NCP13992MM240WGEVB

All-in-One Power Supply Evaluation Board User's Manual

240 W Power Supply using NCP1618, NCP13992, NCP4306 and NCP431

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EVAL BOARD USER'S MANUAL

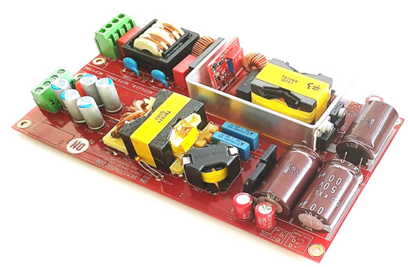

Figure 1. Evaluation Board Photo

Description

This evaluation board user's manual provides basic information about a high efficiency, low no−load power consumption reference design that was tailored to power All−in−One PC or similar type of equipment that accepts 12 VDC on the input. The power supply implements PFC front stage to assure unity power factor and low THD, current mode LLC power stage to enhance transient response and secondary side synchronous rectification to maximize efficiency. This design note provides brief information about controllers' implementation into design, their interconnections and cooperation. Please use links in literature section to get detail technical information about NCP1618, NCP13992, NCP4306 and NCP431.

The NCP1618 is an innovative multimode power factor controller. The controller automatically change operation mode depending on conditions so that the efficiency is optimized over the line and load range. In very light−load conditions, the circuit enters a soft−skip cycle mode. NCP1618 enters Continuous Conduction Mode (CCM) under Heavy−Load Conditions, while Frequency−Clamped Critical Conduction Mode (FCCrM) is used for Medium− and Light−Load Conditions. PFC−OK Output serves as Brown−Out signal for LLC controller as well as communication interface which sends NCP1618 into stand−by mode (using Soft−skip cycles).

The NCP13992 is a high performance current mode LLC controller for half bridge resonant converters. This controller implements 600 V gate drivers, simplifying layout and reducing external component count. In applications where a PFC front stage is needed, the NCP13992 features a dedicated output to drive the PFC controller. This feature together with quiet skip mode technique further improves light load efficiency of the whole application. Both controllers provide a suite of protection features allowing safe power supply operation in any application. Built−in high voltage input function ease implementation of the controllers in all applications startup circuits.

Features

- Wide Input Voltage Range
- PFC Controller with Multimode Operation
- High Efficiency/ Low No−load Power Consumption
- No Auxiliary SMPS, Fast Startup
- Near Unity Power Factor
- Low Mains & Overload Protection
- Thermal Protection
- Regulated Output Under any Conditions
- Excellent Load & Line Transient Response
- All Magnetics Available as Standard Parts
- Small Form Factor
- Extremely Low No−load Consumption

Table 1. GENERAL PARAMETERS

Device	Applications	Input Voltage	Nominal Output Voltage / Current	Output Power	V_{OUT} Ripple
NCP1618 NCP13992 NCP4306	AOI, Server Power	90 – 265 Vac	12 Vdc / 20 A	240 W	<150 mV @ Full load
Efficiency @ 230 V AC	**Standby Power**	**Operating Temperature**	**Cooling**	**Topology**	**Board size**
4 point AVG 94.11%	<130 mW	0 – 40 °C	Convection Open Frame, Forced in Frame	PFC CrCM LLC + SR	194 × 108 × 27 mm 7.11 W/inch^3

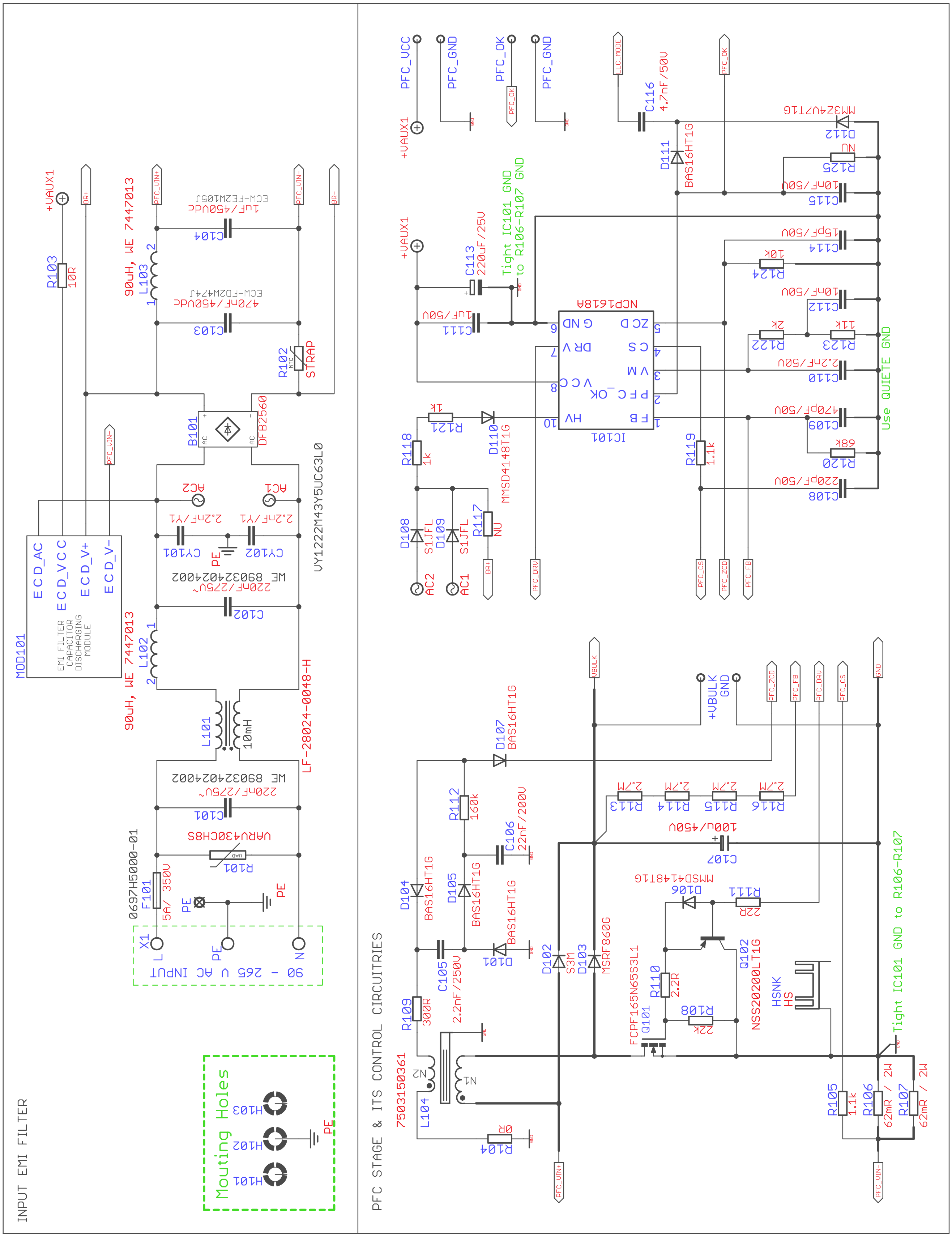

Figure 2. AOI Evaluation Board Schematic − PFC Front Stage

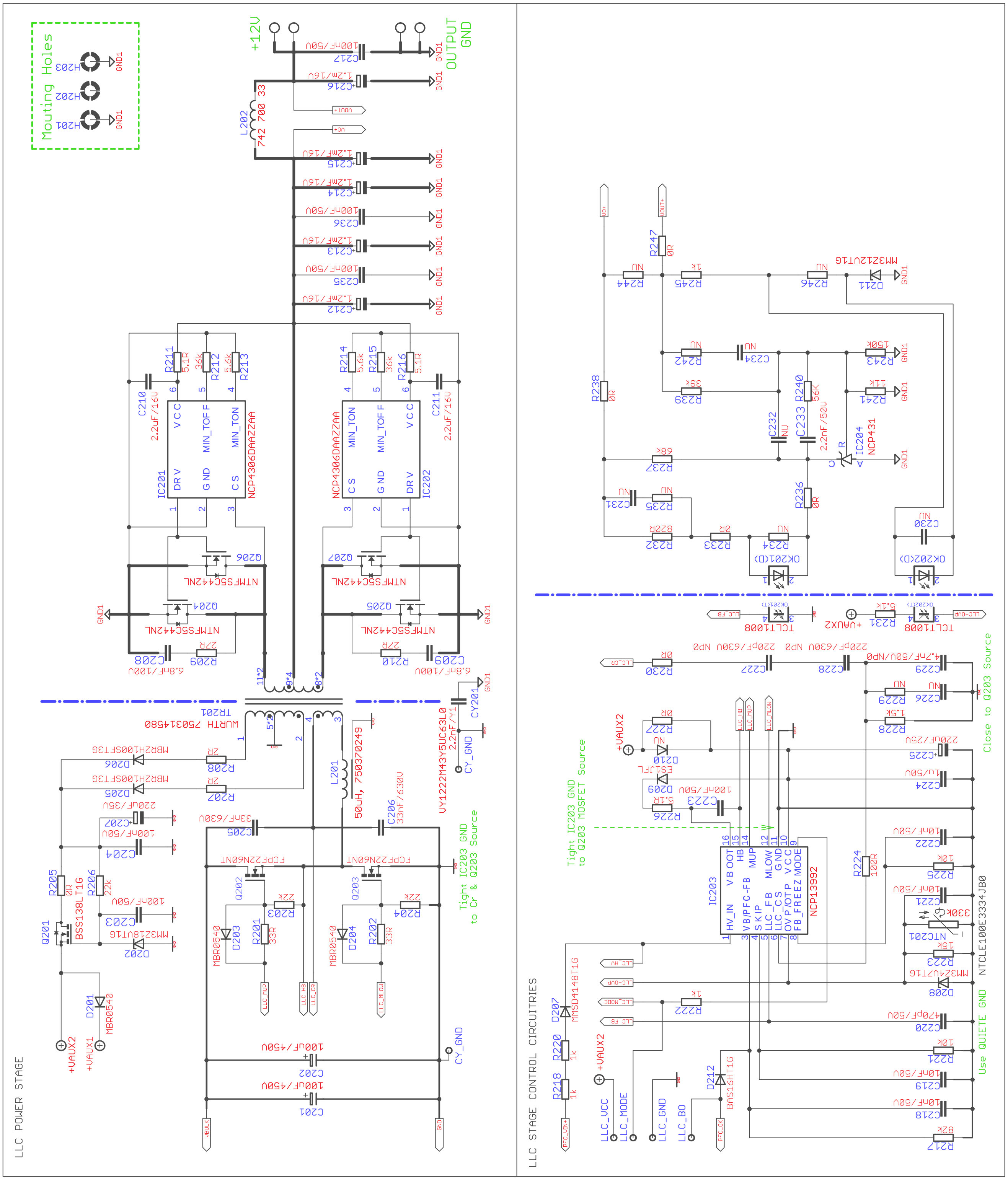

Figure 3. AOI Evaluation Board Schematic − LLC Stage

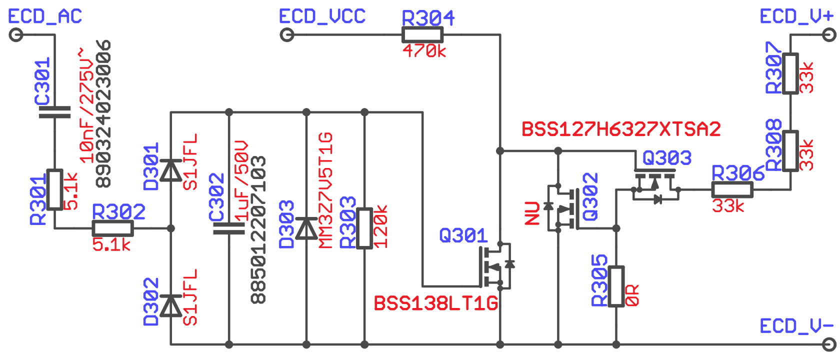

Figure 4. EMI Capacitor Discharging Module (MOD101)

Detailed Descriptions of the Evaluation Board

Input side of evaluation board is protected by a several components. As first, it's a 5 A slow reaction fuse F101, which disconnects input in case wrong manipulation, line overvoltage stress event and unexpected stresses or conditions. Voltage dependent resistor R101 serves as input overvoltage protection triggered at approximately 275 V AC. Demo−board implements inrush−current limiting device, R102 NTC thermistor which is not assembled to allow clear efficiency measurement (Figure 2). It's recommended to assemble R102 in case of testing in hard conditions (using power grid directly or AC power supply without current limit). Use appropriate NTC inrush current limiter in case of need.

EMI filter is formed by components L101, L102, L103, C101, C102, C103, C104, CY101 and CY102 (Figure 2). The IC101 − NCP1618 measures input line voltage via diodes D108, D109, D110 and resistors R118, R121 to detect present of Brown−out/ Brown−in and SAG conditions as well as distinguishes input line level. This circuit also provides PFC Vcc Start−up feature for building controller Vcc supply. The Power Factor Corrector (PFC) power stage implements standard boost PFC topology composed of following power devices; bridge rectifier B101, power (boost) inductor L104, power MOSFET switch Q101, boost power diode D103, bypass diode D102, shunt resistors R106−R107 and bulk capacitors C107, C201−C202. The PFC controller IC101 (NCP1618) senses input voltage directly via pin 10 (HV) through network of D108, D109, D110 and resistors R118, R121. The PFC inductor current is monitored on the shunt resistor R106−R107. The series resistors R105−R119 set maximum current. Capacitor C108 that is connected between those resistors filters noise caused by switching. Maximum current through resistors can be calculated based on NC1618 datasheet. The PFC feedback divider has high impedance (approximately 10.8 MΩ) which ensures low consumption in no−load or light−load mode conditions. PFC FB divider is created from upper resistor R113−R116, lower resistor R120 and capacitor C109. The PFC FB signal is filtered by capacitor C109 to minimize noise caused by the parasitic capacitive coupling between pin and other nodes that handle high dV/dt signals. PFC FB divider sets nominal bulk voltage level which is 400 V approximately. NCP1618 features positive bulk voltage hiccup, so that while LLC Stage runs under burst mode, NCP13992 forces NCP1618 to enter skip mode (stand−by mode), thus bulk−voltage is maintained between +103% and 98 % of nominal bulk voltage i.e. between ~420 V and ~394 V on this design. NCP1618 can be sent into soft−skip−mode (stand−by mode) by two ways. This demo−board implements only one solution – via pulling−down the PFC−OK pin. Refer to NCP1618 datasheet for more detailed description. Devices D111, D112, C116 and R222 are used for PFC−OK pulling−down purpose. Once, IC203 NCP13992 enters to skip, MODE pin (9) goes low level and pulls down PFC−OK for interval longer than 29 μs, which results in establishing PFC stand−by soft skip mode. NCP1618 PFC−OK pin generates signal which is green−light for down−stream LLC converter. If no fault occurs and bulk voltage level is in regulation range, PFC−OK pin sources current which is translated into drop at R217 and this voltage enables NCP13992 operation. NCP1618 has integrated driver but the external PNP transistor Q102 was implemented. The Q102 is connected directly to source of Q101 in order to minimize discharge loop and thus allow faster PFC switch turn−off and also minimizing EMI caused by the driver loop. Q101 Gate turn−on path is secured by R110, R111 and D106, on the contrary turn−off path is realized mainly via R110 and Q102. This solution enables to define required switching speeds for both processes independently. The PFC choke auxiliary winding voltage is processed by circuit R109, R112, R124, C105, C106, C114, D10, D104, D105 and D107. Processed signal is fed into ZCD pin, which detects valleys zero−current and OVP2 events. This pin provides a voltage VM for duty cycle modulation when the circuit operates in continuous conduction mode. The NCP1618 external network connected to the VM pin adjusts the maximum power which can be delivered by the PFC stage. R122−R123 set maximum power in CCM mode, C110−C112 filter noise coupled to this pin.

Schematics diagram in Figure 2 contains module with designator MOD101. Internal schematic diagram of this module is displayed in Figure 4. MOD101 was designed as a part of PFC stage and it's a discrete solution for discharging EMI filter differential capacitors. This element was named as "EMI Capacitor Discharging Module". Module works in very simple way based on charge pump principle made of

C301, R301, R302, D301 and D302. When AC voltage is presented at pin ECD_AC, charge pump creates voltage (at C302/R303) which is clamped by Zener−diode D303. This voltage turn−on MOSFET Q301, which pull−down Gate voltage of Q303. While AC line is presented charge pump continues to operate and generates voltage/current which disables Q303. Once, AC line turns out, charge pump stops and Q303 is turned on and discharges differential capacitors in EMI filter (through bridge rectifier B101).

Entire LLC power stage is displayed in Figure 3. Power stage at primary side of LLC converter is composed of these devices: MOSFETs Q202, Q203, external resonant inductor L201, transformer TR201 and resonant capacitors C205 and C206. The IC203 NCP13992, LLC controller senses primary current indirectly, via resonant capacitor voltage, which is divided down by a capacitive divider, using capacitors C227−C228 and C229. The capacitive divider has to be optimally loaded and in the same time assure fast signal stabilization after application startup. This is achieved by resistor R228. Scaled signal from CS divider passes through resistor R224 which limits maximum current that can flow into the LLC_CS pin. The FB optocoupler OK201 is connected to the LLC_FB pin and defines converter output voltage by pulling down this pin when lower output power is needed. Capacitor C220 forms high frequency pole in FB loop characteristics and helps to eliminate eventual noise that could be coupled to the FB pin by parasitic coupling paths. The VB/PFC−FB pin allows LLC converter operation once input level is approximately above 1.1 V. VB/PFC−FB signal is provided by PFC controller NCP1618, which sources current from PFC−OK pin as aforementioned. VB/PFC−FB pin voltage is filtered by C218. The Skip/REM pin of the NCP13992 is sued for skip threshold adjustment. Resistor R221 is used for this purpose together with noise filtering capacitor C219. The over−voltage and over−temperature protections are implemented via OVP/OTP pin by using resistor R223, temperature dependent resistor NTC201, Zener−diode D208, filtering capacitor C221 and optocoupler OK202. Simple OVP detector is located on the secondary side and it's made of resistor R245, Zener−diode D211 OK202 optocoupler diode. The FB_FREEZE pin (8) defines minimum internal feedback voltage (lower saturation level), which influences maximum switching frequency. Resistor R225 sets FB freeze level and C222 decouples noise. The PFC stand−by mode (or PFC soft−skip) is activated by MODE pin (9), which goes high during LLC stage switching and stays low during idle mode– as described in PFC section.

The VCC decoupling capacitor C224 and also bootstraps capacitor C223 for high side driver powering are located as close to the LLC controller package as possible to minimize parasitic inductive coupling to other IC adjust components due to high driver current peaks that are present in the circuit during drivers rising and falling edge transitions. The bootstrap capacitor is charged via HV bootstrap diode D209 and series resistor R226 which limits charging current and VBOOT to HB power supply slope during initial C223 charging process. The gate driver currents are reduced by added series resistors R201, R202 to optimize EMI signature of the application. Schottky diodes D203 and D204 are used to speed−up the MOSFETs turn−off process. The primary controllers are biased by voltage limiter circuitry, which is used in order to not exceed VCC pin maximum ratings. The upper value of the primary VCC voltage is clamped to approximately 15 V. The VCC clamp is composed of these components: R205, R206, Q201, D202 and C203. The VCC clamp is fed from auxiliary windings via rectifier D205−D206 and current limiting resistor R207−R208. The secondary side synchronous rectification uses IC201 and IC202 NCP4306 SR controllers. Two MOSFTEs are connected in parallel for each SR channel to achieve low total voltage drop − Q204, Q206 and Q205, Q207. RC snubber circuits C208−R209 and C209−R210 are used to damp down the parasitic ringing and thus limit the maximum peak voltage on the SR MOSFETs. The SR controllers are supplied from converter output via resistors R211 and R216. These resistors with decoupling capacitors C210 and C211 form RC filter. The minimum on−time – R213, R214 and minimum off−time – R212, R215 resistors define needed blanking periods that help to overcome SR controllers false triggering to ringing in the SR power stage. Each SR controller implements clever light load detection feature LLD. After first incoming pulse from skip burst, the LLD feature wakes−up the controller from low power mode (50 μA). SR controller enters to stand−by mode after defined period of time (68 μs) once the last pulse from the skip burst ends. Internal setup cares about LLD feature timing thus eliminates need for complicated external light−load guard circuitry. The NCP4306 LLD feature offers great benefits compare to the traditional solutions, in which SR operation and no−load consumption is much less efficient. The output filtering capacitor bank composes from low ESR electrolytic capacitors C212 to C215 and ceramic capacitors C217, C235 and C236. Output filter L202, C216 is used to smooth output voltage from switching glitches. The output voltage of the converter is regulated by standard shunt regulator NCP431− IC204. The regulation optocoupler OK201 is driven via resistor R232 which defines loop gain. The NCP431 is biased via resistor R237 in case there is no current flowing via regulation optocoupler –which can happen before the nominal V_{OUT} level is reached or during transients from no−load to full−load conditions. The output voltage is adjusted by divider R239, R241, and R243. The feedback loop compensation network is formed partially by resistor R240 and capacitor C233.

PCB layout is prepared with options so user can modify demo−board accordingly if needed – please refer to schematics. The PCB consists of a 2 layer FR4 board with 70 μm copper thickness to minimize resistance in secondary side where high currents are conducted. Leaded components are assembled form the top side of the board and all SMT components are place from the bottom only. The board was designed to work as open frame with natural air flow cooling. Forced air flow cooling management should be considered in case the board is packed into some box or target application.

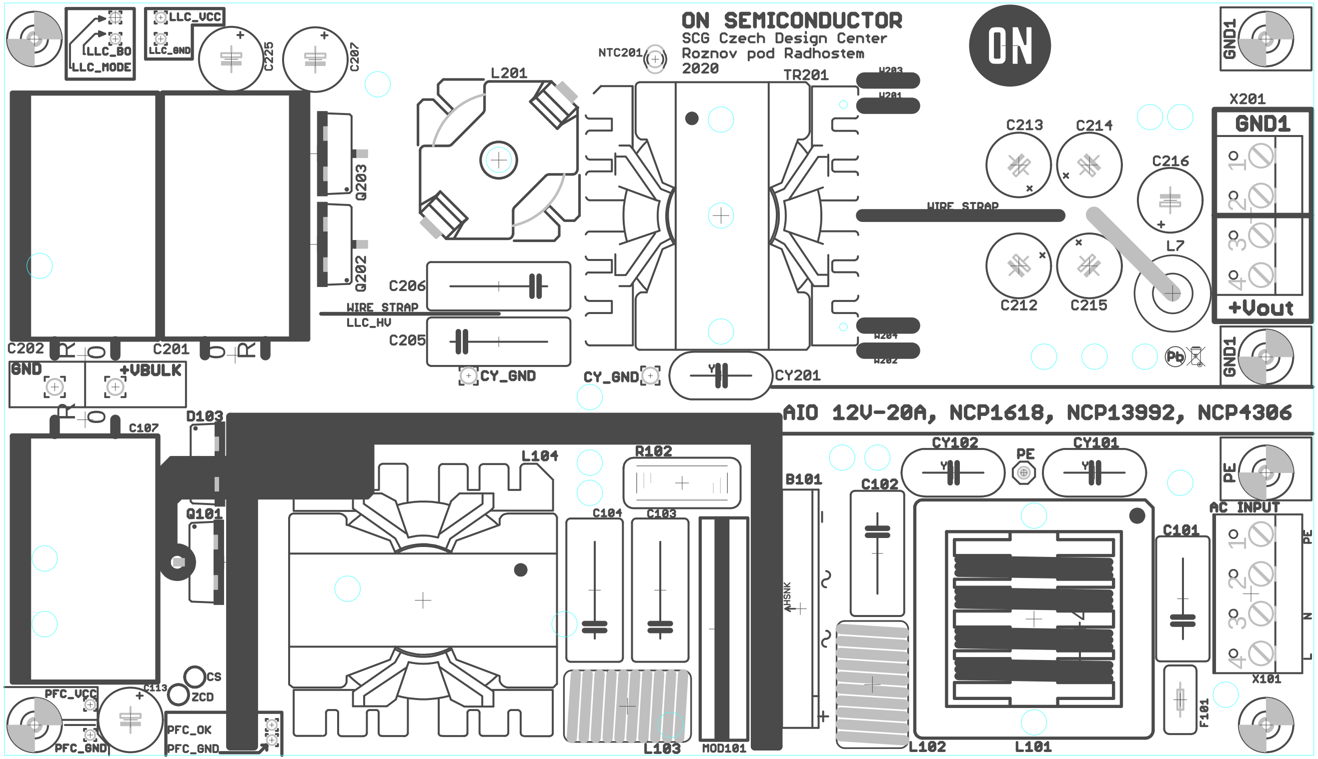

Figure 5. Evaluation Board − Top Side Components

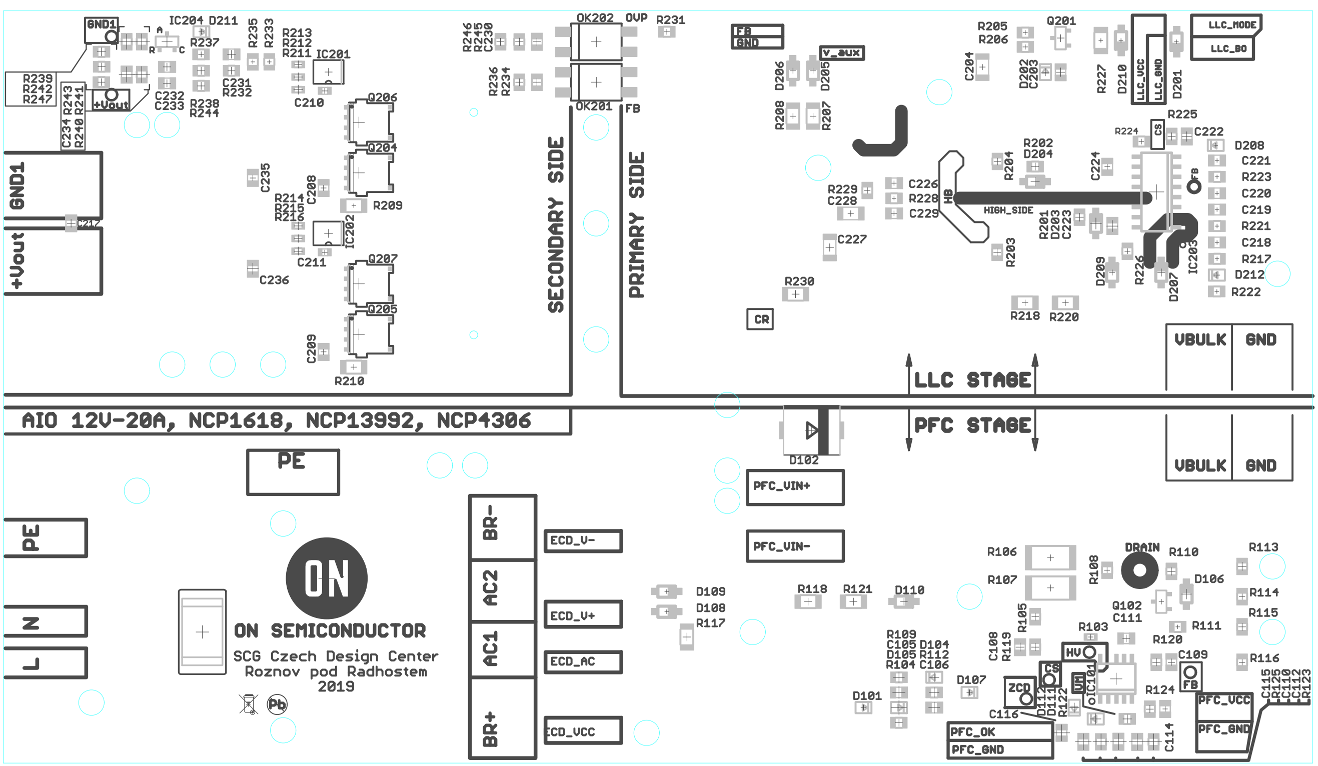

Figure 6. Evaluation Board − Bottom Side Components

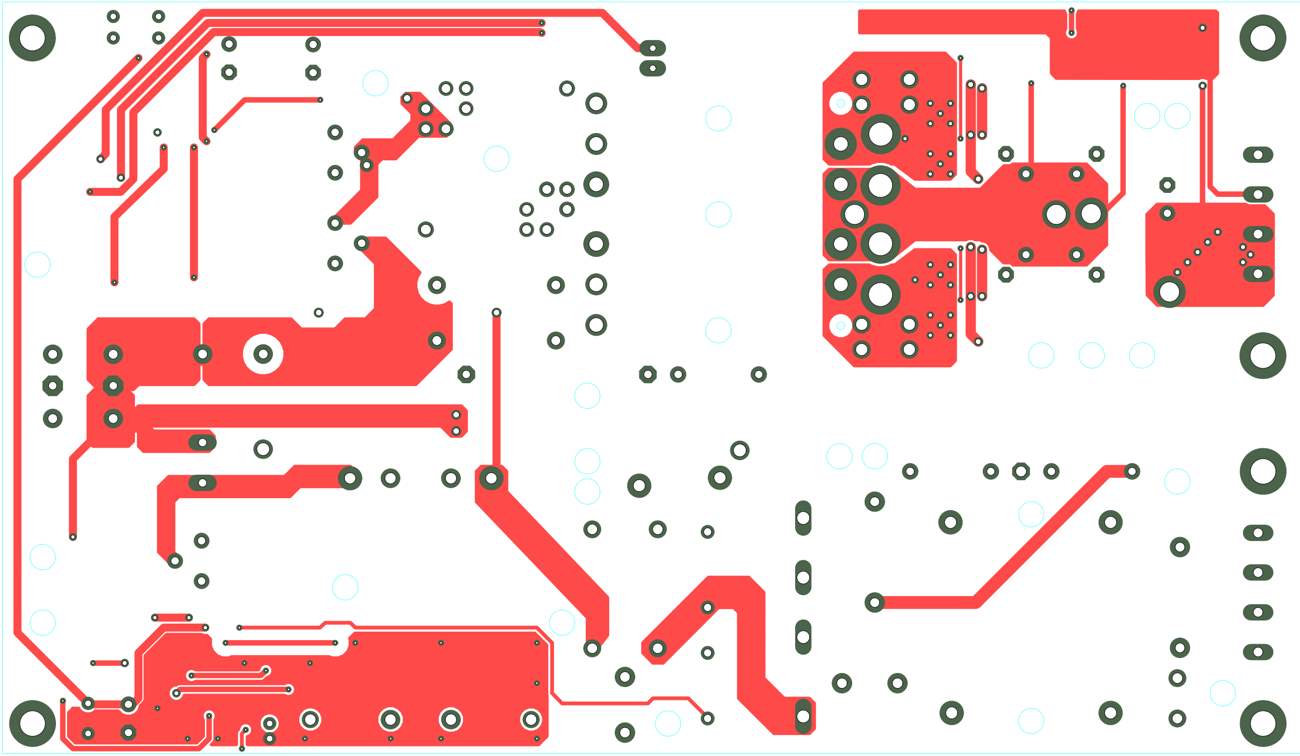

Figure 7. Evaluation Board − PCB Design of Top Layer

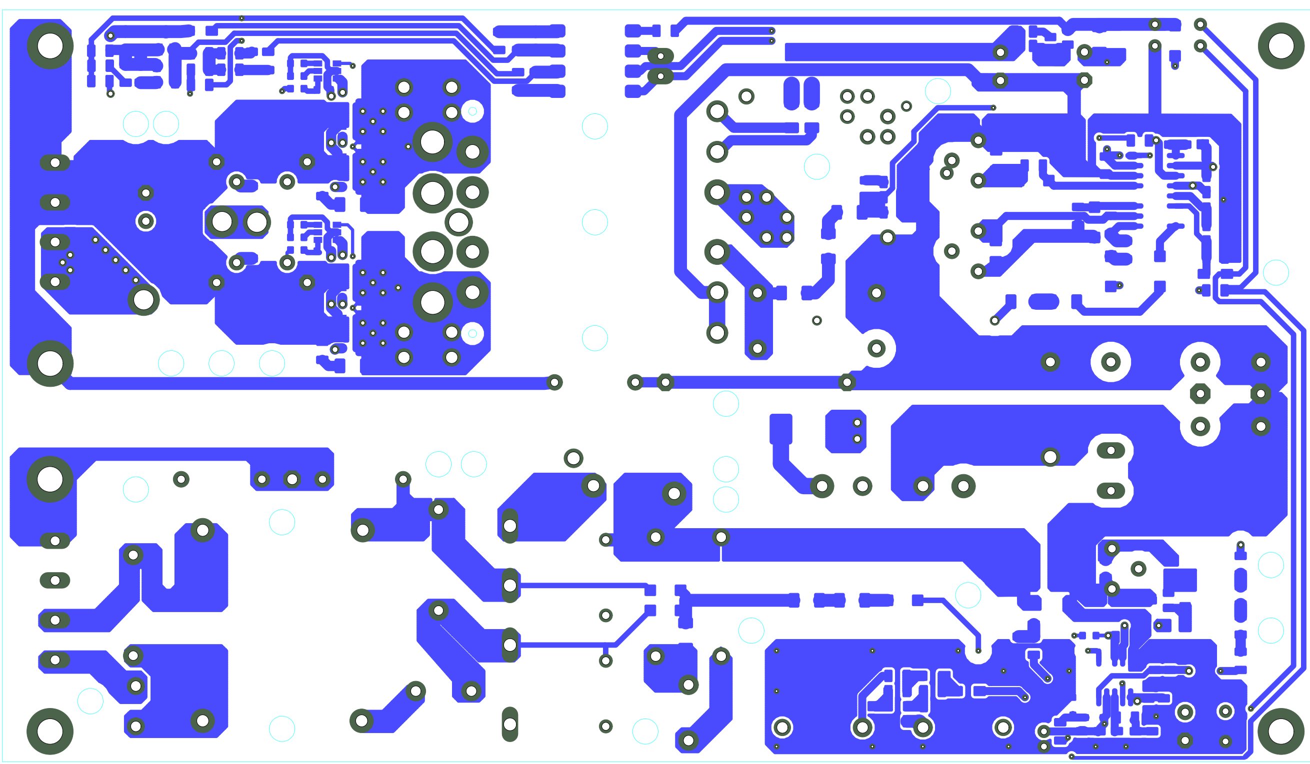

Figure 8. Evaluation Board − PCB Design of Bottom Layer

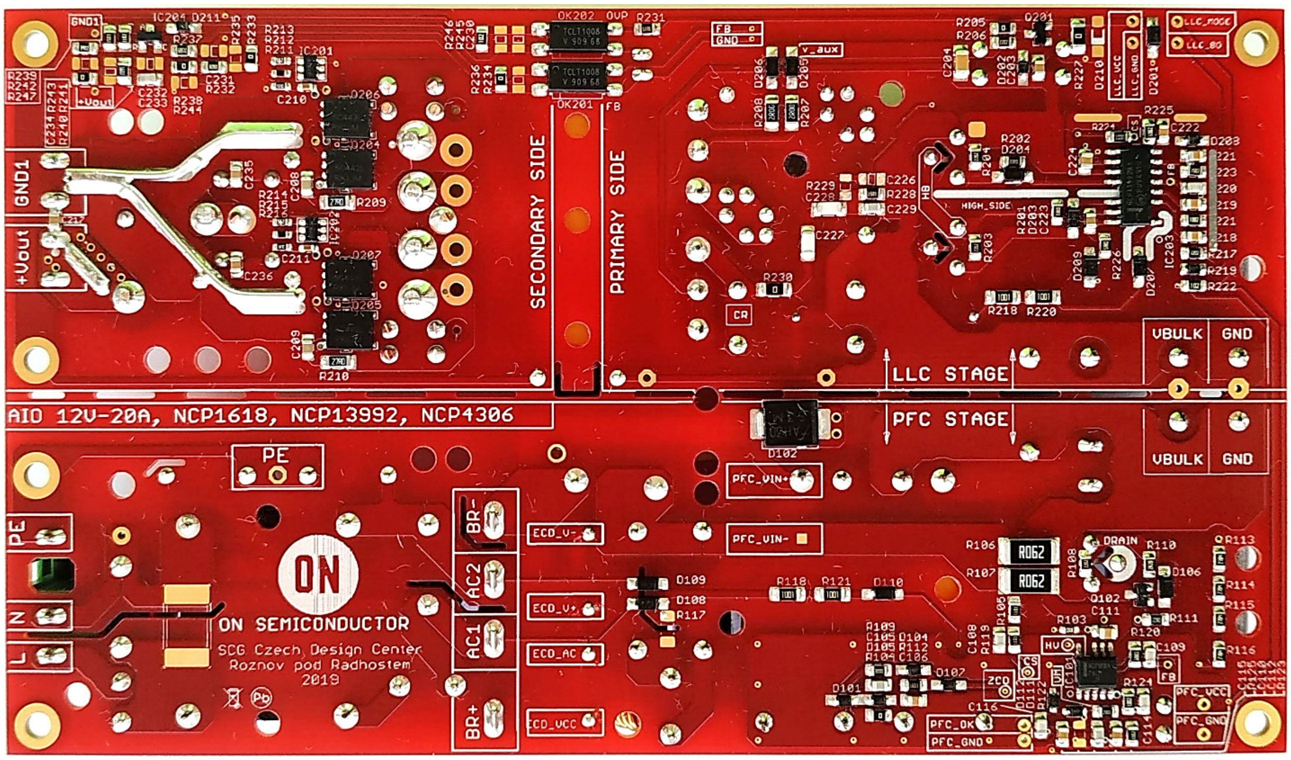

Figure 9. Evaluation Board Photograph − Bottom Side

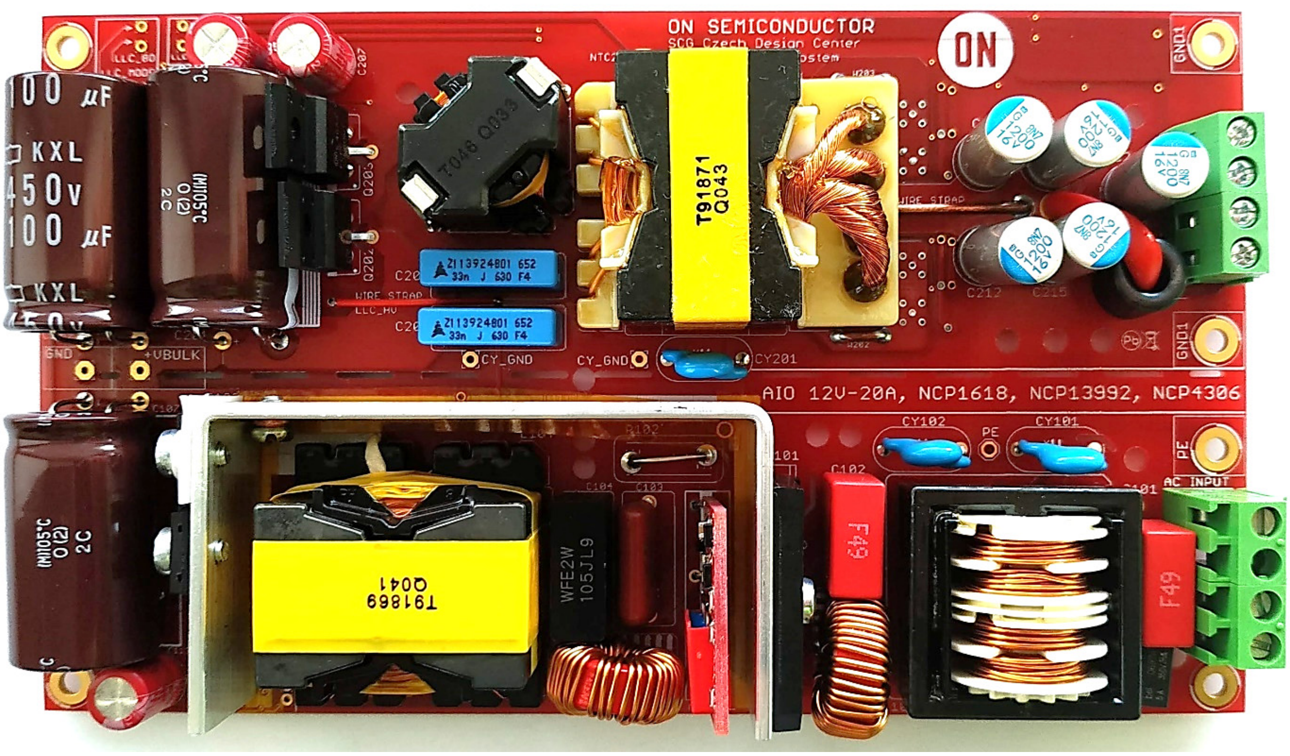

Figure 10. Evaluation Board Photograph − Top Side

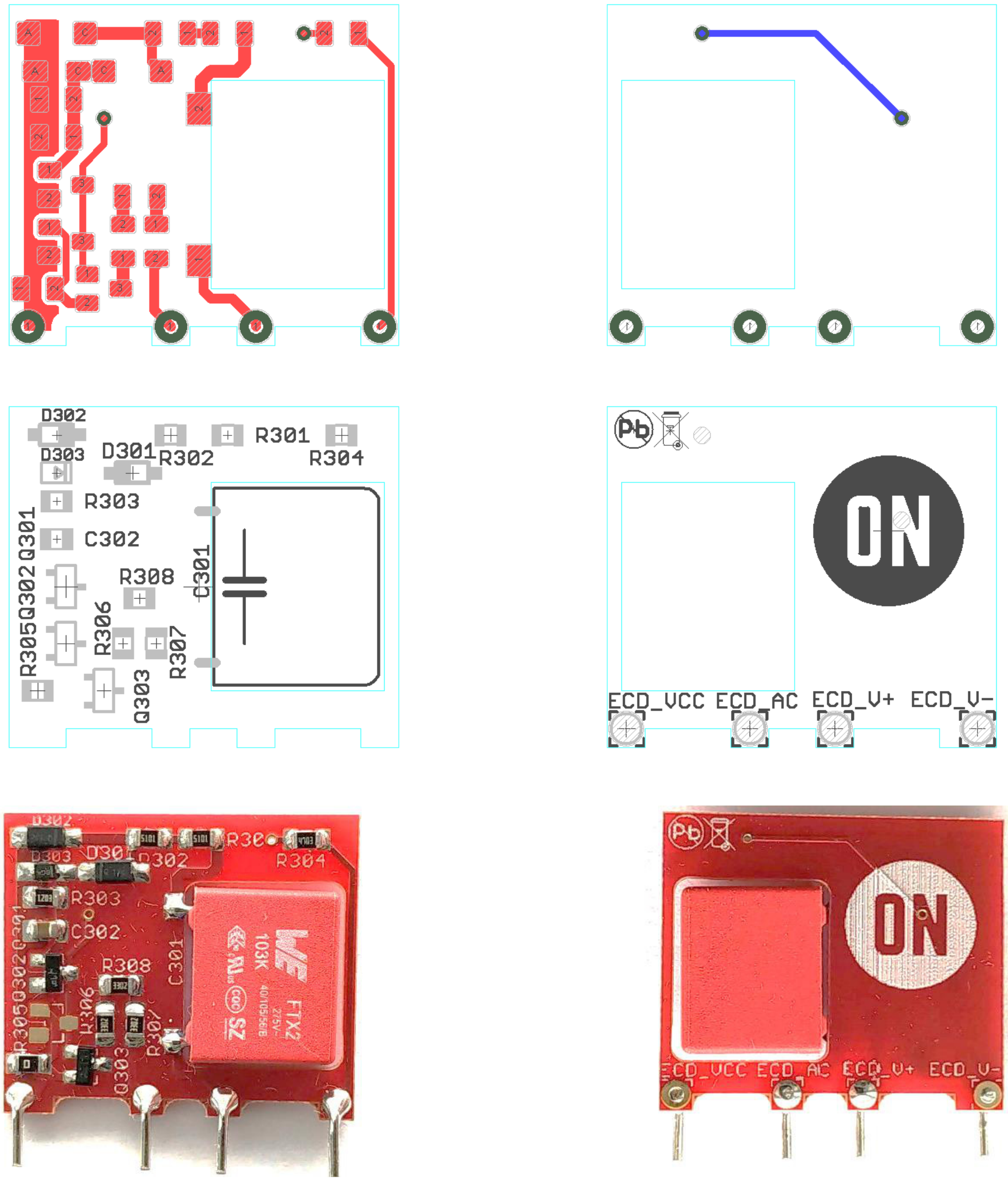

Figure 11. EMI Capacitor Discharging Module (MOD101) − PCB Layout Design, Assembling, Photographs

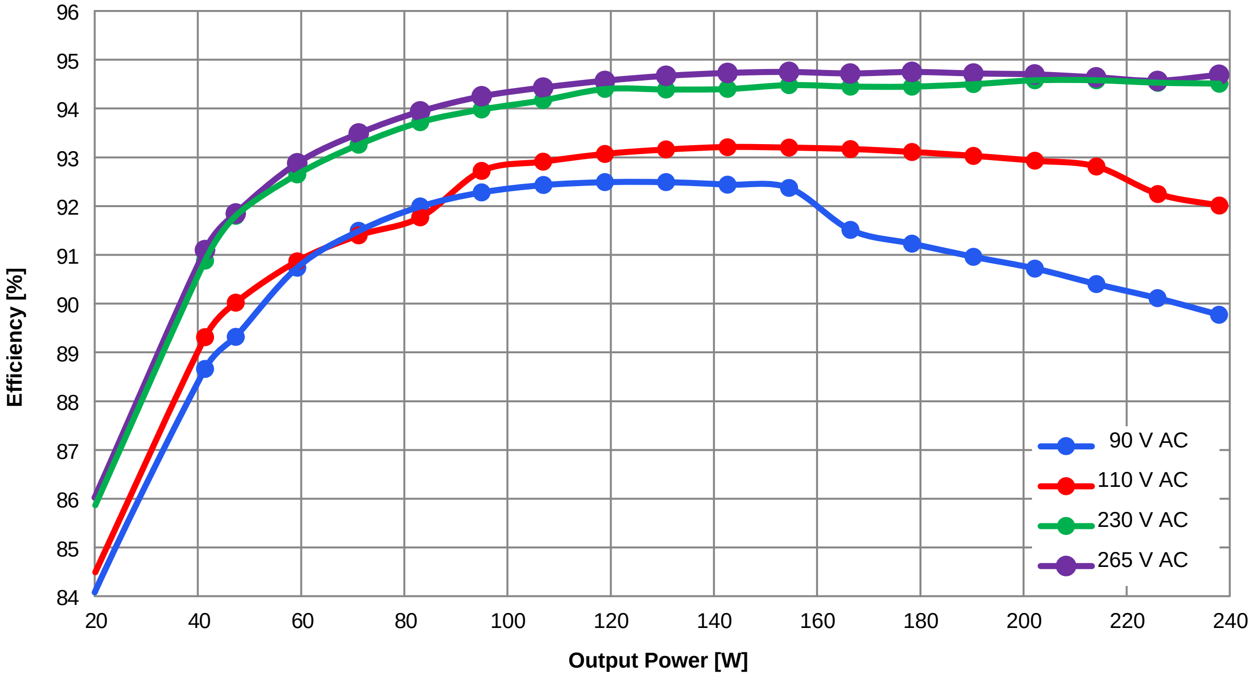

Figure 12. EFFICIENCY vs. Output Power

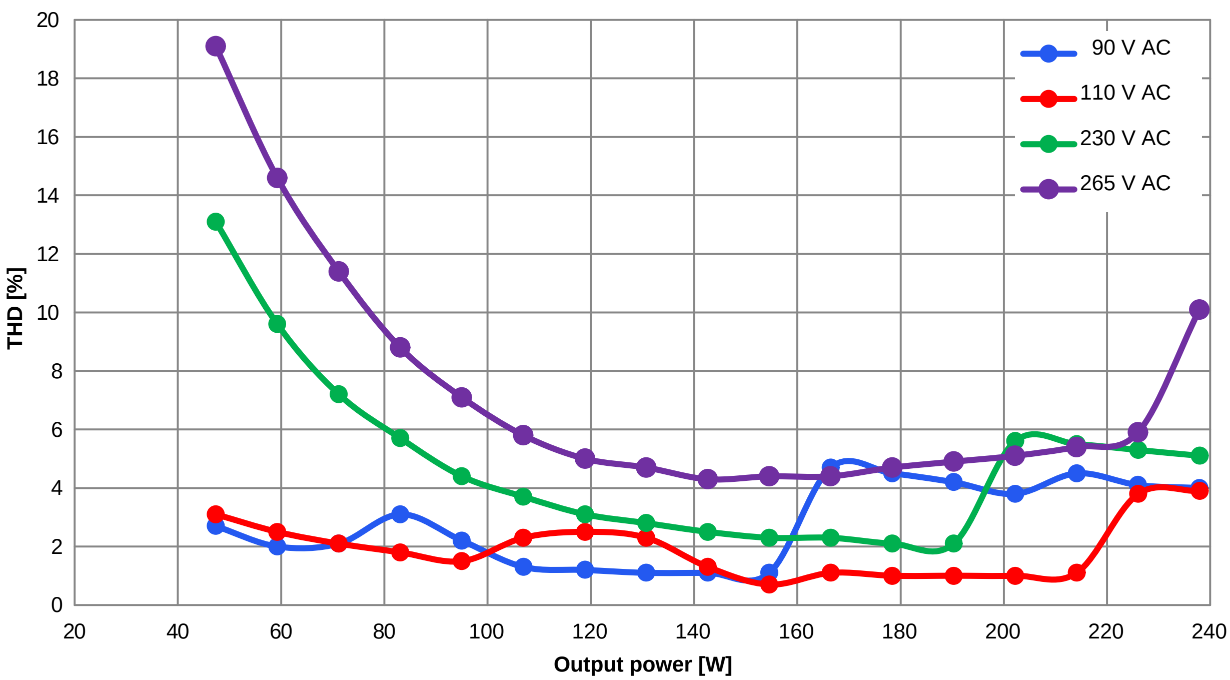

Figure 13. Input Current vs. Output Power

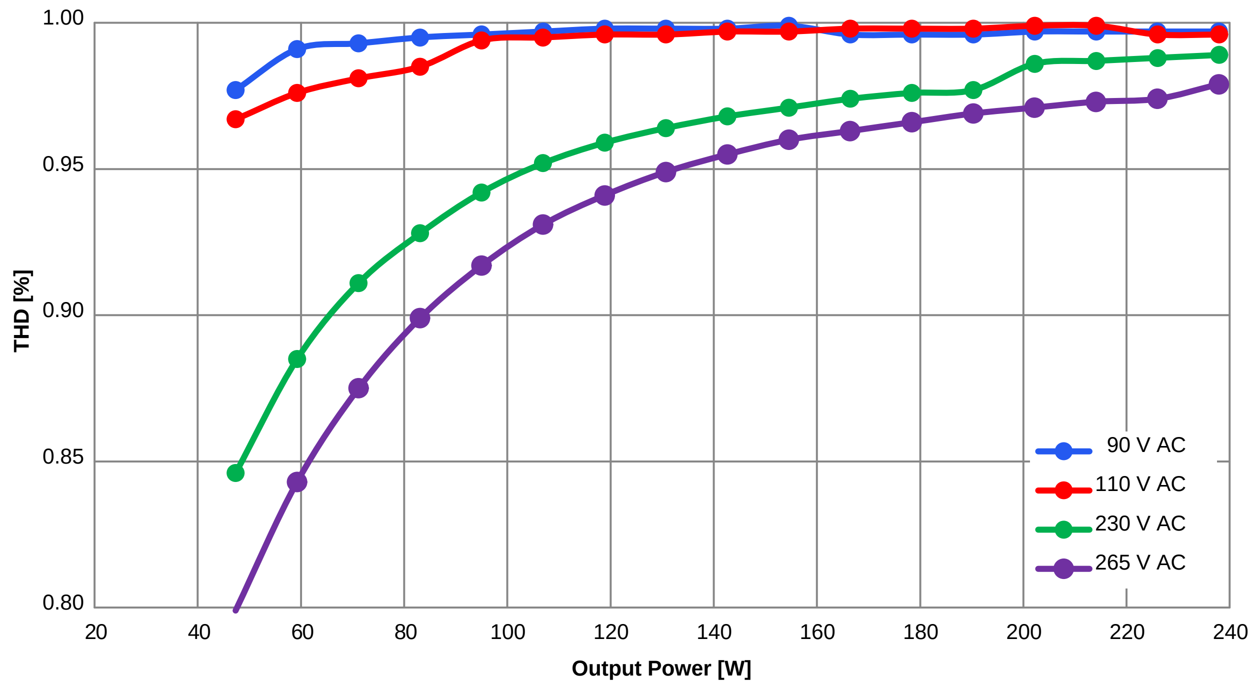

Figure 14. POWER FACTOR vs. Output Power

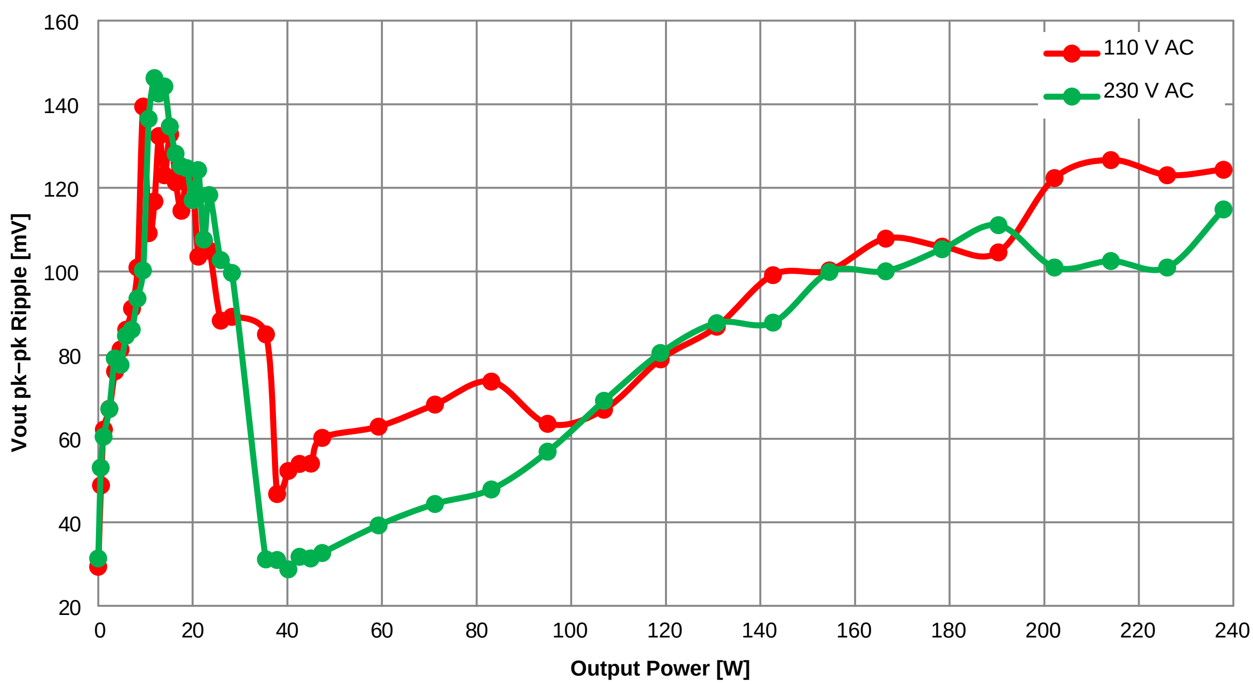

Figure 15. Output Voltage Ripple (pk−pk) vs. Output Power

Table 2. EFFICIENCY DATA MEASURED AND AVERAGED FROM 10 BUILT EVALUATION BOARDS

LOAD	Consumption [mW] or Efficiency [%]		
	@ 110 V AC	@ 230 V AC	@ 265 V AC
NO−LOAD	< 110	< 120	< 130
Load 120 mW	< 250	< 250	< 260
Load 500 mW	< 660	< 670	< 680
Load 20% − 4 A	90.02	91.80	91.85
Load 25% − 5 A	91.40	92.65	92.88
Load 50% − 10 A	93.07	94.40	94.57
Load 75% − 15 A	93.11	94.45	94.75
Load 100% − 20 A	92.01	94.51	94.69
4 point AVG	92.40	94.00	94.22

The following figures illustrate conduced EMI signatures under full loading for different input line voltage levels.

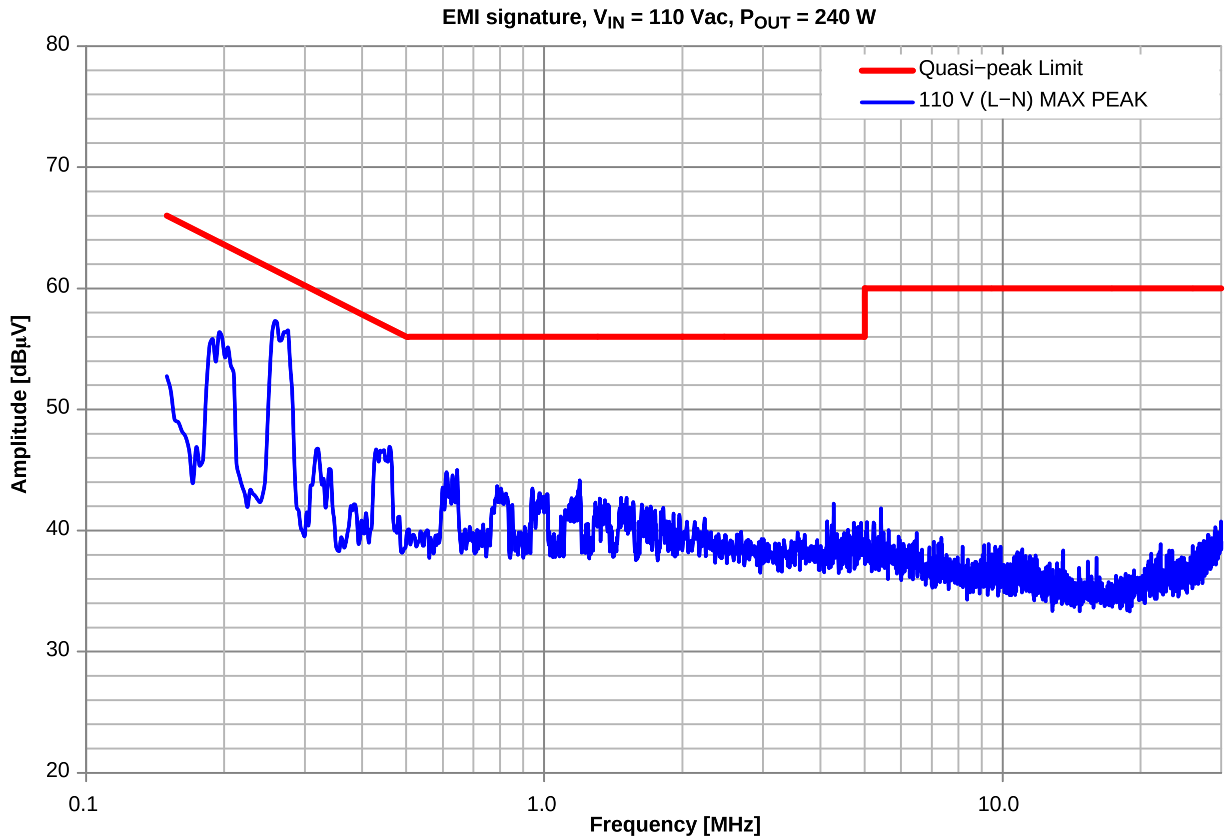

Figure 16. EMI Signature Comparison @ 110 VAC & Full−load (measured MAX Peak)

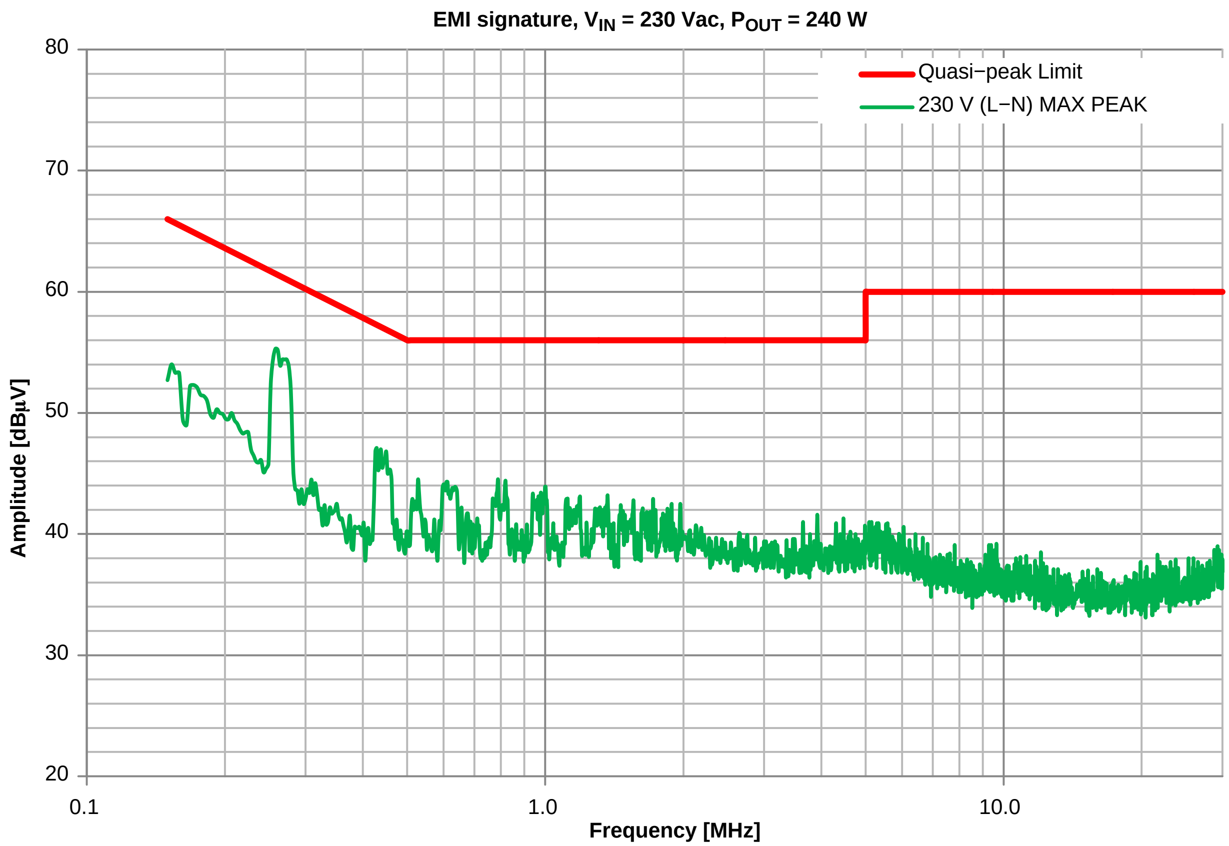

Figure 17. EMI Signature Comparison @ 230 VAC & Full−load (measured MAX Peak)

Evaluation Demo−board Connections and Power−up and Test Procedure

IMPORTANT NOTES:

- Do not apply extreme voltage to the input terminals!
- Be careful, high DC voltage is presented!
- Do not apply DC voltage to the input terminals!
- The demo is not optimized for surge, lightning, etc.
- This reference board requires thermal management especially at very low line voltage. Use fan for excessive heat spreading.
- Follow up power−up and power−down sequences.

Power−up sequence:

1. Connect AC Supply to the demoboard AC input.
2. Connect Electronic Load at the output terminals with proper polarity
3. Set AC Supply voltage in range 85 to 265V AC.
4. Turn AC Supply on.
5. Check output terminals voltage, approximately 12 V.
6. Modify electronic load current to desired level while output voltage is monitored.

Power−down sequence:

1. Turn AC Supply off.
2. Discharge bulk capacitor for manipulating further

OPERATING WAVEFORM

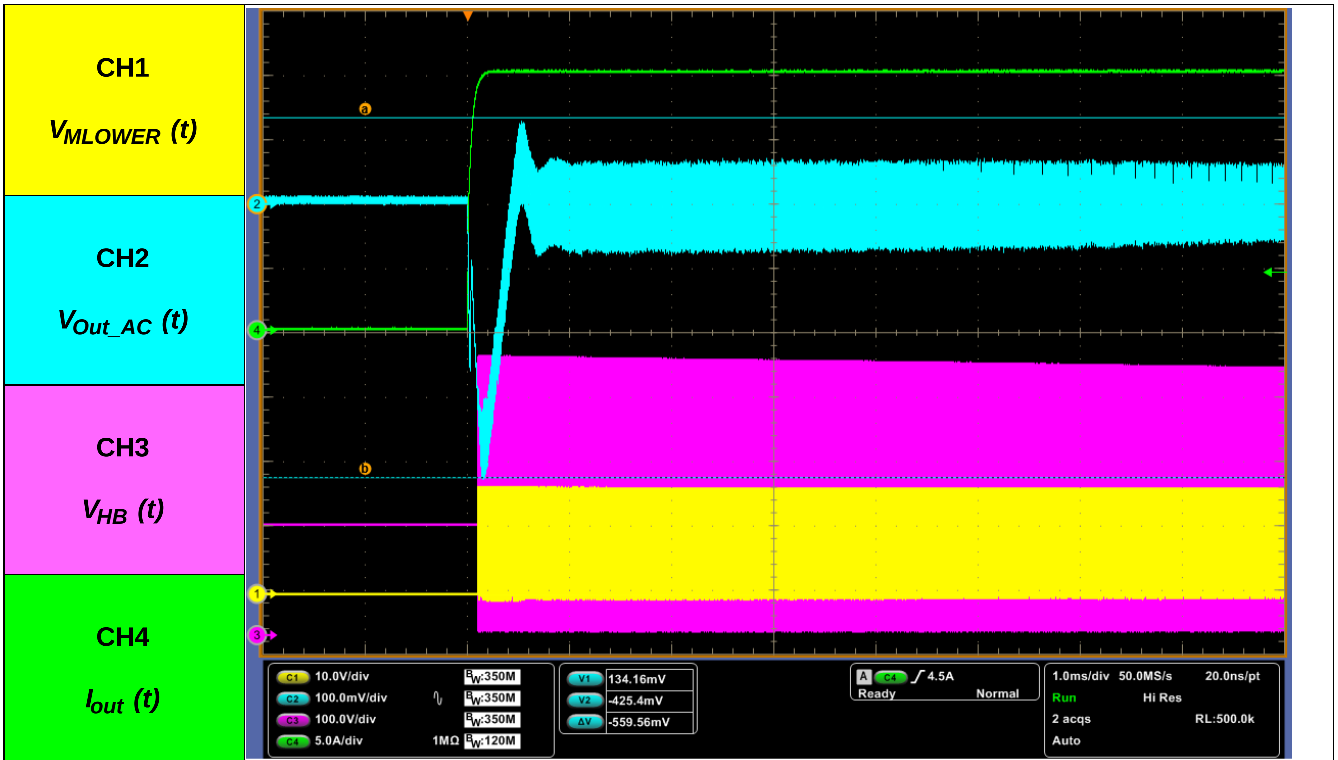

Figure 18. 110 V AC/ STEP LOAD 0 – 20 A

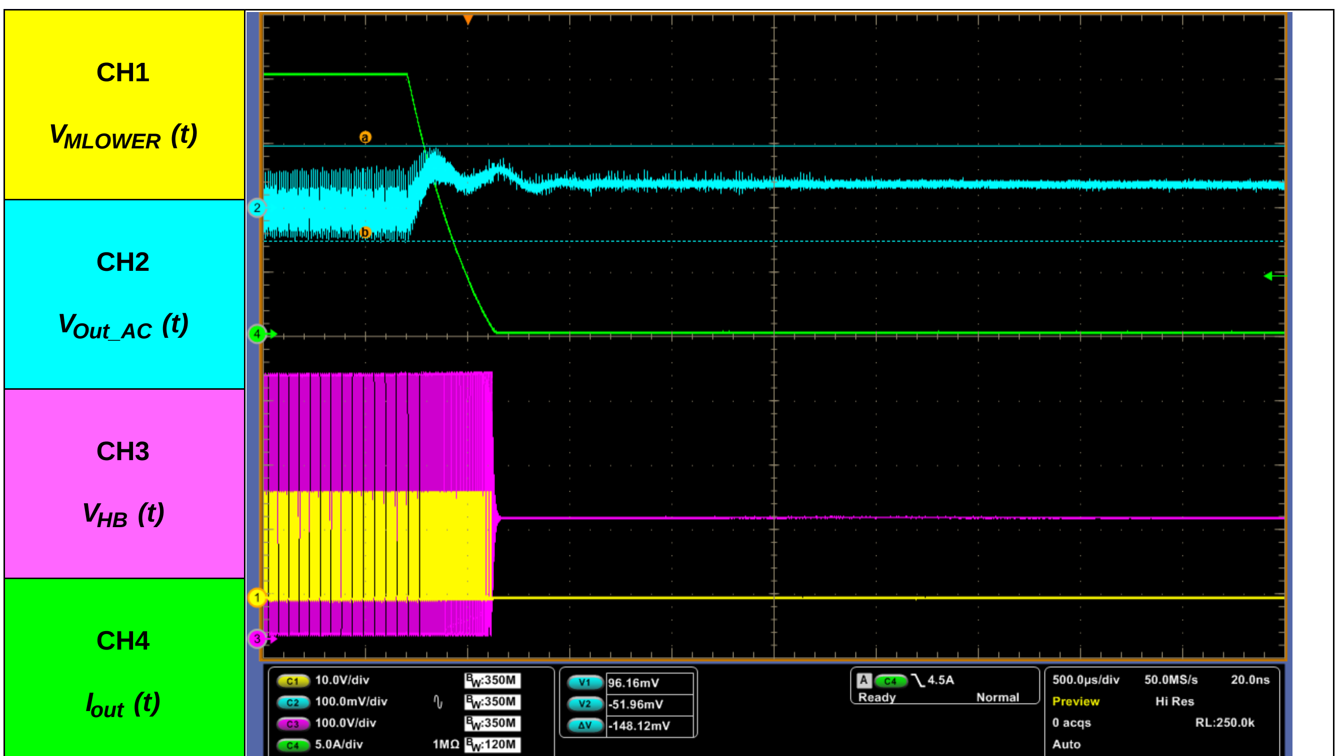

Figure 19. 110 V AC/ STEP LOAD 20 – 0 A

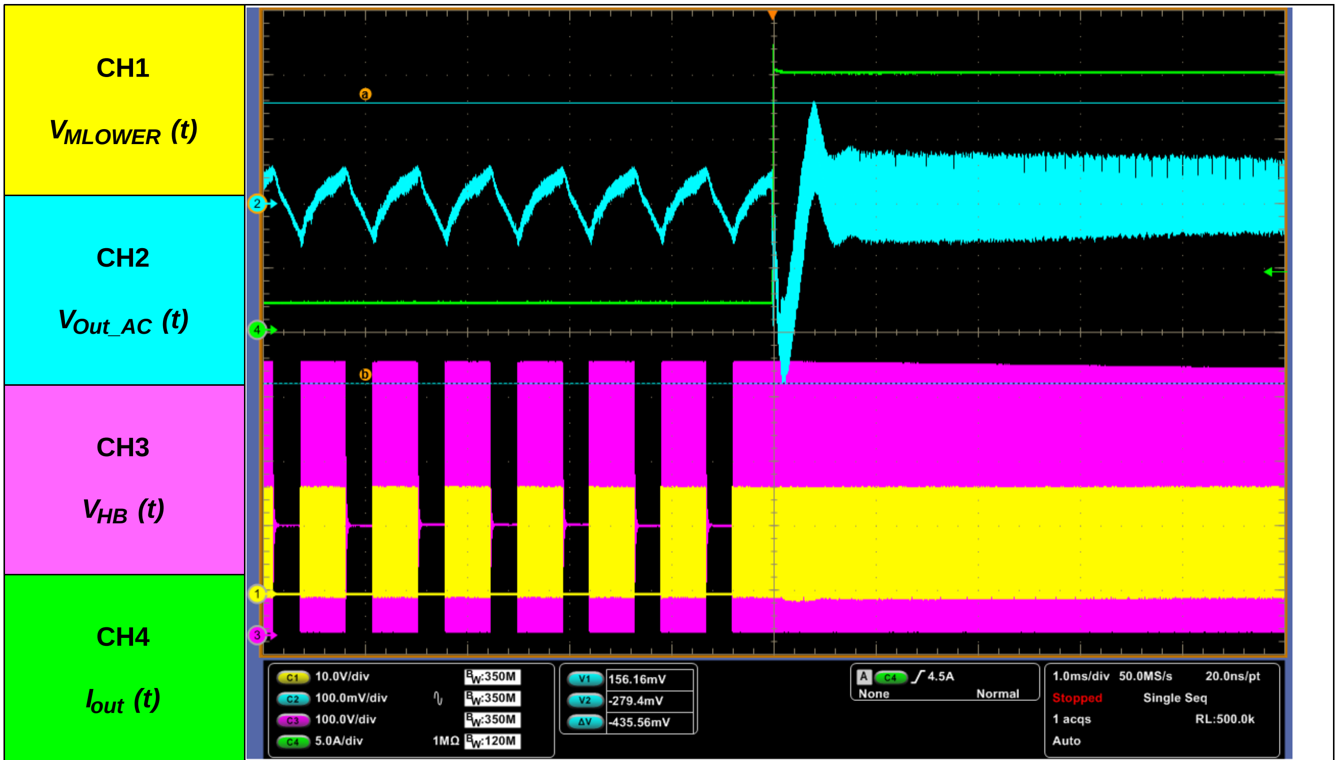

Figure 20. 110 V AC/ STEP LOAD 2 A – 20 A

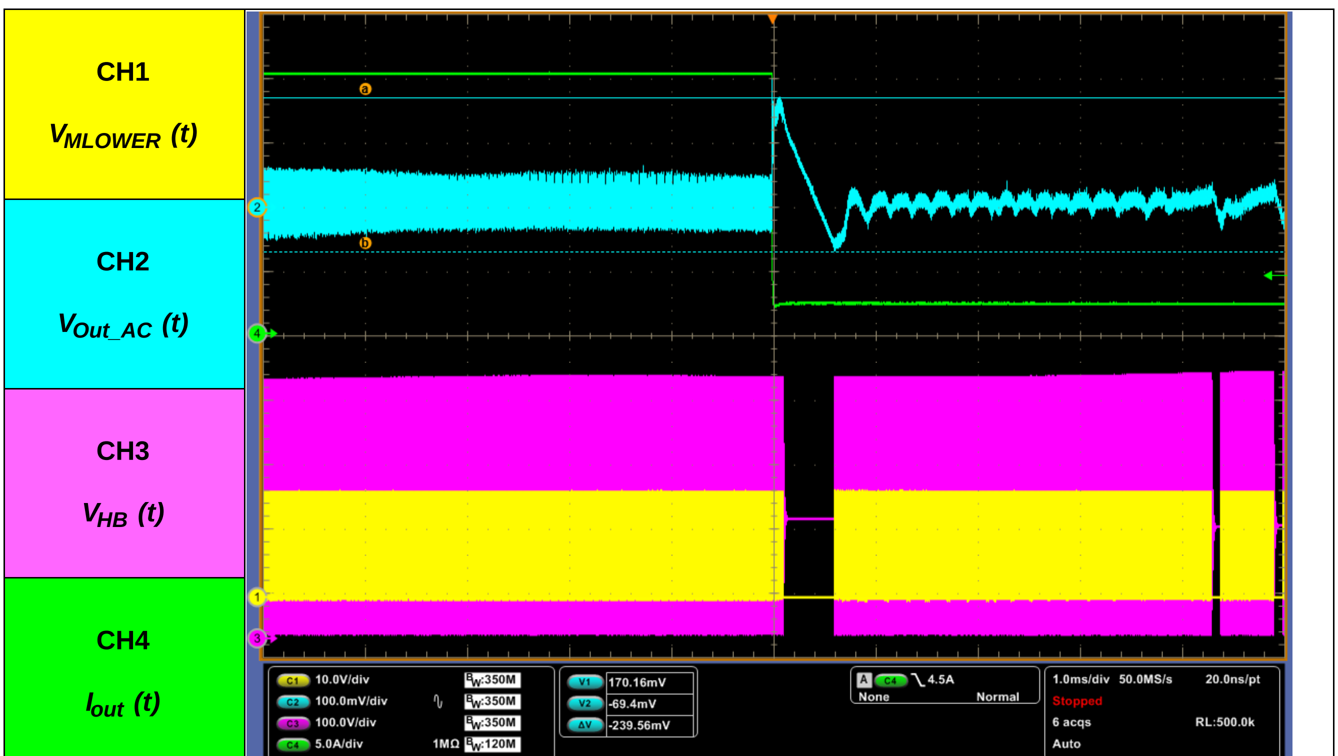

Figure 21. 110 V AC/ STEP LOAD 20 A – 2 A

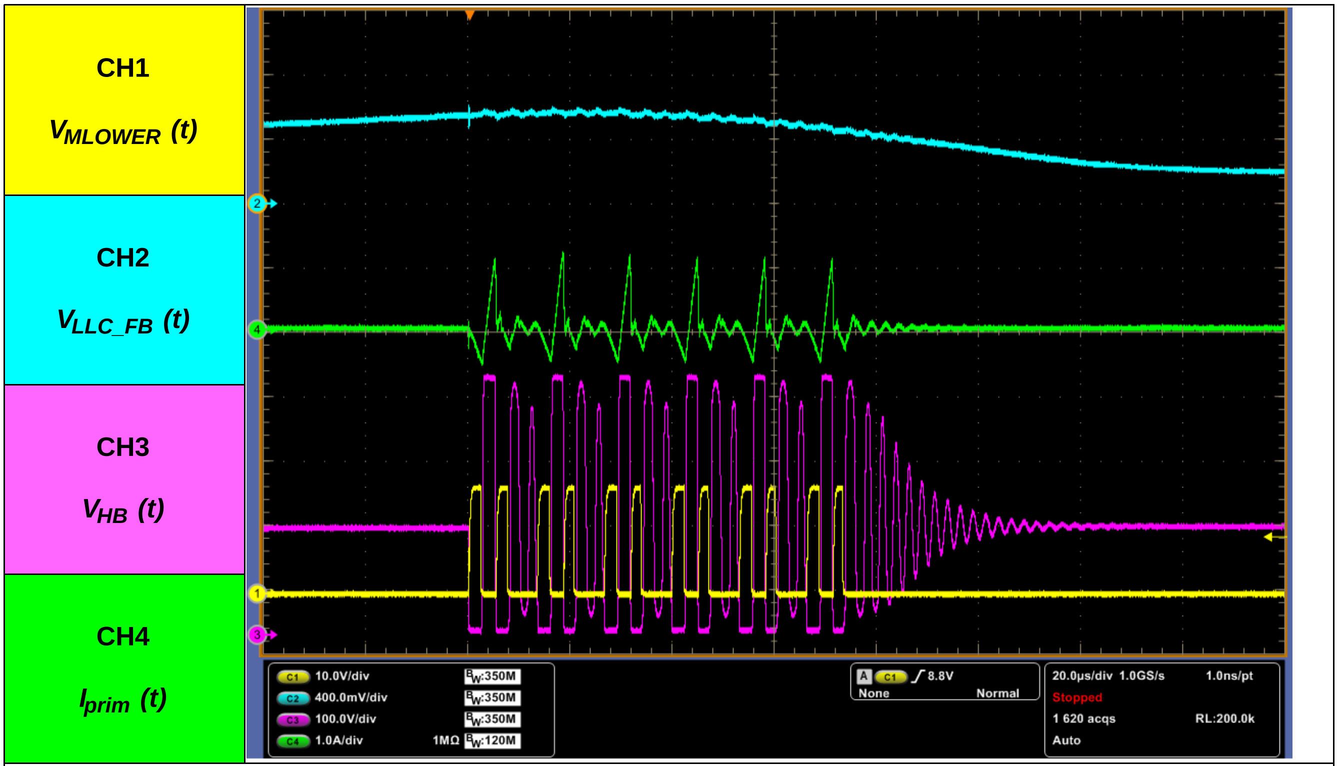

Figure 22. 110 V AC/ LLC SKIP MODE, No−load

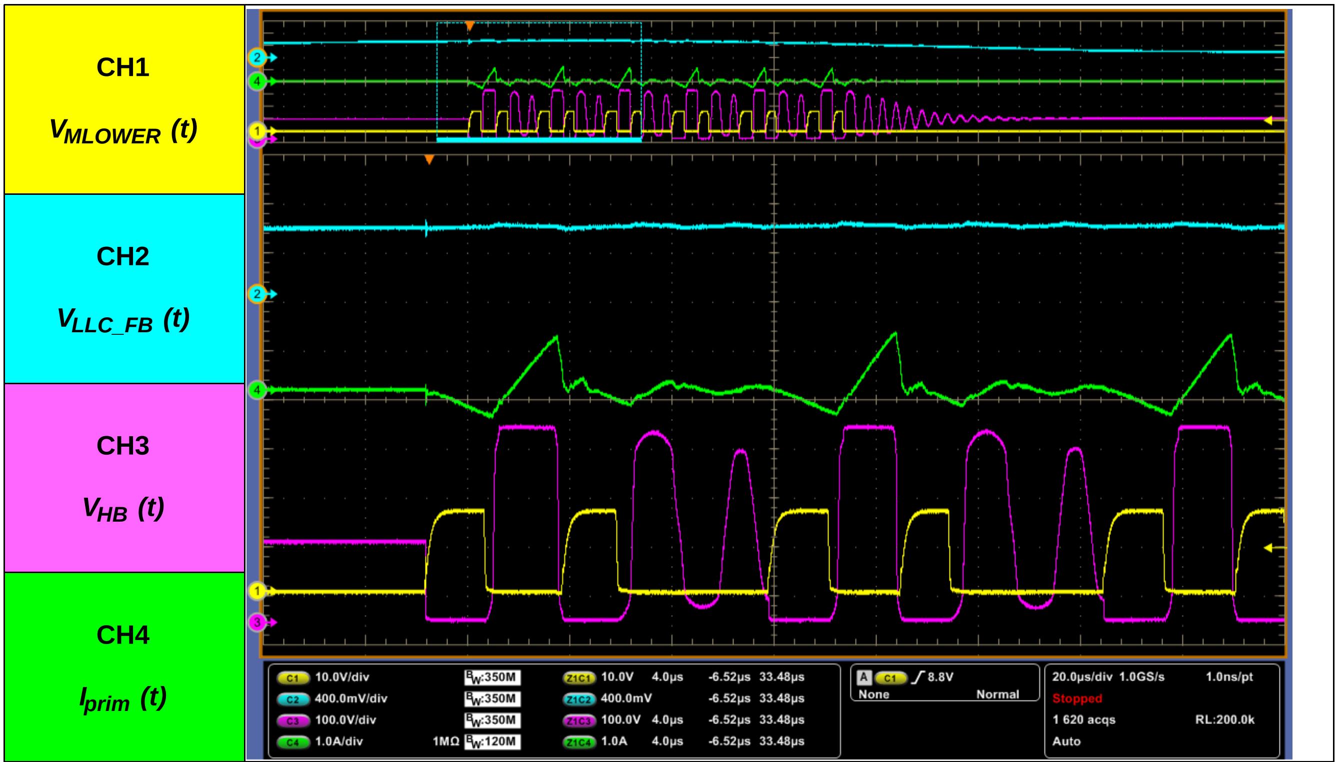

Figure 23. 110 V AC/ LLC SKIP MODE, No−load − detailed view

CH1 V_{MLOWER} (t)	
CH2 V_{LLC_FB} (t)	
CH3 V_{HB} (t)	
CH4 I_{prim} (t)	

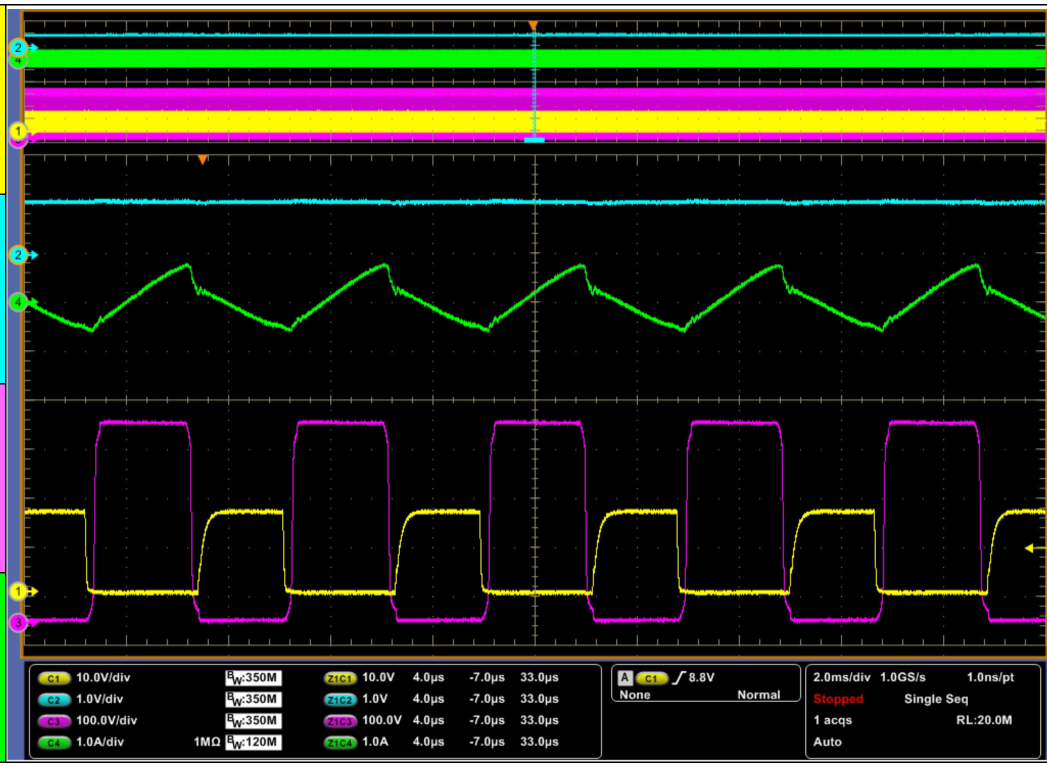

Figure 24. 110 V AC/ LLC NORMAL MODE, LOAD 3.15 A

CH1 V_{MLOWER} (t)	
CH2 V_{LLC_FB} (t)	
CH3 V_{HB} (t)	
CH4 I_{prim} (t)	

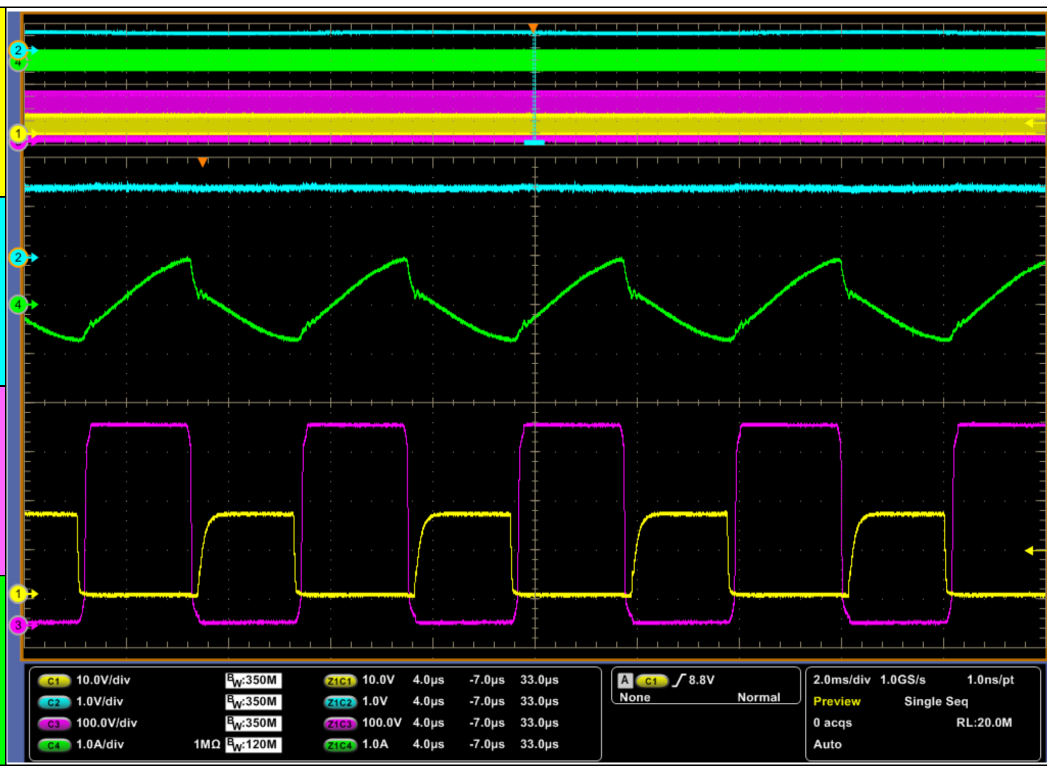

Figure 25. 110 V AC/ LLC NORMAL MODE, LOAD 5 A

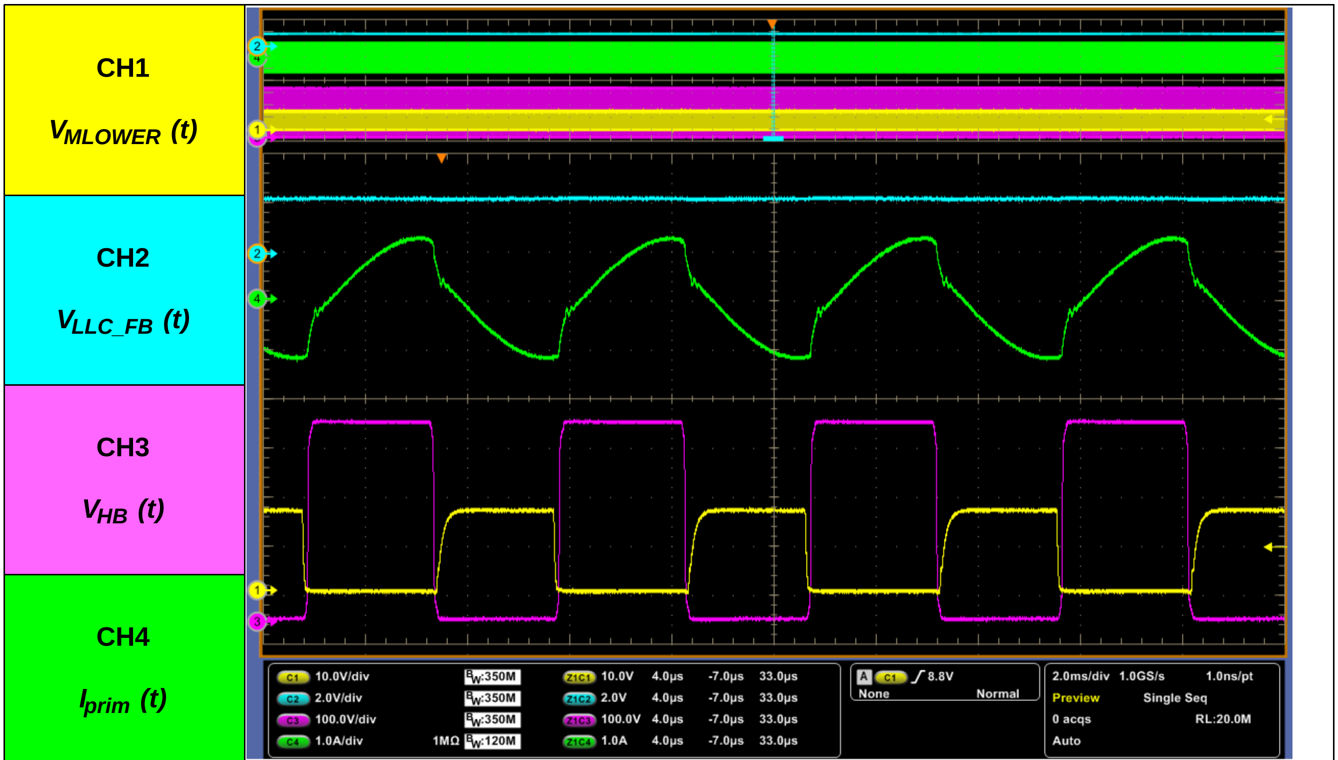

Figure 26. 110 V AC/ LLC NORMAL MODE 10 A

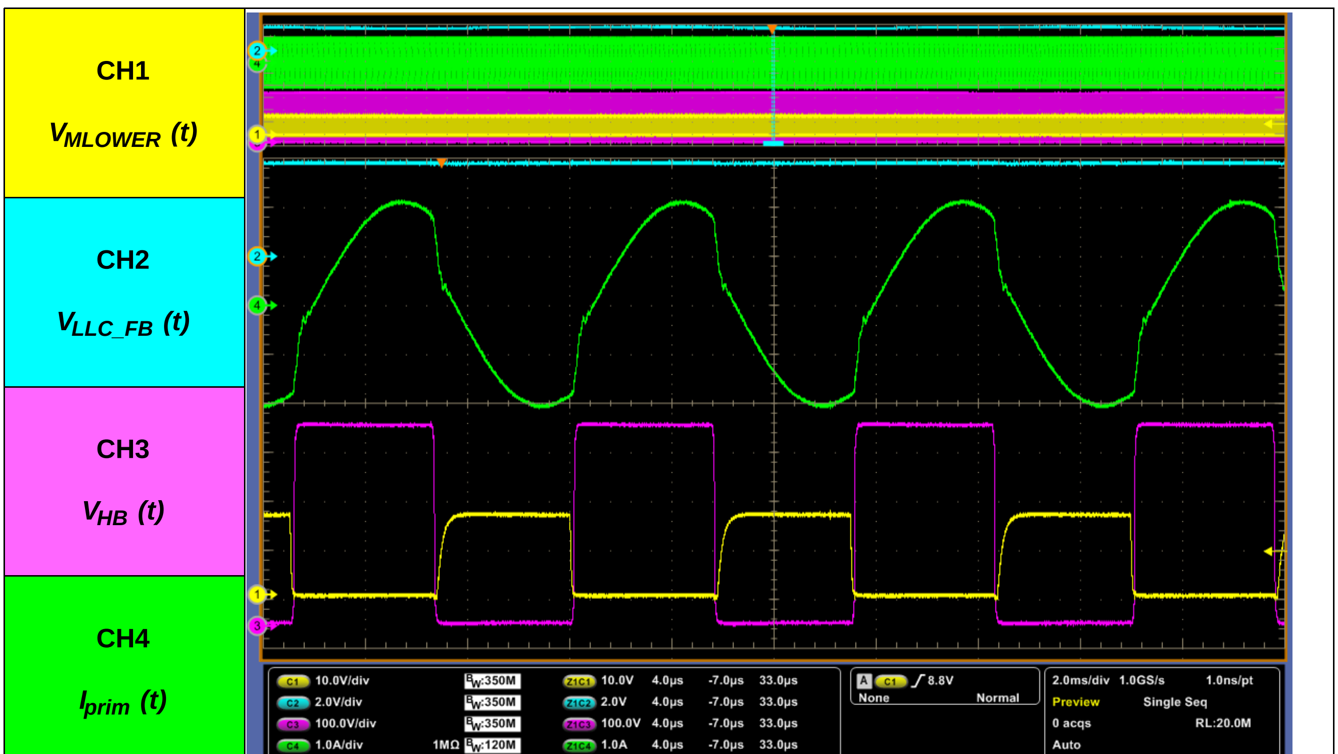

Figure 27. 110 V AC/ LLC NORMAL MODE, LOAD 20 A

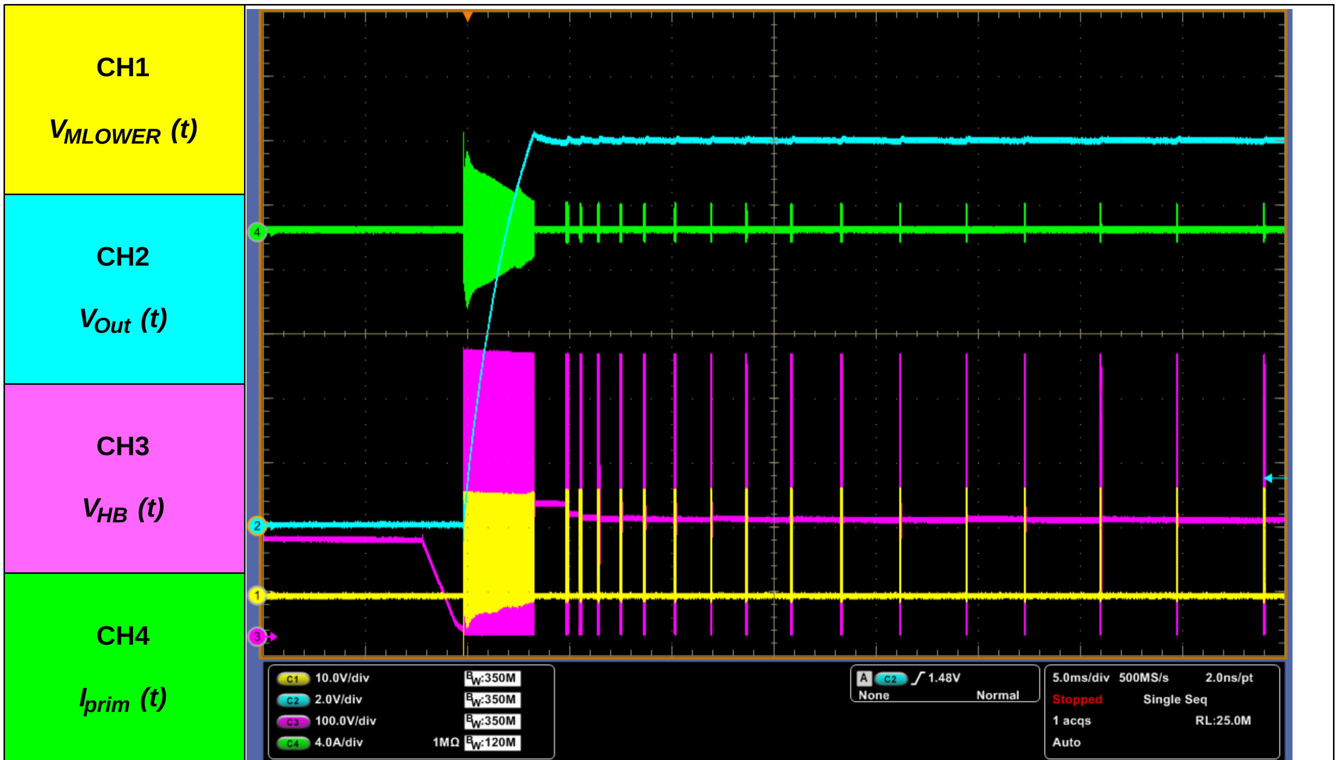

Figure 28. 110 V AC/ LLC START−UP into 0 A

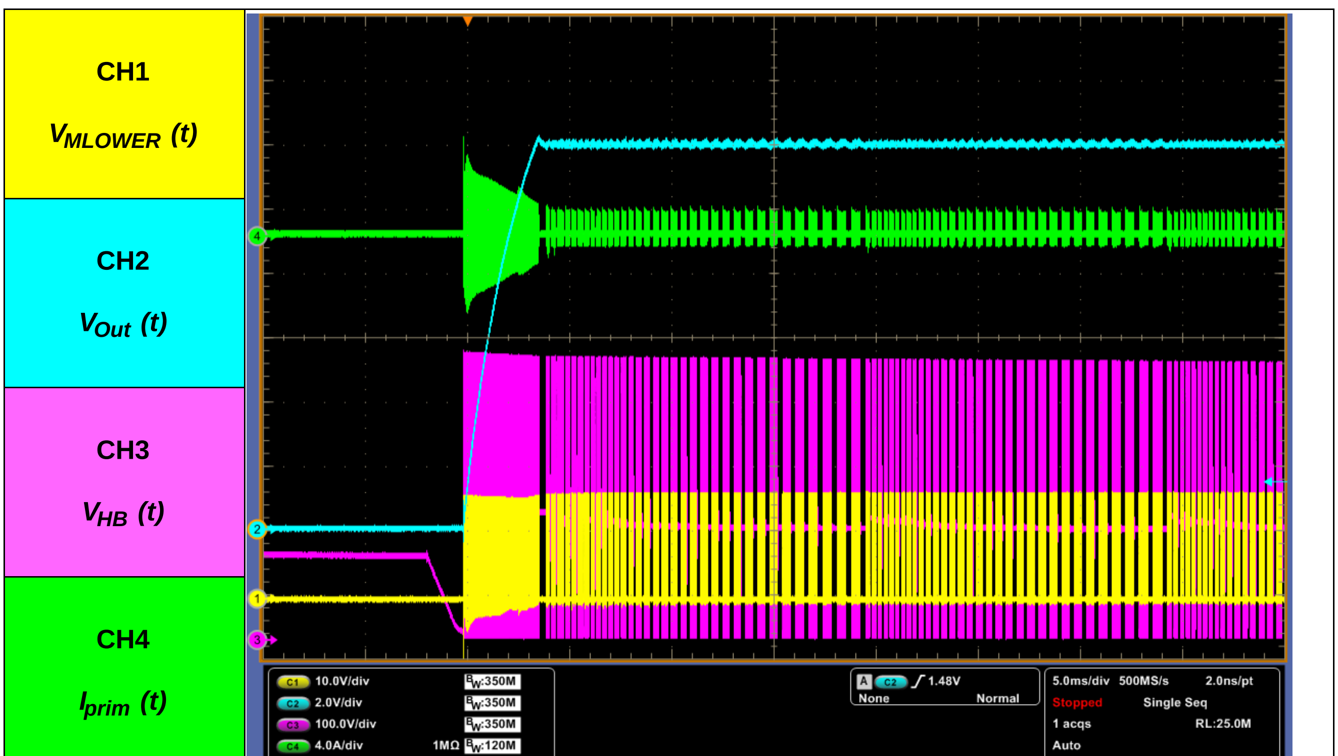

Figure 29. 110 V AC/ LLC START−UP into 2 A

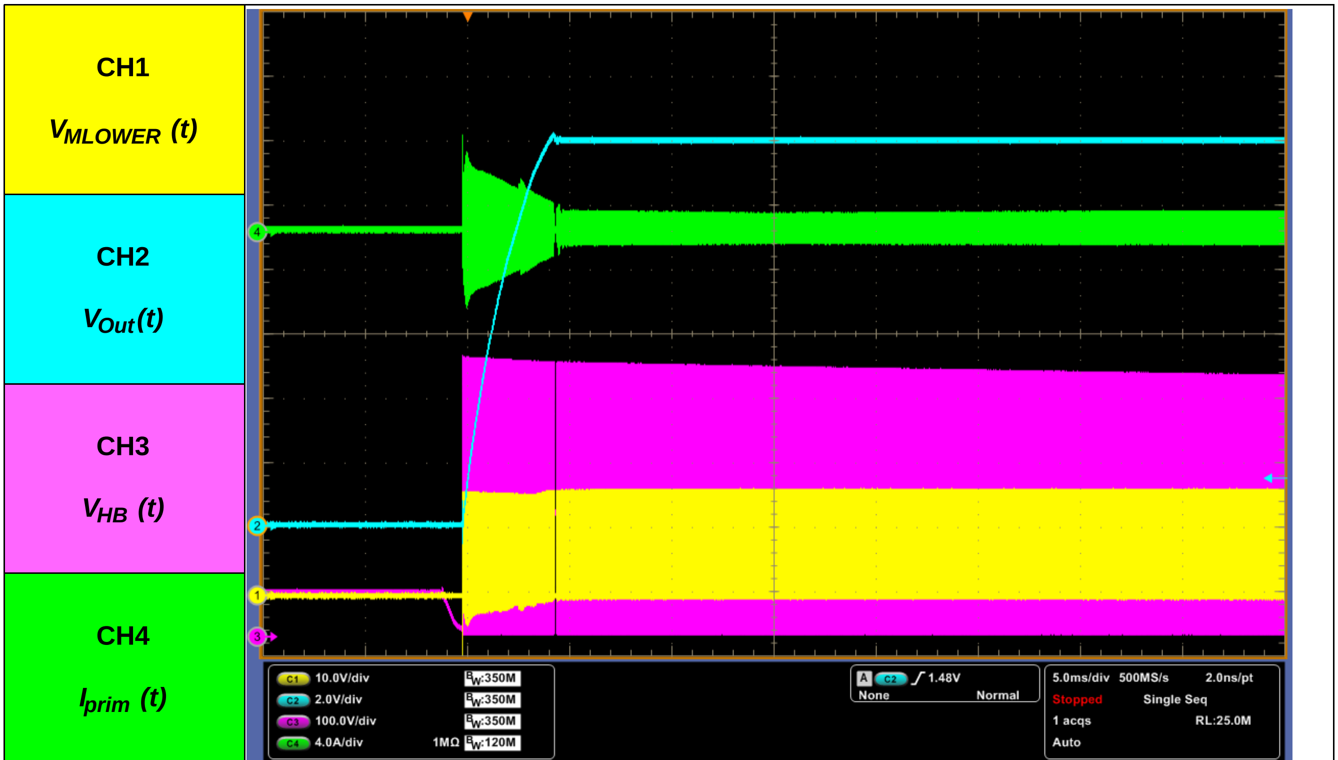

Figure 30. 110 V AC/ LLC START−UP into 5 A

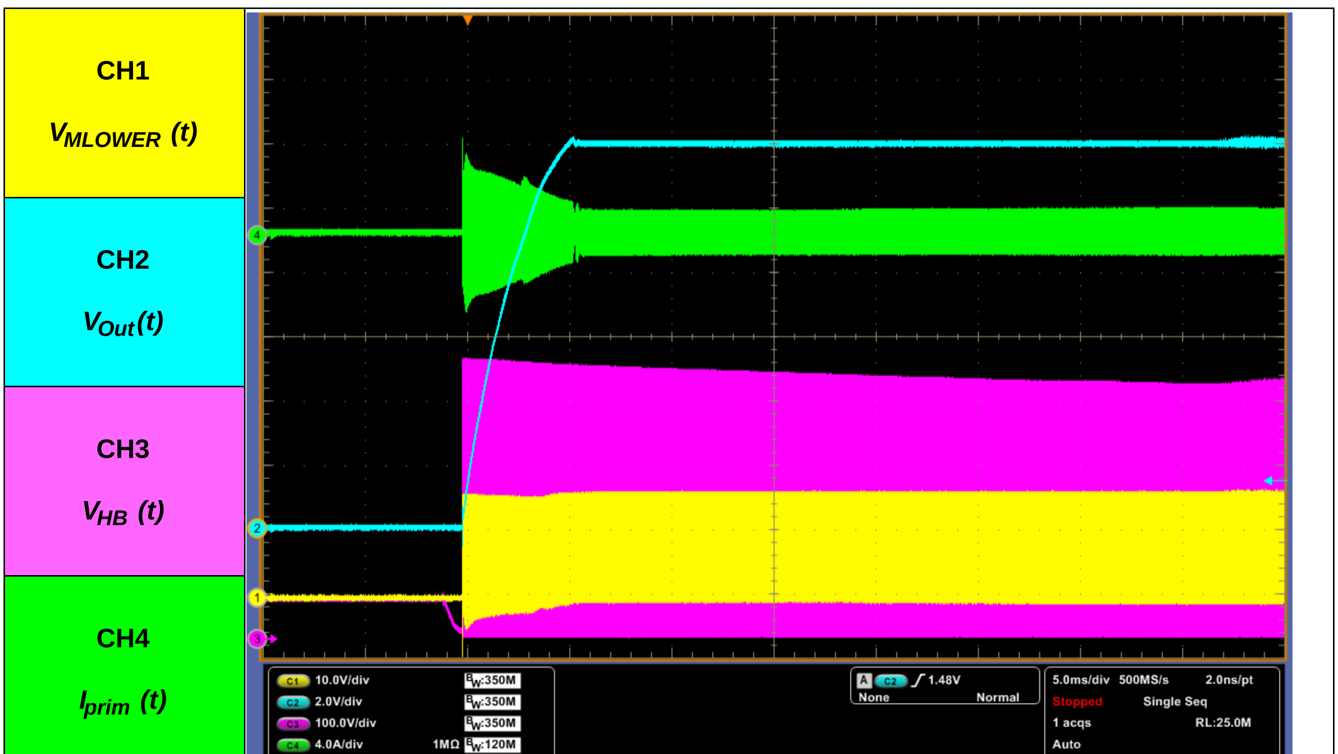

Figure 31. 110 V AC/ LLC START−UP into 10 A

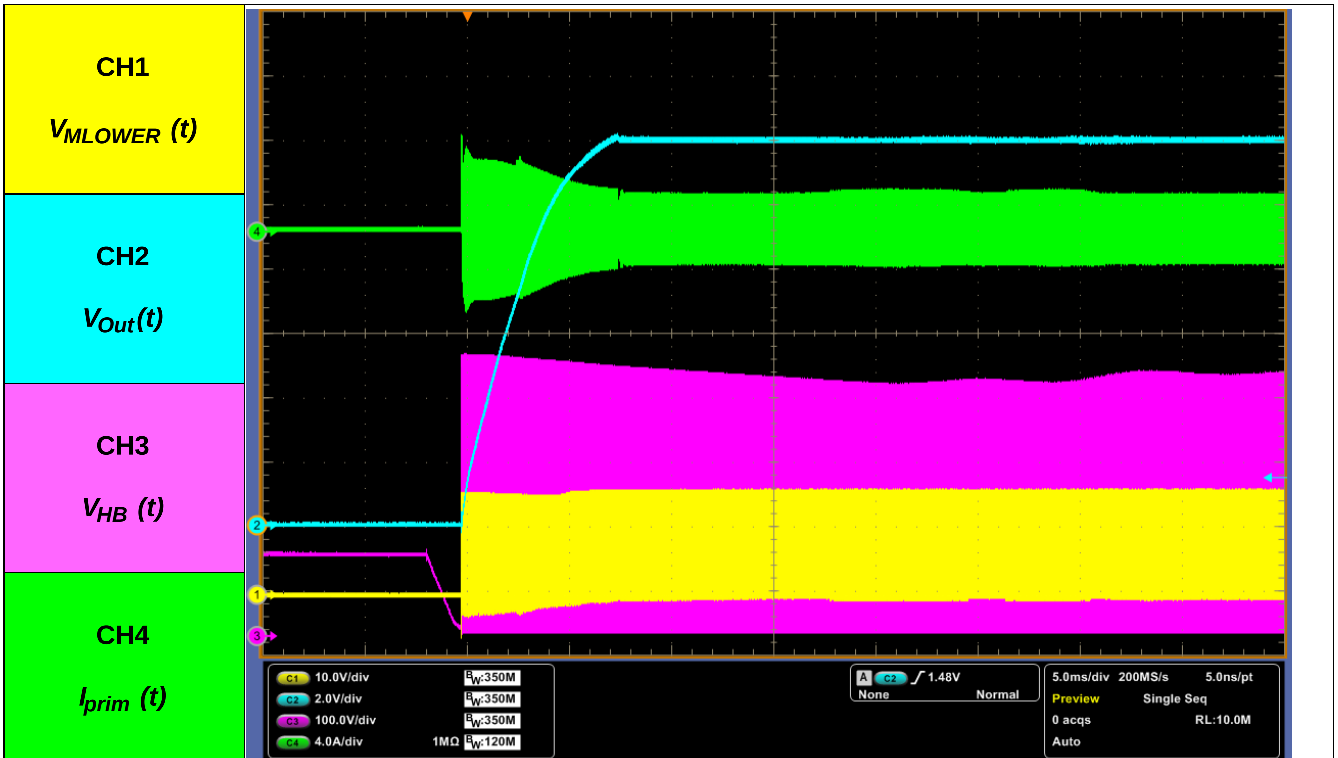

Figure 32. 110 V AC/ LLC START−UP into 20 A

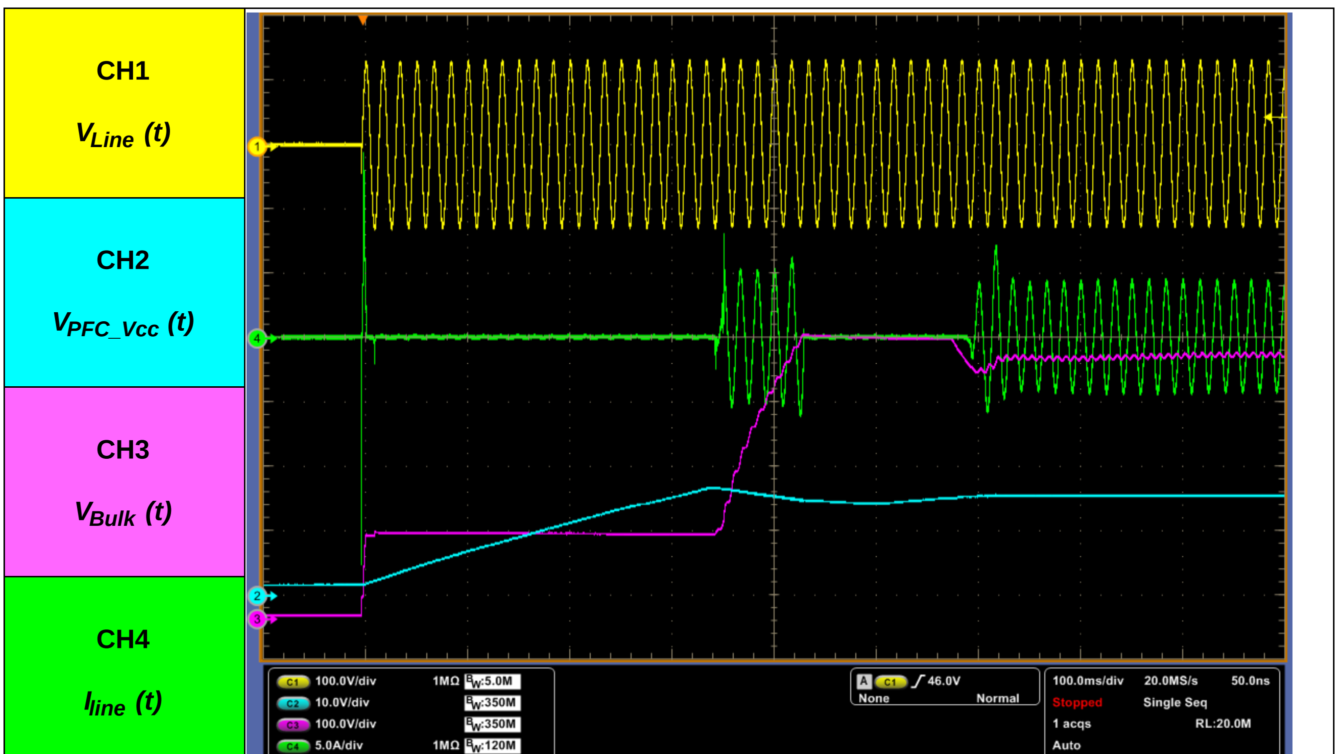

Figure 33. 90 V AC/ Load 20 A, PFC START−UP (No inrush limiter)

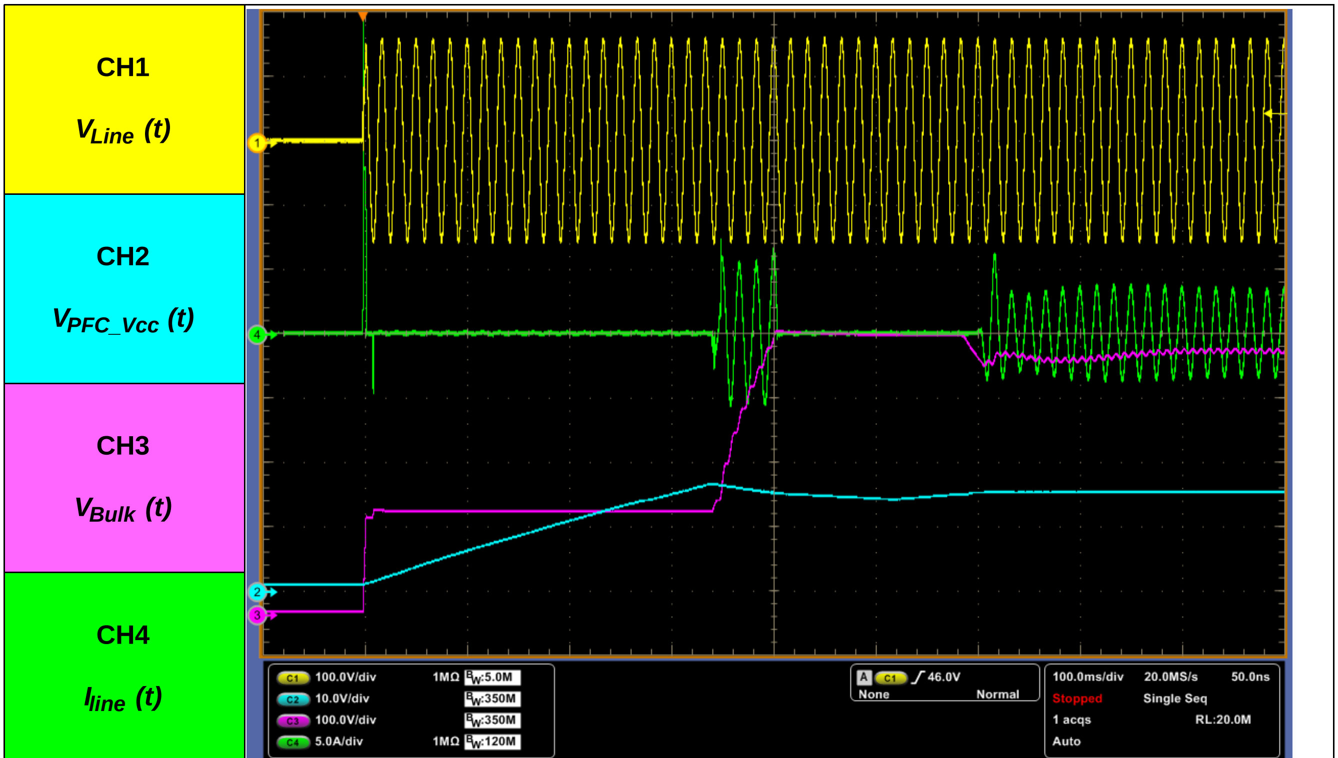

Figure 34. 110 V AC/ Load 20 A, PFC START−UP (No inrush limiter)

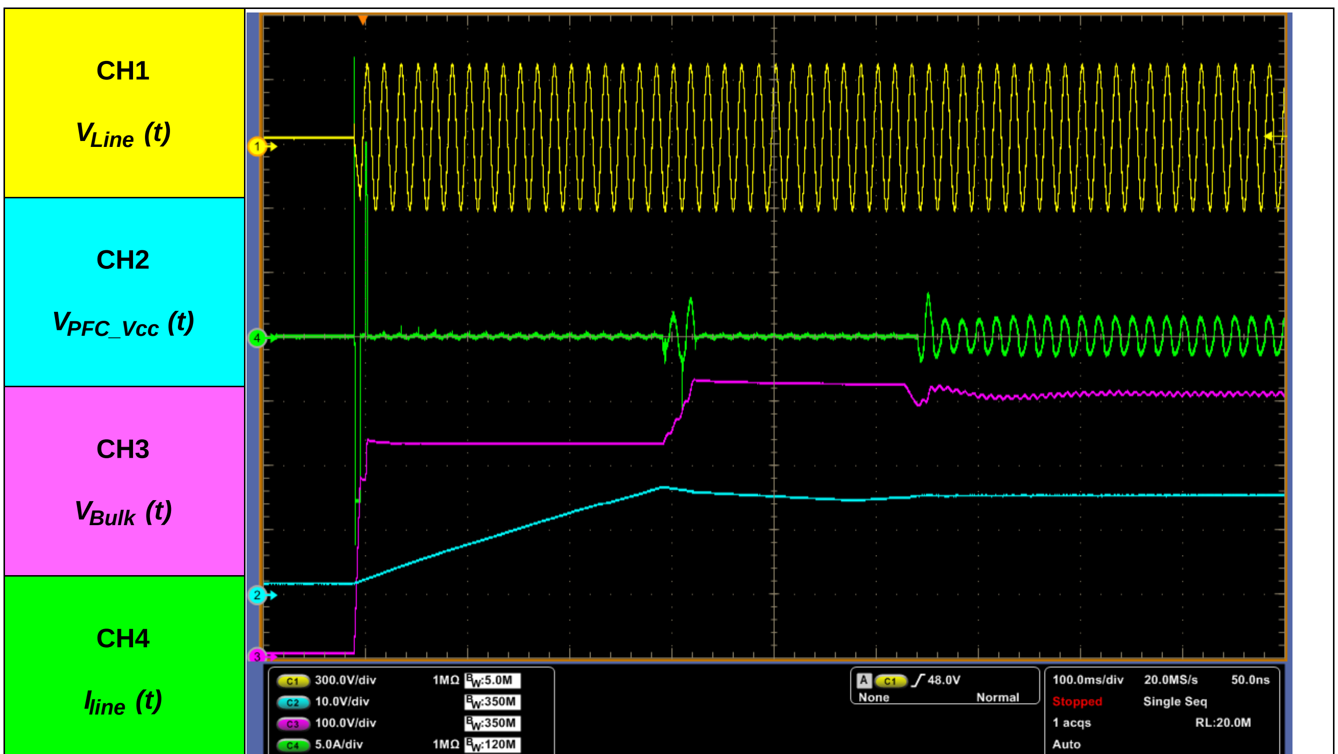

Figure 35. 230 V AC/ Load 20 A, PFC START−UP (No inrush limiter)

CH1	Q101 V_{GS} (t)
CH2	V_{out}(t)
CH3	V_{Bulk} (t)
CH4	I_{line} (t)

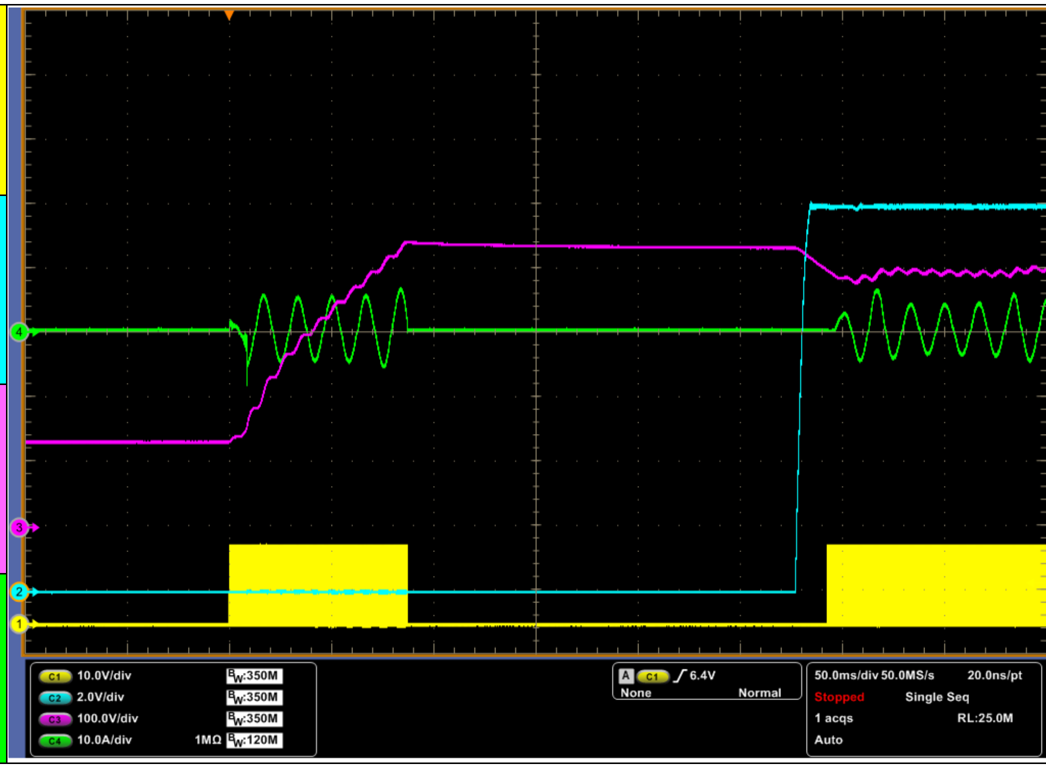

Figure 36. 90 V AC/ Load 20 A, PFC/ LLC START−UP (No inrush limiter)

CH1	Q101 V_{GS} (t)
CH2	V_{out}(t)
CH3	V_{Bulk} (t)
CH4	I_{line} (t)

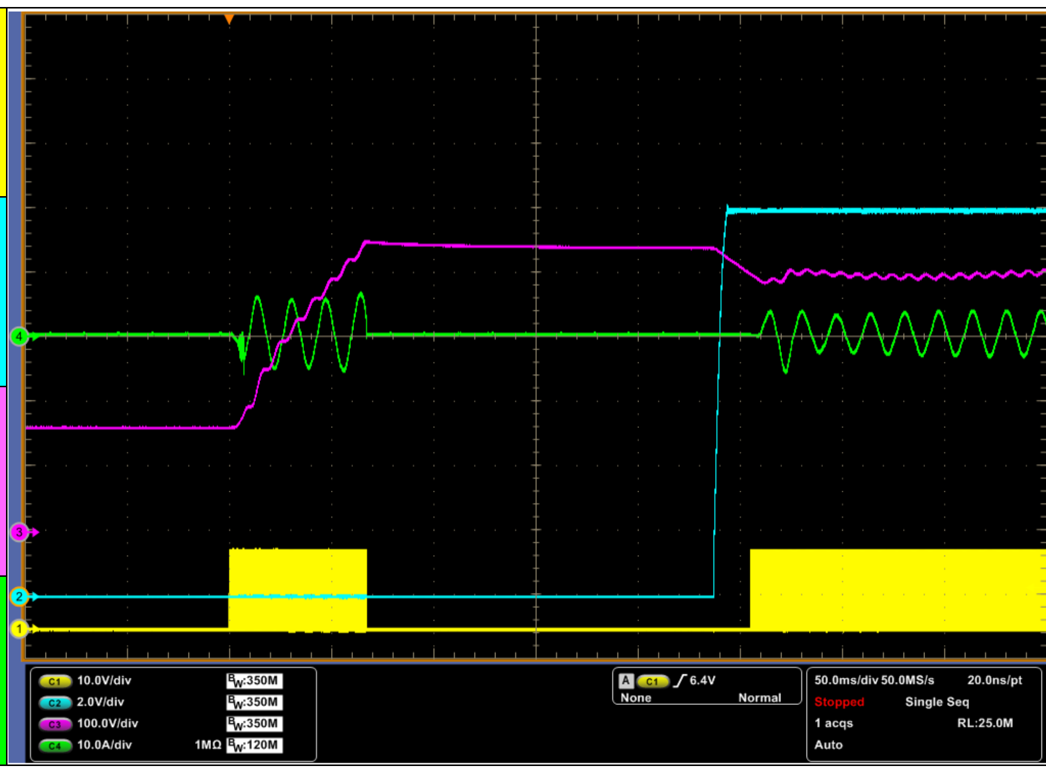

Figure 37. 110 V AC/ Load 20 A, PFC/ LLC START−UP (No inrush limiter)

Figure 38. 230 V AC/ Load 20 A, PFC/ LLC START−UP (No inrush limiter)

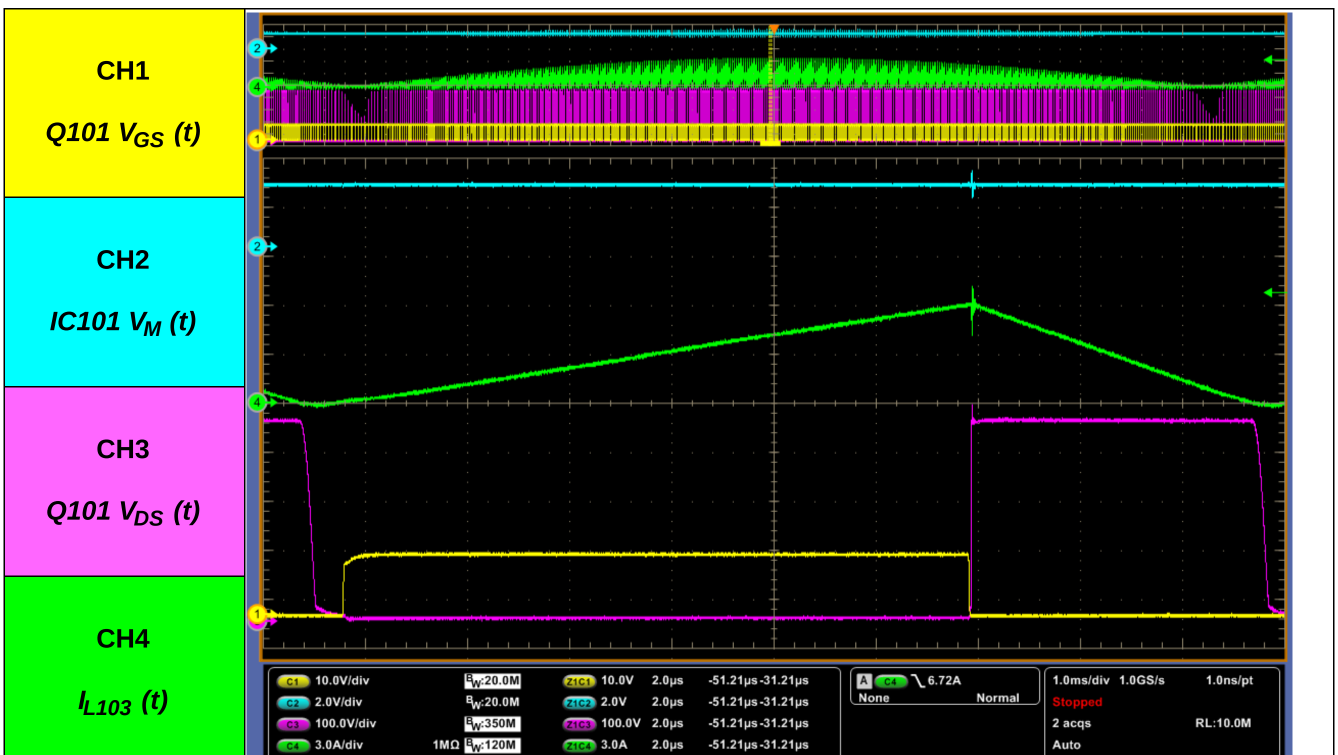

Figure 39. 90 V AC/ Load 13 A, PFC CrM MODE – before entering CCM

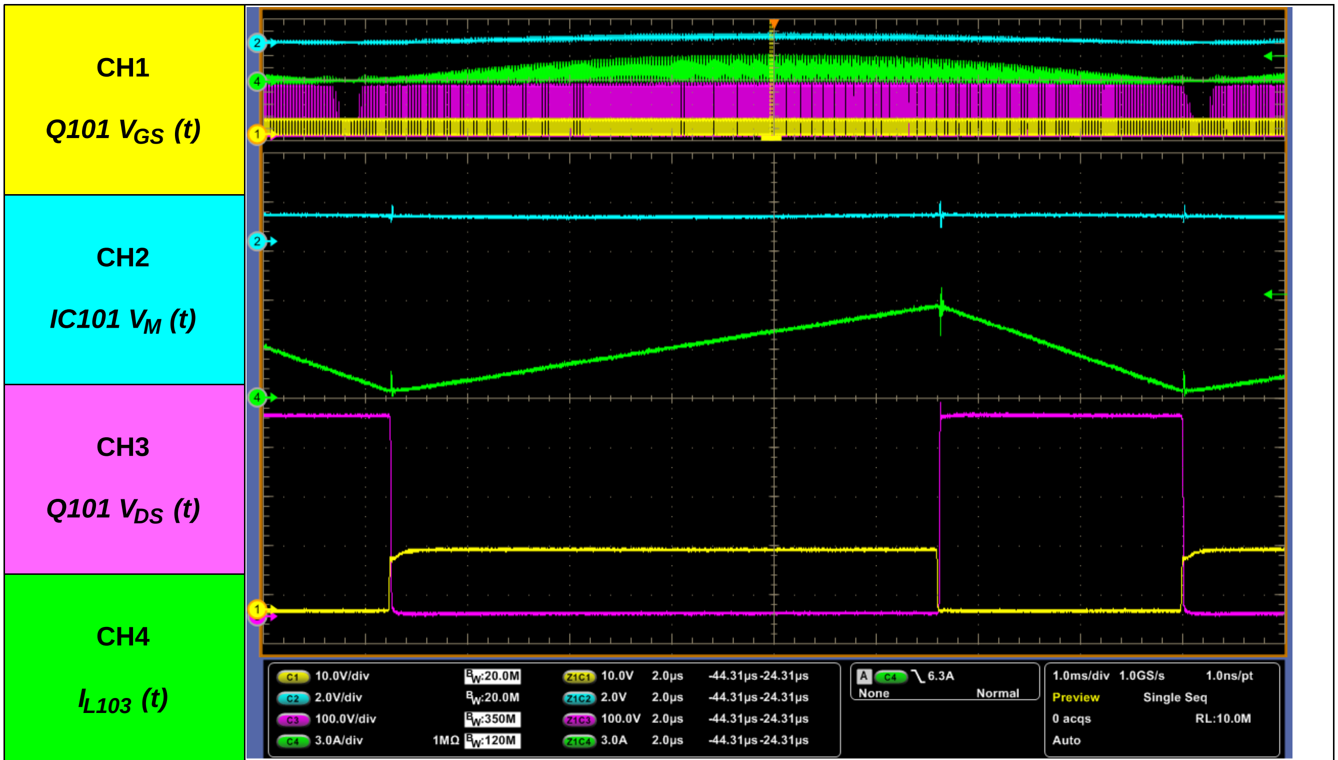

Figure 40. 90 V AC/ Load 14 A, PFC CCM MODE

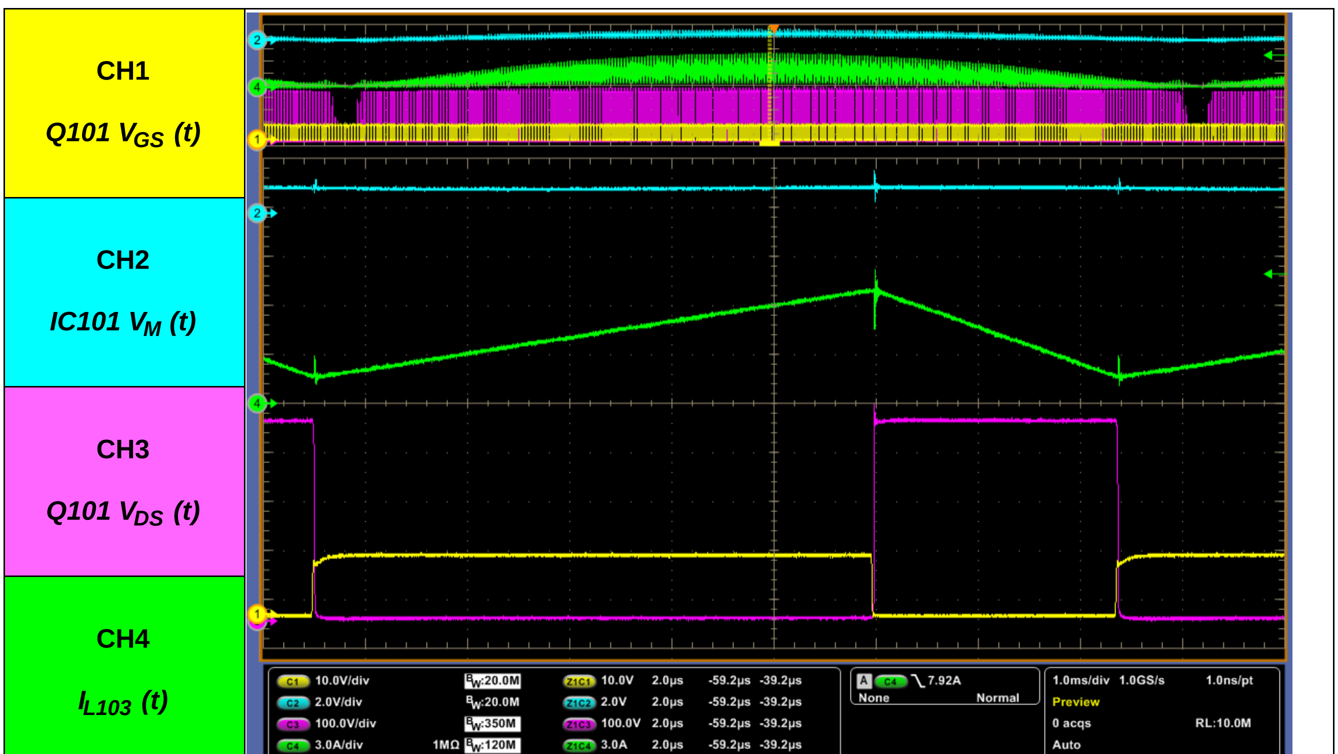

Figure 41. 90 V AC/ Load 20 A, PFC CCM MODE

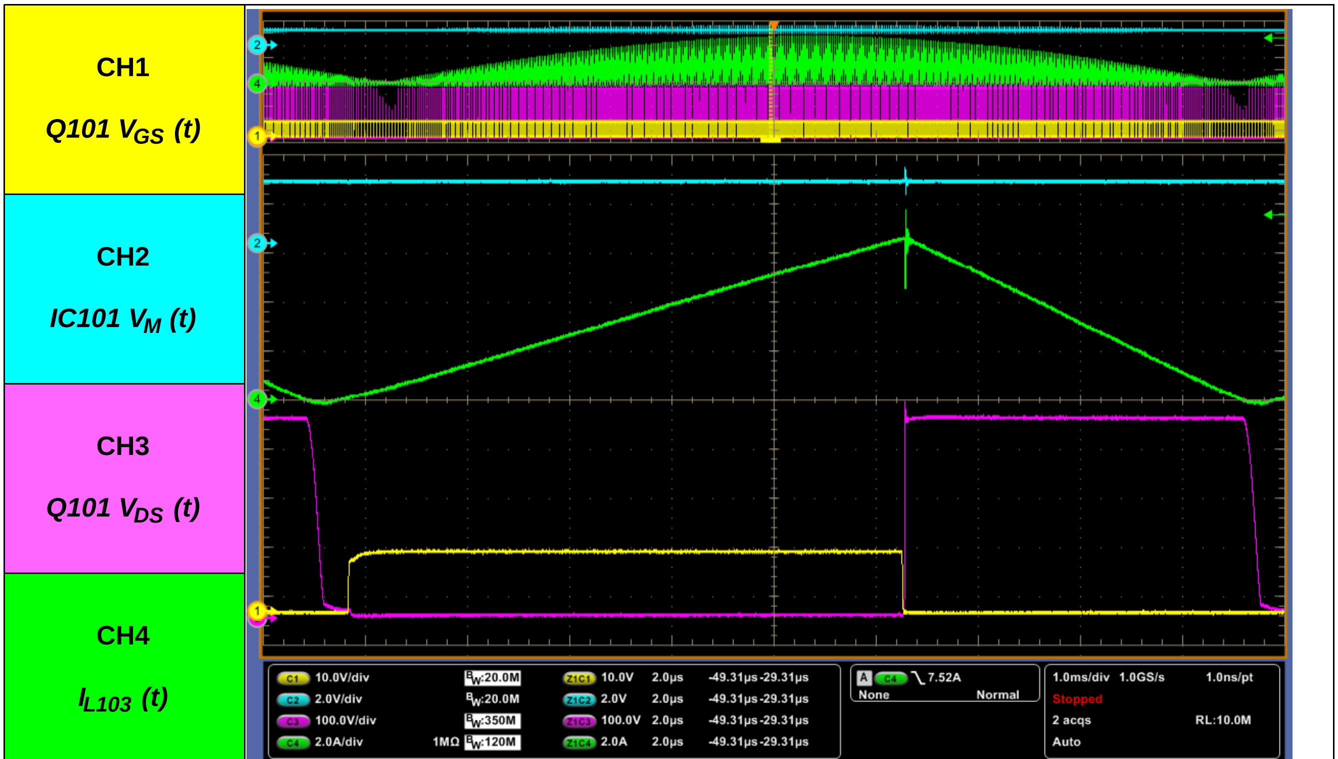

Figure 42. 110 V AC/ Load 18 A, PFC CrM MODE – before entering CCM

Figure 43. 110 V AC/ Load 20 A, PFC CCM MODE

CH1 $Q101\ V_{GS}\ (t)$

CH2 $IC101\ V_M\ (t)$

CH3 $Q101\ V_{DS}\ (t)$

CH4 $I_{L103}\ (t)$

Figure 44. 230 V AC/ Load 20 A, PFC CrM MODE

CH1 $Q101\ V_{GS}\ (t)$

CH2 $IC101\ V_M\ (t)$

CH3 $Q101\ V_{DS}\ (t)$

CH4 $I_{L103}\ (t)$

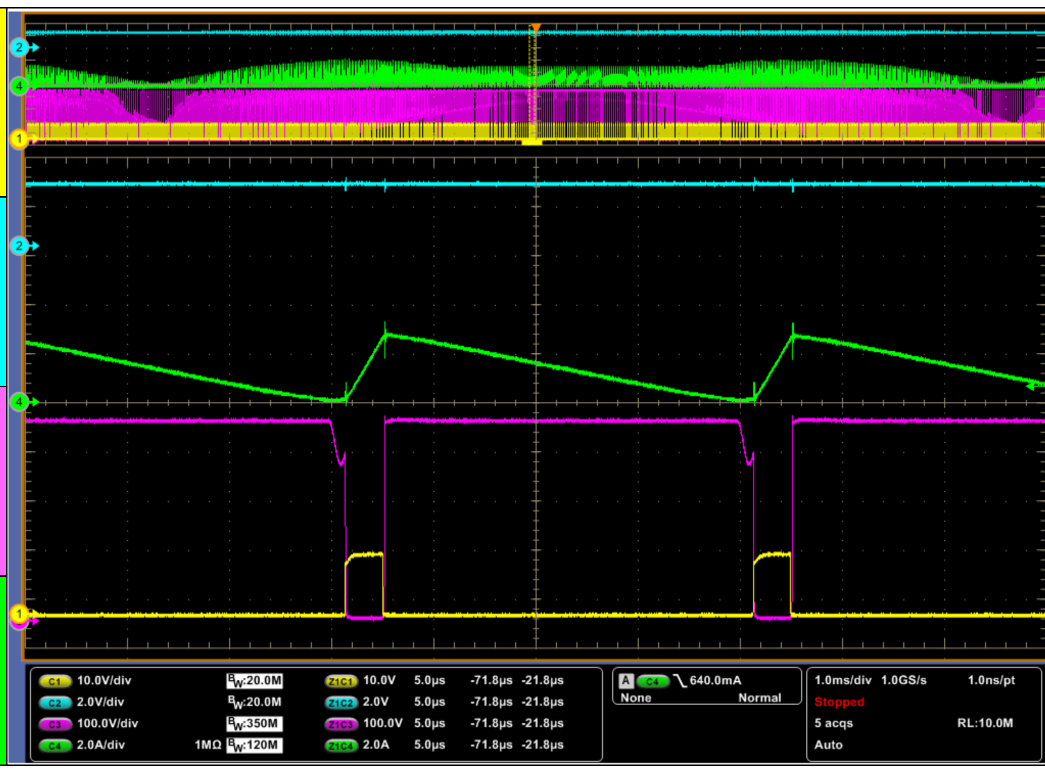

Figure 45. 265 V AC/ Load 18 A, PFC CrM MODE

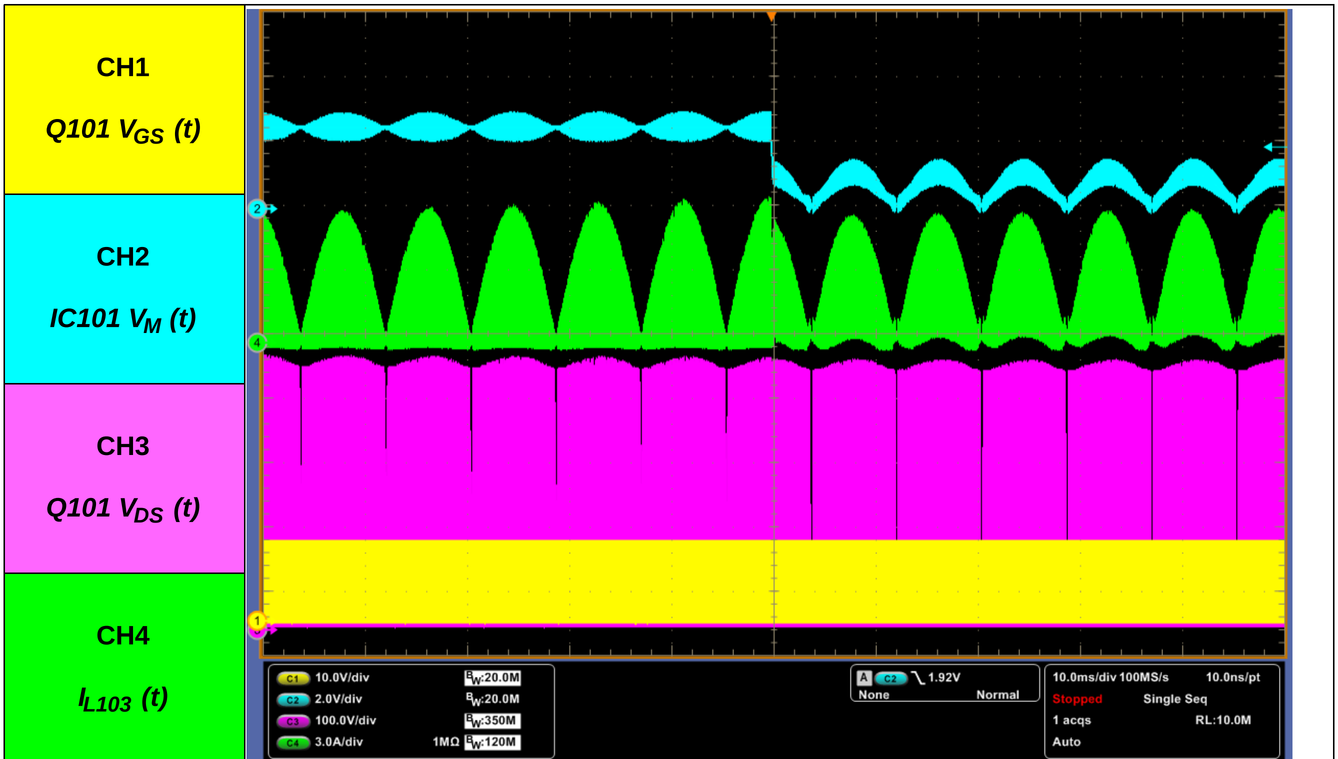

Figure 46. 90 V AC/ Load slowly rising through margin (13 / 14 A), PFC Transition from CrM to CCM

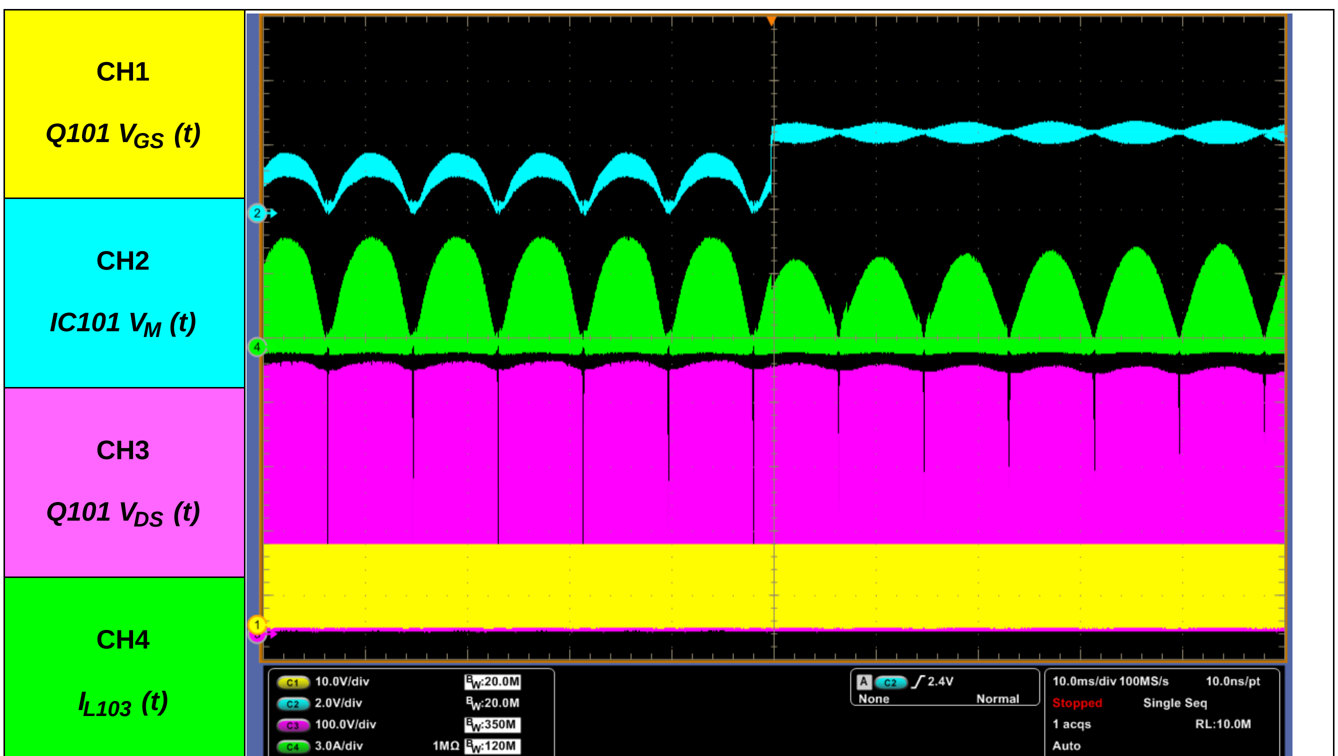

Figure 47. 90 V AC/ Load slowly decreasing through margin (14/ 13 A), PFC Transition from CCM to CrM

CH1

IC101 V_{PFC_OK} (t)

CH2

IC203 V_{MODE} (t)

CH3

V_{Bulk} (t)

CH4

I_{line} (t)

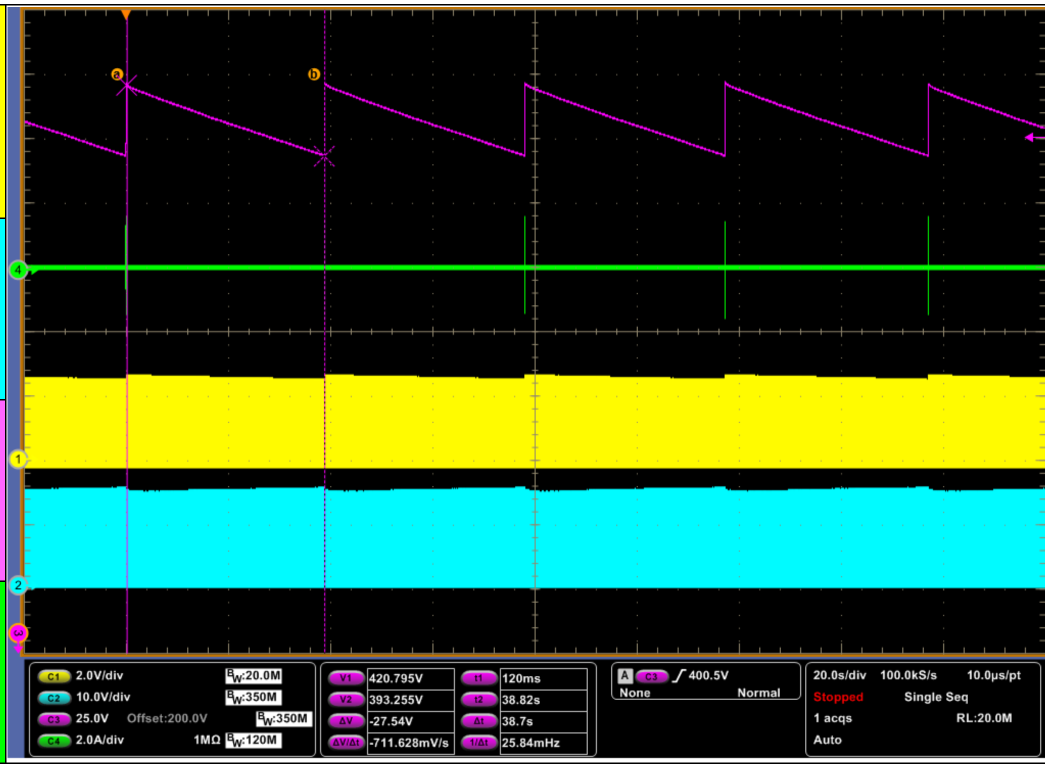

Figure 48. 110 V AC/ No−load, PFC Soft−skip mode − V_{Bulk} Hiccups

CH1

V_{Line} (t)

CH2

V_{Out} (t)

CH3

N/A

CH4

I_{line} (t)

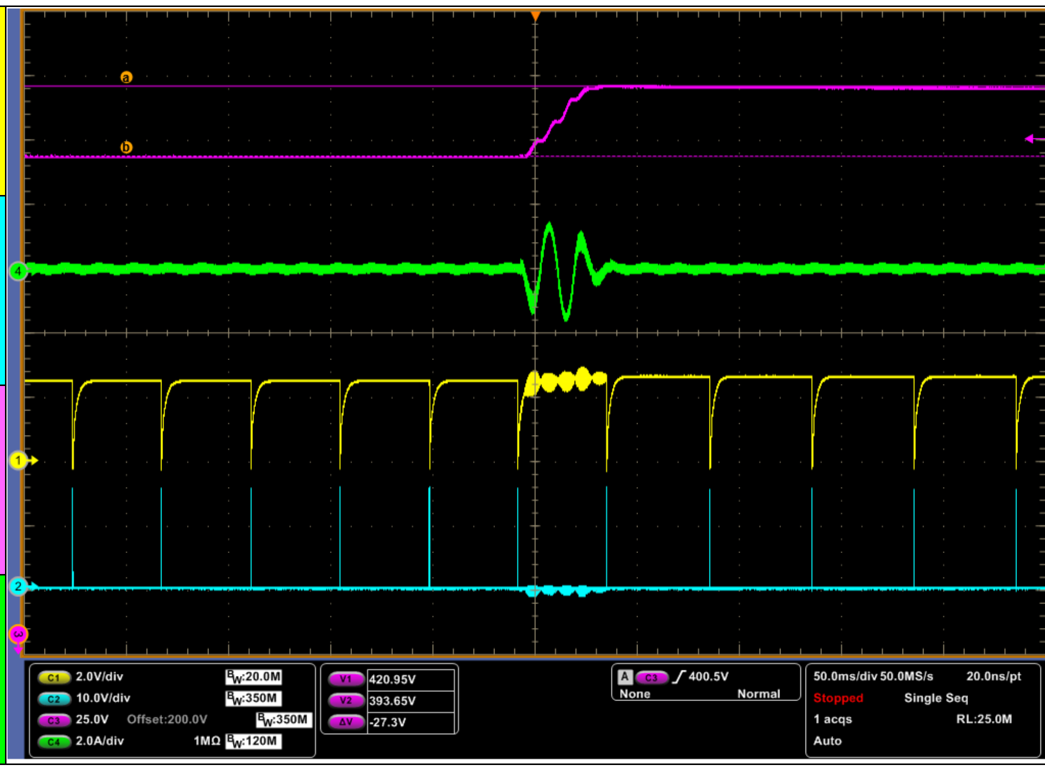

Figure 49. 110 V AC/ No−load, PFC Soft−skip mode − V_{Bulk} Hiccups/ PFC Burst detail

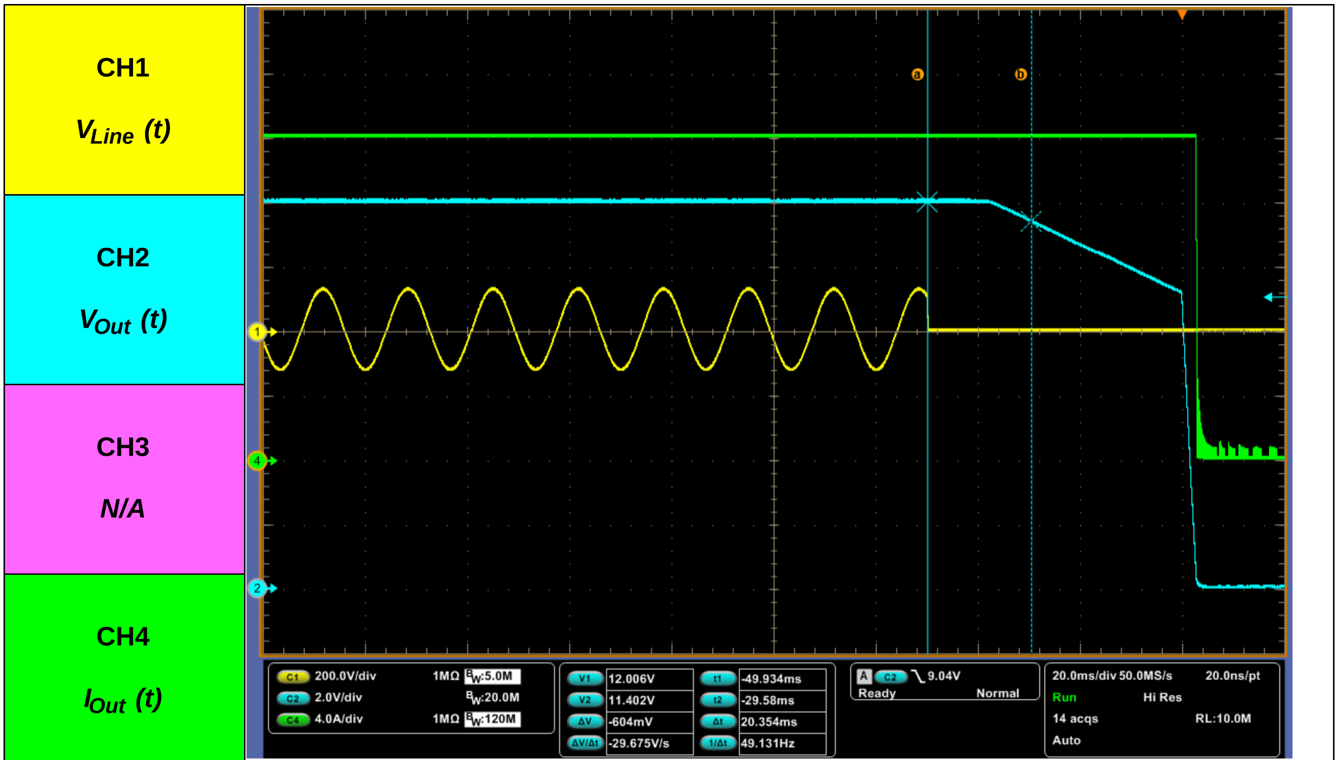

Figure 50. 90 V AC/ Load 20 A, Hold−up time for 5% regulation – 20 ms

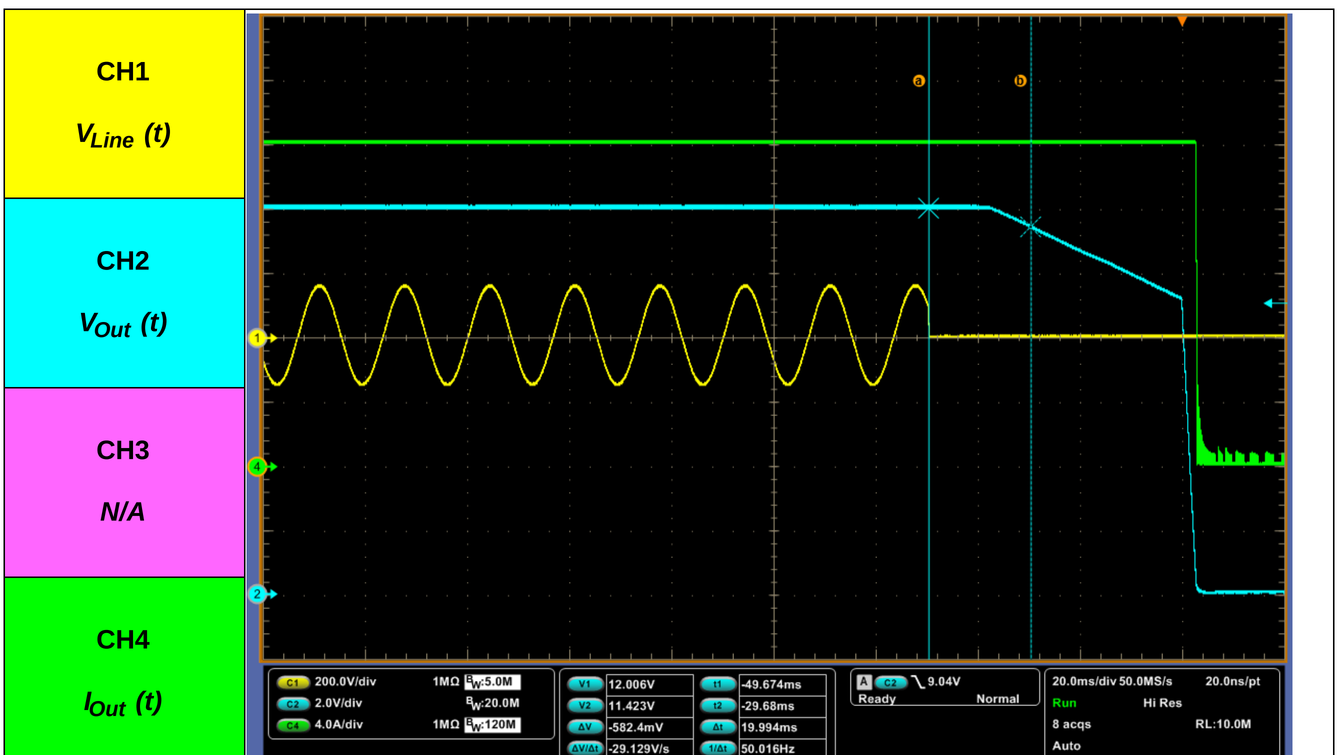

Figure 51. 110 V AC/ Load 20 A, Hold−up time for 5% regulation – 20 ms

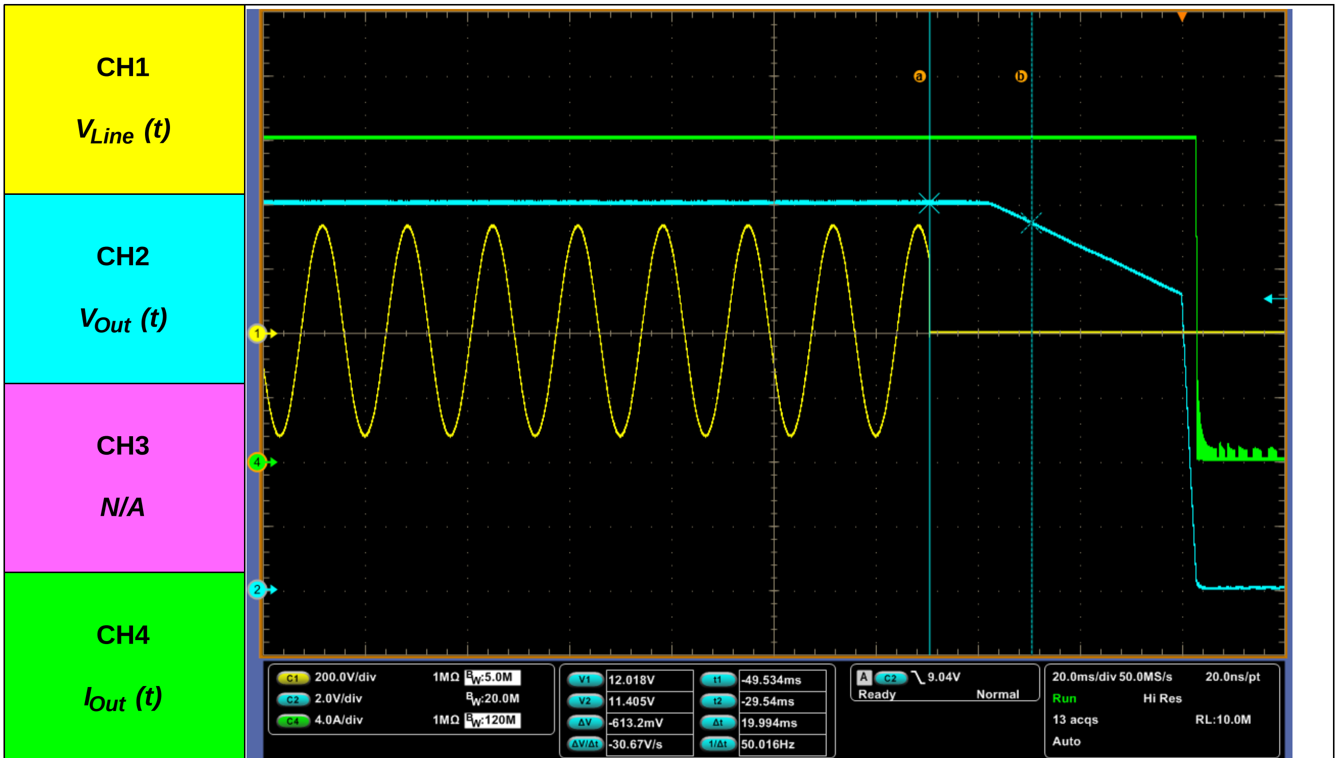

Figure 52. 230 V AC/ Load 20 A, Hold−up time for 5% regulation – 20 ms

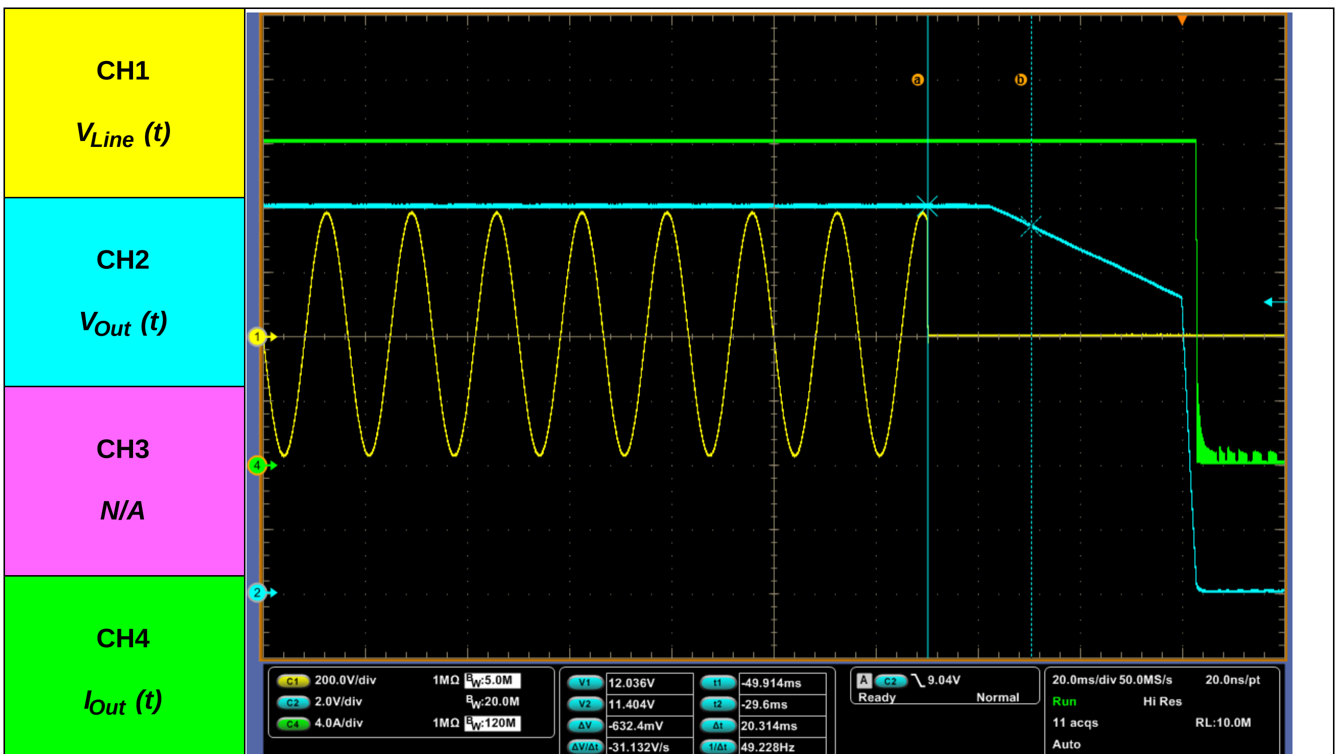

Figure 53. 265 V AC/ Load 20 A, Hold−up time for 5% regulation – 20 ms

Literature

High−Voltage, Multimode Power Factor Controller
NCP1618: https://www.onsemi.com/pub/Collateral/NCP1618−D.PDF

High Performance Current Mode Resonant Controller with Integrated High Voltage Drivers:
NCP13992: https://www.onsemi.com/pub/Collateral/NCP13992−D.PDF

Secondary Side Synchronous Rectifier Controllers:
NCP4306: https://www.onsemi.com/pub/Collateral/NCP4306−D.PDF

Voltage Reference, Programmable Shunt Regulator
NCP431: https://www.onsemi.com/pub/Collateral/NCP431−D.PDF

N−Channel SupreMOS® MOSFET 600 V, 22 A, 165 mΩ
FCPF22N60NT: https://www.onsemi.com/pub/Collateral/FCPF22N60NT−D.pdf

Power Rectifier, Soft Recovery, Switch−mode, 8 A, 600 V
MSRF860G: https://www.onsemi.com/pub/Collateral/MSR860−D.PDF

N−Channel SupreMOS® MOSFET 600 V, 13 A, 258 mΩ
FCPF165N65S3L1: https://www.onsemi.com/pub/Collateral/FCPF165N65S3L1−D.PDF

Single N−Channel Power MOSFET 40 V, 130 A, 2.5 mΩ
NVMFS5C442NL: https://www.onsemi.com/pub/Collateral/NVMFS5C442NL−D.PDF

Table 3. BILL OF MATERIALS

Parts	Qty	Value	Package	Description	Manufacturer	Part Number	Substitution
MAIN BOARD							
C101, C102	2	220nF/275V~	C102−064X133	CAPACITOR	Wurth	890324024002	Not allowed
C103	1	470nF/450Vdc	C150−072X183	CAPACITOR	Panasonic	ECW−FD2W474J	Not allowed
C104	1	1uF/450Vdc	C150−072X183	MPP CAPACITOR	Panasonic	ECW−FE2W105J	Not allowed
C105	1	2.2nF/250V	C0805	CAPACITOR	Wurth	885342007005	Not allowed
C106	1	22nF/200V	C0805	CAPACITOR	Wurth	885342207006	Not allowed
C107, C201, C202	3	100u/450V	EC_18X30_7.5	CAPACITOR Electrolytic	United Chemi−Con	EKXL451ELL101MM30S	Allowed
C108	1	220pF/50V	C0805	CAPACITOR	Wurth	885012007059	Allowed
C109, C220	2	470pF/50V	C0805	CAPACITOR	Wurth	885012007061	Allowed
C110, C233	2	2.2nF/50V	C0805	CAPACITOR	Wurth	885012007065	Allowed
C111, C224	2	1uF/50V	C0805	CAPACITOR	Wurth	885012207103	Allowed
C112, C115, C218, C219, C221, C222	6	10nF/50V	C0805	CAPACITOR	Wurth	885012207092	Allowed
C113, C225	2	220uF/25V	E3.5−8	CAPACITOR Electrolytic	Wurth	860040474004	Allowed
C114	1	15pF/50V	C0805	CAPACITOR	Wurth	885012007052	Allowed
C116	1	4.7nF/50V	C0805	CAPACITOR	Wurth	885012007067	Allowed
C203, C217, C223, C235, C236	3	100nF/50V	C0805	CAPACITOR	Wurth	885012207098	Allowed
C204	1	100nF/50V	C1206	CAPACITOR	Wurth	885012208087	Allowed
C205, C206	2	33nF/630V	C150−064X183	CAPACITOR	Epcos	B32652A6333J	Allowed
C207	1	220uF/35V	E3,5−8	CAPACITOR Electrolytic	Wurth	860010574011	Allowed
C208, C209	2	6.8nF/100V	C0805	CAPACITOR	Wurth	885012207121	Allowed
C210, C211	2	2.2uF/16V	C0603	CAPACITOR	Wurth	885012106018	Allowed
C212, C213, C214, C215, C216	5	1.2mF/16V	E3.5−8	CAPACITOR POLYMER	United Chemi−Con	APSG160ELL122MH20S	Not allowed
C227, C228	2	220pF/630V NP0	C1206	CAPACITOR	KEMET	C1206C221JBGACAUTO	Not allowed
C229	1	4.7nF/50V/NP0	C0805	CAPACITOR	Wurth	885012007067	Not allowed
CY101, CY102, CY201	3	2.2nF/Y1	YC10B5	Y CAPACITOR	Murata	DE1E3KX222MN4AP01F	Not allowed
F101	1	5A/ 350V SLOW	0697H	FUSE	Bel Fuse	0697H5000−01	Allowed
L101	1	10mH	LF−280XX	COMMON MODE INDUCTOR	ICE COMPONENTS	LF−28024−0048−H	Not allowed
L102, L103	2	90uH	TO18	DIF. MODE INDUCTOR	Wurth	7447013	Not allowed
L104	1	260uH	PQ32/20−4	PFC INDUCTOR	Sumida	T91869	7503150361
L201	1	50uH	RM8	Resonant inductor	Sumida	T91870	750370249
L202	1	1 turn	FERRITE BEAD 09X05	POWER FERRITE BEAD	Wurth	74270033	Not allowed
NTC201	1	330k, 5%	THT	NTC	Vishay	NTCLE100E3334JB0	Allowed
R101	1	275 VAC	LITTELFUSE	VARISTOR	Littelfuse	V430CH8S	Not allowed
R102	1	STRAP	N/A	NTC THERMISTOR	N/A	N/A	N/A
R103	1	10R	R0603	RESISTOR	VARIOUS	VARIOUS	Allowed

Table 3. BILL OF MATERIALS (continued)

Parts	Qty	Value	Package	Description	Manufacturer	Part Number	Substitution
R104, R205, R233, R236, R238, R247	6	0R	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
R105, R119	2	1.1k	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
R106, R107	2	62m / 2W	R6332W	RESISTOR	TE Connectivity / Holsworthy	RLP73N3AR062JTE	Similar type
R108, R203, R204, R206	4	22k	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
R109	1	300R	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
R110	1	2.2R	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
R111	1	22R	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
R112	1	160k	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
R113, R114, R115, R116	4	2.7M 1%	R0805	RESISTOR	ROHM Smiconductor	KTR18EZPF2704	Similar type
R118, R121, R218, R220	4	1k	R1206	RESISTOR	VARIOUS	VARIOUS	Allowed
R120, R237	2	68k	R0805	RESISTOR	TE Connectivity / Holsworthy	CRGCQ0805F68K	Similar type
R122	1	2k	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
R123, R241	2	11k	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
R124, R221, R225	3	10k	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
R201, R202	2	33R	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
R207, R208	2	2R	R1206	RESISTOR	VARIOUS	VARIOUS	Allowed
R209, R210	2	27R	R1206	RESISTOR	VARIOUS	VARIOUS	Allowed
R211, R216	2	5.1R	R0603	RESISTOR	VARIOUS	VARIOUS	Allowed
R212, R215	2	36k	R0603	RESISTOR	VARIOUS	VARIOUS	Allowed
R213, R214	2	5.6k	R0603	RESISTOR	VARIOUS	VARIOUS	Allowed
R217	1	82k	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
R222, R245	2	1k	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
R223	1	15k	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
R224	1	100R	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
R226	1	5.1R	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
R227, R230	2	0R	R1206	RESISTOR	VARIOUS	VARIOUS	Allowed
R228	1	1.5k	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
R231	1	5.1k	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
R232	1	820R	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
R239	1	39k	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
R240	1	56k	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
R243	1	150k	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
TR201	1	600uH/ n = 16	PQ3220	LLC TRANSFORMER	Sumida	T91871	Not allowed
X101, X201	4	Pitch 5.08 mm	WR−TBL Series 2365	SCREW TERMINAL	Wurth	691236510002	Allowed
C226, C230, C231, C232, C234	5	NOT USED	C0805	CAPACITOR	N/A	N/A	N/A
R117	1	NOT USED	R1206	RESISTOR	N/A	N/A	N/A

Table 3. BILL OF MATERIALS (continued)

Parts	Qty	Value	Package	Description	Manufacturer	Part Number	Substitution
R125, R229, R234, R235, R242, R244, R246	7	NOT USED	R0805	RESISTOR	N/A	N/A	N/A
B101	1	DFB2560	SIP−4	Bridge Rectifier	ON Semiconductor	DFB2560	Not allowed
D201, D203, D204	3	MBR0540	SOD123	DIODE	ON Semiconductor	MBR0540	Similar type
D101, D104, D105, D107, D111, D212	6	BAS16HT1G	SOD323	DIODE	ON Semiconductor	BAS16HT1G	Similar type
D102	1	S3M	SMC	DIODE	ON Semiconductor	S3M	Similar type
D103	1	MSRF860G	TO−220−2 FullPak	POWER DIODE	ON Semiconductor	MSRF860G	Similar type
D106, D110, D207	3	MMSD4148T1G	SOD123	DIODE	ON Semiconductor	MMSD4148T1G	Similar type
D108, D109	2	S1JFL	SOD123	DIODE	ON Semiconductor	S1JFL	Allowed
D112, D208	2	MM3Z4V7T1G	SOD323	ZENER DIODE	ON Semiconductor	MM3Z4V7T1G	Not allowed
D202	1	MM3Z18VT1G	SOD323	ZENER DIODE	ON Semiconductor	MM3Z18VT1G	Not allowed
D205, D206	2	MBR2H100SFT3G	SOD123	DIODE	ON Semiconductor	MBR2H100SFT3G	Not allowed
D209	1	ES1JFL	SOD123	DIODE	ON Semiconductor	ES1JFL	Not allowed
D211	1	MM3Z12VT1G	SOD323	ZENER DIODE	ON Semiconductor	MM3Z12VT1G	Not allowed
IC101	1	NCP1618A	SO10	PFC CONTROLLER	ON Semiconductor	NCP1618A	Not allowed
IC201, IC202	2	NCP4306	TSOP6	SR DRIVER	ON Semiconductor	NCP4306DAAZZAA	Not allowed
IC203	1	NCP13992	SO16	LLC CONTROLLER	ON Semiconductor	NCP13992	Not allowed
IC204	1	NCP431	SOT23	SHUNT REGULATOR	ON Semiconductor	NCP431BISNT1G	Not allowed
OK201, OK202	2	TCLT1008	SOP−4	OPTOCOUPLER	VISHAY	TCLT1008	Not allowed
Q101	1	FCPF165N65S3L1	TO−220−2 FullPak	POWER MOSFET	ON Semiconductor	FCPF165N65S3L1	FCPF22N60NT
Q102	1	NSS20200LT1G	SOT23	NPN Transistor	ON Semiconductor	NSS20200LT1G	Similar type
Q201	1	BSS138LT1G	SOT23	MOSFET	ON Semiconductor	BSS138LT1G	Similar type
Q202, Q203	2	FCPF22N60NT	TO−220−2 FullPak	POWER MOSFET	ON Semiconductor	FCPF22N60NT	Similar type
Q204, Q205, Q206, Q207	4	NTMFS5C442NL	SO8FL	POWER MOSFET	ON Semiconductor	NTMFS5C442NLT1G	Similar type
D210	1	NOT USED	SOD123	DIODE	N/A	N/A	N/A

MOD101 − EMI FILTER CAPACITOR DISCHARGING MODULE

Parts	Qty	Value	Package	Description	MANUFACTURER	PART NUMBER	Substitution
C301	1	10nF/275V~	C102−043X133	MPP CAPACITOR	Wurth	890324023006	Allowed
C302	1	1uF/50V	C0805	CAPACITOR	Wurth	885012207103	Similar type
D301, D302	2	S1JFL	SOD123	DIODE	ON Semiconductor	S1JFL	Not allowed
D303	1	MM3Z7V5T1G	SOD323	ZENER DIODE	ON Semiconductor	MM3Z7V5T1G	Not allowed
Q301	1	BSS138LT1G	SOT23	MOSFET	ON Semiconductor	BSS138LT1G	Similar type
Q303	1	BSS127	SOT23	MOSFET	Infineon	BSS127H6327XTSA2	Not allowed
R301, R302	2	5.1k	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
R303	1	120k	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
R304	1	470k	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
R305	1	0R	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
R306, R307, R308	3	33k	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
Q302	1	NOT USED	SOT23	MOSFET	N/A	N/A	N/A

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