Test Report: PMP41031

350-V to 1500-V Input 150-W Isolated Auxiliary Power Reference Design

Description

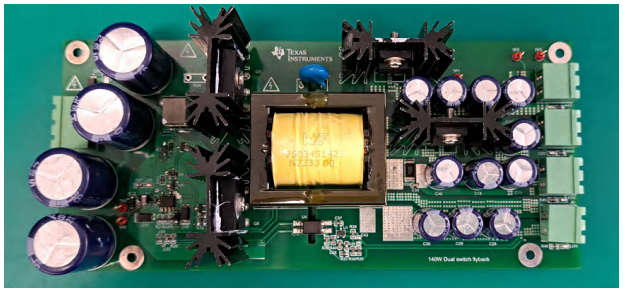
This reference design provides four isolated outputs of 24 V, 15 V, –15 V, 8 V and maximum 150-W output with two-switch flyback topology. The power supply can be powered from 350-V to 1500-V DC input. This design uses the valley switching UCC28740 flyback controller. The design achieves 89.11% efficiency at 600-V input and 86.17% efficiency at 1500-V input, full-load condition.

Features

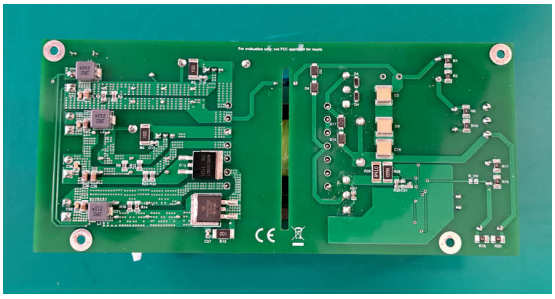
- Wide input range from 350-V to 1500-V DC
- Two-switch flyback topology recycles leakage energy
- Quasi-resonant mode controller improves efficiency
- Less voltage stress on the primary switch
- Peak efficiency of 89.11% at 600-V input and 150-W output
- 86.17% efficiency at 1500-V input and 150-W output

Applications

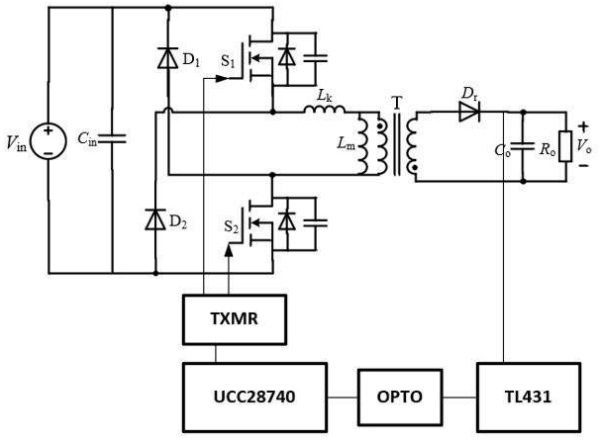
- Power conversion system (PCS)
- String inverter
- DC fast charging station



Top of Board



Bottom of Board



Block Diagram

1 Test Prerequisites

1.1 Voltage and Current Requirements

Table 1-1. Voltage and Current Requirements

Parameter	Specifications
Input voltage range	350 V to 1500 V DC
Output voltage and current	24 V at 3 A, 15 V at 3 A, –15 V at 0.8 A, 8 V at 2 A
Output power	150 W
Switching frequency	70 kHz at full load

1.2 Required Equipment

1. DC Source: IT-M3906D-1500-12
2. Chroma DC Source 62024P-600-8
3. Electronic load: Chroma, 6314A
4. Oscilloscope: Tektronix, DPO 3054
5. Infrared Thermal Camera: Fluke, TiS55
6. True-RMS-Multimeter: Fluke, 287C
7. Digital Power Meter: Yokogawa WT310

1.3 Dimensions

The board size is 176 mm × 78.3 mm × 35 mm (open frame).

2 Testing and Results

2.1 Efficiency Graphs

Efficiency is shown in the following figure.

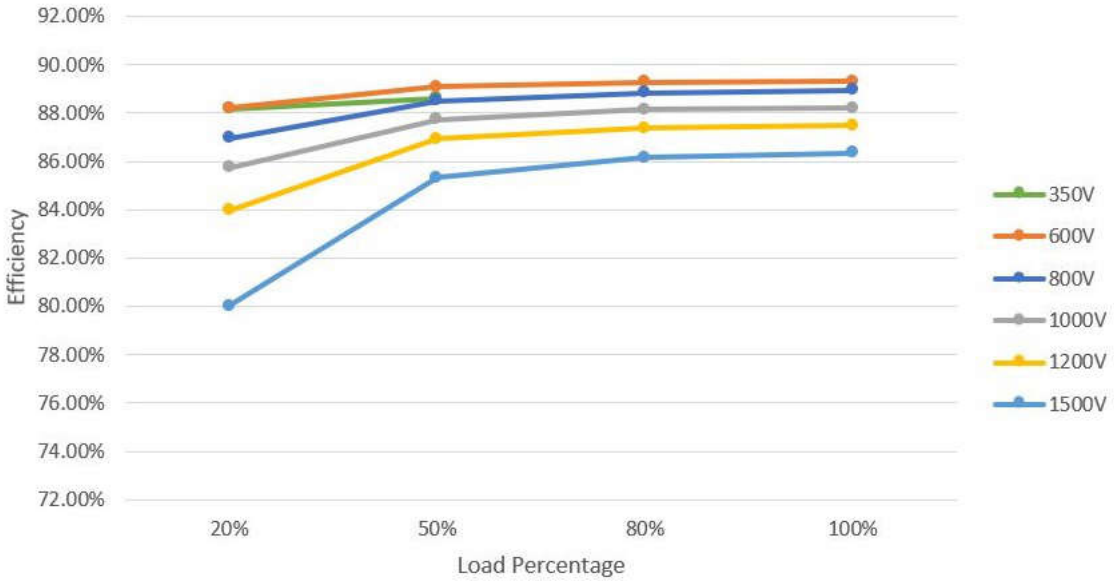


Figure 2-1. Efficiency Graph

2.2 Efficiency Data

Efficiency data is shown in the following table.

Table 2-1. PMP41031 Efficiency Data

V_{IN} (V)	Load Percentage	V_{O1}(V)	I_{O1}(A)	V_{O2}(V)	I_{O2}(A)	V_{O3}(V)	I_{O3}(A)	V_{O4}(V)	I_{O4}(A)	P_{OUT} (W)	P_{IN} (W)	Efficiency (%)
350	0%	24.030	0.000	16.245	0.000	–15.910	0.000	8.328	0.000	0.000.	0.454	
350	20%	24.020	0.600	16.040	0.594	–16.120	0.159	8.130	0.398	29.734	34.060	87.3%
350	50%	24.000	1.500	15.980	1.493	–16.110	0.398	8.100	0.996	74.328	84.226	88.25%
600	0%	24.020	0.000	16.155	0.000	–15.740	0.000	8.240	0.000	0.000	0.556	
600	20%	24.020	0.600	16.050	0.594	–16.130	0.159	8.150	0.398	29.750	34.068	87.33%
600	50%	24.020	1.500	16.010	1.493	–16.060	0.398	8.110	0.996	74.393	83.856	88.71%
600	80%	24.010	2.400	16.010	2.389	–16.050	0.638	8.110	1.594	119.037	133.662	89.06%
600	100%	24.010	3.000	16.000	2.989	–16.060	0.798	8.120	1.992	148.842	167.028	89.11%
800	0%	24.020	0.000	16.252	0.000	–15.887	0.000	8.452	0.000	0.000	0.666	
800	20%	24.020	0.600	16.030	0.594	–16.140	0.159	8.130	0.398	29.732	34.537	86.09%
800	50%	24.006	1.500	16.010	1.493	–16.060	0.398	8.110	0.996	74.363	84.368	88.14%
800	80%	24.010	2.400	16.000	2.389	–16.070	0.638	8.120	1.594	119.042	134.328	88.62%
800	100%	24.010	3.000	16.010	2.989	–16.070	0.798	8.110	1.992	148.860	167.712	88.76%
1000	0%	24.020	0.000	16.217	0.000	–15.850	0.000	8.443	0.000	0.000	0.779	
1000	20%	24.020	0.600	16.030	0.594	–16.140	0.159	8.130	0.398	29.732	35.027	84.88%
1000	50%	24.000	1.500	16.010	1.493	–16.060	0.398	8.110	0.996	74.363	85.120	87.36%
1000	80%	24.010	2.400	16.000	2.389	–16.070	0.638	8.120	1.594	119.042	135.390	87.92&
1000	100%	24.010	3.000	16.020	2.989	–16.080	0.798	8.110	1.992	148.898	169.160	88.02%
1200	0%	24.020	0.000	16.167	0.000	–15.767	0.000	8.338	0.000	0.000	0.928	
1200	20%	24.010	0.600	16.030	0.594	–16.140	0.159	8.120	0.398	29.722	35.758	83.12%
1200	50%	23.980	1.500	16.010	1.493	–16.060	0.398	8.110	0.996	74.333	85.848	86.59%
1200	80%	23.980	2.400	15.980	2.389	–16.050	0.638	8.100	1.594	118.877	136.392	87.16%
1200	100%	23.980	3.000	16.010	2.989	–16.060	0.781	8.100	1.992	148.467	170.076	87.29%
1500	0%	24.020	0.000	16.252	0.000	–15.872	0.000	8.462	0.000	0.000	1.251	
1500	20%	24.010	0.600	16.050	0.594	–16.130	0.159	8.150	0.398	29.744	37.551	79.21%
1500	50%	23.980	1.500	16.010	1.493	–16.060	0.398	8.110	0.996	74.333	87.465	84.99%
1500	80%	23.980	2.400	15.980	2.389	–16.050	0.638	8.100	1.594	118.877	138.330	85.94%
1500	100%	23.990	3.000	16.010	2.989	–16.060	0.781	8.100	1.992	148.497	172.335	86.17%

2.3 Thermal Images

Table 2-2 shows the thermal images at the four voltages. All images were captured with 25ºC ambient, after a 30-minute warm up and with an airflow of 200 LFM.

Table 2-2. Thermal Image Data

	Temperature (°C)			
	600 V_{IN}	800 V_{IN}	1000 V_{IN}	1500 V_{IN}
High-side switch Q1	46.3	47.3	49.4	55.4
Low-side switch Q2	42.4	43.5	43.2	47.3
Transformer	52.2 winding 52.4 Core	55.2 winding 54.3 core	59.2 winding 55.2 Core	62.3 winding, 58.2 Core
Secondary diode (24 V)	50.5	52.1	53.1	55.2
Secondary diode (15 V)	47.2	48.5	49.3	53.2
Secondary diode (–15 V)	41.4	42.3	44.6	45.6
Secondary diode (8 V)	46.2	47.2	48.5	50.3
UCC28740	34.5.	36.1	39.2	41.2

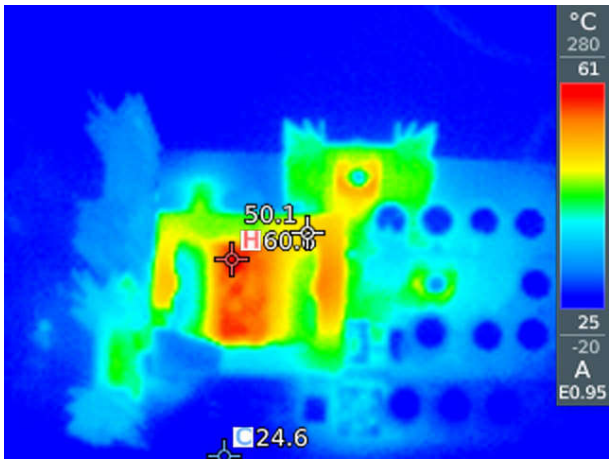


Figure 2-2. Thermal Image at 1500 V_{IN} Full Load

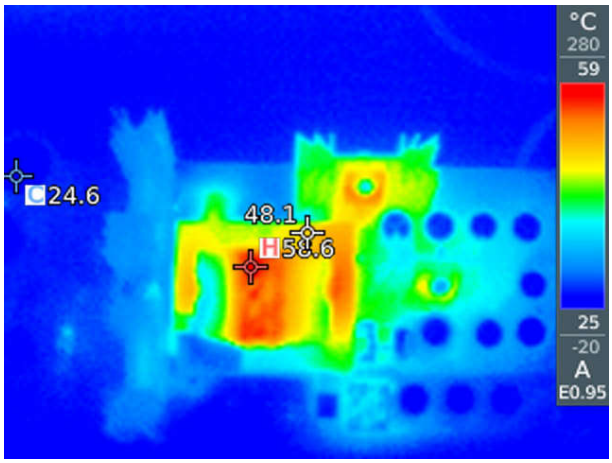


Figure 2-3. Thermal Image at 1000 V_{IN} Full Load

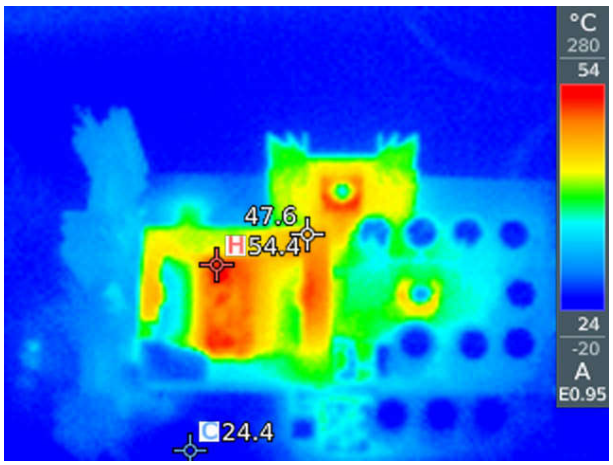


Figure 2-4. Thermal Image at 800 V_{IN} Full Load

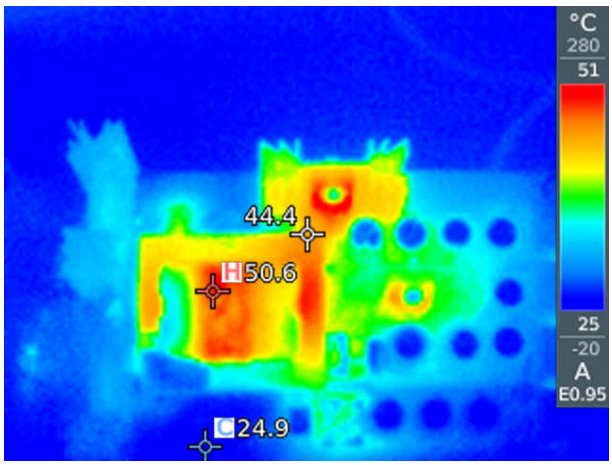


Figure 2-5. Thermal Image at 600 V_{IN} Full Load

3 Waveforms

3.1 Switching

Switching behavior is shown in the following figures.

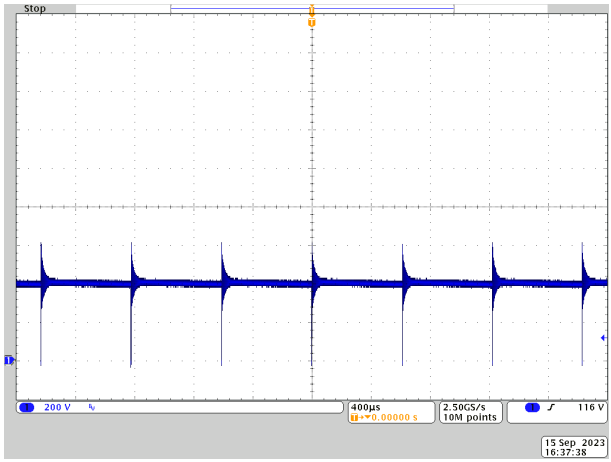


Figure 3-1. V_{DS} of Low-Side Switch at 600 V_{IN}, 0-A Load

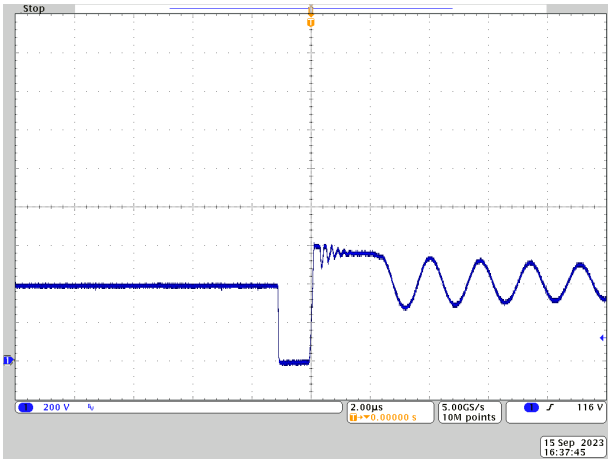


Figure 3-2. V_{DS} of Low-Side Switch Zoom at 600 V_{IN}, 0-A Load

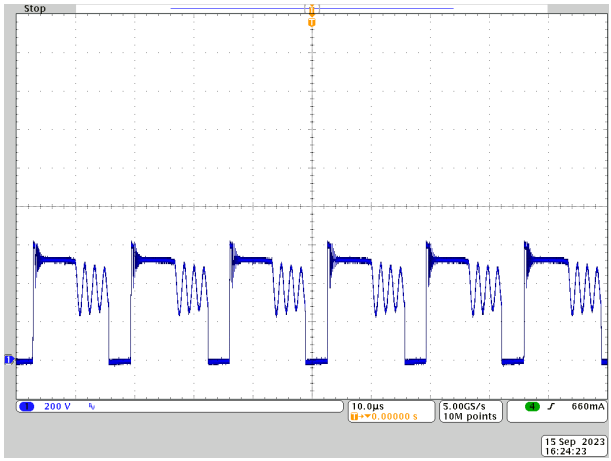
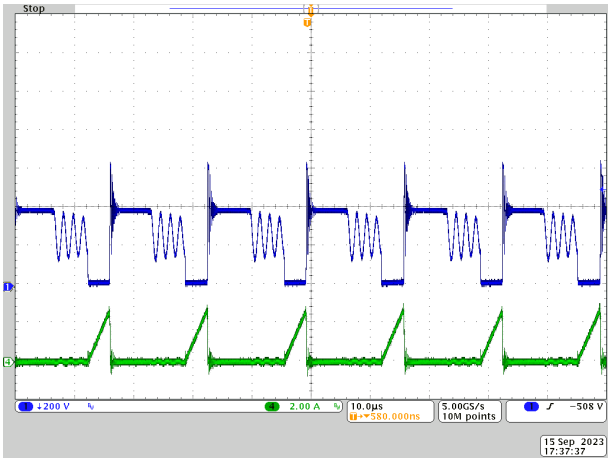


Figure 3-3. V_{DS} of Low-Side Switch Zoom at 600 V_{IN}, Full Load



CH1: V_{DS} of High-Side Switch at 600 V_{IN}, Full Load
CH4: Primary Current

Figure 3-4. High-Side Switch at 600 V_{IN}, Full Load

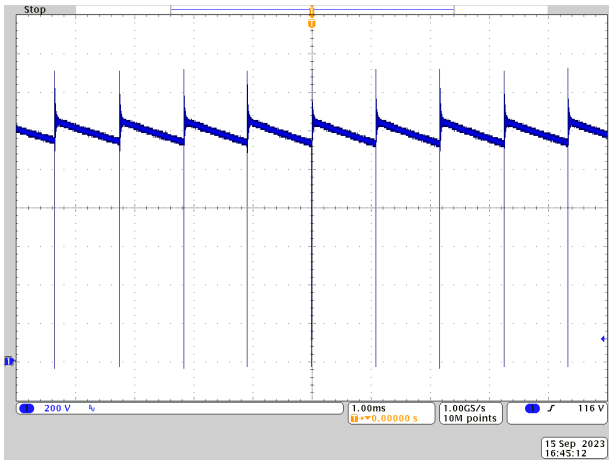


Figure 3-5. V_{DS} of Low-Side Switch at 1500 V_{IN}, 0-A Load

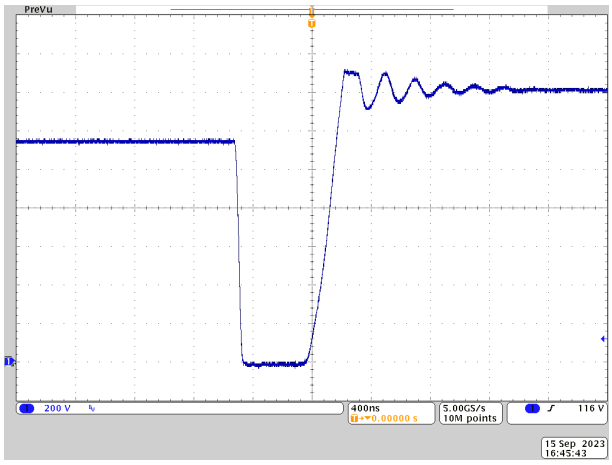
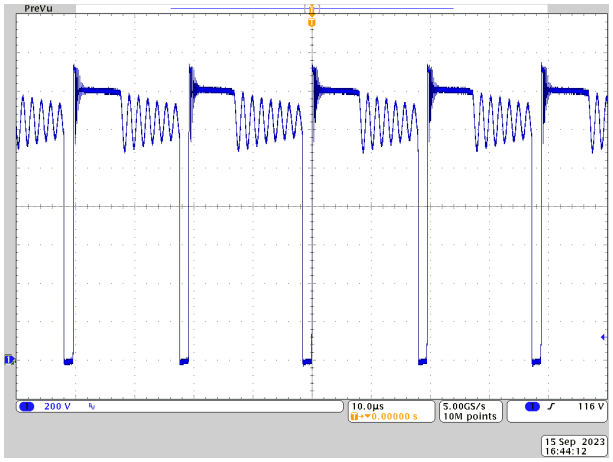
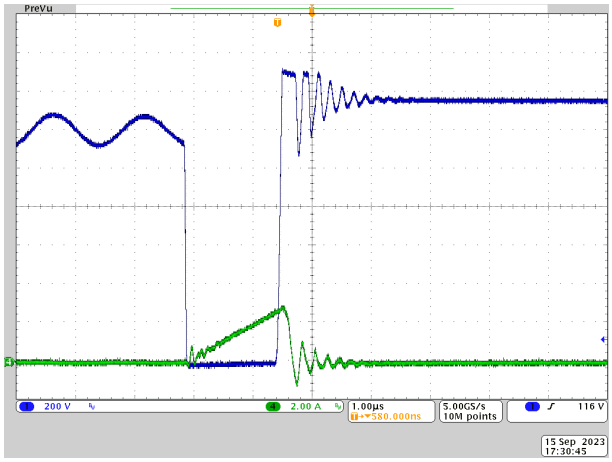


Figure 3-6. V_{DS} of Low-Side Switch Zoom at 1500 V_{IN}, 0-A Load



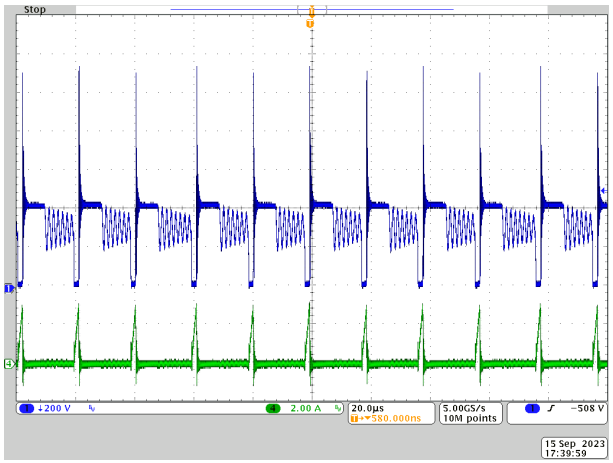
CH1: V_{DS} of Low-Side Switch at 1500 V_{IN} Full Load

Figure 3-7. V_{DS} of Low-Side Switch at 1500 V_{IN}, Full Load



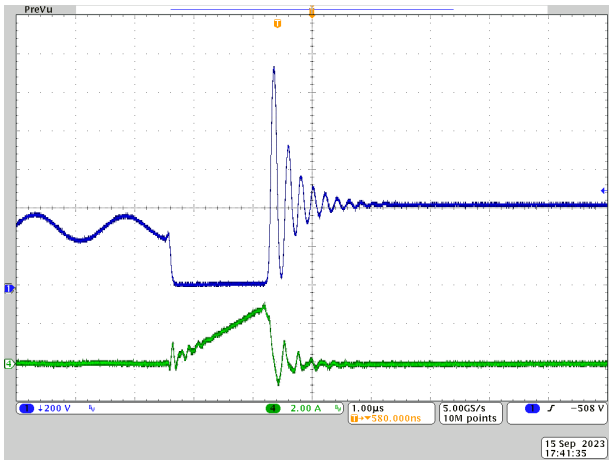
CH1: V_{DS} of Low-Side Switch Zoom at 1500 V_{IN}, Full Load
CH4: Primary current

Figure 3-8. V_{DS} of Low-Side Switch Zoom at 1500 V_{IN}, Full Load



CH1: V_{DS} of High-Side Switch at 1500 V_{IN}, Full Load
CH4: Primary current

Figure 3-9. V_{DS} of High-Side Switch at 1500 V_{IN}, Full Load



CH1: V_{DS} of High-Side Switch Zoom at 1500 V_{IN}, Full Load,
CH4: Primary current

Figure 3-10. V_{DS} of High-Side Switch Zoom at 1500 V_{IN}, Full Load

3.2 Output Voltage Ripple

Output voltage ripple is shown in the following figures.

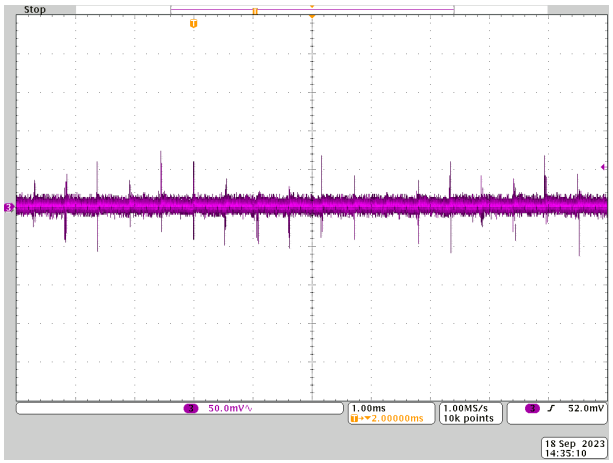


Figure 3-11. 24-V Output Voltage Ripple at 600 V_{IN}, 0-A Load, Other Channel Open Load

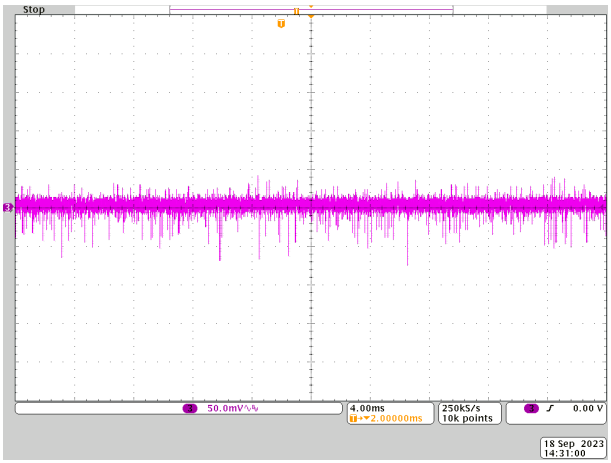


Figure 3-12. 24-V Output Voltage Ripple at 600 V_{IN}, Full Load, Other Channel Full Load

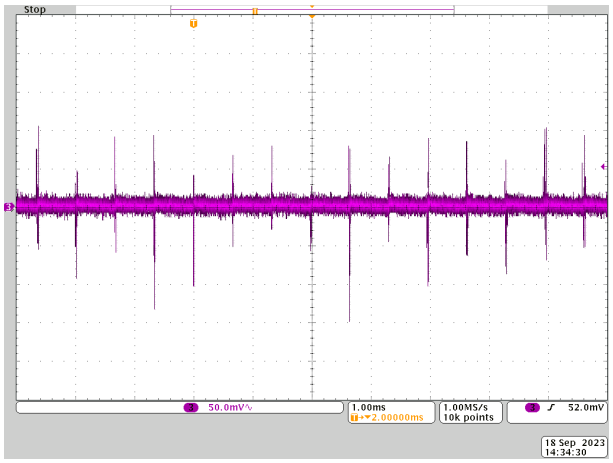


Figure 3-13. 24-V Output Voltage Ripple at 1500 V_{IN}, 0-A Load, Other Channel Open Load

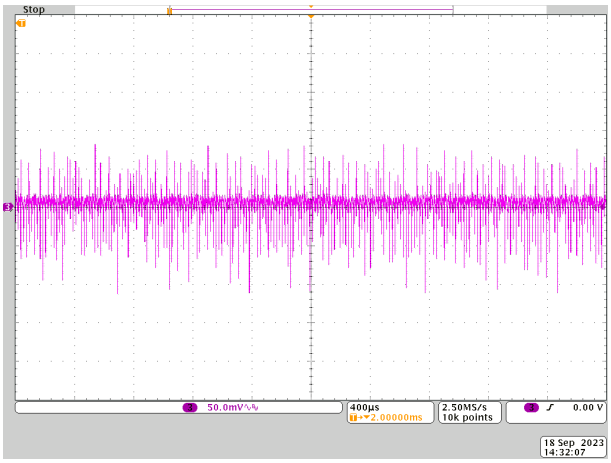
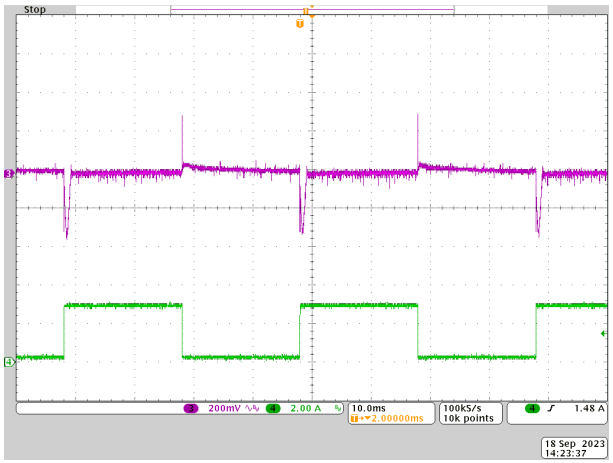


Figure 3-14. 24-V Output Voltage Ripple at 1500 V_{IN}, Full Load, Other Channel Full Load

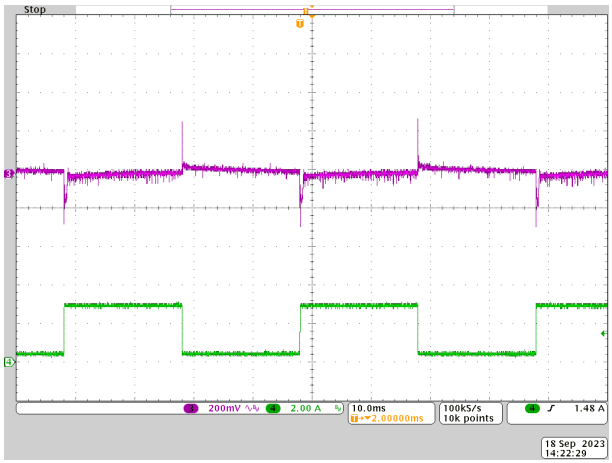
3.3 Load Transients

Load transient response waveforms are shown in the following figures.



CH3: 24-V output voltage, CH4: output load current

Figure 3-15. 24-V Output Load Transient From 0.5 A to 3 A at 600 V_{IN}, Other Channel Full Load

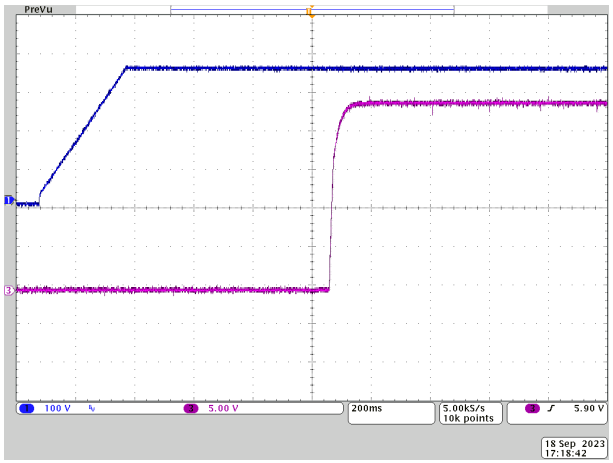


CH3: 24-V output voltage, CH4: 24-V output current

Figure 3-16. 24-V Output Load Transient From 0.5 A to 3 A at 1500 V_{IN}, Other Channel Full Load

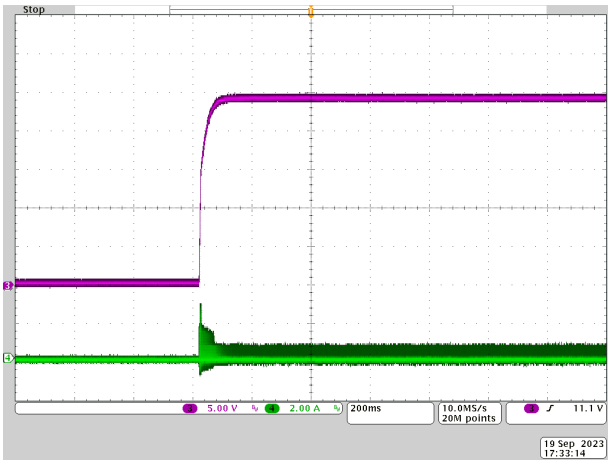
3.4 Start-Up and Power-Down Sequence

Start-up behavior is shown in the following figures.



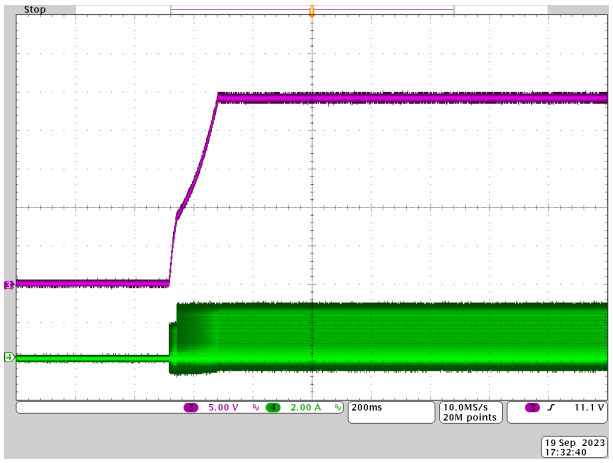
CH1: V_{IN}, CH3: 24-V output voltage

Figure 3-17. Start-Up Waveform at 350 V_{IN}, Half Load



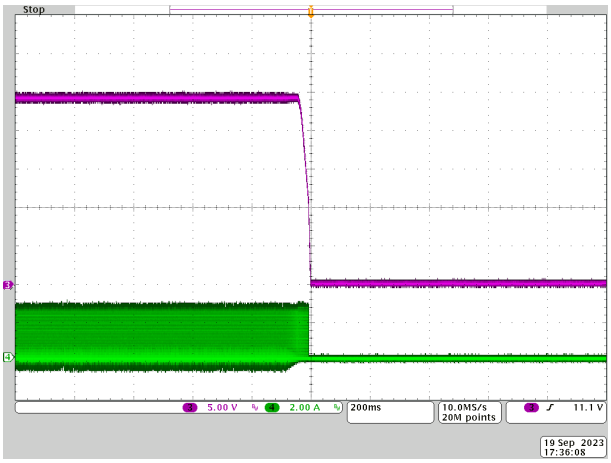
CH3: 24-V output voltage, CH4: primary current

Figure 3-18. Start-Up Waveform at 600 V_{IN}, Open Load



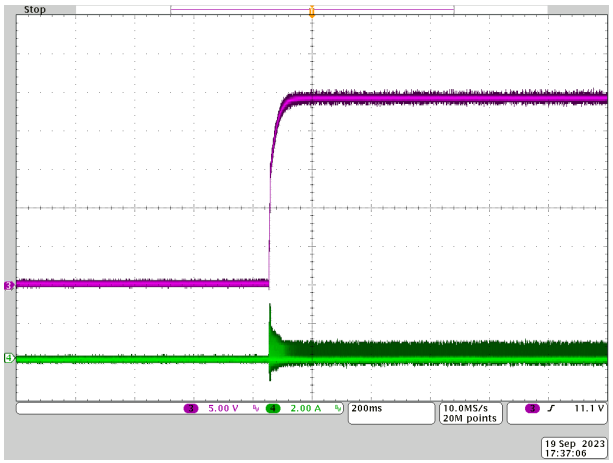
CH3: 24-V output voltage, CH4: primary current

Figure 3-19. Start-Up Waveform at 600 V_{IN}, Full Load



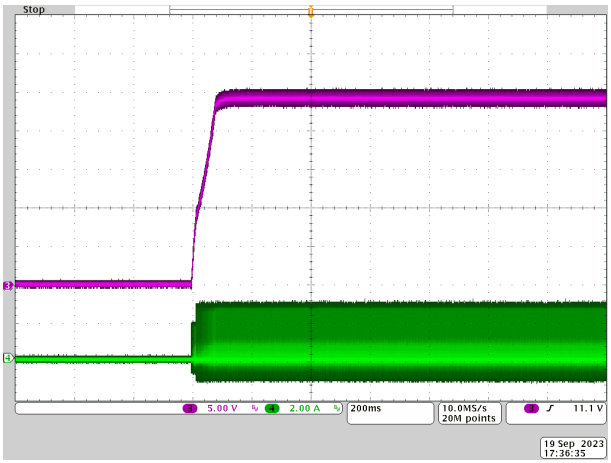
CH3: 24-V output voltage, CH4: primary current

Figure 3-20. Power-Down Waveform at V_{IN} = 600 V, Full Load



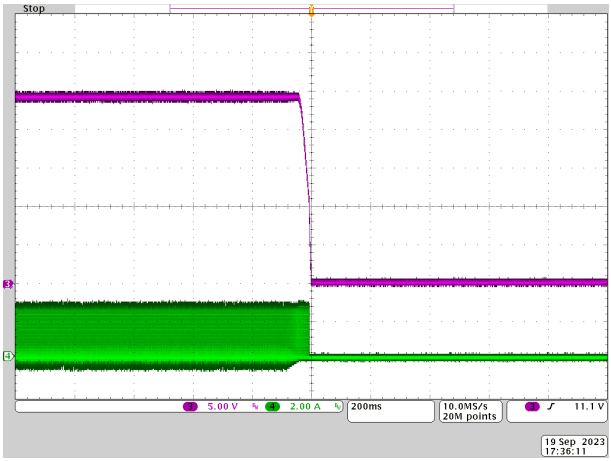
CH3: 24-V output voltage, CH4: primary current

Figure 3-21. Start-Up Waveform at 1500 V_{IN}, Open Load



CH3: 24-V output voltage, CH4: primary current

Figure 3-22. Start-Up Waveform at 1500 V_{IN}, Full Load

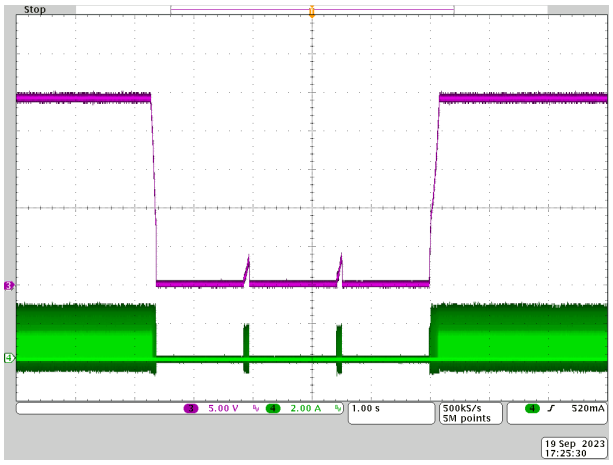


CH3: 24-V output voltage, CH4: primary current

Figure 3-23. Power Down at 1500 V_{IN}, Full Load

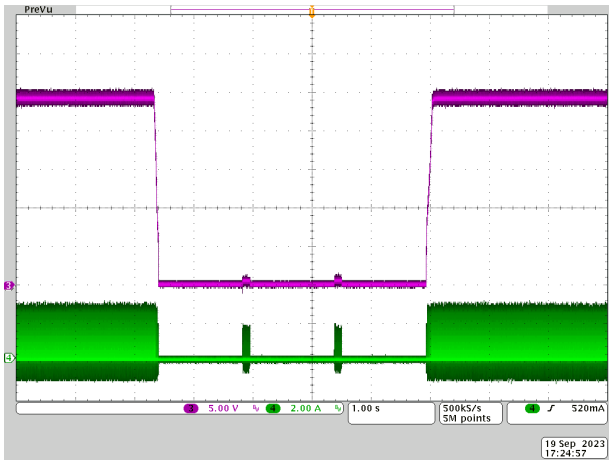
3.5 Overcurrent Protection

Overcurrent protection (OCP) is shown in the following figures. The overcurrent protection was performed at the electrical load end.



CH3: 24-V output voltage, CH4: primary current

Figure 3-24. OCP at 600 V_{IN}

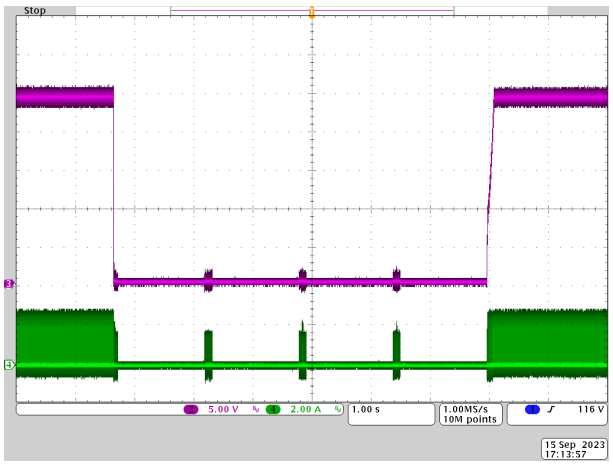


CH3: 24-V output voltage, CH4: primary current

Figure 3-25. OCP at 1500 V_{IN}

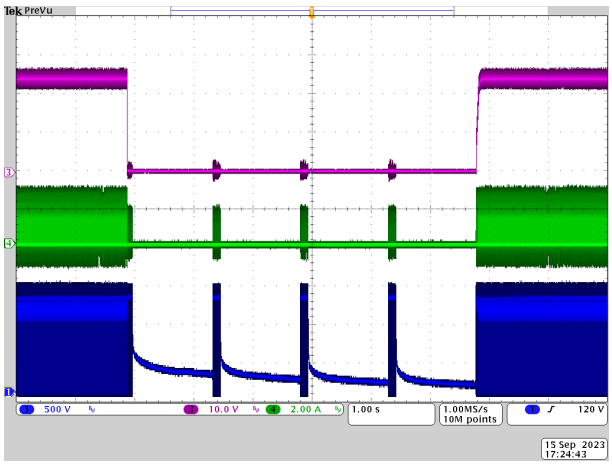
3.6 Short-Circuit Protection

Short-circuit protection (SCP) is shown in the following figures. The short-circuit test was performed at the PCB end.



CH3: 24-V output voltage, CH4: primary current

Figure 3-26. SCP at 600 V_{IN}



CH3: 24-V output voltage, CH4: primary current,
CH1: V_{DS} of low-side switch

Figure 3-27. SCP at 1500 V_{IN}

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