Test Report: PMP22670

24-V to 36-V Input, 3.3-V Output Synchronous Buck Converter Reference Design

Description

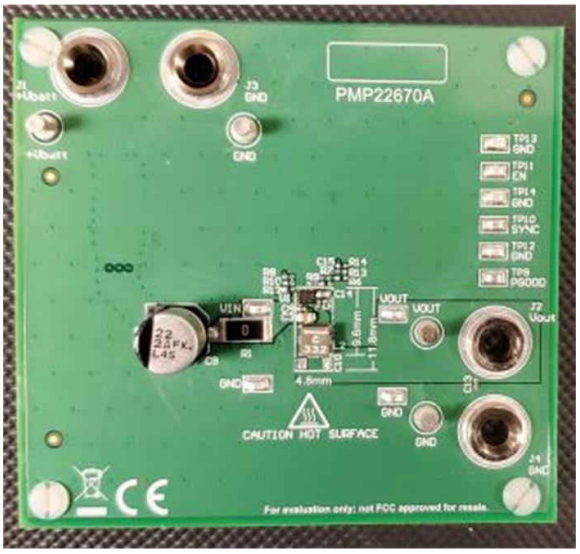
This reference design demonstrates a single-phase buck converter with integrated FETs and a very small design size. The design accepts an input voltage from 24 V_{IN} to 36 V_{IN}, and provides a regulated 3.3-V output up to 1-A continuous and 1.2-A peak. Two revisions of the board were designed and manufactured to compare the EMI and thermal performance between the two PCB layouts. Otherwise, both versions of the boards use the same exact circuitry.

Features

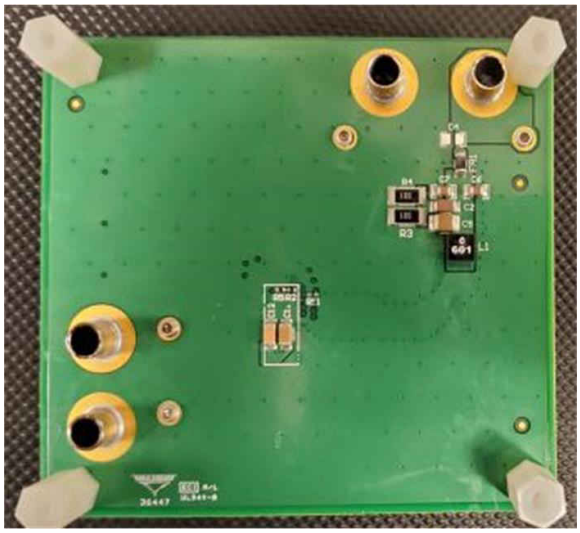
- 2.1-MHz switching frequency avoids AM band
- Very small design size
- Regulator includes integrated FETs
- Optimized for automotive applications
- Regulator features spread-spectrum switching (dithering) for improved EMI performance

Applications

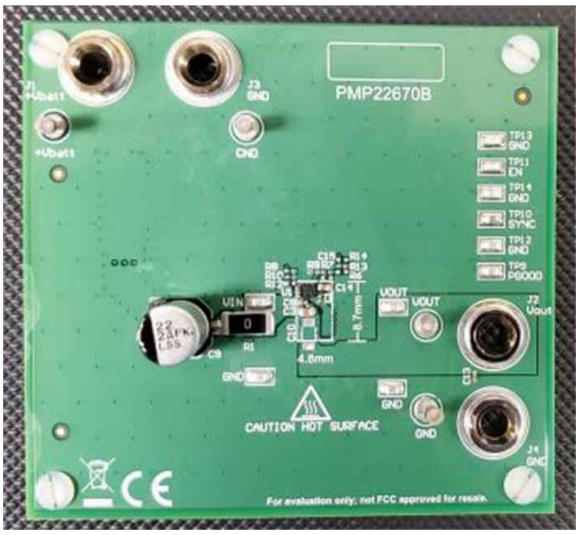
- Mirror replacement, camera mirror system



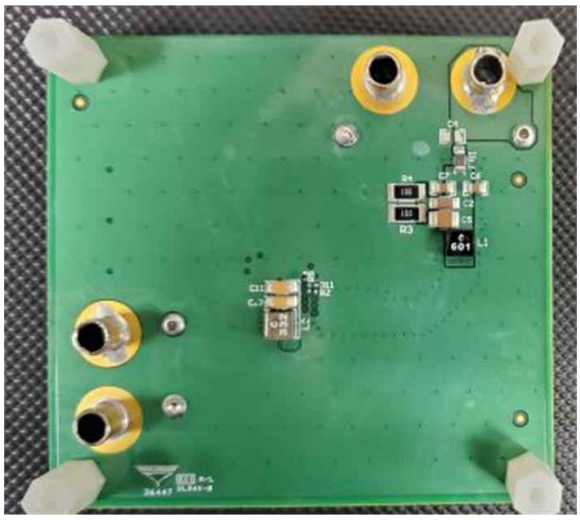
PMP22670A Top Side



PMP22670A Bottom Side



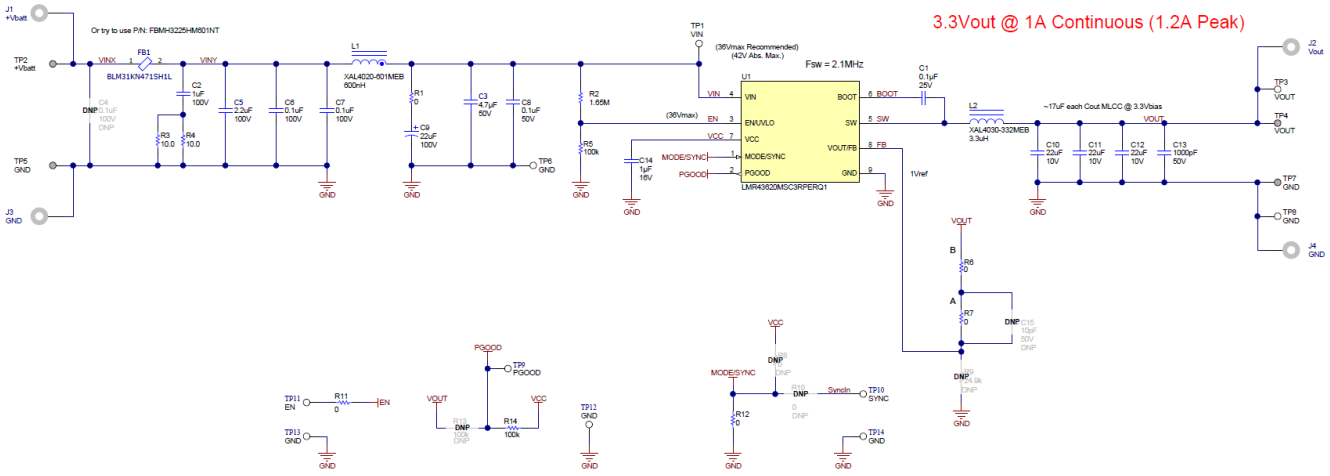
PMP22670B Top Side



PMP22670B Bottom Side

Input Voltage = 24Vin to 36Vin

3.3Vout @ 1A Continuous (1.2A Peak)



Schematic

1 Test Prerequisites

1.1 Voltage and Current Requirements

Table 1-1. Voltage and Current Requirements

Parameter	Specifications
V_{IN}	24 VDC to 36 VDC
V_{OUT}	3.3 VDC
I_{OUT}	1 A continuous (1.2 A maximum)
F_{SW}	2.1 MHz nominal

1.2 Required Equipment

- Power supply
- Electronic load
- Digital multimeters
- Oscilloscope

1.3 Considerations

There are two revisions of this design: RevA which has the inductor mounted on the same side as the regulator and RevB, which has the inductor mounted on the bottom side of the regulator. The circuitry of both are exactly the same. Only the PCB layouts vary slightly. Unless otherwise noted, all tests are performed on the RevB board for this report.

Note

Since this is a pre-released IC, there are certain misbehaviors with the converter that are documented in the errata sheet, which are to be rectified before the release of the product. These misbehaviors have some effect on the switching, output ripple, and load transient response waveforms, and might also have influenced the EMI results, documented in this preliminary test report.

1.4 Dimensions

The board dimensions are 3 in × 2.8 in (76.2 mm × 71.1 mm). The actual solution size is approximately 0.189 in × 0.378 in (4.8 mm × 9.6 mm) for RevA and 0.189 in × 0.343 in (4.8 mm × 8.7 mm) for RevB.

2 Testing and Results

2.1 Efficiency and Power Loss Graphs

The following figure shows the total system efficiency for 24-V, 30-V, and 36-V input voltages at various load currents, for both PFM and FPWM operation modes.

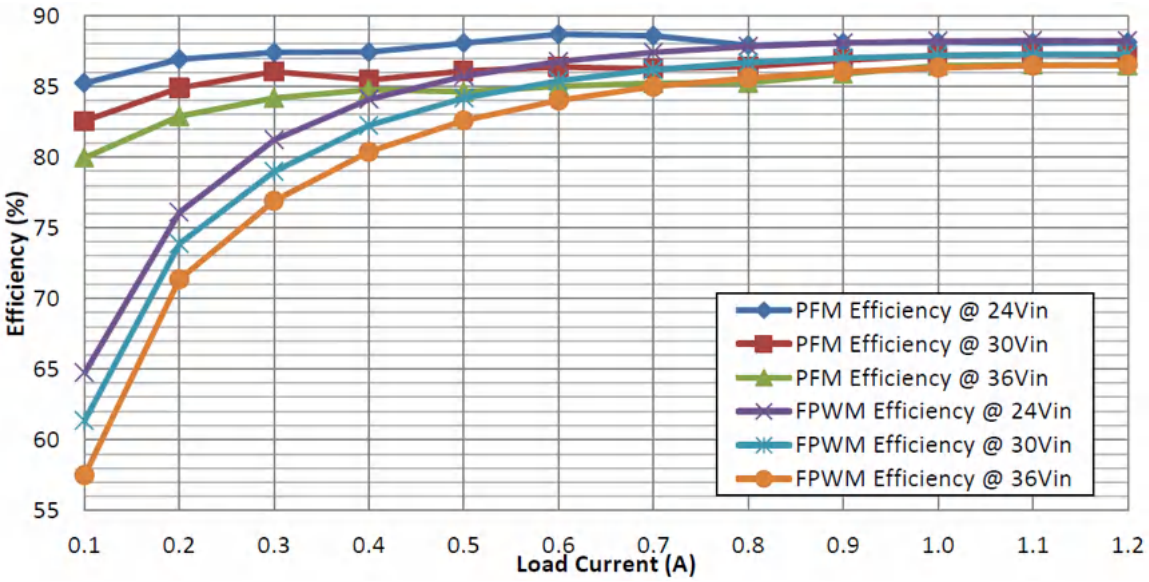


Figure 2-1. PMP22670 Converter Efficiency

The following figure shows the total system power loss for 24-V, 30-V, and 36-V input voltages at various load currents, for both PFM and FPWM operation modes.

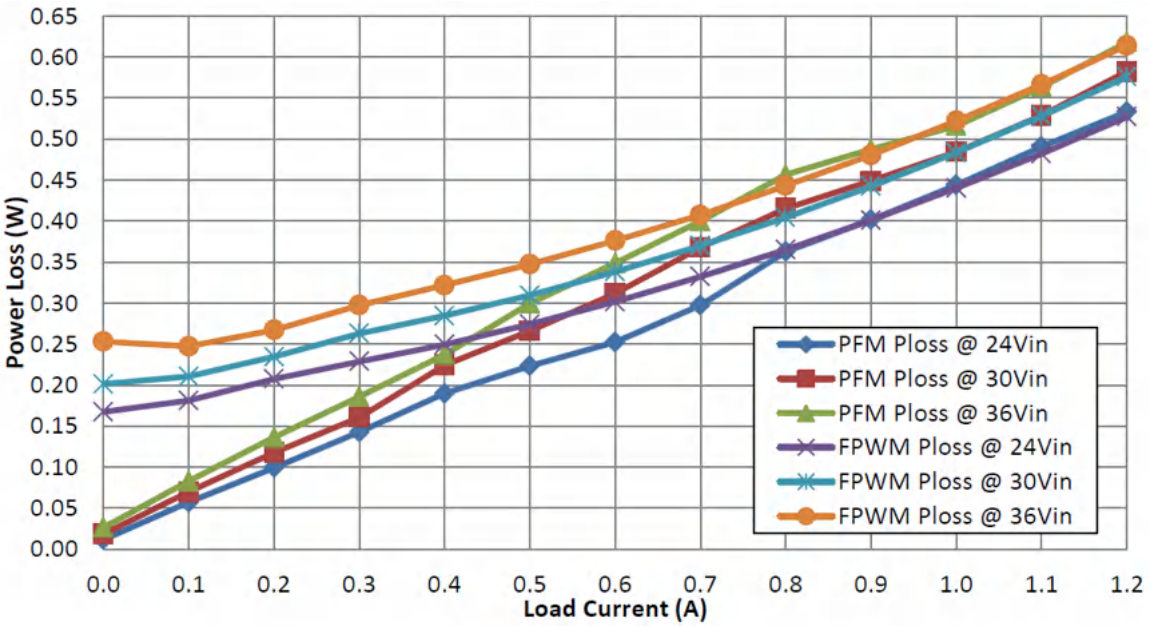


Figure 2-2. PMP22670 Converter Power Loss

2.2 Efficiency Data

The following figures show the efficiency data for 24-V, 30-V, and 36-V input voltages at various load currents.

Vin (V)	Iin (mA)	Vout (V)	Iout (A)	Pin (W)	Pout (W)	Ploss (W)	Efficiency (%)
24	0.4886	3.3347	0	0.0117	0.0000	0.0117	0.00
24	16.11	3.2953	0.1	0.3866	0.3295	0.0571	85.23
24	31.64	3.2953	0.2003	0.7594	0.6600	0.0993	86.92
24	47.16	3.2952	0.3002	1.1318	0.9892	0.1426	87.40
24	62.85	3.2949	0.4002	1.5084	1.3186	0.1898	87.42
24	77.94	3.2946	0.5	1.8706	1.6473	0.2233	88.06
24	92.89	3.2944	0.6001	2.2294	1.9770	0.2524	88.68
24	108.47	3.2942	0.7	2.6033	2.3059	0.2973	88.58
24	124.96	3.294	0.8003	2.9990	2.6362	0.3629	87.90
24	140.28	3.2939	0.9002	3.3667	2.9652	0.4016	88.07
24	155.75	3.2937	1.0001	3.7380	3.2940	0.4440	88.12
24	171.41	3.2936	1.1	4.1138	3.6230	0.4909	88.07
24	186.92	3.2934	1.2002	4.4861	3.9527	0.5333	88.11

Figure 2-3. Efficiency Data 24-V Input (PFM)

Vin (V)	Iin (mA)	Vout (V)	Iout (A)	Pin (W)	Pout (W)	Ploss (W)	Efficiency (%)
30	0.6106	3.3421	0	0.0183	0.0000	0.0183	0.00
30	13.32	3.2953	0.1001	0.3996	0.3299	0.0697	82.55
30	25.92	3.2952	0.2003	0.7776	0.6600	0.1176	84.88
30	38.31	3.2952	0.3001	1.1493	0.9889	0.1604	86.04
30	51.46	3.2949	0.4004	1.5438	1.3193	0.2245	85.46
30	63.76	3.2946	0.4998	1.9128	1.6466	0.2662	86.09
30	76.28	3.2945	0.6	2.2884	1.9767	0.3117	86.38
30	89.13	3.2945	0.7	2.6739	2.3062	0.3678	86.25
30	101.73	3.2943	0.8003	3.0519	2.6364	0.4155	86.39
30	113.8	3.294	0.9001	3.4140	2.9649	0.4491	86.85
30	125.94	3.2938	1	3.7782	3.2938	0.4844	87.18
30	138.39	3.2936	1.1	4.1517	3.6230	0.5287	87.26
30	151.15	3.2934	1.2001	4.5345	3.9524	0.5821	87.16

Figure 2-4. Efficiency Data 30-V Input (PFM)

Vin (V)	Iin (mA)	Vout (V)	Iout (A)	Pin (W)	Pout (W)	Ploss (W)	Efficiency (%)
36	0.732	3.3508	0	0.0264	0.0000	0.0264	0.00
36	11.46	3.2954	0.1001	0.4126	0.3299	0.0827	79.96
36	22.12	3.2953	0.2003	0.7963	0.6600	0.1363	82.89
36	32.62	3.2952	0.3	1.1743	0.9886	0.1858	84.18
36	43.21	3.295	0.4001	1.5556	1.3183	0.2372	84.75
36	54.1	3.2948	0.5002	1.9476	1.6481	0.2995	84.62
36	64.63	3.2949	0.6003	2.3267	1.9779	0.3488	85.01
36	75.18	3.2947	0.7001	2.7065	2.3066	0.3999	85.23
36	85.91	3.2949	0.8001	3.0928	2.6362	0.4565	85.24
36	95.89	3.2941	0.9	3.4520	2.9647	0.4874	85.88
36	105.84	3.2938	1.0001	3.8102	3.2941	0.5161	86.45
36	116.33	3.2937	1.1003	4.1879	3.6241	0.5638	86.54
36	126.99	3.2935	1.2003	4.5716	3.9532	0.6185	86.47

Figure 2-5. Efficiency Data 36-V Input (PFM)

Vin (V)	Iin (mA)	Vout (V)	Iout (A)	Pin (W)	Pout (W)	Ploss (W)	Efficiency (%)
24	6.964	3.3332	0	0.1671	0.0000	0.1671	0.00
24	21.41	3.3234	0.1001	0.5138	0.3327	0.1812	64.74
24	36.14	3.2999	0.2	0.8674	0.6600	0.2074	76.09
24	50.76	3.2928	0.3005	1.2182	0.9895	0.2288	81.22
24	65.31	3.2924	0.4003	1.5674	1.3179	0.2495	84.08
24	80.05	3.2921	0.5003	1.9212	1.6470	0.2742	85.73
24	94.88	3.2919	0.6001	2.2771	1.9755	0.3017	86.75
24	109.85	3.2916	0.7	2.6364	2.3041	0.3323	87.40
24	124.94	3.2913	0.8001	2.9986	2.6334	0.3652	87.82
24	140.14	3.291	0.9001	3.3634	2.9622	0.4011	88.07
24	155.49	3.2908	1.0002	3.7318	3.2915	0.4403	88.20
24	170.91	3.2906	1.1	4.1018	3.6197	0.4822	88.24
24	186.5	3.2904	1.2001	4.4760	3.9488	0.5272	88.22

Figure 2-6. Efficiency Data 24-V Input (FPWM)

Vin (V)	Iin (mA)	Vout (V)	Iout (A)	Pin (W)	Pout (W)	Ploss (W)	Efficiency (%)
30	6.71	3.3365	0	0.2013	0.0000	0.2013	0.00
30	18.14	3.3353	0.1001	0.5442	0.3339	0.2103	61.35
30	29.94	3.3114	0.2004	0.8982	0.6636	0.2346	73.88
30	41.7	3.2928	0.3001	1.2510	0.9882	0.2628	78.99
30	53.37	3.2924	0.3999	1.6011	1.3166	0.2845	82.23
30	65.22	3.2921	0.5003	1.9566	1.6470	0.3096	84.18
30	77.11	3.2918	0.6	2.3133	1.9751	0.3382	85.38
30	89.12	3.2915	0.6999	2.6736	2.3037	0.3699	86.17
30	101.25	3.2913	0.8	3.0375	2.6330	0.4045	86.68
30	113.49	3.2911	0.9001	3.4047	2.9623	0.4424	87.01
30	125.79	3.2908	0.9998	3.7737	3.2901	0.4836	87.19
30	138.27	3.2906	1.1001	4.1481	3.6200	0.5281	87.27
30	150.81	3.2903	1.2	4.5243	3.9484	0.5759	87.27

Figure 2-7. Efficiency Data 30-V Input (FPWM)

Vin (V)	Iin (mA)	Vout (V)	Iout (A)	Pin (W)	Pout (W)	Ploss (W)	Efficiency (%)
36	7.03	3.3378	0	0.2531	0.0000	0.2531	0.00
36	16.16	3.3379	0.1002	0.5818	0.3345	0.2473	57.49
36	25.92	3.3239	0.2003	0.9331	0.6658	0.2673	71.35
36	35.76	3.2999	0.3	1.2874	0.9900	0.2974	76.90
36	45.52	3.2924	0.4	1.6387	1.3170	0.3218	80.37
36	55.37	3.2921	0.5	1.9933	1.6461	0.3473	82.58
36	65.34	3.2918	0.6003	2.3522	1.9761	0.3762	84.01
36	75.33	3.2916	0.7001	2.7119	2.3044	0.4074	84.98
36	85.45	3.2912	0.8	3.0762	2.6330	0.4432	85.59
36	95.62	3.291	0.9	3.4423	2.9619	0.4804	86.04
36	105.96	3.2907	1.0005	3.8146	3.2923	0.5222	86.31
36	116.29	3.2905	1.1001	4.1864	3.6199	0.5666	86.47
36	126.76	3.2903	1.2002	4.5634	3.9490	0.6143	86.54

Figure 2-8. Efficiency Data 36-V Input (FPWM)

2.3 Thermal Images

The thermal images in the following figures show operation at 36-V input voltage at 1.2-A load, with no airflow and ambient at room temperature. This is considered the worst-case operating condition, with the highest power loss. Thermals images were taken of both top and bottom side of the boards and were captured after the board had reached thermal equilibrium.

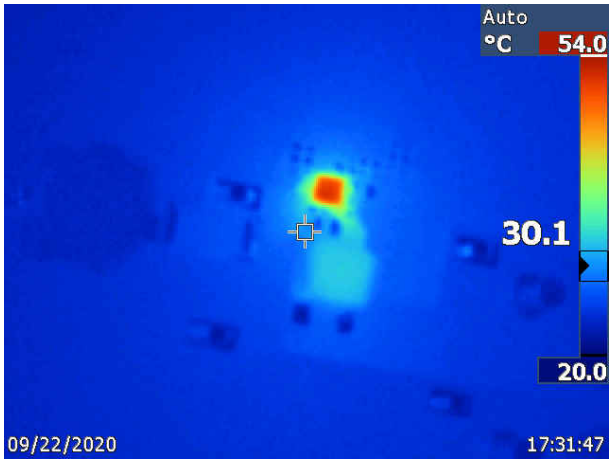


Figure 2-9. Thermal Image, RevA Board, 36-V Input, 1.2-A Load, Top-Side

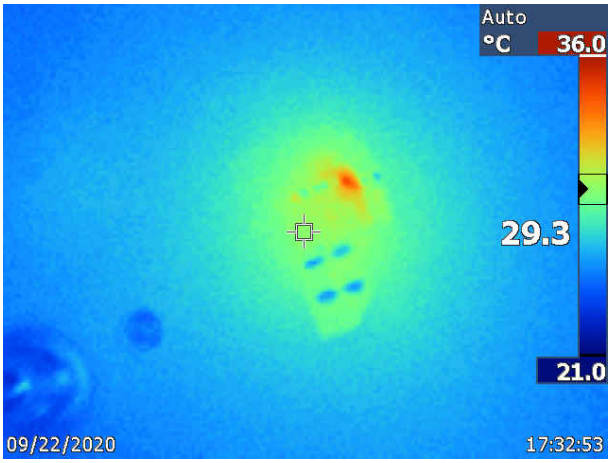


Figure 2-10. Thermal Image, RevA Board, 36-V Input, 1.2-A Load, Bottom-Side

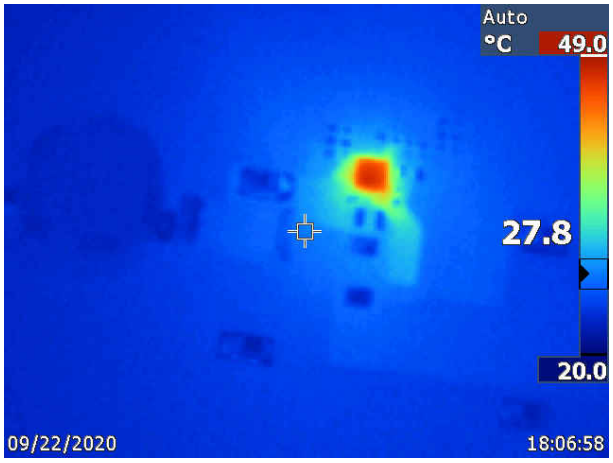


Figure 2-11. Thermal Image, RevB Board, 36-V Input, 1.2-A Load, Top-Side

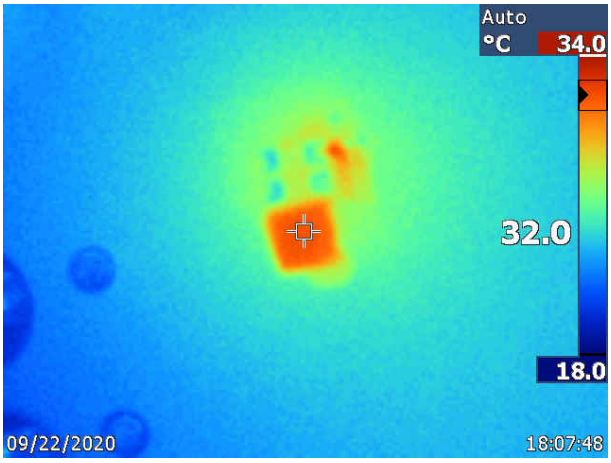


Figure 2-12. Thermal Image, RevB Board, 36-V Input, 1.2-A Load, Bottom-Side

3 Waveforms

3.1 Switching

The following set of figures show the switching waveforms between PFM mode and FPWM mode at 30-V input at no load and 1-A load conditions.

Note

See the Note in the Considerations section.

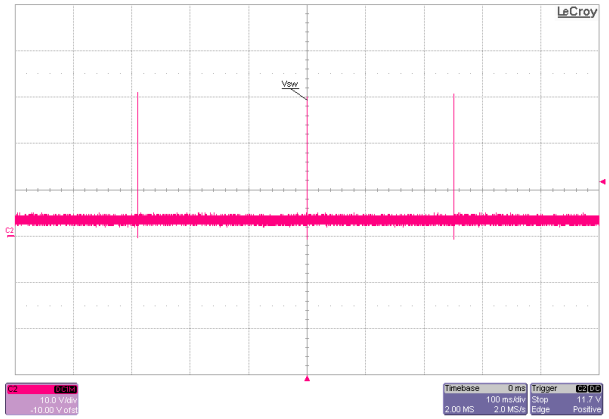


Figure 3-1. Switch Node Voltage, No Load, PFM-Mode

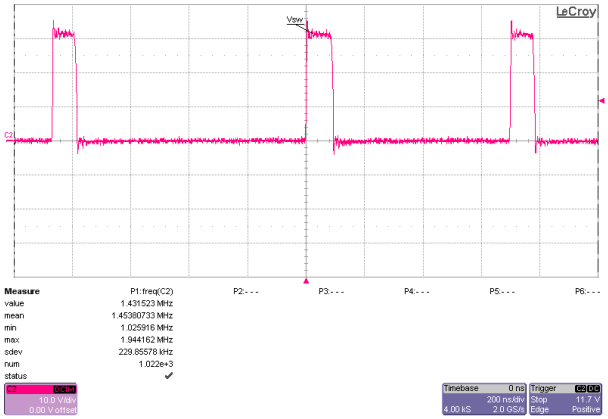


Figure 3-2. Switch Node Voltage, No Load, FPWM-Mode

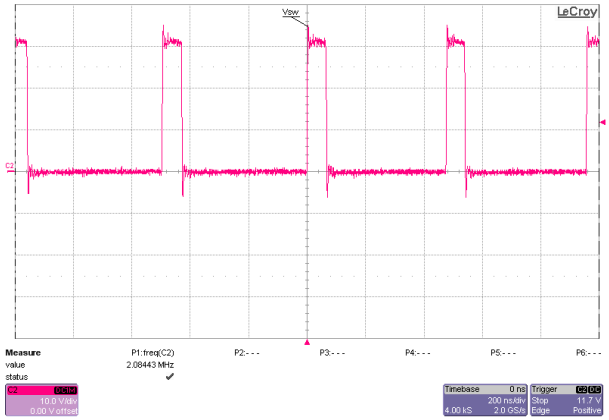


Figure 3-3. Switch Node Voltage, 1-A Load, PFM-Mode

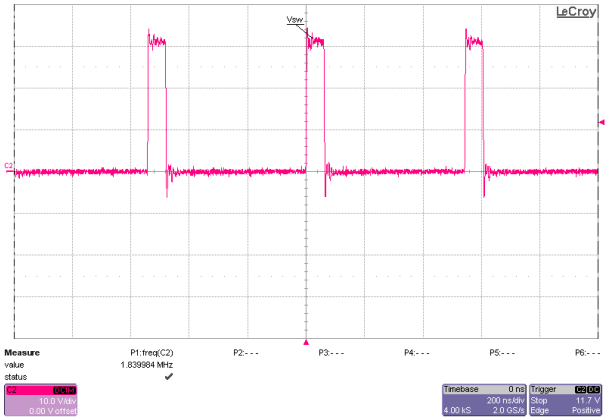


Figure 3-4. Switch Node Voltage, 1-A Load, FPWM-Mode

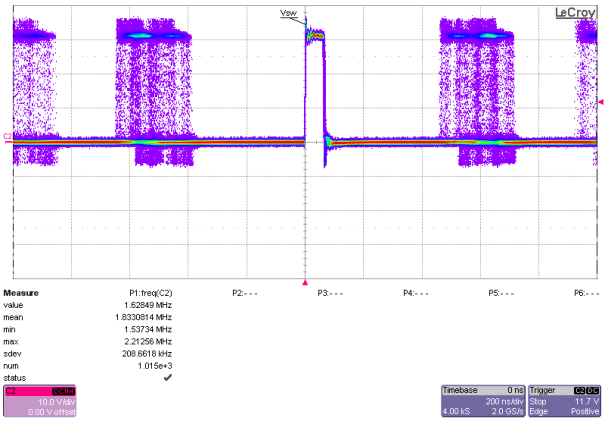


Figure 3-5. Switch Node Voltage, 1-A Load, Displaying Dither, PFM-Mode

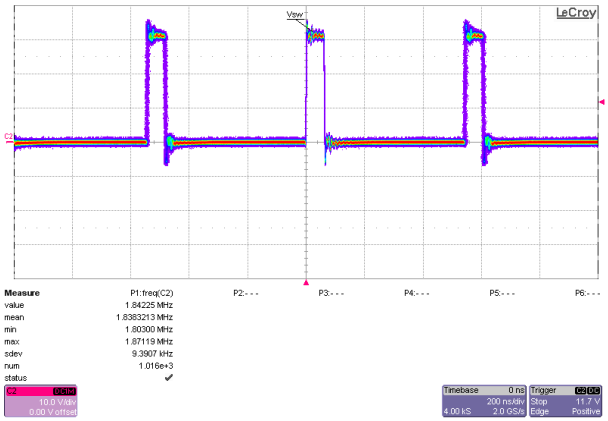


Figure 3-6. Switch Node Voltage, 1-A Load, Displaying Dither, FPWM-Mode

3.2 Output Voltage Ripple

The following set of figures show the output voltage ripple between PFM and FPWM modes, at 30-V input at no load and 1-A load conditions.

Note

See the Note in the Considerations section.

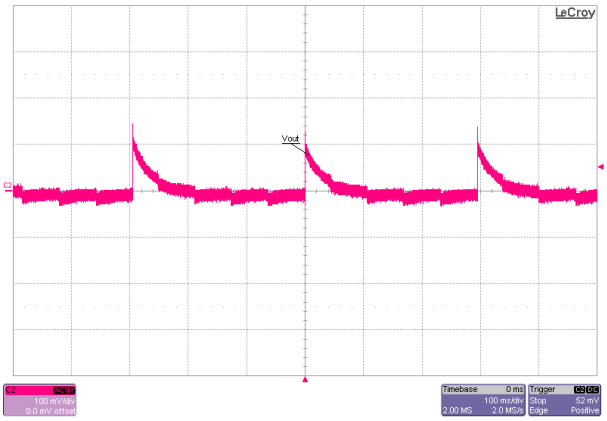


Figure 3-7. Output Voltage Ripple, No Load, PFM-Mode

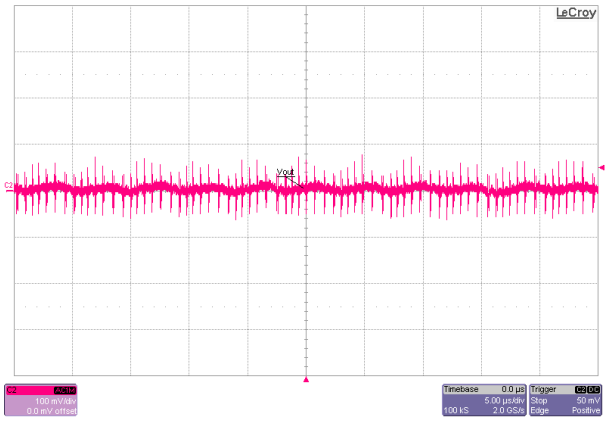


Figure 3-8. Output Voltage Ripple, No Load, FPWM-Mode

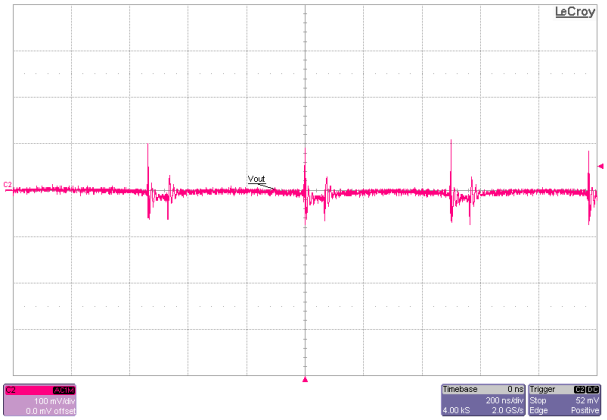


Figure 3-9. Output Voltage Ripple, 1-A Load, PFM-Mode

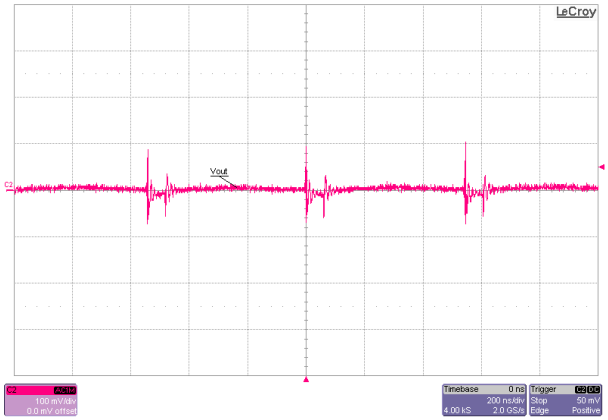


Figure 3-10. Output Voltage Ripple, 1-A Load, FPWM-Mode

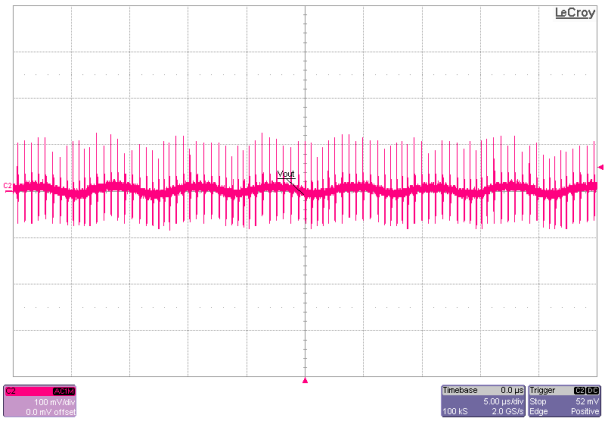


Figure 3-11. Output Voltage Ripple, 1-A Load, Zoomed Out, PFM-Mode

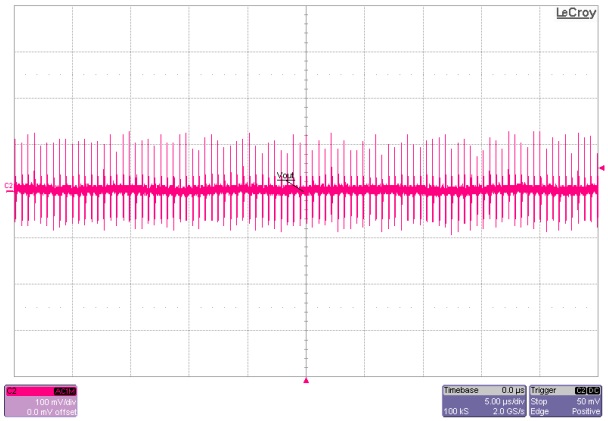


Figure 3-12. Output Voltage Ripple, 1-A Load, Zoomed Out, FPWM-Mode

3.3 Load Transients

The following set of figures show the load transient response between PFM and FPWM modes at 30-V input. The load is stepped from 50% to 100% of the load, corresponding to a 0.5 A to 1 A step.

Note

See the Note in the Considerations section.

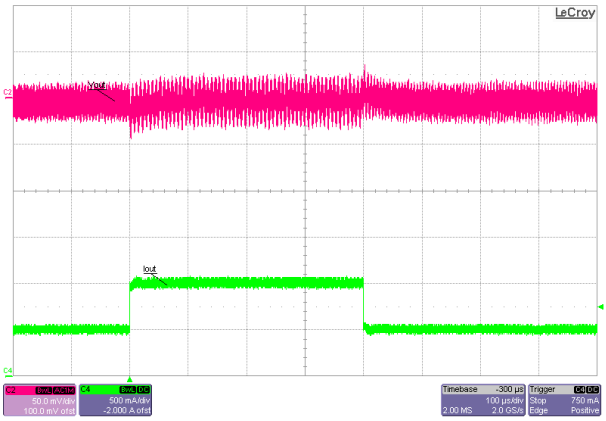


Figure 3-13. Load Transient Response, PFM-Mode

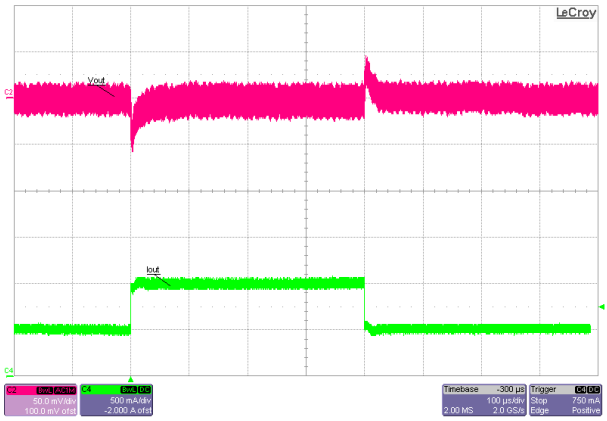


Figure 3-14. Load Transient Response, FPWM-Mode

3.4 Start-up Sequence

The following set of figures show the start-up behavior between PFM and FPWM modes at 30-V input, at no load and 1-A load conditions.

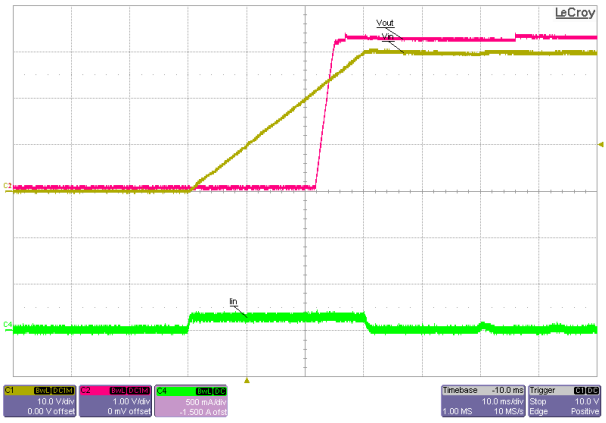


Figure 3-15. Start-up Into No Load, 30-V Input, PFM-Mode

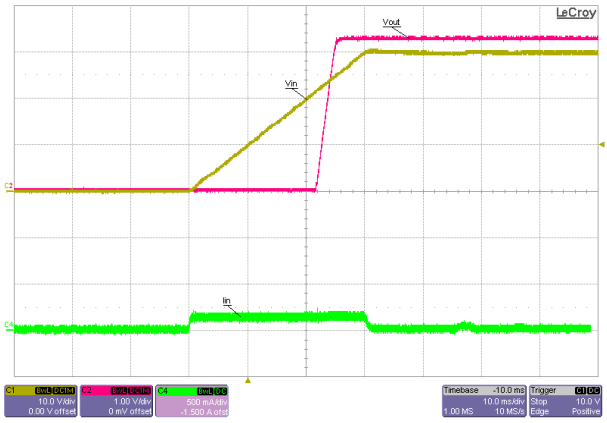


Figure 3-16. Start-up Into No Load, 30-V Input, FPWM-Mode

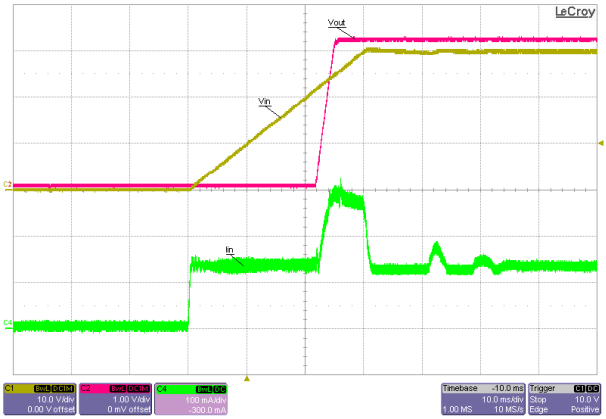


Figure 3-17. Start-up Into 1-A Constant-Current Load, 30-V Input, PFM-Mode

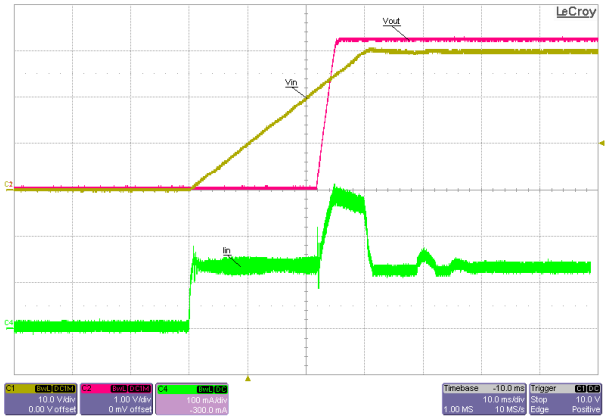


Figure 3-18. Start-up Into 1-A Constant-Current Load, 30-V Input, FPWM-Mode

3.5 Conducted EMI Performance

The following set of figures show the conducted EMI performance of the revision B PCB running at FPWM modes at 24-V, 30-V, and 36-V inputs, at 1.2-A load conditions.

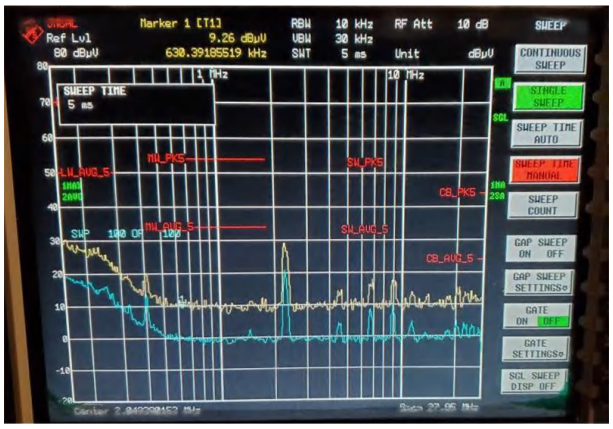


Figure 3-19. Conducted EMI Performance, 24-V Input, Low-Frequency Range

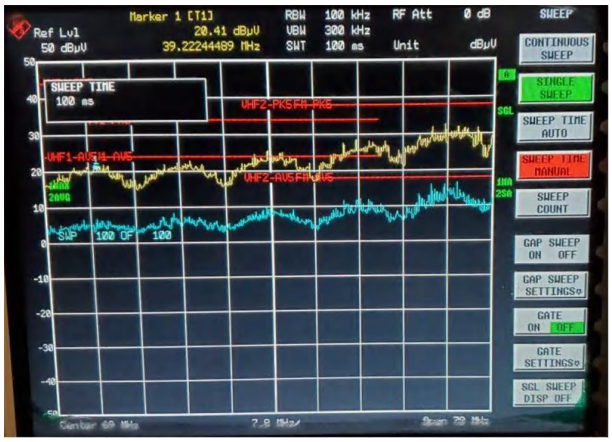


Figure 3-20. Conducted EMI Performance, 24-V Input, High-Frequency Range

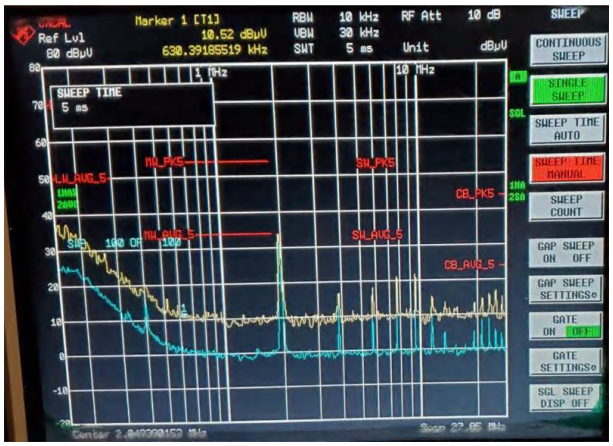


Figure 3-21. Conducted EMI Performance, 30-V Input, Low-Frequency Range

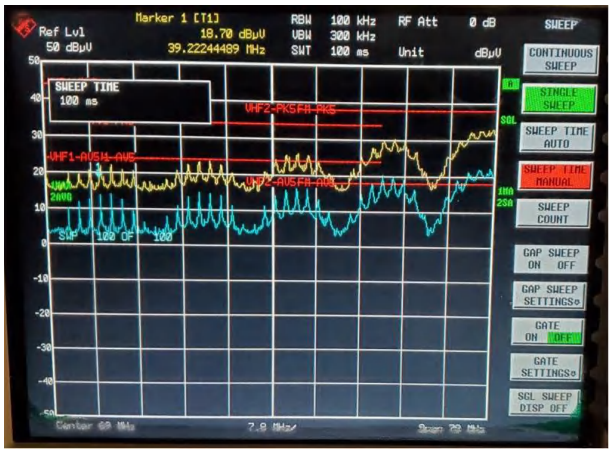


Figure 3-22. Conducted EMI Performance, 30-V Input, High-Frequency Range

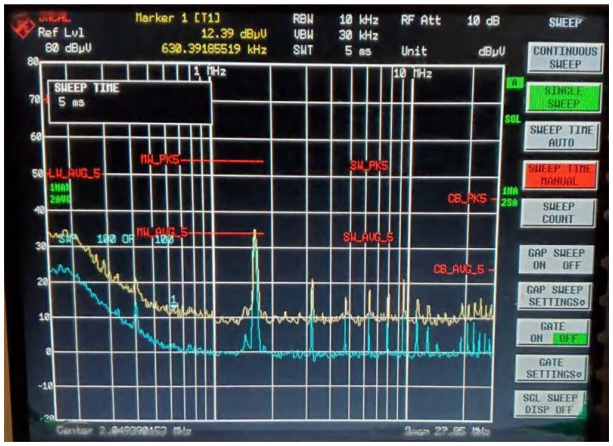


Figure 3-23. Conducted EMI Performance, 36-V Input, Low-Frequency Range

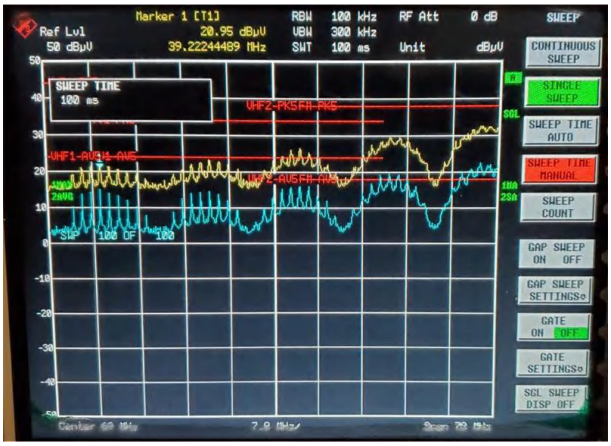


Figure 3-24. Conducted EMI Performance, 36-V Input, High-Frequency Range

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