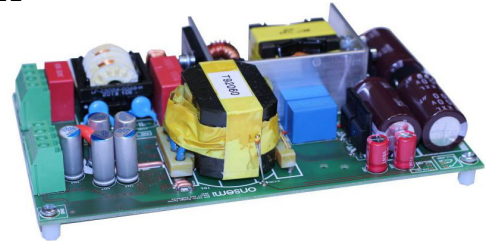


All-in-One Power Supply Evaluation Board User's Manual

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)

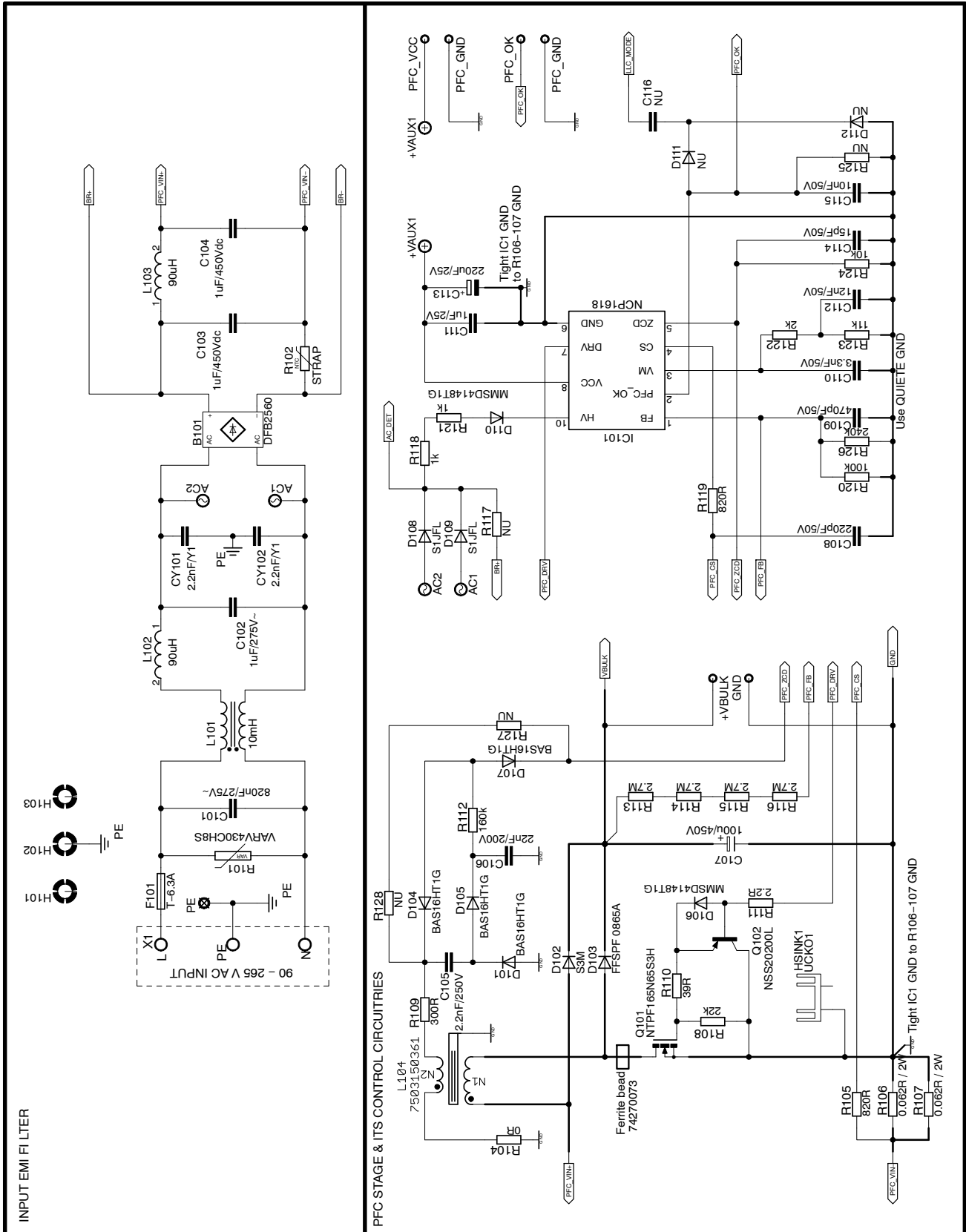


Figure 1. AOI Demo-Board Schematic – PFC Front Stage

NCP13994MM360WGEVB

AOI DEMO-BOARD SCHEMATIC (LLC)

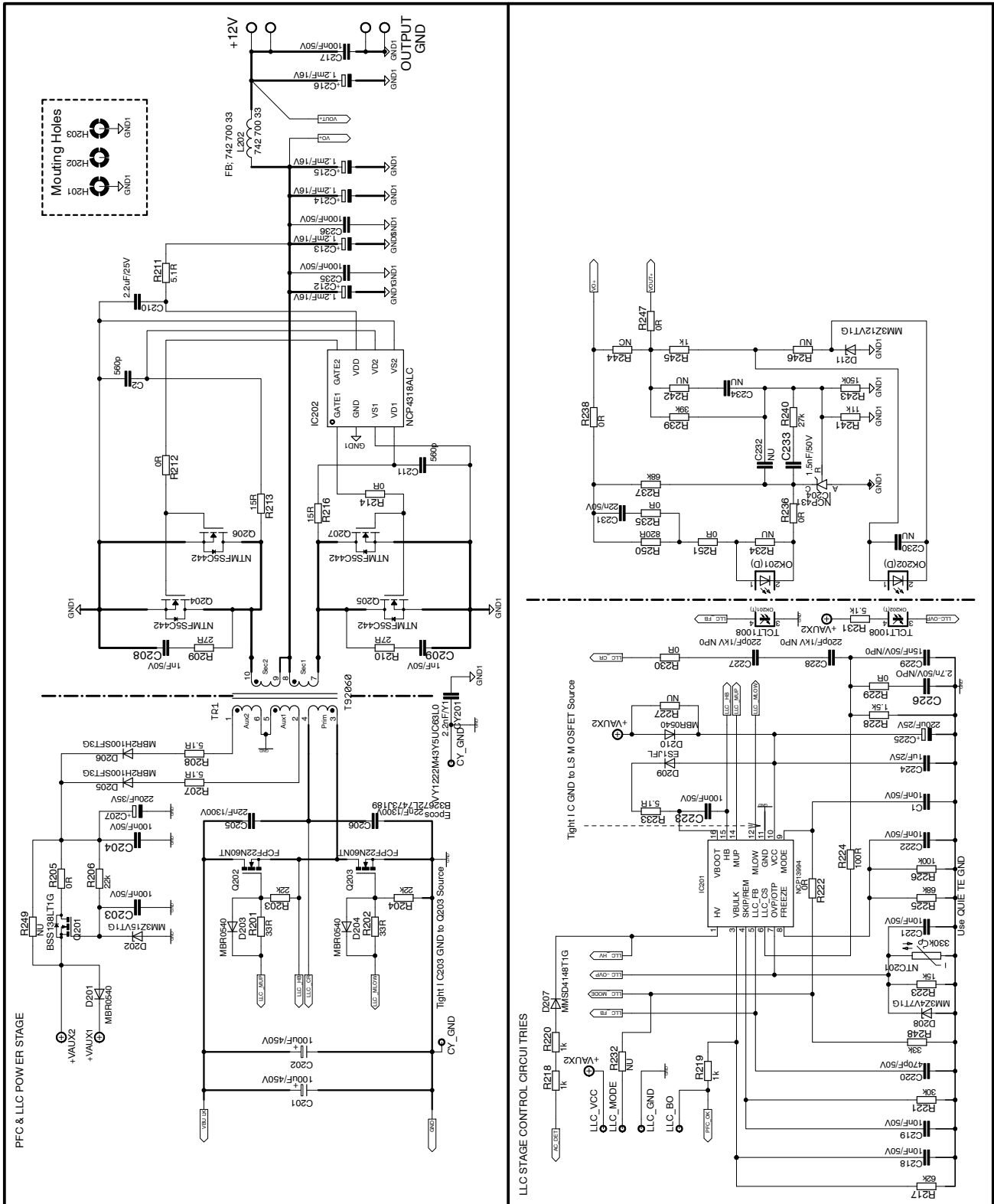


Figure 2. AOI Demo-Board Schematic – LLC Stage

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 M Ω) 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 μ s, 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

NCP13994MM360WGEVB

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 configure 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 MOSFETs 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 from 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.

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EVALUATION BOARD

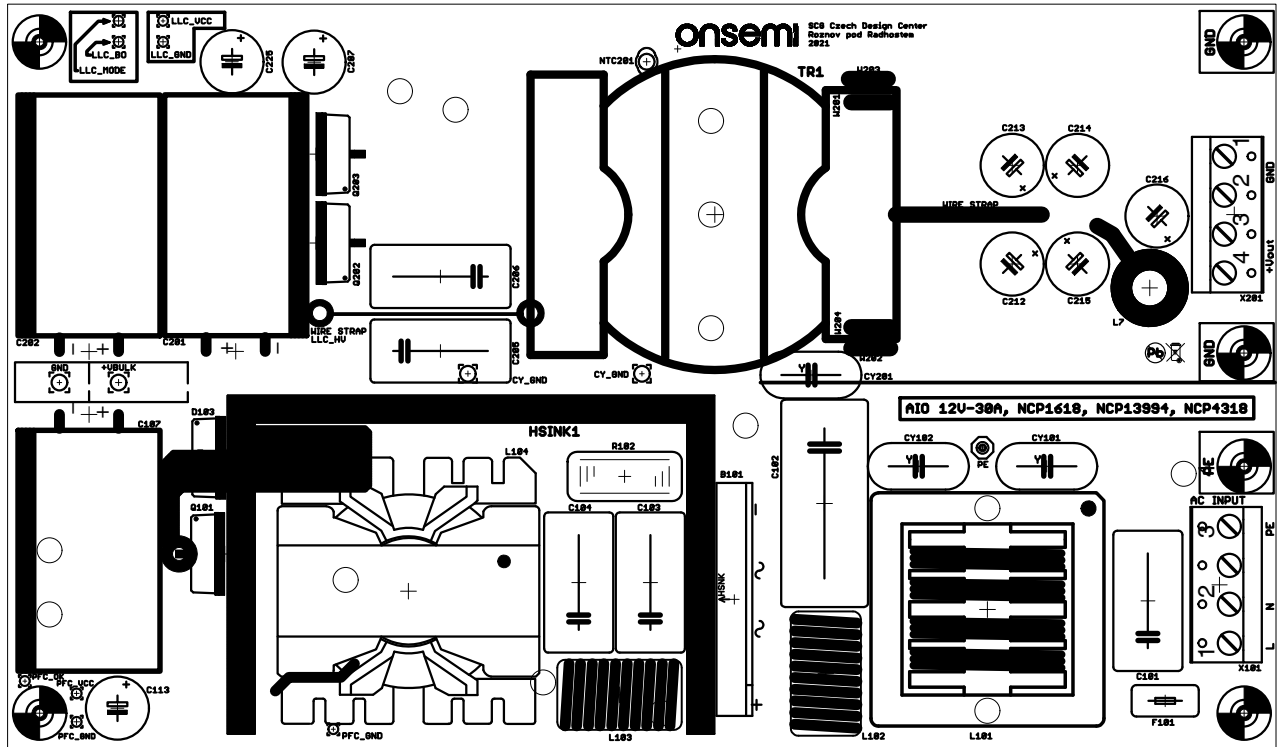


Figure 3. Evaluation Board – Top Side Components

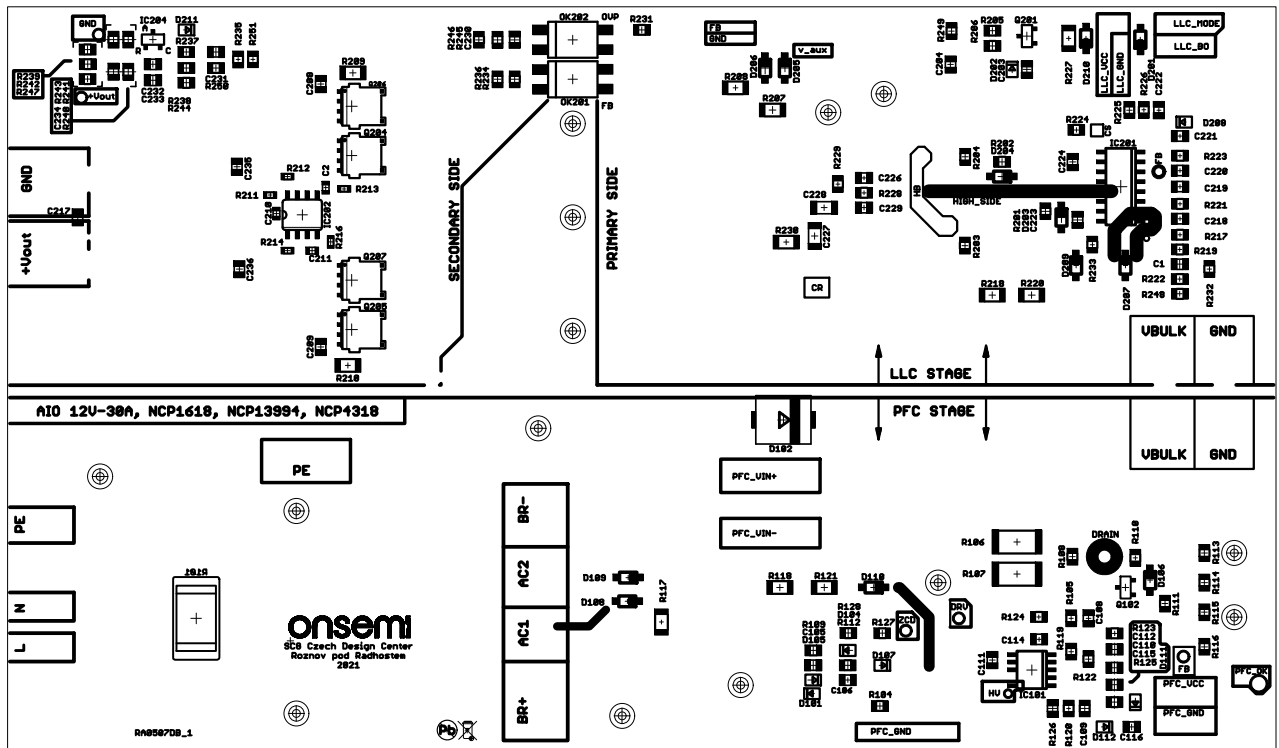


Figure 4. Evaluation Board – Bottom Side Components

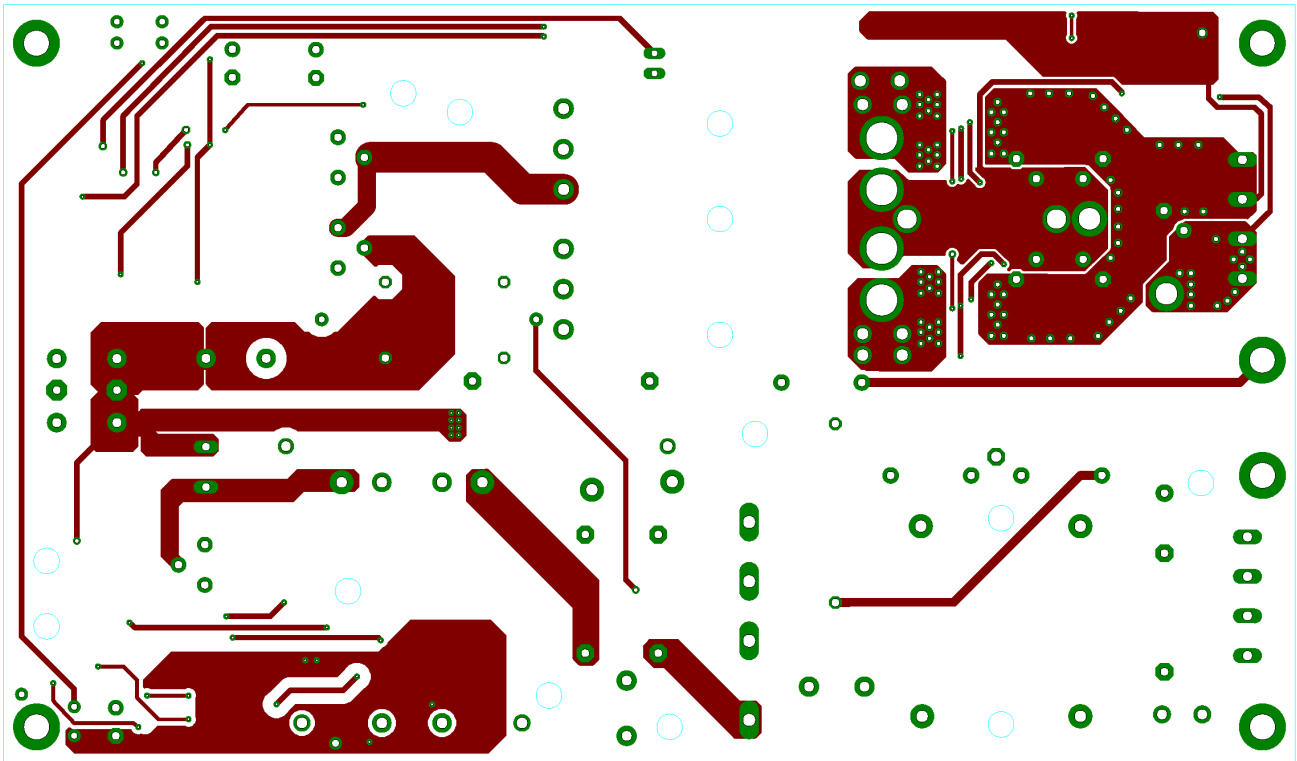


Figure 5. Evaluation Board – PCB Design of Top Layer

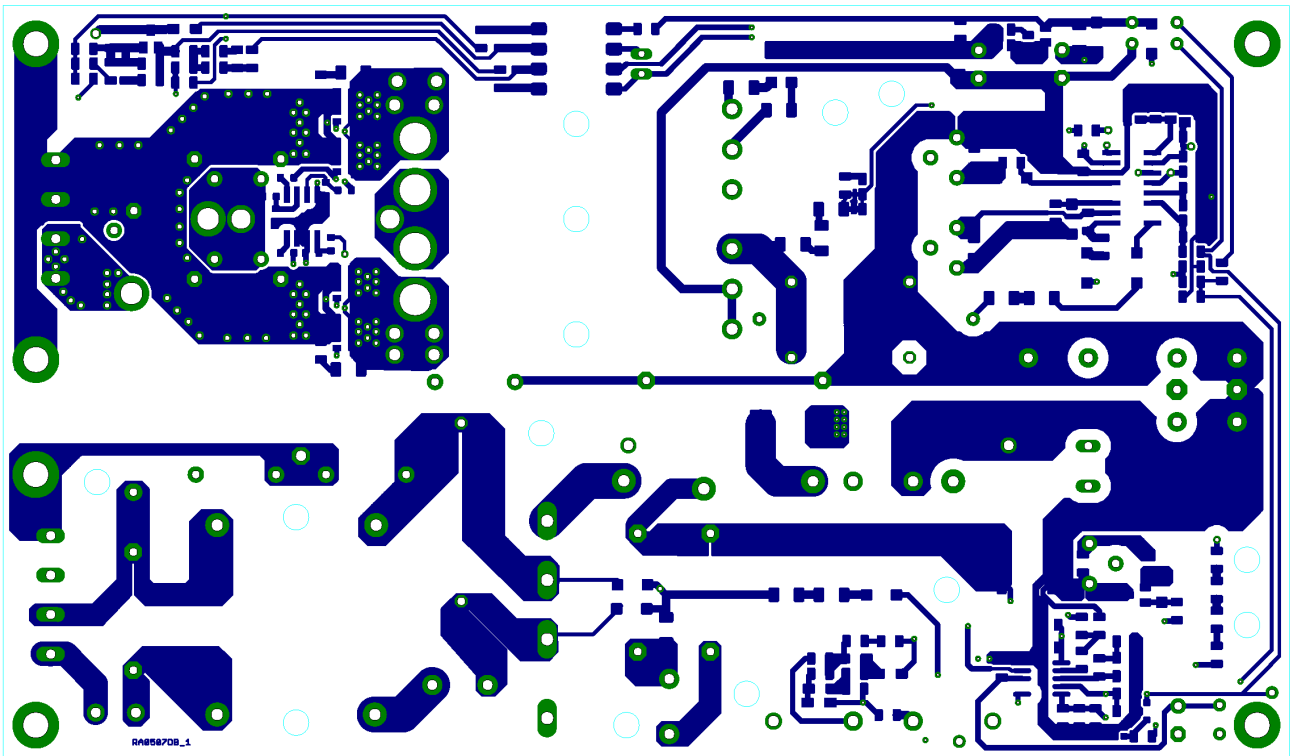


Figure 6. Evaluation Board – PCB Design of Bottom Layer

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EVALUATION BOARD PHOTOGRAPH

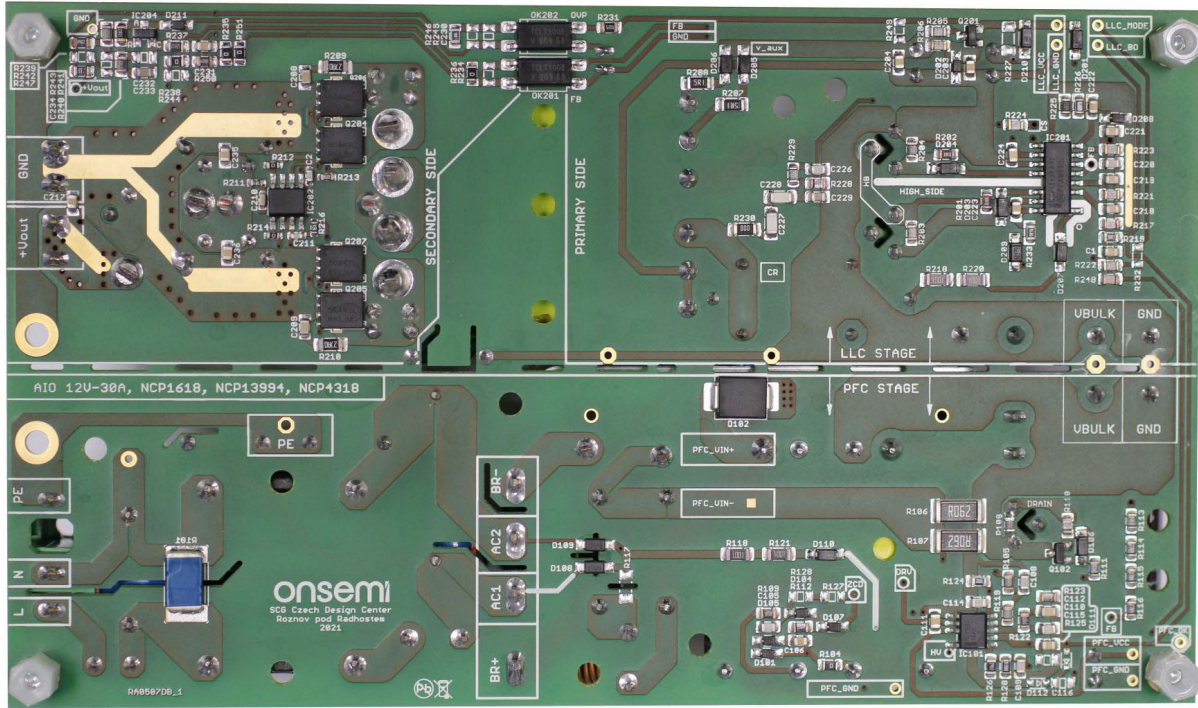


Figure 7. Evaluation Board Photograph- Bottom Side

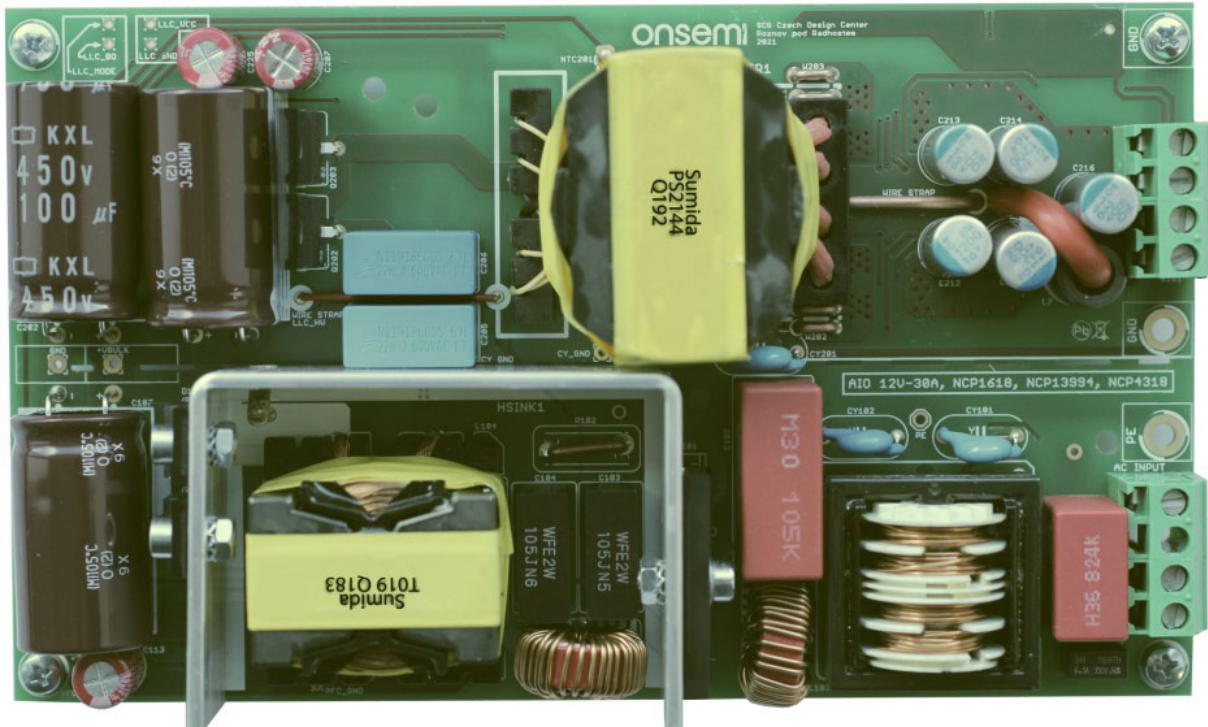


Figure 8. Evaluation Board Photograph- Top Side

NCP13994MM360WGEVB

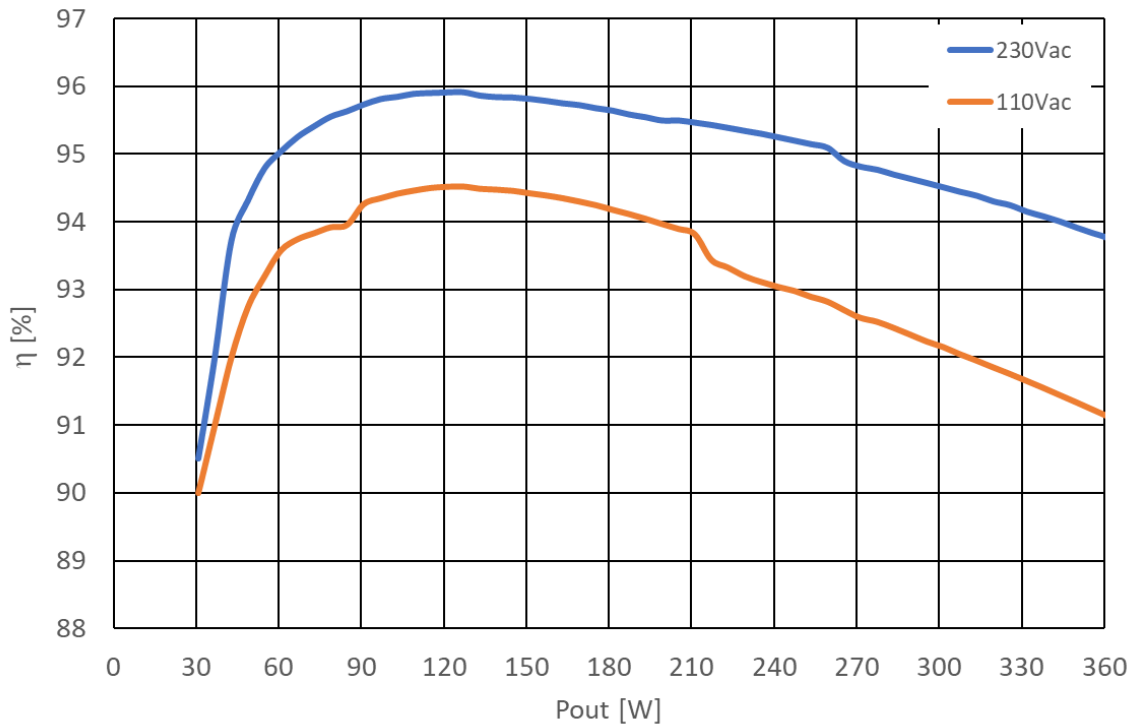


Figure 9. Efficiency vs. Output Power

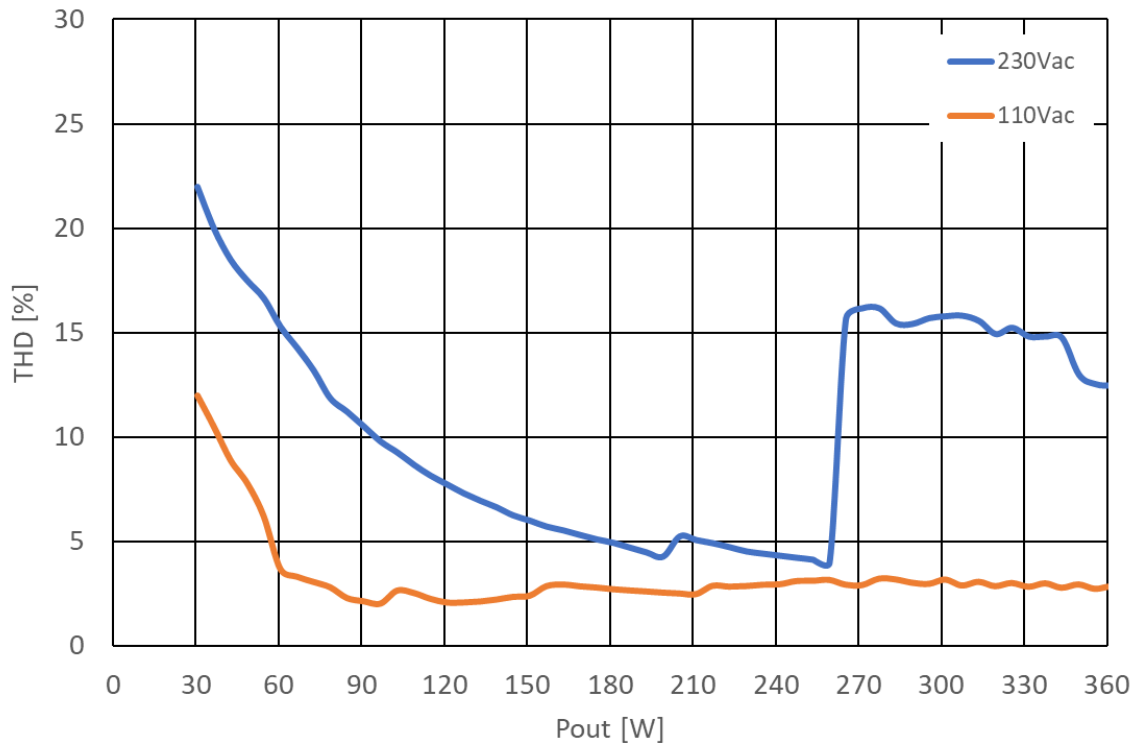


Figure 10. Input Current THD vs. Output Power

NCP13994MM360WGEVB

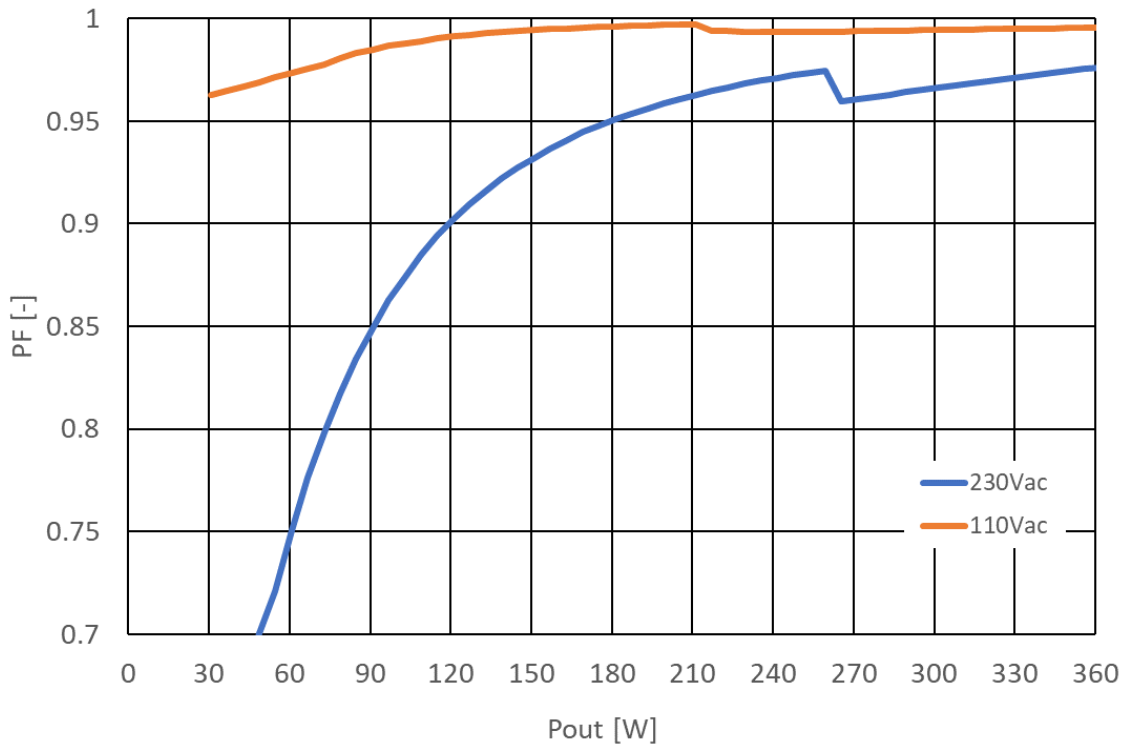


Figure 11. Power Factor vs. Output Power

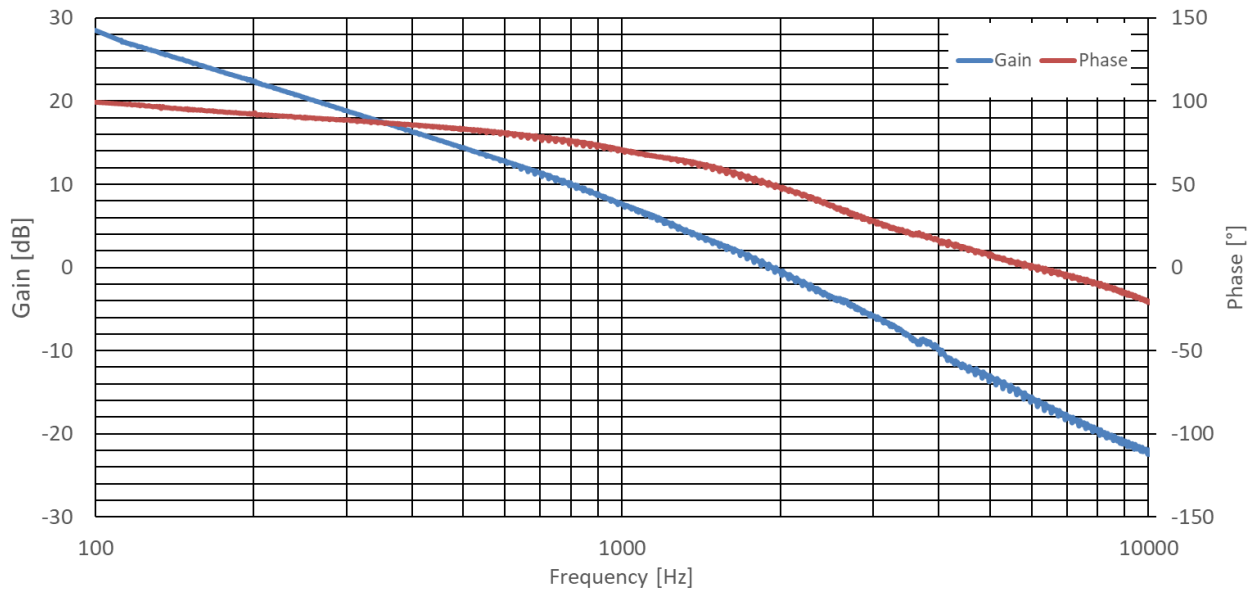


Figure 12. Small Signal Close Loop Response - Iload = 30 A

NCP13994MM360WGEVB

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 | < 250 | < 270 |
| Load 250 mW | < 415 | < 430 |
| Load 500 mW | < 710 | < 720 |
| Load 25% – 7.5 A | 94.26 | 95.73 |
| Load 50% – 15 A | 94.18 | 95.64 |
| Load 75% – 22.5 A | 92.59 | 94.81 |
| Load 100% – 30 A | 91.13 | 93.83 |
| 4 point AVG | 93.04 | 95.00 |

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

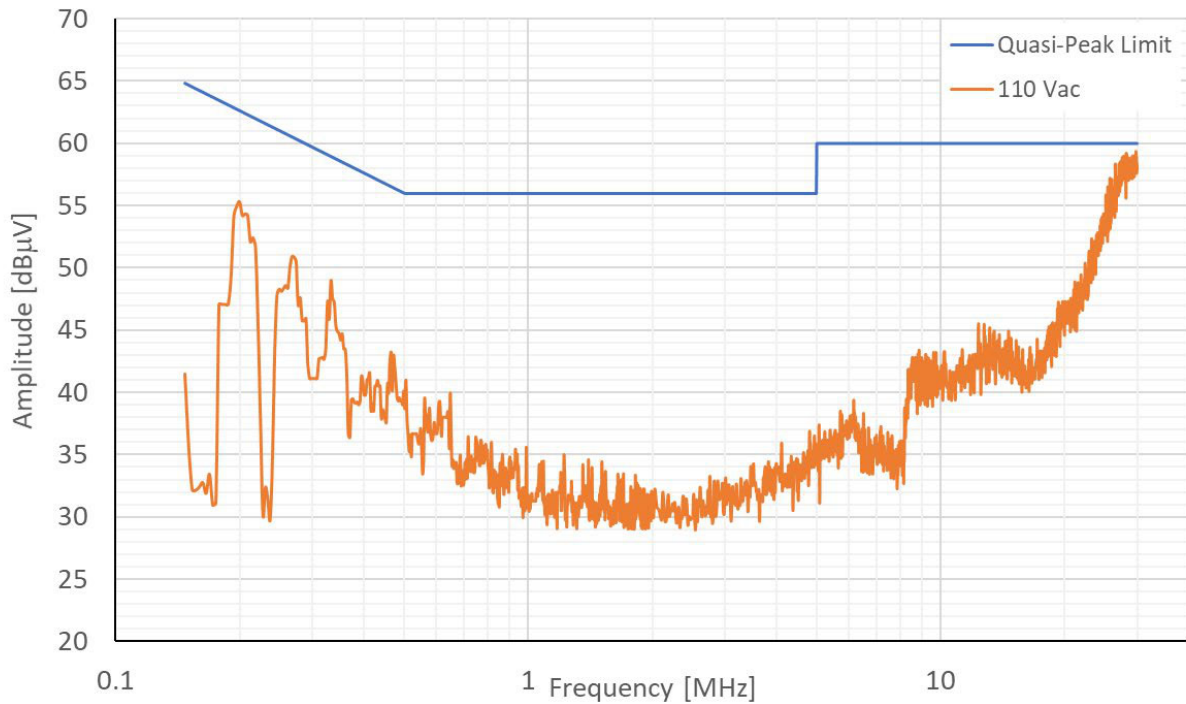


Figure 13. EMI Signature Comparison @ 110 Vac & Full-Load (measured MAX Peak)

NCP13994MM360WGEVB

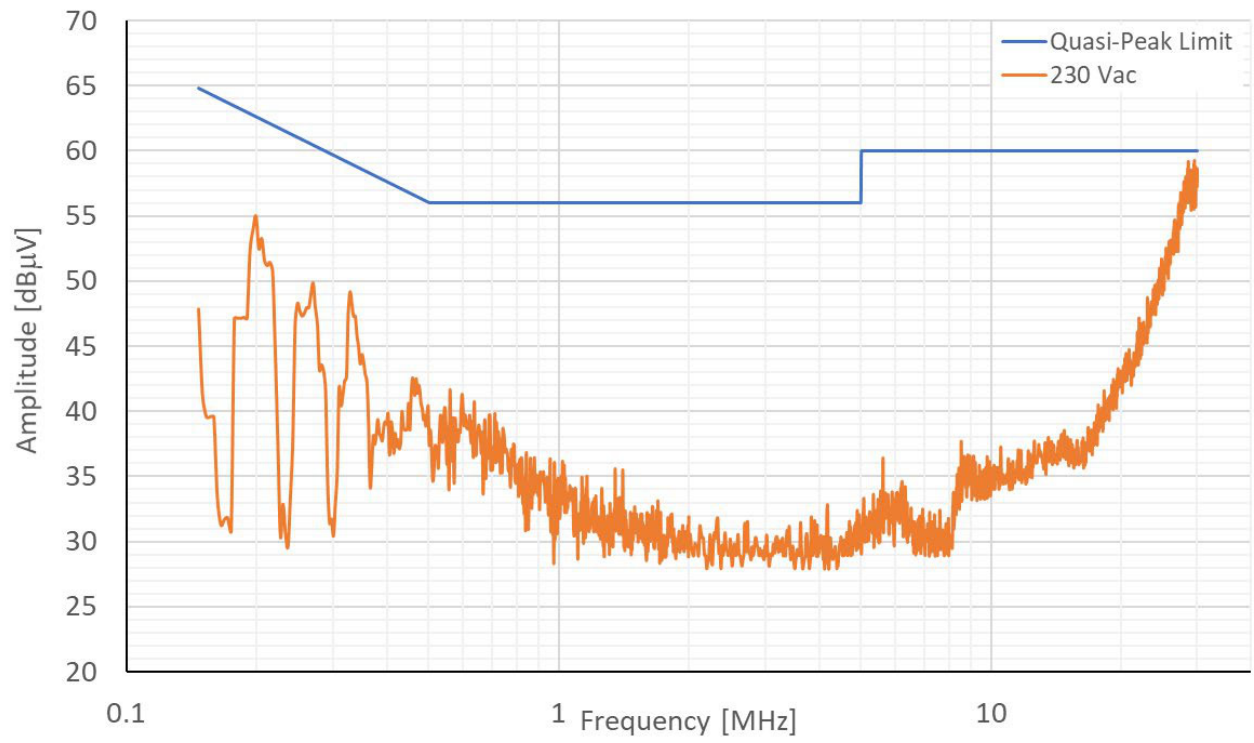


Figure 14. Power Factor vs. Output Power

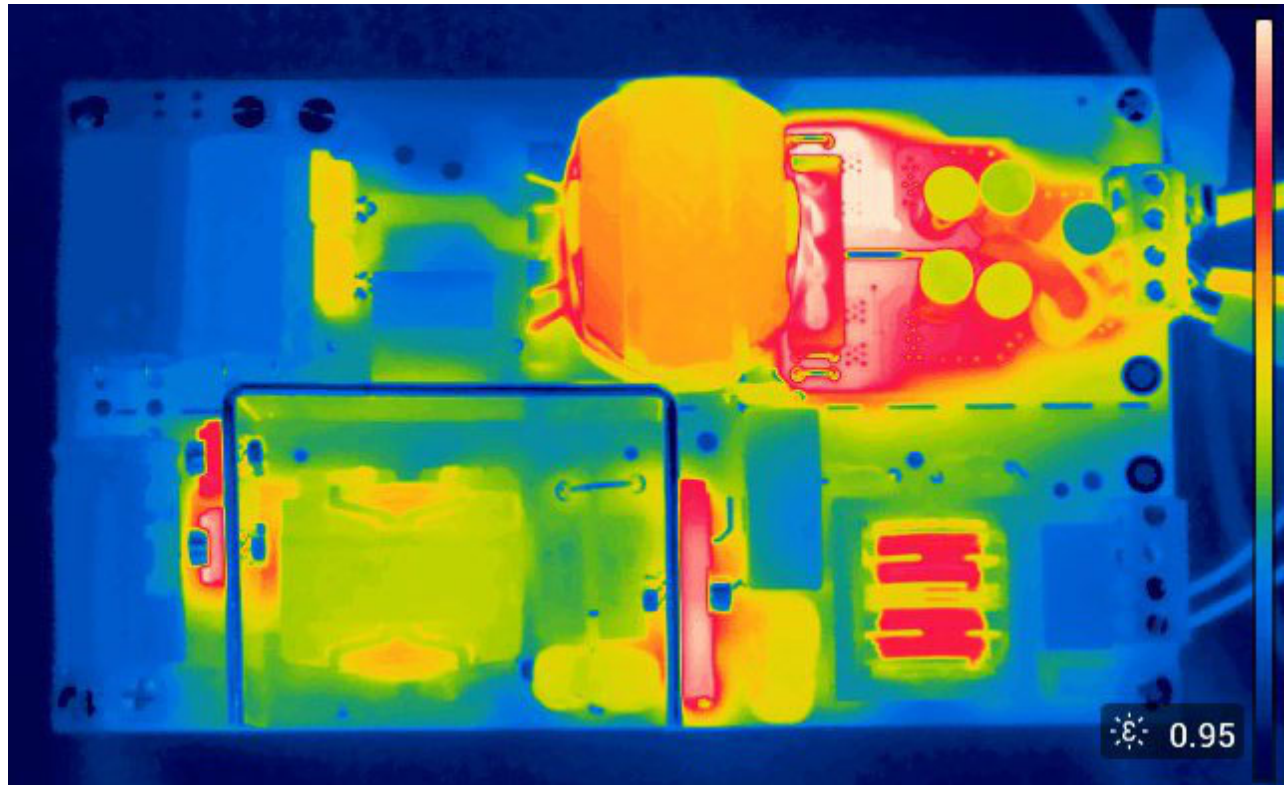


Figure 15. Thermal Radiation @ 110 Vac / Load 30 A

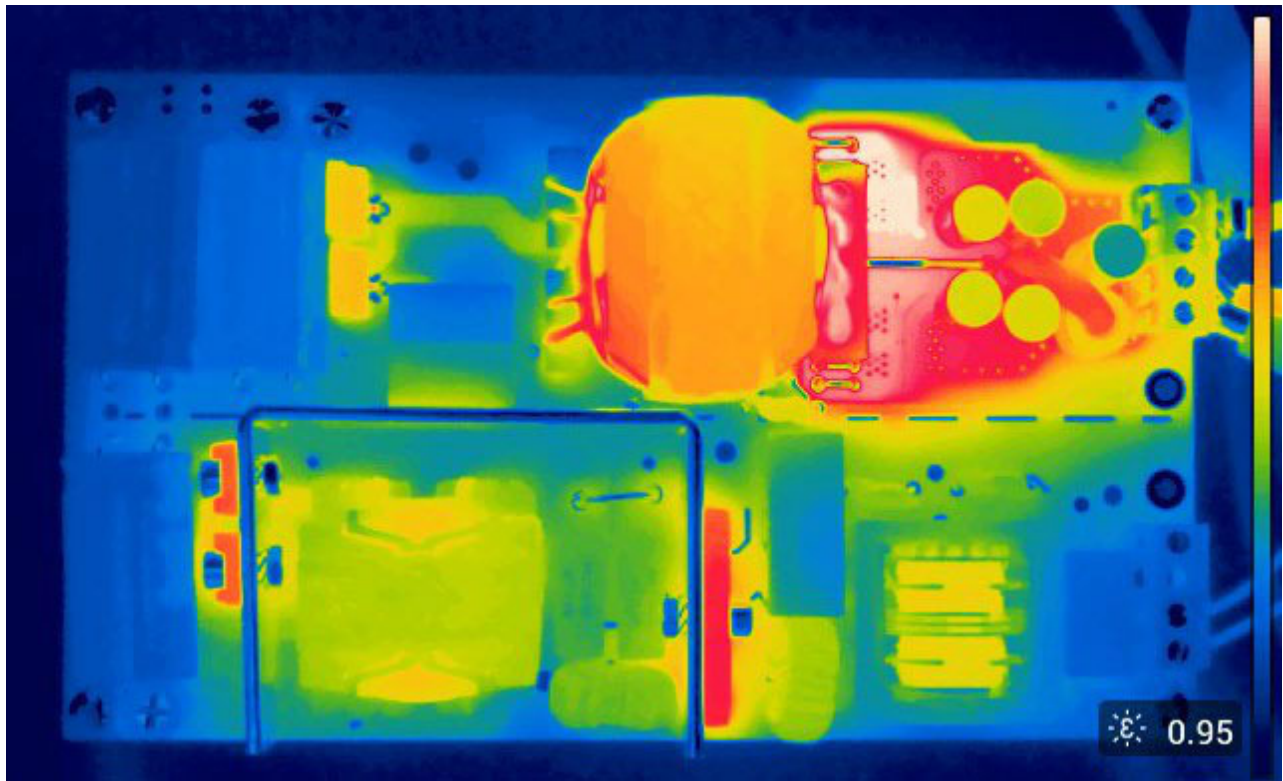


Figure 16. Thermal Radiation @ 230 Vac / Load 30 A

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.

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OPERATING WAVEFORM

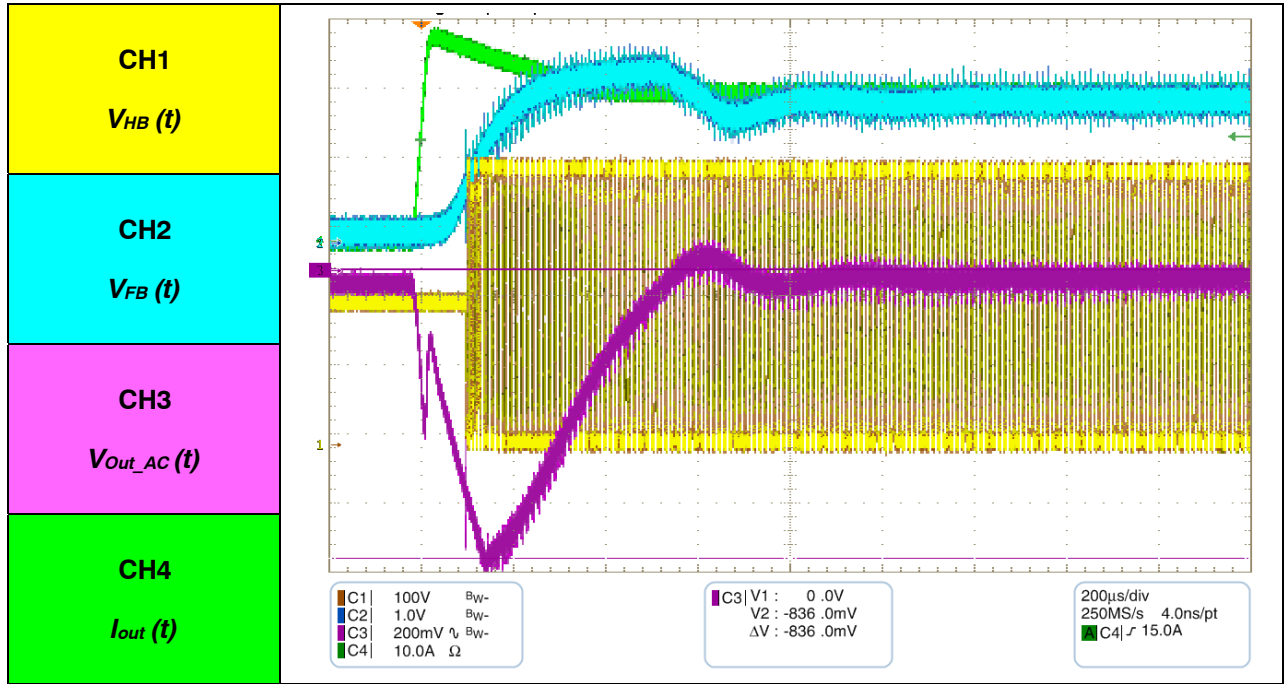


Figure 17. Step Load 0 A – 30 A

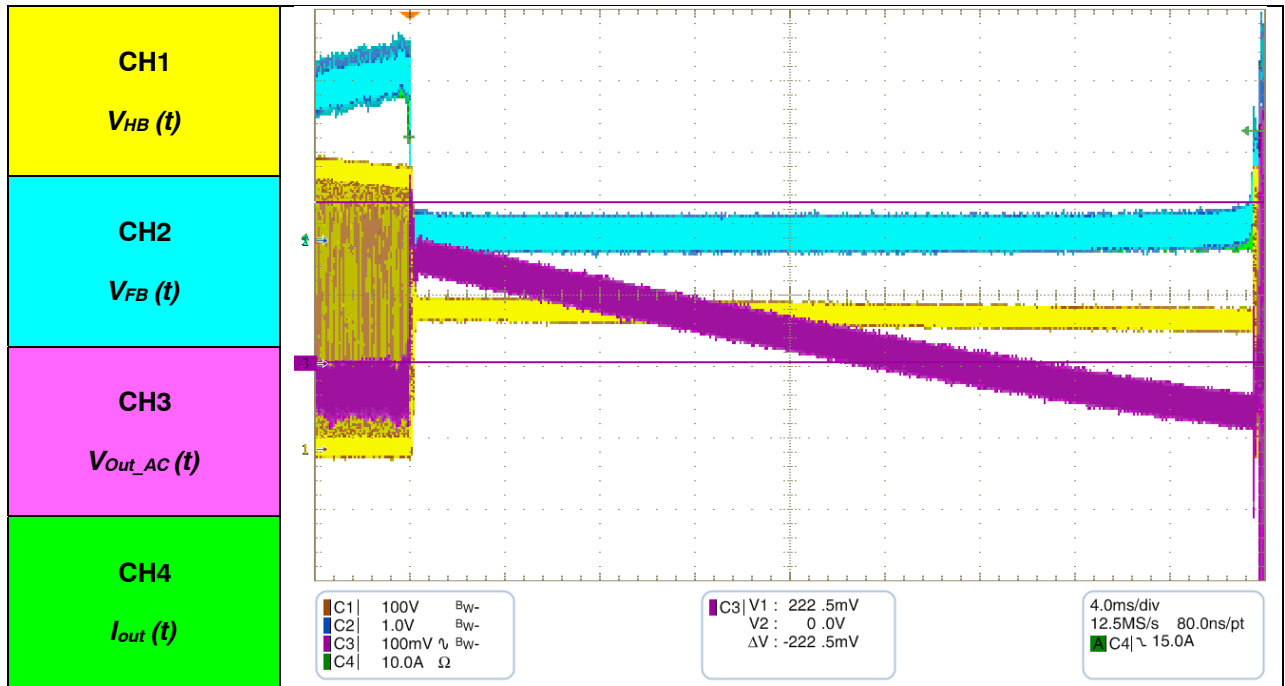


Figure 18. Step Load 30 A – 0 A

NCP13994MM360WGEVB

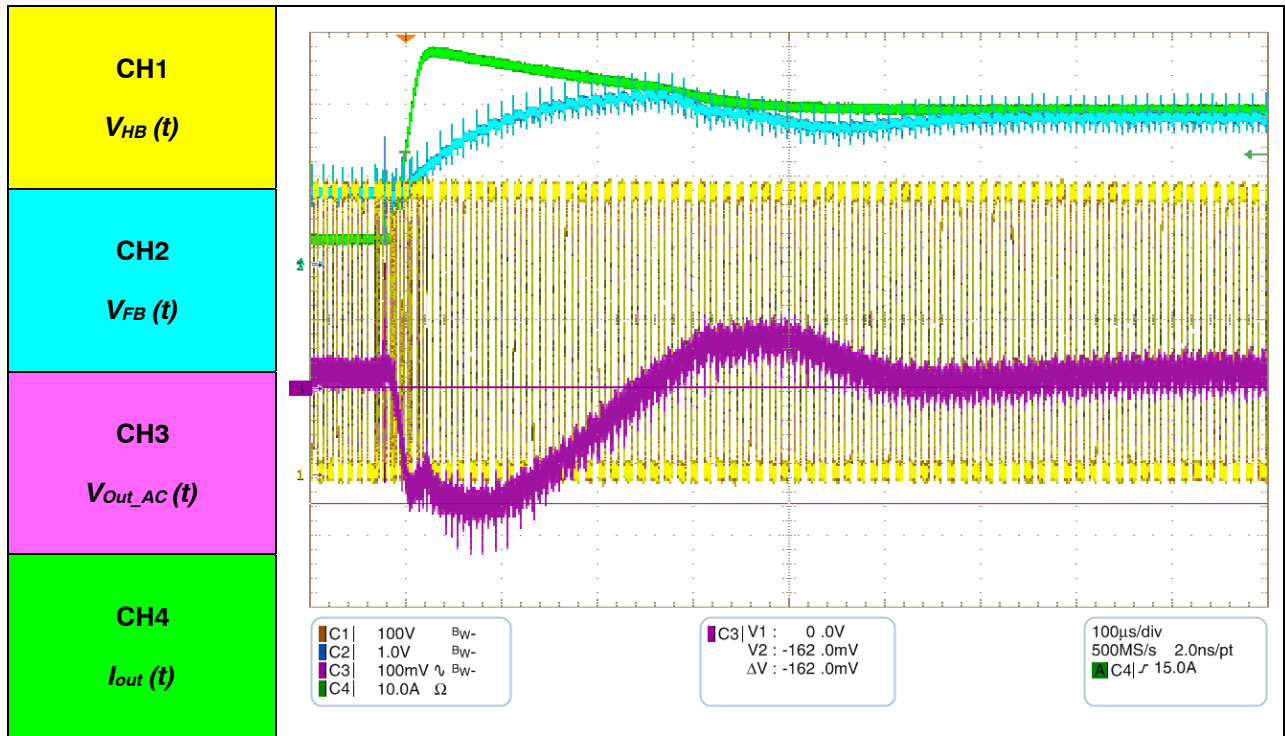


Figure 19. Step Load 3 A – 30 A

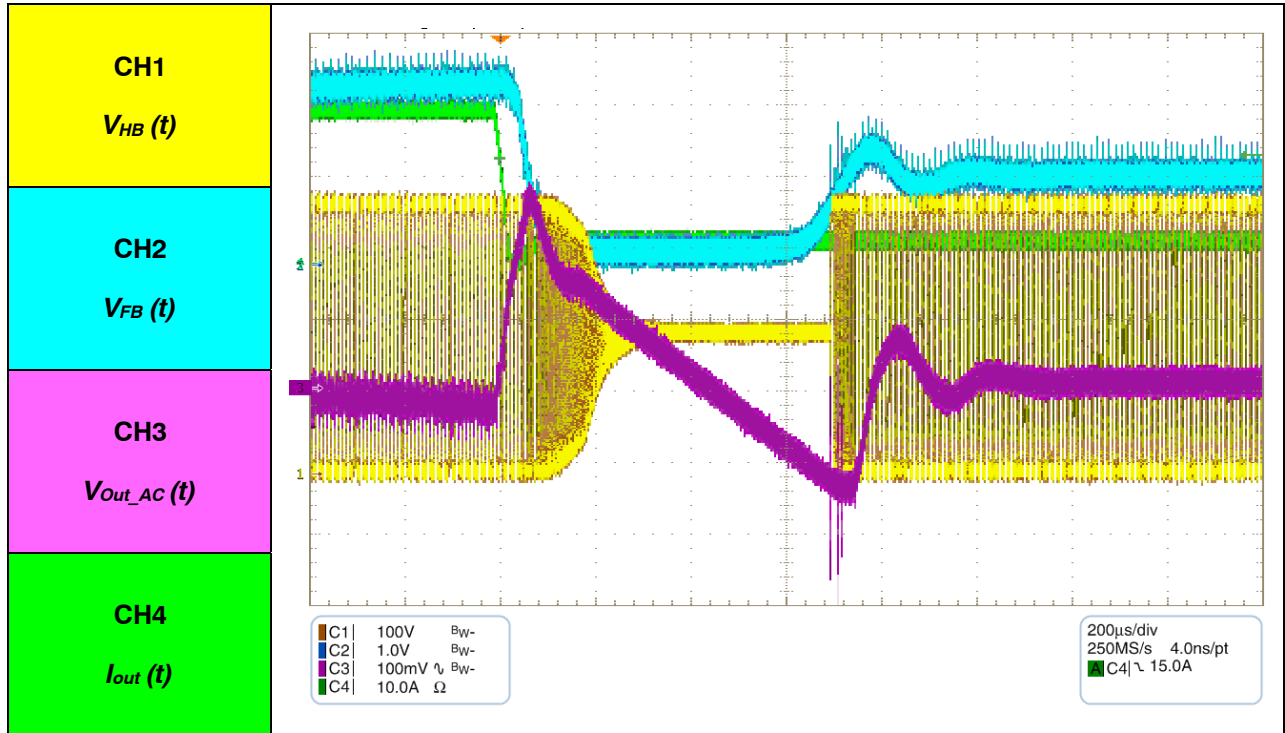


Figure 20. Step Load 30 A – 3 A

NCP13994MM360WGEVB

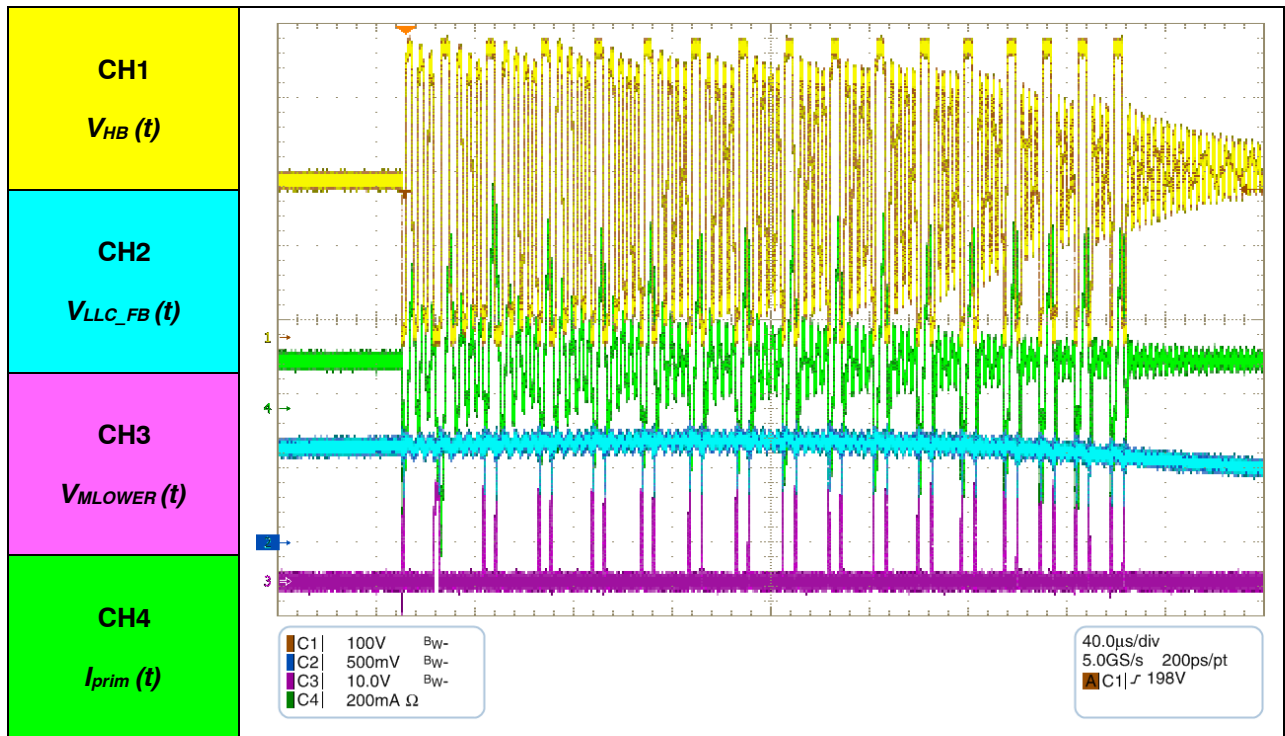


Figure 21. LLC SKIP MODE, No-Load

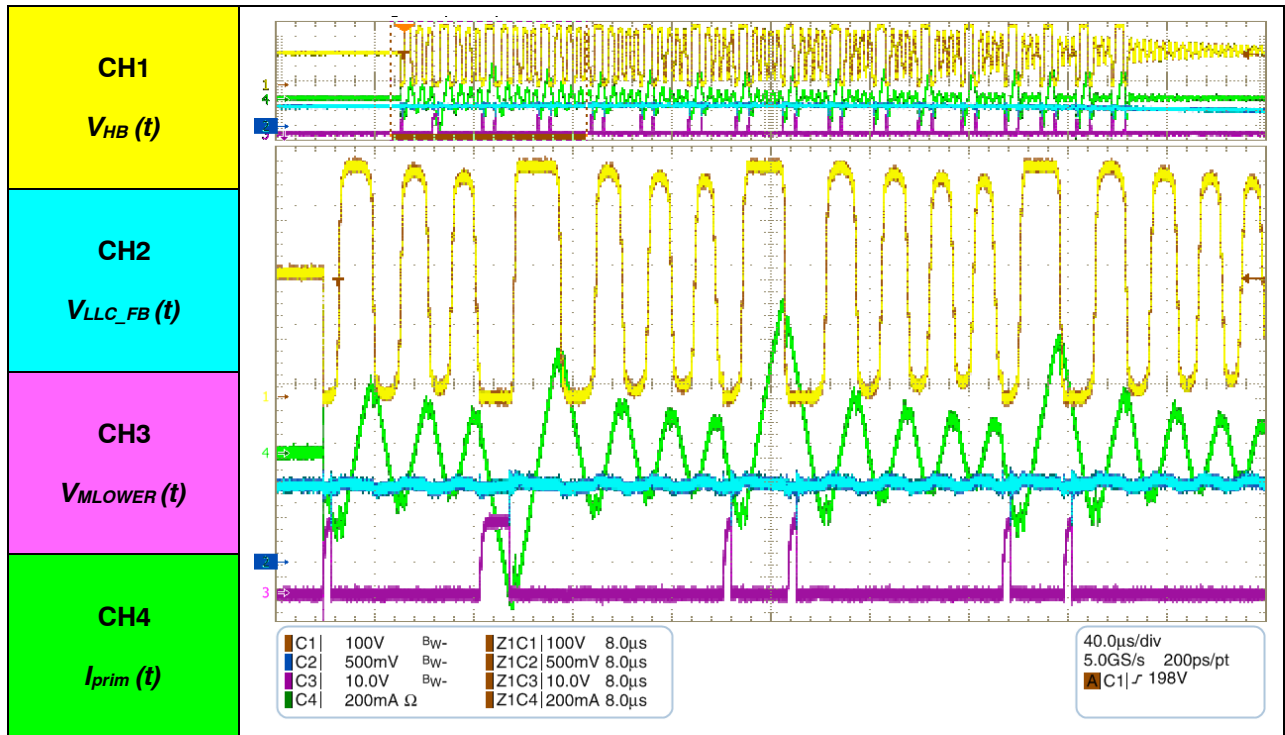


Figure 22. LLC SKIP MODE, No-Load – Detailed View

NCP13994MM360WGEVB

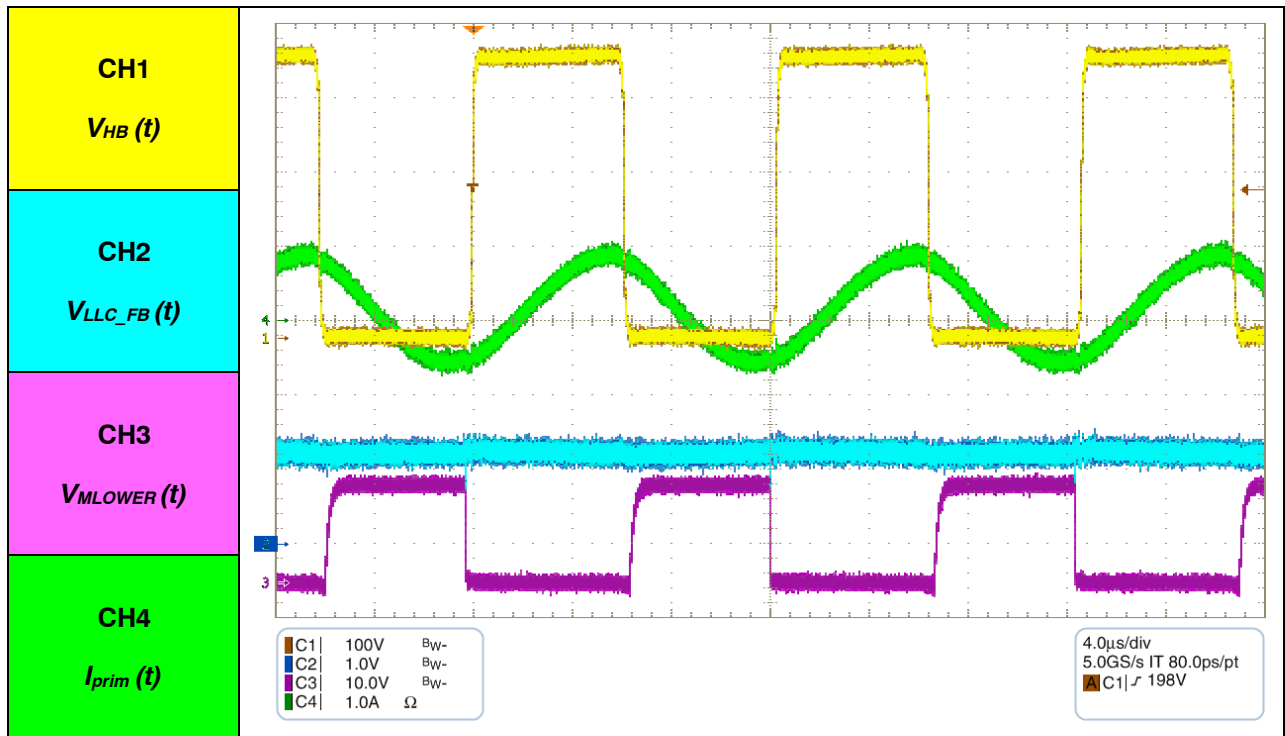


Figure 23. LLC NORMAL MODE, LOAD 3 A

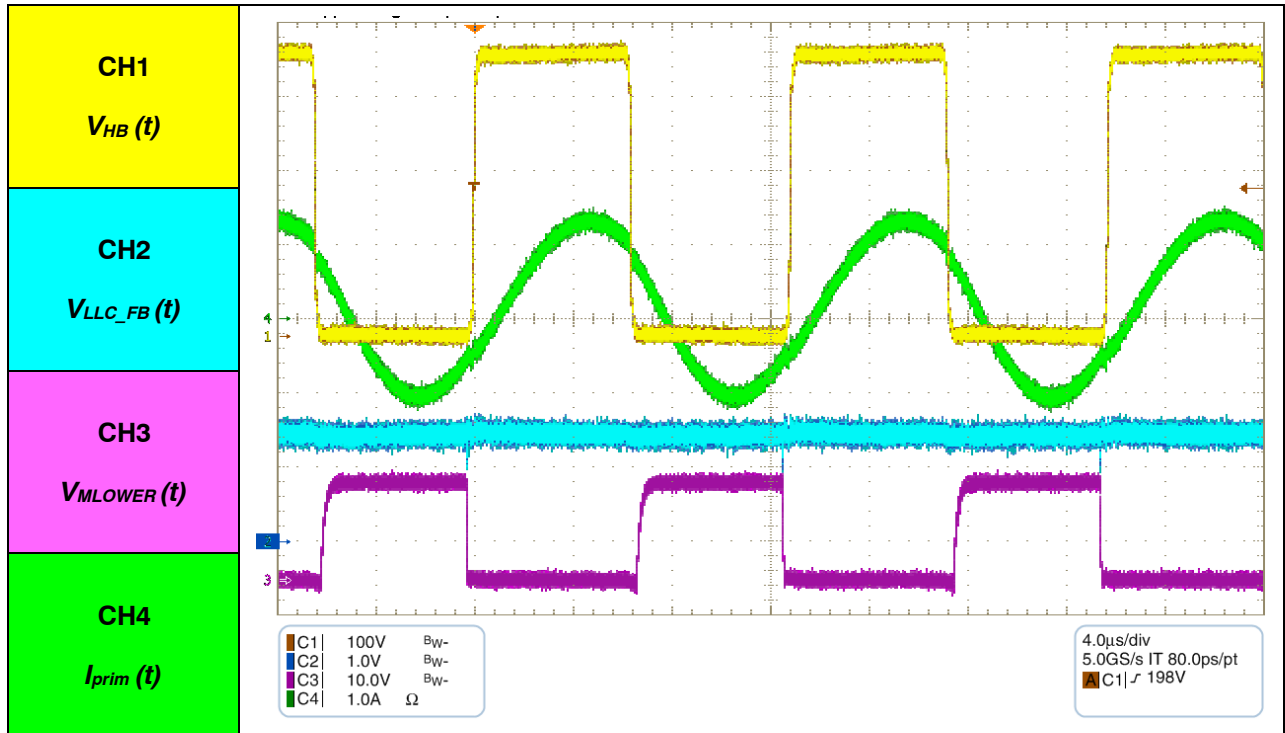


Figure 24. LLC NORMAL MODE, LOAD 10 A

NCP13994MM360WGEVB

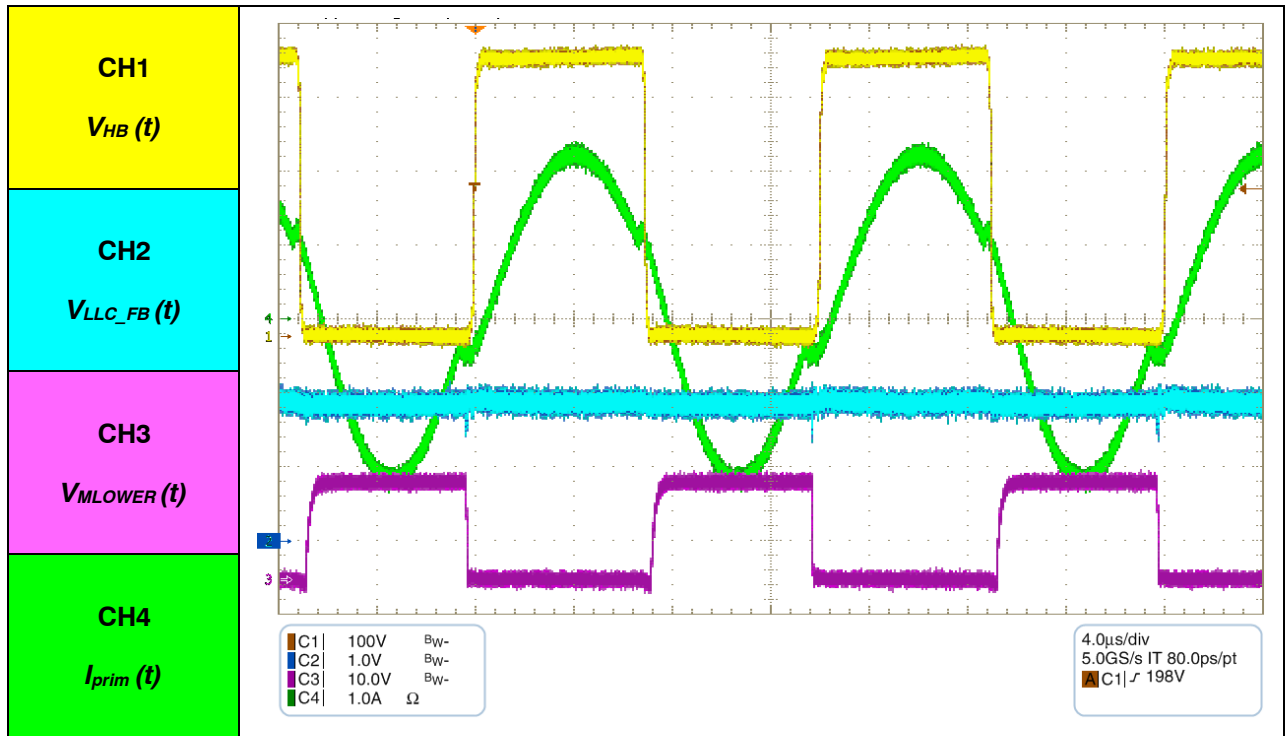


Figure 25. LLC NORMAL MODE 20 A

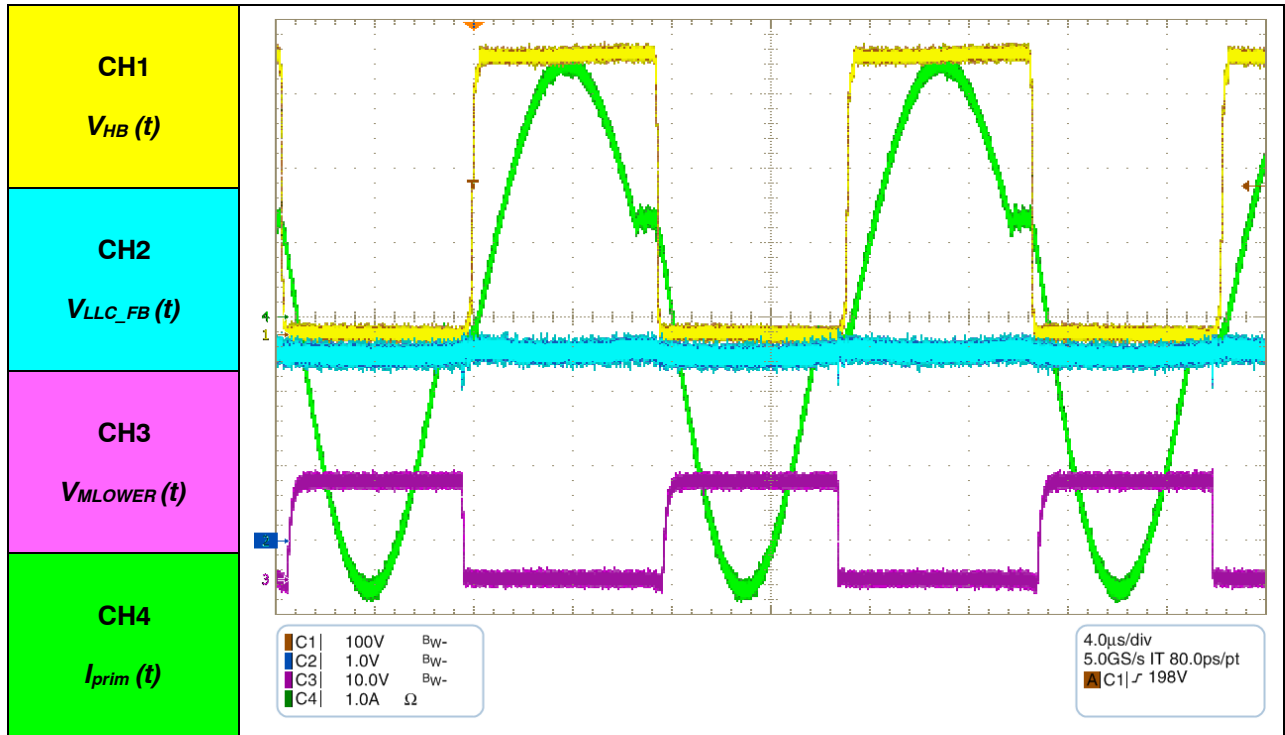


Figure 26. LLC NORMAL MODE, LOAD 30 A

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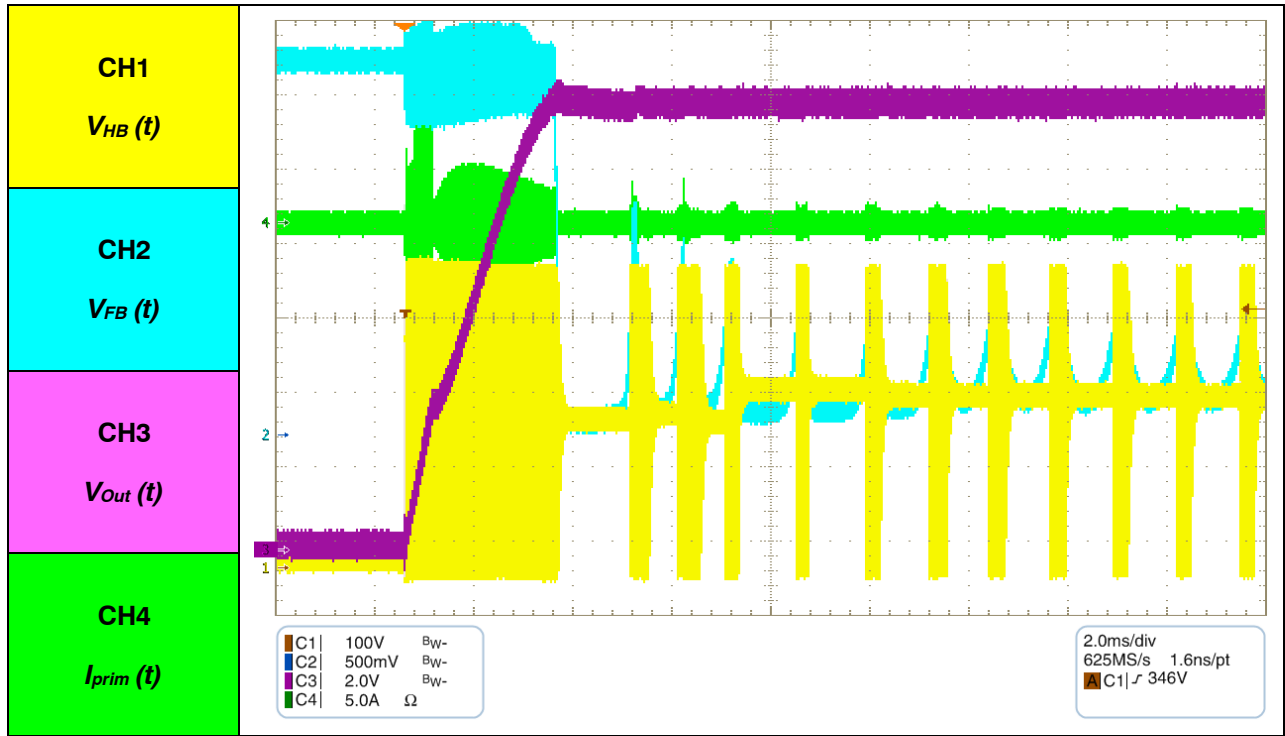


Figure 27. LLC START-UP into 0 A

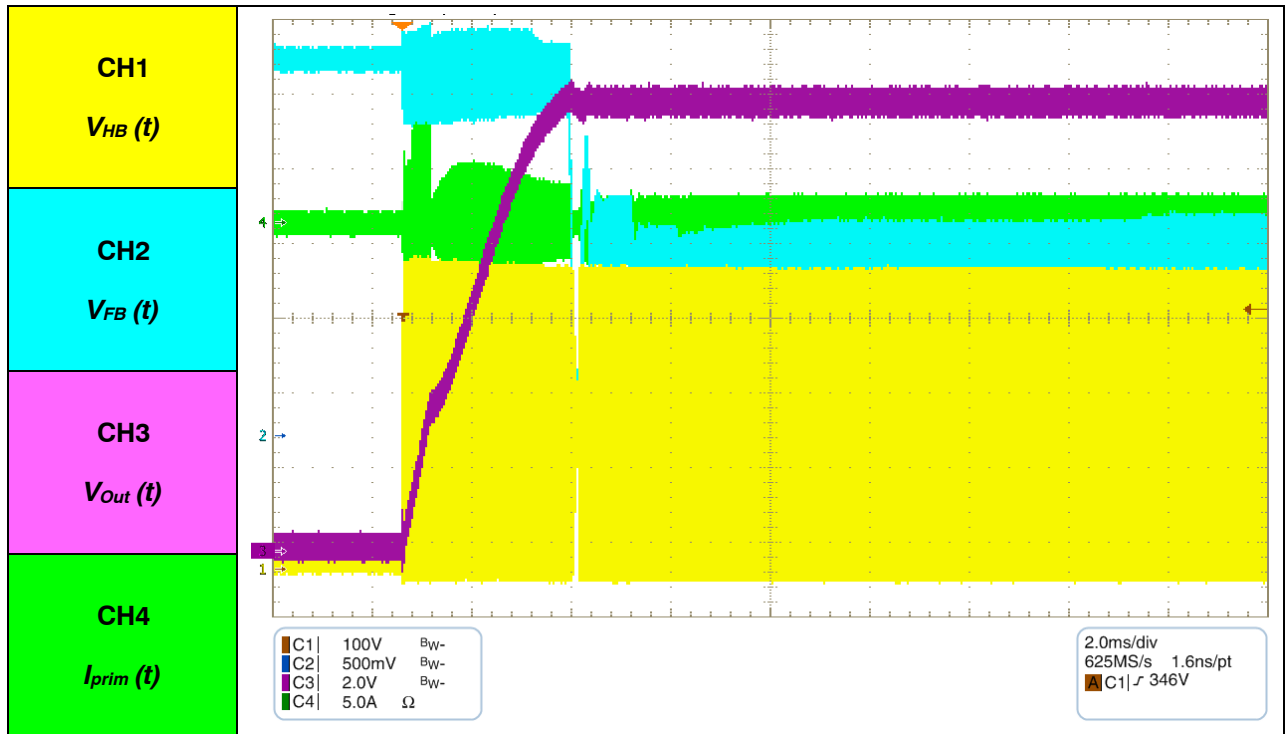


Figure 28. LLC START-UP into 10 A

NCP13994MM360WGEVB

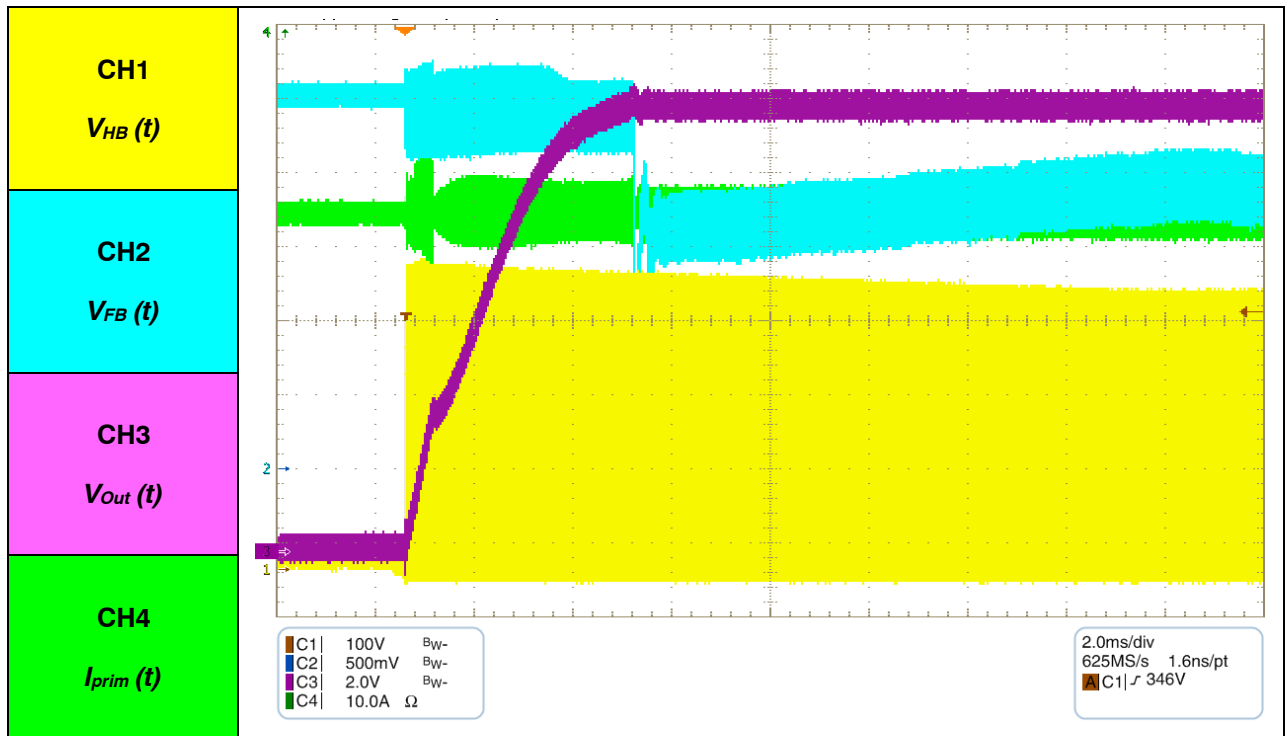


Figure 29. LLC START-UP into 20 A

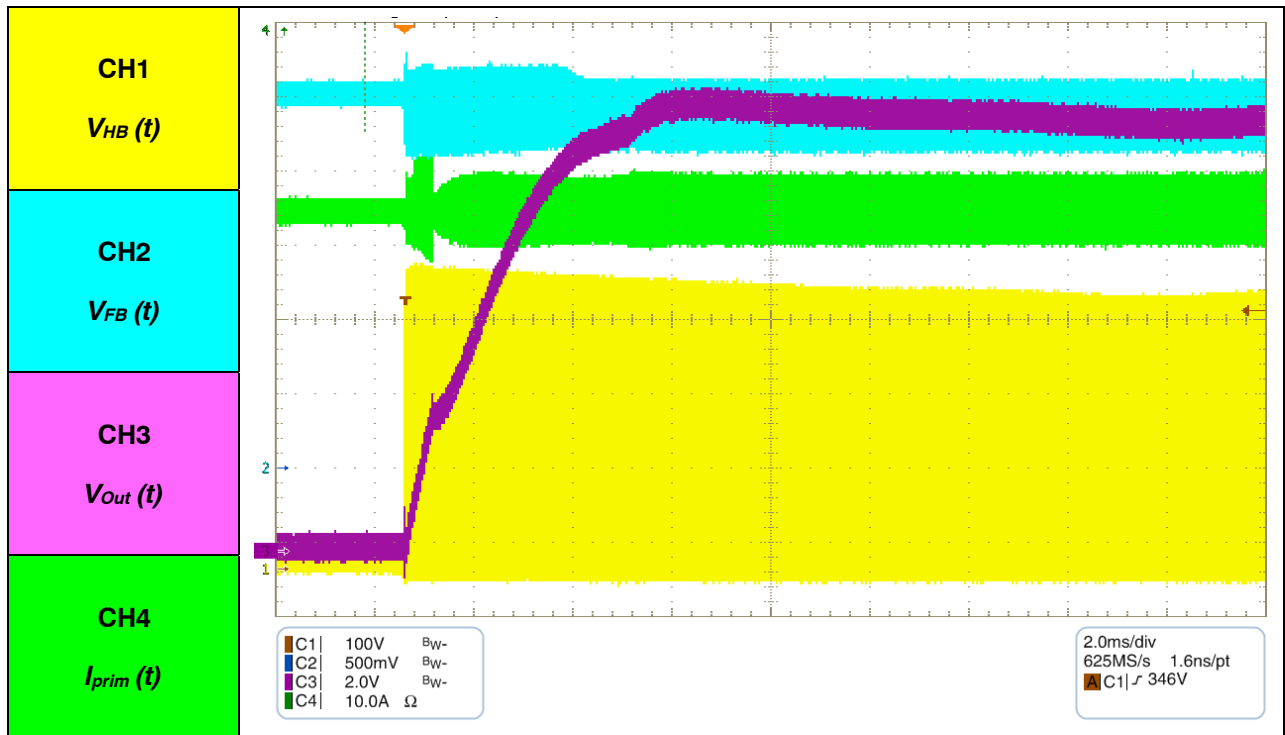


Figure 30. LLC START-UP into 30 A

NCP13994MM360WGEVB

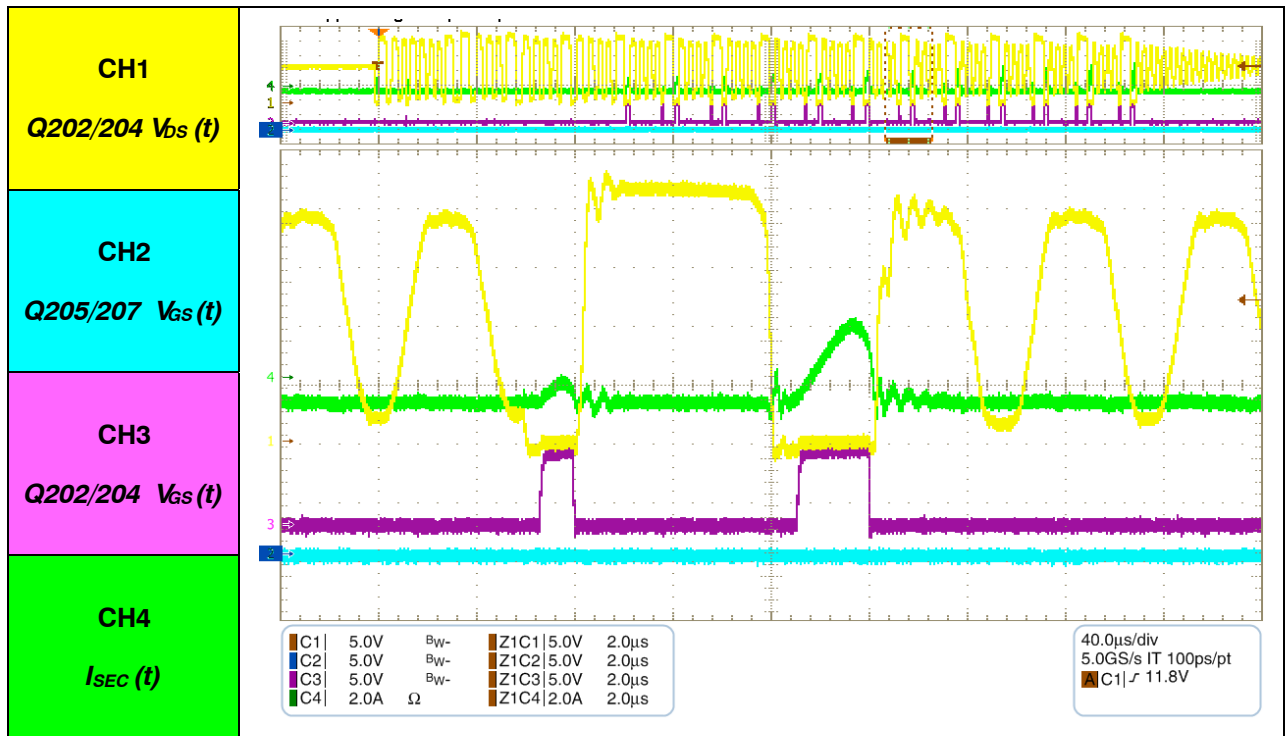


Figure 31. Secondary Side SR Operation – 0 A

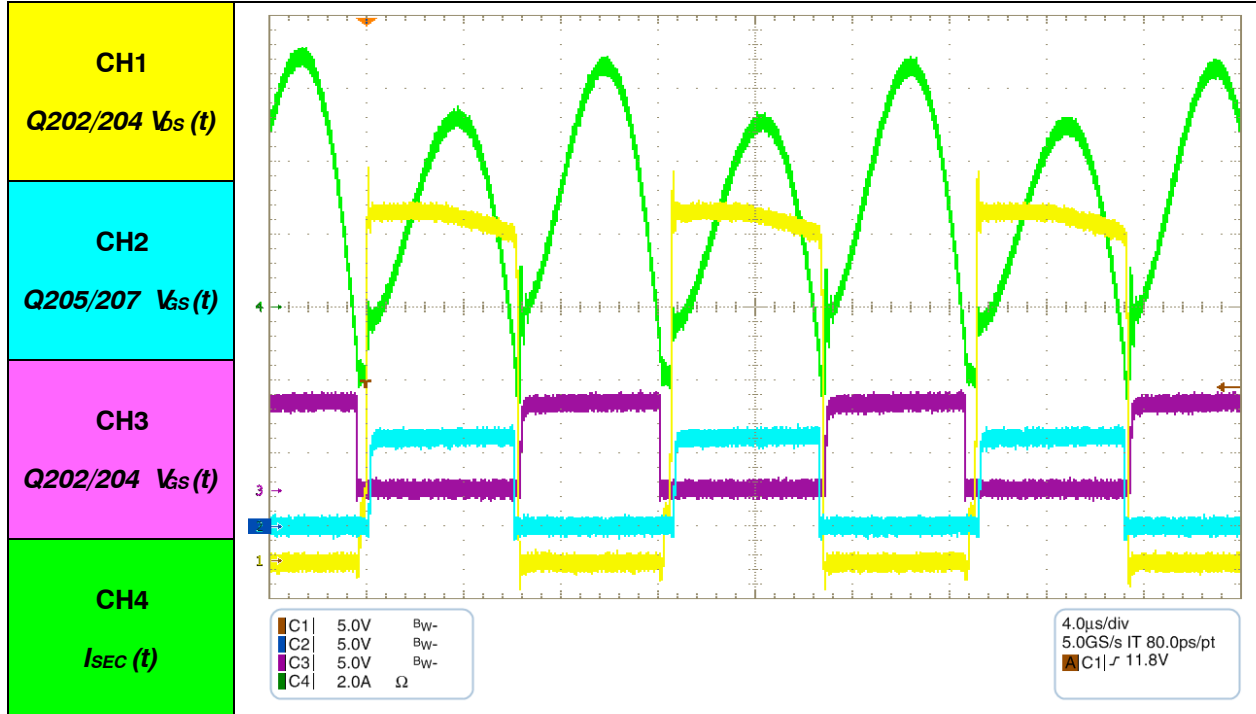


Figure 32. Secondary Side SR Operation – 5 A

NCP13994MM360WGEVB

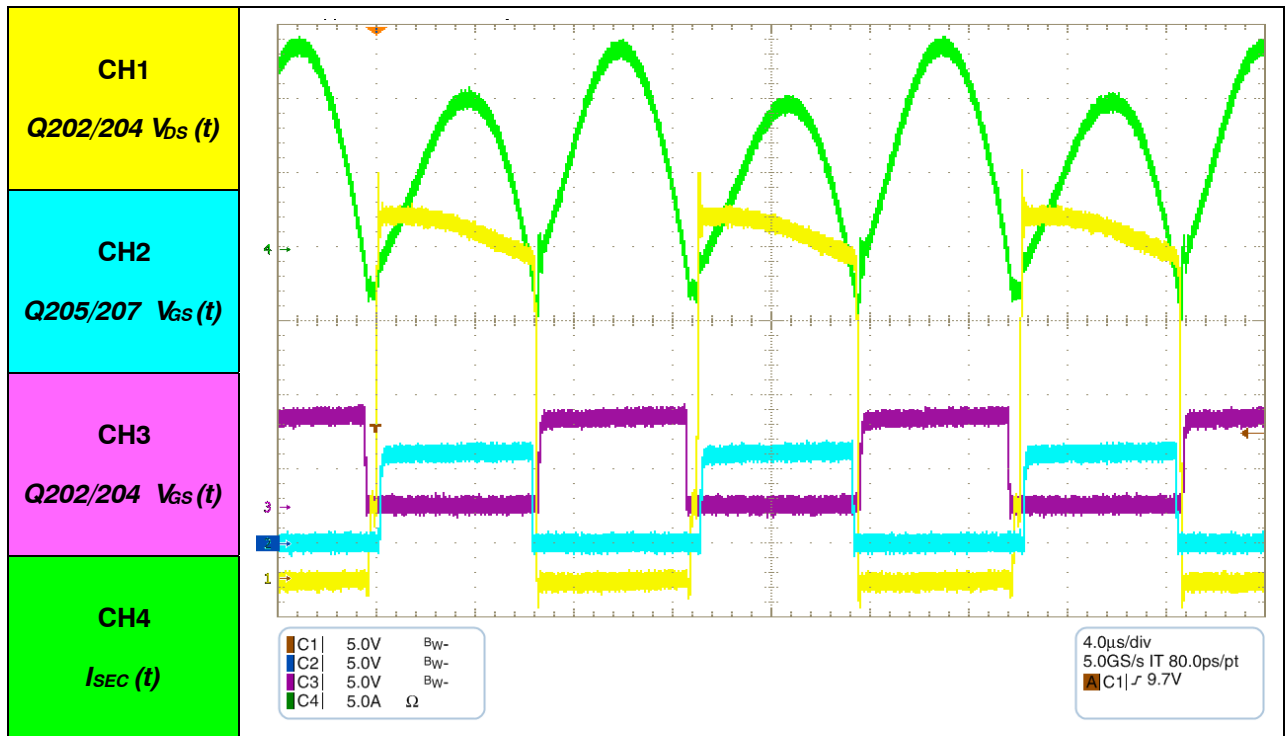


Figure 33. Secondary Side SR Operation – 10 A

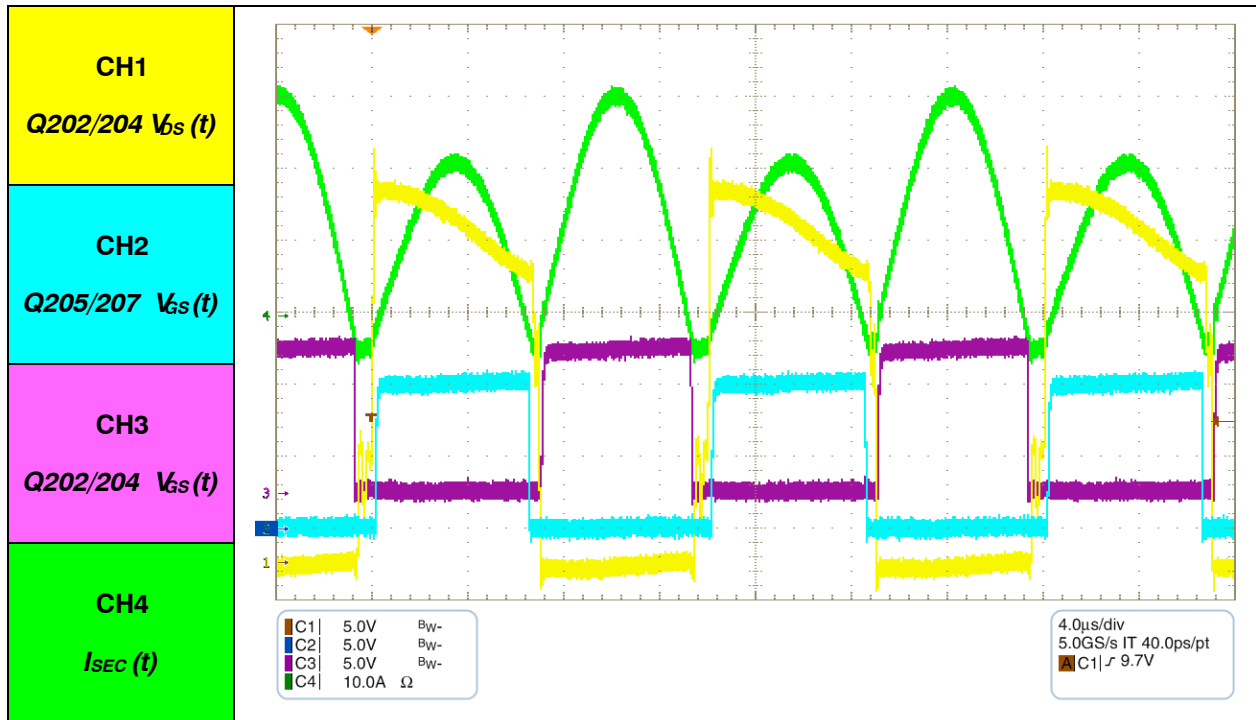


Figure 34. Secondary Side SR Operation – 20 A

NCP13994MM360WGEVB

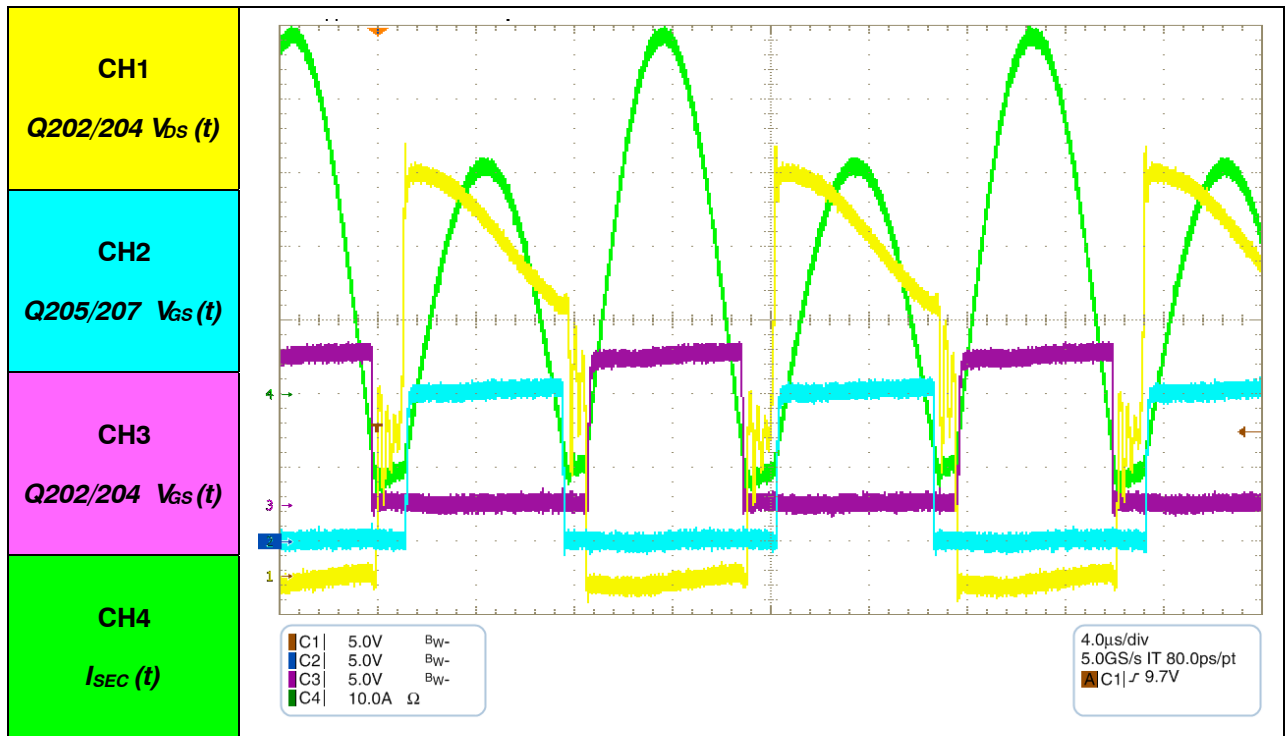


Figure 35. Secondary Side SR Operation – 30 A

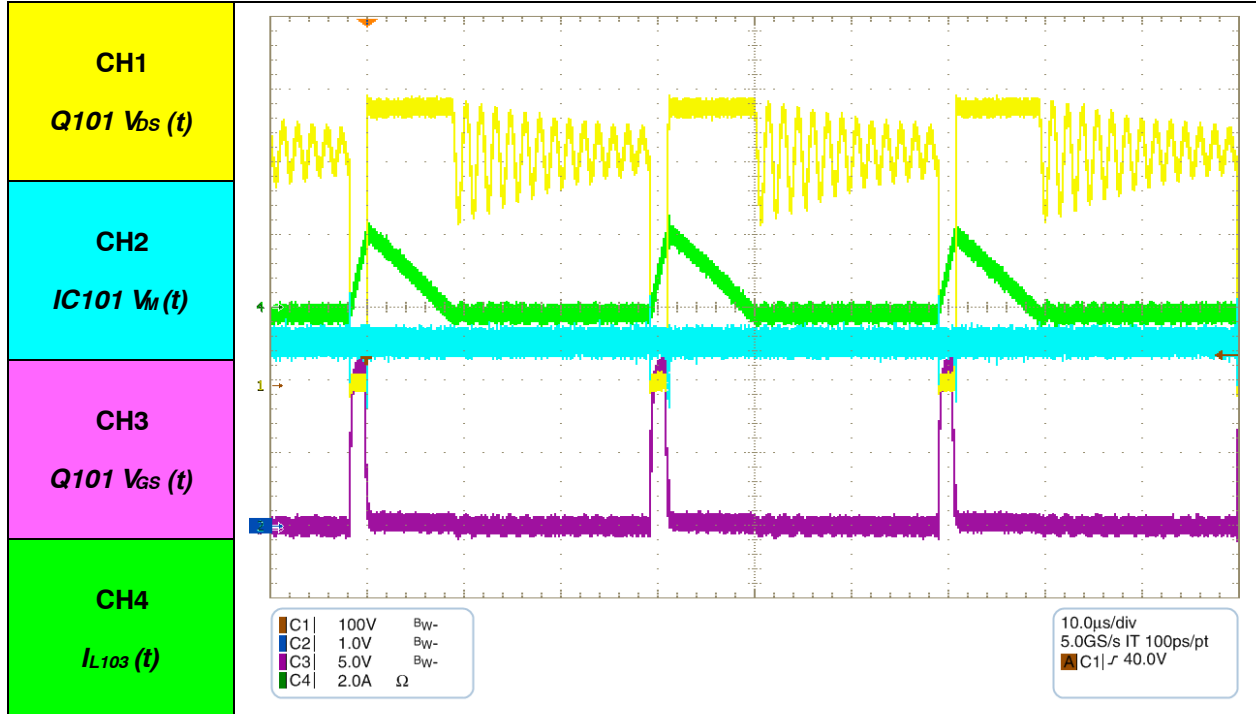


Figure 36. 230 V AC/ Load 5 A, PFC DCM MODE

NCP13994MM360WGEVB

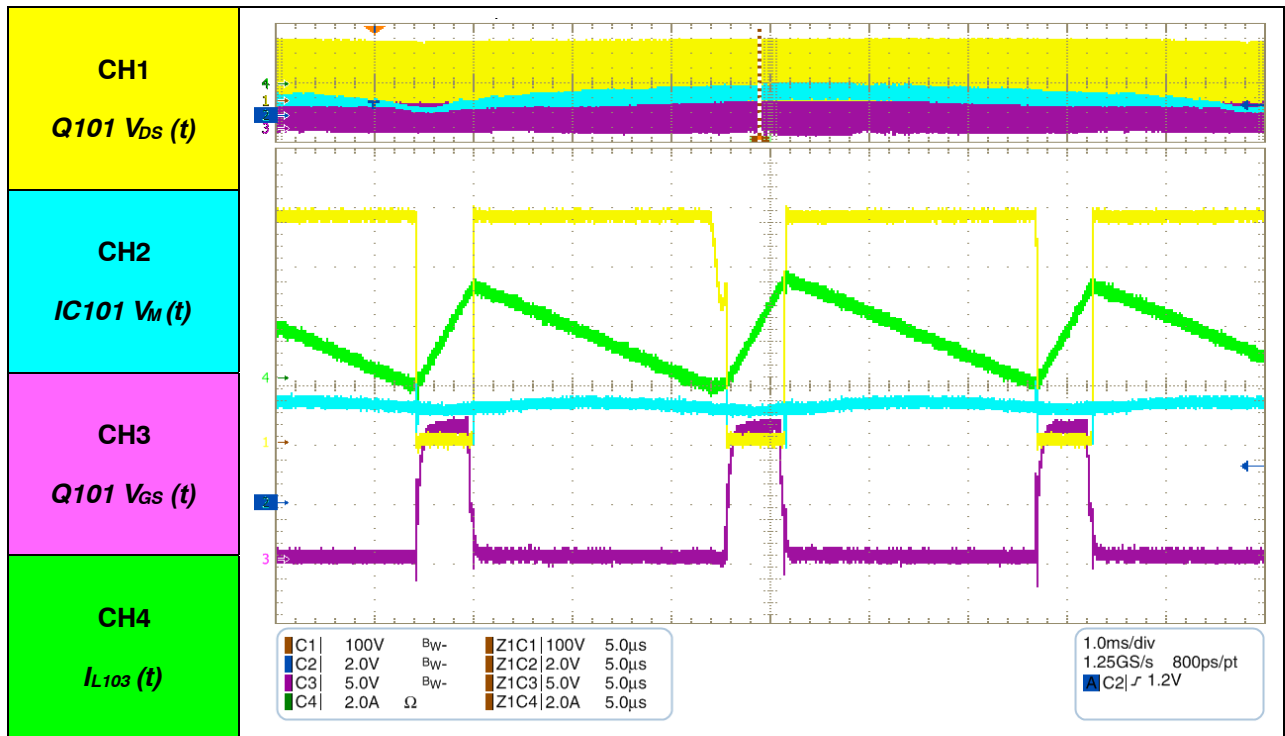


Figure 37. 230 V AC/ Load 24 A, PFC Transition DCM to CrM MODE



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

NCP13994MM360WGEVB

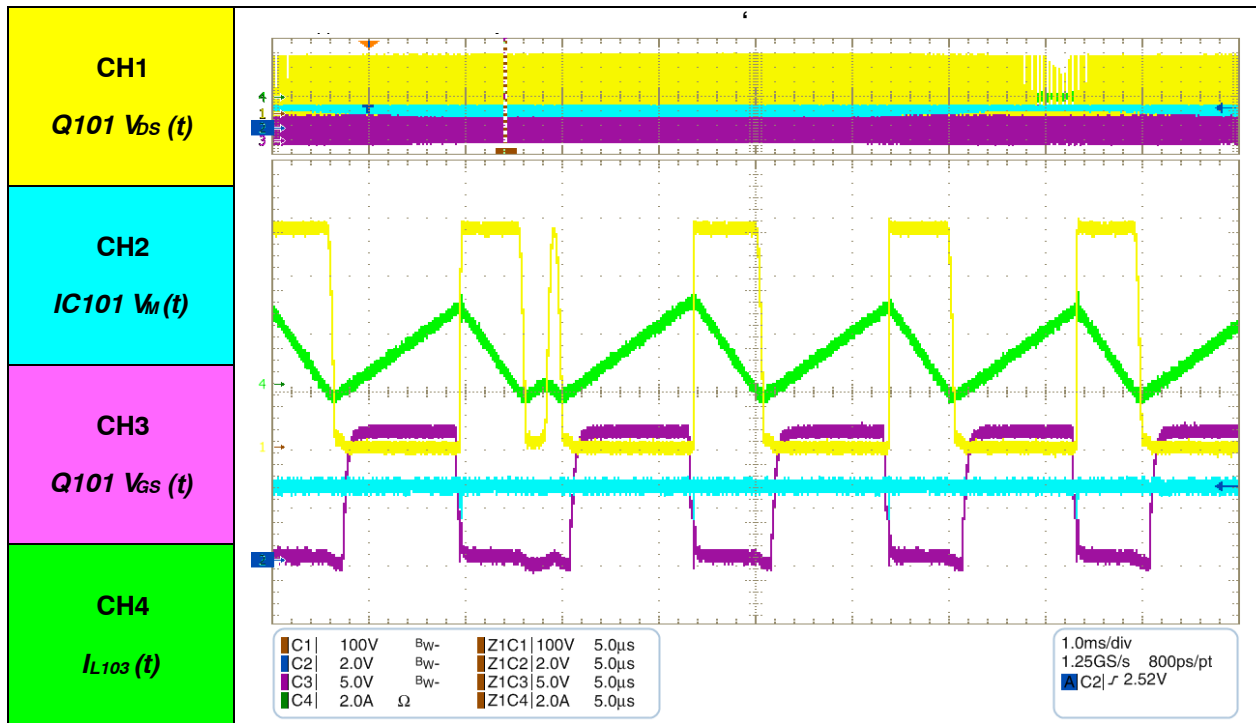


Figure 39. 110 V AC/ Load 9 A, PFC Transition DCM to CrM MODE

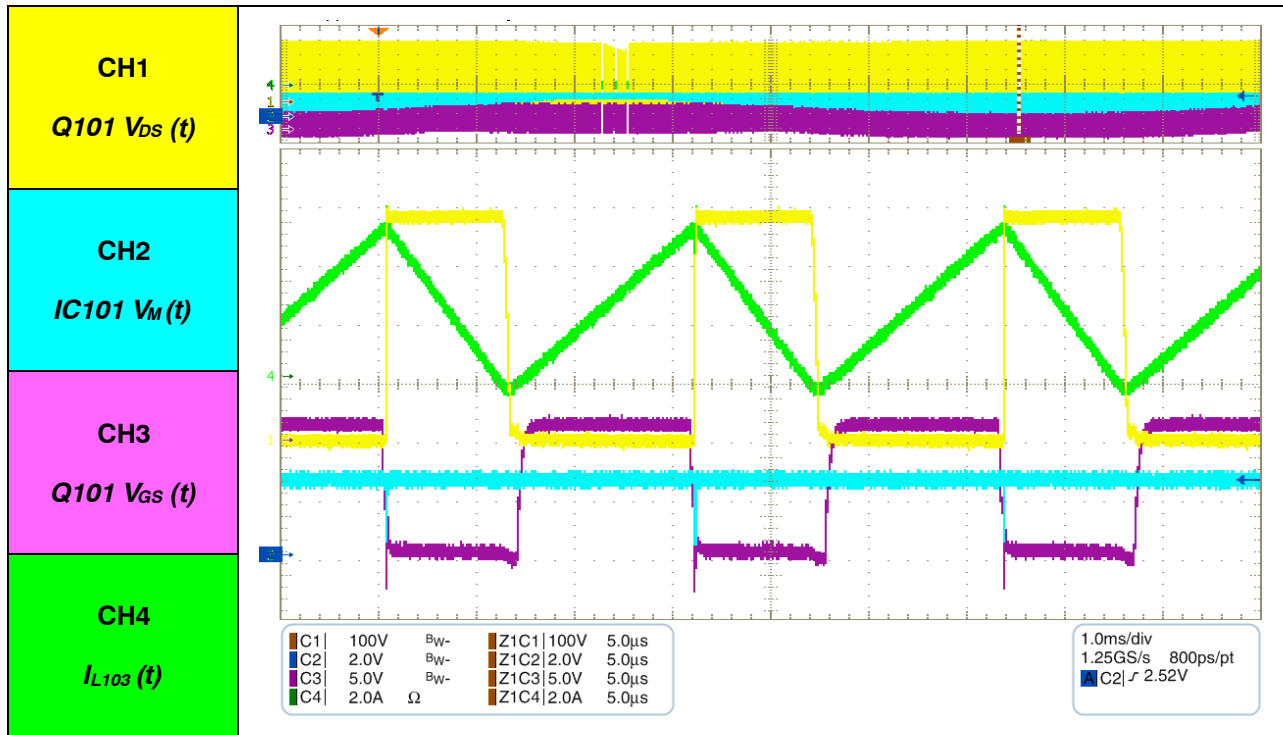


Figure 40. 110 V AC/ Load 15 A, PFC CrM MODE

NCP13994MM360WGEVB

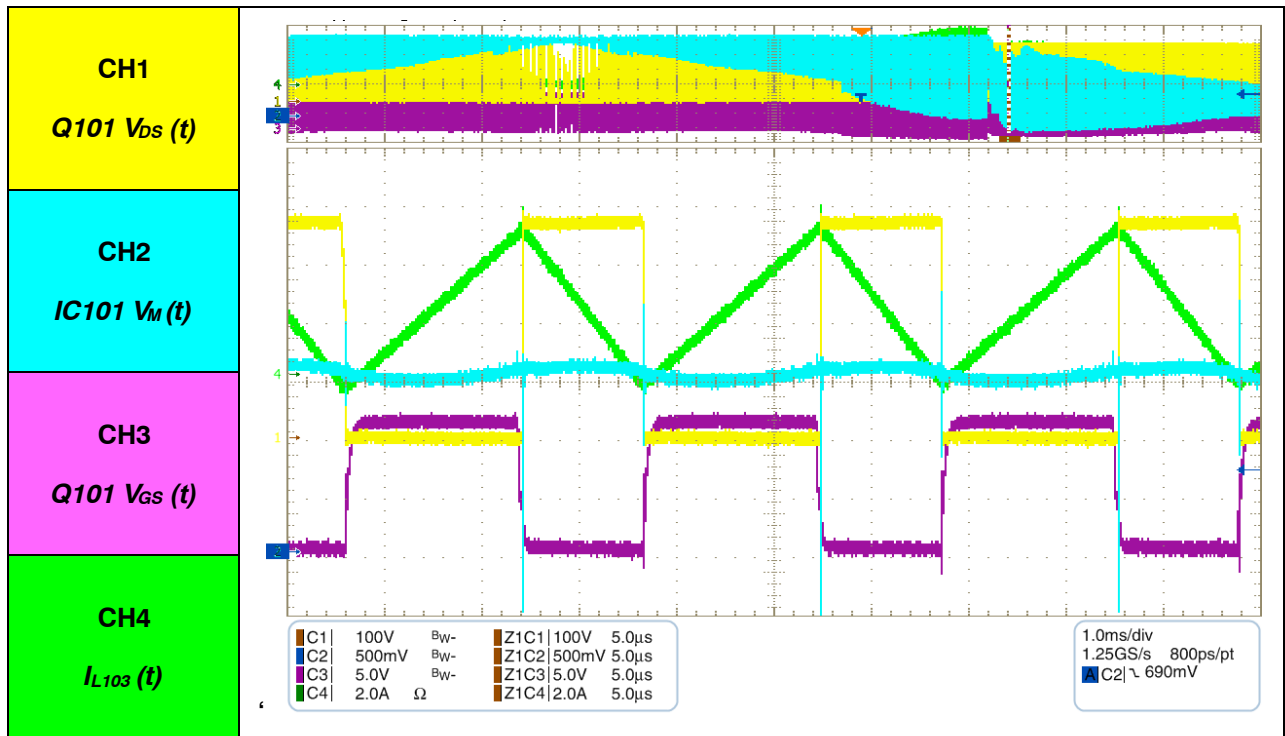


Figure 41. 110 V AC/ Load 7 A, PFC Transition CrM to CCM MODE

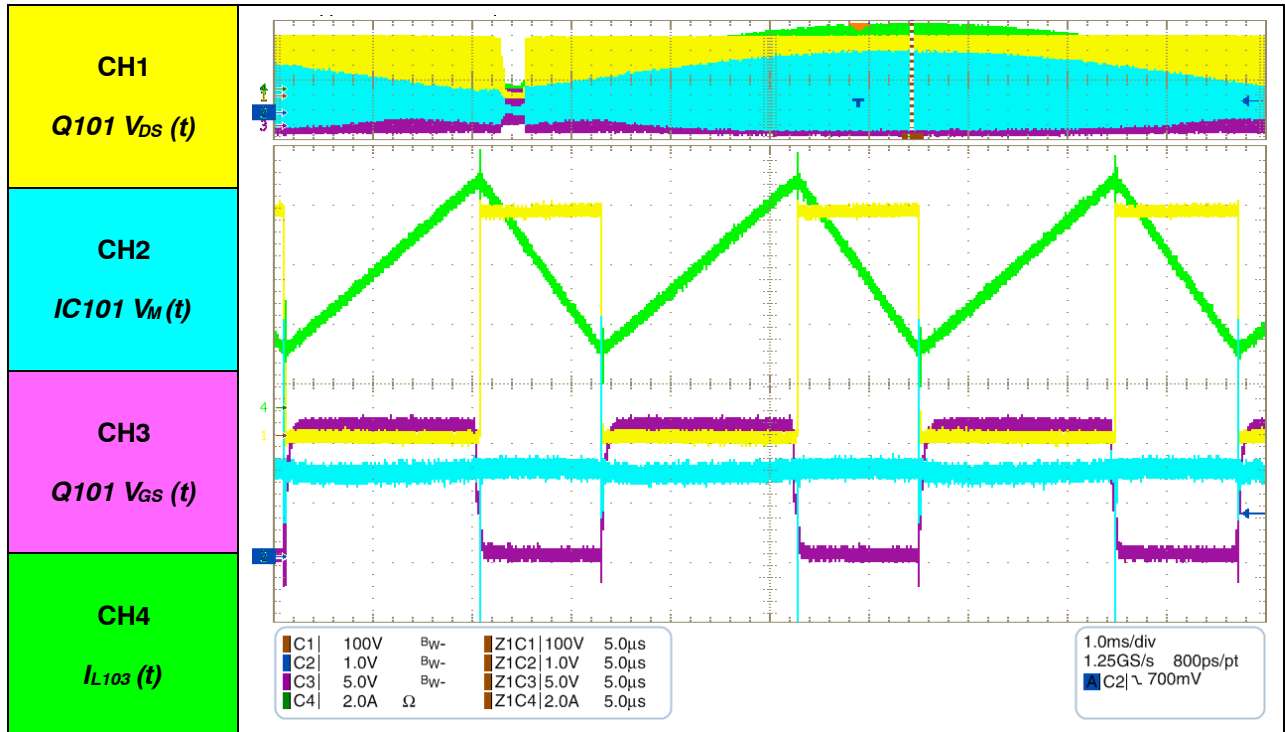


Figure 42. 110 V AC/ Load 30 A, PFC CCM MODE

NCP13994MM360WGEVB

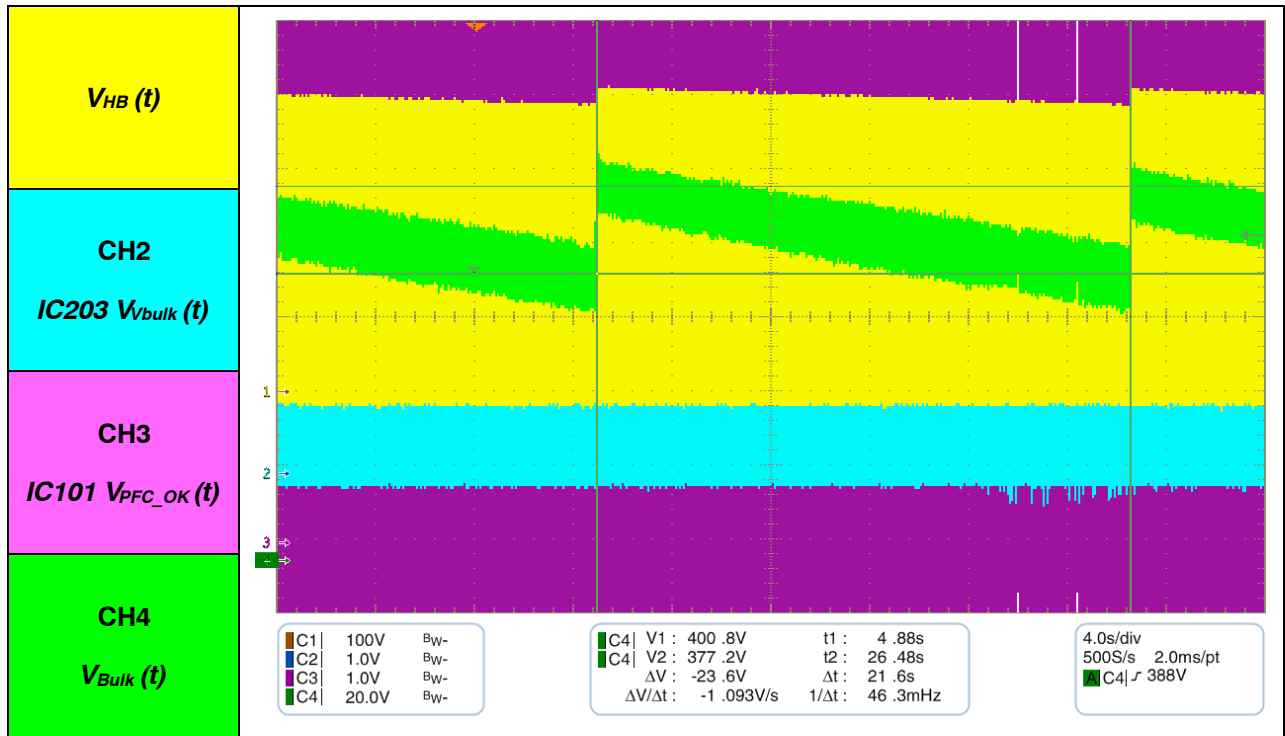


Figure 43. 230 V AC/ No-Load, PFC Soft-Skip Mode – V_{Bulk} Hiccups

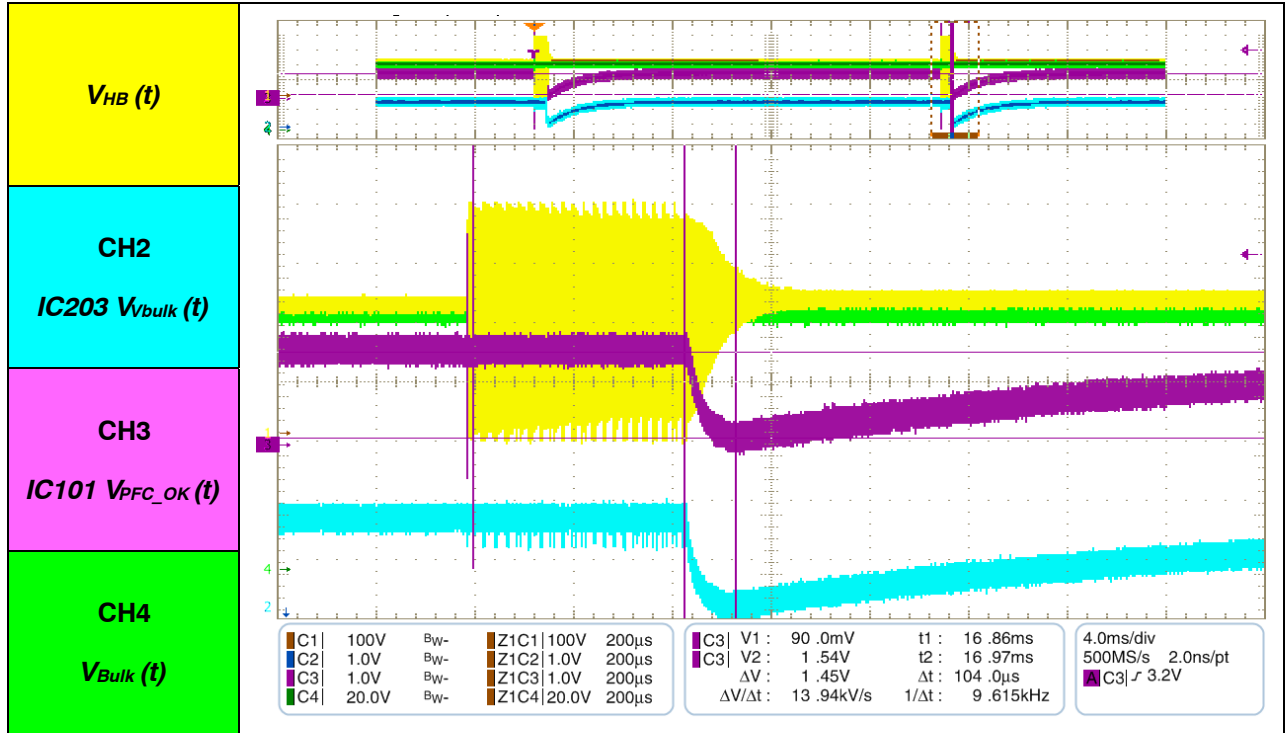


Figure 44. 230 V AC/ No-Load, PFC Soft-Skip Mode – V_{Bulk} Hiccups – Detail

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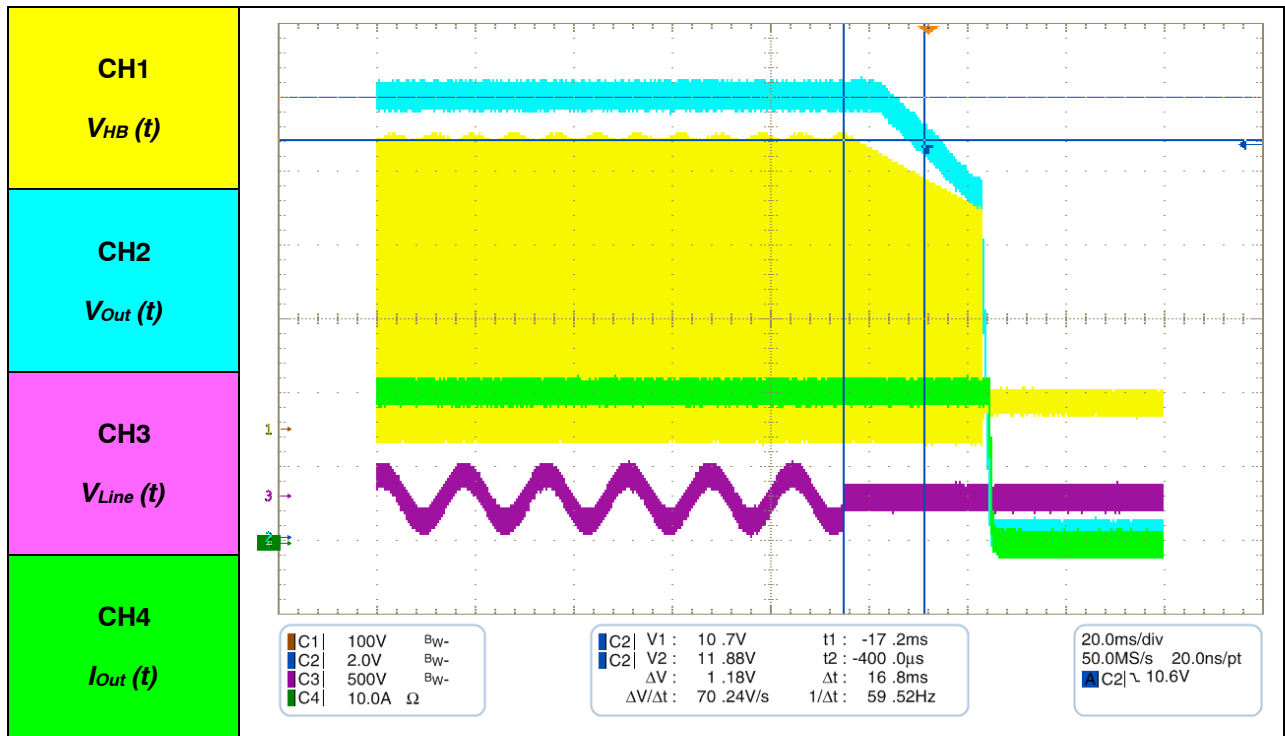


Figure 45. 110 V AC/ Load 30 A, Hold-Up Time for 10% Regulation ~ 17 ms

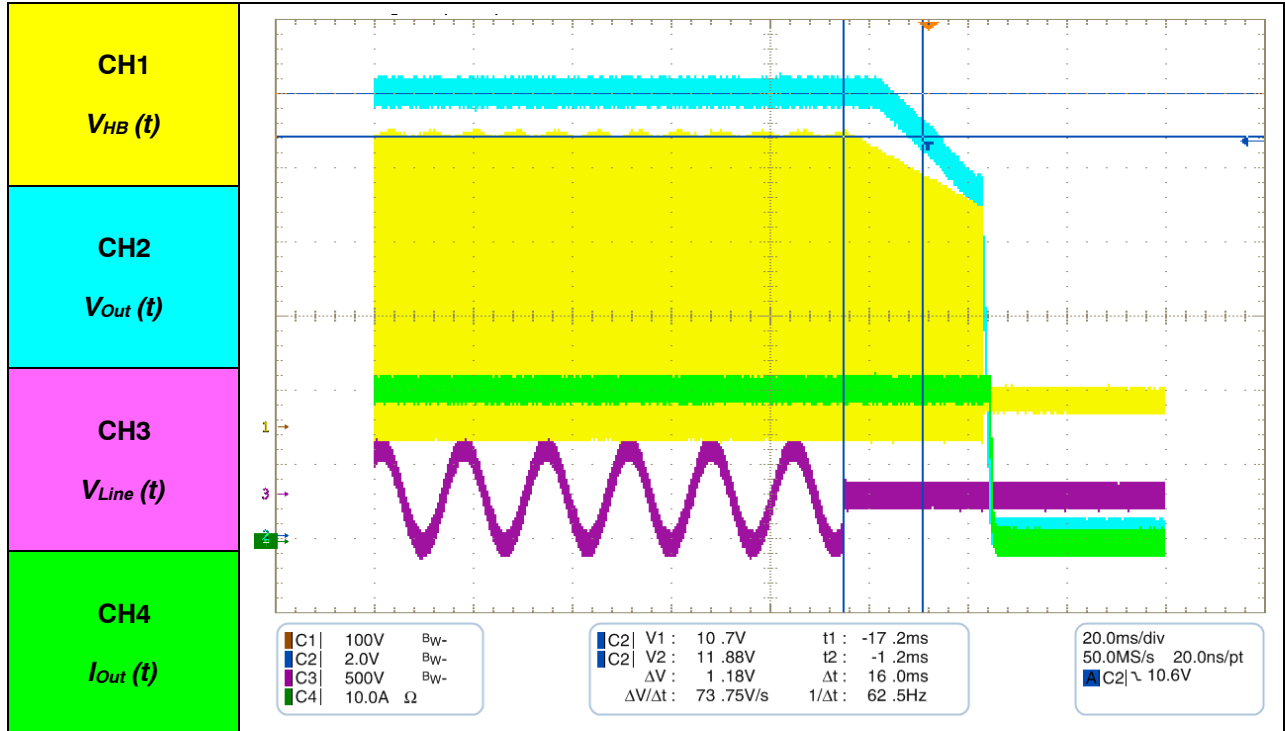


Figure 46. 230 V AC/ Load 30 A, Hold-Up Time for 10% Regulation ~ 16 ms

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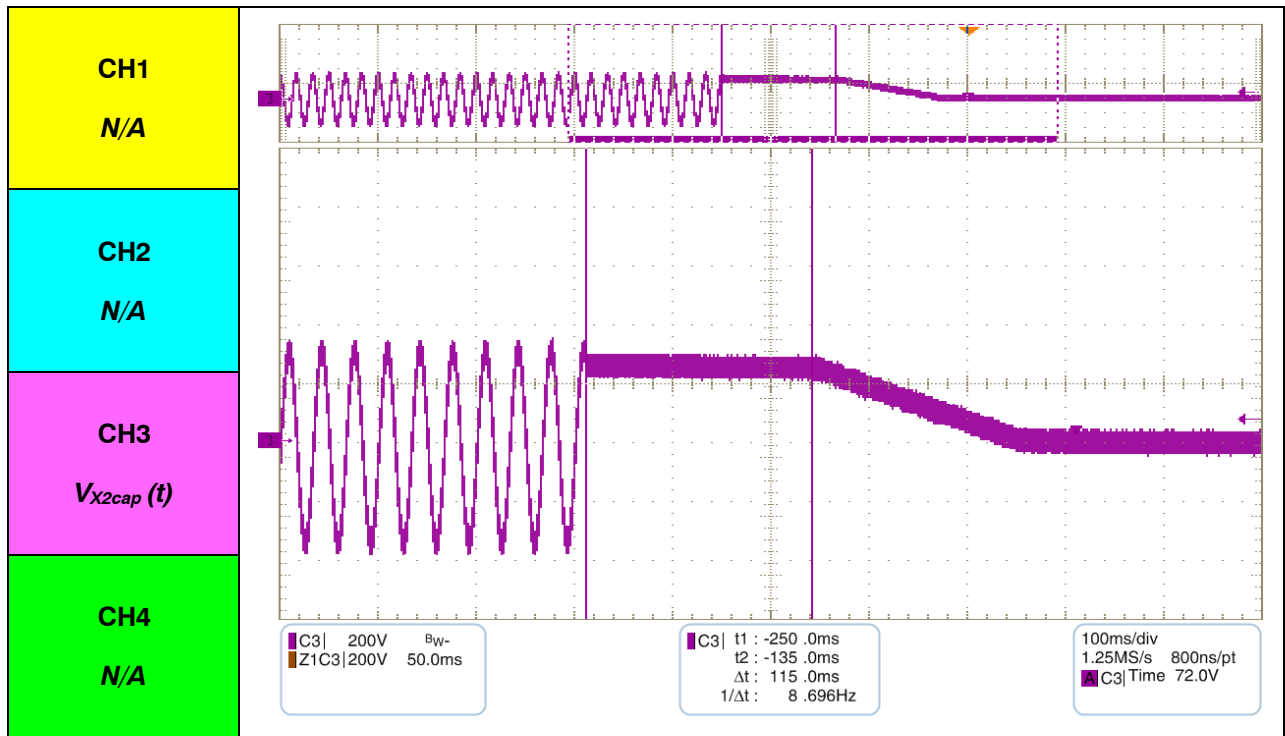


Figure 47. 230 V AC, X2 Cap Discharging after Line Unplug ~ 100 ms

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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 | Würth | 885012207092 | Allowed |
| C101 | 1 | 820 nF/275 V~ | C102-064X133 | MPP CAPACITOR | Würth | 890324025047CS | Allowed |
| C102 | 1 | 1 µF/275 V~ | C150-072X183 | MPP CAPACITOR | Würth | 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 | Würth | 885342007005 | Allowed |
| C106 | 1 | 22 nF/200 V | C0805 | CAPACITOR | Würth | 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 | Würth | 885012007059 | Allowed |
| C109, C220 | 2 | 470 pF/50 V | C0805 | CAPACITOR | Würth | 885012007061 | Allowed |
| C110 | 1 | 3.3 nF/50 V | C0805 | CAPACITOR | Würth | 885012007066 | Allowed |
| C111, C224 | 2 | 1 µF/25 V | C0805 | CAPACITOR | Würth | 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 | Würth | 860040474004 | Allowed |
| C114 | 1 | 15 pF/50 V | C0805 | CAPACITOR | Würth | 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 | Würth | 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 | Würth | 860010574011 | Allowed |
| C208, C209 | 2 | 1 nF/50 V | C0805 | CAPACITOR | Würth | 885012007063 | Allowed |
| C210 | 1 | 2.2 µF/25 V | C0603 | CAPACITOR | Würth | 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 | Würth | 885012207068 | Allowed |
| C233 | 1 | 1.5 nF/50 V | C0805 | CAPACITOR | Würth | 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 |

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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 | Würth | 7447013 | Allowed |
| L104 | 1 | 260 µH | PQ32/25 | PFC INDUCTOR | Sumida | T92063 | Allowed |
| L202 | 1 | - | 09X05 | FERRITE BEAD | Würth | 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 |

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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 μ H/ n = 17 | PQ3220 | LLC TRANSFORMER | Sumida | T92060 | Allowed |
| X101, X201 | 2 | Pitch 5.08 mm | WR-TBL Series 2365 | SCREW TERMINAL | Würth | 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/datasheet/ncp431-d.pdf>

N-Channel SUPREMOS[®] MOSFET 600 V, 22 A, 165 m Ω :

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 m Ω , 19 A:

NTPF165N65S3H: <https://www.onsemi.com/pdf/datasheet/ntpf165n65s3h-d.pdf>

Single N-Channel Power MOSFET 40 V, 130 A, 2.5 m Ω :

NVMFS5C442NL: <https://www.onsemi.com/pub/Collateral/NVMFS5C442NL-D.PDF>

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