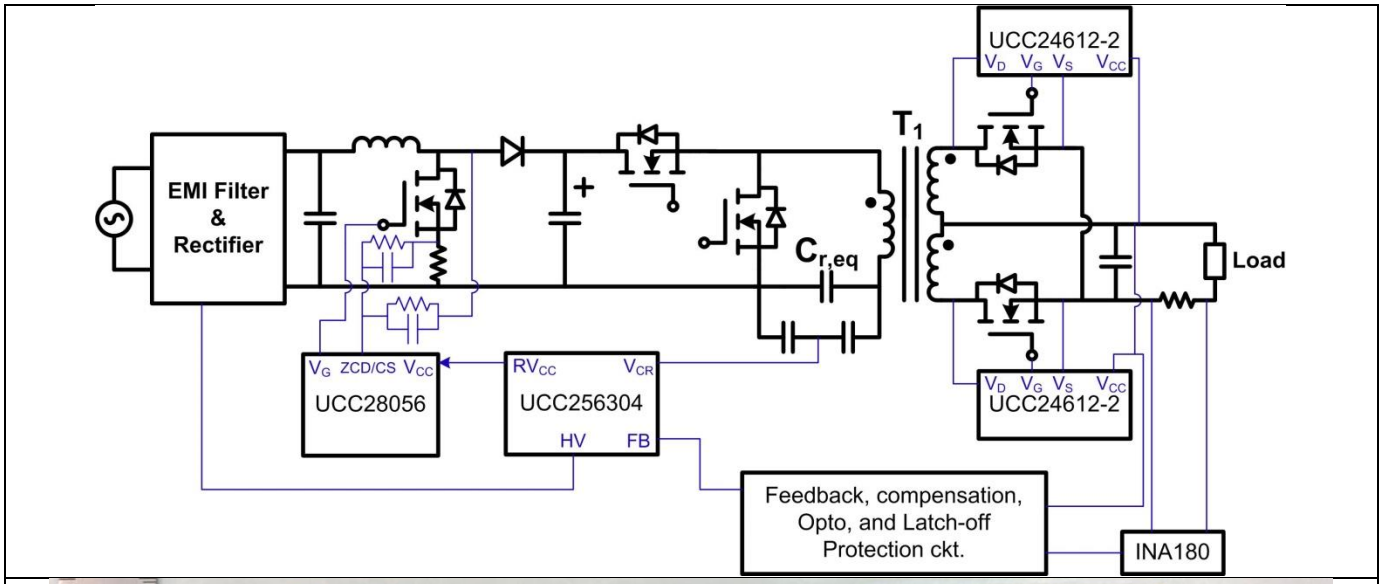
Test Report: PMP21251

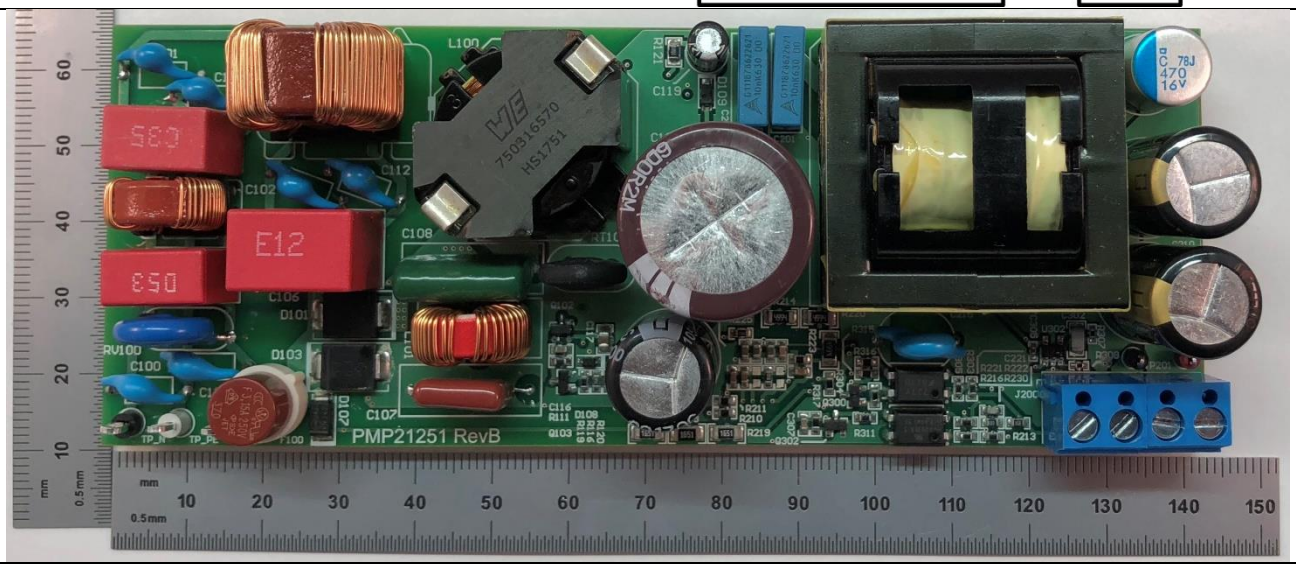
Less than 90mW Ultra-low standby power Auxless AC-DC Power Supply Reference Design

TEXAS INSTRUMENTS

Description

The PMP21251 reference design uses UCC28056 CRM/DCM PFC controller and UCC256304 enhanced LLC controller with integrated driver to provide 12V/10.8A output (continuous, 14.4A peak) from universal AC input. This design achieves 92.4% peak efficiency at 115VAC input and 94.0% peak efficiency at 230VAC input. The efficiency and power factor numbers also meet both 115V and 230V internal 80 PLUS gold specifications and DoE level VI requirement. In addition, the design is able to achieve as low as 89mW power consumption at 230VAC input and no load without turning off PFC.





1 System Specification

1.1 Board Dimension:

Board dimension should be within 55mm x 145mm x 35mm.

1.2 Input Characteristics

1.2.1 AC Input Voltage and Frequency Limitations:

Minimum	Nominal	Maximum	
90	100~240	265	VAC
47	50~60	63	Hz

1.2.2 AC Input Current:

- 1.7A Max. at 100VAC.
- 0.9A Max. at 200VAC.
- Current total harmonic distortion should be less than 20% from 50% to 100% load. 10.8A load current is defined as 100% load.

1.2.3 Power Factor:

Power factor should be greater than 0.9 at 100% load with either 115VAC/60Hz or 230VAC/50Hz input.

1.2.4 Inrush Current:

- Cold start: <50A at both 100VAC and 230VAC input and 25degC ambient temperature.
- Hot start: no component damage.

1.2.5 Efficiency:

All measurements should be made with a voltage total harmonic distortion <5% AC source at an ambient temperature 25degC.

	Minimum Efficiency (%)			
Input Voltage	10% Load	20% Load	50% Load	100% Load
100V	80	87	90	87
115V	84	87	90	87
230V	84	87	90	87

1.2.6 Standby Input Power:

All measurements should be made with a voltage total harmonic distortion <5% AC source at an ambient temperature 25degC.

Ouput Power	True RMS AC Input Power at 100VAC/60Hz 115VAC/60Hz 230VAC/50Hz
22mW	<0.5W
352mW	<1W
1.1W	<2W
2.53W	<4W

1.2.7 Hold Up Time:

Output should maintain in regulation for at least 10mS after AC voltage drop off.

1.3 Output Characteristics

The power supply unit should be able to supply 130W output power continuously and 170W peak power for 20second with 10% duty cycle.

Nominal Output Voltage	12V
Regulation Tolerance	+/- 5%
Ripple and Noise	120mV
Low Frequency Ripple	200mV
Minimum Current	0A
Continuous Current	10.8A
Peak Current	14.4A
Maximum Step Load	7A@0.5A/µS

1.4 Protections

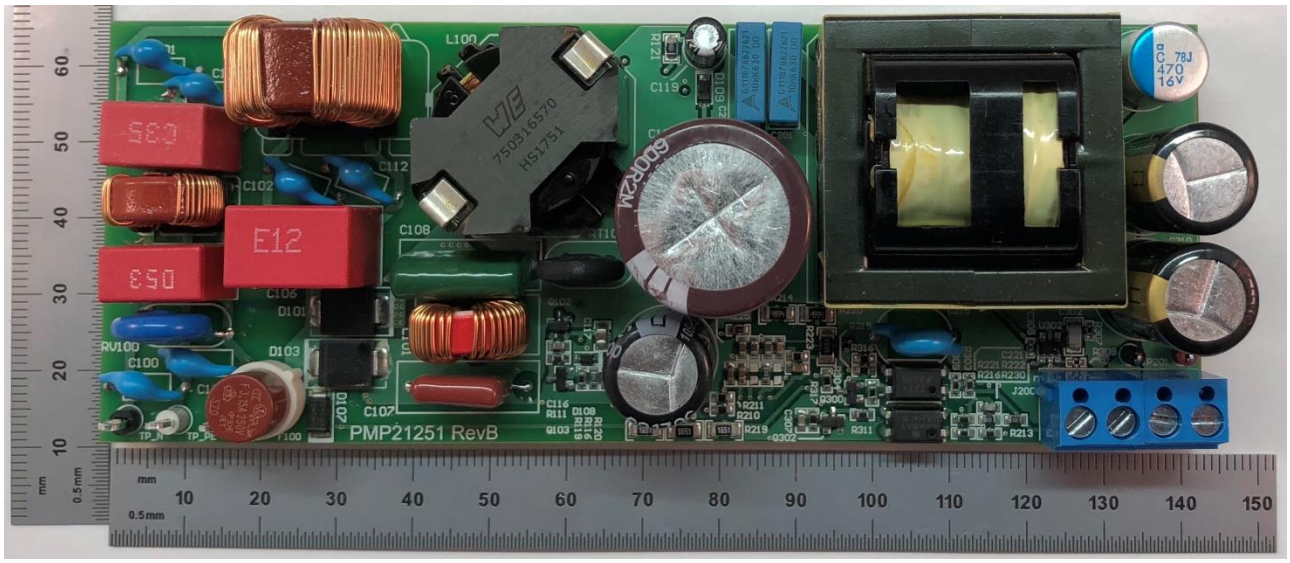
Over Voltage Protection	<15.6V	Non-latched
Over Current Protection	<20A	Latched
Short Circuit Protection	<30mΩ Load Resistance	Latched
Over Temperature Protection	No smoke or fire	Latched

2 Testing and Results

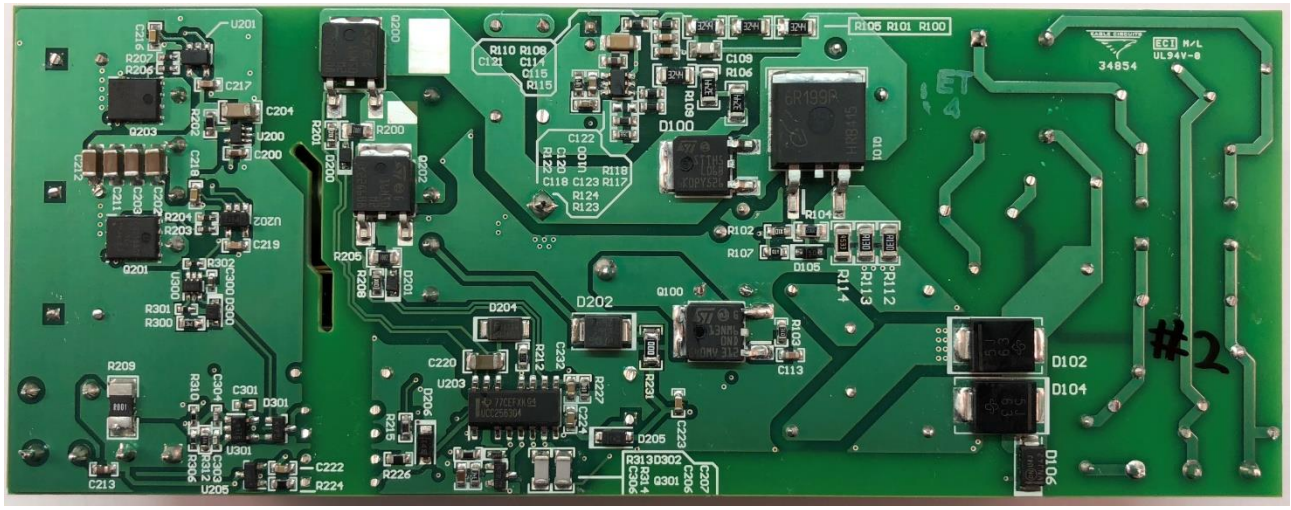
2.1 Board Photos

The photographs below show the top and bottom view of the PMP21251Rev B board. The PMP21251 board is built on PMP21251Rev B PCB.

2.1.1 Top Side

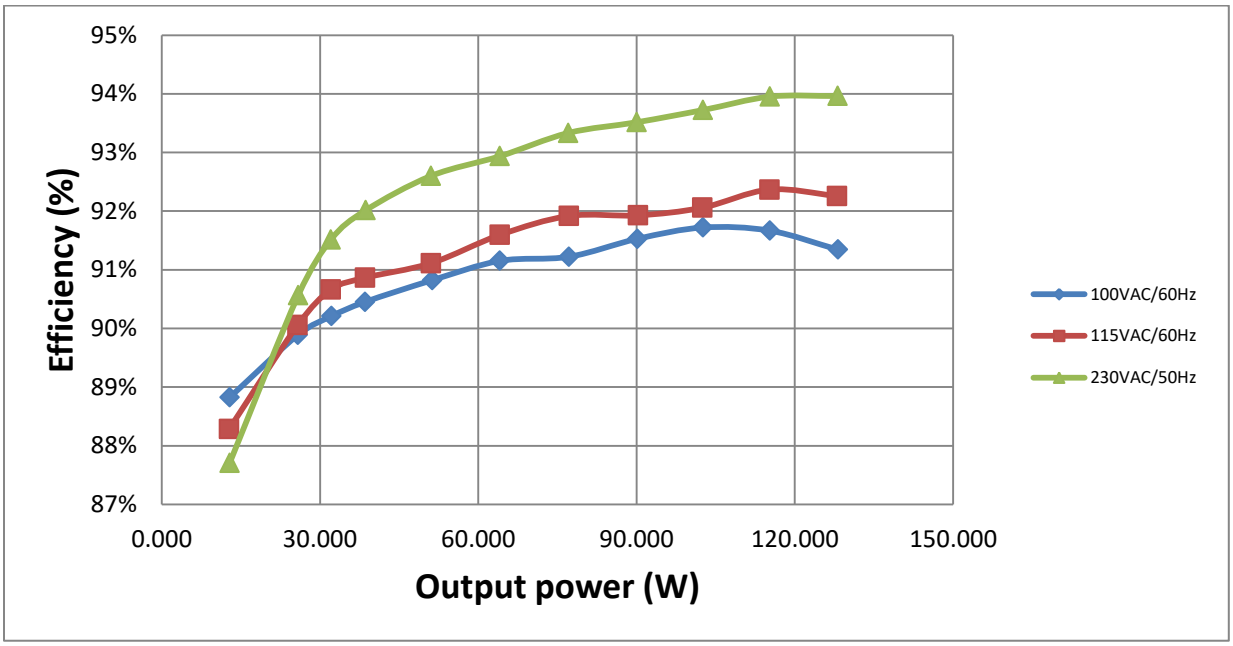


2.1.2 Bottom Side



2.2 Efficiency Data

4-point average efficiency: 91.6% @ 115VAC/60Hz and 93% @ 230VAC/50Hz



2.2.1 100VAC/60Hz Efficiency Measurement

Vin,rms(V)	Iin,rms(A)	Pin(W)	P.F.	ATHD(%)	Vout(V)	Iout(A)	Pout(W)	Losses(W)	Eff. (%)
100.1	1.415	140.37	0.991	12.1%	11.85	10.820	128.217	12.1530	91.34%
100.1	1.269	125.76	0.990	13.0%	11.86	9.720	115.279	10.4808	91.67%
100.0	1.131	111.85	0.988	14.0%	11.86	8.650	102.589	9.2610	91.72%
100.0	0.999	98.48	0.986	15.3%	11.86	7.600	90.136	8.3440	91.53%
100.1	0.860	84.58	0.983	17.0%	11.87	6.500	77.155	7.4250	91.22%
100.1	0.718	70.32	0.979	19.0%	11.87	5.400	64.098	6.2220	91.15%
100.0	0.572	56.46	0.987	8.1%	11.87	4.320	51.278	5.1816	90.82%
100.0	0.433	42.62	0.985	8.7%	11.88	3.245	38.551	4.0694	90.45%
100.1	0.364	35.65	0.981	11.0%	11.88	2.707	32.159	3.4908	90.21%
100.0	0.294	28.68	0.975	10.7%	11.88	2.170	25.780	2.9004	89.89%
100.0	0.205	14.49	0.705	29.4%	11.88	1.083	12.866	1.6190	88.82%

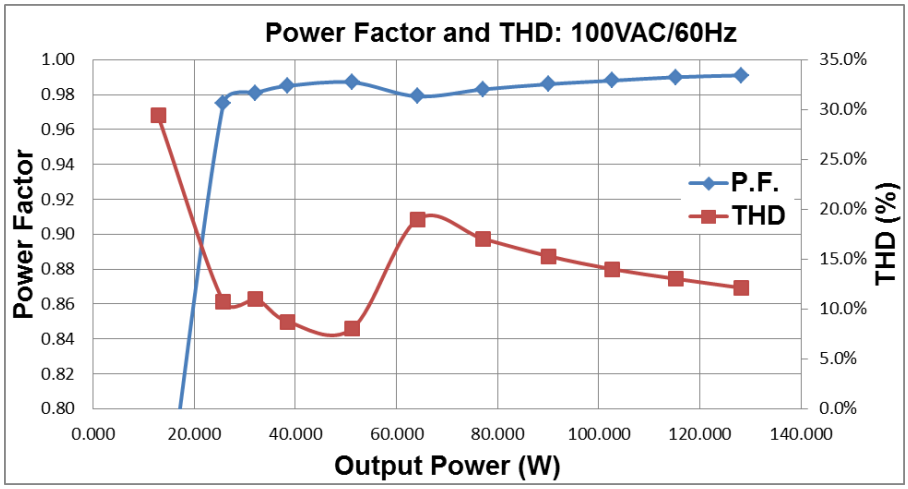
2.2.2 115VAC/60Hz Efficiency Measurement

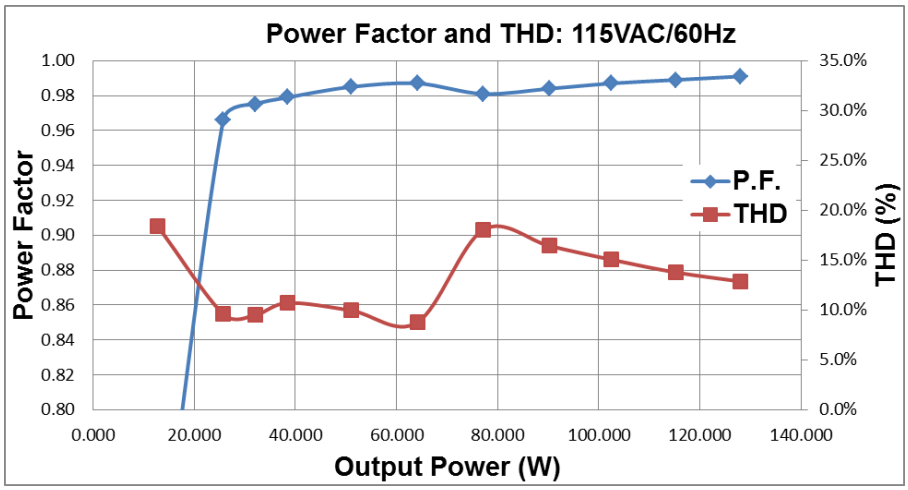
Vin,rms(V)	Iin,rms(A)	Pin(W)	P.F.	ATHD(%)	Vout(V)	Iout(A)	Pout(W)	Losses(W)	Eff. (%)
115.03	1.217	138.72	0.991	12.9%	11.85	10.800	127.980	10.7400	92.26%
115.03	1.096	124.70	0.989	13.8%	11.85	9.720	115.182	9.5180	92.37%
115.05	0.980	111.31	0.987	15.1%	11.86	8.640	102.470	8.8396	92.06%
115.01	0.867	98.18	0.984	16.4%	11.86	7.610	90.255	7.9254	91.93%
115.04	0.744	83.94	0.981	18.0%	11.87	6.500	77.155	6.7850	91.92%
115.07	0.616	69.98	0.987	8.8%	11.87	5.400	64.098	5.8820	91.59%
114.99	0.495	56.02	0.985	10.0%	11.87	4.300	51.041	4.9790	91.11%
115.03	0.377	42.43	0.979	10.7%	11.87	3.248	38.554	3.8762	90.86%
114.99	0.316	35.38	0.975	9.5%	11.88	2.700	32.076	3.3040	90.66%
115.07	0.257	28.60	0.966	9.6%	11.88	2.168	25.756	2.8442	90.06%
115.02	0.181	14.48	0.692	18.4%	11.88	1.076	12.783	1.6961	88.29%

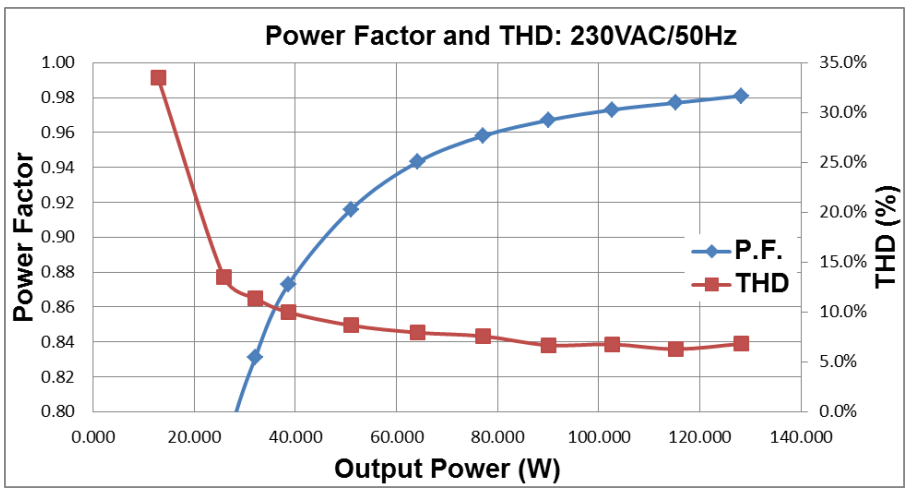
2.2.3 230VAC/50Hz Efficiency Measurement

Vin,rms(V)	Iin,rms(A)	Pin(W)	P.F.	ATHD(%)	Vout(V)	Iout(A)	Pout(W)	Losses(W)	Eff. (%)
230	0.605	136.33	0.981	6.8%	11.85	10.810	128.099	8.2315	93.96%
230	0.546	122.70	0.977	6.3%	11.86	9.720	115.279	7.4208	93.95%
230	0.489	109.46	0.973	6.8%	11.86	8.650	102.589	6.8710	93.72%
230	0.433	96.26	0.967	6.7%	11.86	7.590	90.017	6.2426	93.51%
230	0.375	82.54	0.958	7.6%	11.87	6.490	77.036	5.5037	93.33%
230	0.318	68.97	0.943	7.9%	11.87	5.400	64.098	4.8720	92.94%
230	0.262	55.12	0.916	8.7%	11.87	4.300	51.041	4.0790	92.60%
230	0.209	42.00	0.873	10.0%	11.88	3.253	38.646	3.3544	92.01%
230	0.184	35.05	0.831	11.4%	11.88	2.700	32.076	2.9740	91.51%
230	0.162	28.57	0.769	13.5%	11.88	2.178	25.875	2.6954	90.57%
230	0.128	14.67	0.498	33.5%	11.88	1.083	12.866	1.8040	87.70%

2.3 Power Factor and Total Harmonic Distortion





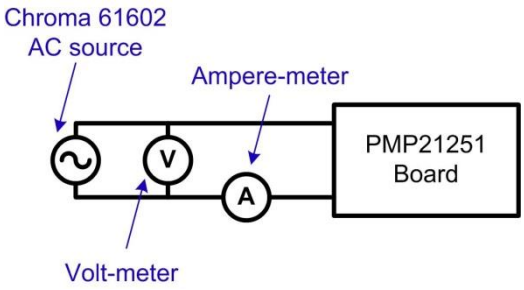


2.4 Standby Input Power

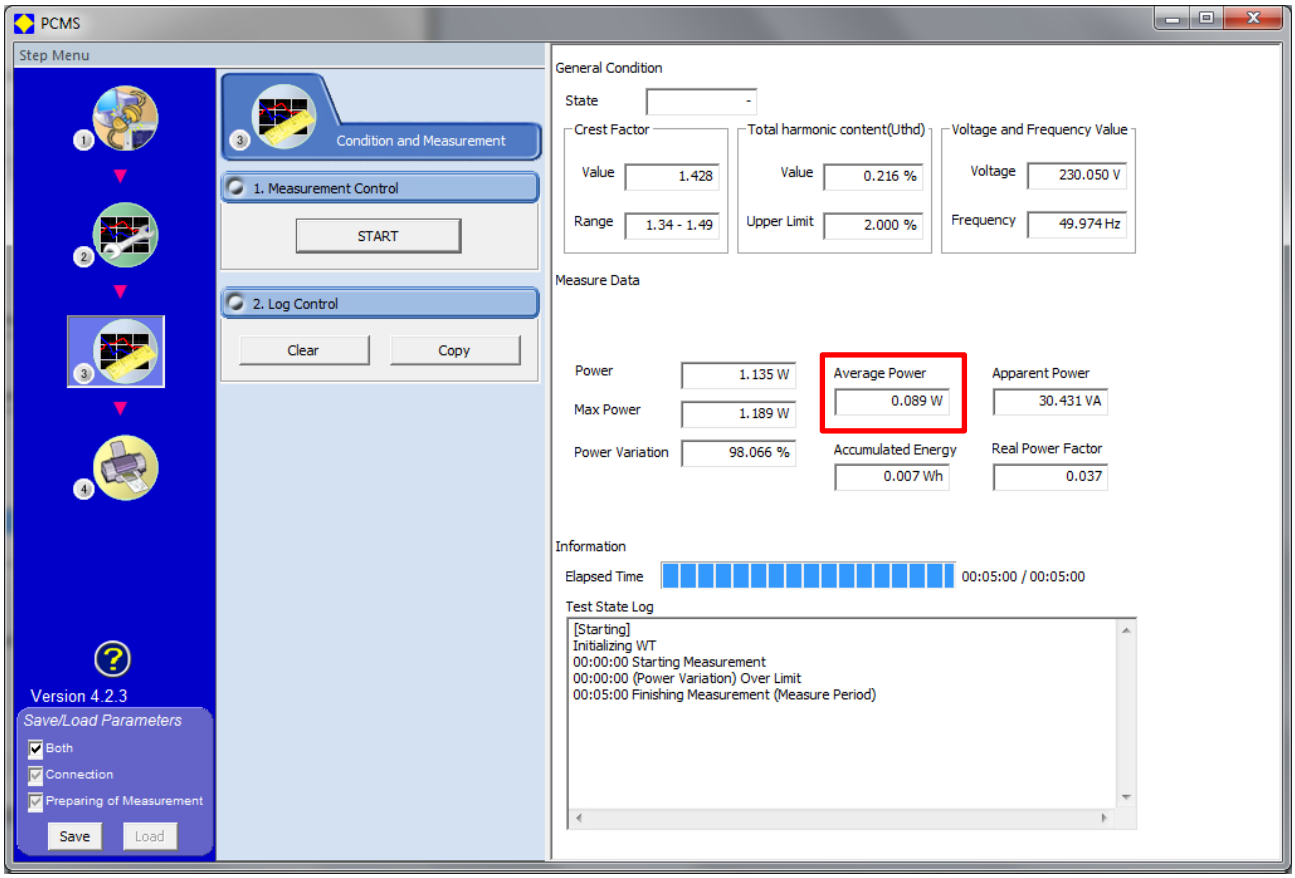
Standby input power was measured with **5 minute averaging** under below t**wo conditions with two different setups**:

2.4.1 Setup #1: Remove Q102, R202, R302, R304, U201, U202, U301, and change R227 to 162kohm, R210 to 110kohm, R211 to 25.5kohm.

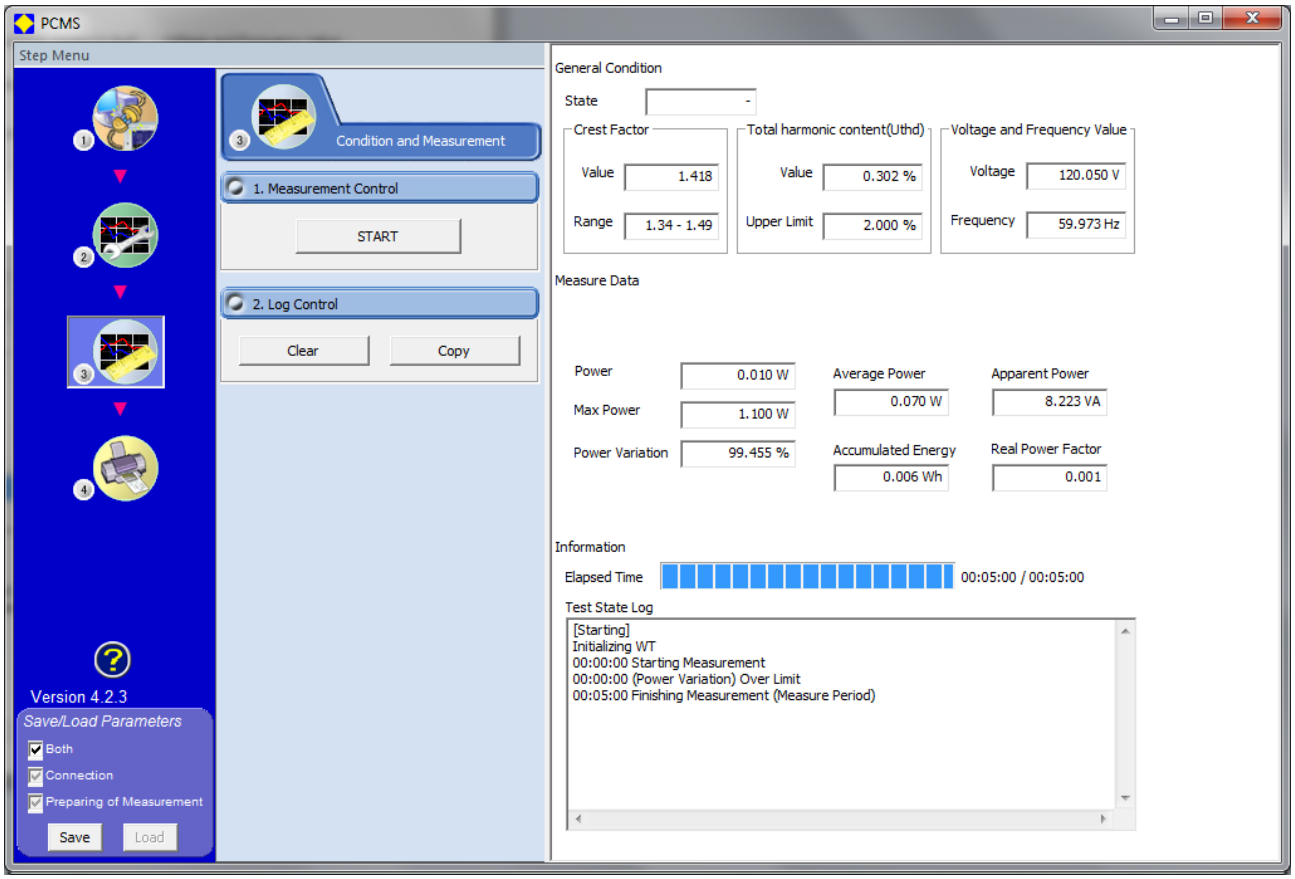
The following measurement was done with Yokogawa WT310 power meter and Chroma 61602 AC source. On the WT310 power meter, voltage range was set to 150V for low line input and 300V for high line input; current range was set to 200mA with crest factor 3 for low line input and 500mA with crest factor 3 for high line input. Also, the voltage measurement and current measurement was configured as below:



2.4.1.1 No load power consumption @ 230VAC/50Hz input: 89mW.



2.4.1.2 No load power consumption @ 120VAC/60Hz input: 70mW.



2.4.2 Setup #2: Without any modifications.

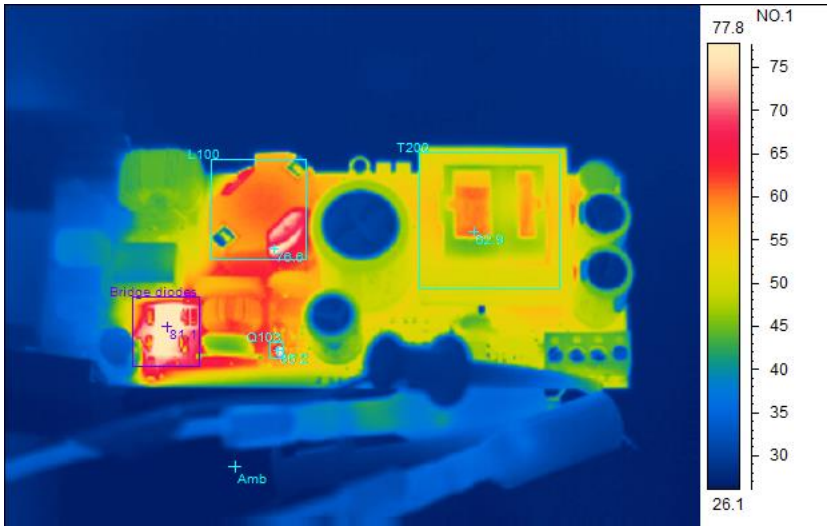
The following measurement was done with Voltech PM1000+ power meter and California Instruments 1251P AC source. A Schneider Electric 2KVA isolated transformer is placed in between the AC source and PMP21251 board. External shunt was using for current meter with scaling factor 0.0125.

Vout(V)	Iout(mA)	Pout(W)	Vin(V)	Iin(mA)	Fin(Hz)	Pin(mW)
11.88	0	0	230.1	59.6	50	226.4
11.88	2.25	0.02673	230.1	59.95	50	239
11.88	31.09	0.3693492	230	63.03	50	742.7
11.88	93.2	1.107216	230	68.61	50	1633
11.88	212.3	2.522124	230.1	78.32	50	3334
11.88	0	0	114.98	40.96	60	225.6
11.88	2.24	0.0266112	114.98	39.64	60	229.7
11.88	31.08	0.3692304	115.08	50.34	60	707.7
11.88	90.9	1.079892	115.08	65.8	60	1586
11.88	211.3	2.510244	114.93	89.44	60	3315

2.5 Thermal Images

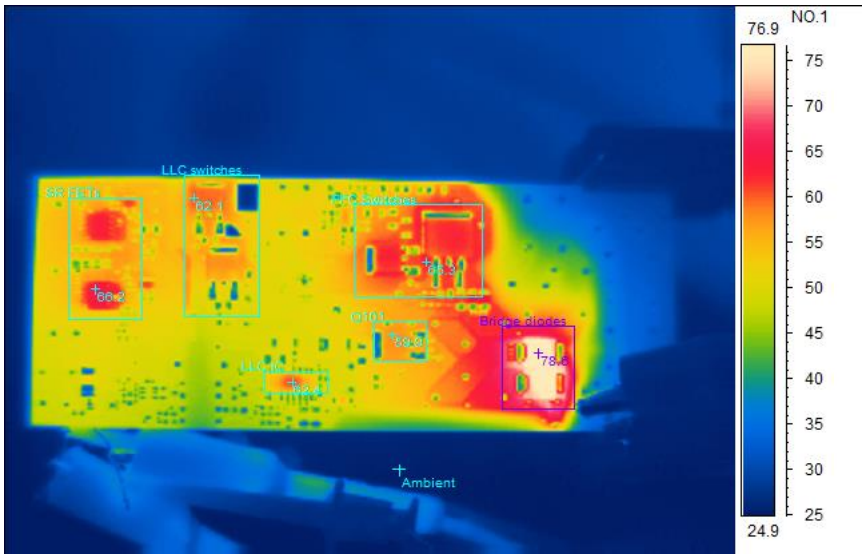
The thermal images below show a top view and bottom view of the board. The board is placed vertically during the test. The ambient temperature was 25ºC with no air flow. The output was loaded with 12V/10.8A.

2.5.1 100V_{AC}/60Hz, Top Side



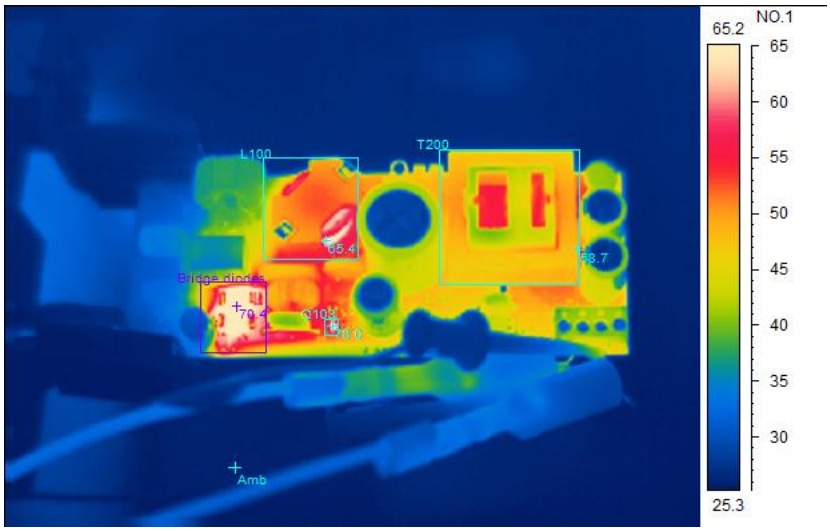
Spot analysis	Value
Amb Temperature	26.3°C
Area analysis	**Value**
Bridge diodesMax	81.1°C
Q103Max	86.2°C
L100Max	76.6°C
T200 Max	62.9°C

2.5.2 100V_{AC}/60Hz, Bottom Side



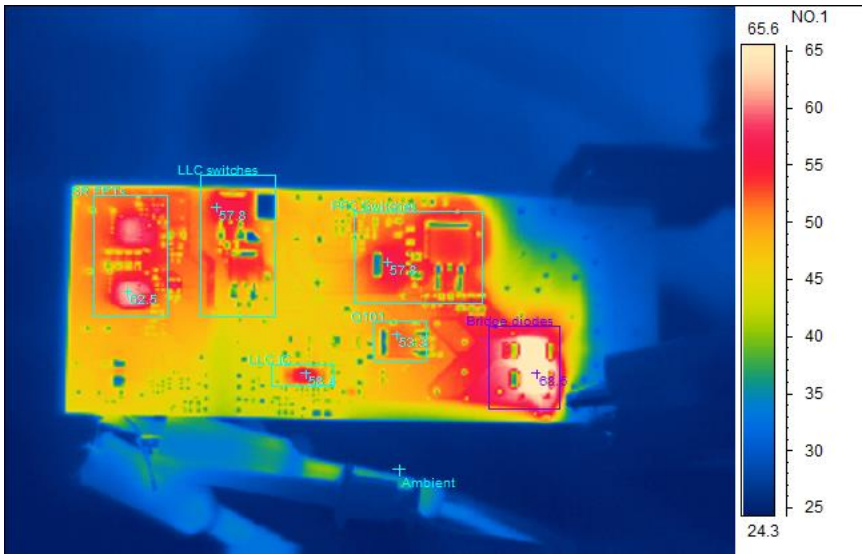
Spot analysis	Value
Ambient Temperature	25.6°C
Area analysis	**Value**
Bridge diodesMax	78.6°C
PFC SwitchesMax	65.3°C
Q101Max	59.9°C
LLC switchesMax	62.1°C
SR FETsMax	66.2°C
LLC ICMax	62.4°C

2.5.3 115V_{AC}/60Hz, Top Side



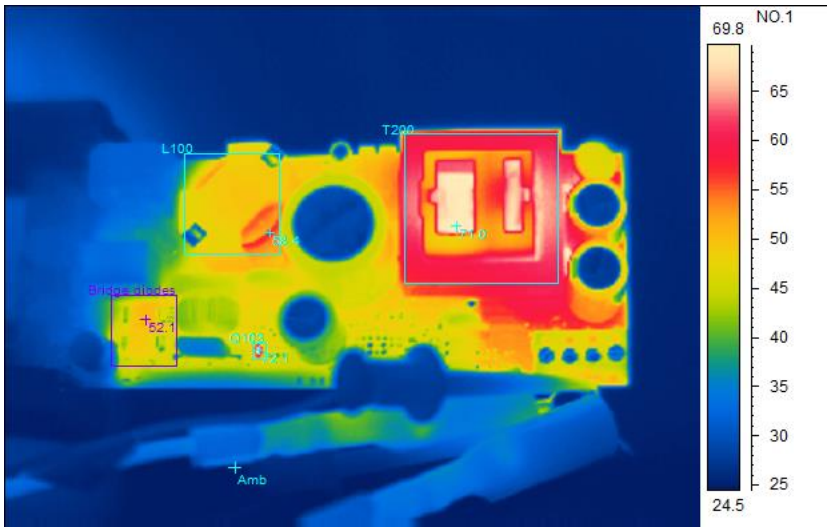
Spot analysis	Value
Amb Temperature	25.9°C
Area analysis	**Value**
Bridge diodesMax	70.4°C
Q103Max	78.0°C
L100Max	65.4°C
T200 Max	58.7°C

2.5.4 115V_{AC}/60Hz, Bottom Side



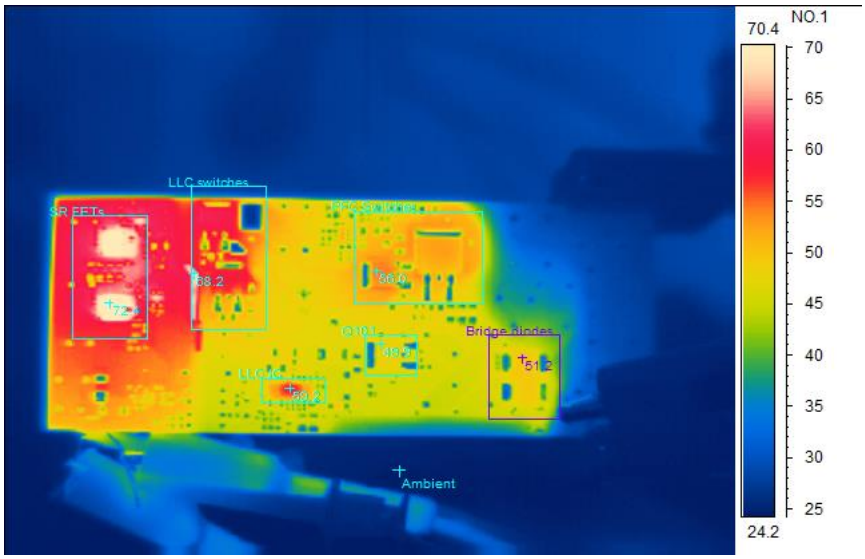
Spot analysis	Value
Ambient Temperature	25.6°C
Area analysis	**Value**
Bridge diodesMax	68.5°C
PFC SwitchesMax	57.8°C
Q101Max	53.3°C
LLC switchesMax	57.8°C
SR FETsMax	62.5°C
LLC ICMax	58.4°C

2.5.5 230V_{AC}/50Hz, Top Side



Spot analysis	Value
Amb Temperature	25.1°C
Area analysis	**Value**
Bridge diodesMax	52.1°C
Q103Max	72.1°C
L100Max	58.4°C
T200 Max	71.0°C

2.5.6 230V_{AC}/50Hz, Bottom Side

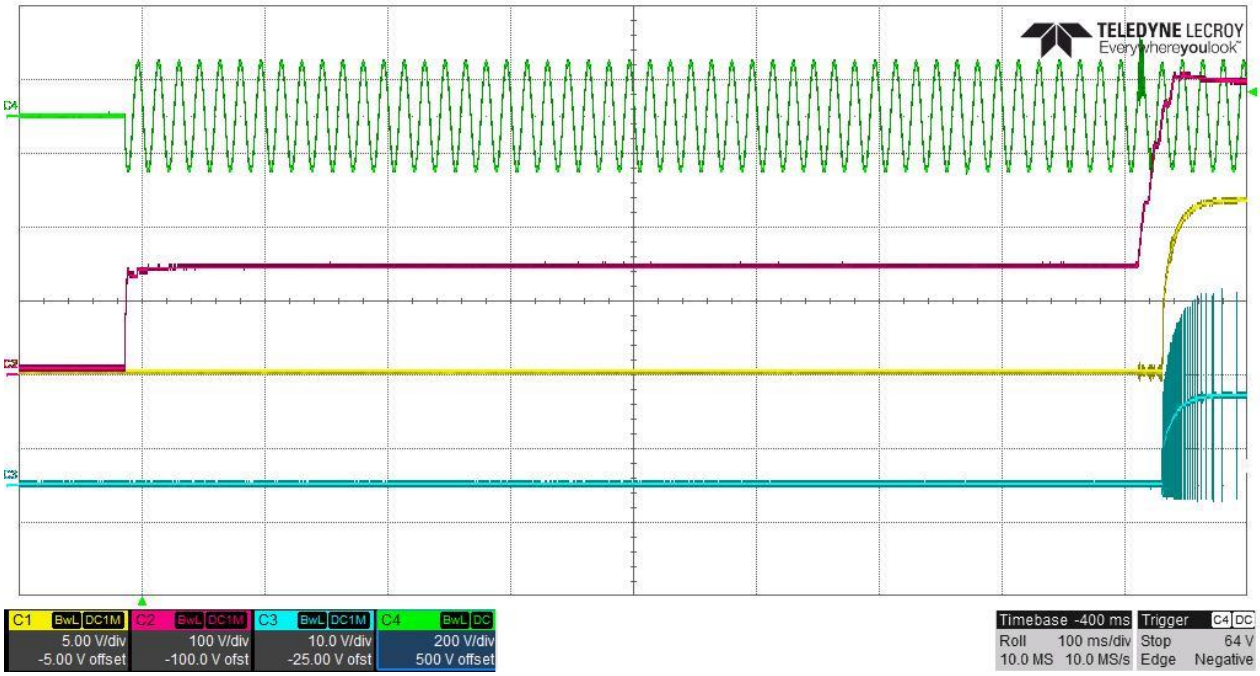


Spot analysis	Value
Ambient Temperature	24.7°C
Area analysis	**Value**
Bridge diodesMax	51.2°C
PFC SwitchesMax	56.0°C
Q101Max	49.9°C
LLC switchesMax	68.2°C
SR FETsMax	72.4°C
LLC ICMax	59.2°C

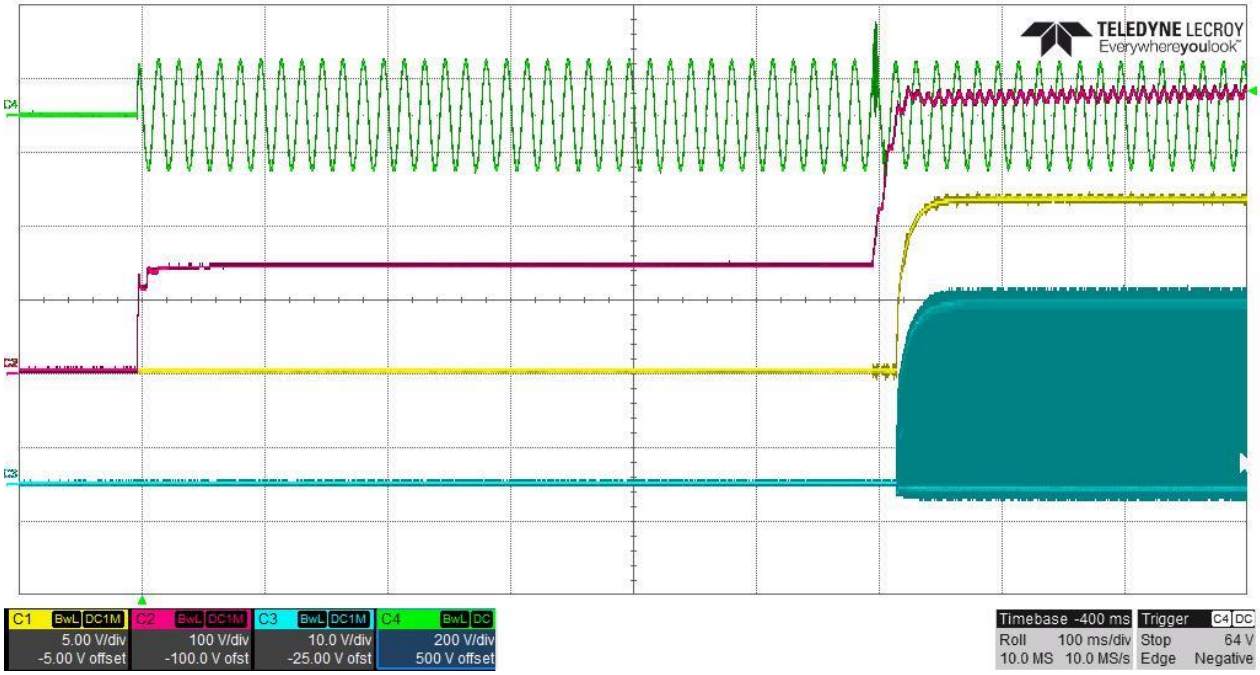
2.6 Startup

The voltages at startup are shown in the images below, where Channel 1 is the input voltage, Channel 2 is the V_{DS} voltage of Q101, Channel 3 is HV to GND, and Channel 4 is output voltage.

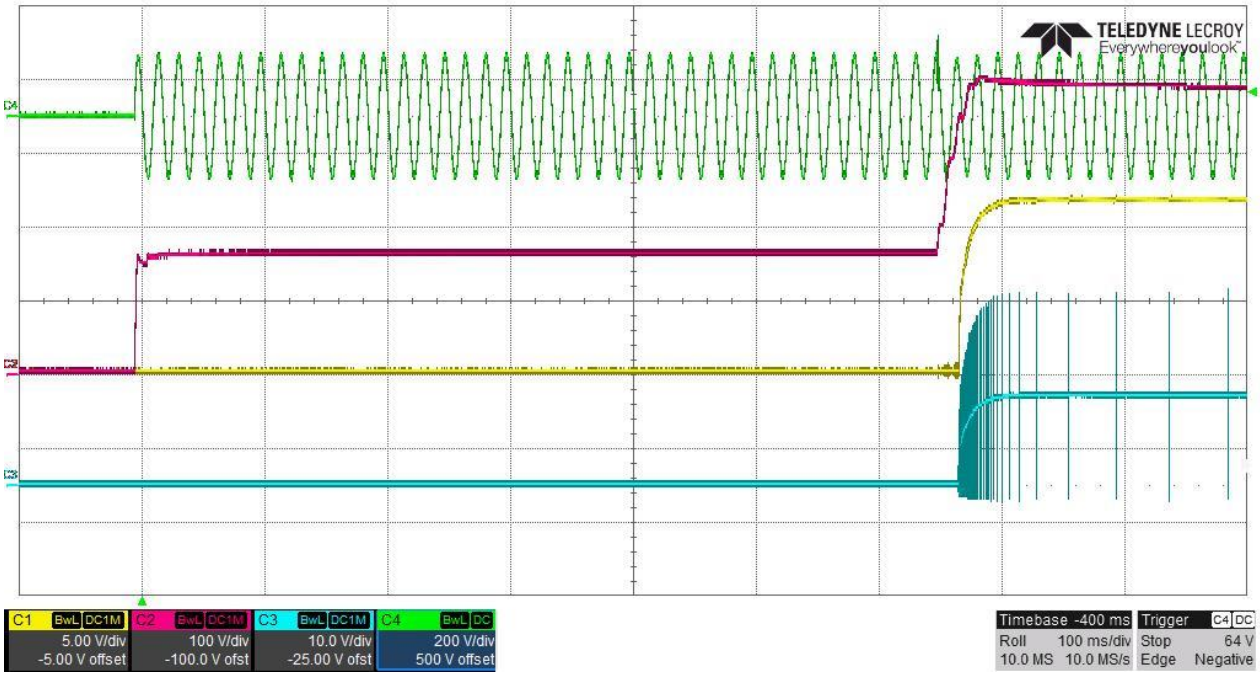
2.6.1 100V_{AC}/60Hz – No Load



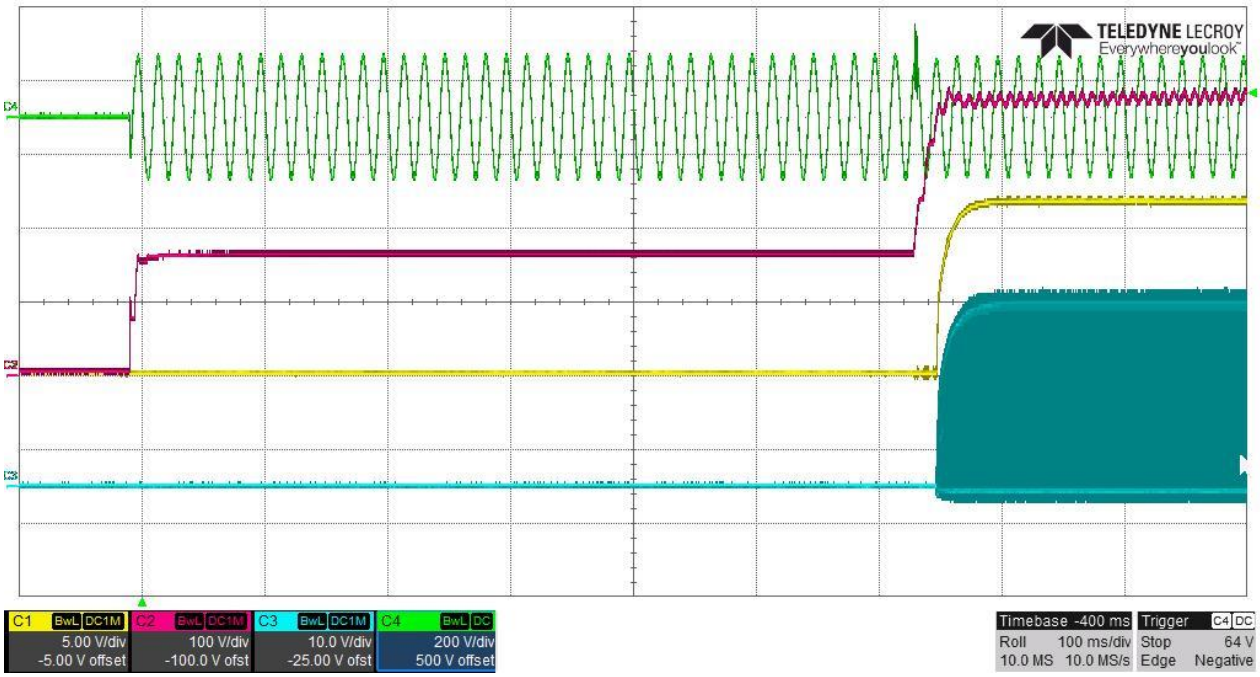
2.6.2 100V_{AC}/60Hz –12V/10.8A



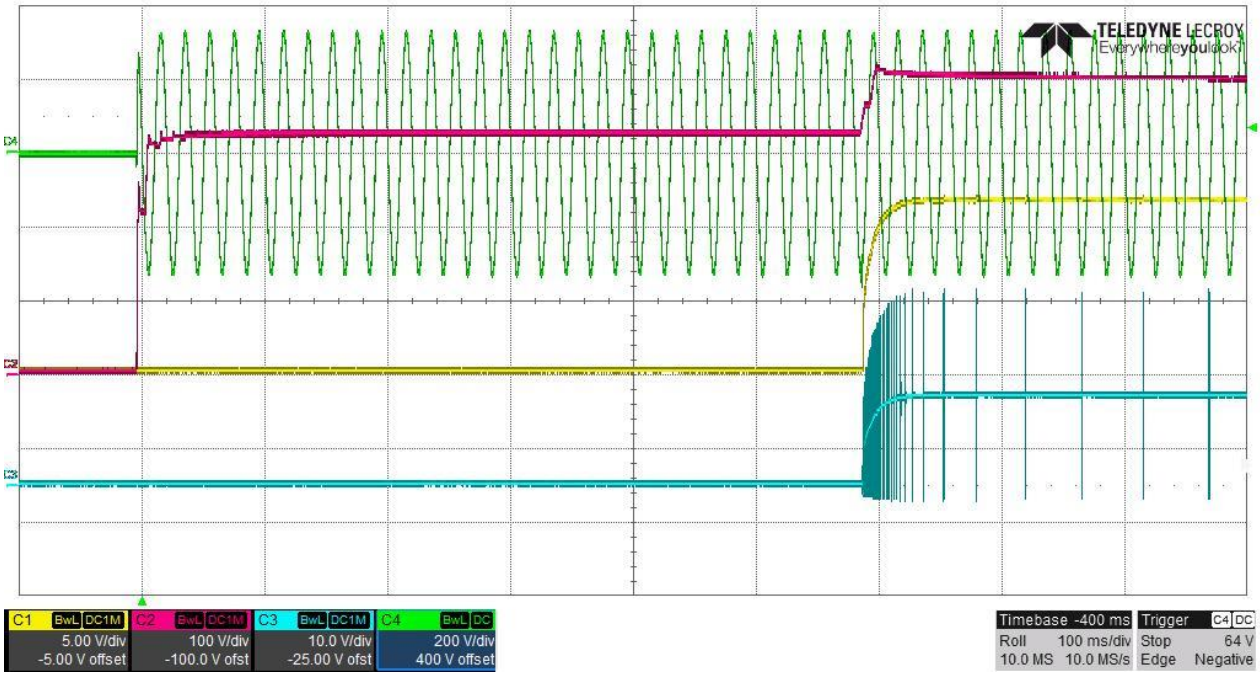
2.6.3 115V_{AC}/60Hz – No Load



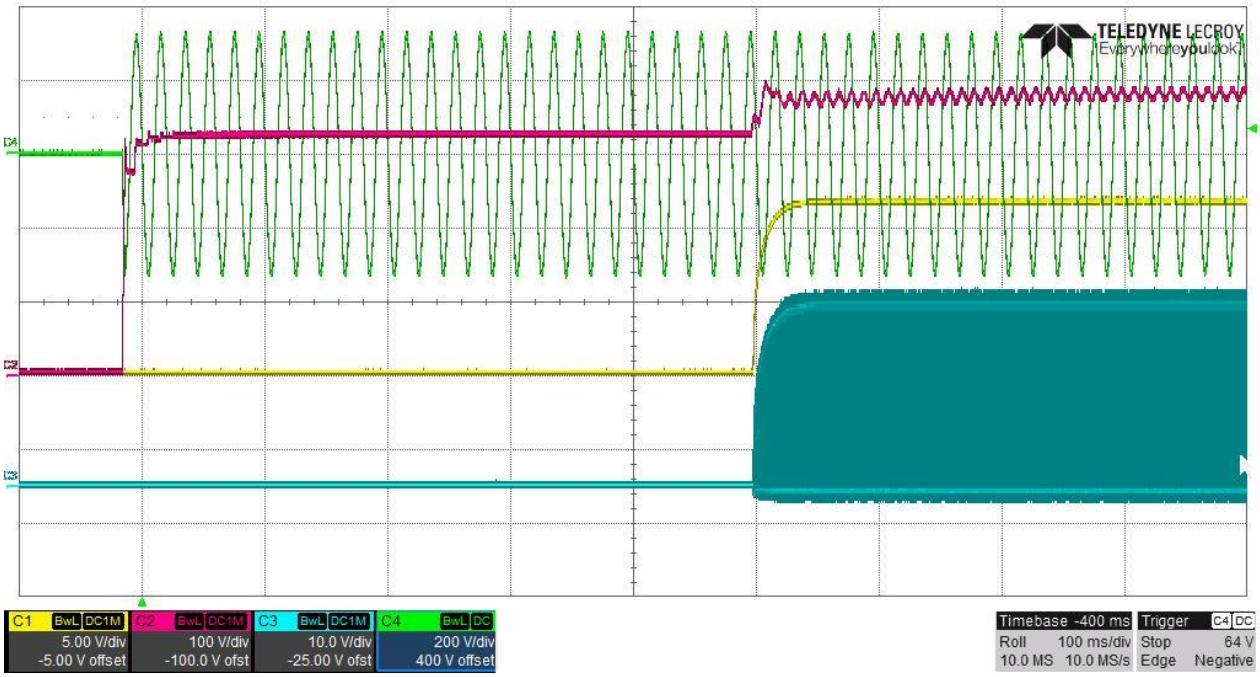
2.6.4 115V_{AC}/60Hz –12V/10.8A



2.6.5 230V_{AC}/50Hz – No Load



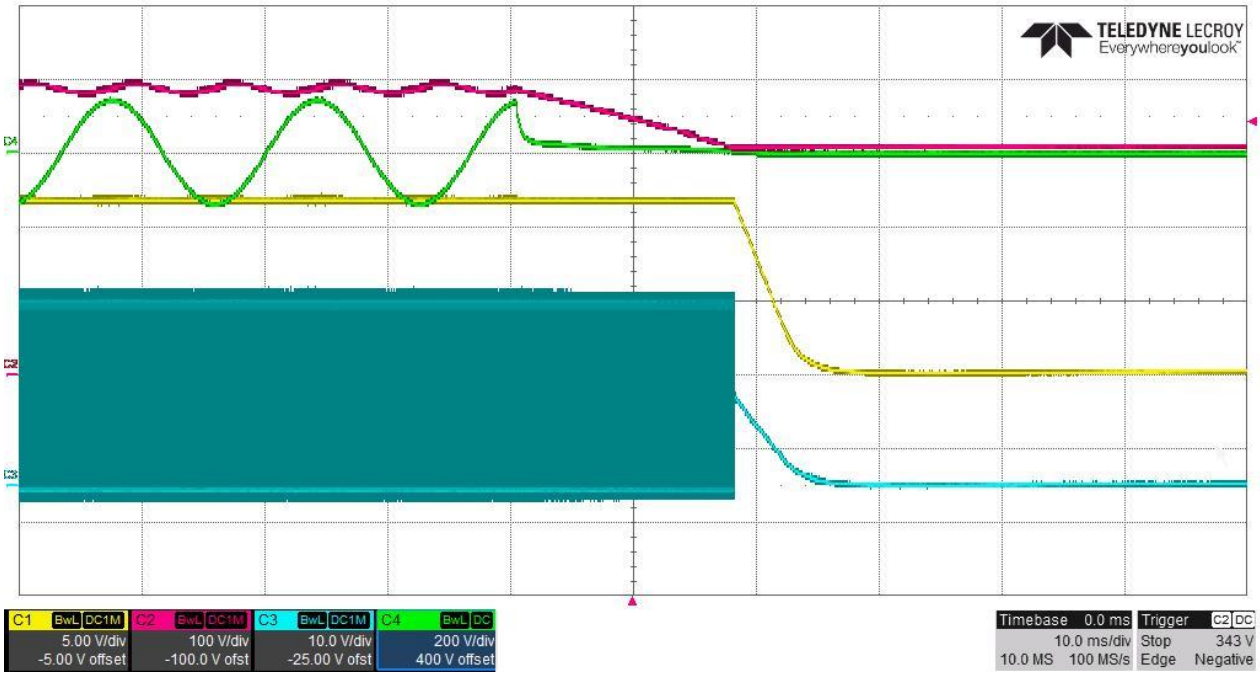
2.6.6 230V_{AC}/50Hz – 12V/10.8A



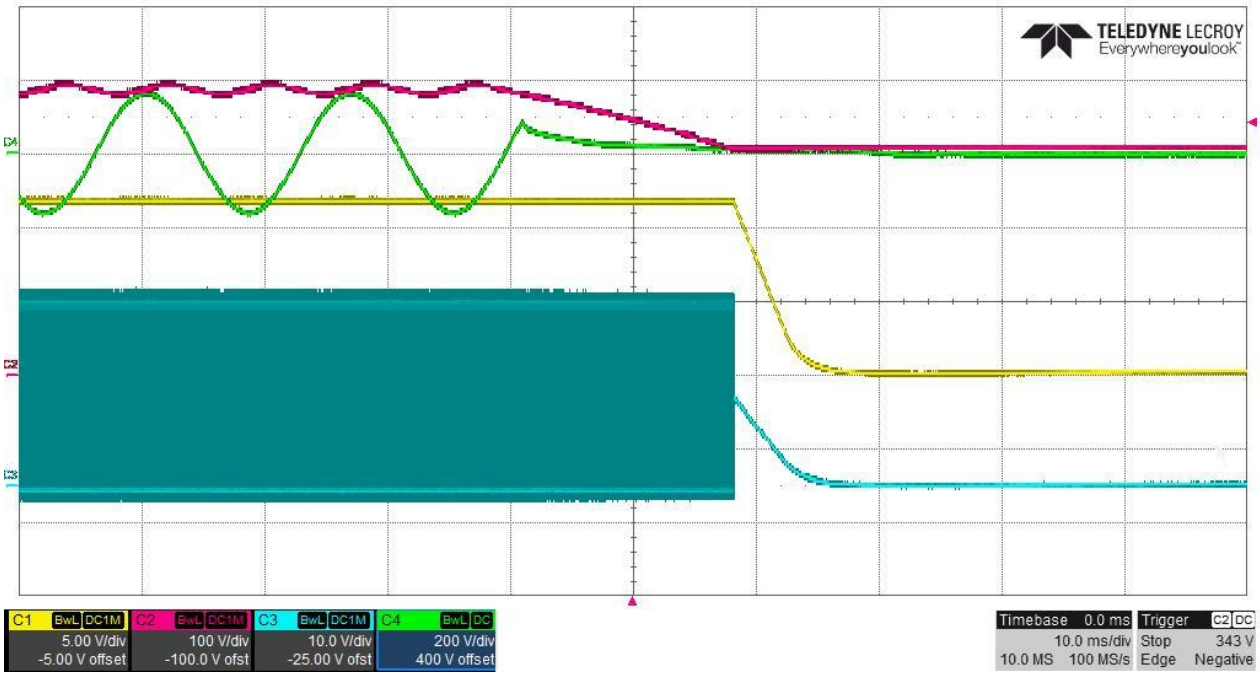
2.7 Turn-off

The voltages at turn-off are shown in the images below, where Channel 1 is the output voltage, Channel 2 is HV to GND, Channel 3 is Q203 V_{DS}, and Channel 4 is the input voltage.

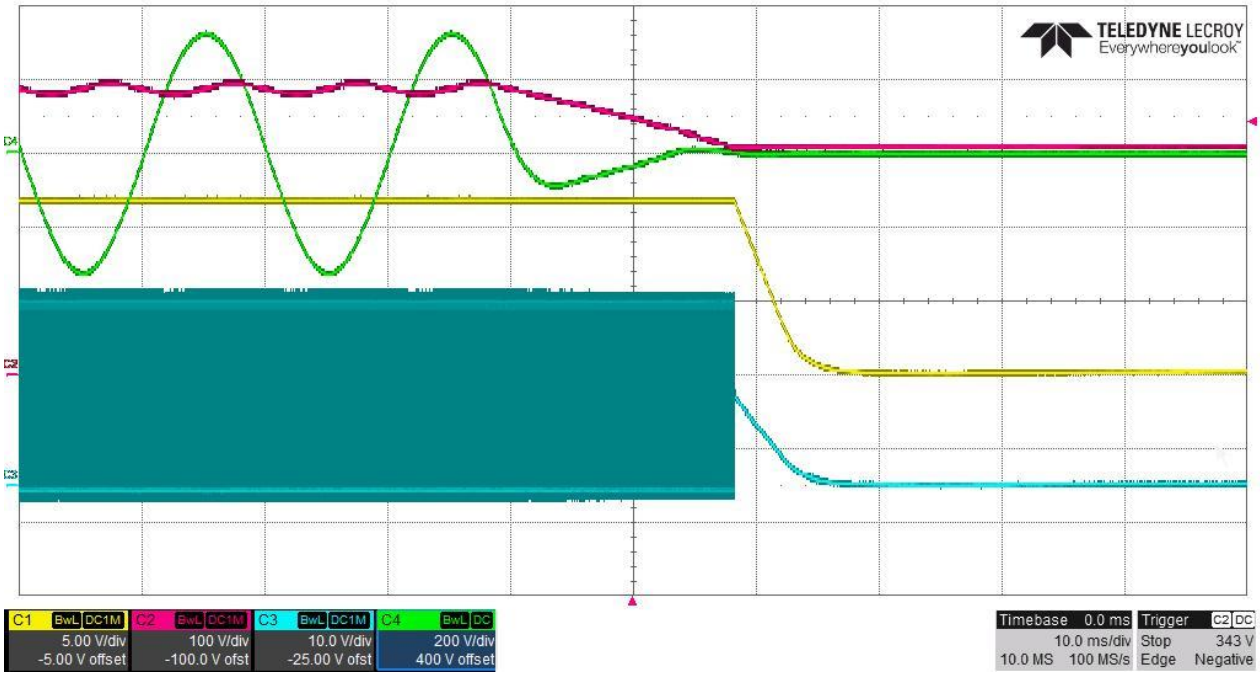
2.7.1 100V_{AC}/60Hz –12V/10.8A



2.7.2 115V_{AC}/60Hz –12V/10.8A



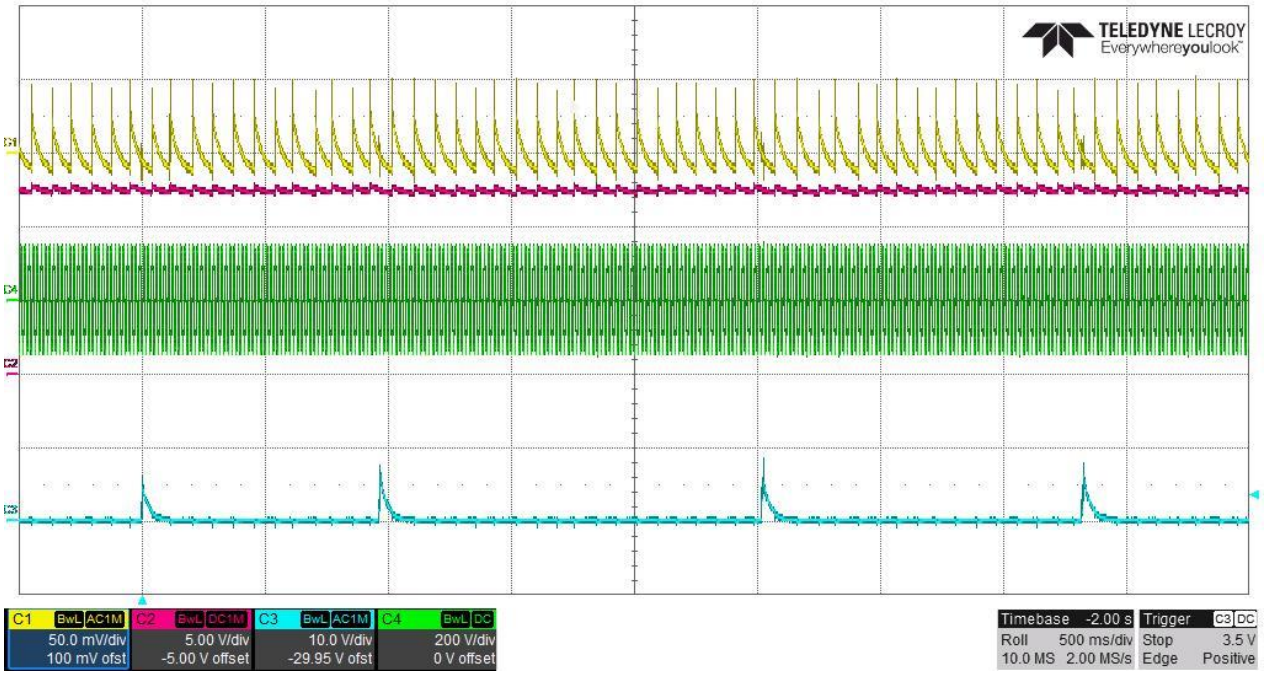
2.7.3 230V_{AC}/50Hz – 12V/10.8A

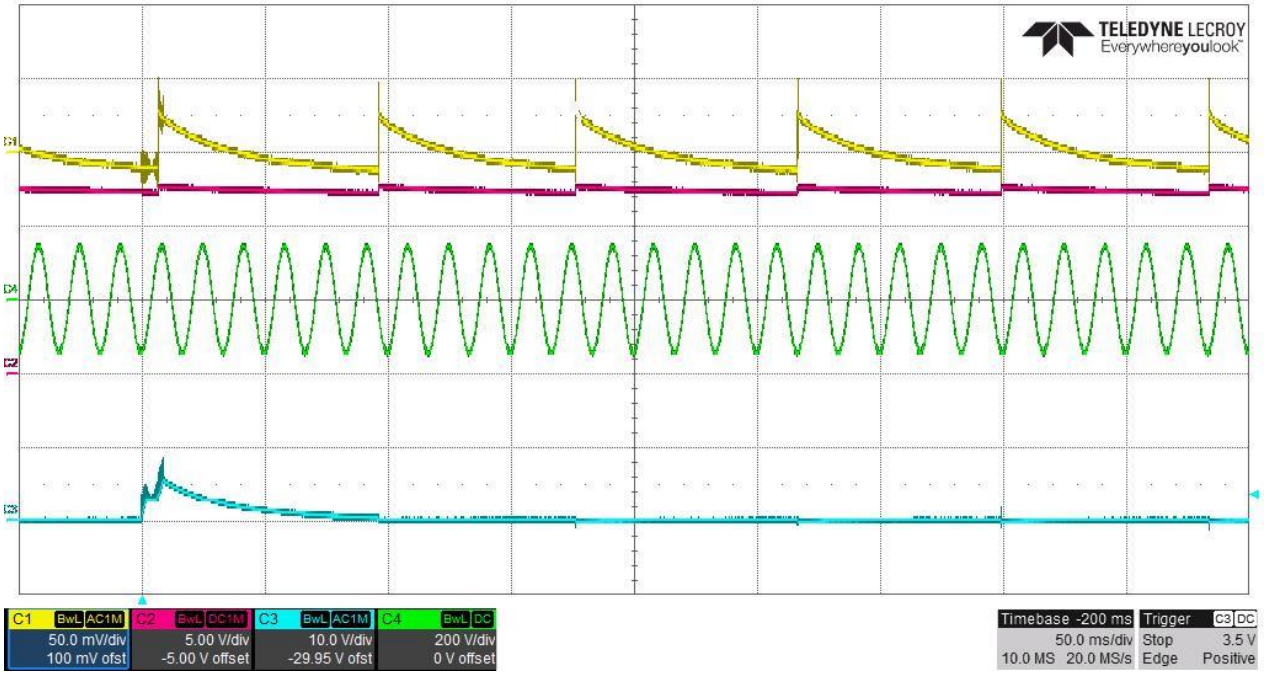


2.8 Ripple Voltages

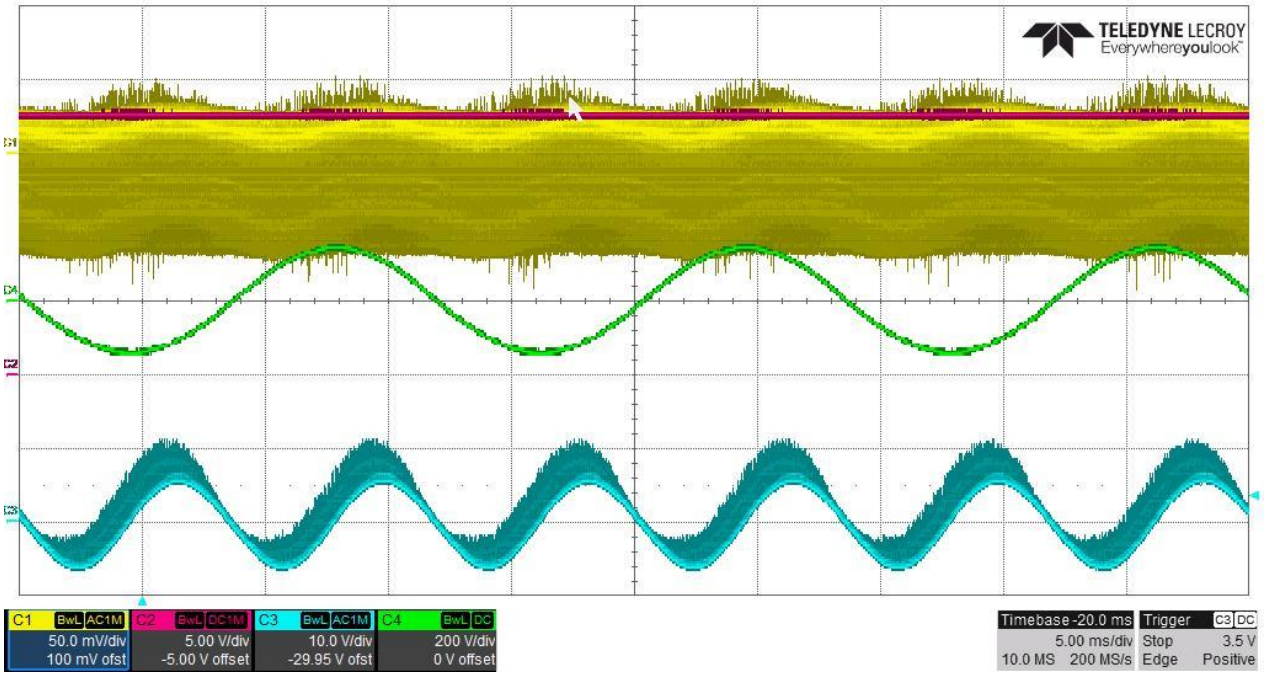
Ripple voltages are shown in the images below, where Channel 1 is the output voltage in AC level, Channel 2 is net VCC_IC voltage, Channel 3 is HV to GND voltage in AC level, and Channel 4 is the input voltage.

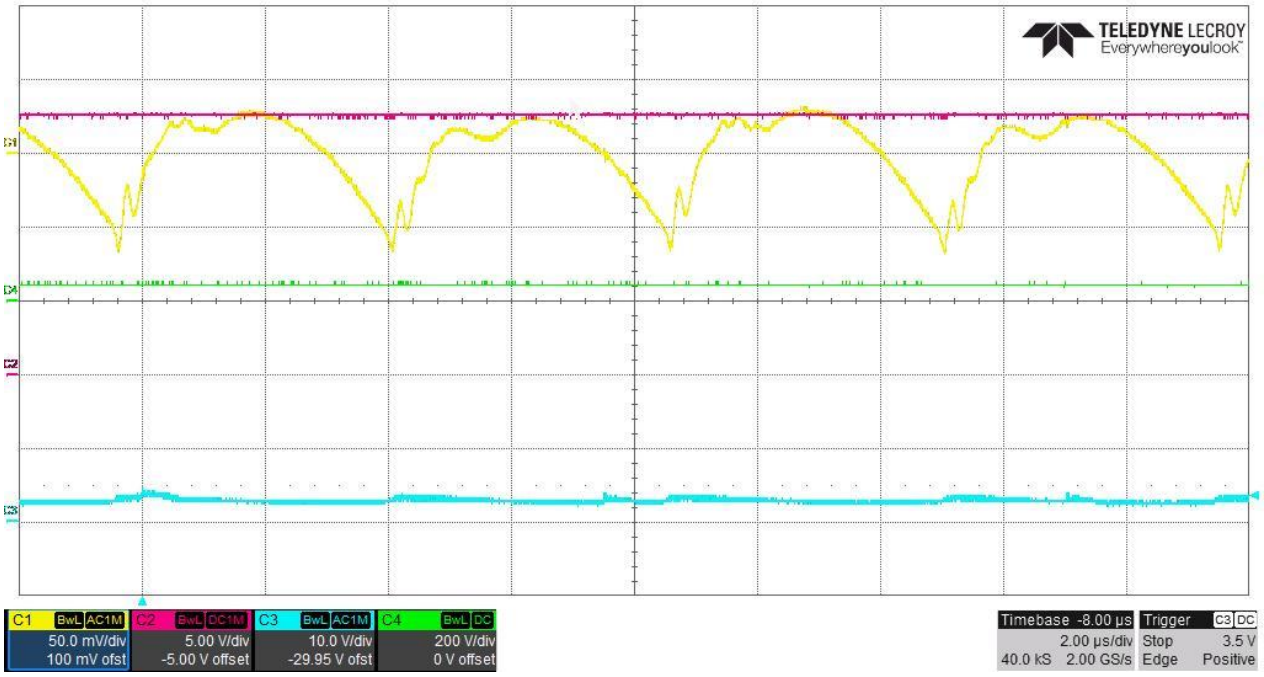
2.8.1 100V_{AC}/60Hz –12V/0A



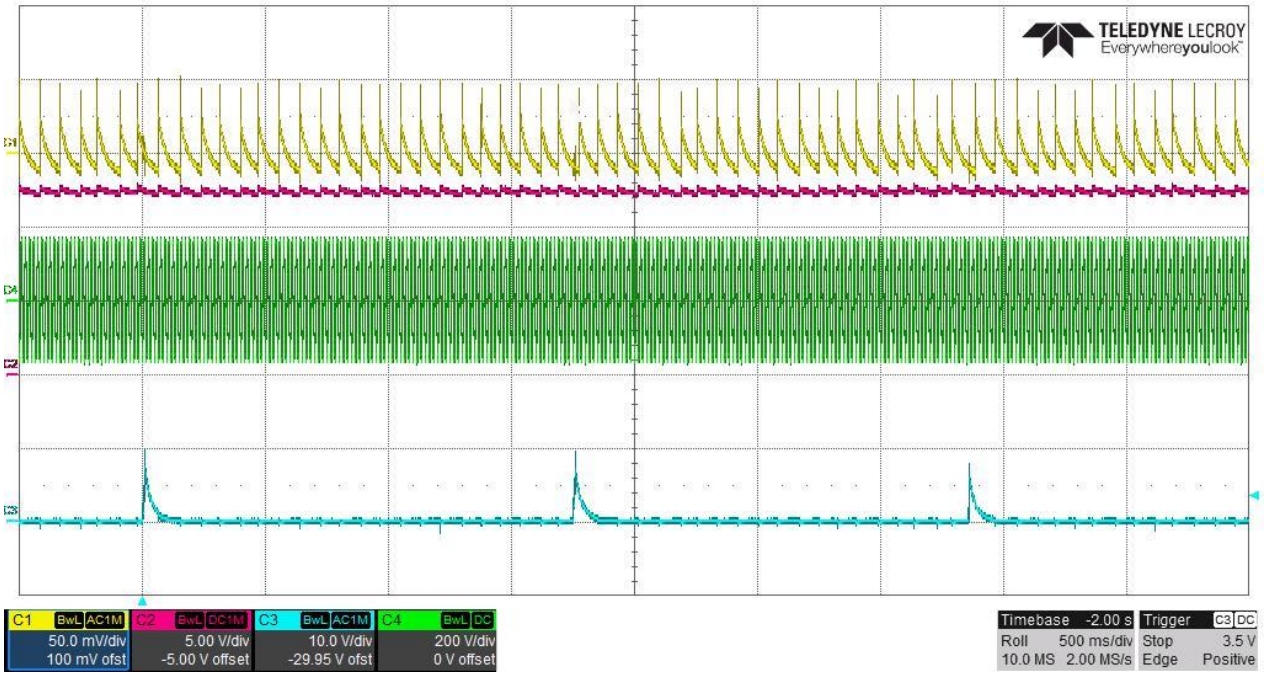


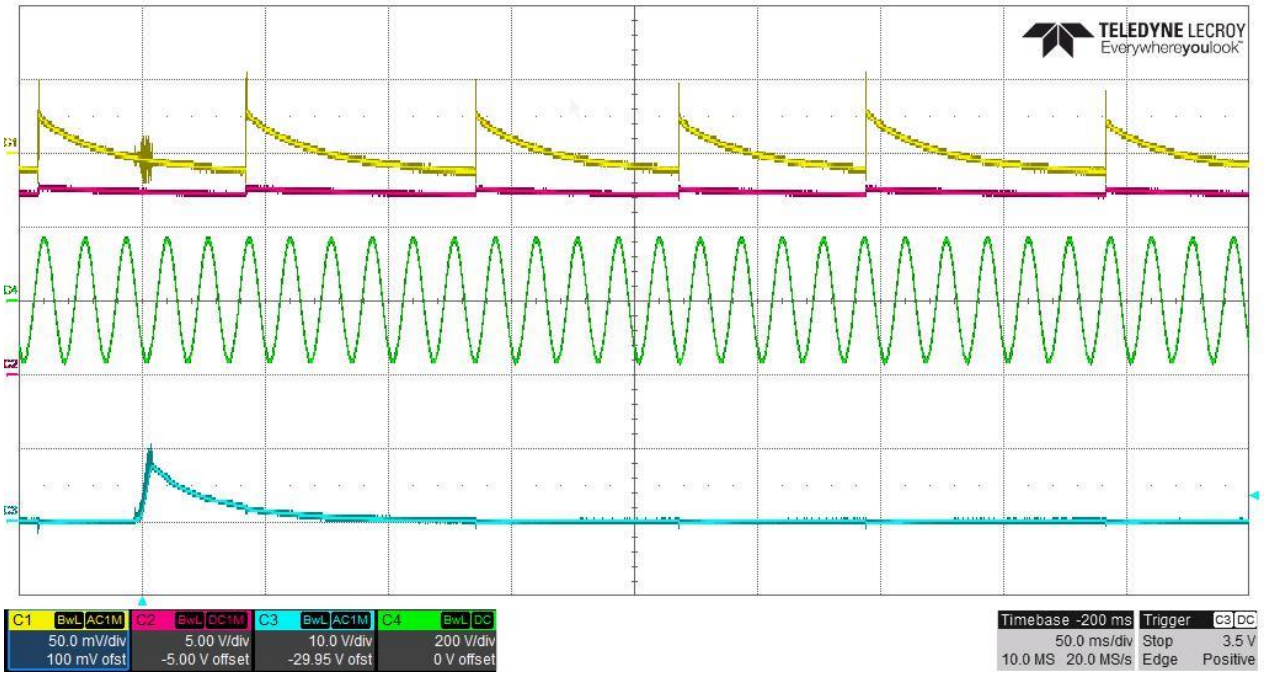
2.8.2 100V_{AC}/60Hz –12V/10.8A



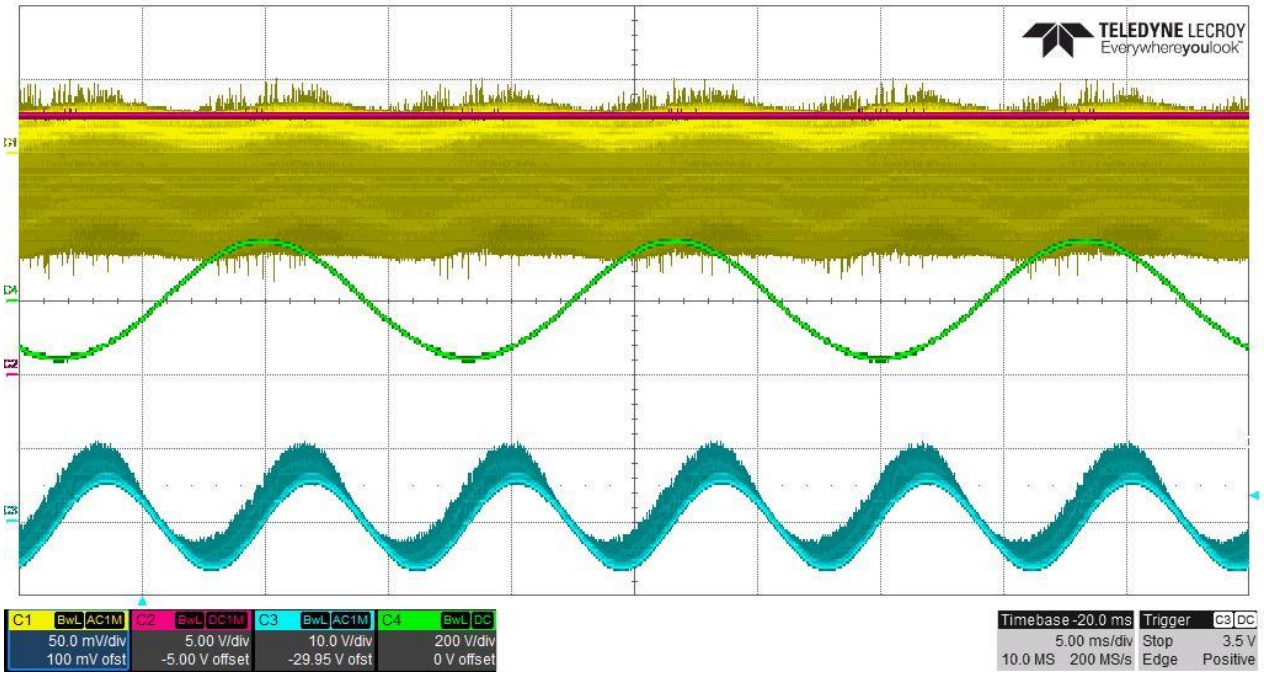


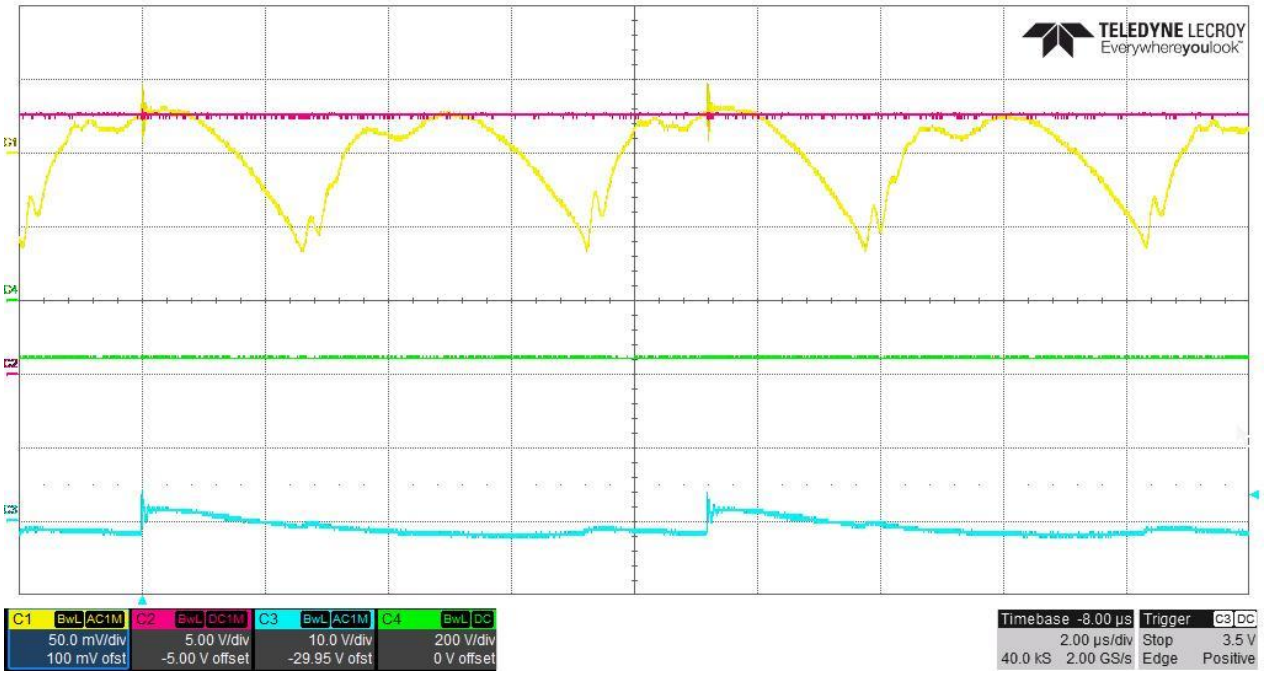
2.8.3 115V_{AC}/60Hz –12V/0A



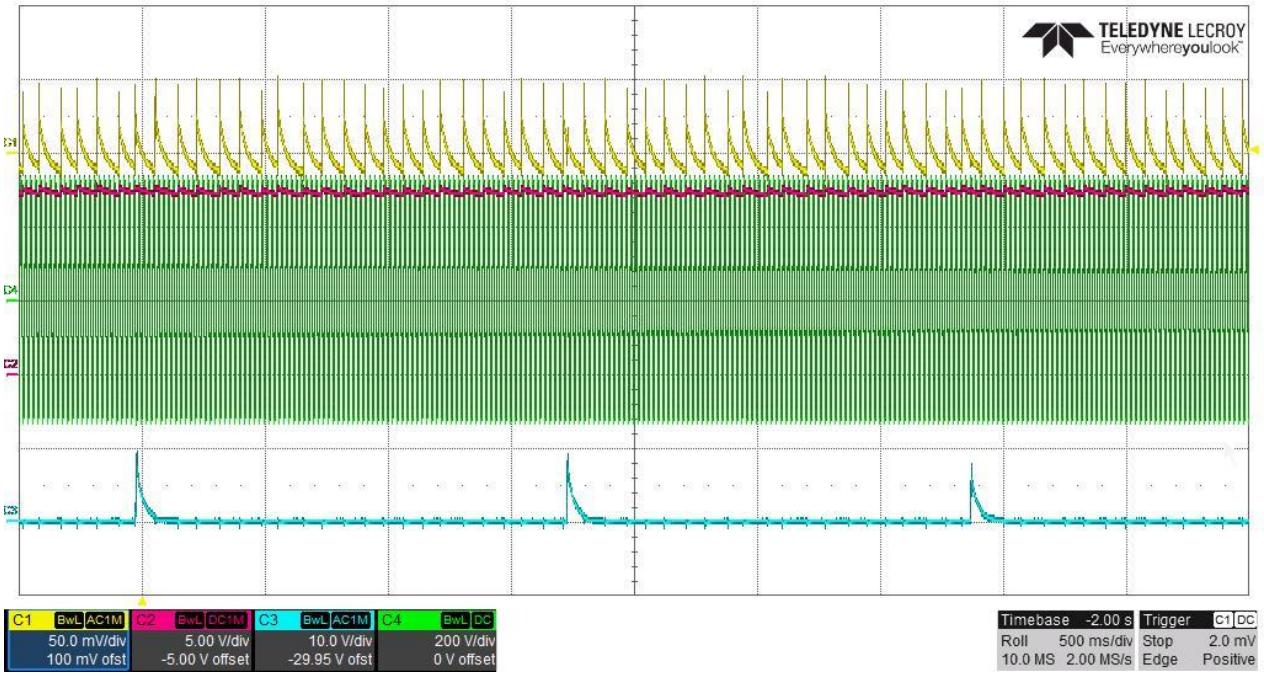


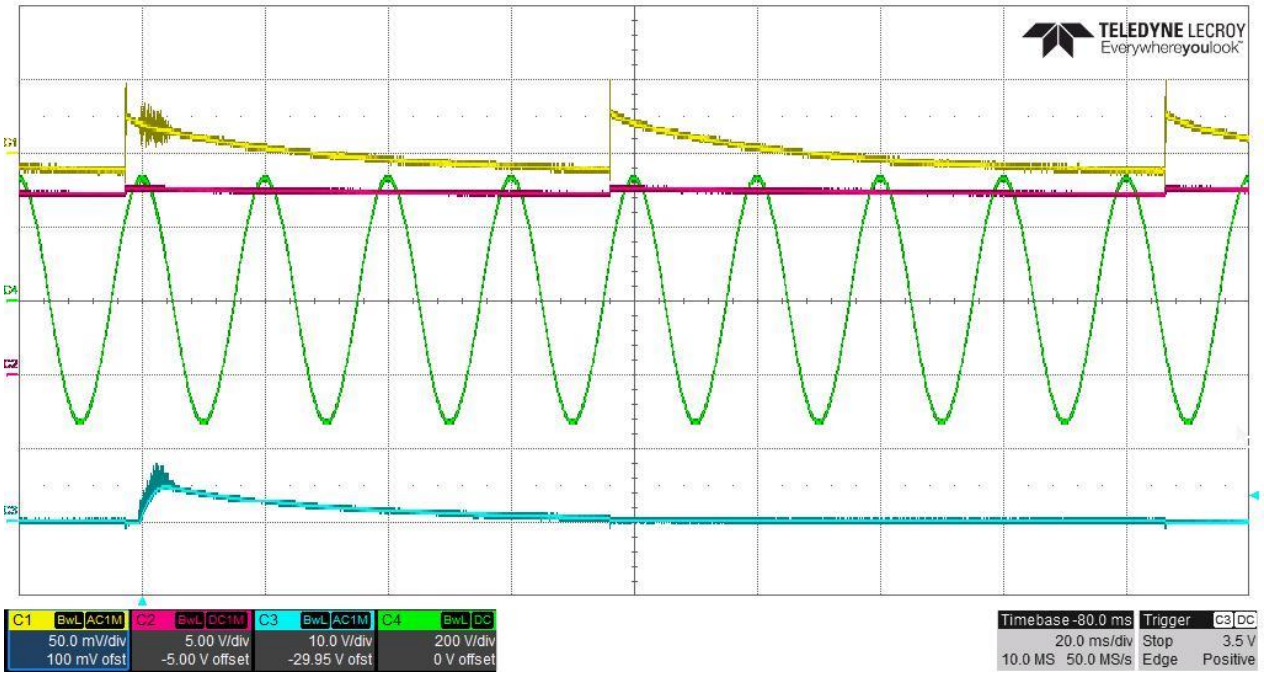
2.8.4 115V_{AC}/60Hz –12V/10.8A



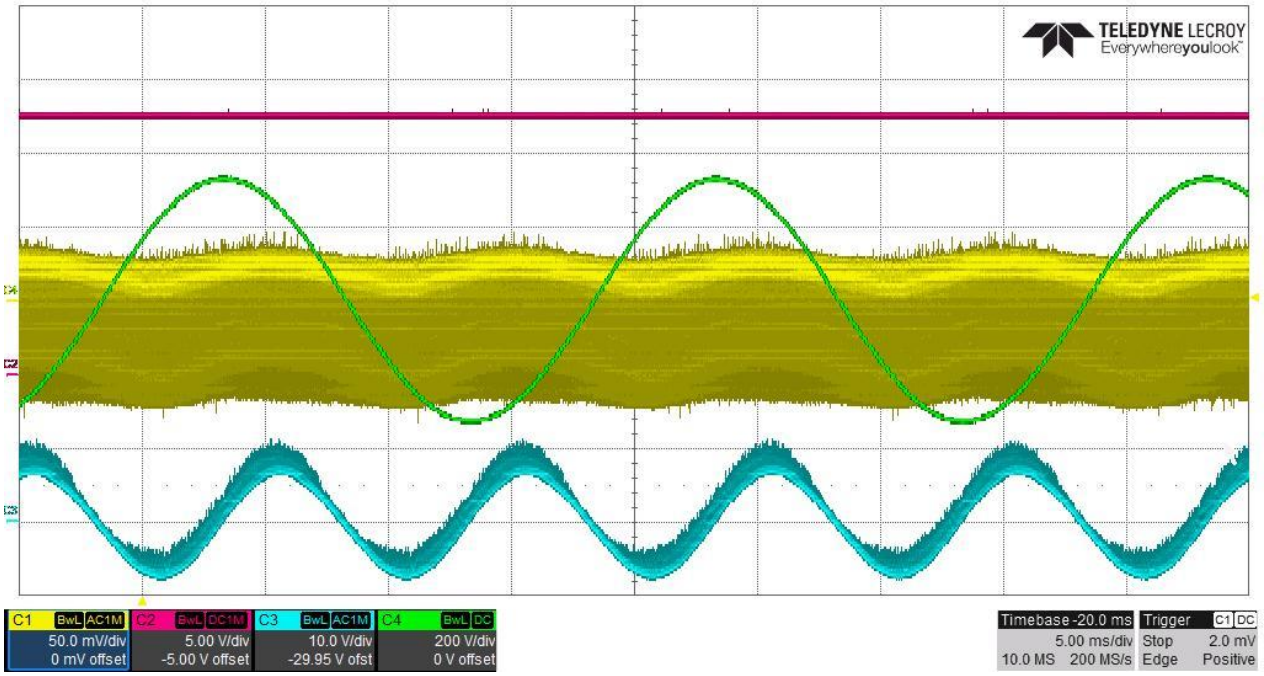


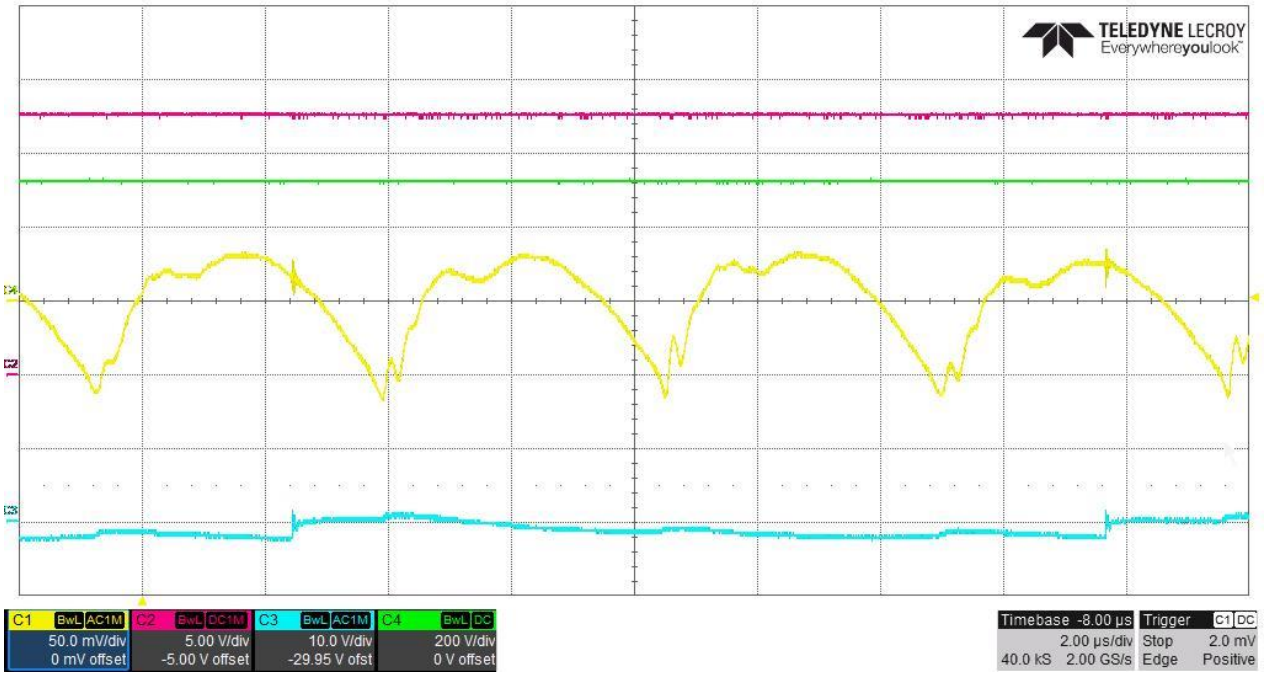
2.8.5 230V_{AC}/50Hz – 12V/0A





2.8.6 230V_{AC}/50Hz – 12V/10.8A

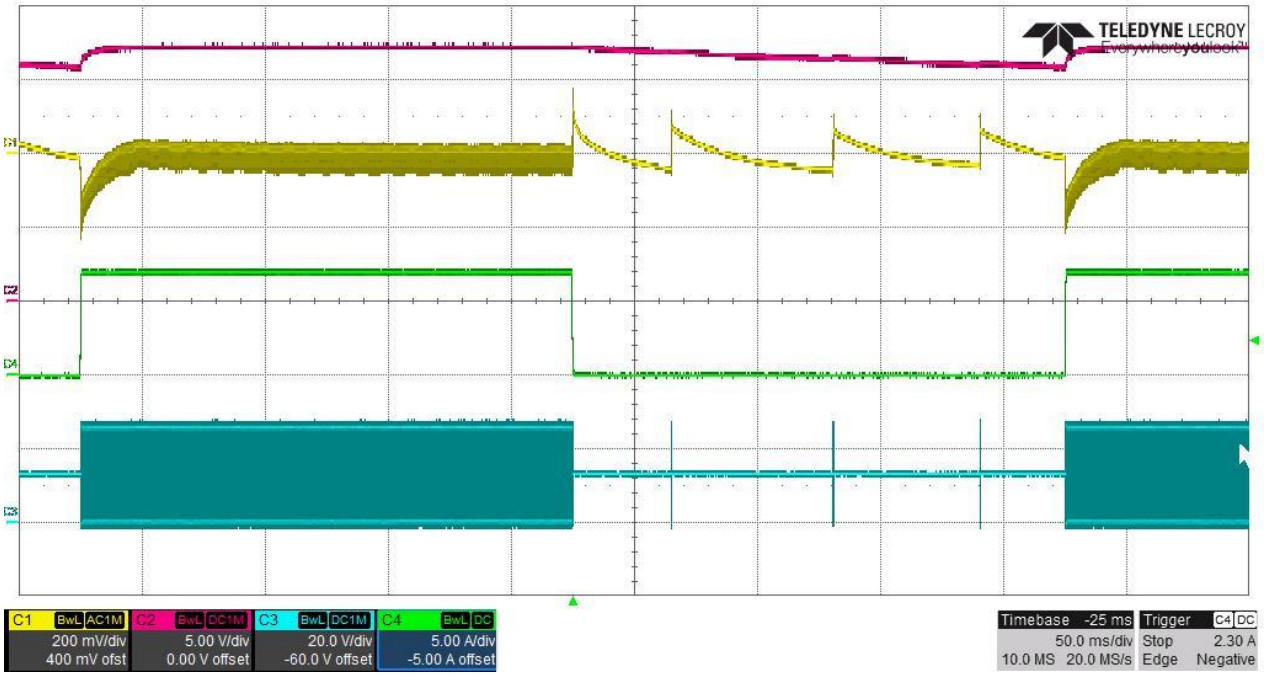




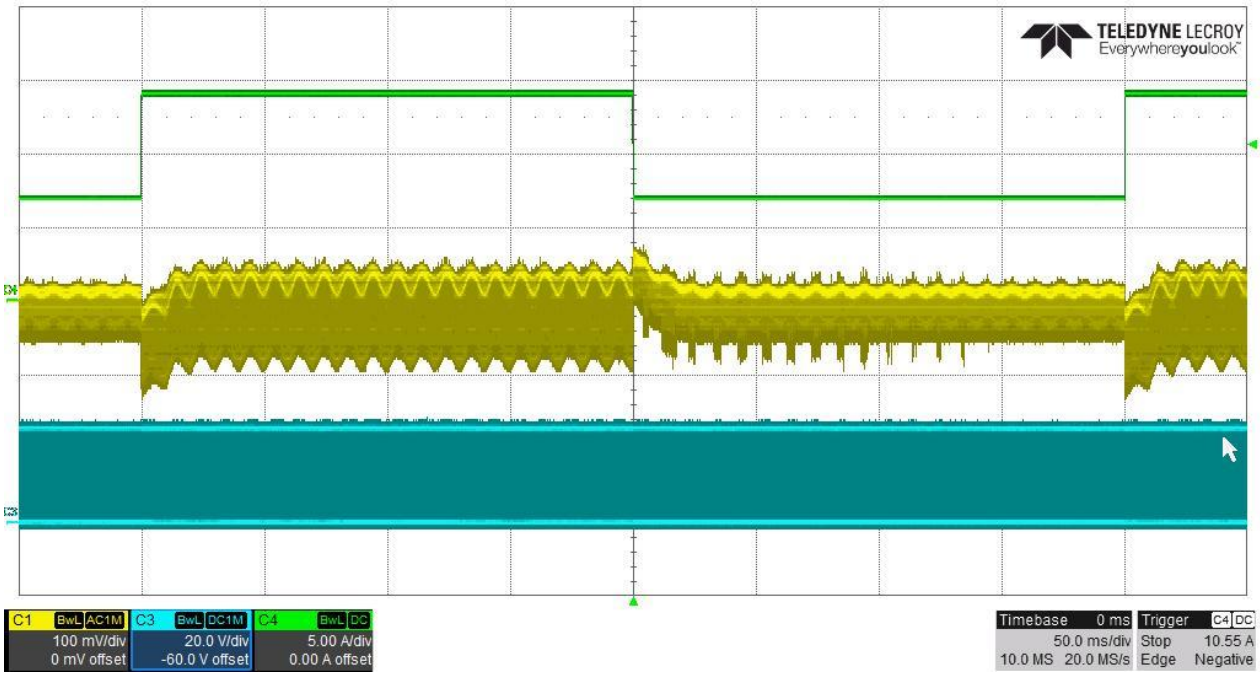
2.9 Load Response

Load response is tested at 230V_{AC}/50Hz input, where Channel 1 is the output voltage in AC level, Channel 3 is Q203 V_{DS}, and Channel 4 is output voltage in AC level.

2.9.1 Load step from 0A to 7A:

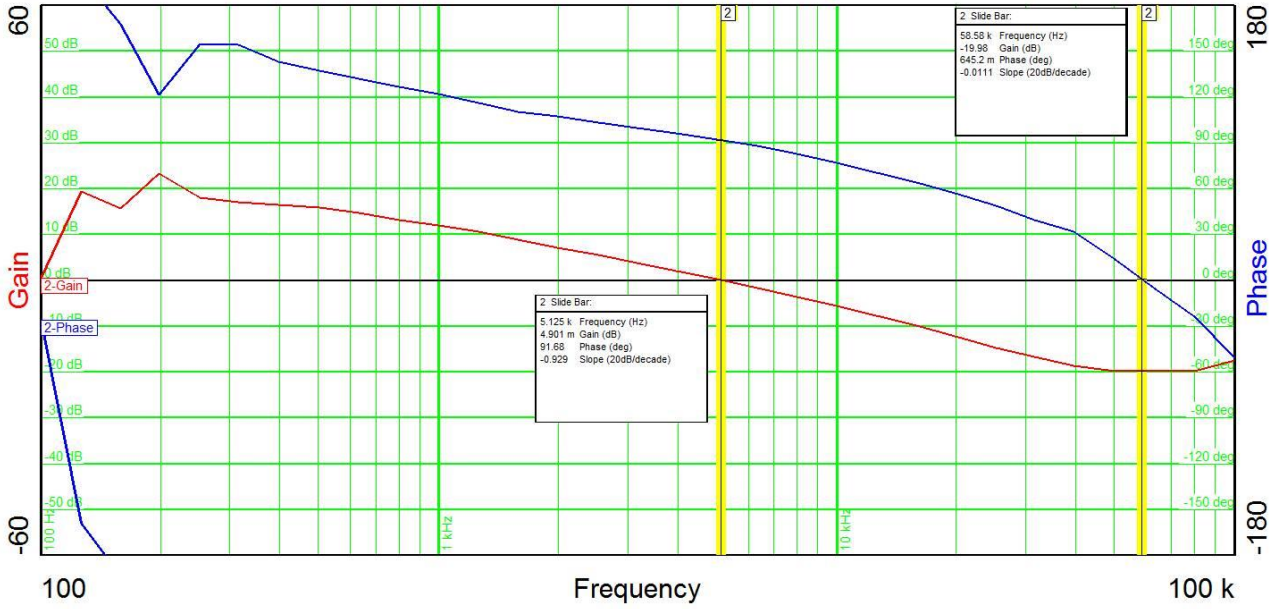


2.9.2 Load step from 7A to 14.4A:



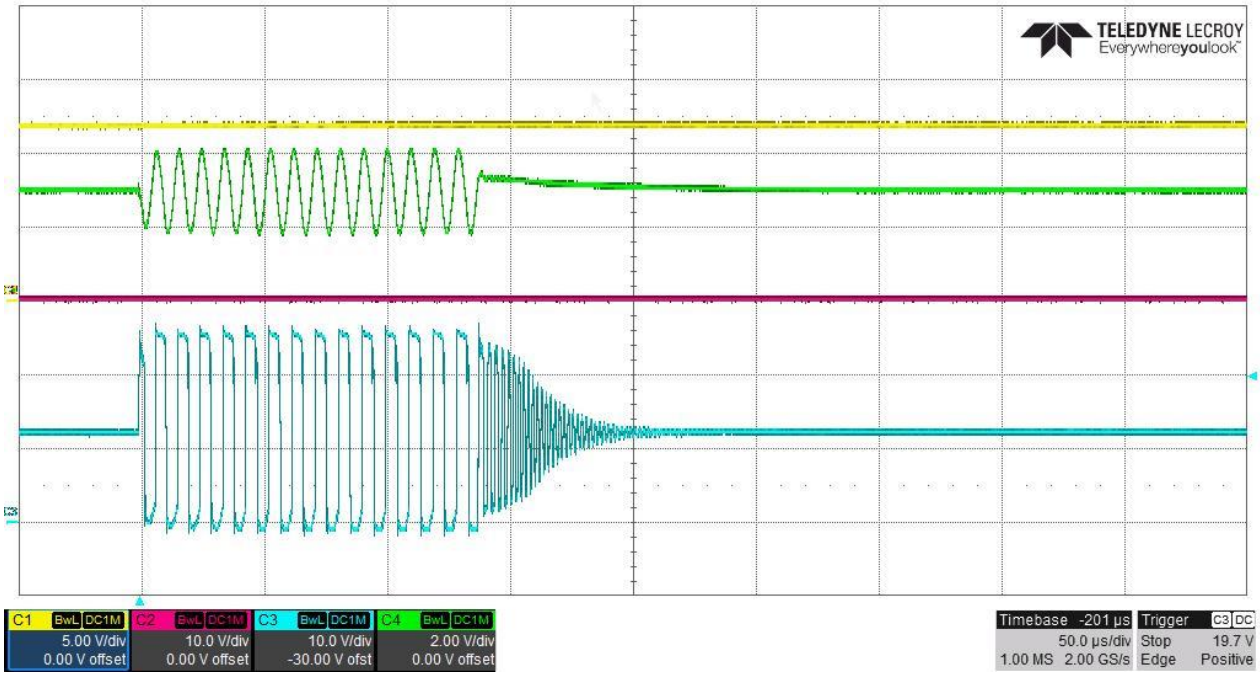
2.10 Frequency Response

Frequency response of the LLC-SRC stage is tested with $230V_{AC}$/50Hz input and 12V/10.8A output. A 20ohm resistor is inserted in between node V_{out} and the load for signal injection.

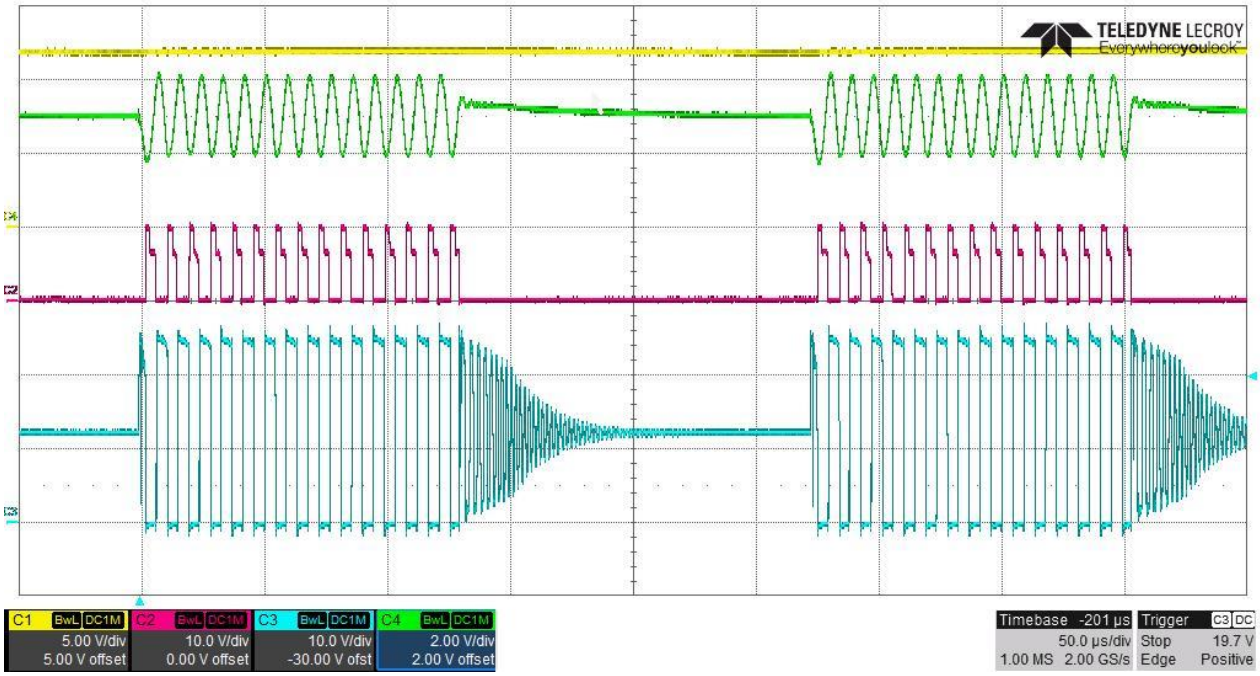


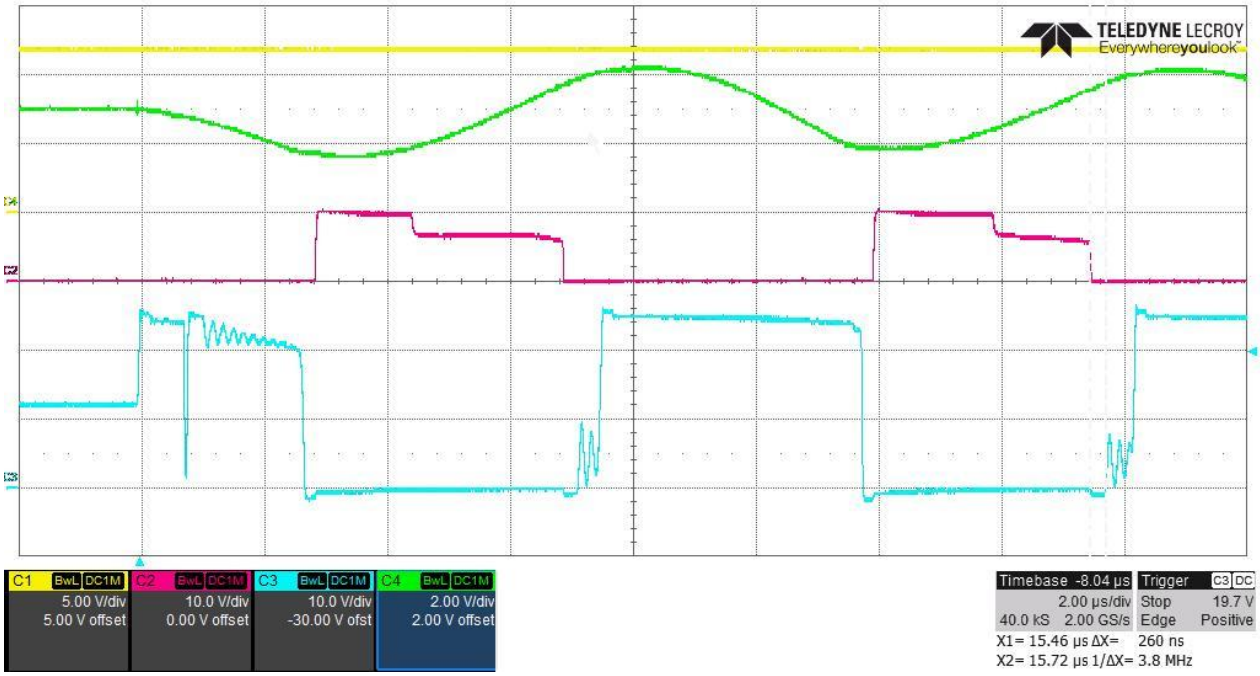
2.11 Key Waveforms

2.11.1 SR FET conduction at 100VAC/60Hz input, 12V/0A output: C1: V_{OUT}, C2: Q203 V_{GS}, C3: Q203 V_{DS}, C4: V_{CR}.

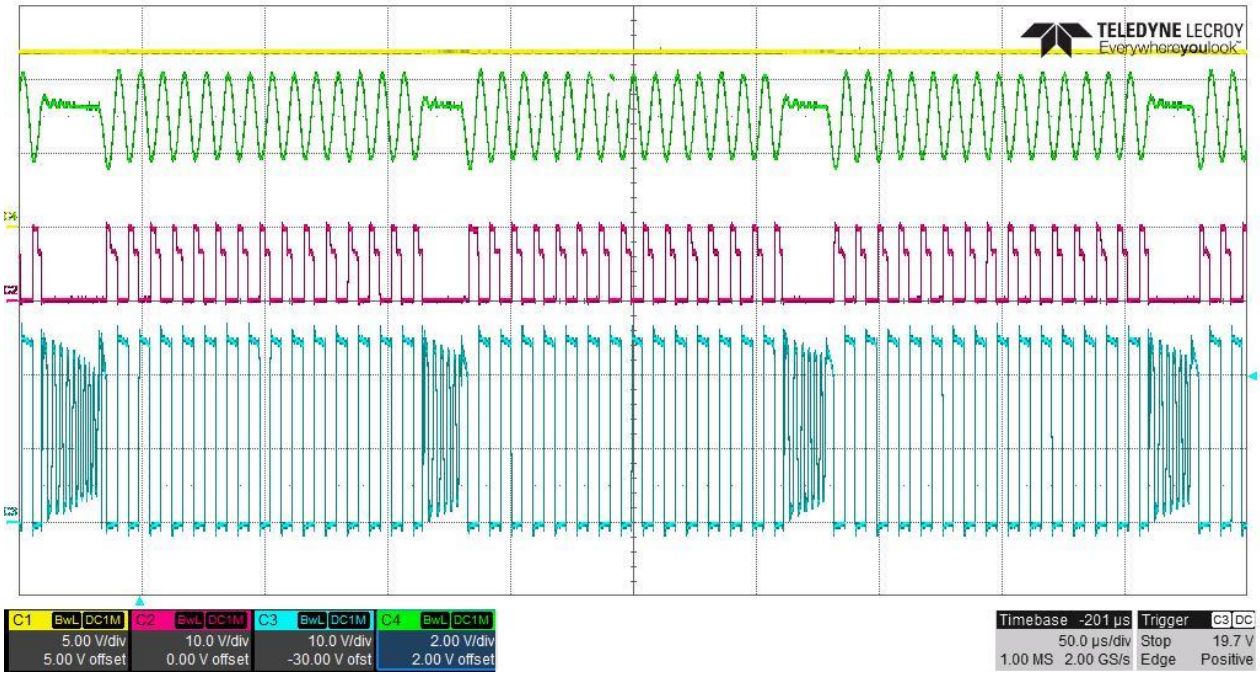


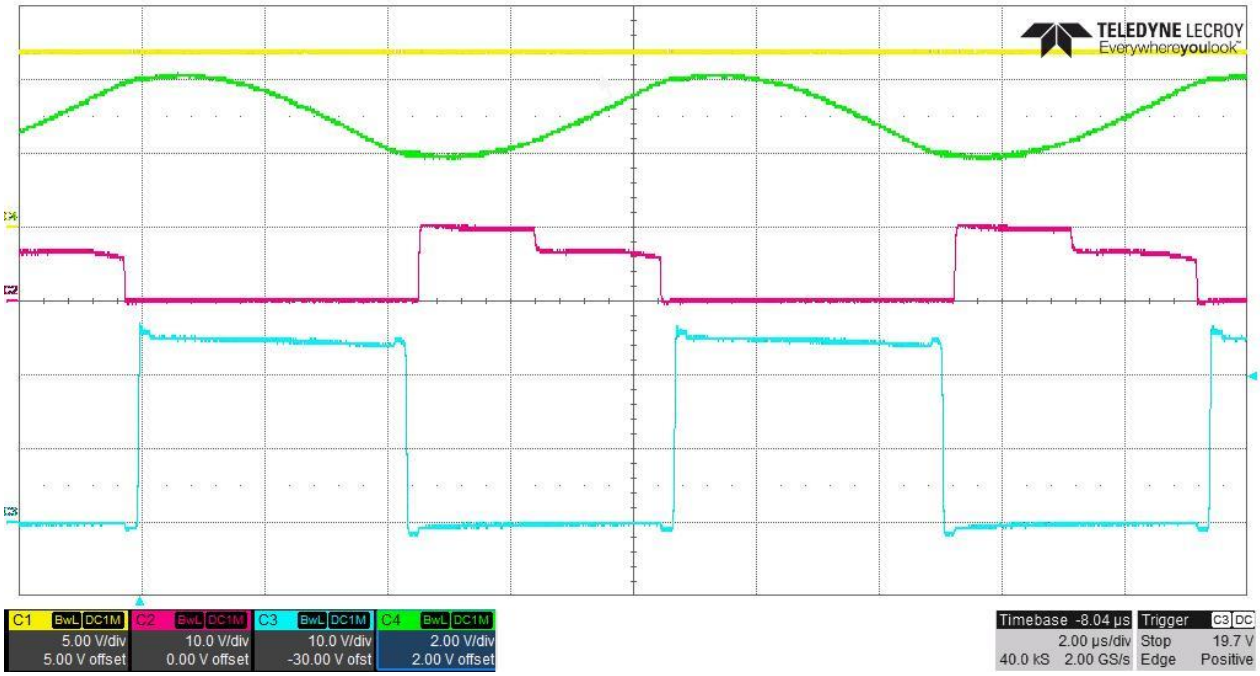
2.11.2 SR FET conduction at 100VAC/60Hz input, 12V/2.7A output: C1: V_{OUT}, C2: Q203 V_{GS}, C3: Q203 V_{DS}, C4: V_{CR}.



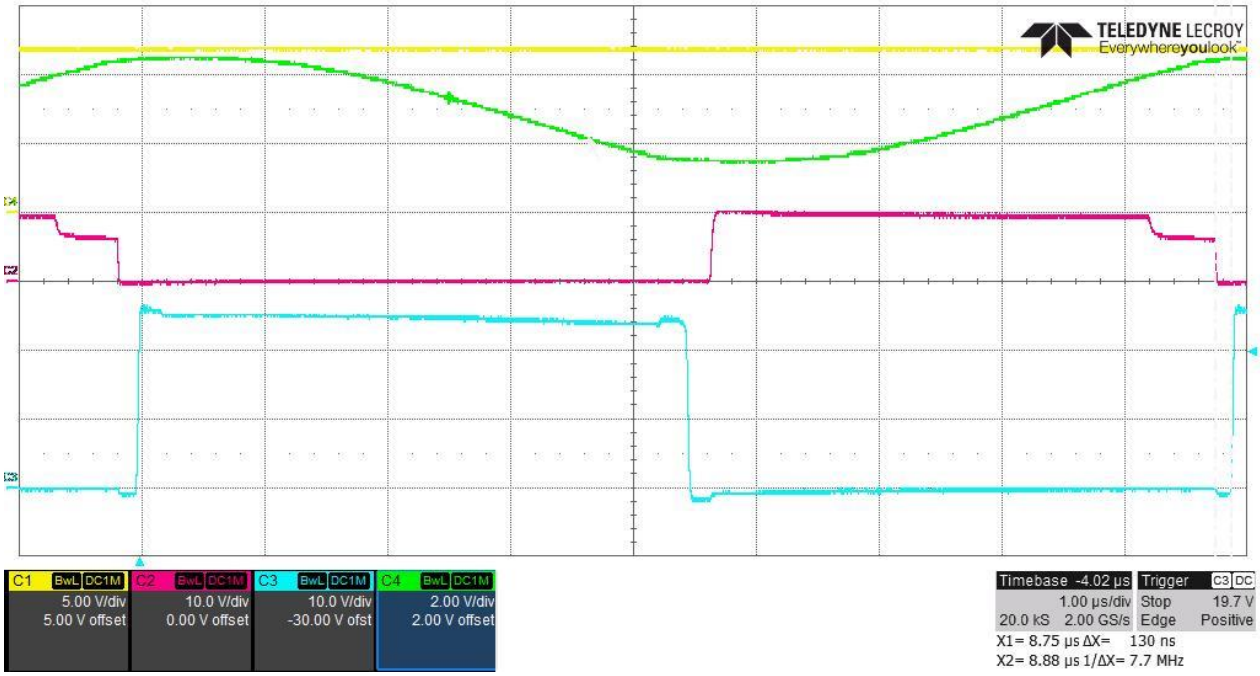


2.11.3 SR FET conduction at 100VAC/60Hz input, 12V/5.4A output: C1: V_{OUT}, C2: Q203 V_{GS}, C3: Q203 V_{DS}, C4: V_{CR}.





2.11.4 SR FET conduction at 100VAC/60Hz input, 12V/10.8A output: C1: V_{OUT}, C2: Q203 V_{GS}, C3: Q203 V_{DS}, C4: V_{CR}.



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