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

360 W Power Supply Using NCP1618, NCP13994, NCP4318 and NCP431

NCP13994MM360WGEVB

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 V DC 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, NCP13994, NCP4318 and NCP431.

The NCP1618 is an innovative multimode power factor controller. The controller automatically changes 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 Discontinuous Conduction Mode (DCM) at 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 NCP13994 is a high−performance current mode LLC controller for half bridge resonant converters. This controller implements 700 V gate drivers, simplifying layout and reducing external component count. In applications where a PFC front stage is needed, the NCP13994 features a output that can be used 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.

Key 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. GENERALS PARAMETERS

Device	Applications	Input Voltage	Nominal Output Voltage / Current	Output Power	V_{OUT} Ripple
NCP1618, NCP13994, NCP4318	AOI, Server Power	90 – 265 Vac	12 Vdc / 30 A	360 W	<150 mV @ Full Load
Efficiency @ 230 V AC	**Standby Power**	**Operating Temperature**	**Cooling**	**Topology**	**Board Size**
4 point AVG 95.00%	<100 mW	0 – 40°C	Forced	PFC + LLC + SR	163 x 96 x 36 mm 10.77 W/inch^3

NCP13994MM360WGEVB

AOI DEMO−BOARD SCHEMATIC (PFC)

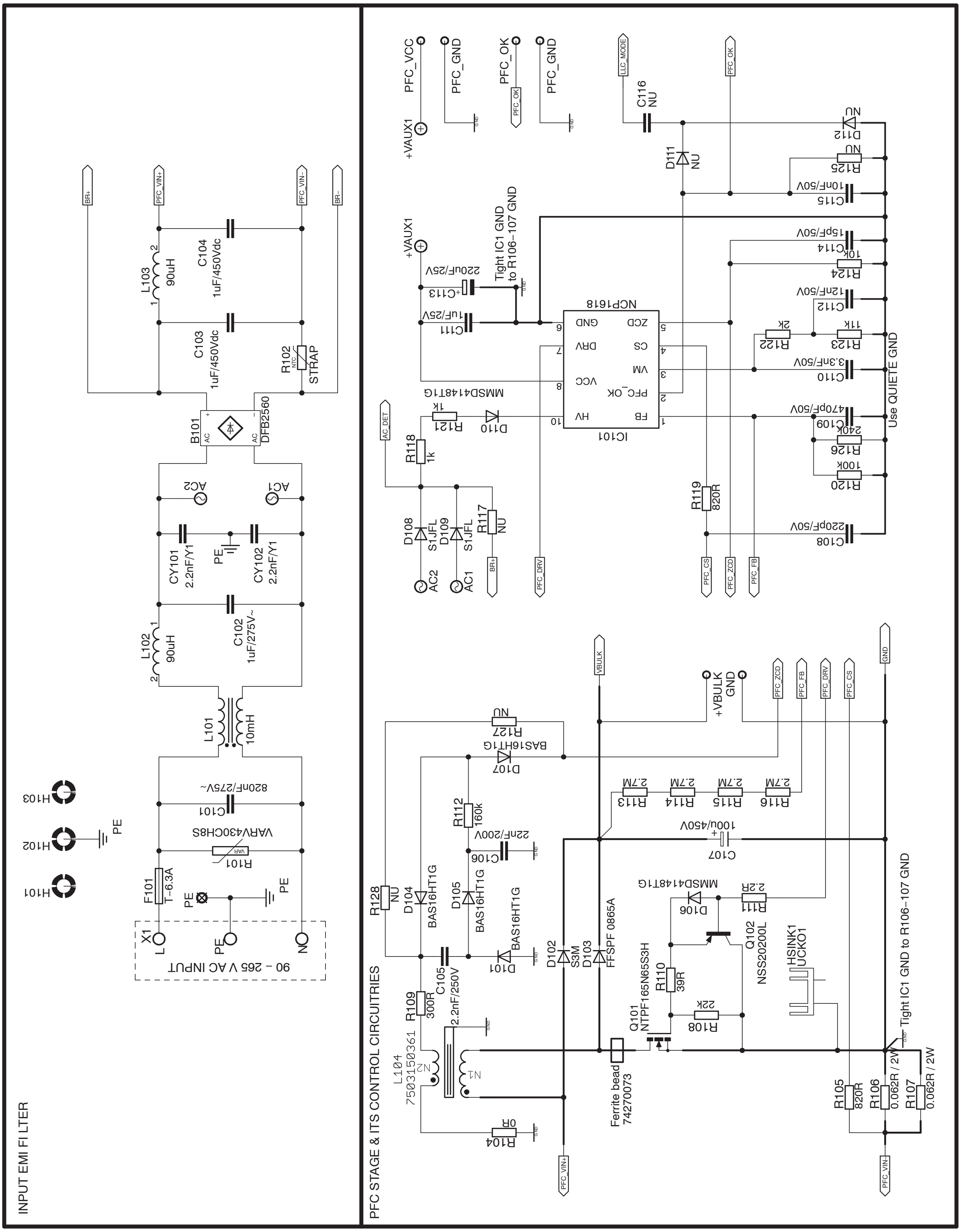

Figure 1. AOI Demo−Board Schematic − PFC Front Stage

NCP13994MM360WGEVB

AOI DEMO−BOARD SCHEMATIC (LLC)

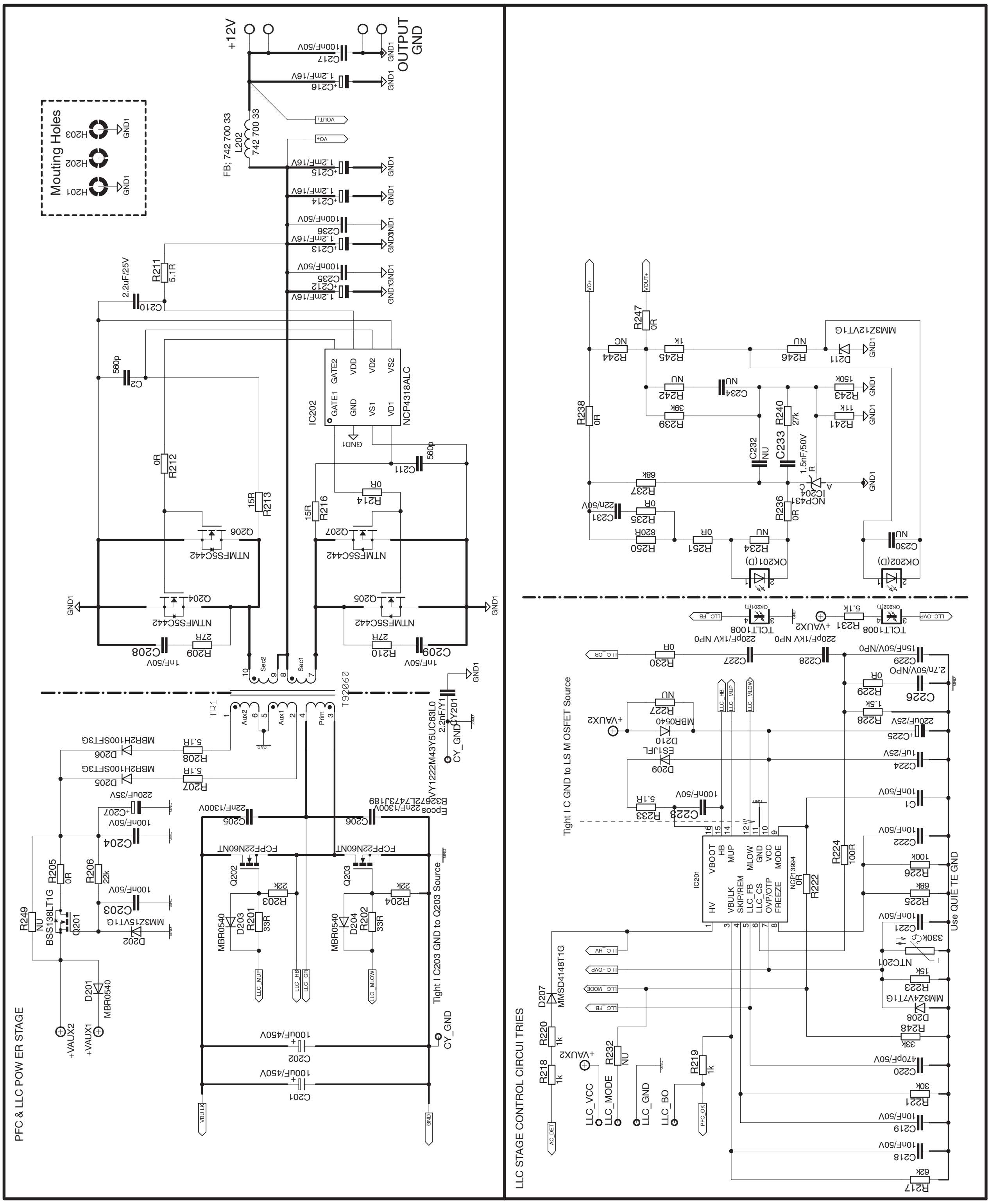

Figure 2. AOI Demo−Board Schematic − LLC Stage

Detailed Descriptions of the Evaluation Board

Input side of evaluation board is protected by a several components. As first, it's a 6.3 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 1). 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 1). 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 and 127 set maximum current. Capacitor C108 that is connected between mentioned resistors filters noise caused by switching. The resistor R127 must be placed as closed as possible to the controller pin. 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 resistors R120, R126 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, NCP13994 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. The PFC−OK is directly pulled−down by IC203 via resistor R219. Once, IC201 NCP13994 enters to skip, VBULK pin (3) generates low level impulse and pulls down PFC−OK for 100 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 NCP13994 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, D01, D104, D105 and D107. Processed signal is fed into ZCD pin, which detects valleys zero−current and OVP2 events. The VM pin provides a voltage 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. Resistors R122 and R123 set maximum power in CCM mode, where capacitors C110 and C112 filter noise coupled to this pin.

Entire LLC power stage is displayed on Figure 2. Power stage at primary side of LLC converter is composed of these devices: MOSFETs Q202, Q203, external resonant inductor L201, transformer TR1 and resonant capacitors C205, C206. The IC203 (NCP13994), LLC resonant 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 VBULK pin allows LLC converter operation once input level is approximately above 1.1 V. VBULK signal is provided by PFC controller NCP1618, which sources current from PFC−OK pin as aforementioned. VBULK pin voltage is filtered by C218. The Skip/REM pin of the NCP13994 is used for skip_in 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) at light−load mode operation, which influences skip burst behavior. Resistors R225, R226 set FB freeze level and C222 decouples noise. The PFC_MODE pin (9) is configurate for skip_out threshold adjustment with resistor R222, R248 and filtering capacitor C1.

The VCC decoupling capacitor C224 and also bootstrap 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 R233 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 IC202 NCP4318 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. This resistor with decoupling capacitor C210 form RC filter. 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 R250 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 SMT components are place from the bottom side. The board requests forced air flow cooling management, especially when the board operates at full load condition for longer time or the board is packed into some box or target application.

EVALUATION BOARD

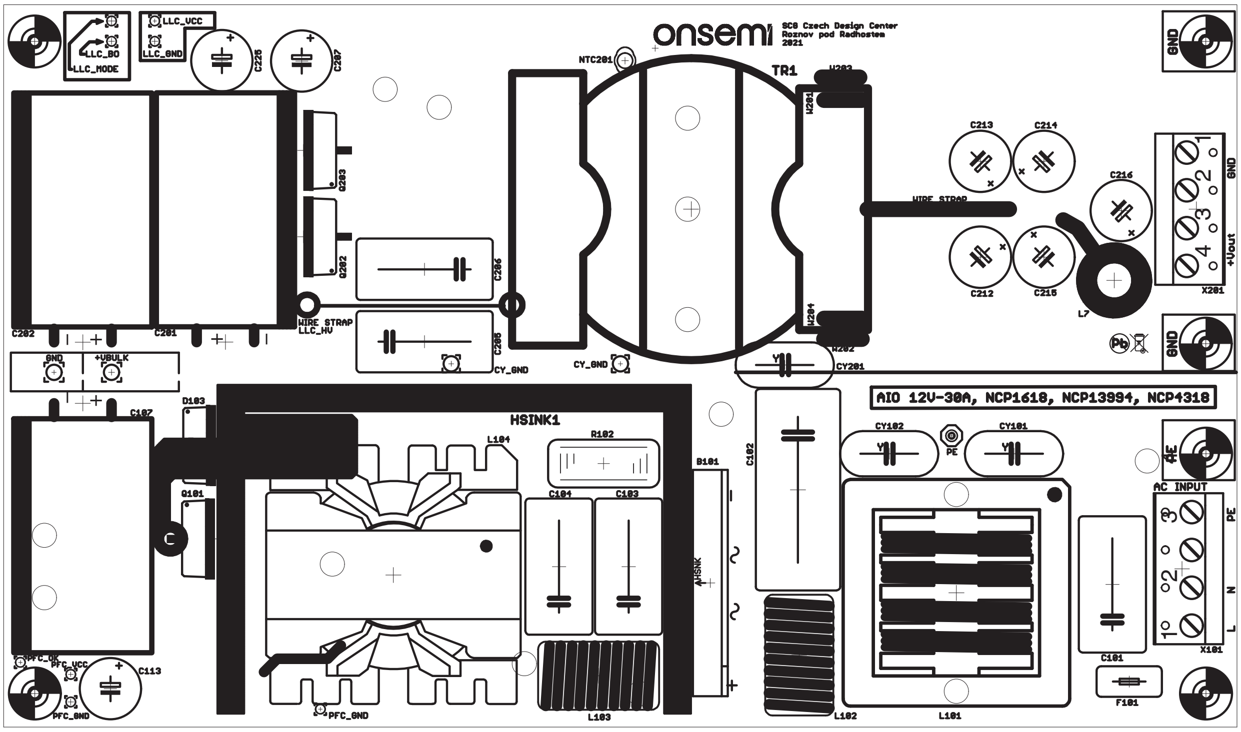

Figure 3. Evaluation Board − Top Side Components

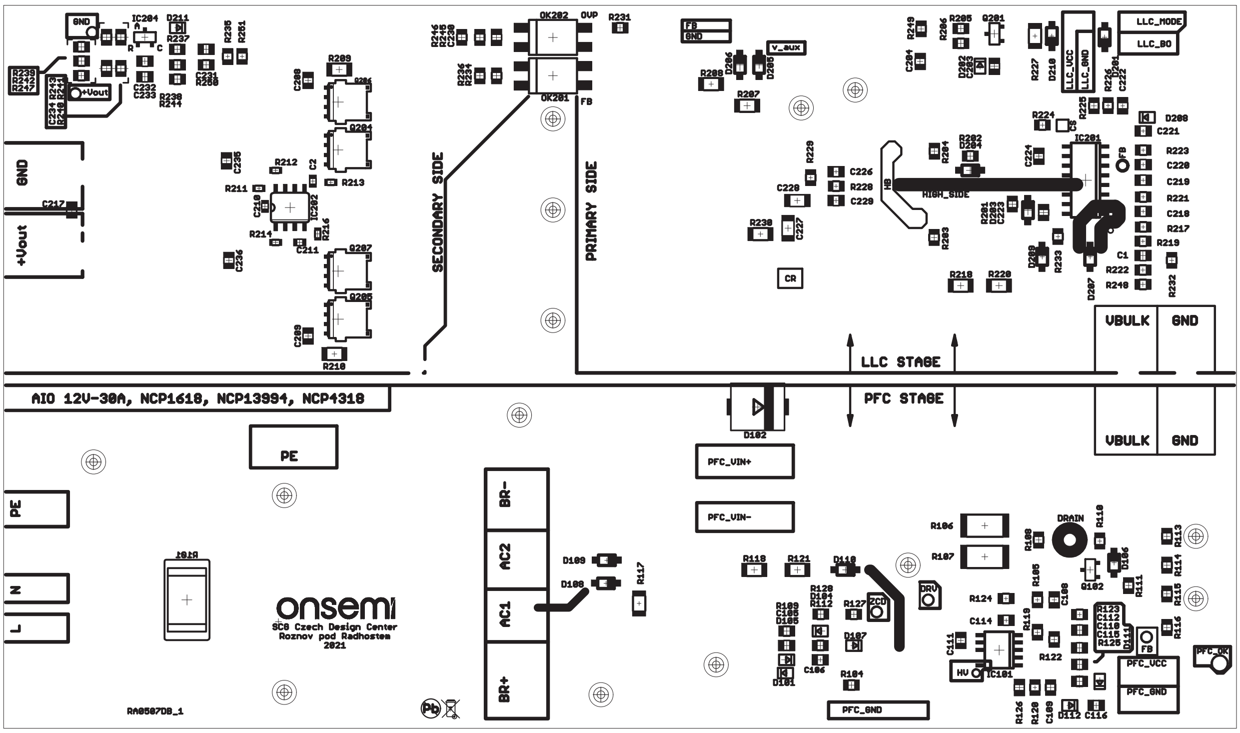

Figure 4. Evaluation Board − Bottom Side Components

PCB

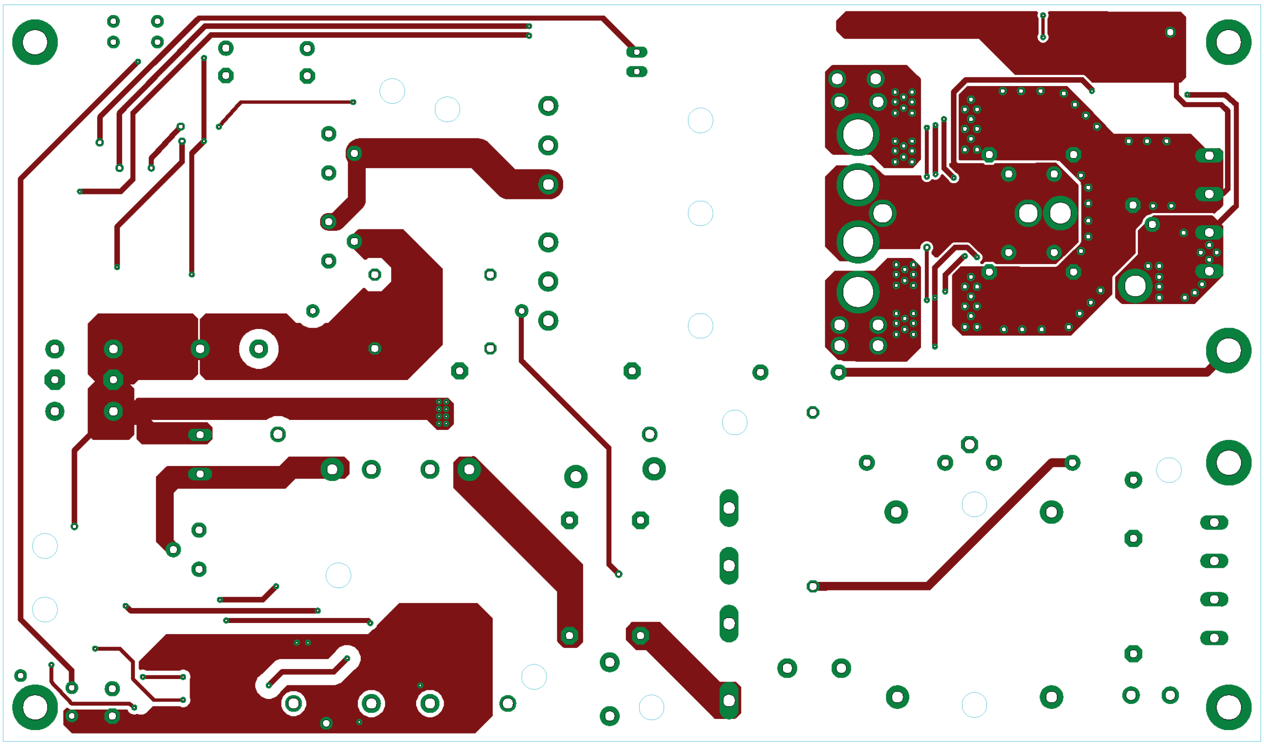

Figure 5. Evaluation Board – PCB Design of Top Layer

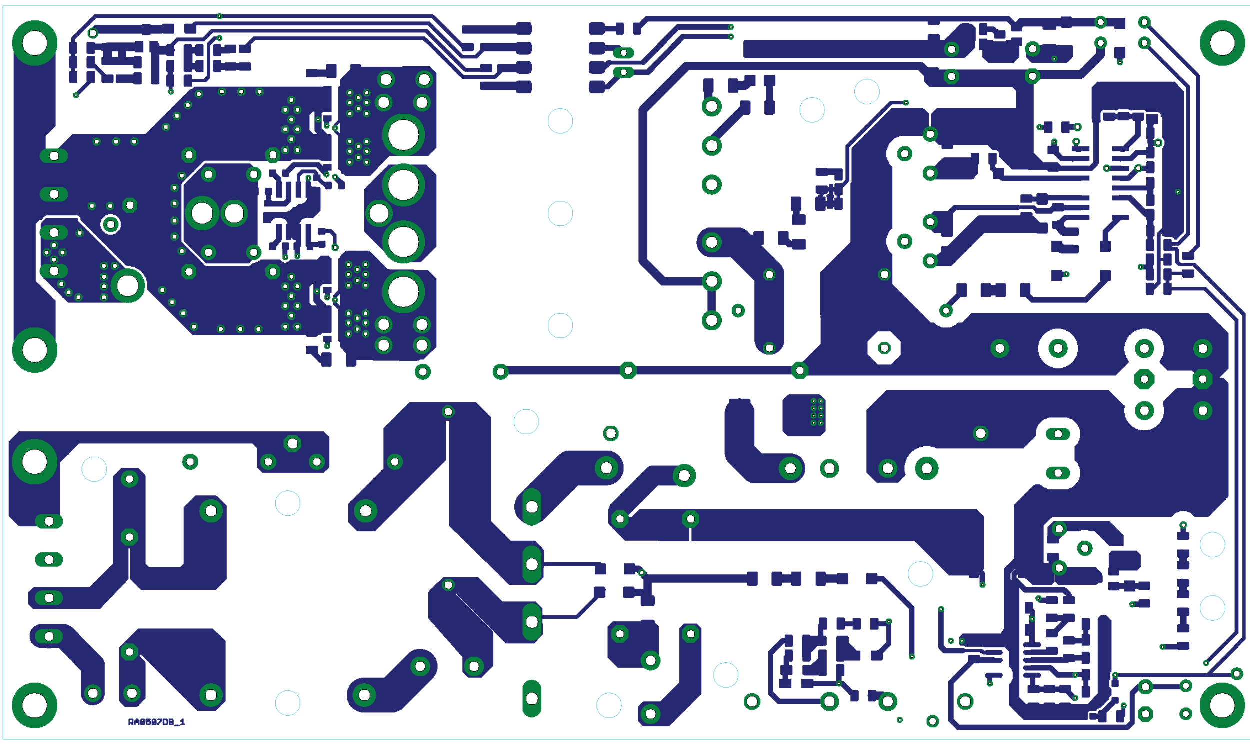

Figure 6. Evaluation Board – PCB Design of Bottom Layer

EVALUATION BOARD PHOTOGRAPH

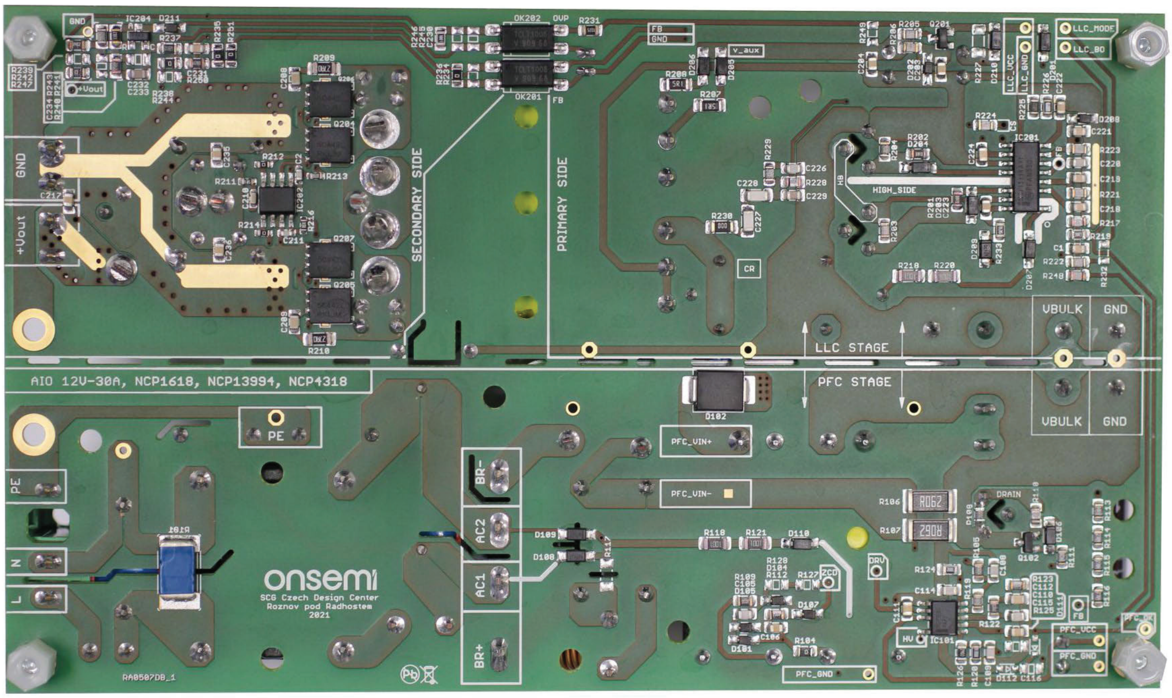

Figure 7. Evaluation Board Photograph− Bottom Side

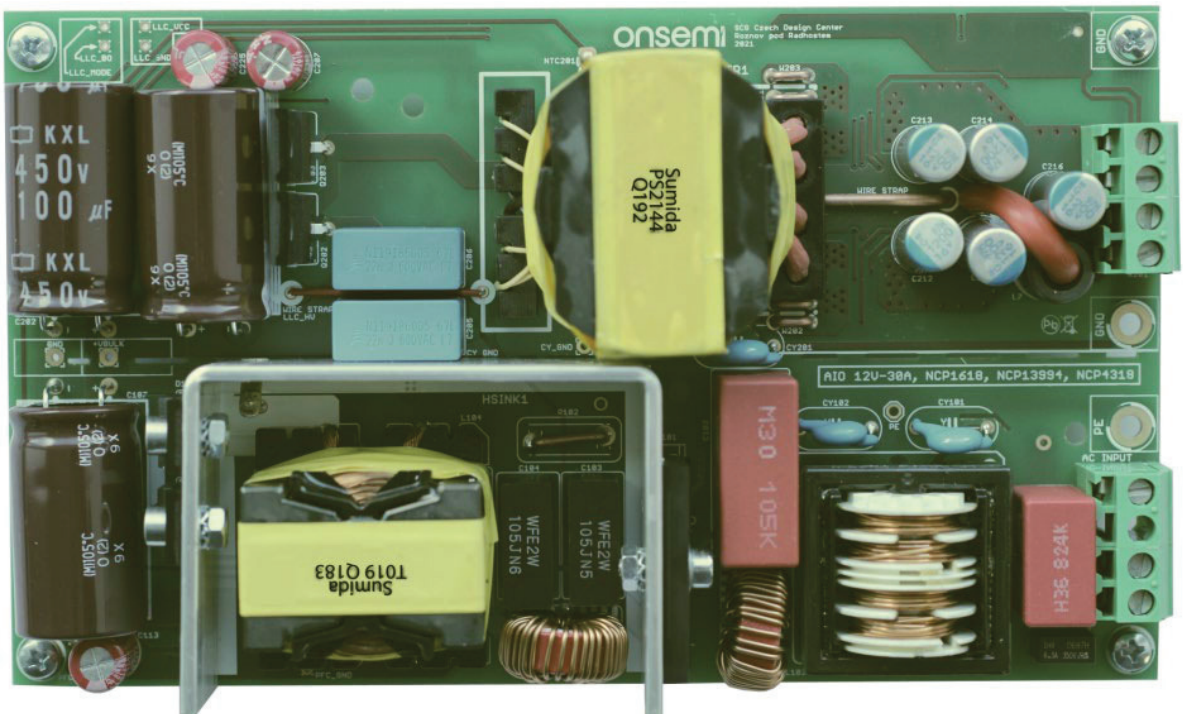

Figure 8. Evaluation Board Photograph− Top Side

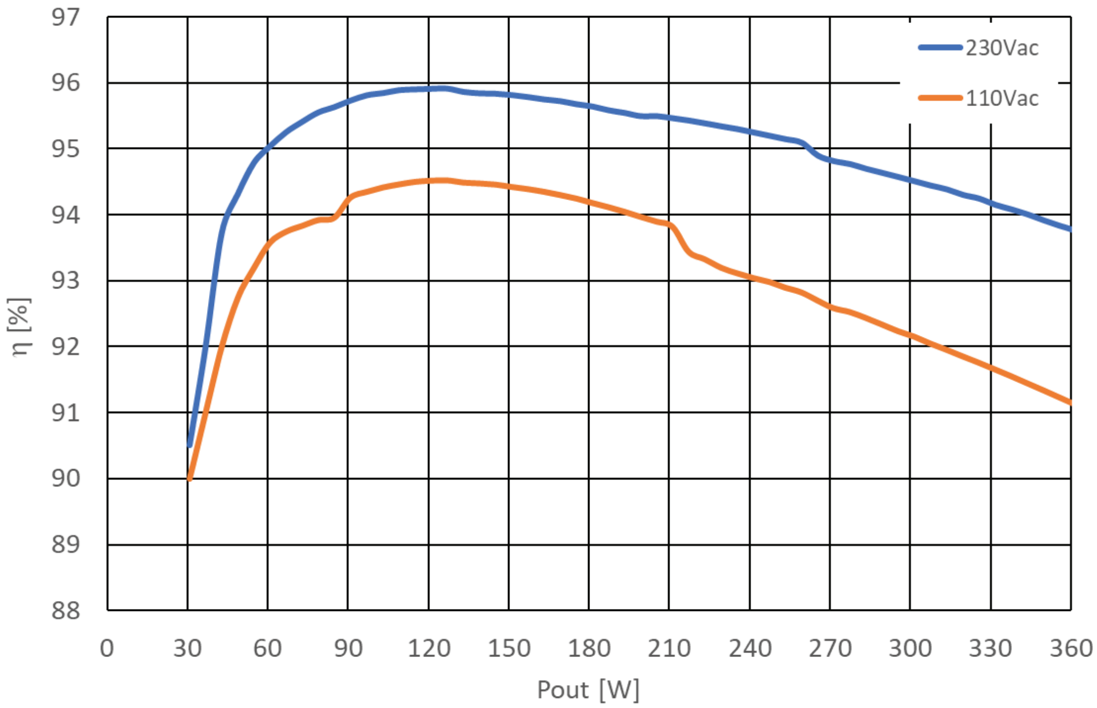

Figure 9. Efficiency vs. Output Power

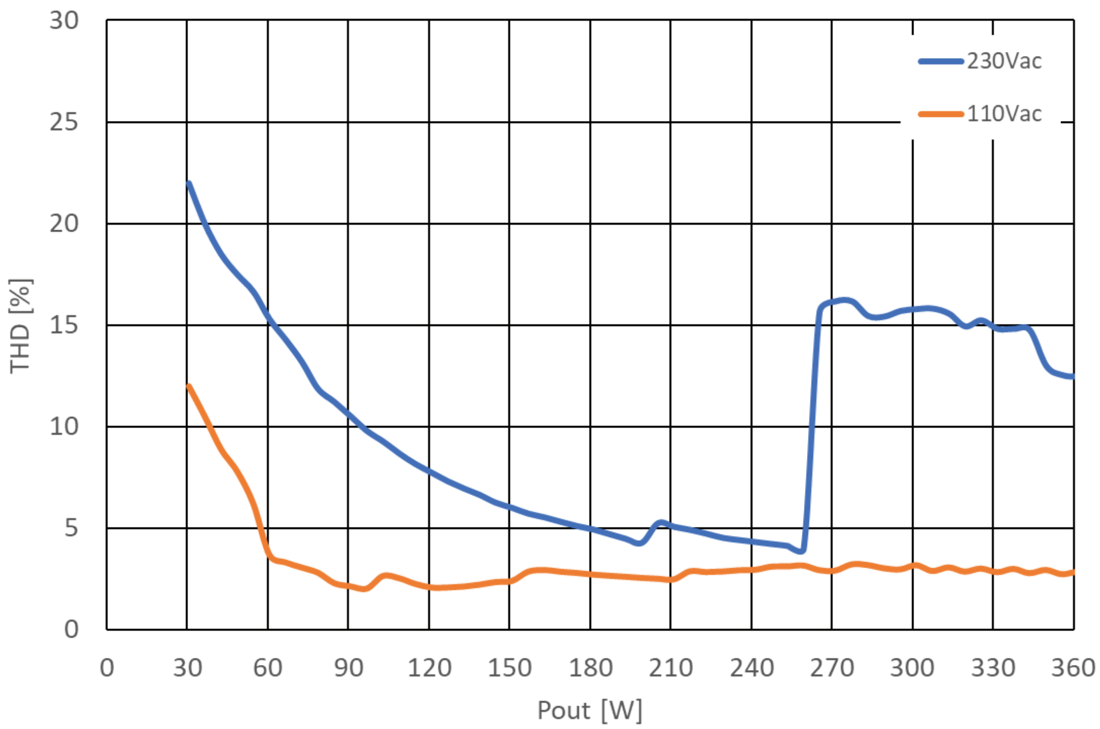

Figure 10. Input Current THD vs. Output Power

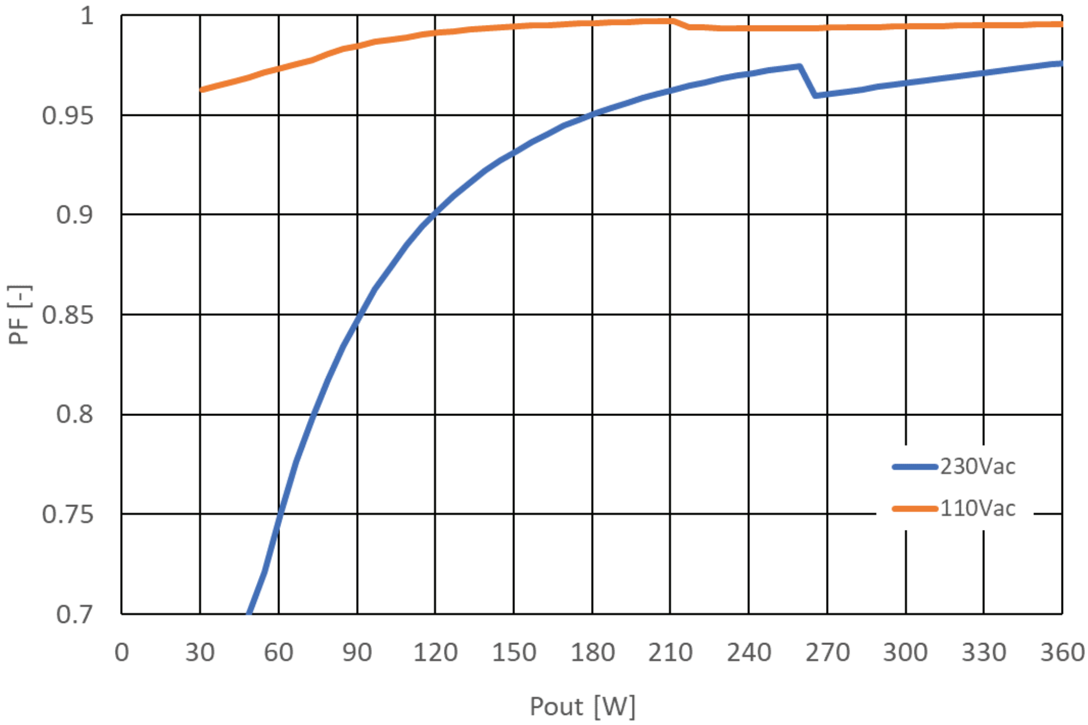

Figure 11. Power Factor vs. Output Power

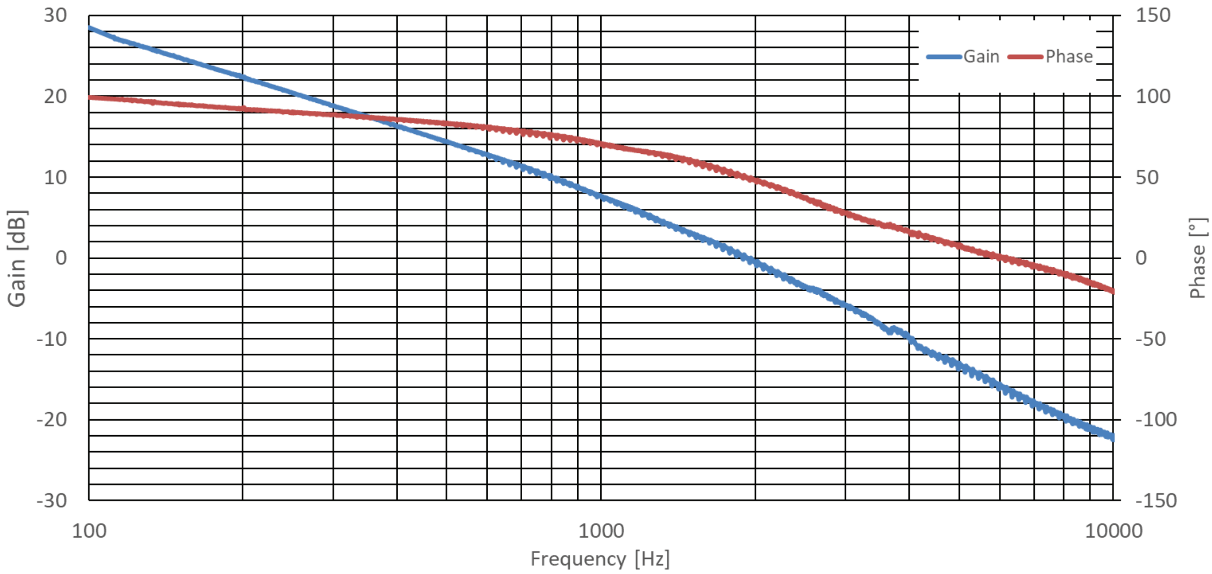

Figure 12. Small Signal Close Loop Response – Iload = 30 A

Table 2. EFFICIENCY DATA MEASURED AVERAGED FROM 10 BUILT DEMO_BOARDS

LOAD	Consumption [mW] or Efficiency [%]	
	@ 110 V AC	**@ 230 V AC**
NO−LOAD	< 80	< 100
Load 120 mW Load 250 mW Load 500 mW	< 250 < 415 < 710	< 270 < 430 < 720
Load 25% − 7.5 A Load 50% − 15 A Load 75% − 22.5 A Load 100% − 30 A	94.26 94.18 92.59 91.13	95.73 95.64 94.81 93.83
4 point AVG	93.04	95.00

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

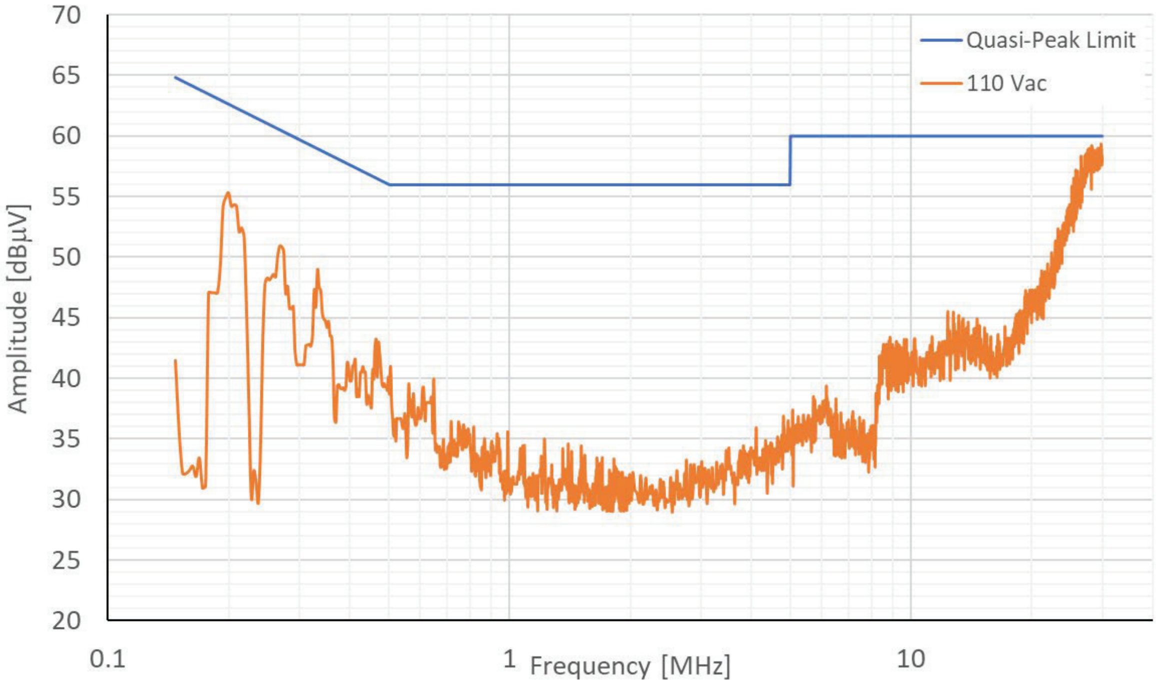

Figure 13. EMI Signature Comparison @ 110 Vac & Full−Load (measured MAX Peak)

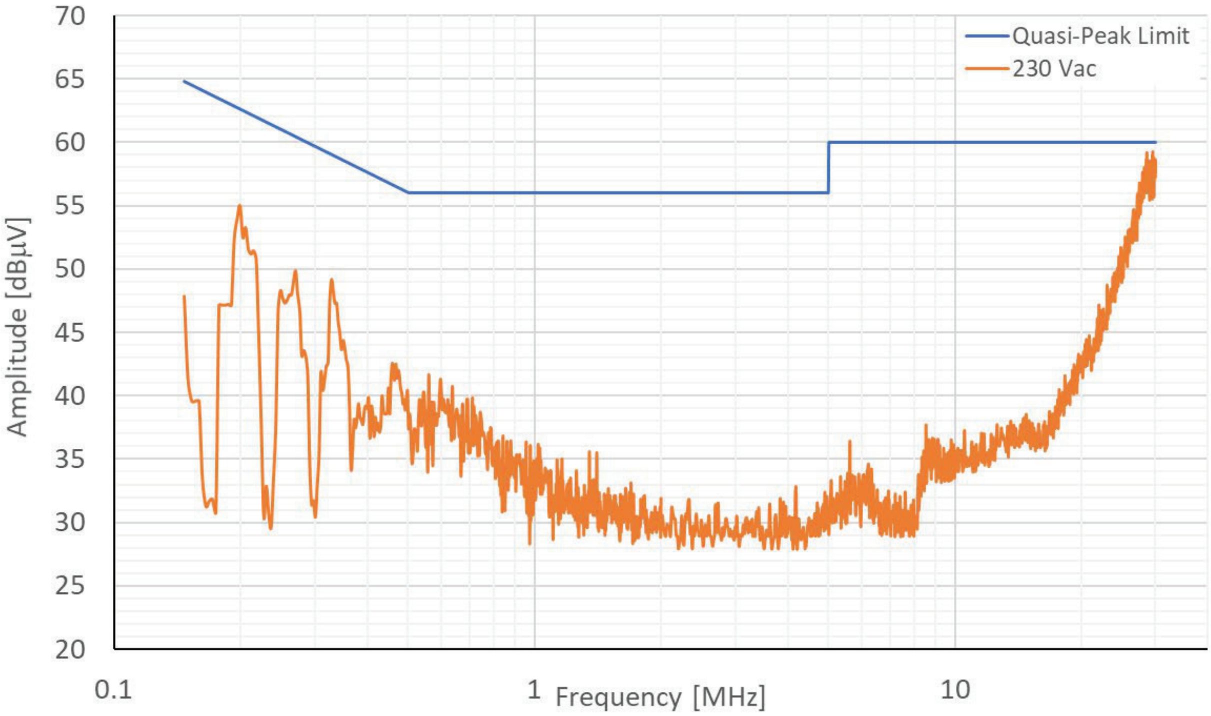

Figure 14. Power Factor vs. Output Power

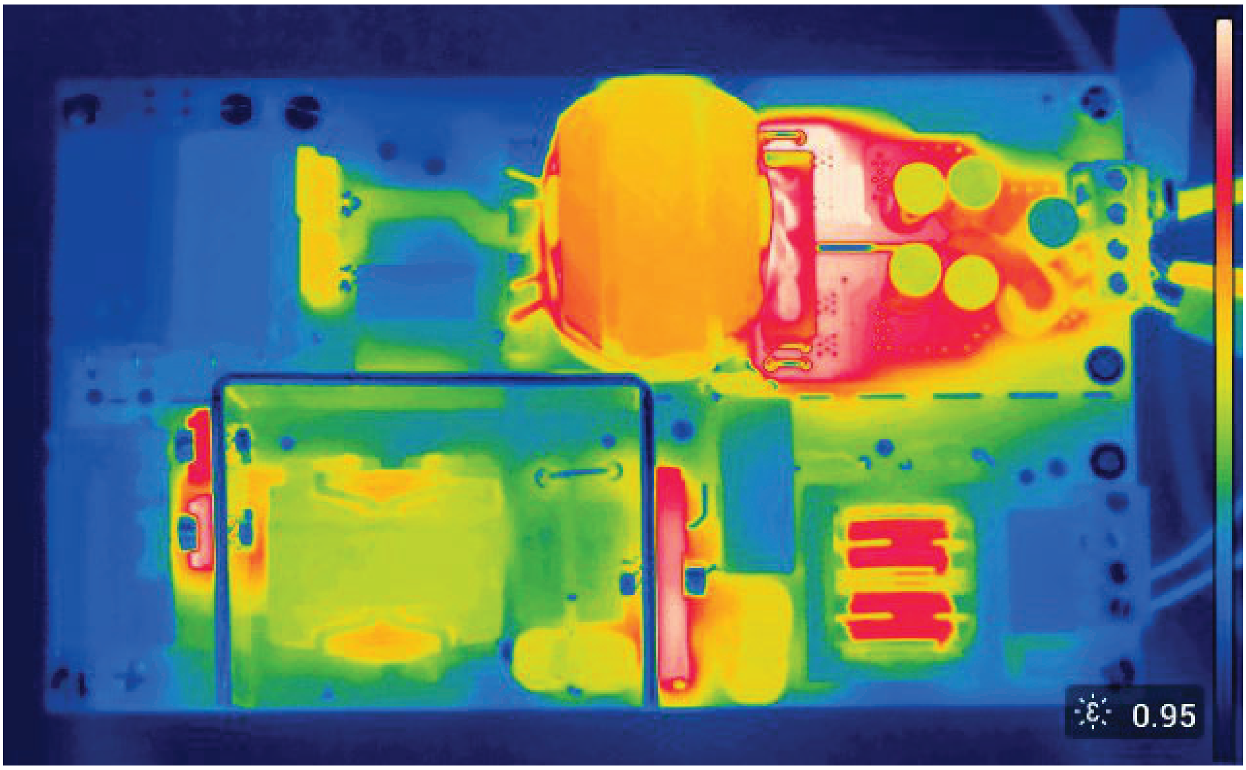

Figure 15. Thermal Radiation @ 110 Vac / Load 30 A

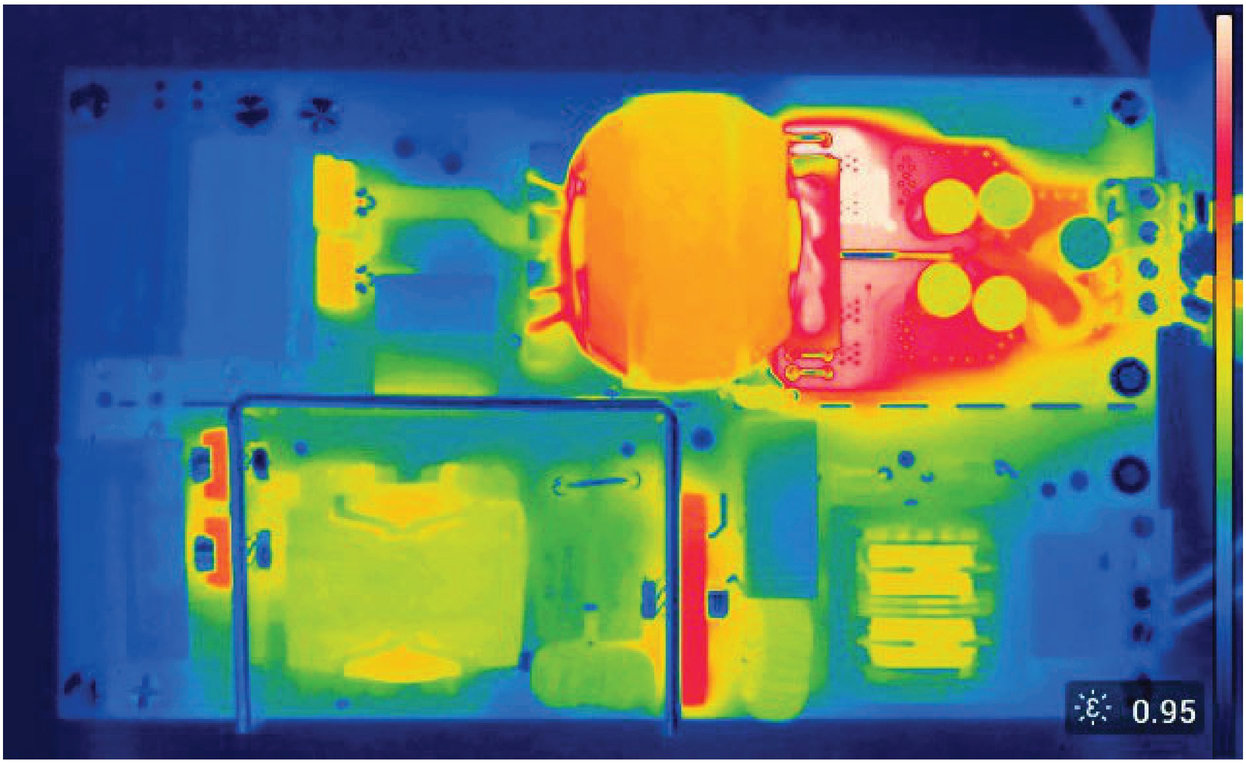

Figure 16. Thermal Radiation @ 230 Vac / Load 30 A

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. 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 265 V 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

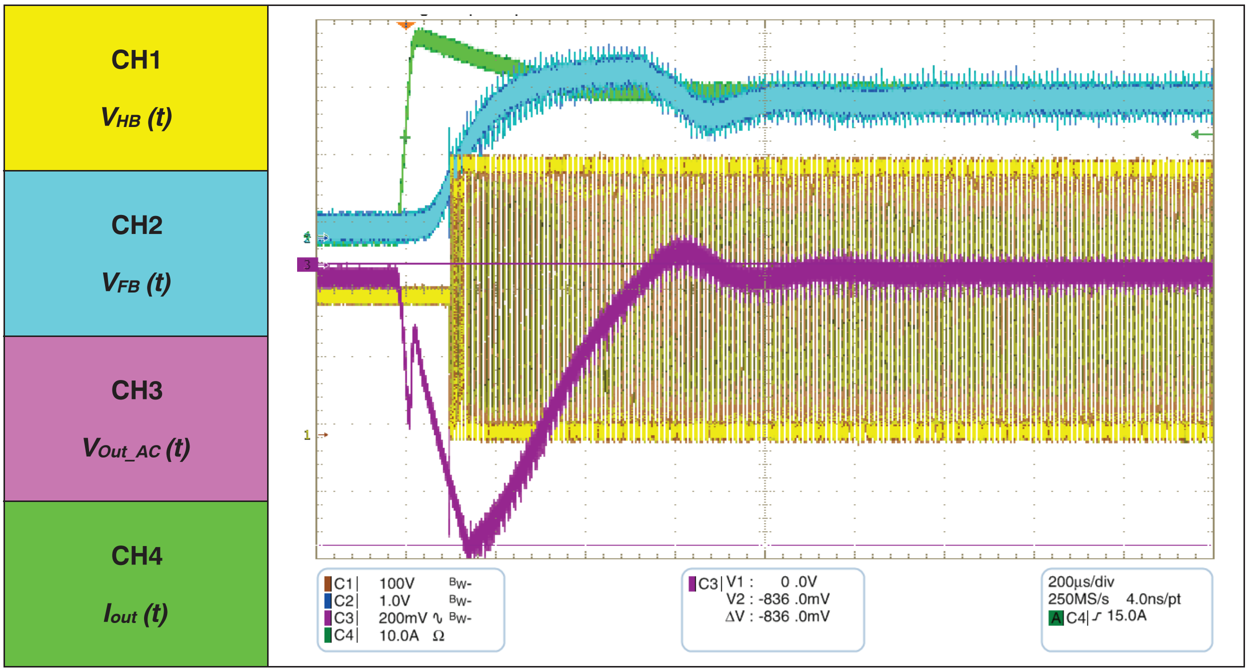

Figure 17. Step Load 0 A – 30 A

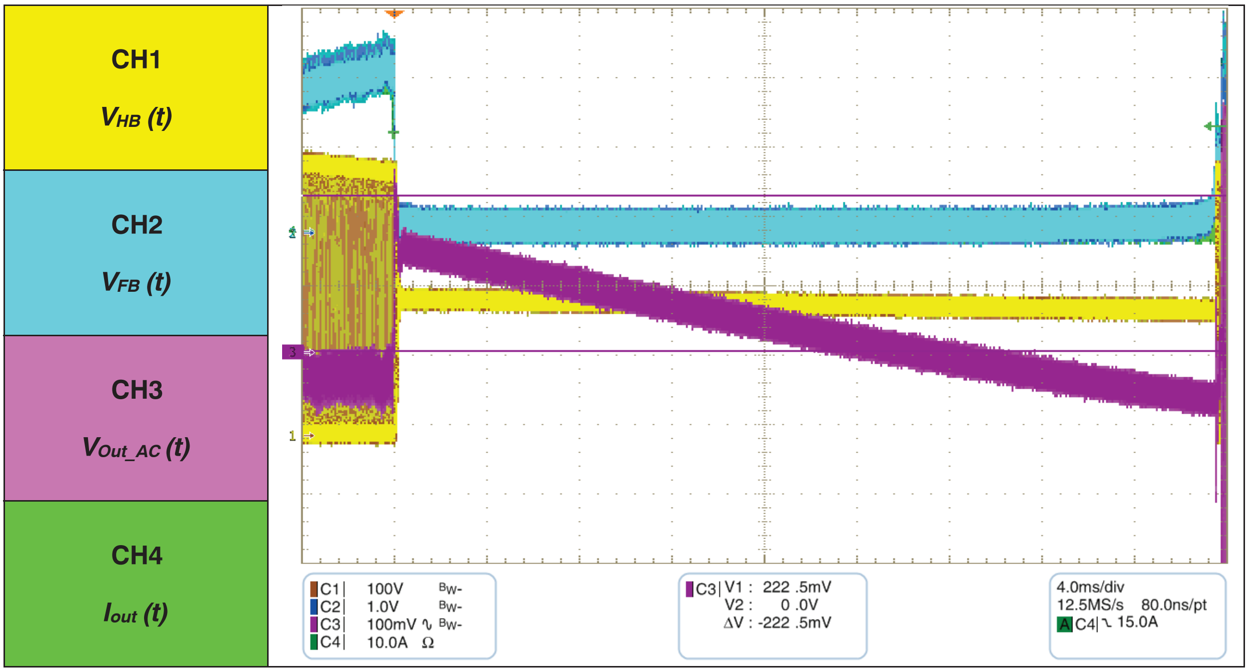

Figure 18. Step Load 30 A – 0 A

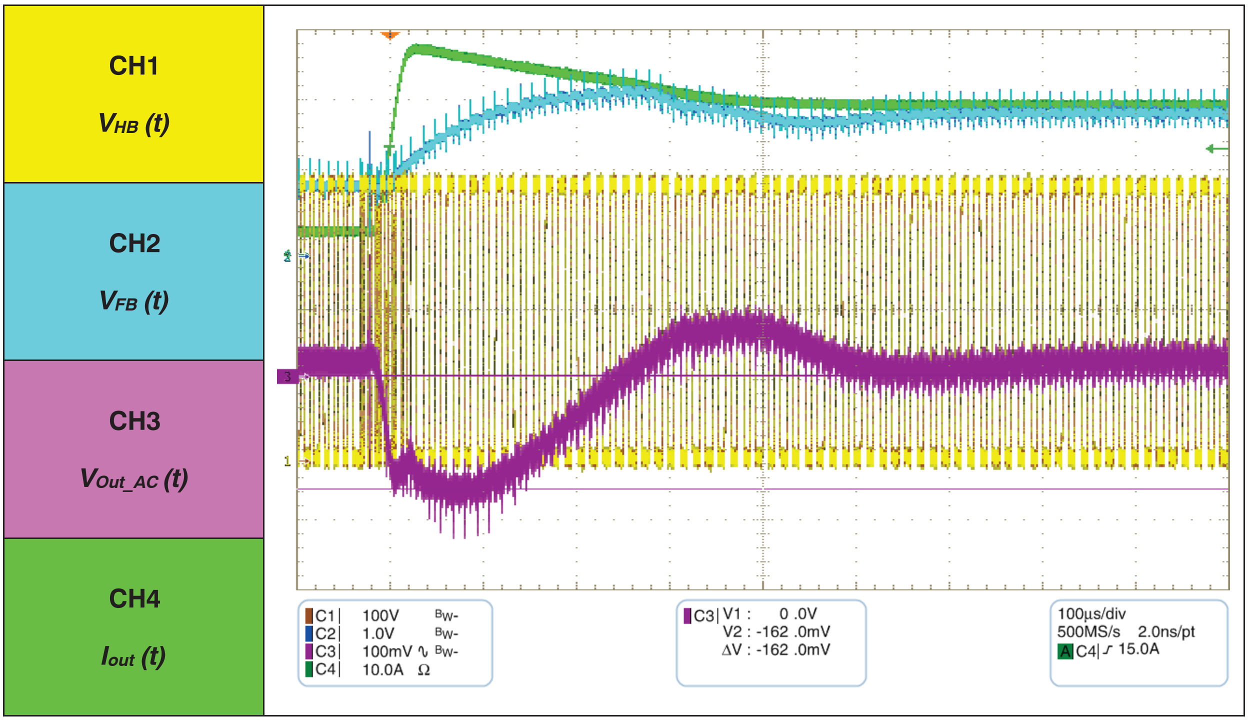

Figure 19. Step Load 3 A – 30 A

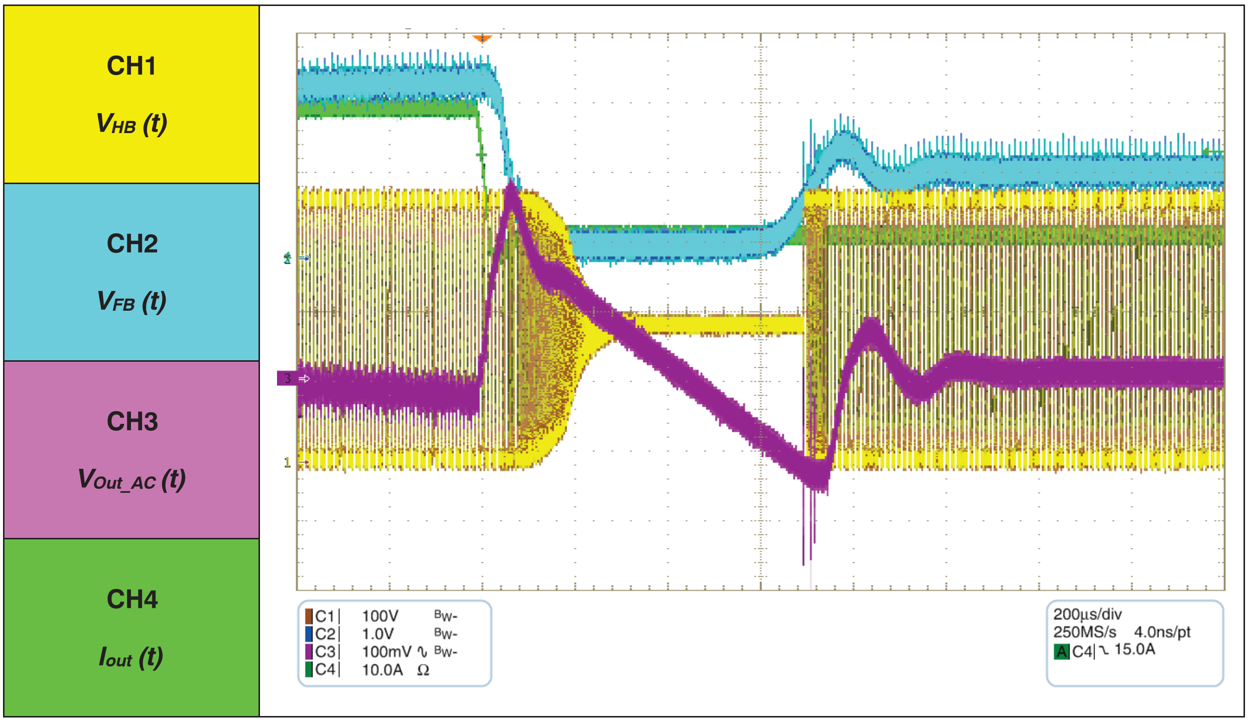

Figure 20. Step Load 30 A – 3 A

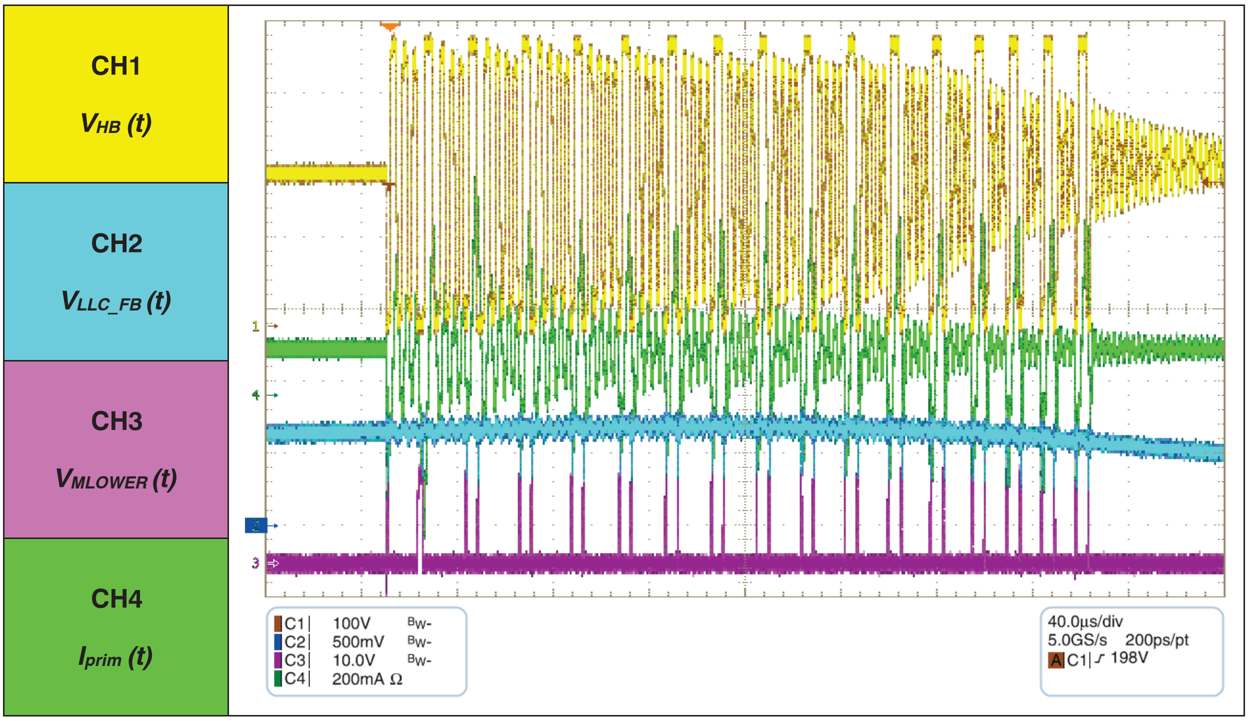

Figure 21. LLC SKIP MODE, No−Load

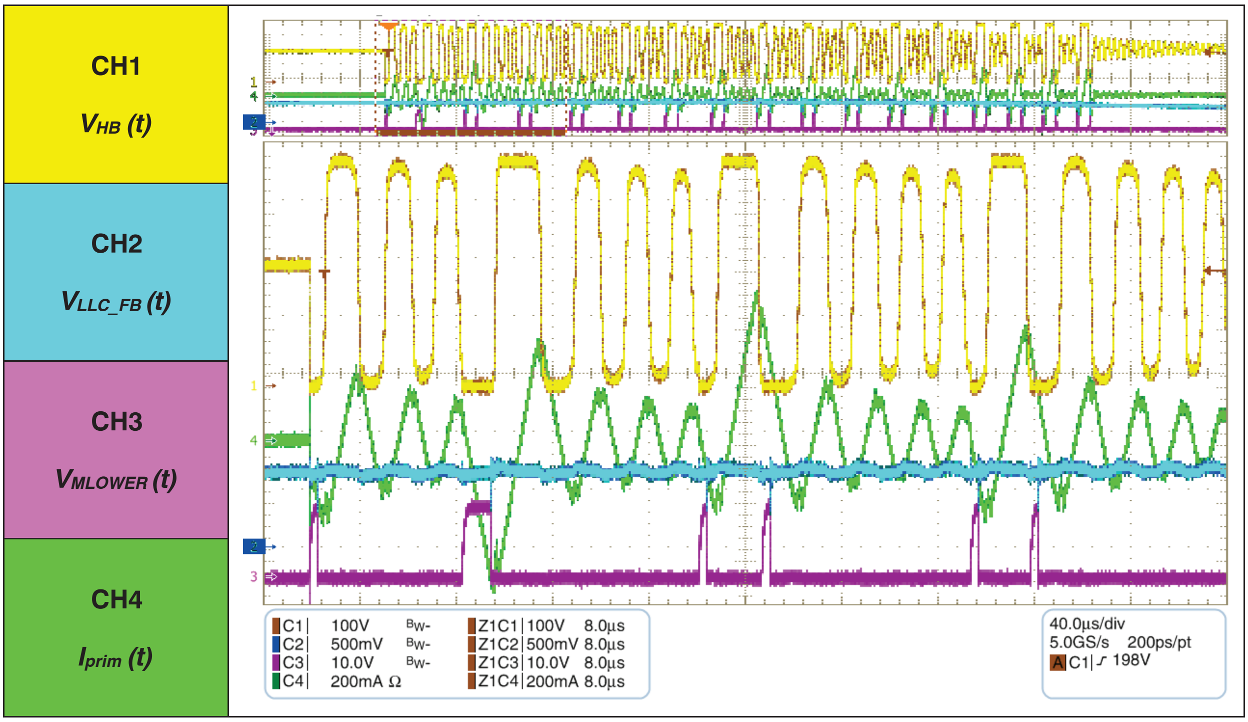

Figure 22. LLC SKIP MODE, No−Load − Detailed View

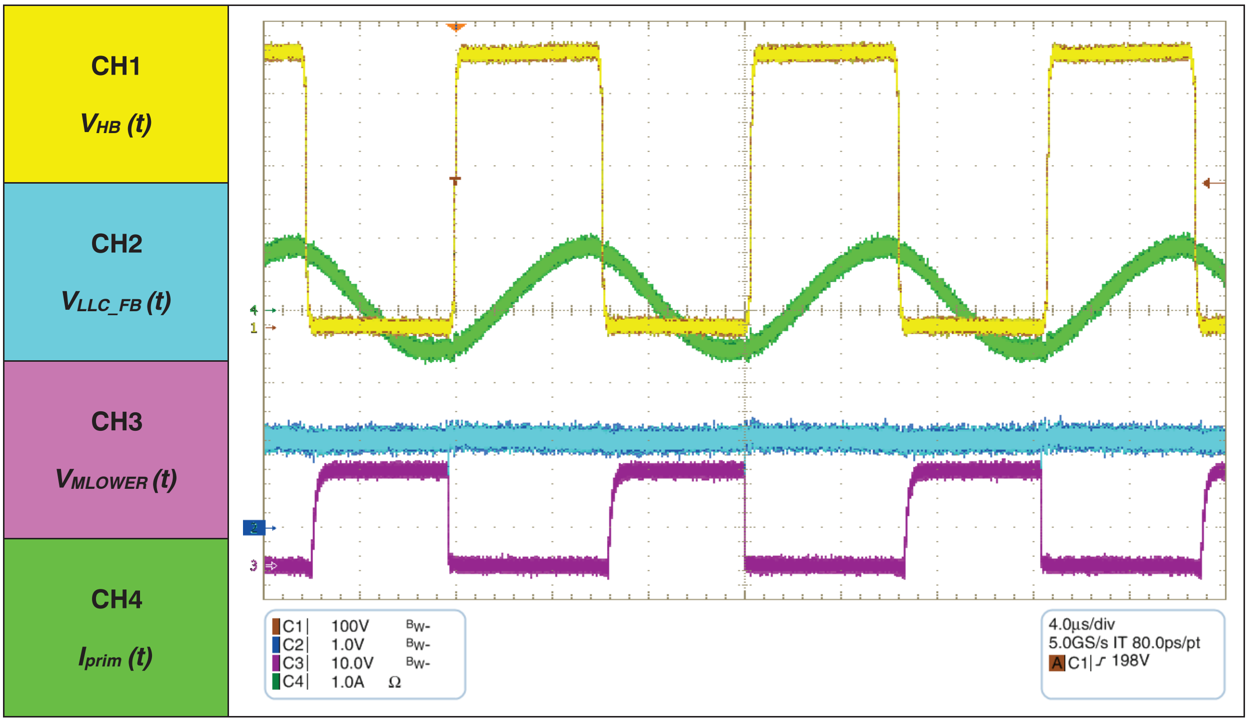

Figure 23. LLC NORMAL MODE, LOAD 3 A

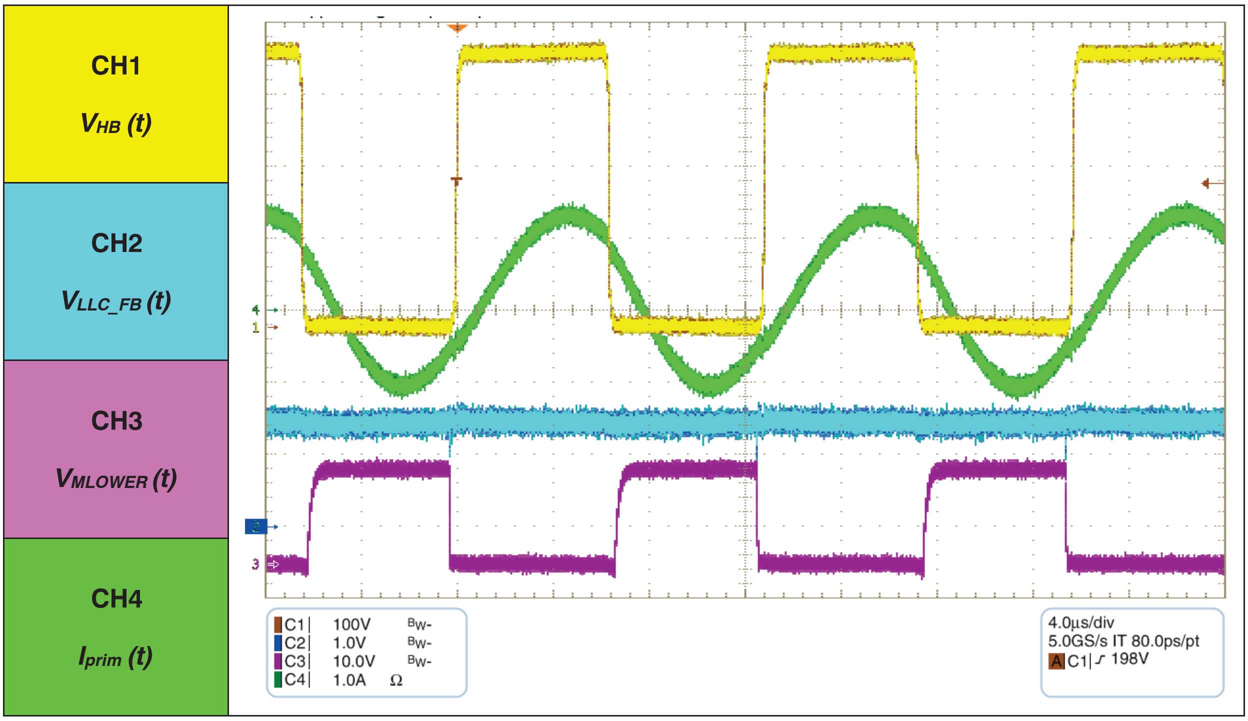

Figure 24. LLC NORMAL MODE, LOAD 10 A

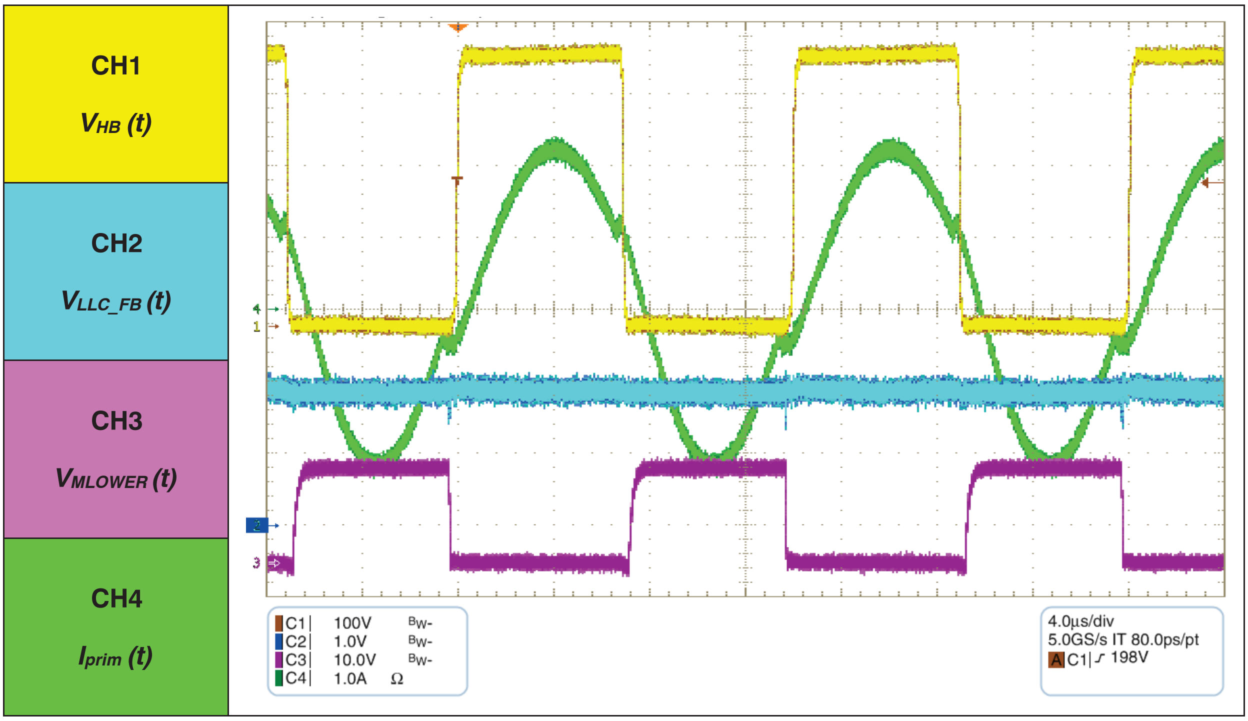

Figure 25. LLC NORMAL MODE 20 A

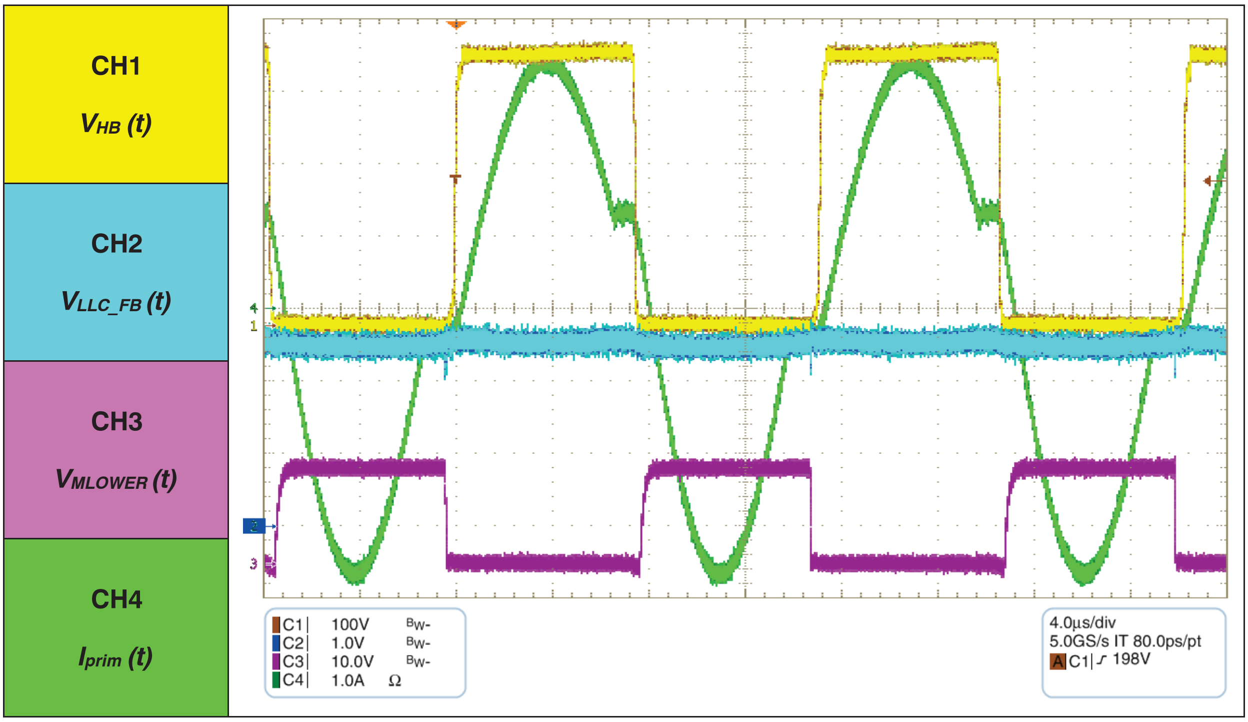

Figure 26. LLC NORMAL MODE, LOAD 30 A

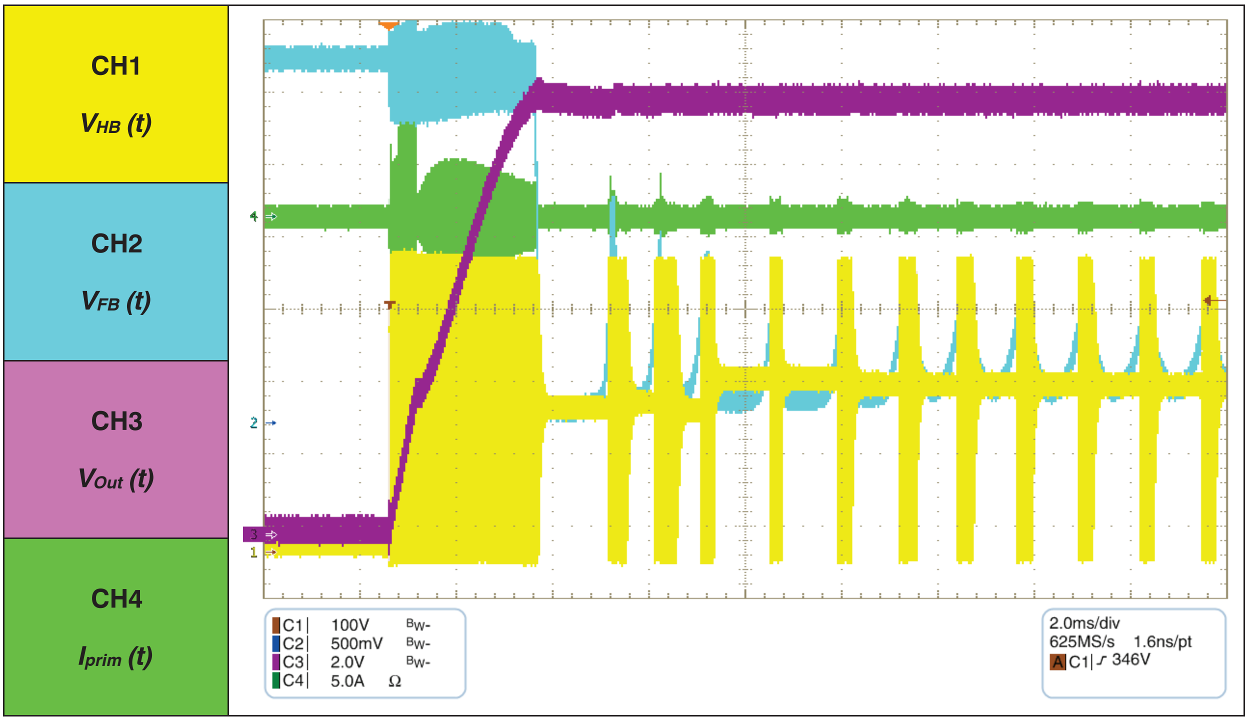

Figure 27. LLC START−UP into 0 A

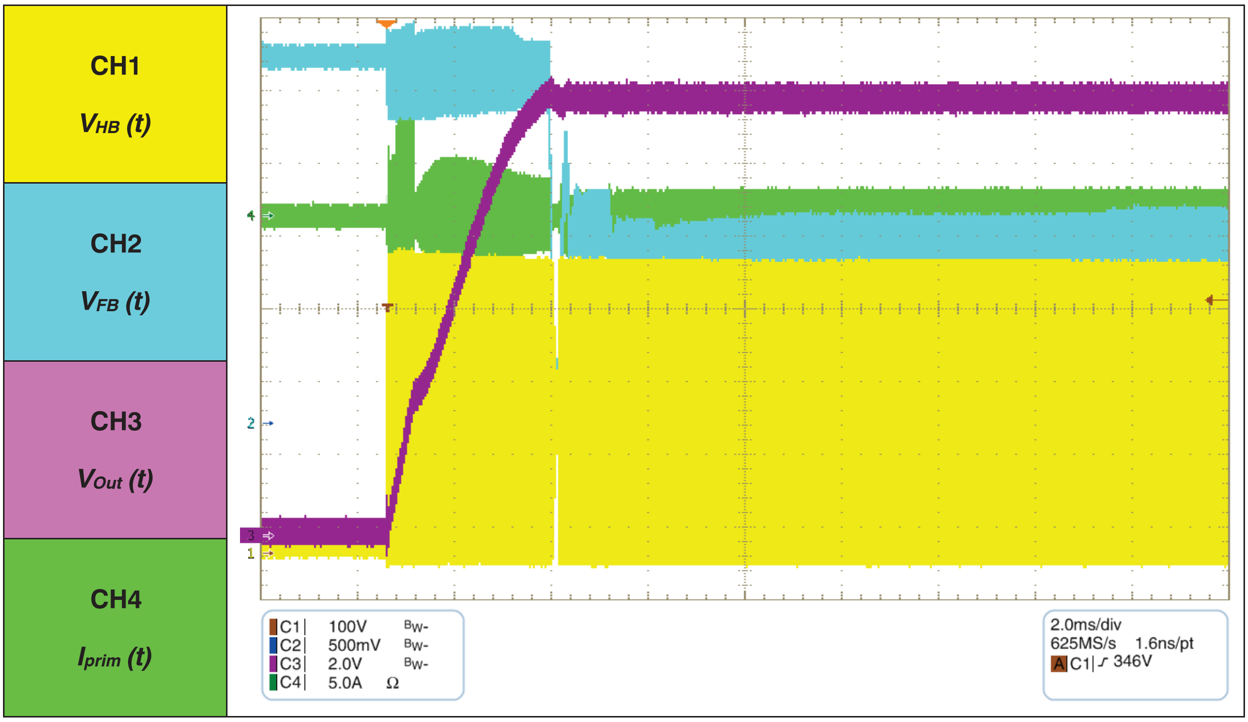

Figure 28. LLC START−UP into 10 A

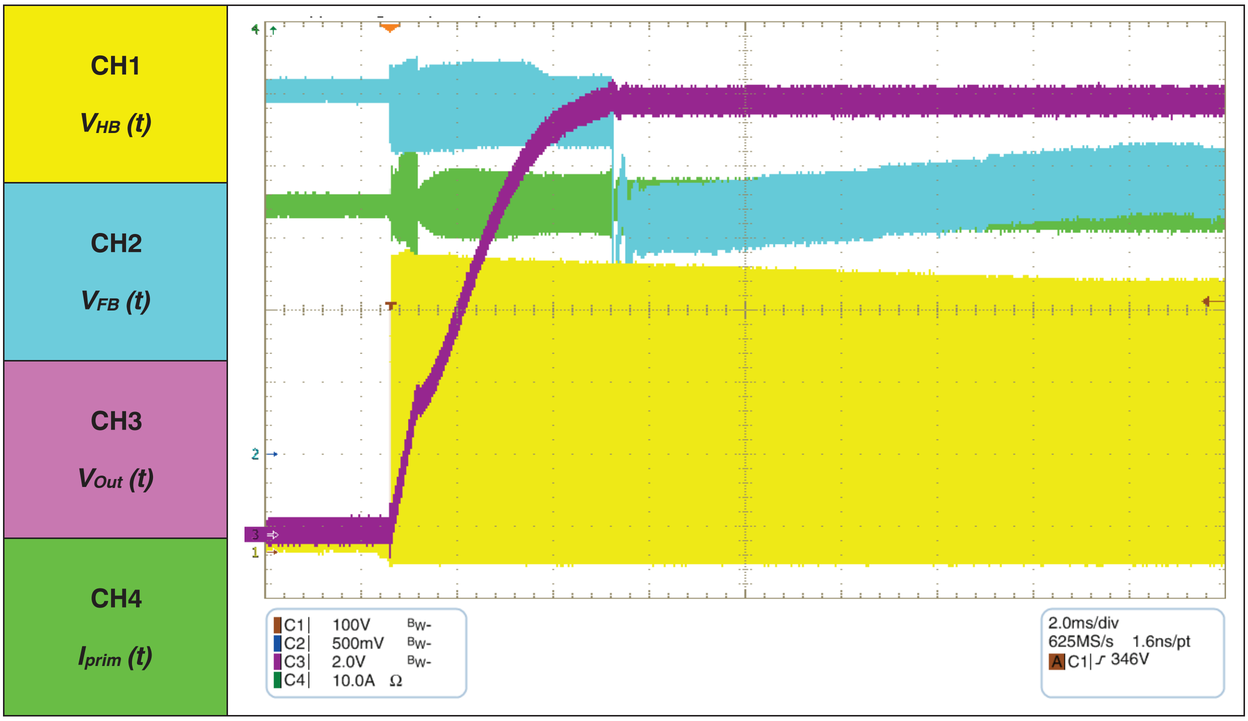

Figure 29. LLC START−UP into 20 A

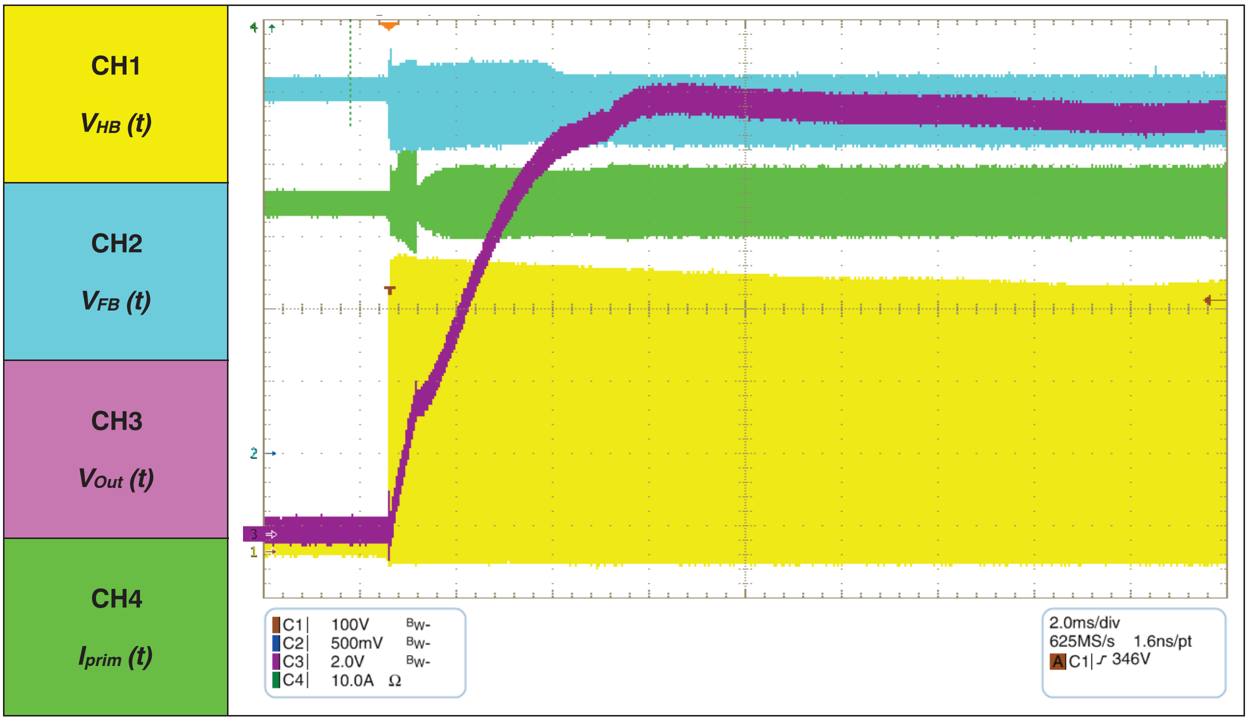

Figure 30. LLC START−UP into 30 A

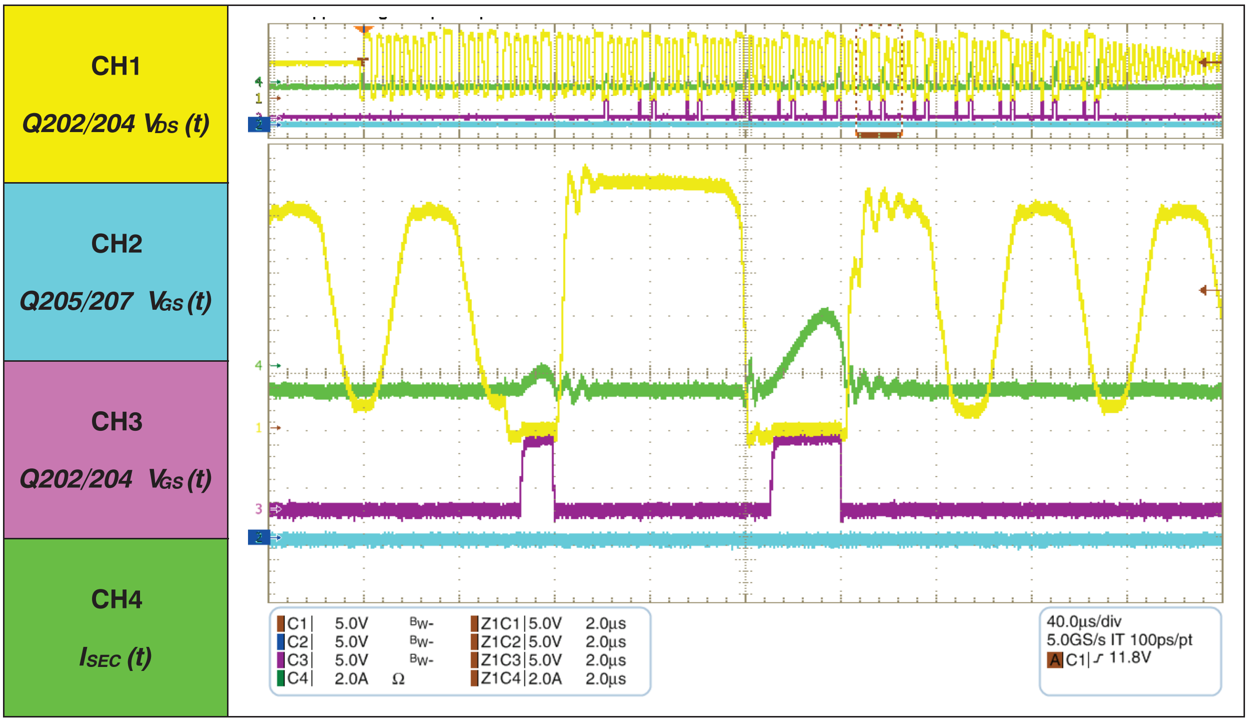

Figure 31. Secondary Side SR Operation – 0 A

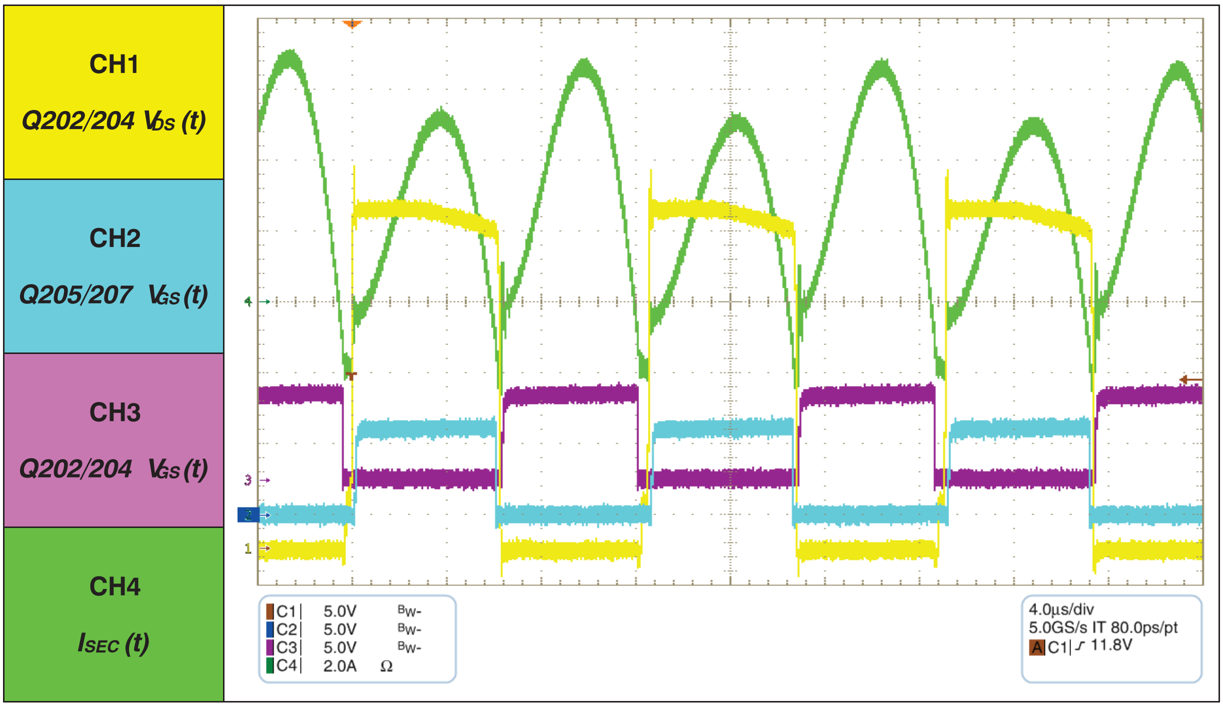

Figure 32. Secondary Side SR Operation – 5 A

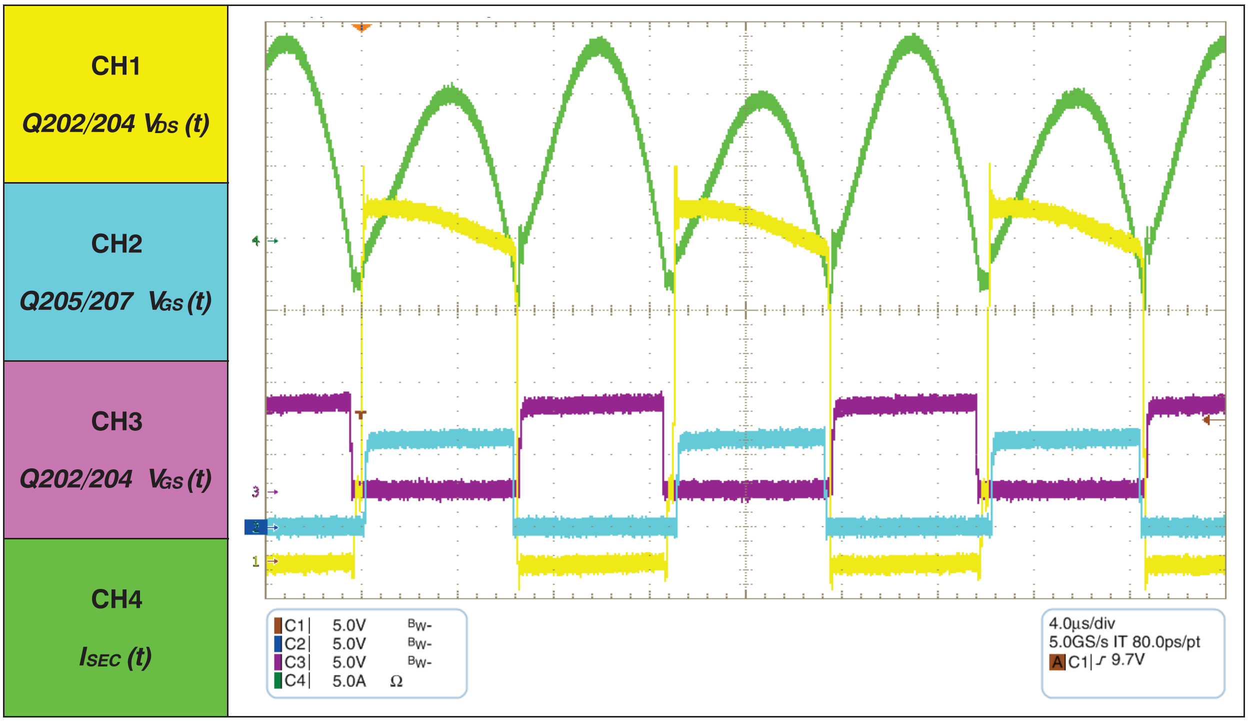

Figure 33. Secondary Side SR Operation – 10 A

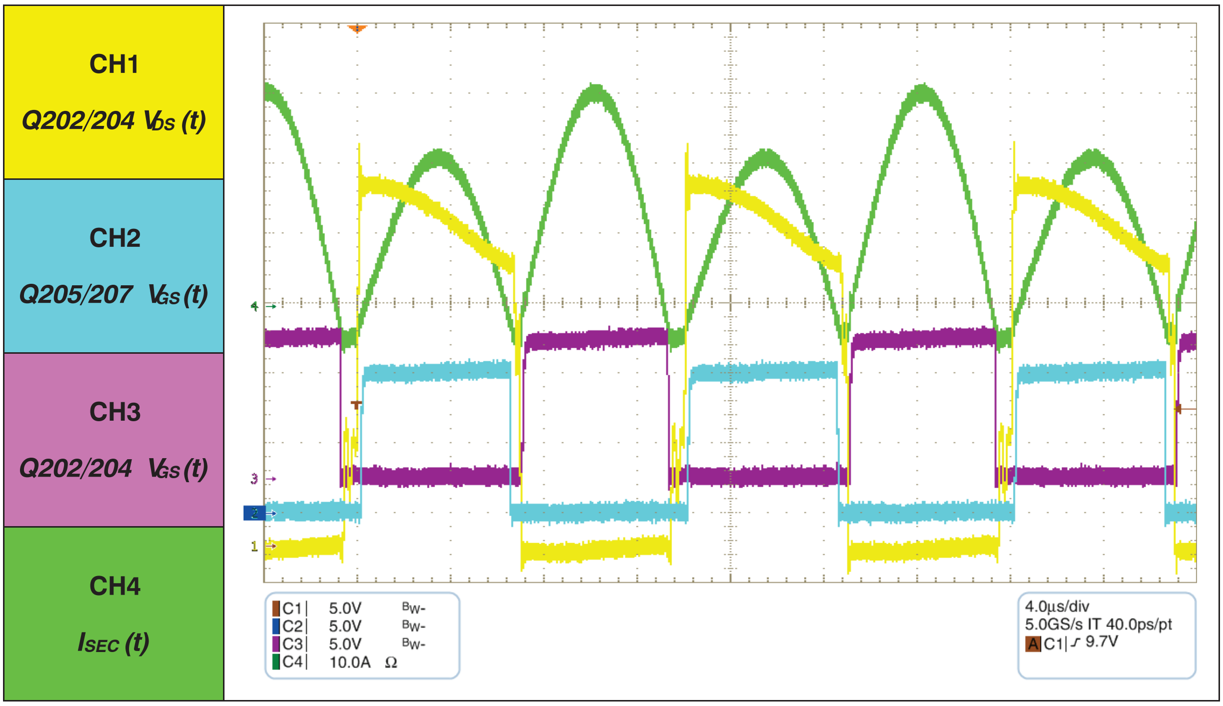

Figure 34. Secondary Side SR Operation – 20 A

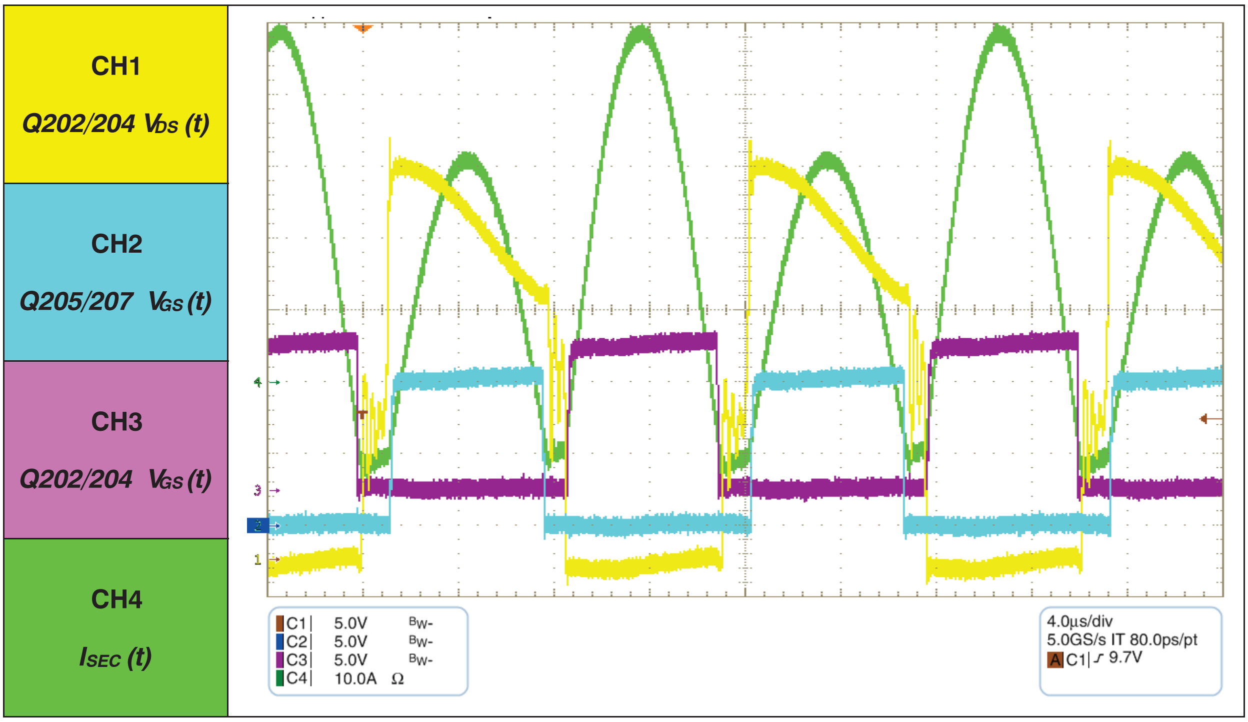

Figure 35. Secondary Side SR Operation – 30 A

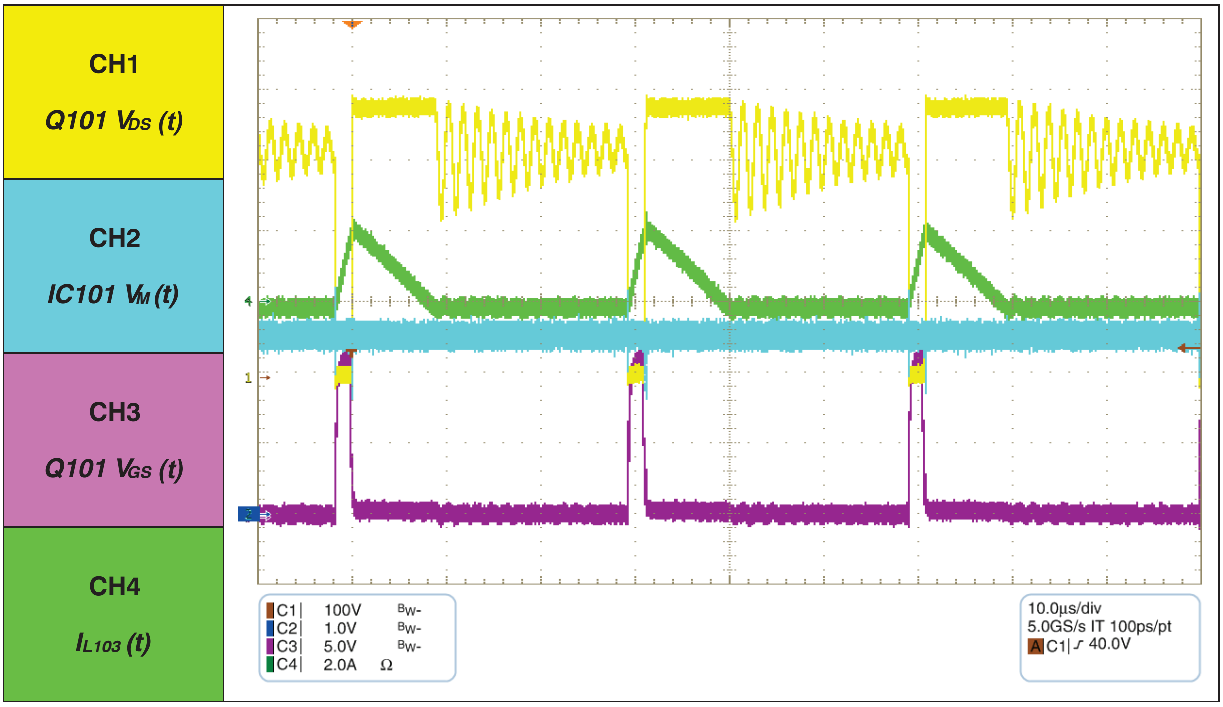

Figure 36. 230 V AC/ Load 5 A, PFC DCM MODE

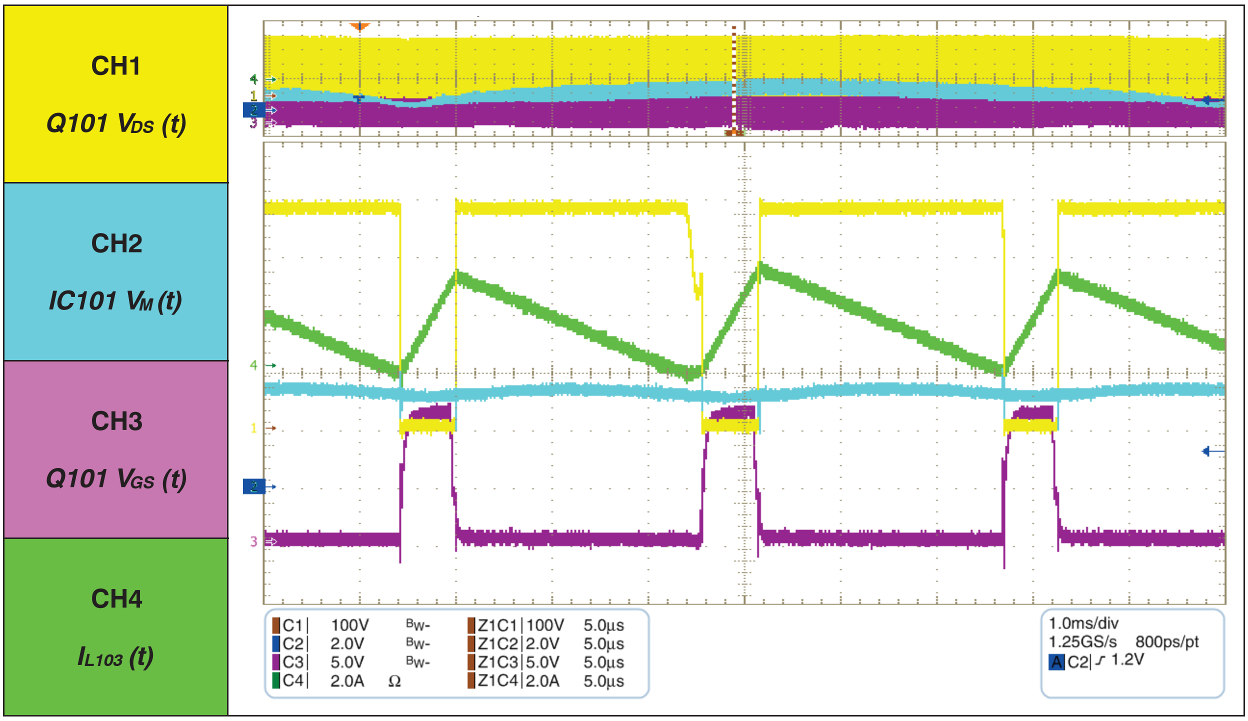

Figure 37. 230 V AC/ Load 24 A, PFC Transition DCM to CrM MODE

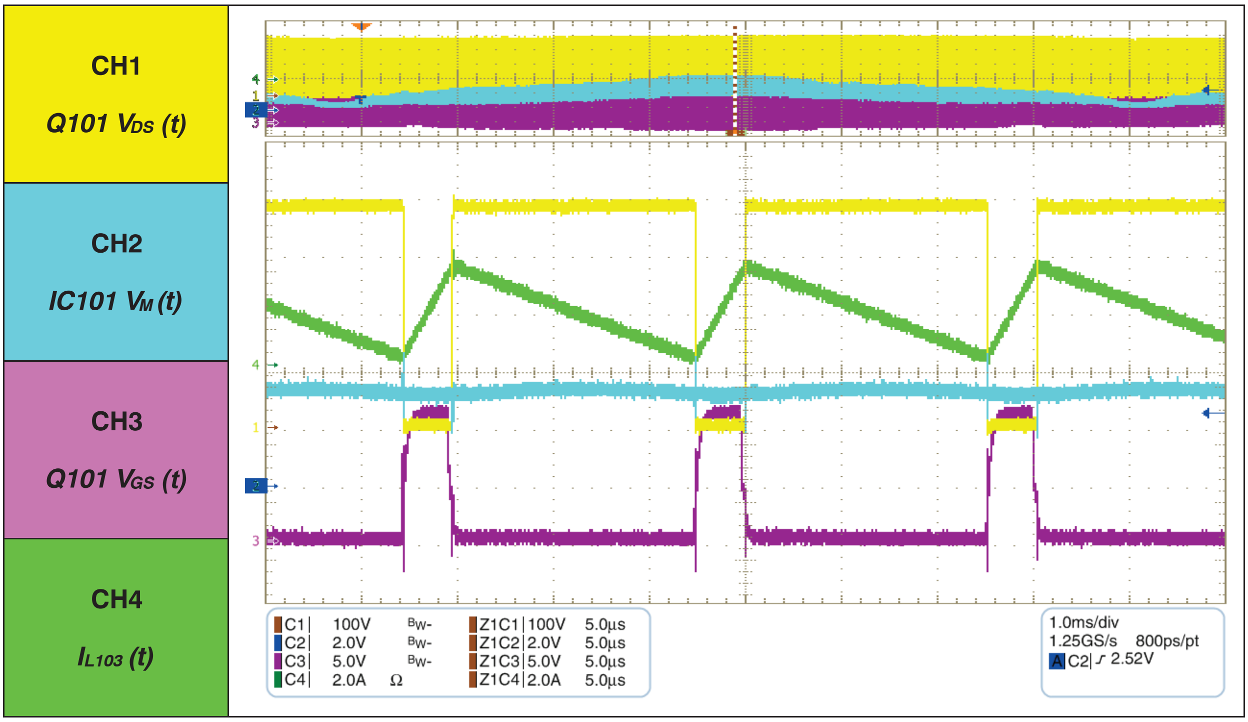

Figure 38. 230 V AC/ Load 30 A, PFC CrM MODE

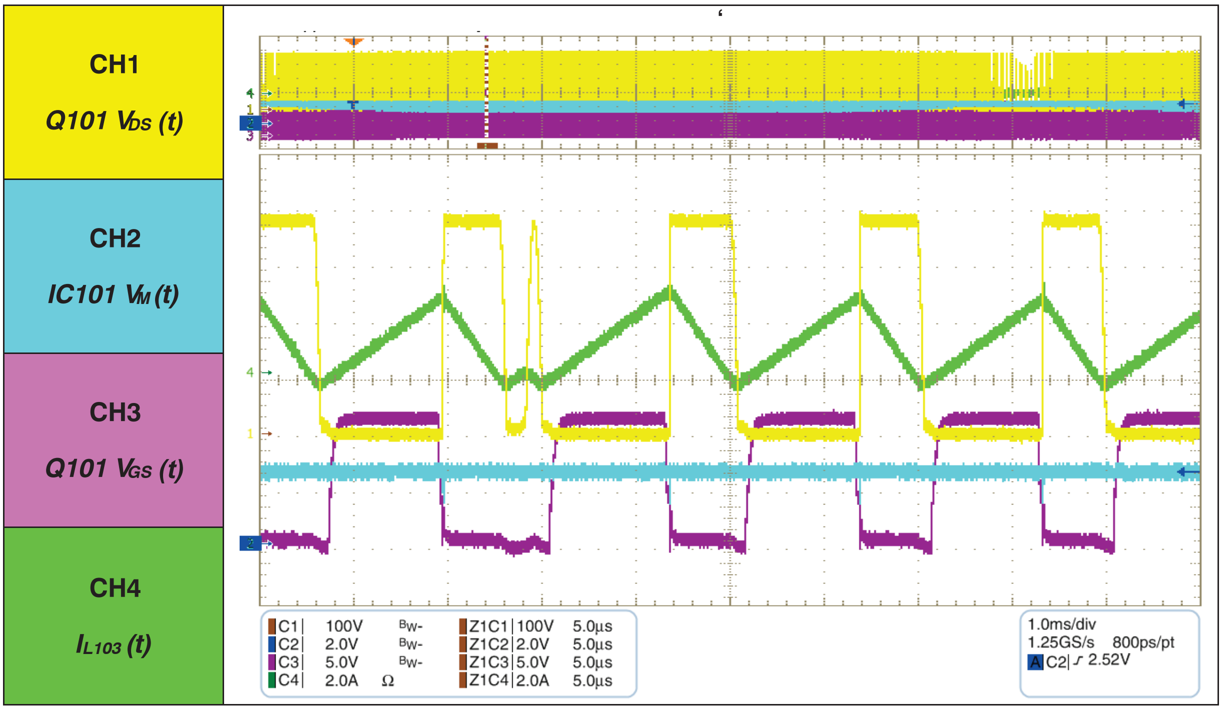

Figure 39. 110 V AC/ Load 9 A, PFC Transition DCM to CrM MODE

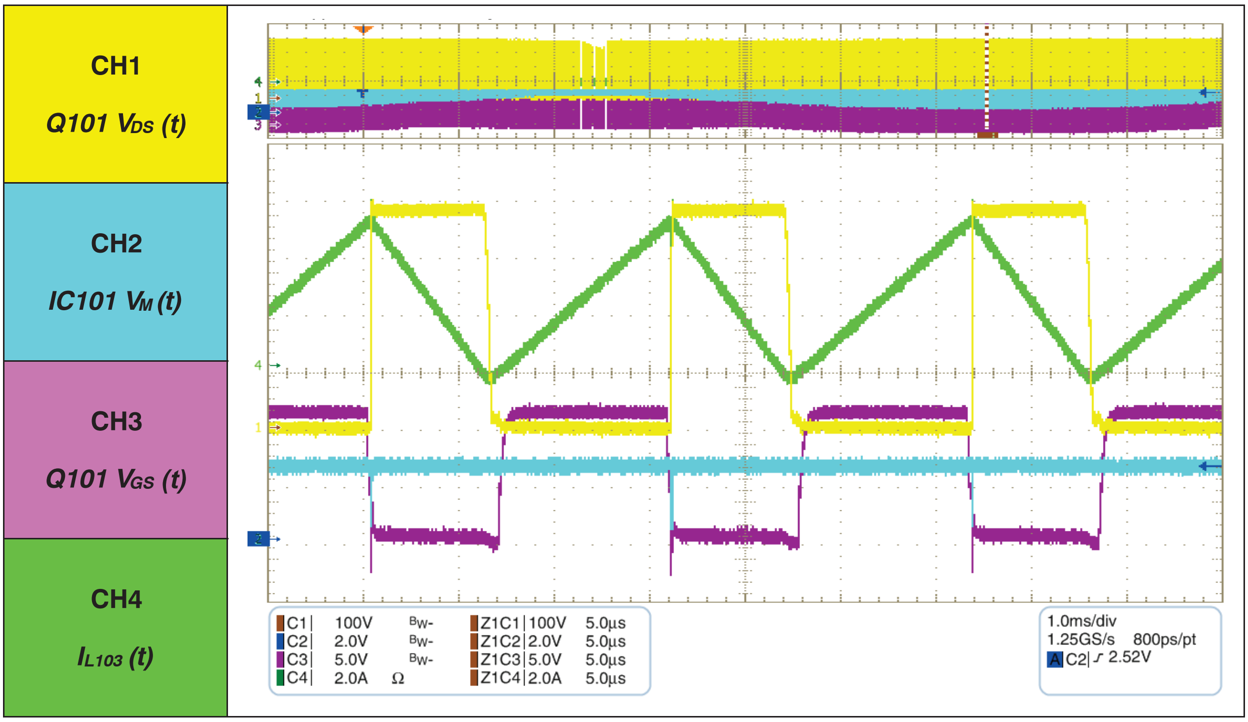

Figure 40. 110 V AC/ Load 15 A, PFC CrM MODE

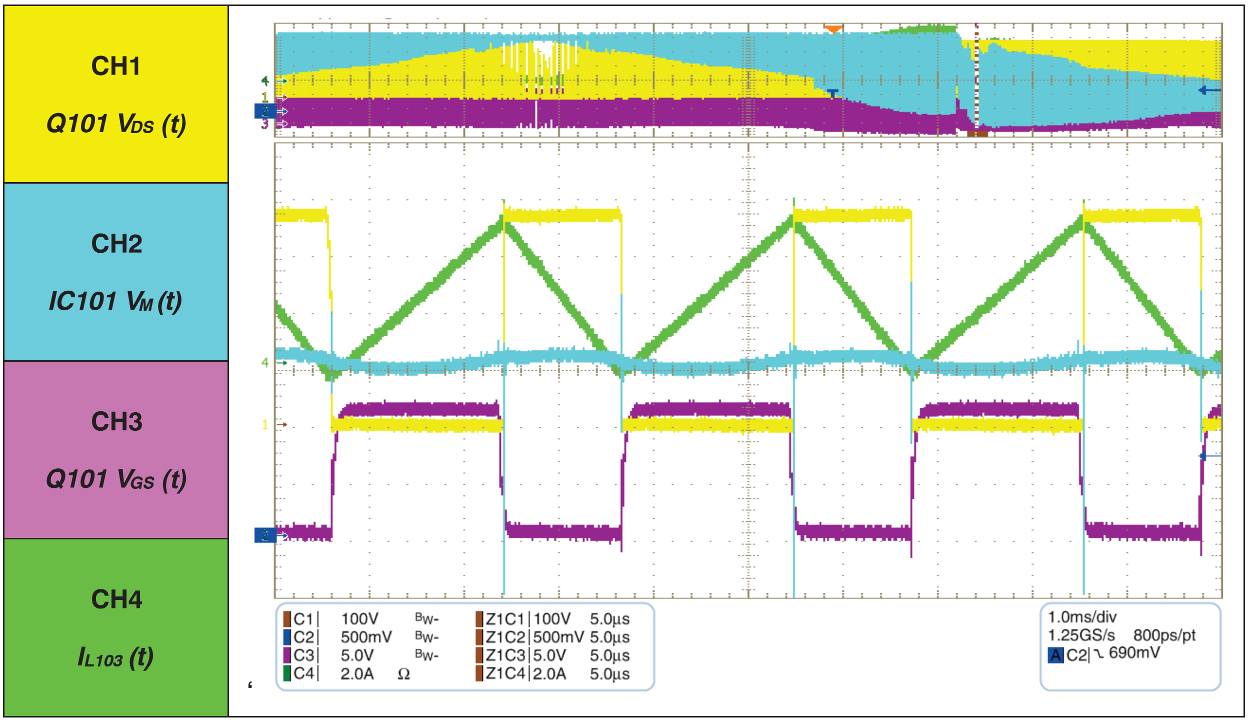

Figure 41. 110 V AC/ Load 7 A, PFC Transition CrM to CCM MODE

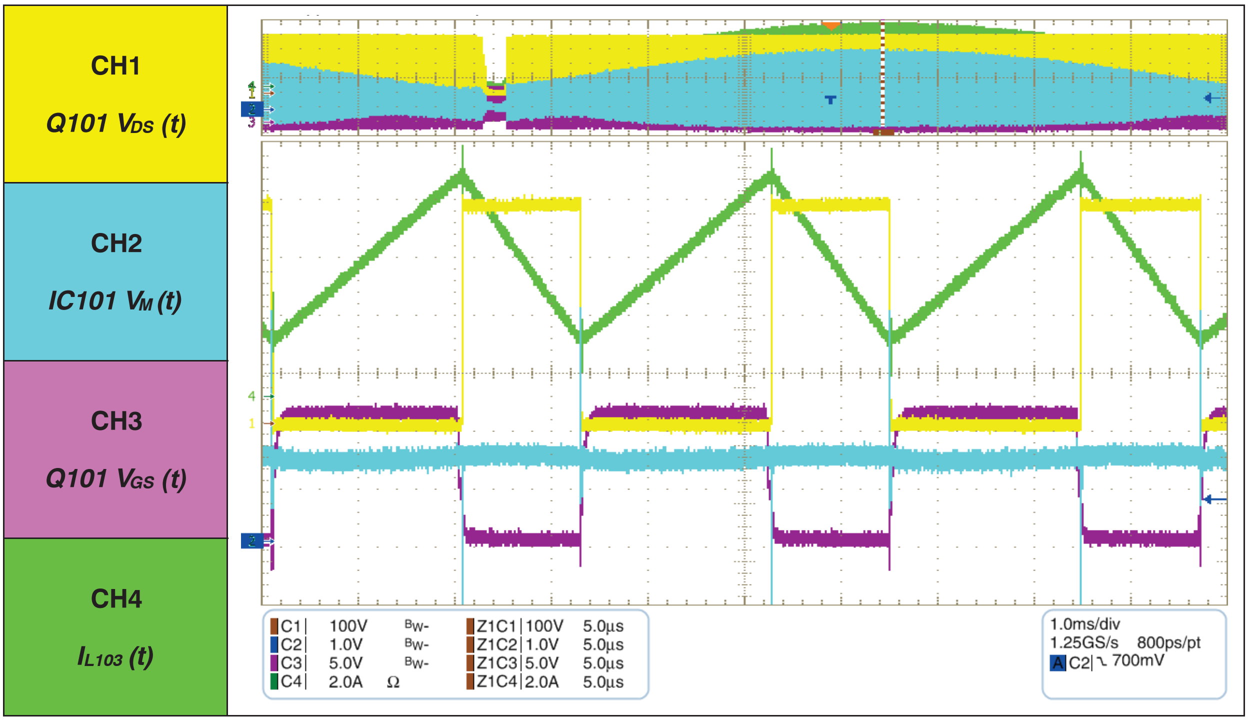

Figure 42. 110 V AC/ Load 30 A, PFC CCM MODE

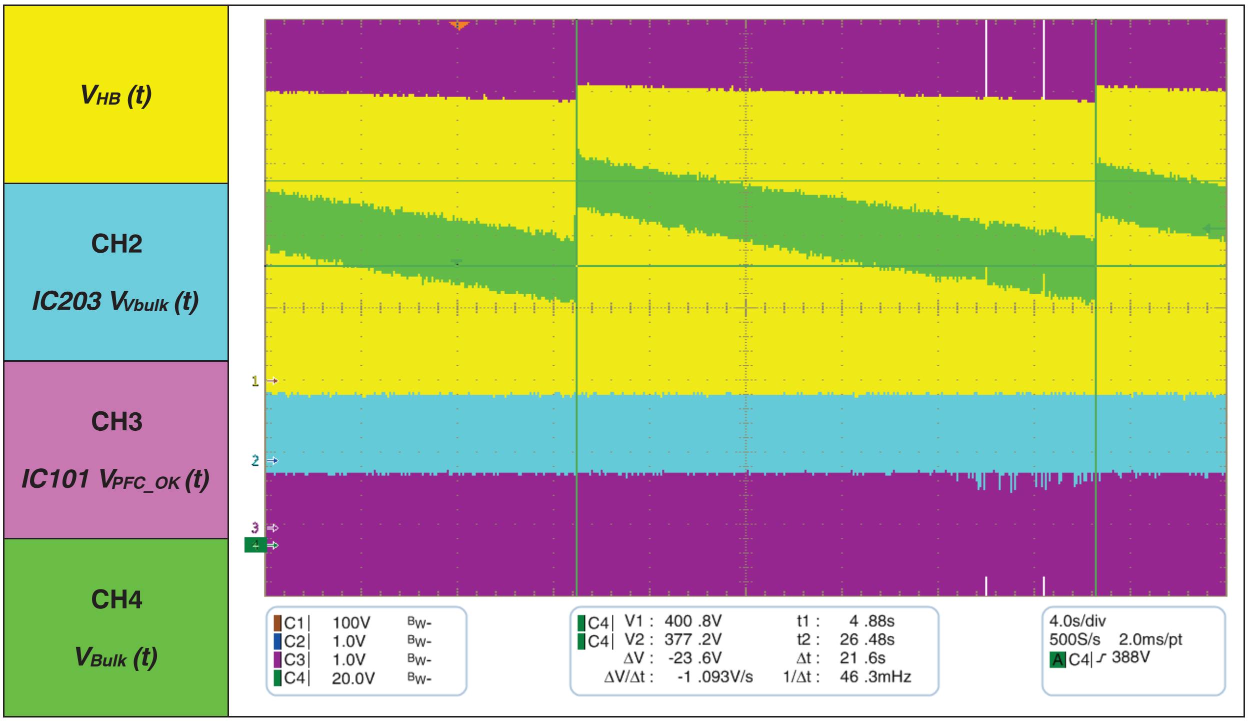

Figure 43. 230 V AC/ No−Load, PFC Soft−Skip Mode − V_{Bulk} Hiccups

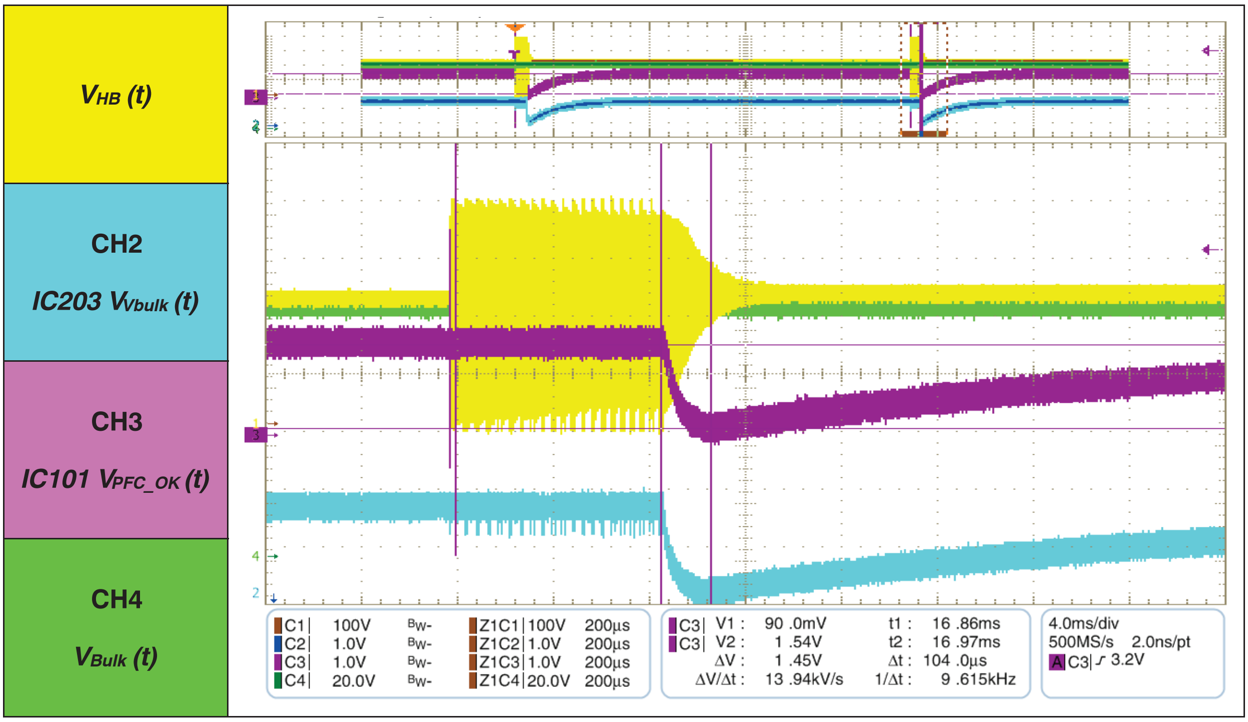

Figure 44. 230 V AC/ No−Load, PFC Soft−Skip Mode − V_{Bulk} Hiccups − Detail

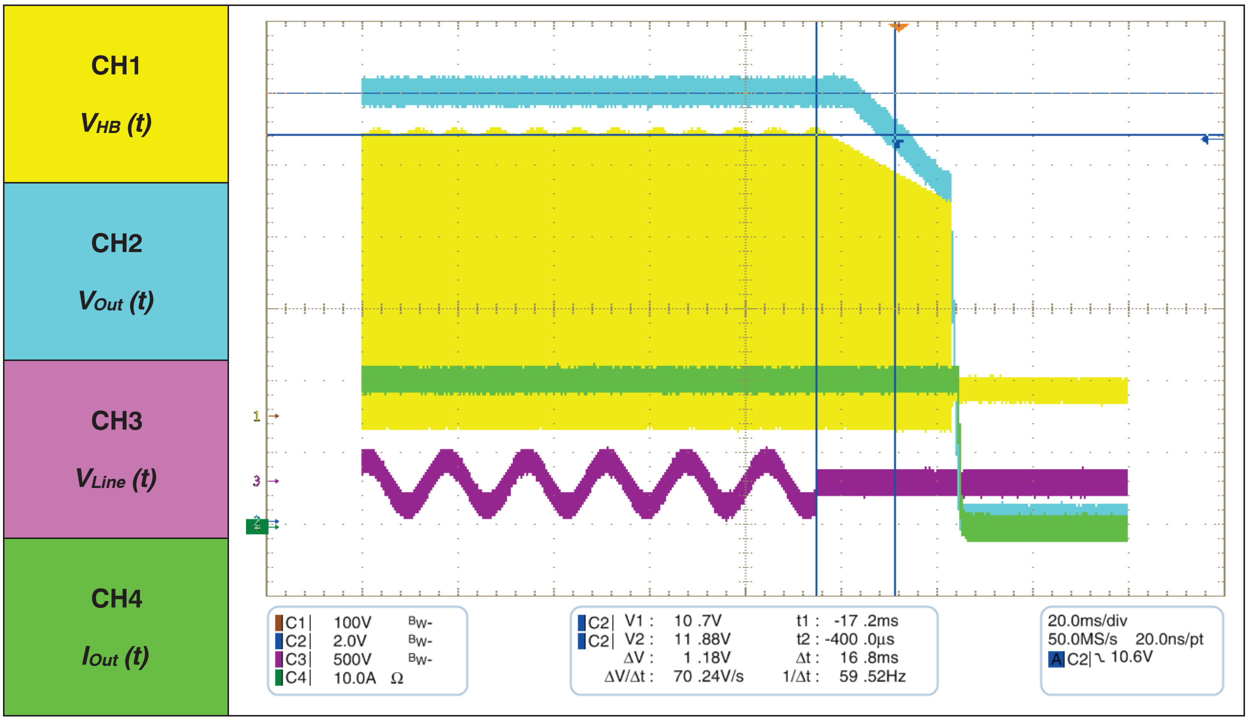

Figure 45. 110 V AC/ Load 30 A, Hold−Up Time for 10% Regulation ~ 17 ms

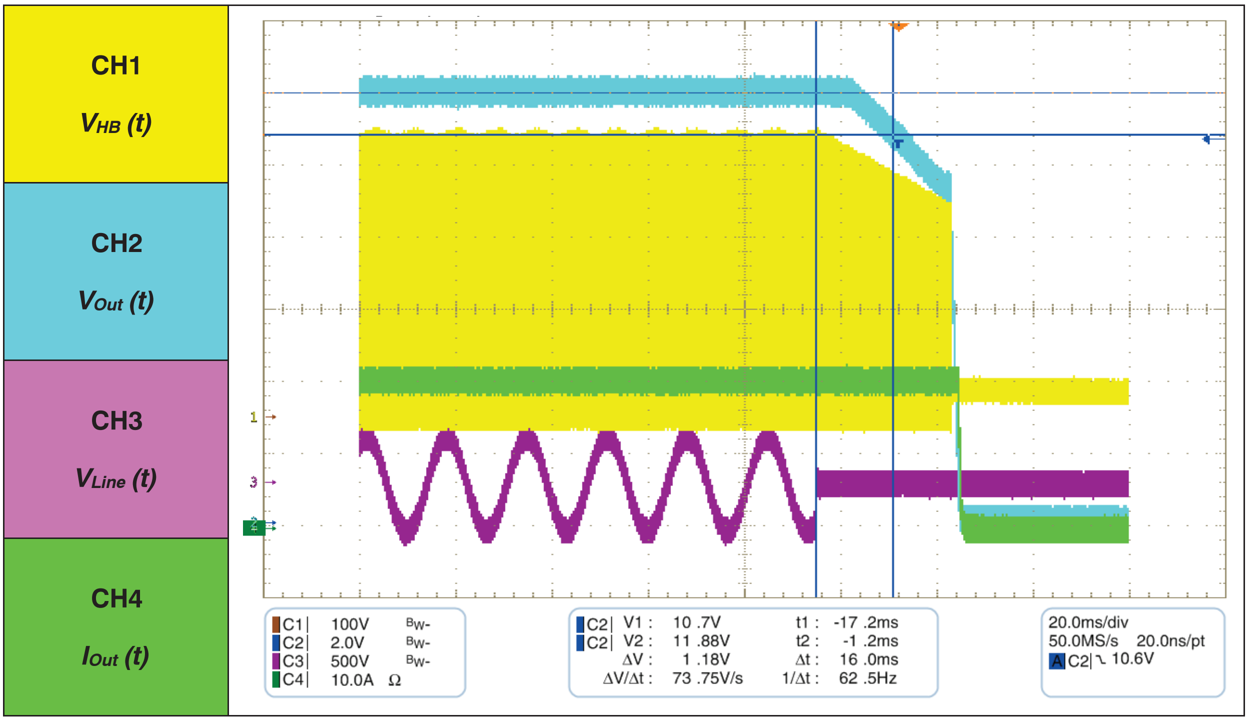

Figure 46. 230 V AC/ Load 30 A, Hold−Up Time for 10% Regulation ~ 16 ms

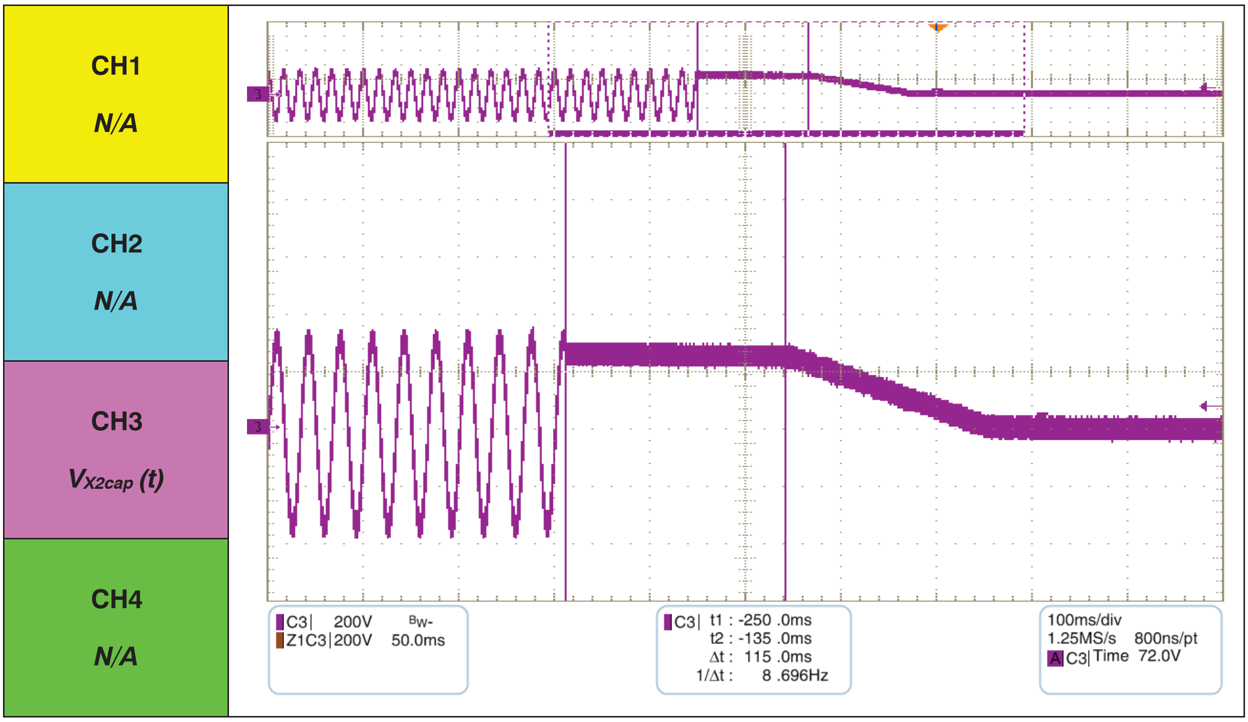

Figure 47. 230 V AC, X2 Cap Discharging after Line Unplug ~ 100 ms

BOM

Table 3. BILL OF MATERIALS

Parts	Qty	Value	Package	Description	Manufacturer	Part Number	Substitution
B101	1	DFB2560	SIP−4	Bridge Rectifier	N/A	N/A	Allowed
C1, C115, C218, C219, C221, C222	6	10 nF/50 V	C0805	CAPACITOR	Wurth	885012207092	Allowed
C101	1	820 nF/275 V~	C102−064X133	MPP CAPACITOR	Wurth	890324025047CS	Allowed
C102	1	1 μF/275 V~	C150−072X183	MPP CAPACITOR	Wurth	890324026027CS	Allowed
C103, C104	2	1 μF/450 Vdc	C150−072X183	MPP CAPACITOR	Panasonic	ECW−FE2W105J	Allowed
C105	1	2.2 nF/250 V	C0805	CAPACITOR	Wurth	885342007005	Allowed
C106	1	22 nF/200 V	C0805	CAPACITOR	Wurth	885342207006	Allowed
C107, C201, C202	3	100 μ/450 V	EC_18X31_R	ELECTROLYTIC CAPACITOR	United Chemi−Con	EKXL451ELL101MM30S	Allowed
C108	1	220 pF/50 V	C0805	CAPACITOR	Wurth	885012007059	Allowed
C109, C220	2	470 pF/50 V	C0805	CAPACITOR	Wurth	885012007061	Allowed
C110	1	3.3 nF/50 V	C0805	CAPACITOR	Wurth	885012007066	Allowed
C111, C224	2	1 μF/25 V	C0805	CAPACITOR	Wurth	885012207103	Allowed
C112	1	12 nF/50 V	C0805	CAPACITOR	Kemet	C0805C123K5RACTU	Allowed
C113, C225	2	220 μF/25 V	E3, 5−8	ELECTROLYTIC CAPACITOR	Wurth	860040474004	Allowed
C114	1	15 pF/50 V	C0805	CAPACITOR	Wurth	885012007052	Allowed
C116, C230, C232, C234	4	Not Used	C0805	CAPACITOR	N/A	N/A	N/A
C2, C211	2	560 p/25 V	C0603	CAPACITOR	Kemet	C0603C561J5RACAUTO	Allowed
C203, C204, C217, C223, C235, C236	6	100 nF/50 V	C0805	CAPACITOR	Wurth	885012207098	Allowed
C205, C206	2	22 nF/1300 V	C150−084X183	MKP CAPACITOR	EPCOS	B3672L1223J189	Allowed
C207	1	220 μF/35 V	E3,5−8	ELECTROLYTIC CAPACITOR	Wurth	860010574011	Allowed
C208, C209	2	1 nF/50 V	C0805	CAPACITOR	Wurth	885012007063	Allowed
C210	1	2.2 μF/25 V	C0603	CAPACITOR	Wurth	885012106018	Allowed
C212, C213, C214, C215, C216	5	1.2 mF/16 V	E3,5−8	POLYMER CAPACITOR	United Chemi−Con	APSG160ELL122MH20S	Allowed
C226	1	2.7 nF/50 V/NPO	C0805	CAPACITOR	Kemet	C0805C272J5GACTU	Allowed
C227, C228	2	220 pF/1 kV/NP0	C1206	CAPACITOR	Kemet	C1206C221JBGACAUTO	Allowed
C229	1	15 nF/50 V/NP0	C0805	CAPACITOR	TDK	C2012C0G1H153J085AA	Allowed
C231	1	22 nF/50 V	C0805	CAPACITOR	Wurth	885012207068	Allowed
C233	1	1.5 nF/50 V	C0805	CAPACITOR	Wurth	885012007089	Allowed
CY101, CY102, CY201	3	2.2 nF/Y1	YC10B5	Y CAPACITOR	Murata	DE1E3KX222MN4AP01F	Allowed
D101, D104, D105, D107	4	BAS16HT1G	SOD5323	DIODE	**onsemi**	BAS16HT1G	Not Allowed
D102	1	S3M	SMC	DIODE	**onsemi**	S3M	Not Allowed
D103	1	FFSPF0865A	TO−220−2 FullPak	DIODE	**onsemi**	FFSPF0865A	Not Allowed
D106, D110, D207	3	MMSD4148T1G	SOD123	DIODE	**onsemi**	MMSD4148T1G	Not Allowed
D108, D109	2	S1JFL	SOD123	DIODE	**onsemi**	S1JFL	Not Allowed
D111, D112	2	Not Used	SOD323	DIODE	N/A	N/A	N/A
D201, D203, D204, D210	4	MBR0540	SOD123	DIODE	**onsemi**	MBR0540	Not Allowed
D202	1	MM3Z15VT1G	SOD323	DIODE	**onsemi**	MM3Z15VT1G	Not Allowed
D205, D206	2	MBR2H100SFT3G	SOD123	DIODE	**onsemi**	MBR2H100SFT3G	Not Allowed
D208	1	MM3Z4V7T1G	SOD323	DIODE	**onsemi**	MM3Z4V7T1G	Not Allowed
D209	1	ES1JFL	SOD123	DIODE	**onsemi**	ES1JFL	Not Allowed

Table 3. BILL OF MATERIALS (continued)

Parts	Qty	Value	Package	Description	Manufacturer	Part Number	Substitution
D211	1	MM3Z12VT1G	SOD323	DIODE	**onsemi**	MM3Z12VT1G	Not Allowed
F101	1	T−6.3 A	0697H	FUSE	Bel Fuse	0697H5000−01	Allowed
IC101	1	NCP1618	SO10	PFC CONTROLLER	**onsemi**	NCP1618	Not Allowed
IC203	1	NCP13994	SO16	LLC CONTROLLER	**onsemi**	NCP13994AA	Not Allowed
IC204	1	NCP431	SOT23	SHUNT REGULATOR	**onsemi**	NCP431BISNT1G	Not Allowed
IC205	1	NCP4318	SO08	SR DRIVER	**onsemi**	NCP4318ALCDR2G	Not Allowed
L101	1	2 x 4.8 mH	LF−280XX	COMMON MODE INDUCTOR	ICE COMPONENTS	LF−28024−0048−H	Allowed
L102, L103	2	90 μH	LITEON_1251_MC1	DIF. MODE INDUCTOR	Wurth	7447013	Allowed
L104	1	260 μH	PQ32/25	PFC INDUCTOR	Sumida	T92063	Allowed
L202	1	−	09X05	FERRITE BEAD	Wurth	74270033	Allowed
NTC201	1	330k	THT	NTC	Vishay	NTCLE100E3334JB0	Allowed
OK201, OK202	2	TCLT1008	SOP−4	OPTOCOUPLER	Vishay	TCLT1008	Not Allowed
Q101	1	NTPF165N65S3H	TO−220−2 FullPak	POWER MOSFET	**onsemi**	NTPF165N65S3L1	Not Allowed
Q102	1	NSS20200L	SOT23	PNP TRANSISTOR	**onsemi**	NSS20200LT1G	Not Allowed
Q201	1	BSS138LT1G	SOT23	MOSFET	**onsemi**	BSS138LT1G	Not Allowed
Q202, Q203	2	FCPF22N60NT	TO−220−2 FullPak	POWER MOSFET	**onsemi**	FCPF22N60NT	Not Allowed
Q204, Q205, Q206, Q207	4	NTMFS5C442	SO8_FL	POWER MOSFET	**onsemi**	NTMFS5C442NLT1G	Not Allowed
R101	1	275 VAC	LITTELFUSE	VARISTOR	Littelfuse	VARV430CH8S	Allowed
R102	1	STRAP	N/A	THERMISTOR	N/A	N/A	Allowed
R104, R205, R222, R229, R235, R236, R238, R247, R251	9	OR	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
R105, R119, R250	3	820R	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
R106, R107	2	0.062R / 2 W	R6332W	RESISTOR	TE Connectivity / Holsworthy	RLP73N3AR062JTE	Allowed
R108, R203, R204, R206	4	22k	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
R109	1	300R	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
R110	1	39R	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
R111	1	2.2R	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	Allowed
R117, R227	2	Not Used	R1206	RESISTOR	N/A	N/A	N/A
R118, R121, R218, R220	4	1k	R1206	RESISTOR	VARIOUS	VARIOUS	Allowed
R120, R226	2	100k	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
R122	1	2k	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
R123, R241	2	11k	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
R124	1	10k	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
R125, R127, R128, R232, R234, R242, R246, R249	8	Not Used	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
R126	1	240k	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
R201, R202	2	33R	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
R207, R208	2	5.1R	R1206	RESISTOR	VARIOUS	VARIOUS	Allowed
R209, R210	2	27R	R1206	RESISTOR	VARIOUS	VARIOUS	Allowed
R211	1	5.1R	R0603	RESISTOR	VARIOUS	VARIOUS	Allowed
R212, R214	2	0R	R0603	RESISTOR	VARIOUS	VARIOUS	Allowed
R213, R216	2	15R	R0603	RESISTOR	VARIOUS	VARIOUS	Allowed
R217	1	62k	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed

Table 3. BILL OF MATERIALS (continued)

Parts	Qty	Value	Package	Description	Manufacturer	Part Number	Substitution
R219, R245	2	1k	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
R221	1	24k	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
R223	1	15k	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
R224	1	100R	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
R225, R237	2	68k	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
R228	1	1.5k	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
R230	1	0R	R1206	RESISTOR	VARIOUS	VARIOUS	Allowed
R231	1	5.1k	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
R233	1	5.1R	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
R239	1	39k	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
R240	1	27k	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
R243	1	150k	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
R244	1	Not Used	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
R248	1	33k	R0805	RESISTOR	VARIOUS	VARIOUS	Allowed
TR1	1	800 μH/ n = 17	PQ3220	LLC TRANSFORMER	Sumida	T92060	Allowed
X101, X201	2	Pitch 5.08 mm	WR−TBL Series 2365	SCREW TERMINAL	Wurth	691236510002	Allowed

REFERENCES

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:
NCP13994: *TBD*

Secondary Side Synchronous Rectifier Controllers:
NCP4318: https://www.onsemi.com/pdf/datasheet/ncp4318−d.pdf

Voltage Reference, Programmable Shunt Regulator:
NCP431: https://www.onsemi.com/pdf/datsheet/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, 650 V:
FFSPF0865A: https://www.onsemi.com/pdf/datasheet/ffspf0865a−d.pdf

MOSFET − Power, N-Channel, SUPERFET® III, FAST 650 V, 165 mΩ, 19 A:
NTPF165N65S3H: https://www.onsemi.com/pdf/datasheet/ntpf165n65s3h−d.pdf

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

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