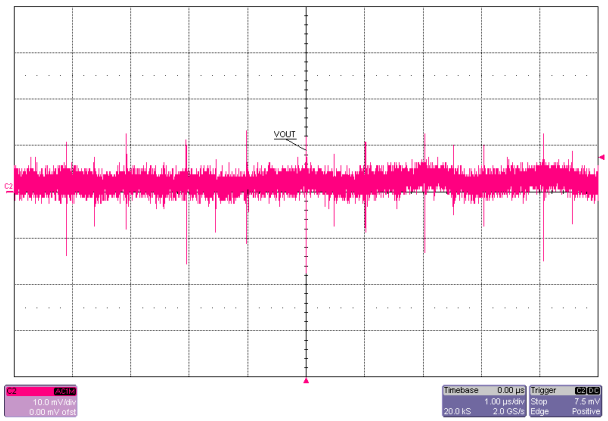

Figure 3-14. 12-V Input, 24-A Load

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3.3 Short-Circuit Protection

Short-circuit protection is shown in the following figures.

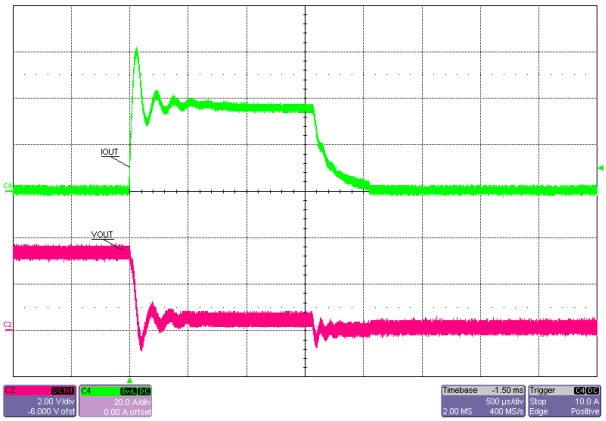

Figure 3-15. 12-V Input, Short Circuit

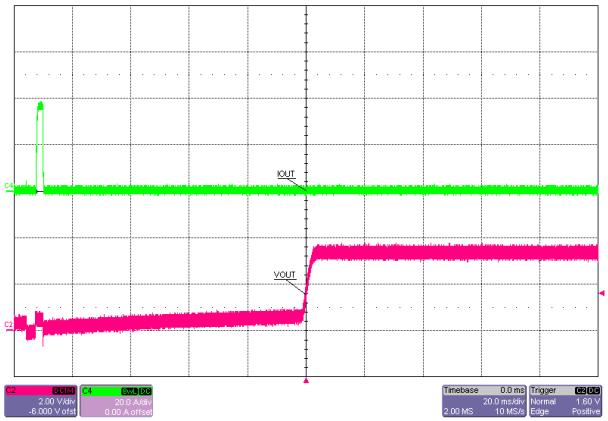

Figure 3-16. 12-V Input, Short Circuit Recovery

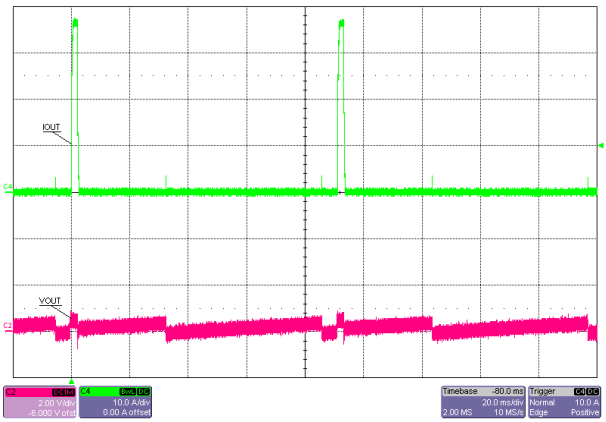

Figure 3-17. 12-V Input, Short Circuit Cycling

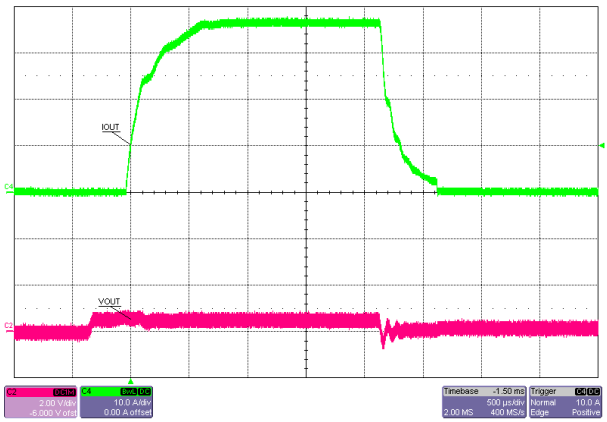

Figure 3-18. 12-V Input, Short Circuit Cycling

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3.4 Load Transients

Load transient response is shown in the following figures.

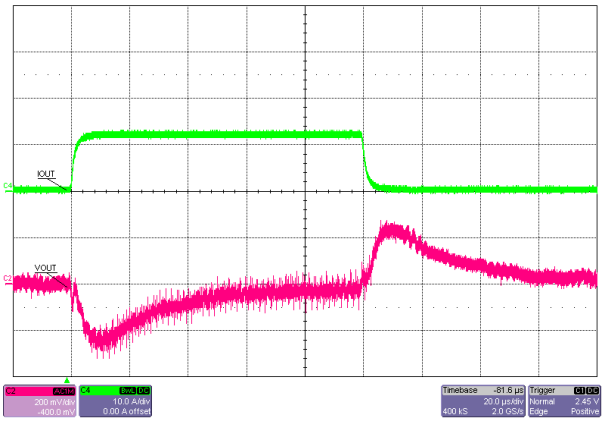

Figure 3-19. 12-V Input, 0-A to12-A Load Step, FPWM

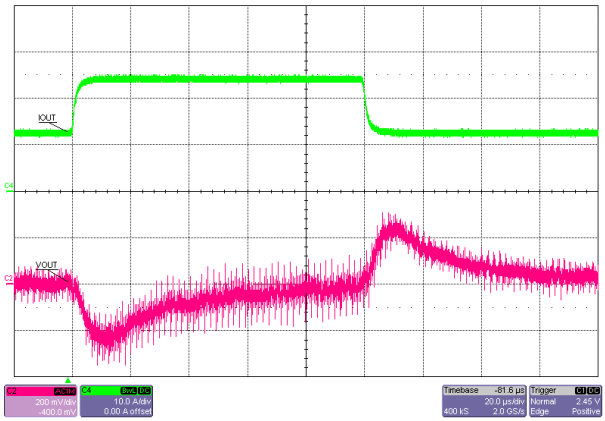

Figure 3-20. 12-V Input, 12-A to 24-A Load Step

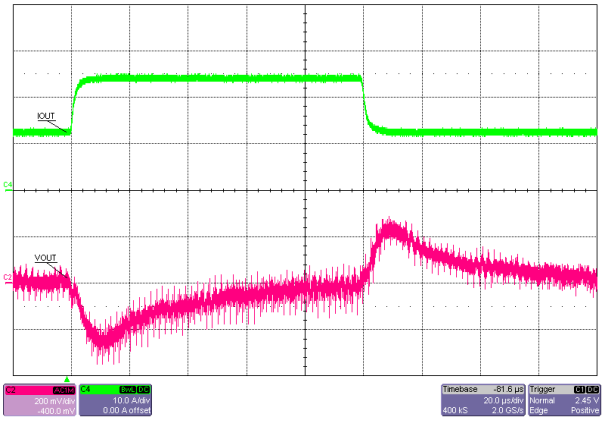

Figure 3-21. 8-V Input, 12-A to 24-A Load Step

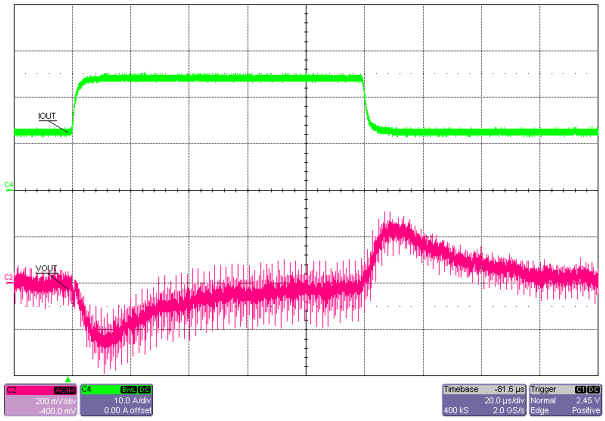

Figure 3-22. 16-V Input, 12-A to 24-A Load Step

3.5 Start-Up Sequence

Start-up behavior is shown in the following figures.

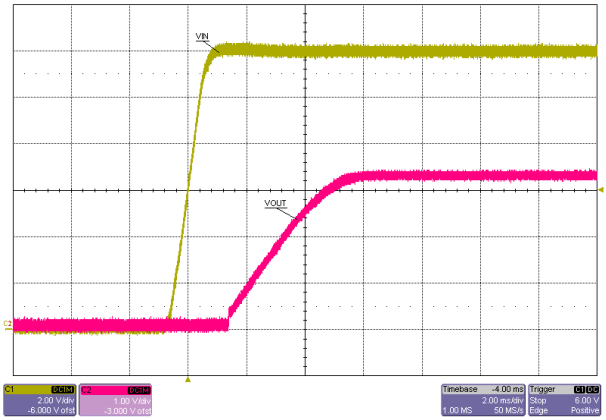

Figure 3-23. 12-V Input, 0-A Load

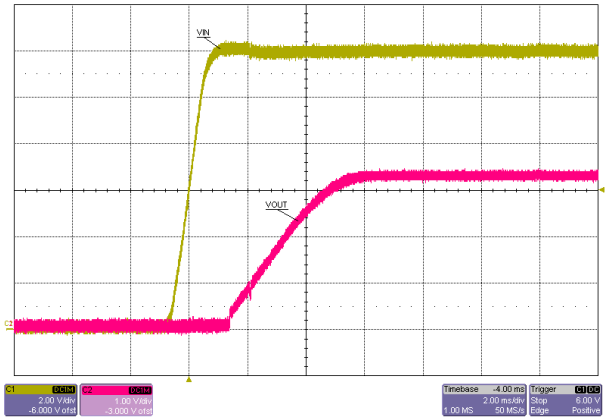

Figure 3-24. 12-V Input, 24-A Load

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