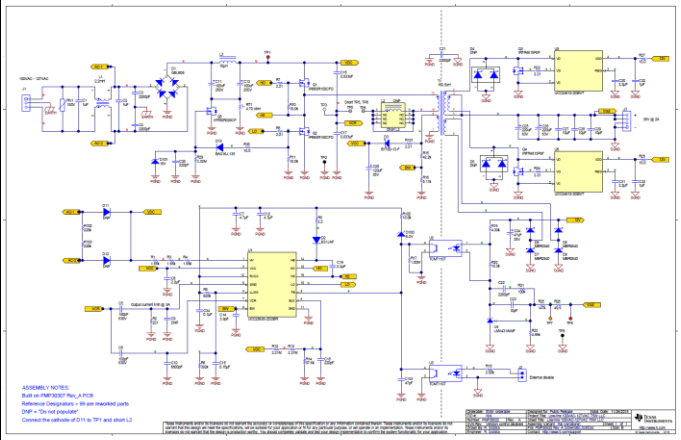
Test Report: PMP30522

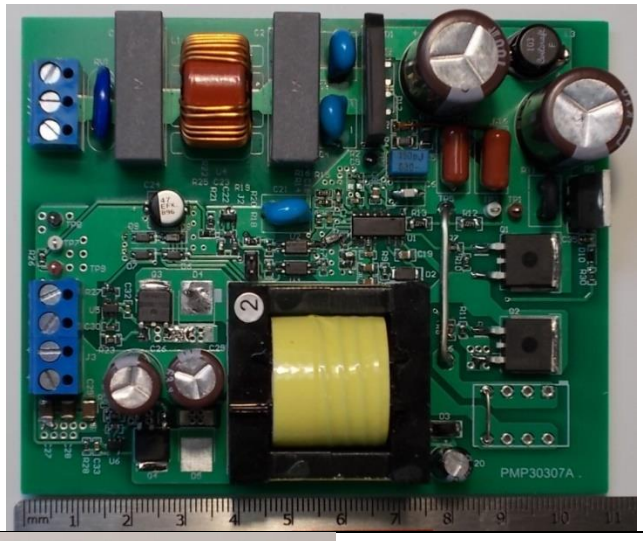
110 VAC to 38 V at 2 A Single Stage LLC Resonant Converter Reference Design

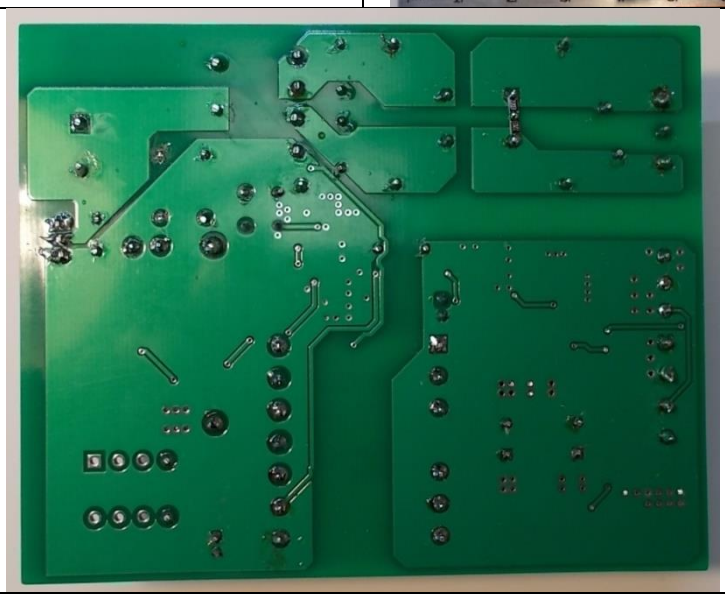
Description

This reference design is a half bridge LLC resonant converter, typically combined to PFC front end. It works directly from mains (100 VAC - 127 VAC) and supplies 38 V at 2 A. The burst mode feature keeps the curve flat in a range of 86% - 94% when load is varied between 1% and 100%.

The reference design PMP30522 Rev_A has been built on PMP30307 Rev_A PCB







1 Test Prerequisites

1.1 Voltage and Current Requirements

Table 1. Voltage and Current Requirements

PARAMETER	SPECIFICATIONS
Input Voltage	100VAC – 127VAC
Output Voltage	38VDC
Output Current	2A

1.2 Required Equipment

- 0…130VAC, (minimum current limit 3Arms), AC constant voltage source (VS1)
- Electronic load, (constant current range 0…2A)
- Oscilloscope (min. 100 MHz bandwidth)
- Current probe (min. 100 KHz bandwidth)
- Optional: infrared camera

1.3 Considerations

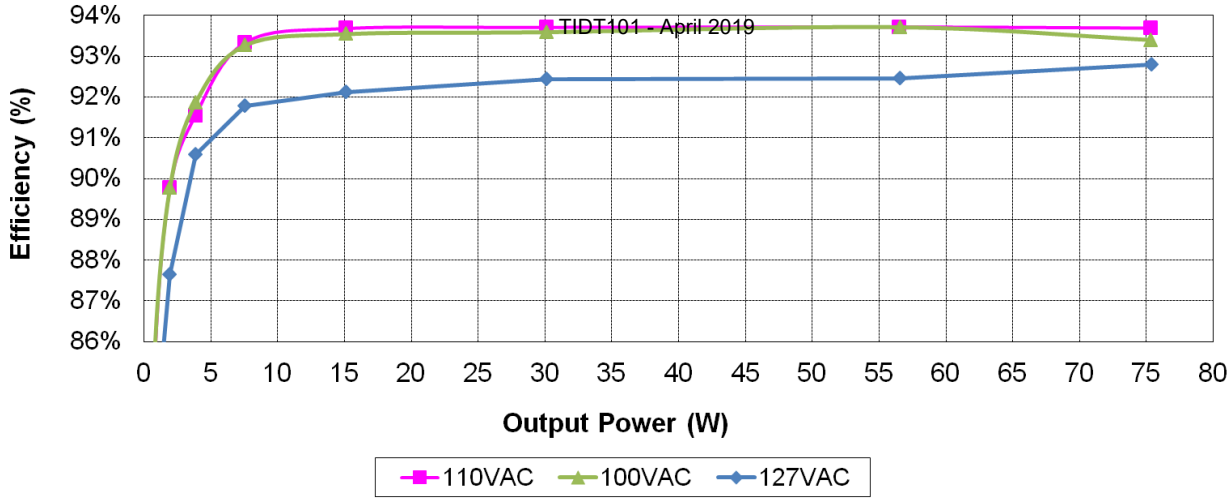
a) Connect the source VS1 to J1-1 and J1-3; earth connection to J1-2.
b) Connect the load to J3(3-4) (plus) and J3(1-2) (ground)
c) Attach current probe to the jumper that connects TP5 and TP6, to measure the resonant current.
d) After turn off, wait ~ 5 minutes until C11 and C13 input capacitors are completely discharged (warning: HIGH VOLTAGE)

2 Testing and Results

2.1 Efficiency Graph and Data

2.1.1 Efficiency Graph:

The efficiency graph, versus output power, is shown below.
The input voltage has been set respectively to 110VAC, 100VAC and 127VAC.



2.1.2 Efficiency Data:

The efficiency graph reports the data from the table shown below:

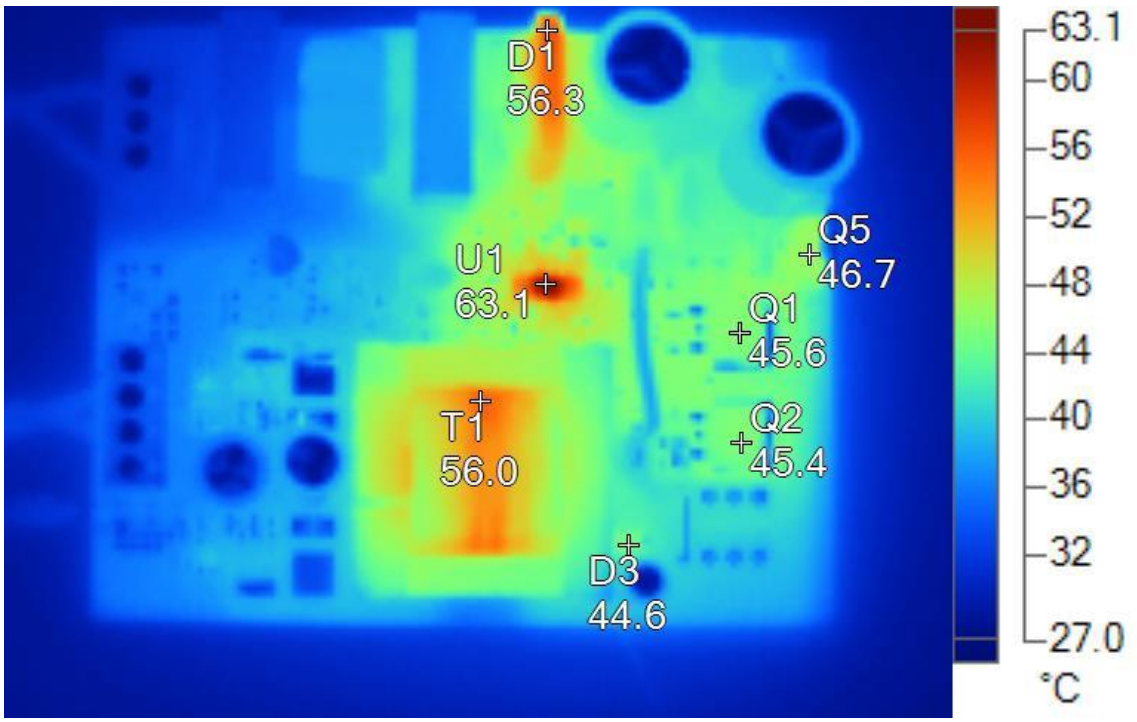
Vin (AC)	Pin (W)	Vout (V)	Iout (mA)	Pout (W)	Efficiency (%)
110	0.1083	37.68	0	0	0%
110	0.3068	37.67	5.5	0.207	67.53%
110	0.5225	37.66	11.0	0.414	79.28%
110	0.9578	37.66	21.8	0.821	85.72%
110	2.148	37.66	51.2	1.928	89.77%
110	4.199	37.65	102.1	3.844	91.55%
110	8.104	37.65	200.9	7.564	93.34%
110	16.14	37.65	401.6	15.12	93.68%
110	32.15	37.65	800.2	30.13	93.71%
110	60.30	37.65	1501	56.51	93.72%
110	80.41	37.65	2001	75.34	93.69%

Vin (AC)	Pin (W)	Vout (V)	Iout (mA)	Pout (W)	Efficiency (%)
100	0.1013	37.66	0	0	0%
100	0.3056	37.67	5.7	0.215	70.3%
100	0.5207	37.67	11.1	0.418	80.3%
100	0.9555	37.67	21.8	0.821	85.9%
100	2.148	37.66	51.2	1.928	89.8%
100	4.186	37.66	102.1	3.845	91.9%
100	8.108	37.66	200.8	7.562	93.3%
100	16.16	37.66	401.4	15.12	93.5%
100	32.19	37.65	800.2	30.13	93.6%
100	60.36	37.66	1502	56.57	93.7%
100	80.66	37.65	2001	75.34	93.4%

Vin (AC)	Pin (W)	Vout (V)	Iout (mA)	Pout (W)	Efficiency (%)
127	0.1127	37.74	0	0	0%
127	0.3226	37.66	5.7	0.215	66.5%
127	0.5426	37.66	11.1	0.418	77.0%
127	0.9865	37.66	21.9	0.825	83.6%
127	2.200	37.66	51.2	1.928	87.6%
127	4.249	37.66	102.2	3.849	90.6%
127	8.243	37.66	200.9	7.566	91.8%
127	16.41	37.66	401.4	15.12	92.1%
127	32.60	37.66	800.2	30.14	92.4%
127	61.16	37.65	1502	56.55	92.5%
127	81.21	37.66	2001	75.36	92.8%

2.2 Thermal Image

The graph and table below show the thermal picture of the converter supplied at 110VAC, 60Hz. The image has been taken after the board was running for 45 minutes, placed horizontal on the bench, at full load, with ambient temperature of 25°C and in still air condition.

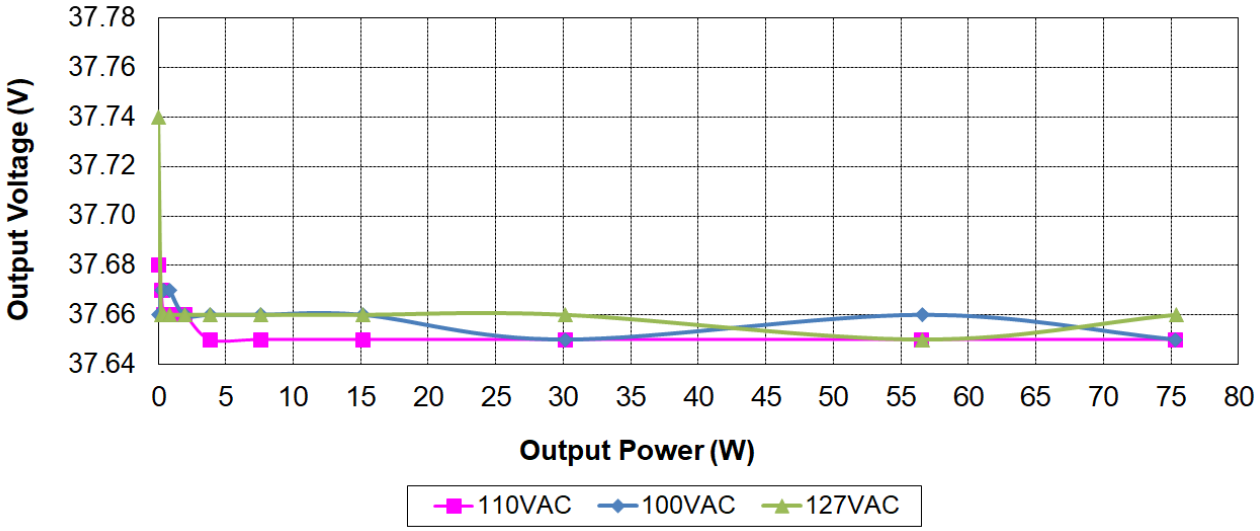


Main Image Markers

Name	Temperature	Emissivity	Background
T1	56.0°C	0.95	25.0°C
U1	63.1°C	0.95	25.0°C
D1	56.3°C	0.95	25.0°C
Q5	46.7°C	0.95	25.0°C
Q1	45.6°C	0.95	25.0°C
Q2	45.4°C	0.95	25.0°C
D3	44.6°C	0.95	25.0°C

2.3 Static Output Voltage Variation versus Load

The output voltage regulation versus load current is shown in the graph below.



2.4 Dimensions

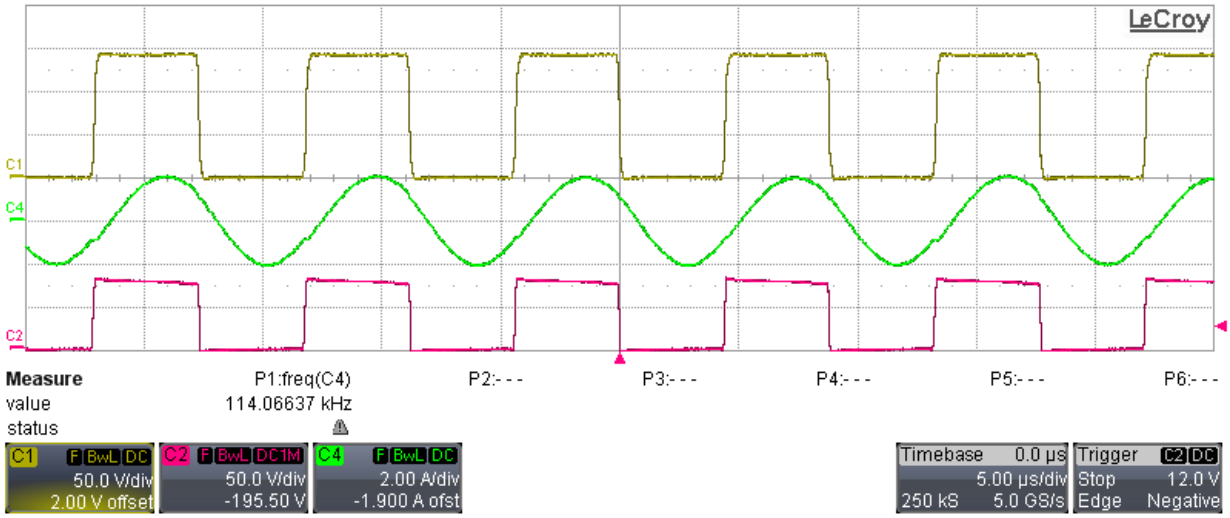
The board dimensions are 88.3 mm x 109.2 mm, height 25 mm.

3 Waveforms

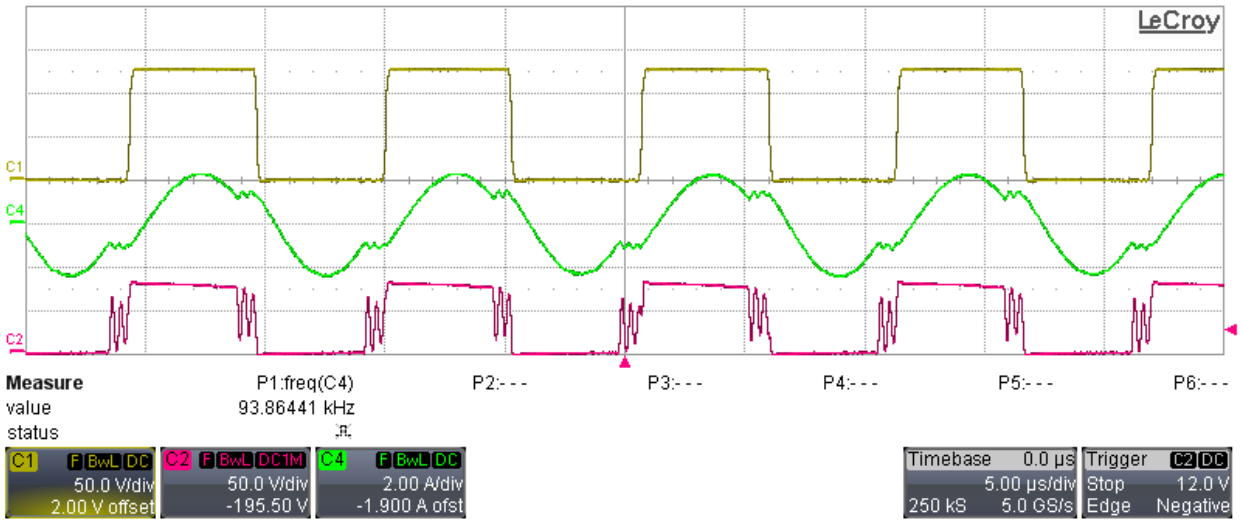
3.1.1 Switching Waveforms on Drain of main FETs

The switching waveforms have been measured by supplying the converter at 110VAC, 100VAC and 127VAC in full load condition (waveforms referred to primary or secondary ground).

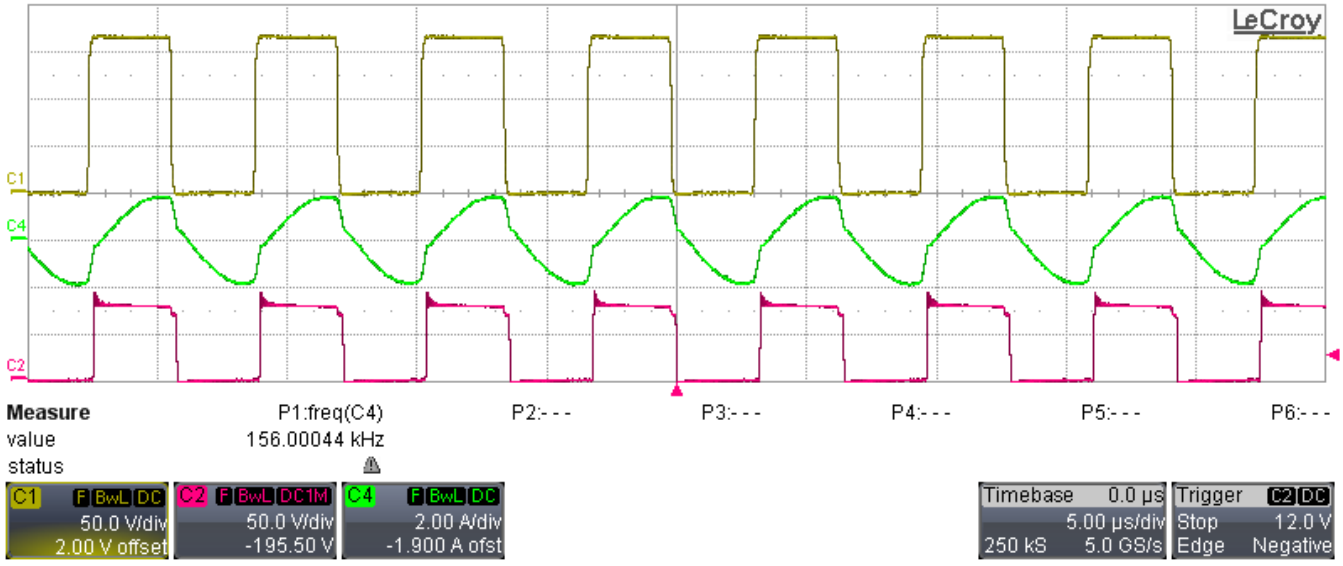
C1: Q2-Vds (50V/div, 5usec/div, 200MHz BWL), C2: Q3-Vds (50V/div, 200 MHz BWL)
C4: Resonant current (TP5-TP6) (2A/div, 200 MHz BWL)
Vin = 110VAC, full load.



C1: Q2-Vds (50V/div, 5usec/div, 200MHz BWL), C2: Q3-Vds (50V/div, 200 MHz BWL)
C4: Resonant current (TP5-TP6) (2A/div, 200 MHz BWL)
Vin = 100VAC, full load.

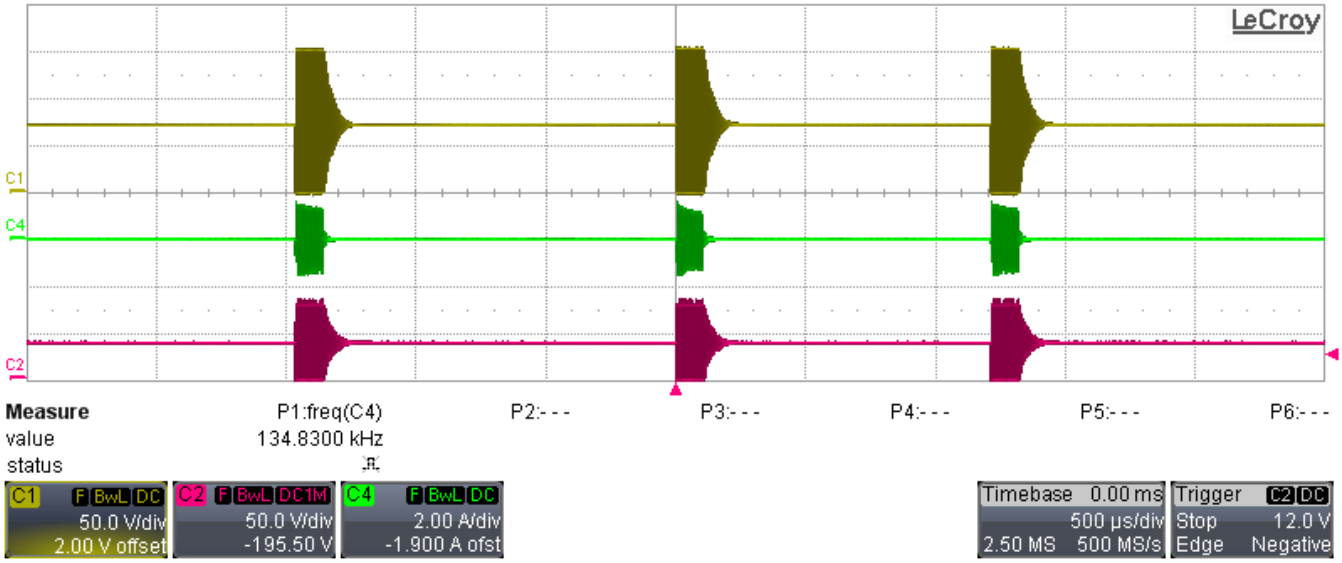


C1: Q2-Vds (50V/div, 5usec/div, 200MHz BWL), C2: Q3-Vds (50V/div, 200 MHz BWL)
C4: Resonant current (TP5-TP6) (2A/div, 200 MHz BWL)
Vin = 127VAC, full load.

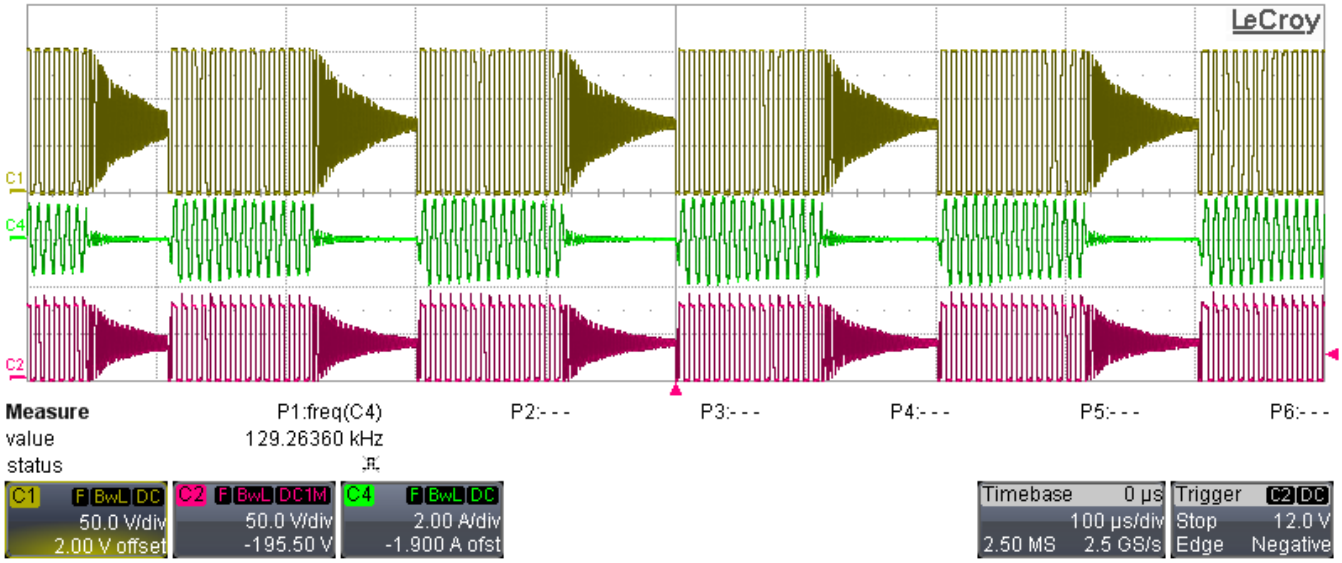


3.1.2 Switching Waveforms during Burst Mode

C1: Q2-Vds (50V/div, 500usec/div, 200 MHz BWL), C2: Q3-Vds (50V/div, 200 MHz BWL)
C4: Resonant current (TP5-TP6) (2A/div, 200 MHz BWL)
Vin = 110VAC, Iout = 100mA.



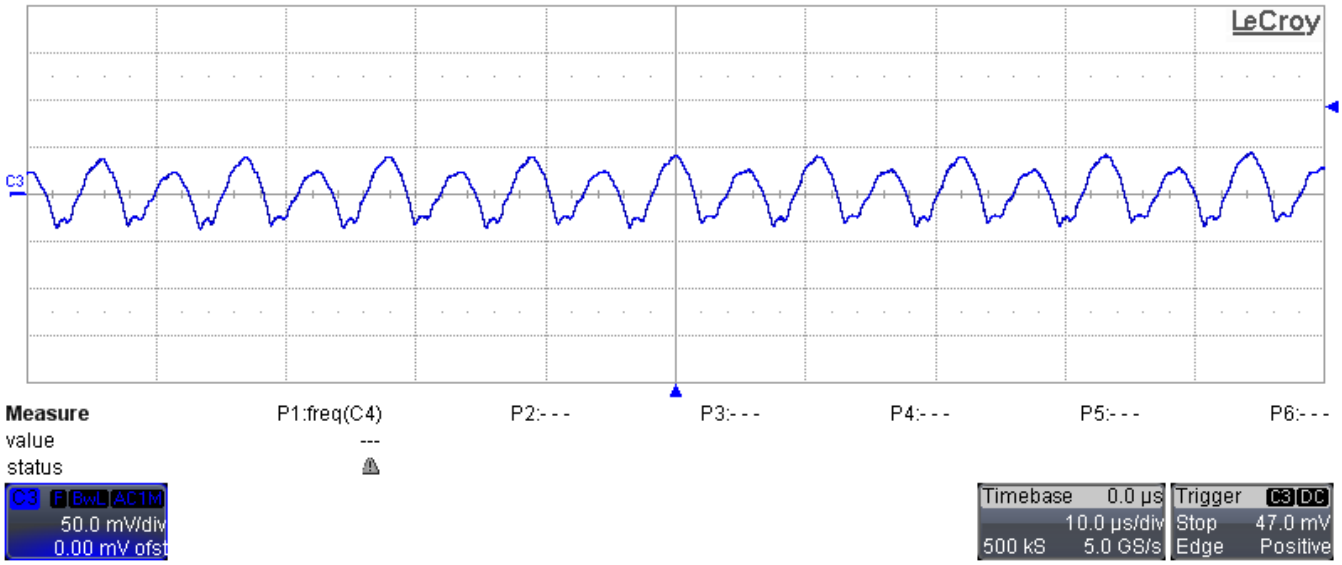
C1: Q2-Vds (50V/div, 100usec/div, 200 MHz BWL), C2: Q3-Vds (50V/div, 200 MHz BWL)
C4: Resonant current (TP5-TP6) (2A/div, 200 MHz BWL)
Vin = 110VAC, Iout = 1A.



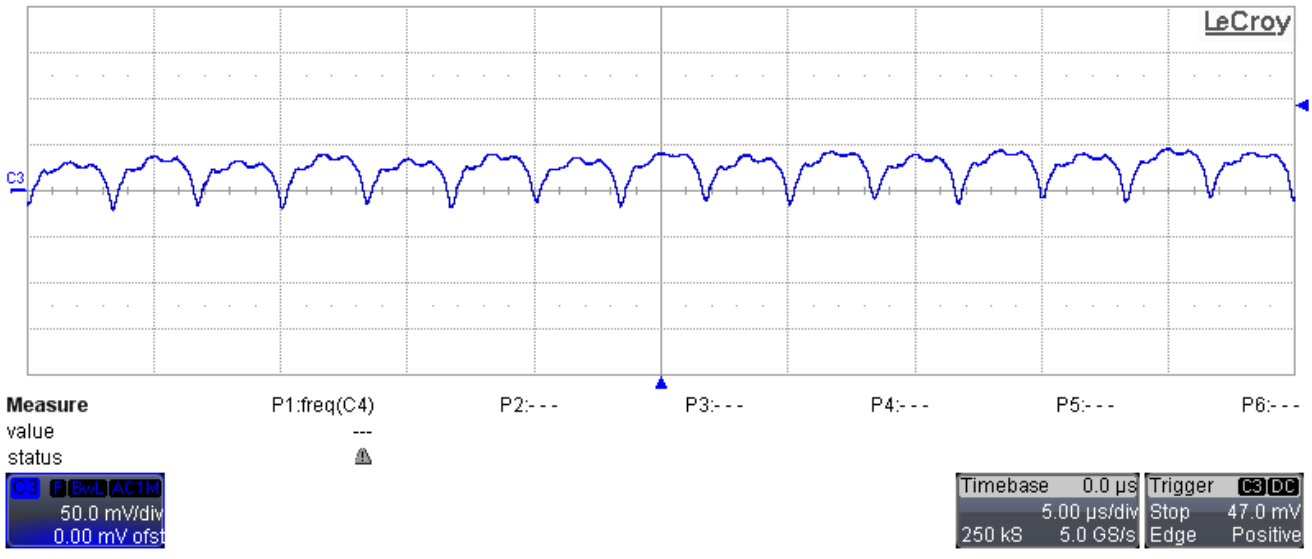
3.2 Output Voltage Ripple

The output voltage ripple has been measured by supplying the converter at minimum and maximum input AC voltage, in full load and light load (burst mode) conditions.

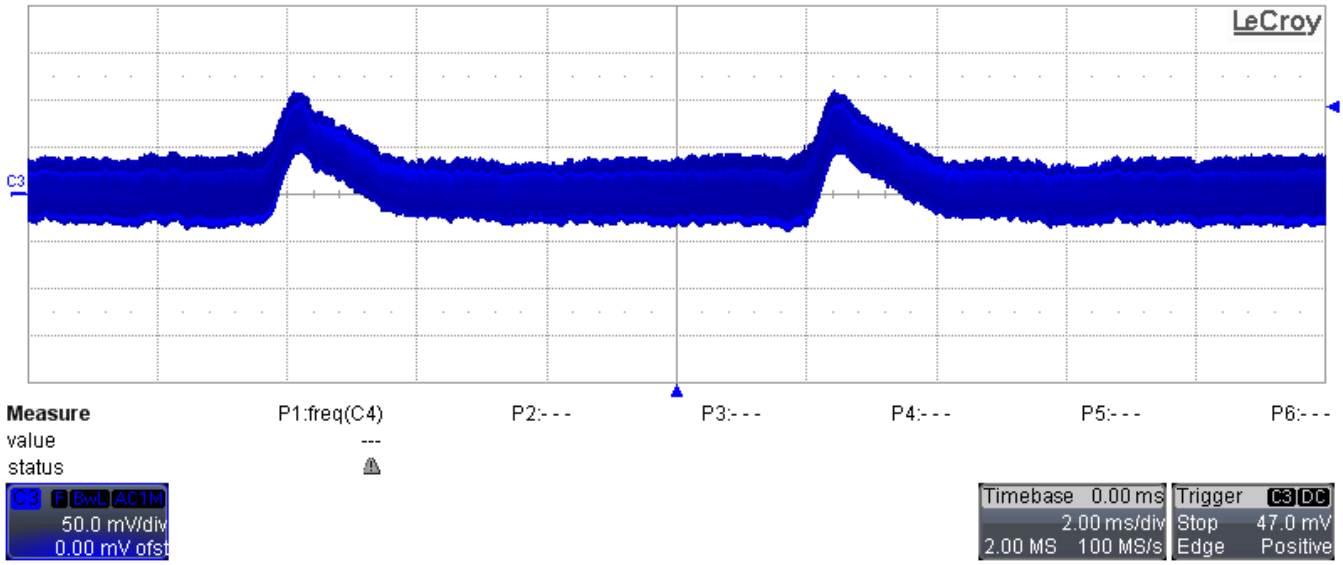
C1: Vout (50mV/div, 10usec/div, AC coupling, 20 MHz BWL)
Vin = 100VAC, full load.



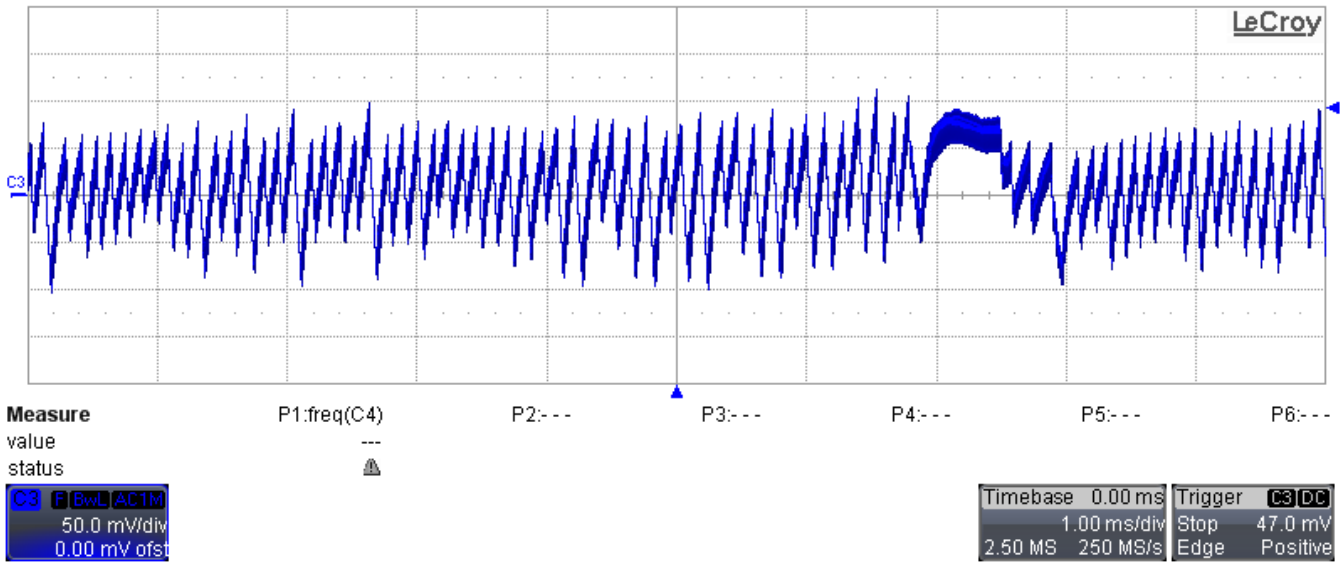
C1: Vout (50mV/div, 5usec/div, AC coupling, 20 MHz BWL)
Vin = 127VAC, full load.



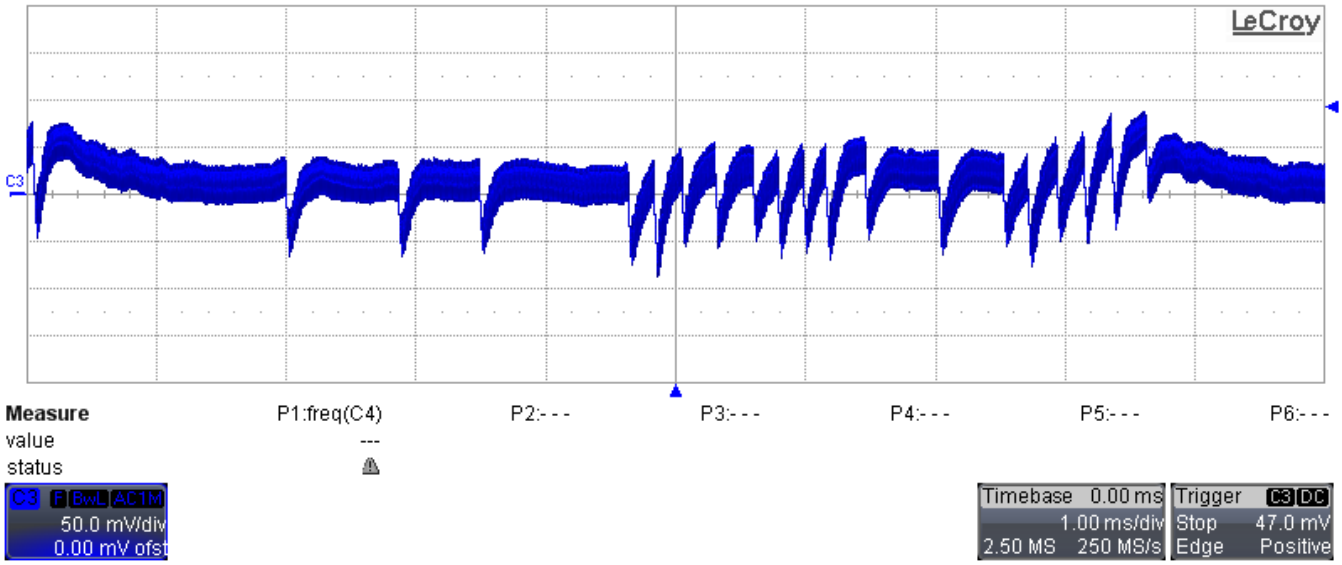
C1: Vout (50mV/div, 2msec/div, AC coupling, 20 MHz BWL)
Vin = 100VAC, full load (120 Hz ripple)



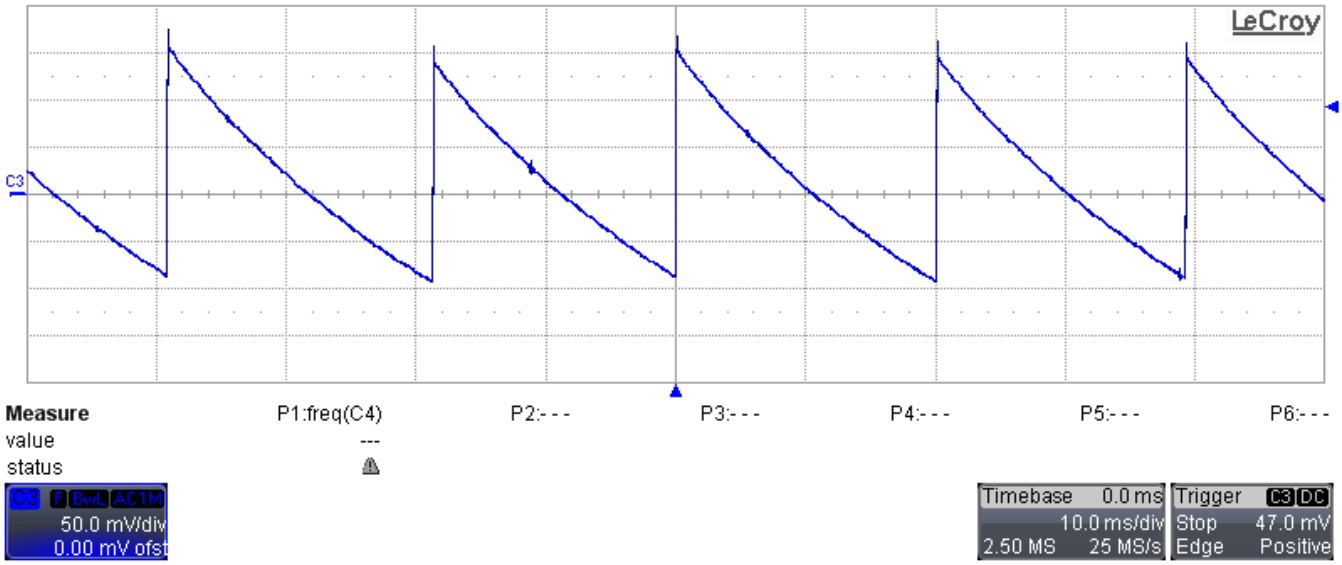
C1: Vout (50mV/div, 1msec/div, AC coupling, 20 MHz BWL)
Vin = 127VAC, Iout =1.2A, burst mode



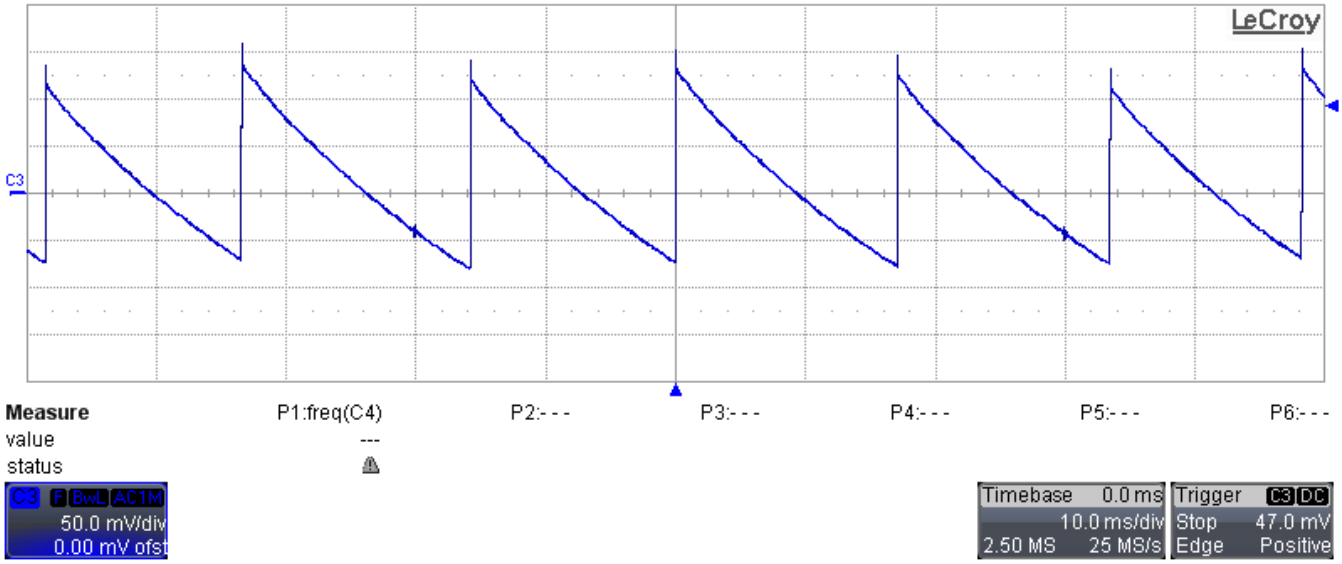
C1: Vout (50mV/div, 1msec/div, AC coupling, 20 MHz BWL)
Vin = 100VAC, Iout =1.2A, burst mode



C1: Vout (50mV/div, 10msec/div, AC coupling, 20 MHz BWL)
Vin = 100VAC, Iout =5mA, burst mode



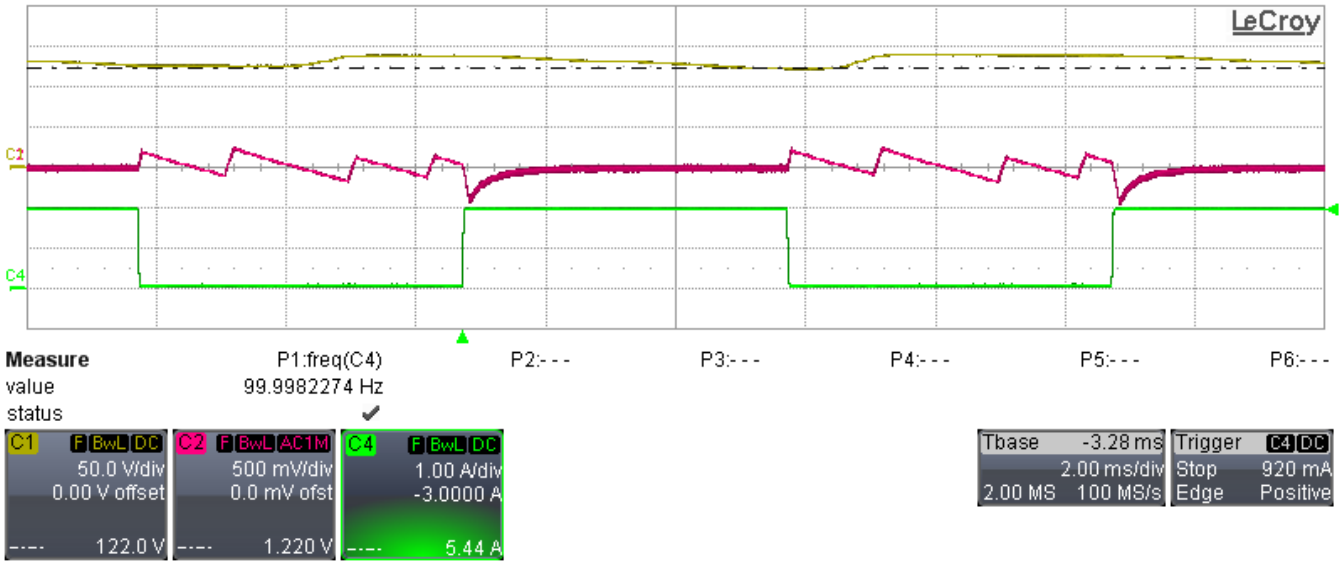
C1: Vout (50mV/div, 10msec/div, AC coupling, 20 MHz BWL)
Vin = 127VAC, Iout =5mA, burst mode



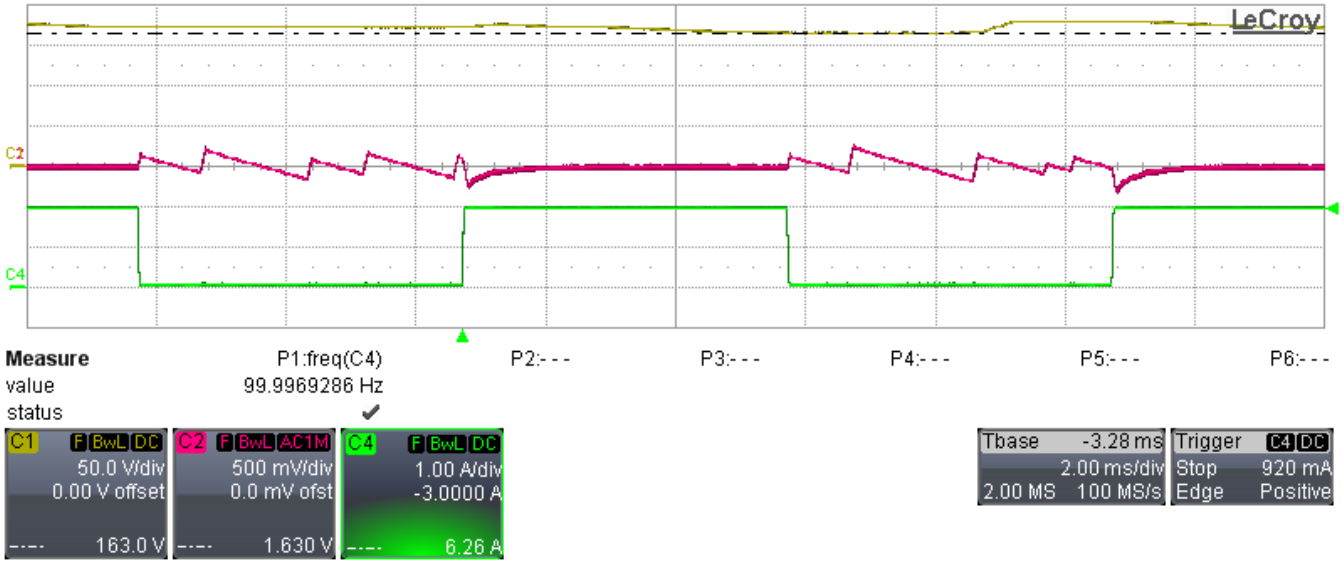
3.3 Load Transients

The output voltage variation, during load transients, has been measured by supplying the converter at 100VAC and 127VAC. The output current has been switched between 100mA and 2A.
For all waveforms the bandwidth of the scope has been set to 20 MHz.

C1: Voltage on TP1 (50V/div, 2msec/div, DC coupling), C2: Vout (500mV/div, AC coupling)
C4: Output current (1A/div, DC coupling)
Vin = 100VAC, Iout = 100mA to 2A



C1: Voltage on TP1 (50V/div, 2msec/div, DC coupling), C2: Vout (500mV/div, AC coupling)
C4: Output current (1A/div, DC coupling)
Vin = 127VAC, Iout = 100mA to 2A

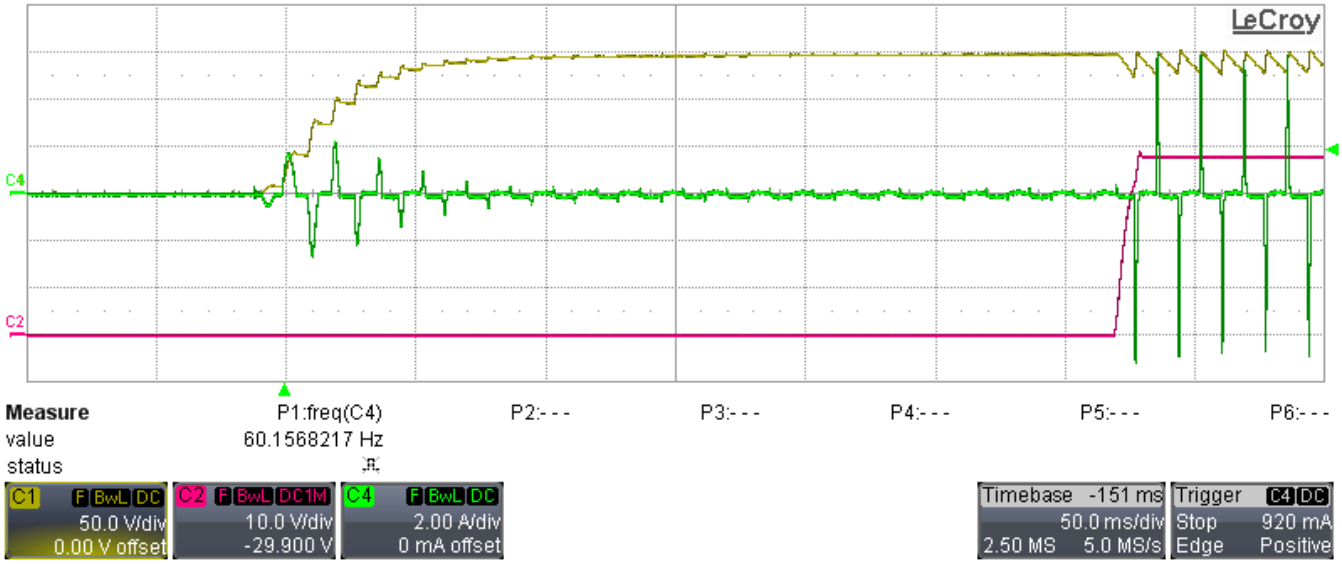


3.4 Start-up and shut-down Sequences

3.4.1 Start-up Sequence

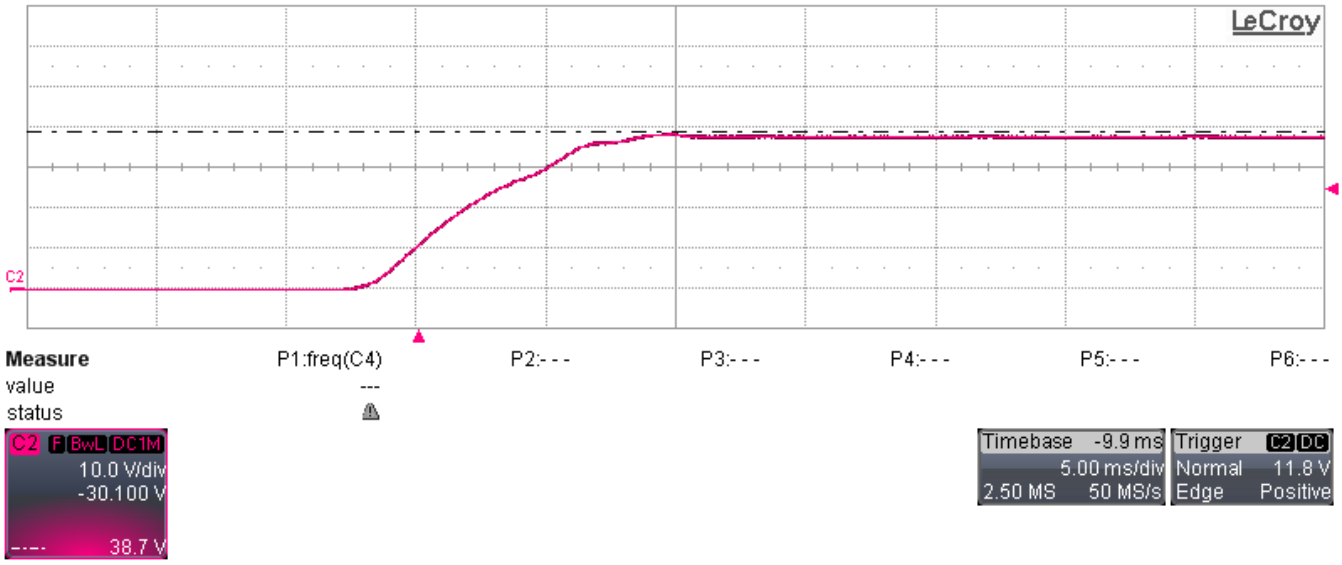
During this test, the AC source has been turned on and the delay between AC and Vout startup has been measured.

C1: Voltage on TP1 (50V/div, 50msec/div, DC coupling), C2: Vout (10V/div, DC coupling)
C4: Input AC current (2A/div, DC coupling)
Vin = 110VAC, Iout = full load

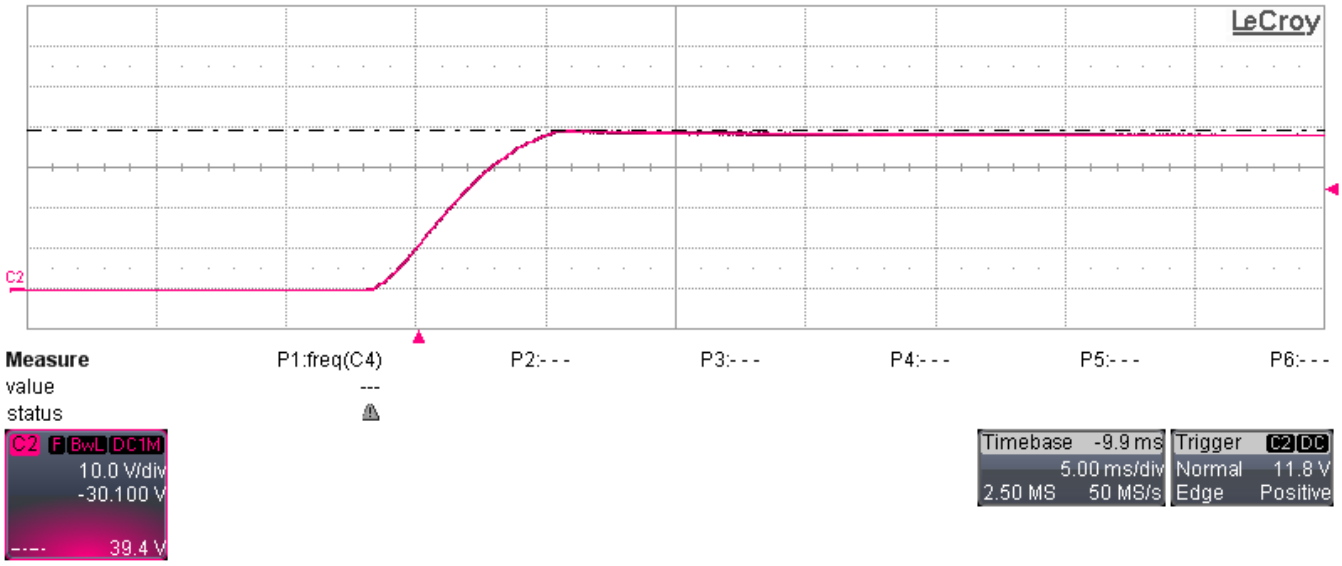


3.4.2 Startup

C2: Vout (10V/div, 5msec/div, DC coupling, 20 MHz BWL)
Vin = 110VAC, full load

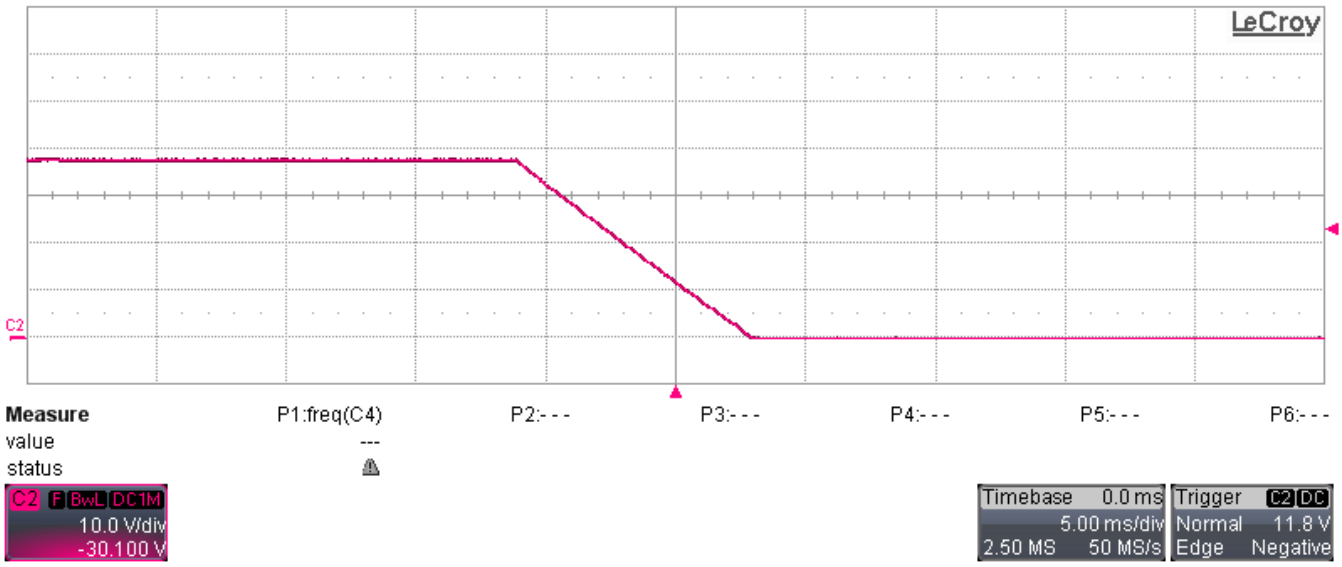


C2: Vout (10V/div, 5msec/div, DC coupling, 20 MHz BWL)
Vin = 110VAC, zero load

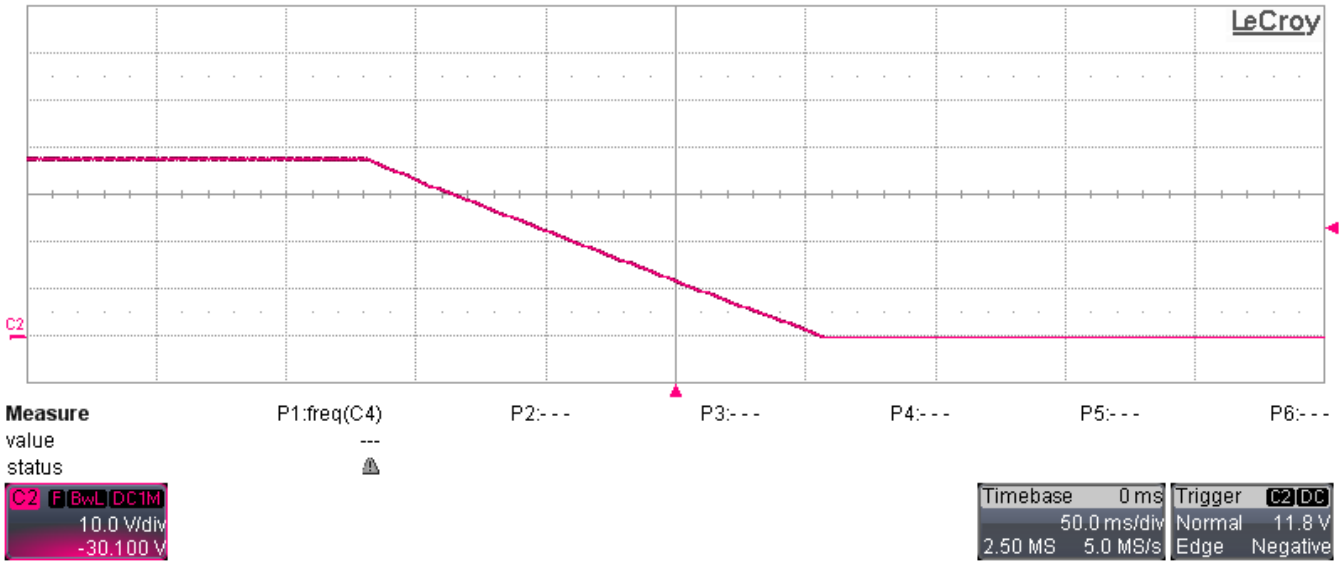


3.4.3 Shutdown

C2: Vout (10V/div, 5msec/div, DC coupling, 20 MHz BWL)
Vin = 110VAC, full load



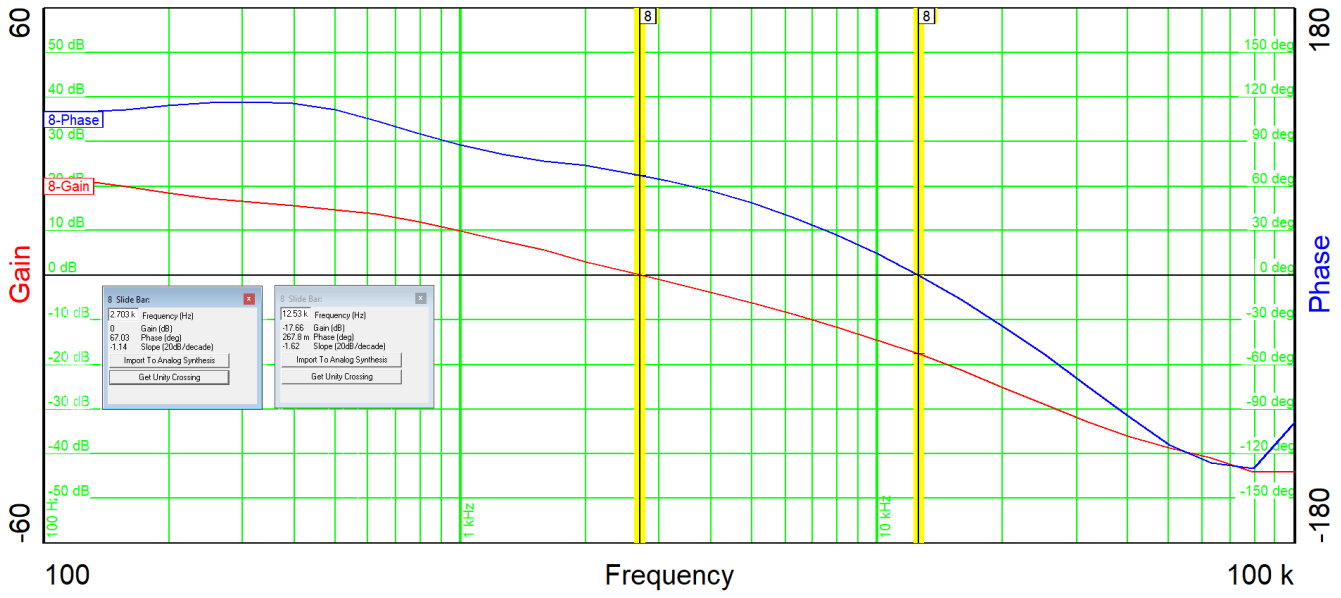
C2: Vout (10V/div, 50msec/div, DC coupling, 20 MHz BWL)
Vin = 110VAC, Iout = 100mA



3.5 Bode Plot

The following graph shows the bode plot of the converter, when supplied at 110VAC and fully loaded. Here is the result, in terms of crossover frequency, phase margin and gain margin:

Parameter	Value
Crossover frequency:	2.703 KHz
Phase margin:	67.03 deg.
Gain margin:	17.66 dB



3.6 Under-voltage lockout (UVLO) and Over-voltage Protection (OVP)

The following values are the thresholds regarding turn on and off, during UVLO and OVP:

	ON	OFF
UVLO:	**98.7VAC**	**85.8VAC (@ full load), 54.0VAC (@ 100mA)**
OVP:	**126.5VAC**	**132.7VAC (@100mA)**

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