Test Report: PMP22606

Universal AC Input, 390-V, 1-kW CCM Boost Power Factor Regulator Reference Design

Description

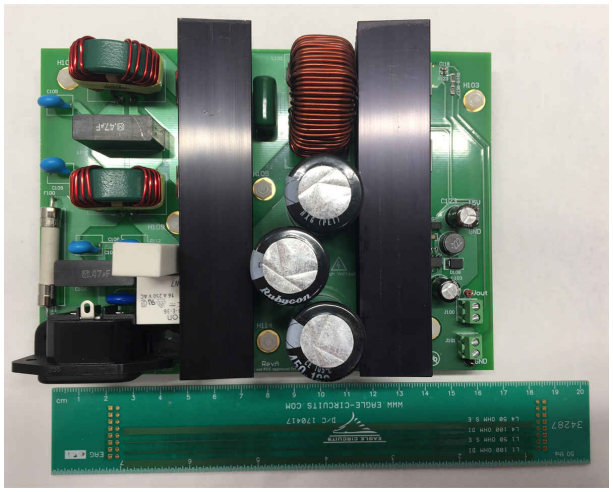
This reference design uses the UCC28180 continuous conduction mode (CCM) power factor correction (PFC) controller to generate a 390-V, 1-kW output from a universal AC input. Additionally, the UCC28880 converter is used as bias supply in this design. Over 95% peak efficiency is achieved at 120-V_{AC}, 60-Hz input and over 97% efficiency is achieved at 230-V_{AC}, 50-Hz input.

Features

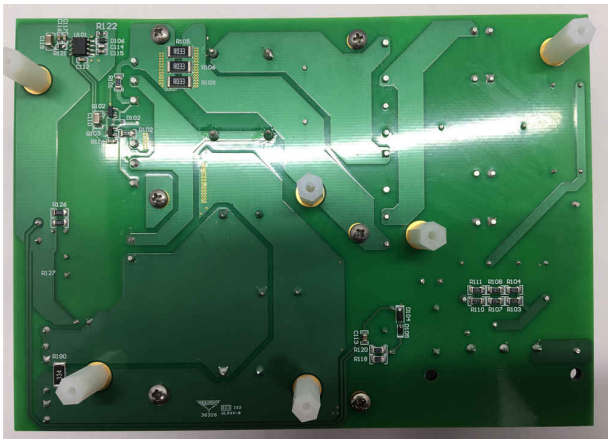
- Continuous conduction mode boost power factor regulator
- 130-kHz switching frequency
- 95% peak efficiency at 120 VAC, 60 Hz
- 97% peak efficiency at 230 VAC, 50 Hz
- Conduction EMI test result included

Applications

- Appliances: battery charger
- Industrial AC-DC



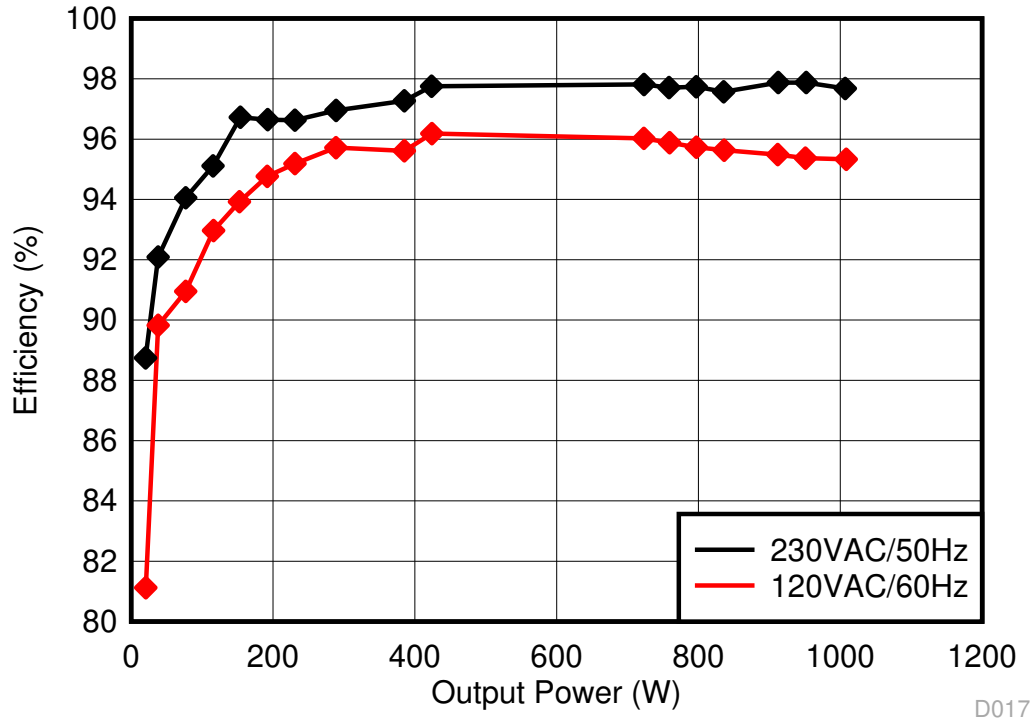
Top Board Photo



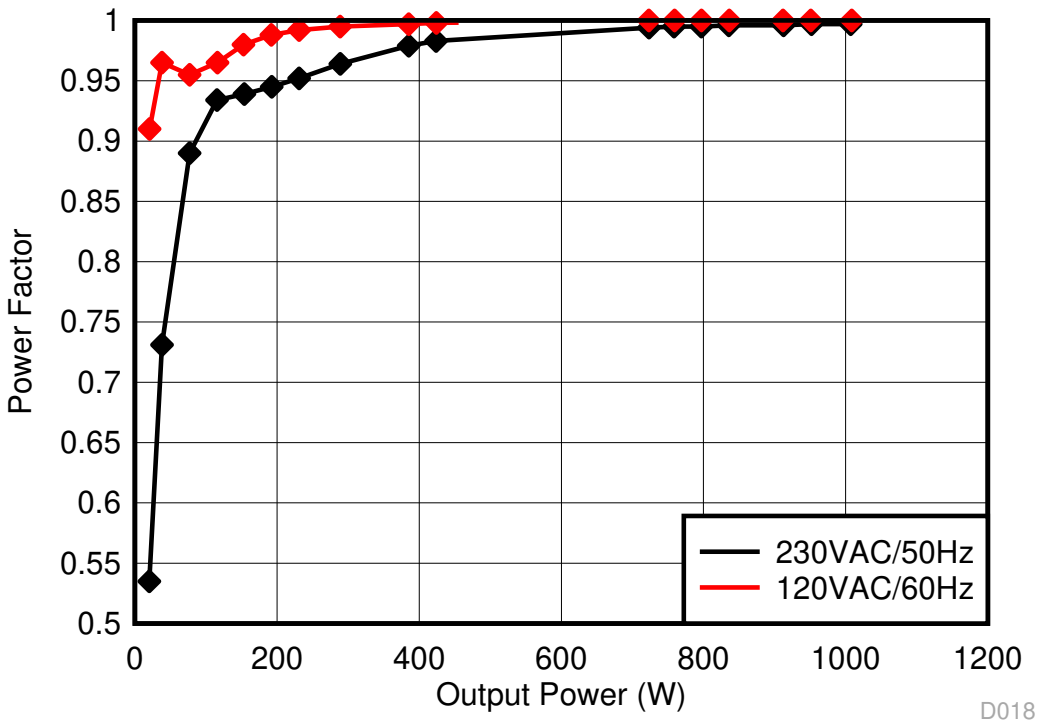
Bottom Board Photo

1 Efficiency and Power Factor

The efficiency curves of total supply are shown in the following tables and graphs. Efficiency tests are performed with natural airflow.



Efficiency



Power Factor

1.1 Graph Results

Vin,rms(V	Iin,rms(A)	Pin(W)	P.F.	Vout(V)	Iout(A)	Pout(W)	Losses(W)	Eff. (%)
119.3	8.877	1058	1	385.55	2.616	1008.599	49.4012	95.3307
119.4	8.359	997.2	1	385.5	2.467	951.0285	46.1715	95.36989
119.4	8.003	955	1	385.41	2.366	911.8801	43.11994	95.48482
119.5	7.323	874.4	1	385.18	2.171	836.2258	38.17422	95.63424
119.5	6.97	832.6	1	385.05	2.07	797.0535	35.5465	95.73066
119.4	6.635	791.9	1	384.84	1.973	759.2893	32.61068	95.88197
119.5	6.307	753.1	1	384.66	1.88	723.1608	29.9392	96.02454
119.8	3.691	441	0.998	385.6	1.1	424.16	16.84	96.18141
119.8	3.372	402.9	0.997	385.6	0.999	385.2144	17.6856	95.61042
119.9	2.528	301.7	0.995	385.04	0.75	288.78	12.92	95.7176
119.9	2.041	242.7	0.992	385.04	0.6	231.024	11.676	95.18912
119.9	1.711	202.7	0.988	384.95	0.499	192.0901	10.60995	94.76569
120	1.383	162.7	0.98	384.92	0.397	152.8132	9.88676	93.92332
120	1.08	125	0.965	384.8	0.302	116.2096	8.7904	92.96768
120.1	0.737	84.6	0.955	384.73	0.2	76.946	7.654	90.95272
120.1	0.366	42.4	0.965	384.7	0.099	38.0853	4.3147	89.82382
120.1	0.234	25.6	0.91	384.58	0.054	20.76732	4.83268	81.12234

Figure 1-1. 120 V_{AC}, 60 Hz

Vin,rms(V	Iin,rms(A)	Pin(W)	P.F.	Vout(V)	Iout(A)	Pout(W)	Losses(W)	Eff. (%)
229.6	4.505	1031	0.997	385.41	2.613	1007.076	23.92367	97.67957
229.6	4.25	972.6	0.997	385.4	2.47	951.938	20.662	97.87559
229.7	4.075	932.5	0.996	385.1	2.37	912.687	19.813	97.87528
229.7	3.744	856.5	0.996	385.1	2.17	835.667	20.833	97.56766
229.7	3.566	815.4	0.995	385	2.07	796.95	18.45	97.73731
229.8	3.397	776.3	0.995	385.03	1.97	758.5091	17.7909	97.70824
229.8	3.236	739.4	0.994	384.69	1.88	723.2172	16.1828	97.81136
229.9	1.918	433.5	0.983	385.24	1.1	423.764	9.736	97.75409
230	1.759	396	0.979	385.2	1	385.2	10.8	97.27273
230	1.344	298	0.964	385.22	0.75	288.915	9.085	96.95134
230	1.092	239.2	0.952	385.22	0.6	231.132	8.068	96.62709
230.1	0.917	199.3	0.945	385.23	0.5	192.615	6.685	96.64576
230.1	0.737	159.3	0.939	385.2	0.4	154.08	5.22	96.72316
230.1	0.565	121.5	0.934	385.2	0.3	115.56	5.94	95.11111
230.1	0.4	81.9	0.89	385.16	0.2	77.032	4.868	94.05617
230.1	0.244	41.4	0.731	385.1	0.099	38.1249	3.2751	92.08913
230.1	0.185	23	0.535	385.1	0.053	20.4103	2.5897	88.74043

Figure 1-2. 230 V_{AC}, 50 Hz

2 Thermal Images

The thermal images in this section show top and bottom views of the board. All images were taken after 20 minutes of operation.

2.1 Thermal Test With Natural Convection (120 V_{AC}, 60 Hz, 384 V at 1.88-A Output)

Measurements		
Bx1	Max	73.7 °C
Bx2	Max	86.1 °C
Bx3	Max	83.4 °C
Bx4	Max	52.2 °C
Sp1		23.2 °C

Parameters	
Emissivity	0.94
Refl. temp.	20 °C

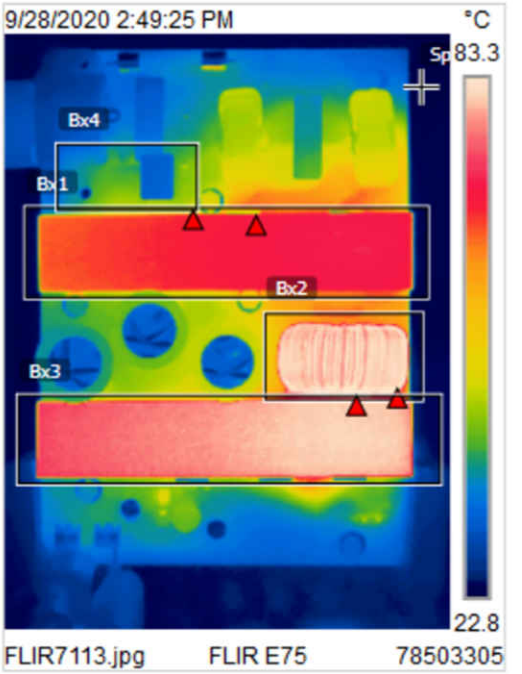


Figure 2-1. Top of the Board

Measurements		
Bx1	Max	91.3 °C
	Min	24.4 °C
	Average	54.8 °C
Sp1		25.2 °C

Parameters	
Emissivity	0.94
Refl. temp.	20 °C

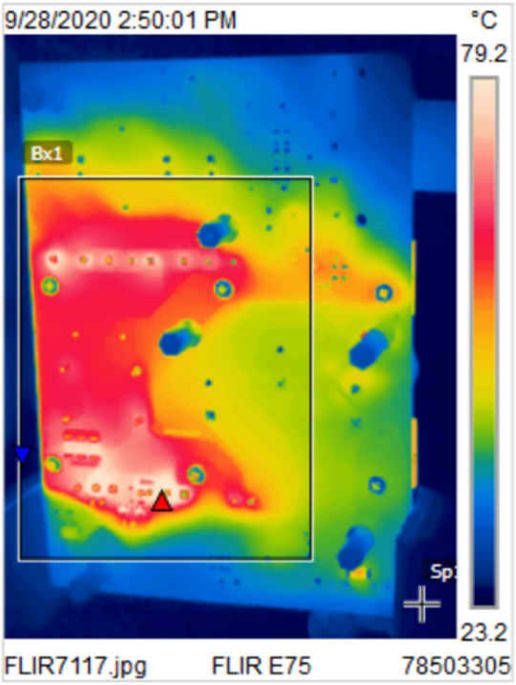


Figure 2-2. Bottom of the Board

2.2 Thermal Test With Forced Air Flow (120 V_{AC}, 60 Hz, 385 V at 2.6-A Output)

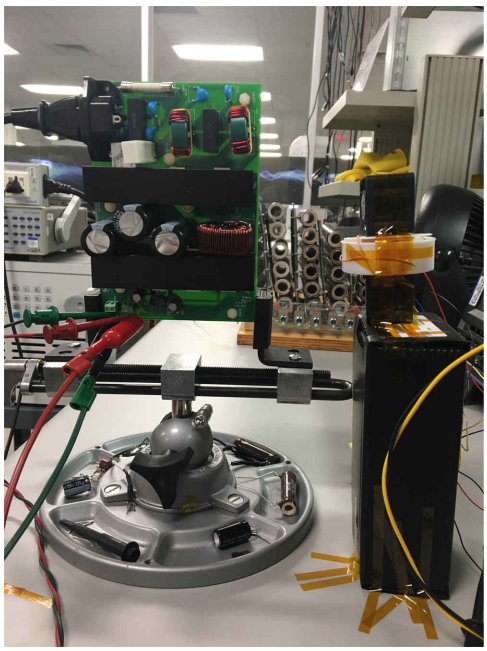


Figure 2-3. Test Setup (Around 4.5 W Electrical Power per fan, 2 fans in total)

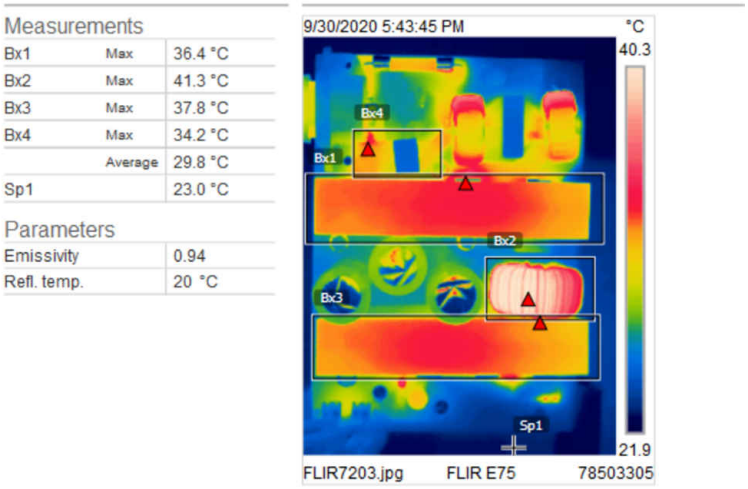


Figure 2-4. Top of the Board

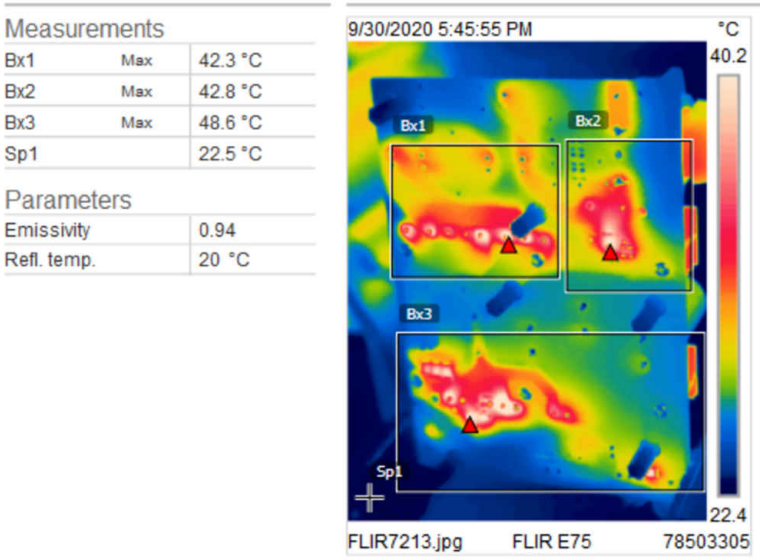


Figure 2-5. Bottom of the Board

2.3 Thermal Test With Natural Convection (230 V_{AC}, 50 Hz, 385 V at 2.6-A output)

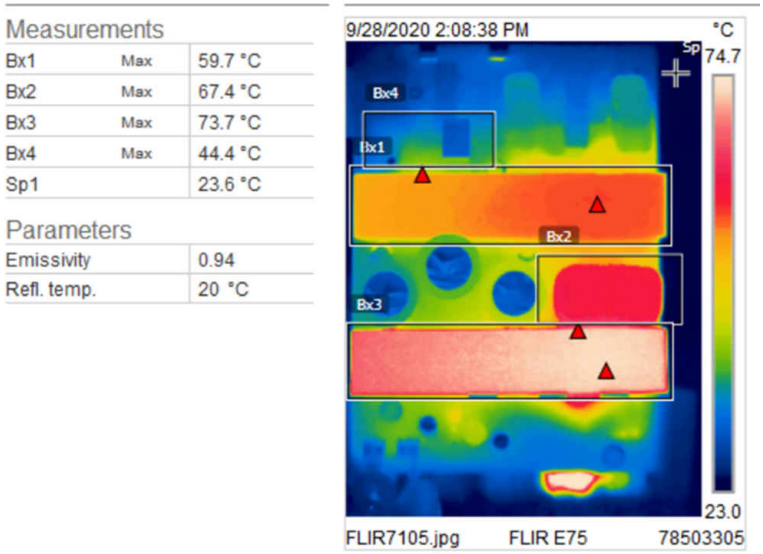


Figure 2-6. Top of the Board

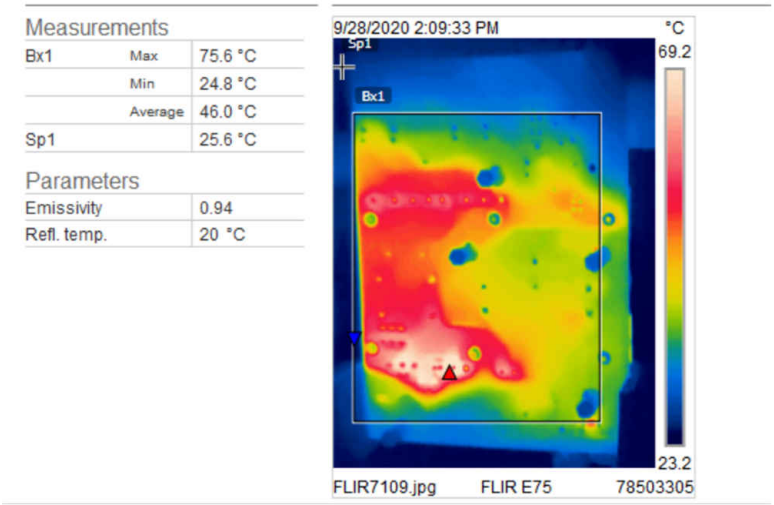
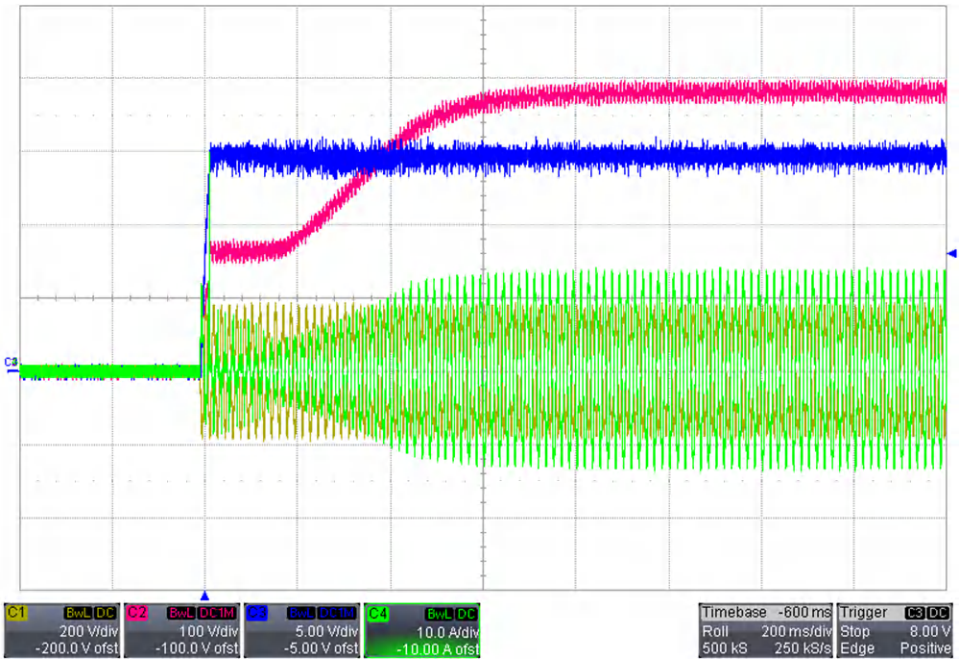


Figure 2-7. Bottom of the Board

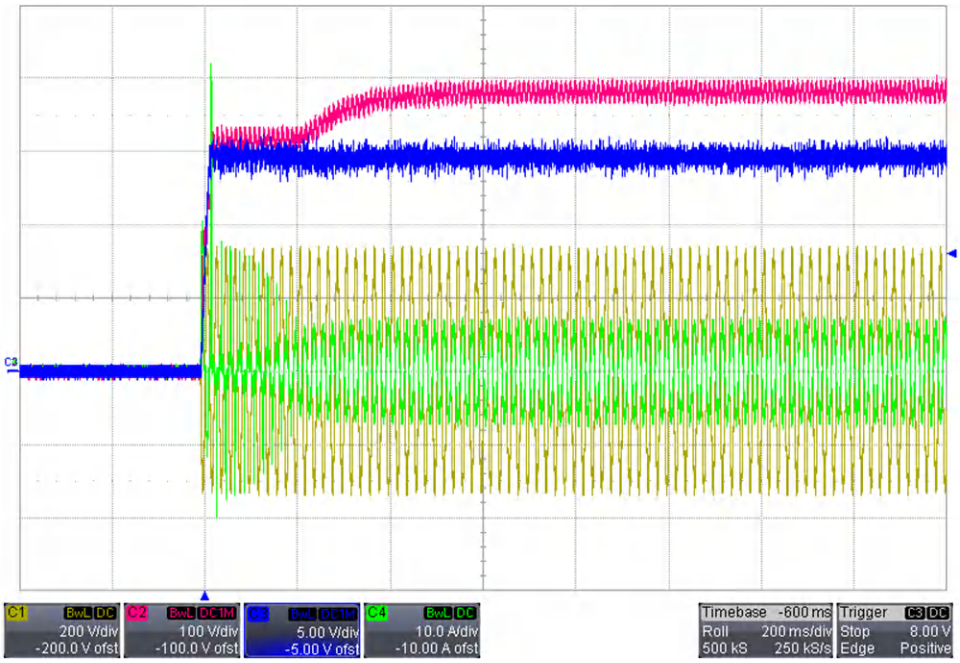
3 Start-up

The voltages and current at start-up are shown at the following images. TI recommends start-up at low load (< 300 W) but not at no load.



C1 = V_{IN}, C2 = V_{OUT}, C3 = 15-V Bias, C4 = I_{IN}

Figure 3-1. 120 V_{AC}, 60 Hz – Full Load on J100

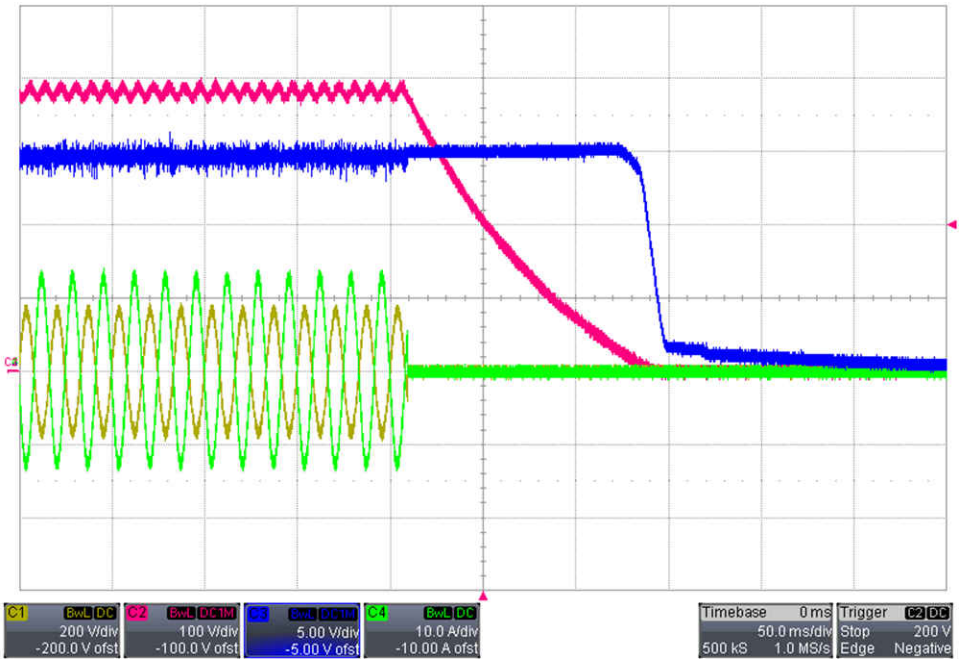


C1 = V_{IN}, C2 = V_{OUT}, C3 = 15-V Bias, C4 = I_{IN}

Figure 3-2. 230 V_{AC}, 50 Hz – Full Load on J100

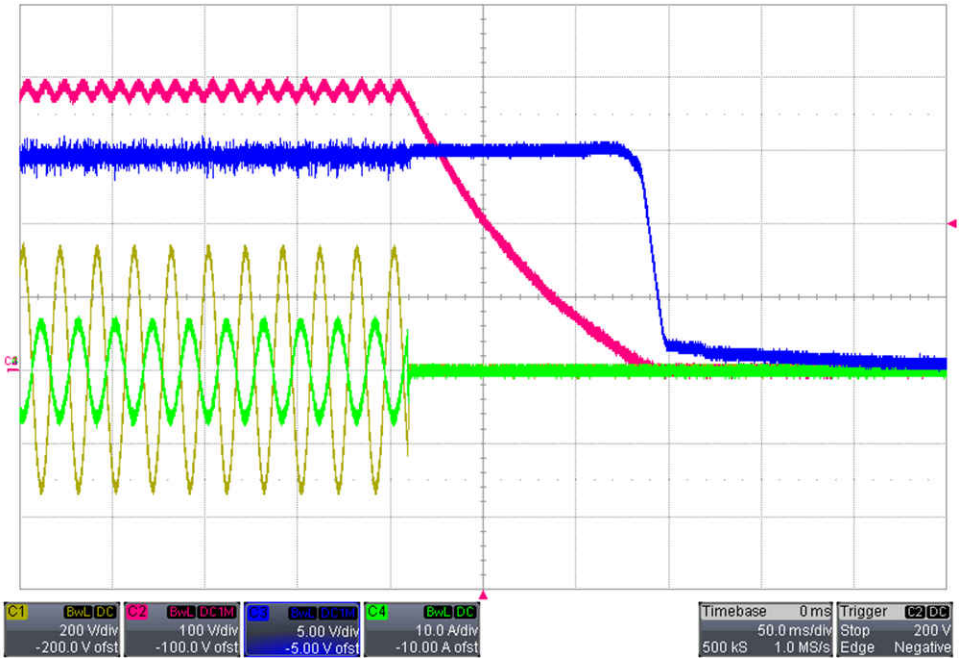
4 Turn-off

The voltage and current at turn-off are illustrated in the following images.



C1 = V_{IN}, C2 = V_{OUT}, C3 = 15-V Bias, C4 = I_{IN}

Figure 4-1. 120 V_{AC}, 60 Hz – Full Load on J100

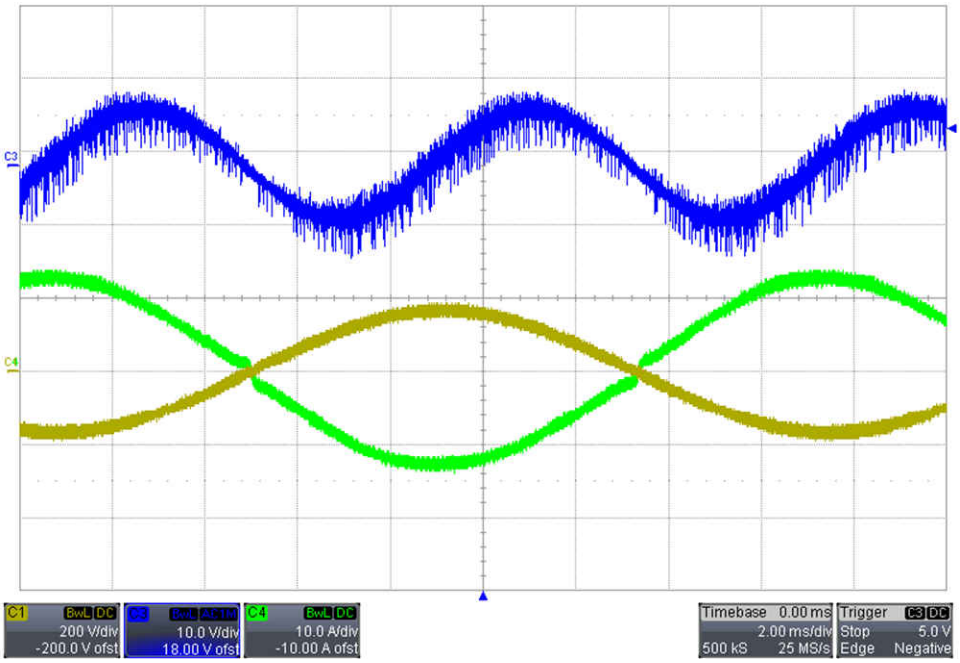


C1 = V_{IN}, C2 = V_{OUT}, C3 = 15-V Bias, C4 = I_{IN}

Figure 4-2. 230 V_{AC}, 50 Hz – Full Load on J100

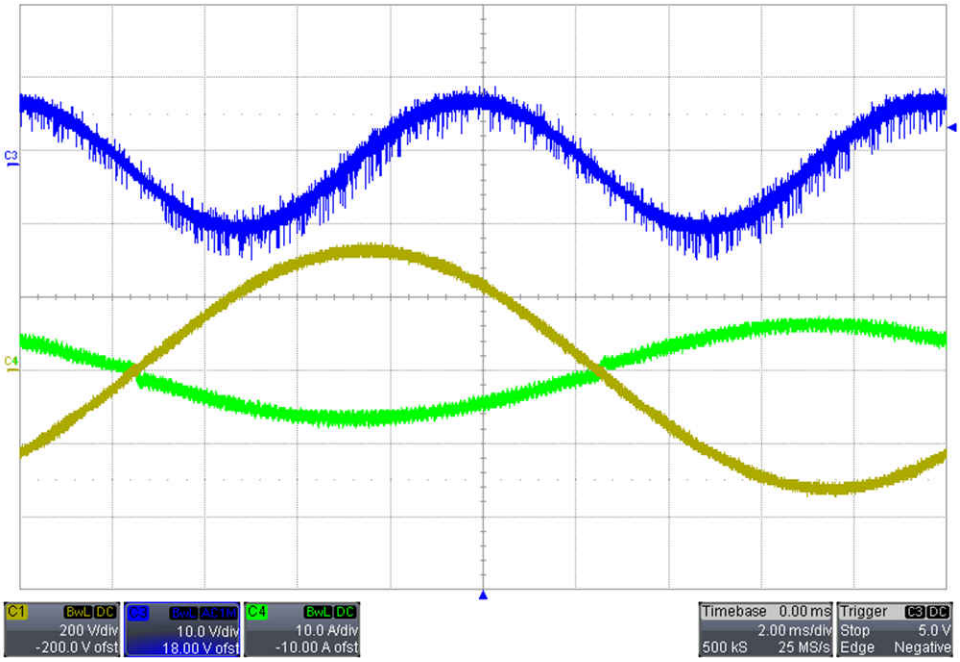
5 Output Voltage Ripple

This section illustrates the AC-coupled output voltage ripple waveforms for C103.



C1 = V_{IN}, C3 = V_{OUT}, C4 = I_{IN}

Figure 5-1. 120 V_{AC}, 60 Hz – Full Load on J100

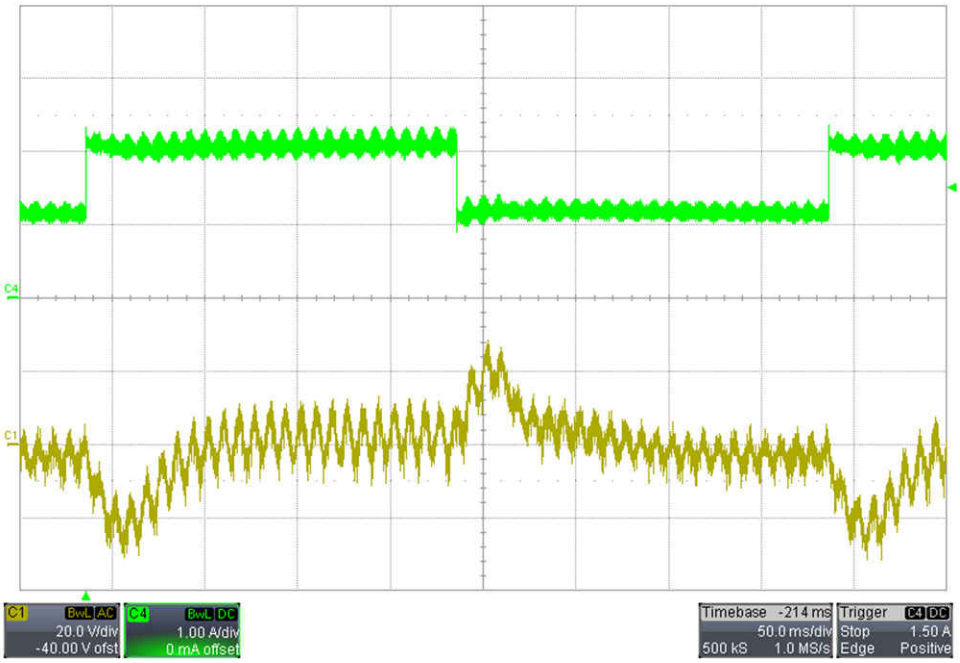


C1 = V_{IN}, C3 = V_{OUT}, C4 = I_{IN}

Figure 5-2. 230 V_{AC}, 50 Hz – Full Load on J100

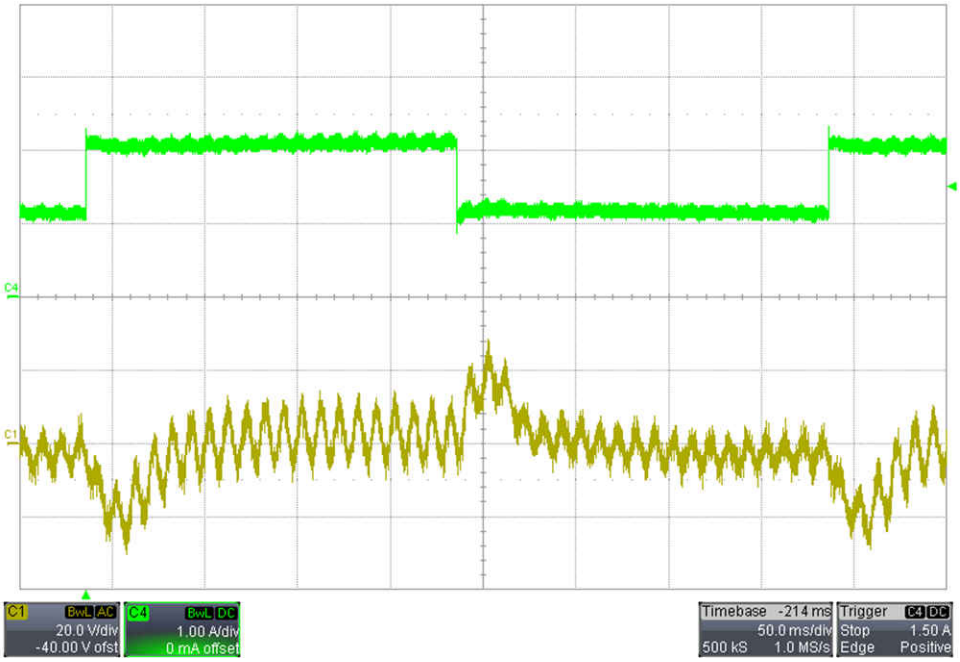
6 Transient Response

The following waveforms illustrate the transient response for this reference design.



C1 = V_{OUT}, C4 = I_{OUT}

Figure 6-1. 120 V_{AC}, 60 Hz – 1.1-A to 2.1-A Load Transient

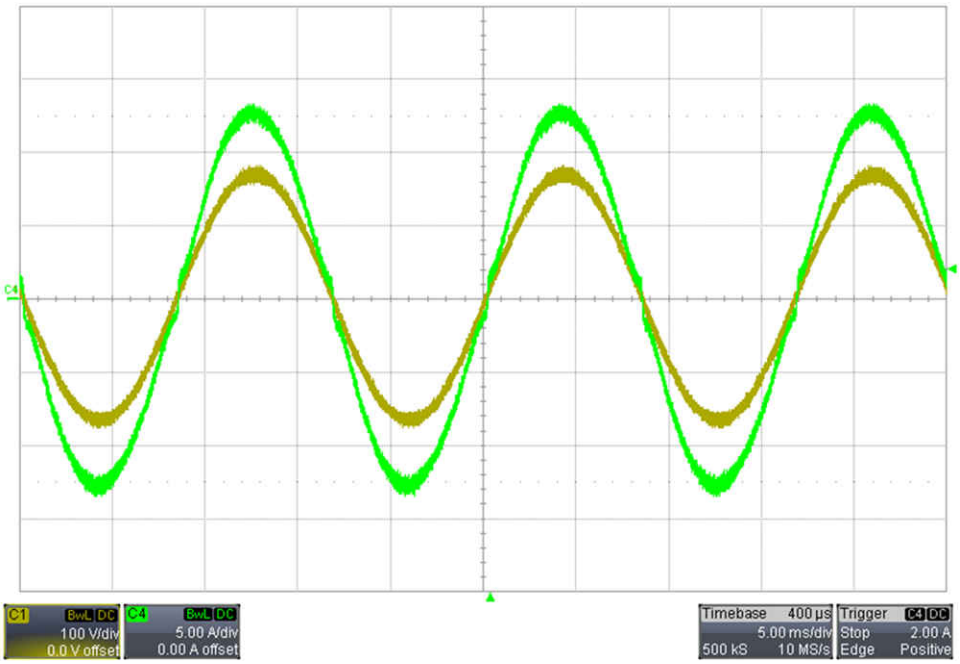


C1 = V_{OUT}, C4 = I_{OUT}

Figure 6-2. 230 V_{AC}, 50 Hz – 1.1-A to 2.1-A Load Transient

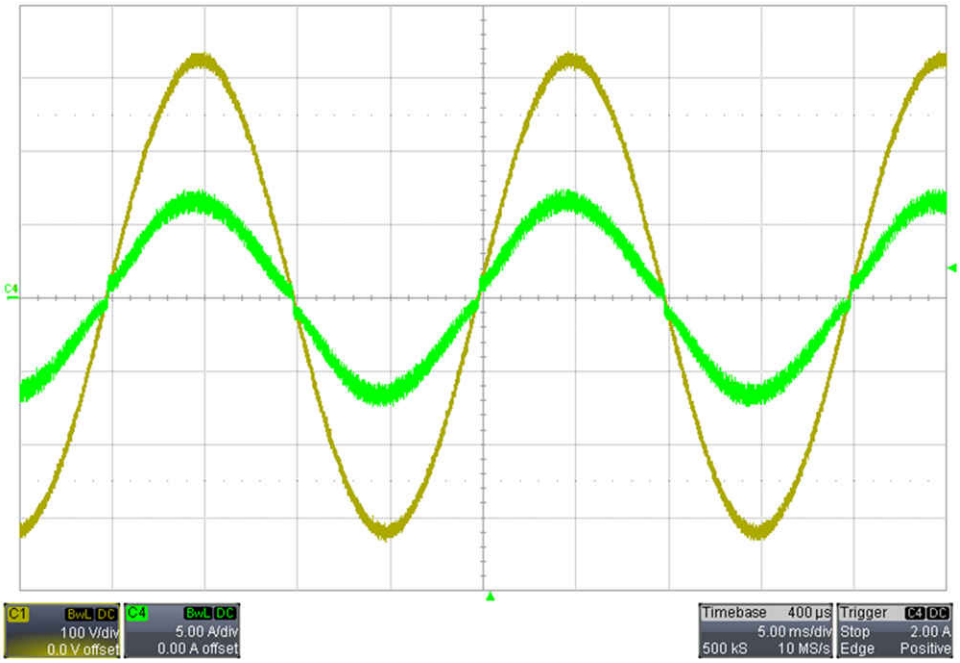
7 Key Waveform

The following images illustrate the key waveforms for this reference design.



C1 = V_{IN}, C4 = I_{IN}

Figure 7-1. 120 V_{AC}, 60 Hz, 1000 W



C1 = V_{IN}, C4 = I_{IN}

Figure 7-2. 230 V_{AC}, 50 Hz, 1000 W

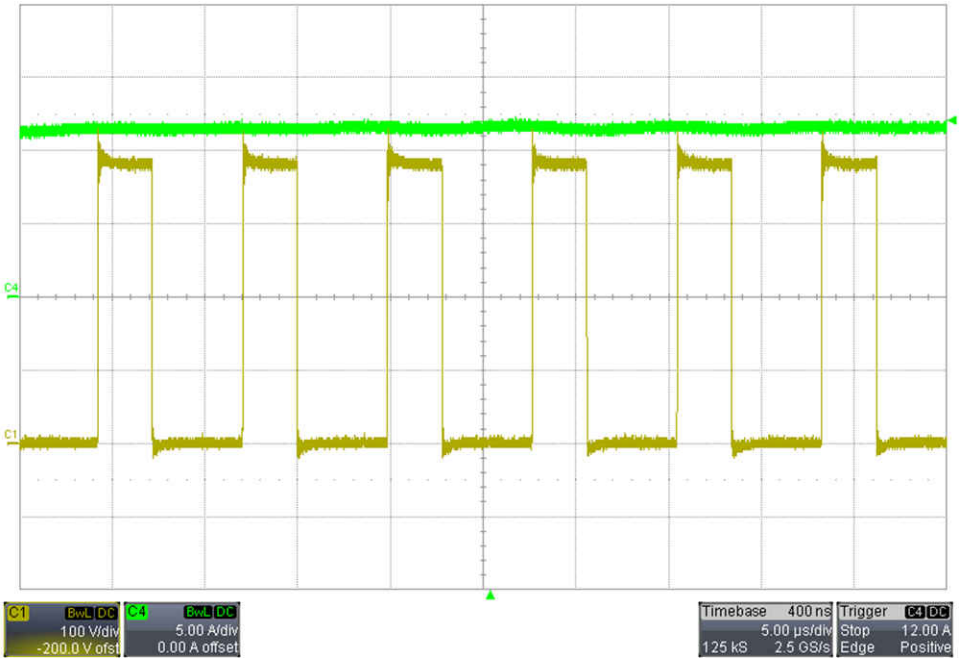
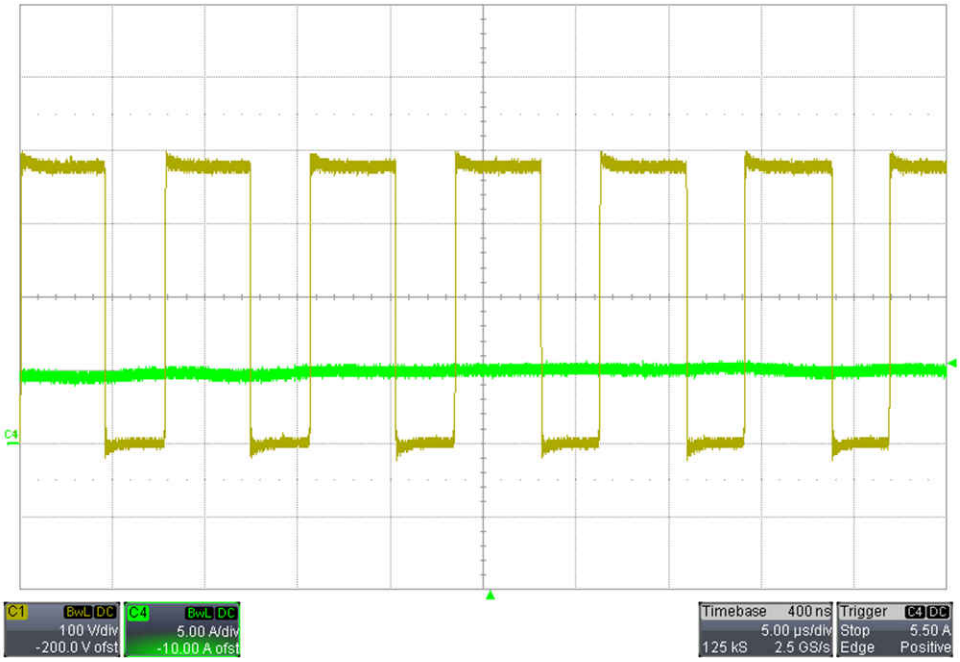


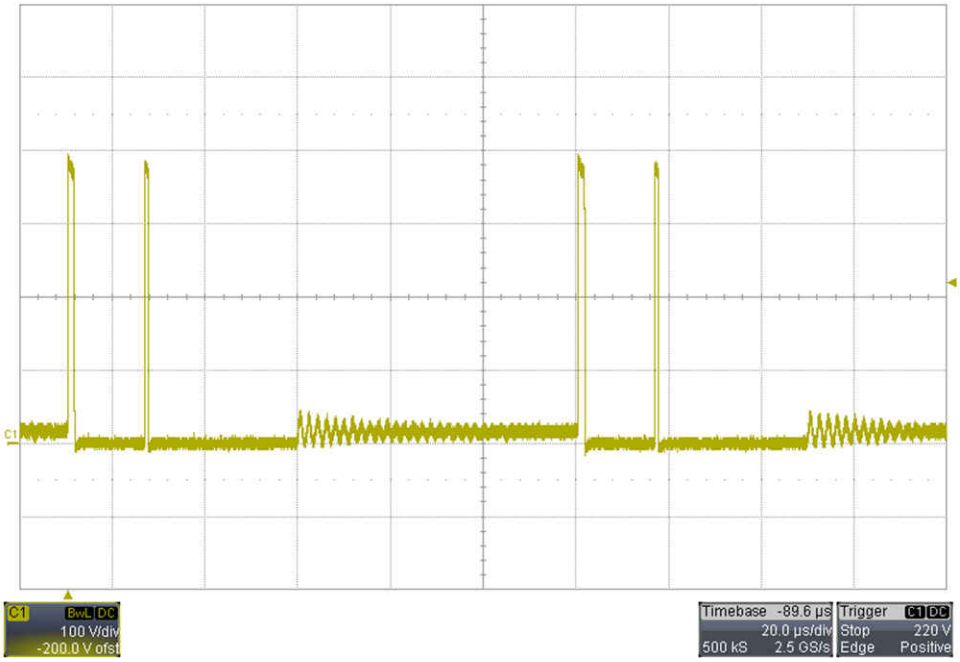
Figure 7-3. Q100 at 1000 W From J100, 120 V_{AC}, 60 Hz

C1 = V_{DS}, C4 = I_{IN}



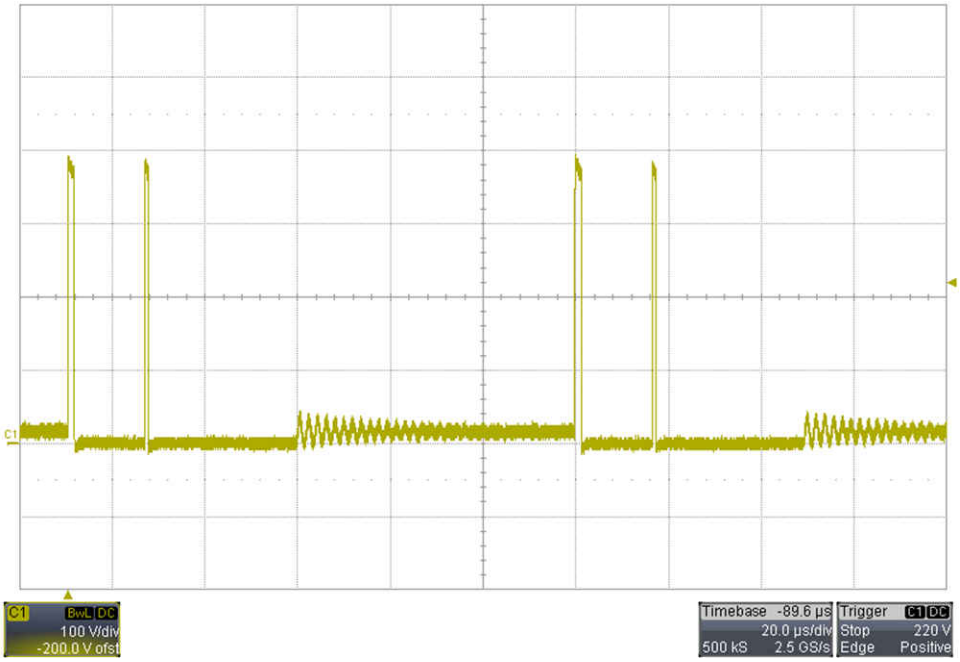
C1 = V_{DS}, C4 = I_{IN}

Figure 7-4. Q100 at 1000 W From J100, 230 V_{AC}, 50 Hz



C1 = D108 Voltage

Figure 7-5. D108 at 1000 W From J100, 120 V_{AC}, 60 Hz



C1 = D108 Voltage

Figure 7-6. D108 at 1000 W From J100, 230 V_{AC}, 50 Hz

8 Conducted Emission

The conducted emission graphs are illustrated in the following images.

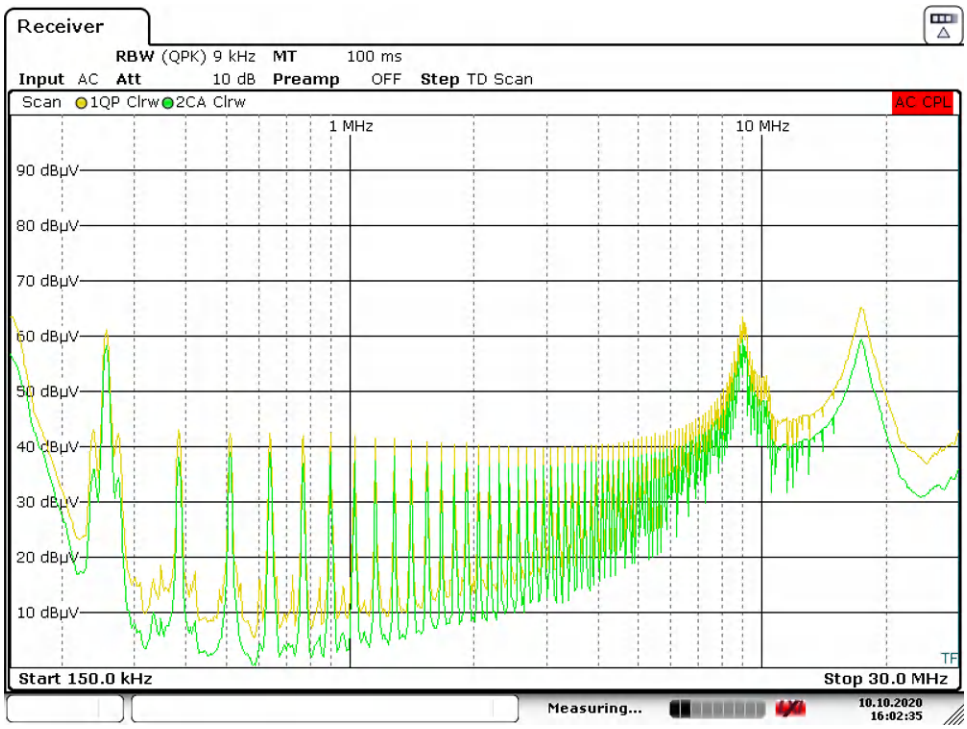


Figure 8-1. 120 V_{AC}, 60-Hz Input at Around 0.85-A Output, Line (Trace 1 = Quasi-Peak, Trace 2 = Average)

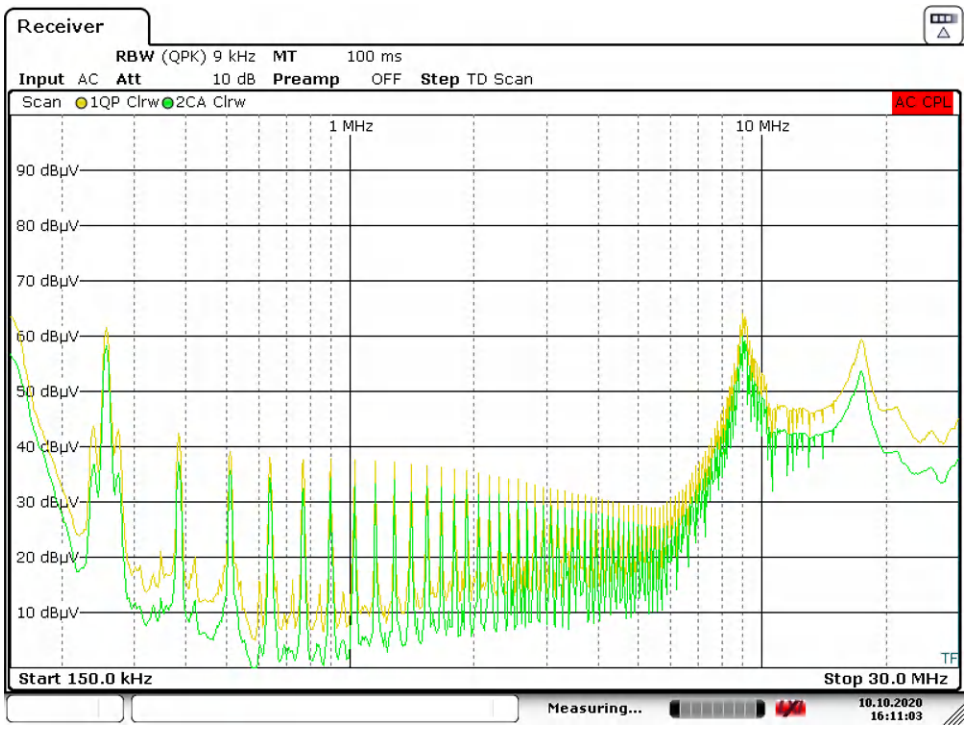


Figure 8-2. 120 V_{AC}, 60-Hz Input at Around 0.85 A-Output, Neutral (Trace 1 = Quasi-Peak, Trace 2 = Average)

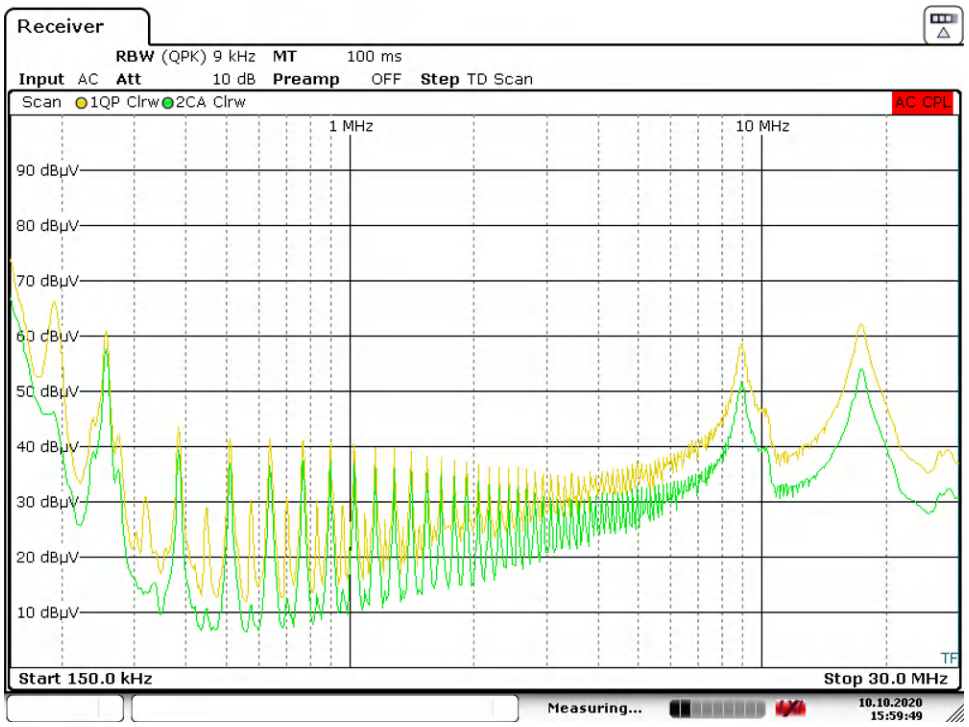


Figure 8-3. 230 V_{AC}, 50-Hz Input at Around 0.85-A Output, Line (Trace 1 = Quasi-Peak, Trace 2 = Average)

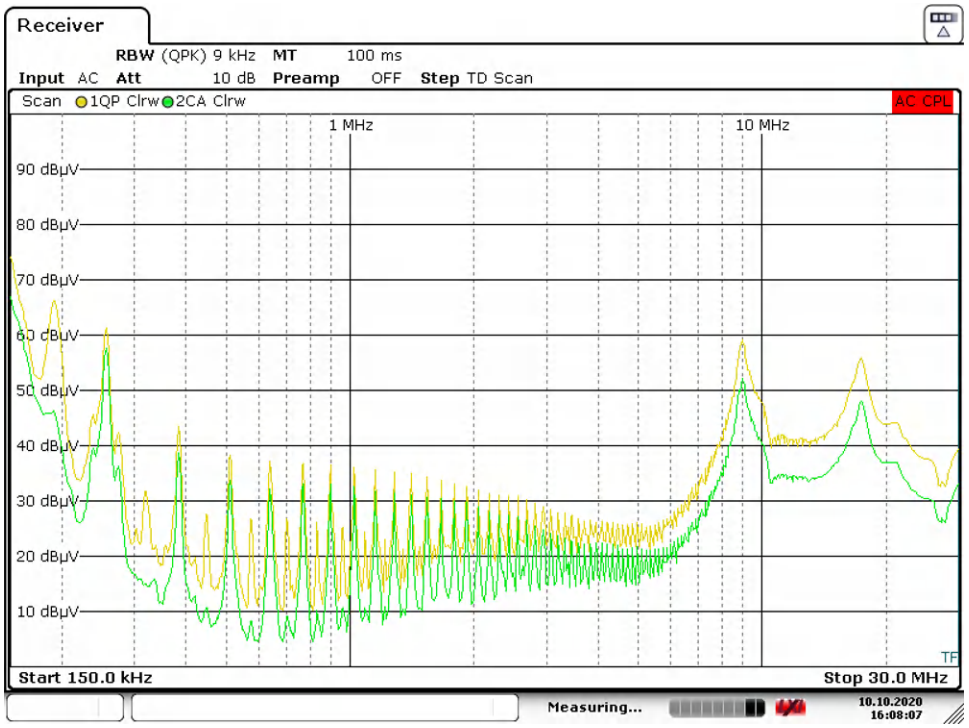


Figure 8-4. 230 V_{AC}, 50-Hz Input at Around 0.85-A Output, Neutral (Trace 1 = Quasi-Peak, Trace 2 = Average)

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