3 kW telecom rectifier test report

Introduction

The STDES-3KWTLCP reference design introduces a complete ST digital power solution for a 3 kW/53.5 V power supply targeting the latest 5G telecom rectifier application.

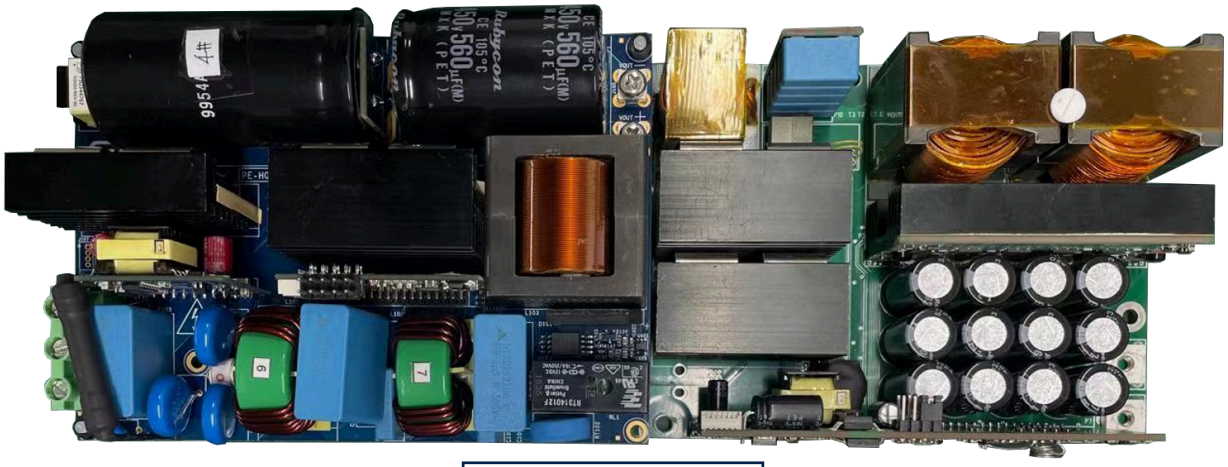
The circuit configuration consists of a front-end AC-DC bridgeless totem pole converter and a back-end DC-DC isolated full-bridge LLC converter. The front-end totem pole converter provides power factor correction (PFC) and total harmonic distortion (THD). The LLC converter provides safety isolation and a tightly regulated output voltage.

This reference design opens the path to a compact solution and offers a high peak efficiency. The measured peak efficiency of the complete PSU at 230 V_{AC} is 96.3%. The overall outline dimensions of the PSU are 105 mm x 281 mm x 41 mm, which yields a power density up to 40 W/inch³.

The STDES-3KWTLCP is a fully assembled kit developed for performance evaluation only, not available for sale.

This document describes the converter hardware, a summary of the experimental results, and the design recommendations for the complete ST solution.

Figure 1. STDES-3KWTLCP 3 kW telecom rectifier reference design



Fully assembled board developed for performance evaluation only, not available for sale

1 Safety instructions

Attention: *This evaluation kit is designed for demonstration purposes only and is not intended for domestic or industrial installations.*

Danger: *The high voltage levels used to operate this evaluation board could provoke a serious electrical shock. This evaluation board has to be used in a suitable laboratory by qualified personnel only, familiar with the installation, use, and maintenance of power electrical systems.*

During operation, do not touch the board as some of its components could reach a very high temperature.

2 Kit overview

2.1 Features

- Input voltage range: 90 to 264 V_{AC}
- Output voltage: 53.5 V
- Maximum output power: 3 kW at 230 V, 1.5 kW at 115 V_{AC}
- Peak efficiency: 96.3%
- Power density: 40 W/in^3
- Power factor >0.98 at 100% load
- Total harmonic distortion <5% at 100% load

2.2 Specifications

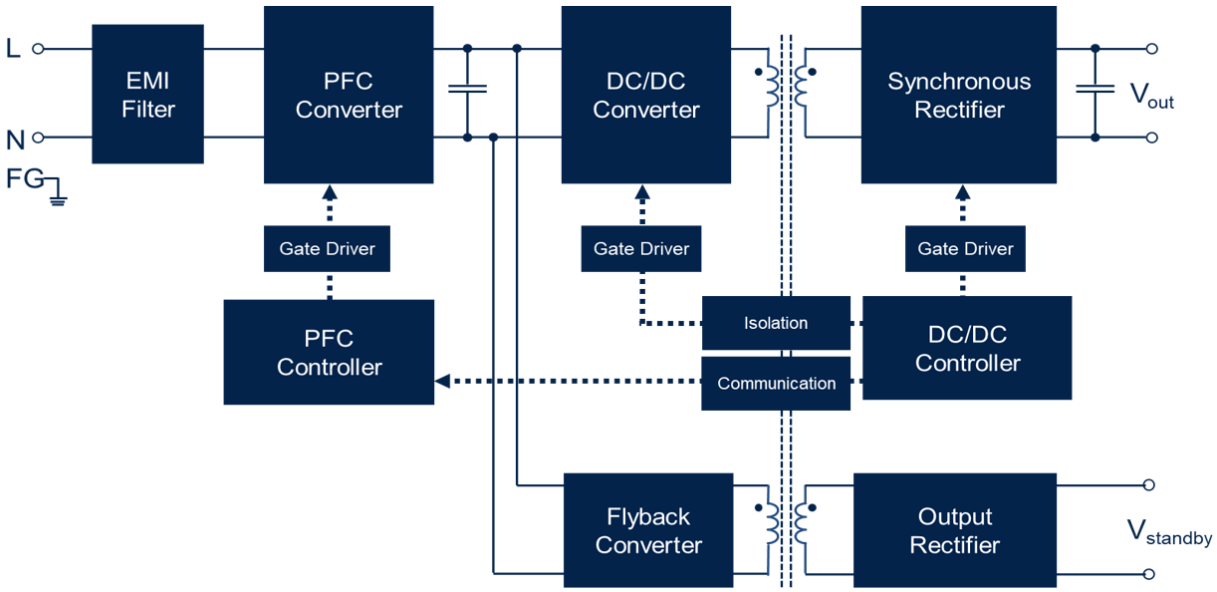
Table 1. STDES-3KWTLCP electrical specifications

Symbol	Description	Conditions	Min.	Typical	Max.	Units
V_{AC}	Input AC voltage	-	90		264	V
f_{AC}	Input AC frequency	-	47		63	Hz
V_{out}	Output voltage	25%-50%-25% dynamic load	50.8	53.5	56.2	V
P_{out}	Output power	V_{AC} = 115 V			1500	W
		V_{AC} = 230 V			3000	W
I_{out}	Output current	V_{AC}=115 V			28	A
		V_{AC} = 230 V			56	A
η	Peak efficiency	V_{AC} = 230 V_{AC}		96		%
iTHD	Total harmonic distortion	V_{AC} = 230 V_{AC}/3000 W		5		%
		V_{AC} = 115 V_{AC}/1500 W				
PF	Power factor	V_{AC} = 230 V_{AC}/3000 W		0.98		
		V_{AC} = 115 V_{AC}/1500 W				
I_{inrush}	Inrush current				30	A
T_{holdup}	Holdup time	Full load	10			ms
V_{brown_out}	Input voltage protection		85			V
V_{brown_in}					87	V
PFC_OVP	PFC output voltage protection	V_{PFC_OVP}			450	V
PFC_OCP	PFC input current protection	I_{PFC_OCP}		20		A
LLC_OVP	LLC output voltage protection	V_{LLC_OVP}			59	V
LLC_OCP	LLC output current protection	I_{LLC_OCP}			65	A

2.3 Block diagram and simplified schematics

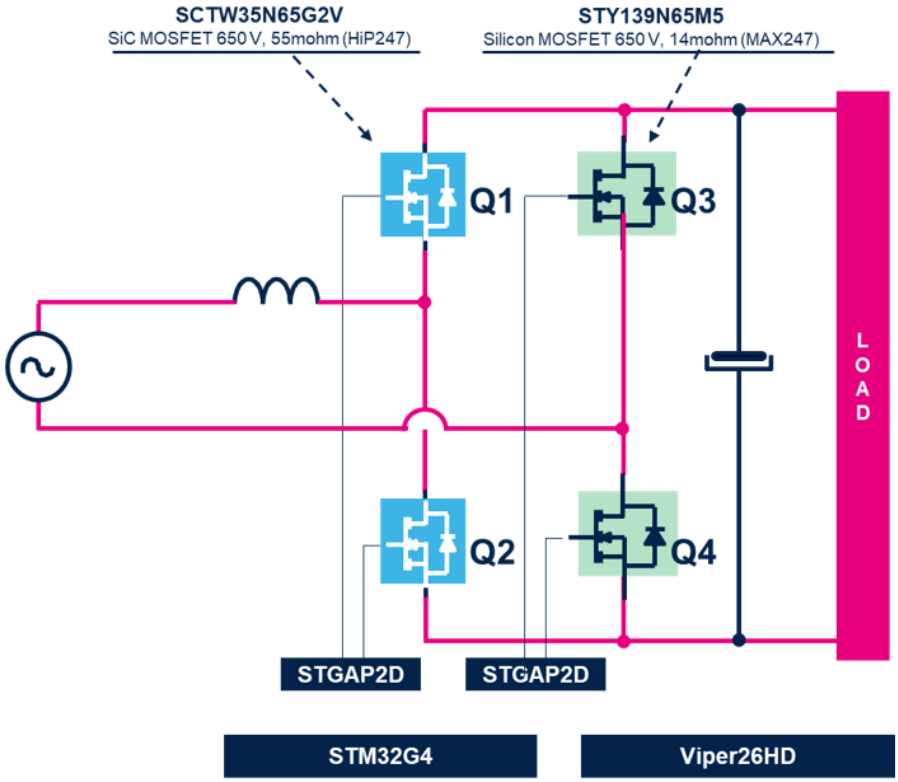
This AC-DC telecom rectifier consists of a PFC boost converter, which provides regulated bulk voltage from a universal AC input, while demanding a high-quality current from the grid. The DC-DC stage converts the bulk voltage to a 53.5 V regulated output. Both converters have a dedicated controller that manages the converter control as well as the system behavior.

Figure 2. **STDES-3KWTLCP block diagram**



The figure below shows the circuit configuration of the bridgeless totem pole PFC.

Figure 3. **Simplified schematic of the bridgeless totem pole PFC**



The high-speed leg uses the 650 V SIC MOSFETs (SCTW35N65G2V) for better reverse recovery capability and low parasitic parameters. This significantly reduces the switching loss.

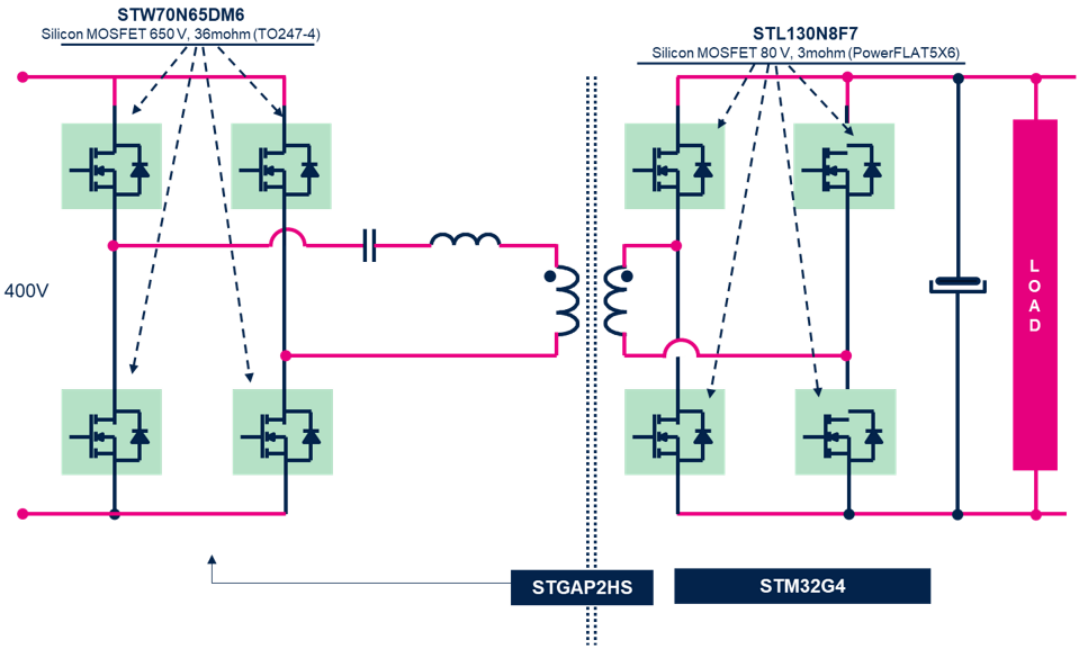
As there is a significant conduction loss on the low speed leg, a low $R_{ds(on)}$ super-junction MOSFET (STY139N65M5) is used to improve the overall efficiency.

The galvanic isolated driver IC is selected as a driving circuit. The STGAP2D provides a 4 A driving current capability. The common mode transient immunity (CMTI) is up to 100 V/ns.

An STM32G474RBT6 microcontroller controls the totem pole in terms of PFC, THD, voltage regulation, input overcurrent protection (OCP), overvoltage protection (OVP), brown in/out, soft-start, and inrush current limit.

The figure below shows the simplified schematic of the full bridge LLC converter.

Figure 4. Simplified schematic of the full bridge LLC



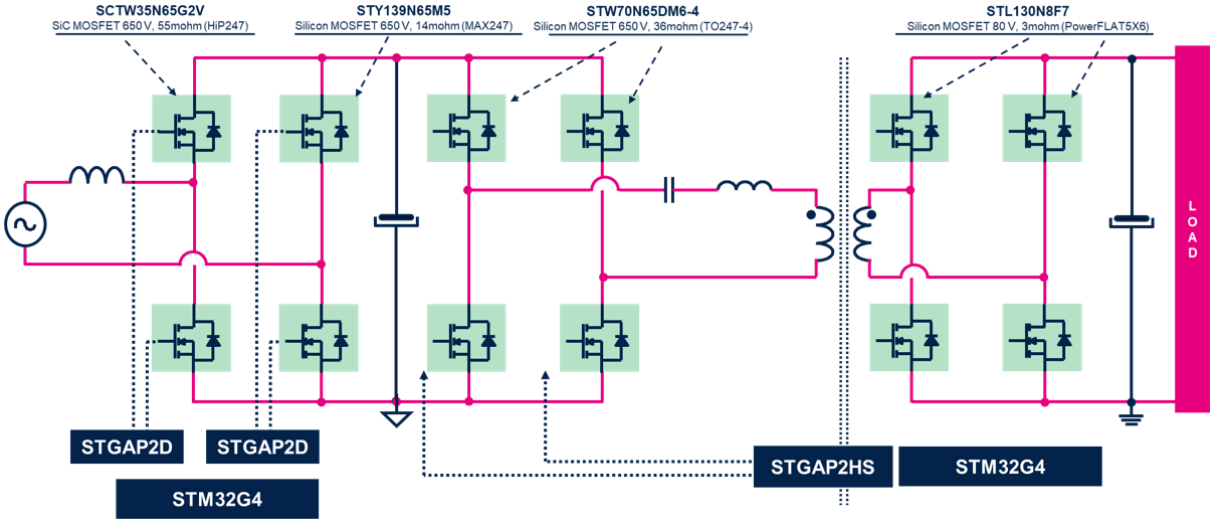
The full bridge primary section of the LLC converter is based on MDmesh DM6 power MOSFETs for a high efficiency performance. The PWM switching frequency is digitally controlled to regulate the output voltage.

The converter operates at near resonant frequencies to maximize the efficiency and achieve zero voltage switching (ZVS) over the entire operating range. The STGAP2HS provides a high driving current capability for the primary side MOSFETs and galvanic isolation between the secondary control and the primary driving signal to build a compact design.

To reduce conduction losses, synchronous rectification (SR) with STripFET F7 power MOSFETs is applied on the secondary side and coupled with the half-bridge driver IC. The control board includes an STM32G474RBT6 microcontroller, which controls the LLC converter, manages the voltage regulation, output OCP, OVP, UVP, soft-start, SR control, and high frequency burst mode under light loads to reduce power loss.

The figure below shows a simplified diagram of the prototype, including the main power semiconductor switches, the controllers, and the drivers of the two main conversion stages.

Figure 5. **Simplified schematic of the prototype**



While the PFC controller is located at one of the input V_{AC} rails, the LLC controller is referenced to the ground of the insulated output of the complete PSU.

2.4 Kit components

The STDES-3KWTLCP reference design consists of two independent power boards: the totem pole PFC converter and the full bridge LLC converter.

Figure 6. Totem pole PFC component placement

1. AC input connector
2. EMI filter
3. Inrush current limiter
4. Auxiliary power board
5. Control board
6. Line frequency switching devices
7. High frequency switching devices
8. PFC choke
9. PFC output capacitors
10. PFC output connectors

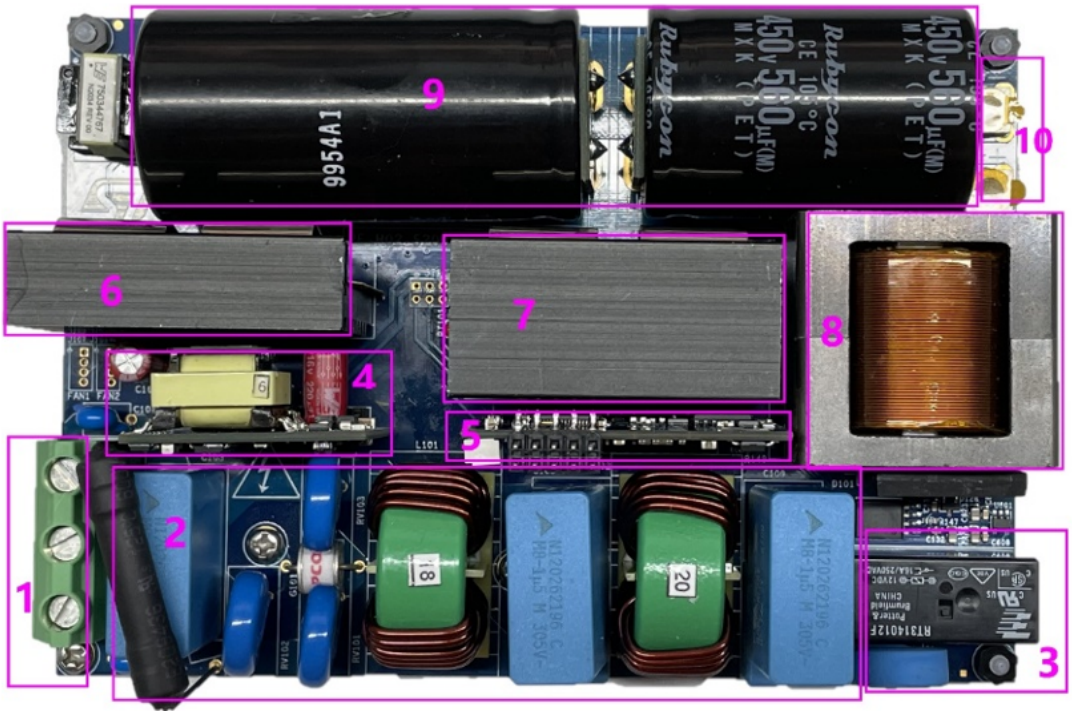
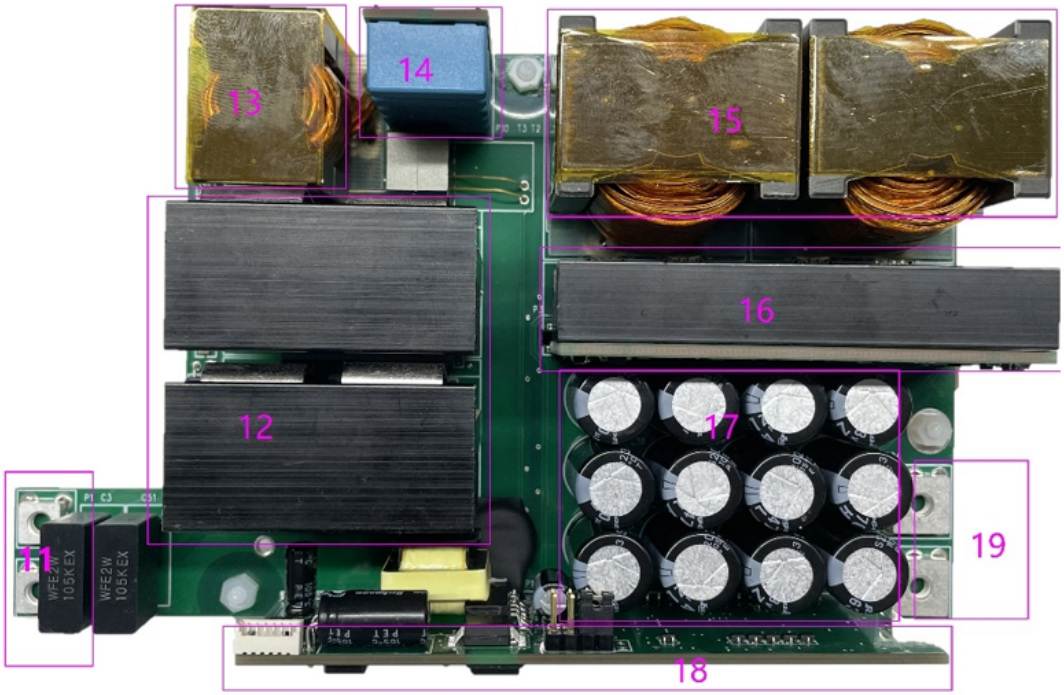


Figure 7. **Full bridge LLC component placement**

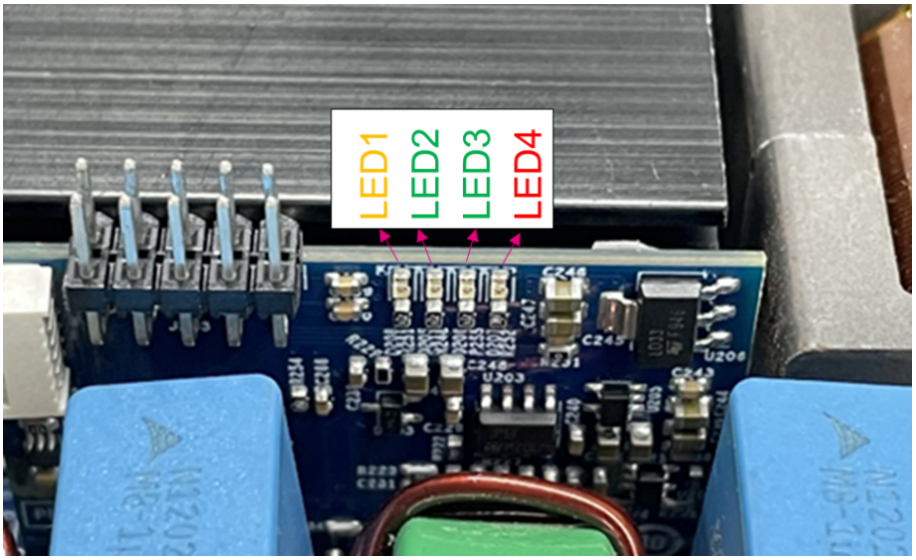
11. LLC input connectors
12. Primary side switching devices
13. Resonant inductor
14. Resonant capacitors
15. Main transformers
16. Synchronous rectifier MOSFET
17. Output e-cap
18. Auxiliary power and control board
19. LLC output connectors



2.4.1 PFC LED status

The figure below shows the LEDs that indicate the PFC status.

Figure 8. **Status LEDs for the PFC**



The table below shows the LED definition for different scenarios.

Table 2. LED definitions

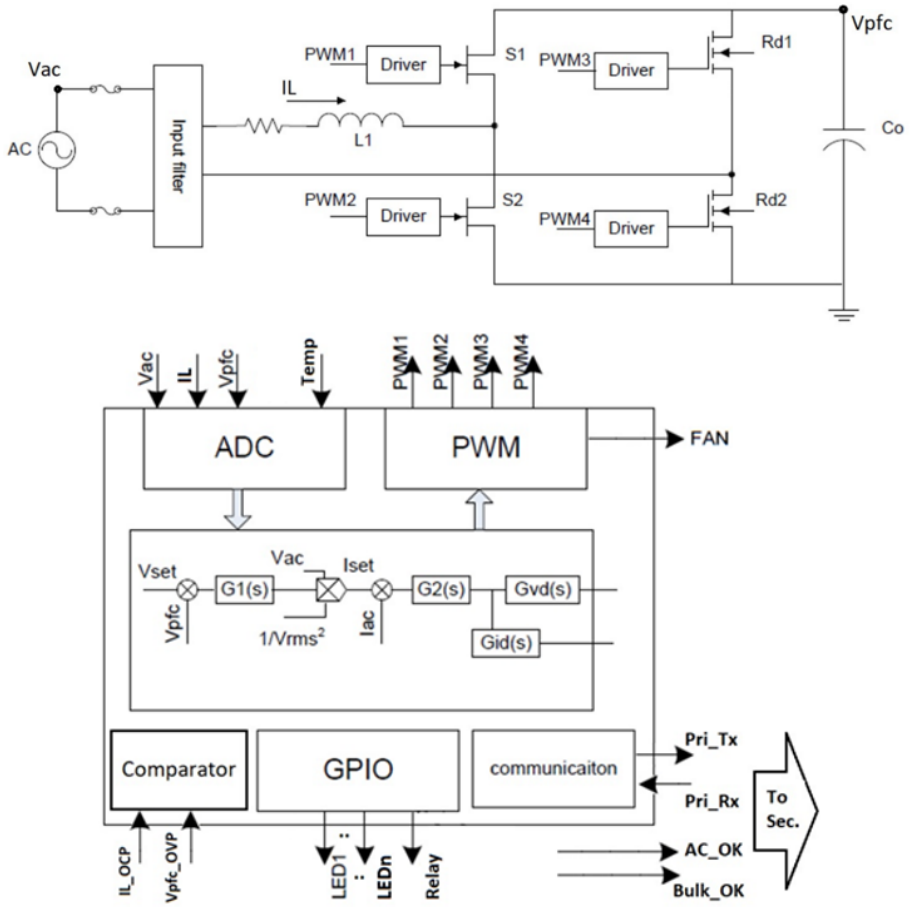
LED	Reference	Definition	Color	Comments
LED1	D208	Watchdog	Yellow	Reserved
LED2	D205	AC voltage	Green	ON: AC input normal Blink: AC input abnormal
LED3	D206	DC voltage	Green	ON: DC output normal Blink: DC output precharge OFF: DC fault or disabled
LED4	D207	Fault indicator	Red	Reserved

3 Firmware overview

3.1 Totem pole PFC firmware design

The totem pole PFC is designed through digital control. The STM32G474RBT6 controls the algorithm and housekeeping functions. The figure below shows the function block diagram and the MCU pin definitions.

Figure 9. Digital control functional block of the totem pole PFC



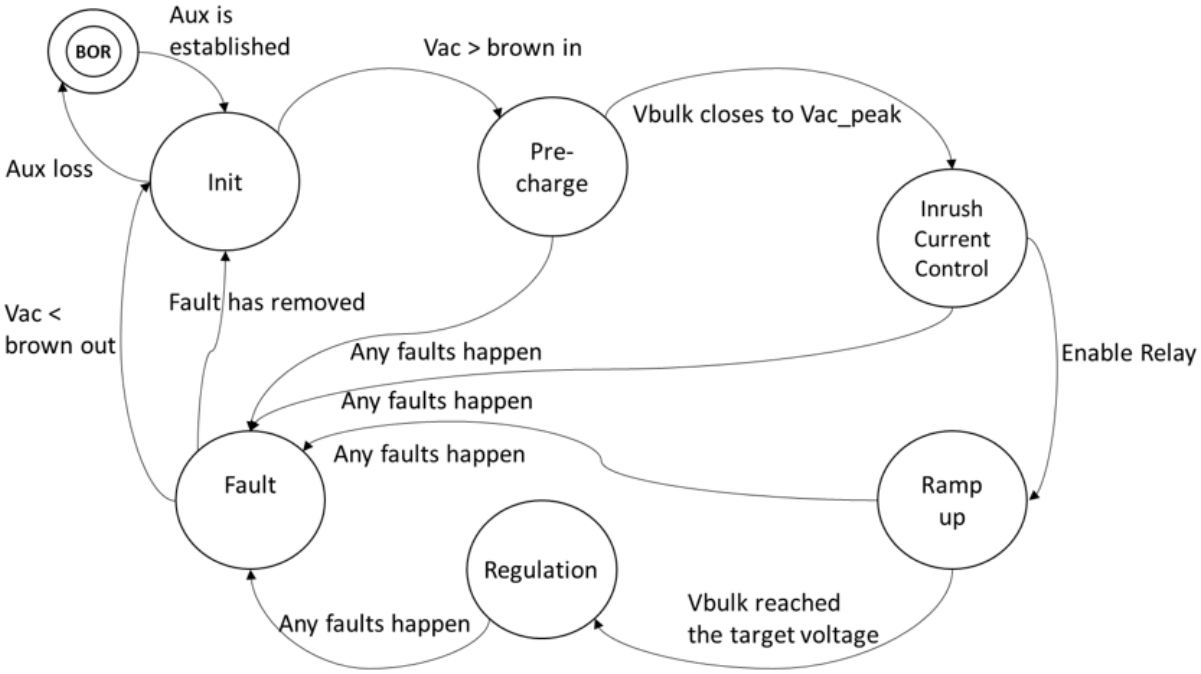
3.2 PFC MCU pin definitions

- PWM:
  - PWM1, PWM2: high-speed PWM at switching frequency (70 KHz)
  - PWM3, PWM4: low speed PWM at line frequency (50 Hz/60 Hz)
- ADC:
  - V_{AC}: line voltage with voltage offset (1.65 V)
  - IL: inductor current with voltage offset (1.65 V)
  - Vpfc: PFC output voltage (bulk voltage)
  - Temp: hotspot temperature at PFC side
- Comparator:
  - IL_OCP: cycle-by-cycle current protection
  - Vpfc_OVP: overvoltage protection on the bulk capacitor

- GPIO:
  - LED1-n: LED indicators
  - Relay: relay control for inrush current
  - AC_OK: indicating AC status to secondary side
  - Bulk_OK: indicating bulk voltage status to secondary side
- Communication:
  - Pri_Tx/Rx: transmitter/receiver channel from primary to secondary side

3.3 State machine of the PFC

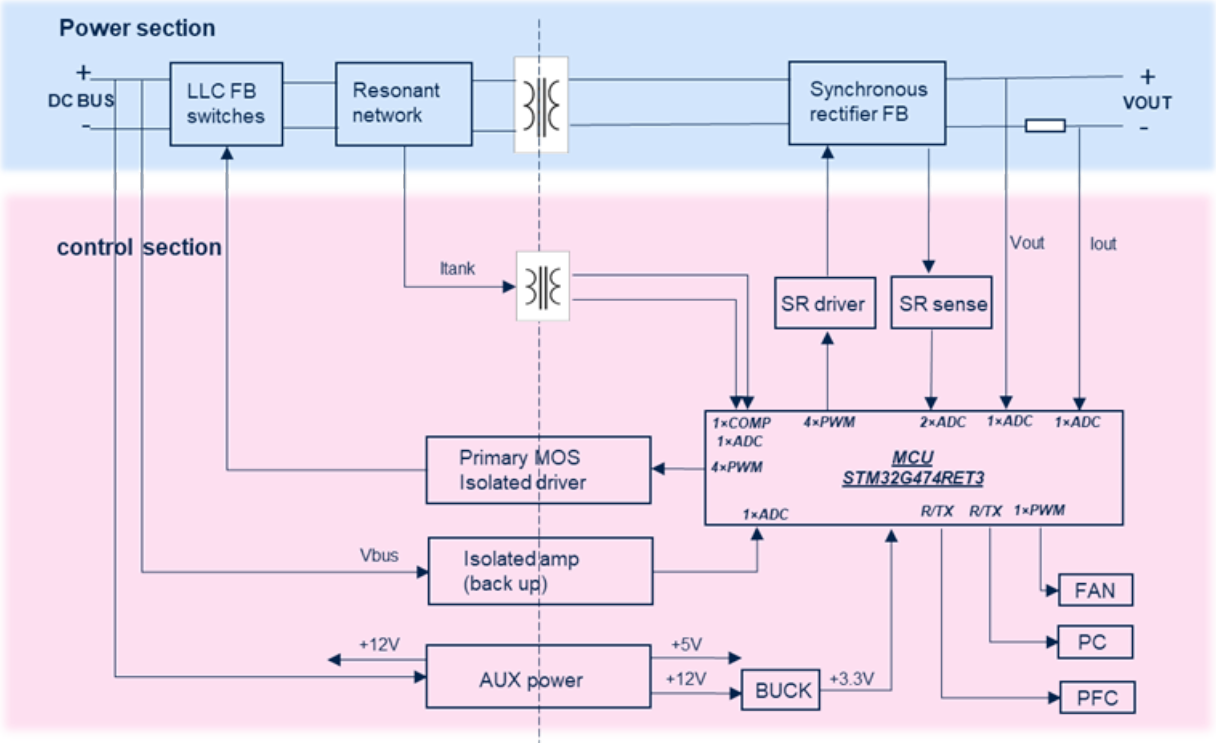
Figure 10. PFC state machine



3.4 Full bridge LLC firmware design

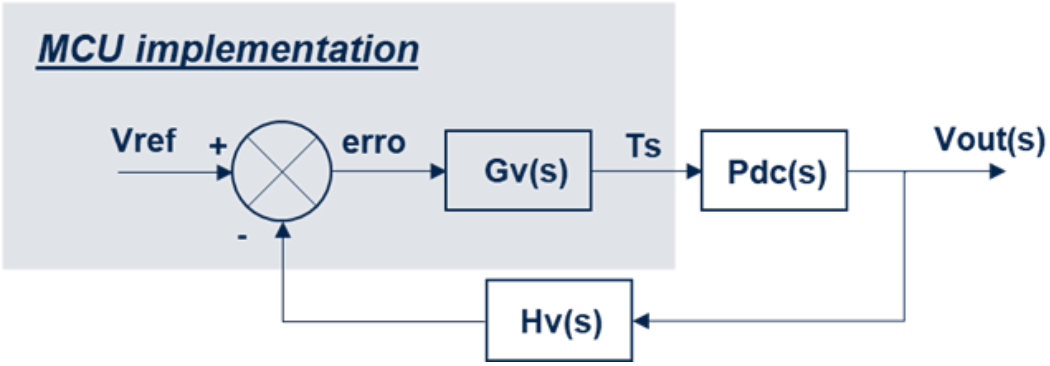
The full bridge LLC is designed through digital control. The STM32G474RET3 controls the algorithm and housekeeping functions. The figure below shows the function block diagram and the MCU pin definitions.

Figure 11. **Digital control functional block of the full bridge LLC**



The control architecture adopted for the LLC is average current mode using the outer voltage loop and the inner power loop, as shown below.

Figure 12. **Control architecture of the full bridge LLC**



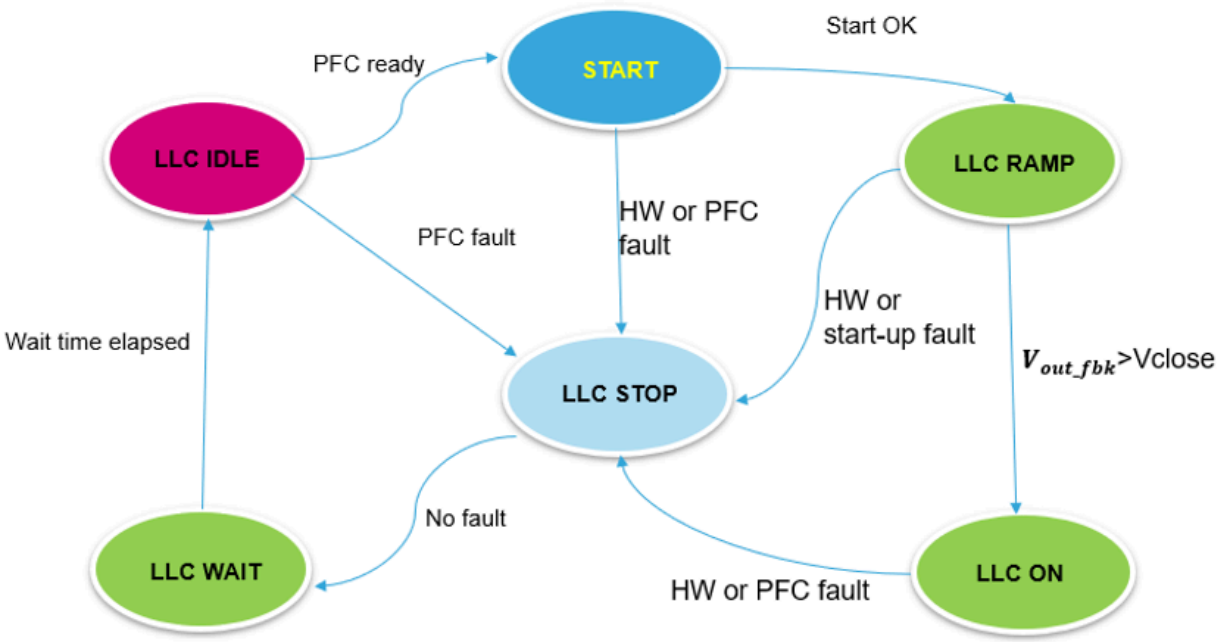
3.5 LLC MCU pin definitions

- PWM
  - PWM1, PWM2: primary PWM (resonance frequency: 115 KHz)
  - PWM3, PWM4: SR PWM
- ADC:
  - V_{OUT}: output voltage sample, regular channel
  - Secondary current: output current with voltage offset (1.65 V), regular channel
  - V_{DC}: SR MOS V_{DS} sample, injection channel
  - Temp: hotspot temperature at SR heat sink, regular channel

- Comparator:
  - Primary tank current: COMP2 trigger OCP
  - V_{OUT}: COMP6 trigger OVP
- GPIO:
  - LED1-n: LED indicators
  - Bulk OK input: for DC-DC startup
- Communication:
  - Pri_Tx/Rx: transmitter/receiver channel to primary side
  - PC_Tx/Rx: transmitter/receiver channel to PC GUI

3.6 State machine of the LLC

Figure 13. **LLC state machine**



Default fault settings:

- Input UVP: 320 V
- Primary side fast OCP: 35 A
- Output OVP: 60 V
- Output OCP: 65 A
- OTP: 60°C (SR heatsink)

4 Test setup

4.1 Test conditions and equipment

Table 3. Input and output test conditions

Symbol	Description	Conditions	Min.	Typ.	Max.	Units
V_{AC}	Input AC voltage		90		264	V
f_{AC}	Input AC Frequency		47		63	Hz
V_{out}	Output voltage	25%-50%-25% dynamic load	50.8	53.5	56.2	V
P_{out}	Output power	V_{AC} = 115 V			1500	W
		V_{AC} = 230 V			3000	W
I_{out}	Output current	V_{AC} = 115 V			28	A
		V_{AC} = 230 V			56	A

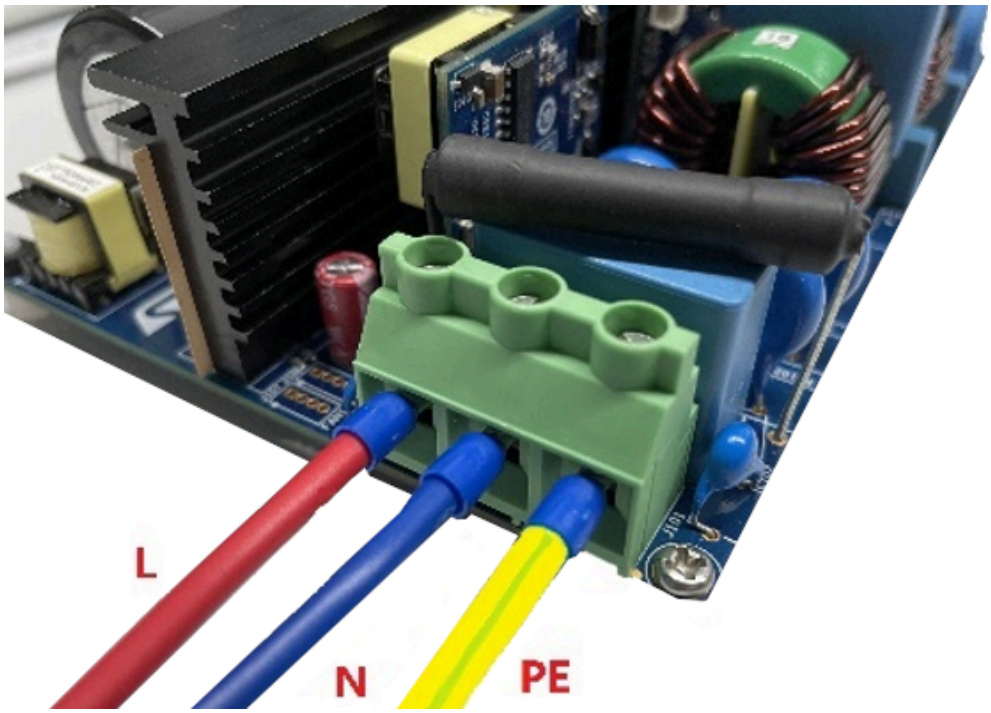
Table 4. Instrumentation and equipment

Item	Type	Description
1	AC power source, 4.5 kVA	To be connected to the AC input.
2	Electronic DC load, 150 V, 600 A	The electronic DC load needs to be set in CC (constant current) mode. To be connected to the DC output.
3	Digital oscilloscope	To read the waveforms.
4	Current probe	To measure the current waveforms.
5	Differential voltage probe	To measure the voltage waveforms.
6	Digital multimeter	To check the input power quality.

4.2 Procedure

Step 1. Connect the line (L), neutral (N) and earth (PE) wires with J101 connectors to an unpowered main plug.

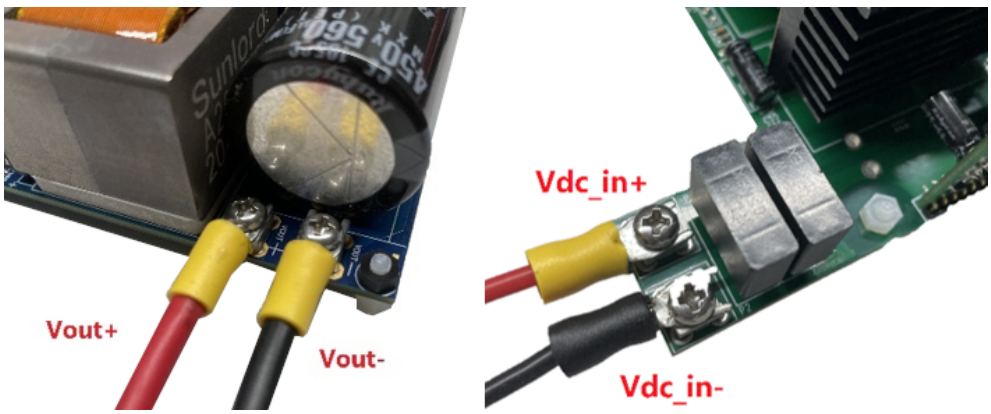
Figure 14. AC input wire connection



Step 2. Connect the PFC output V_{OUT}+ (J104) to the LLC input connector V_{DC_IN}+ (P1).

Step 3. Connect the PFC output V_{OUT}- (J105) connector to the LLC input connector V_{DC_IN}- (P2).

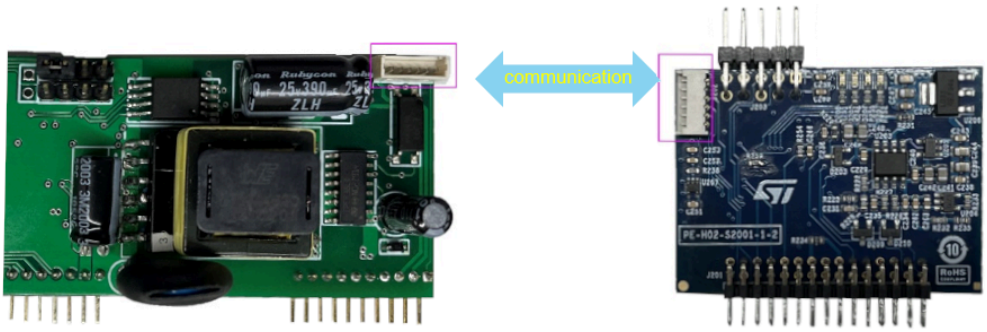
Figure 15. Bus connection between the PFC output terminal (on the left) and the LLC input terminal (on the right)



The communication between the PFC and the LLC is based on the UART protocol. Digital I/O signals indicate `PFC OK` and `AC OK`.

Step 4. Connect the wires between the PFC and LLC control boards as shown below.

Figure 16. Communication wires between the PFC (on the right) and LLC (on the left) control boards

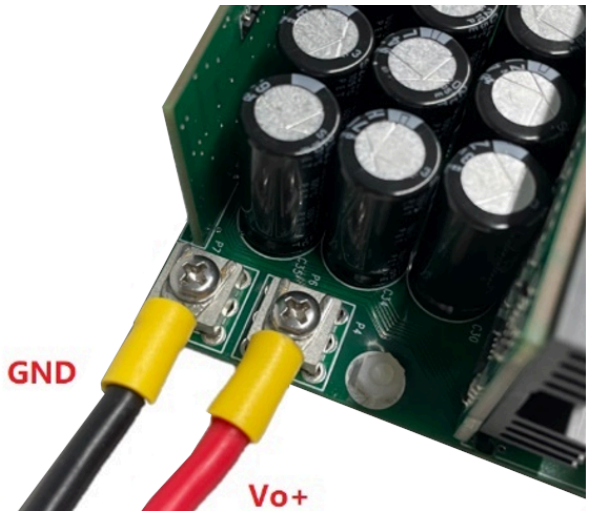


Step 5. When using an electronic load, follow the substeps below.

Step 5a. Connect the positive terminal of the electronic DC load to the Vo+ (P6) connector.

Step 5b. Connect the negative terminal of the electronic DC load to the GND (P7) connector.

Figure 17. LLC output connection

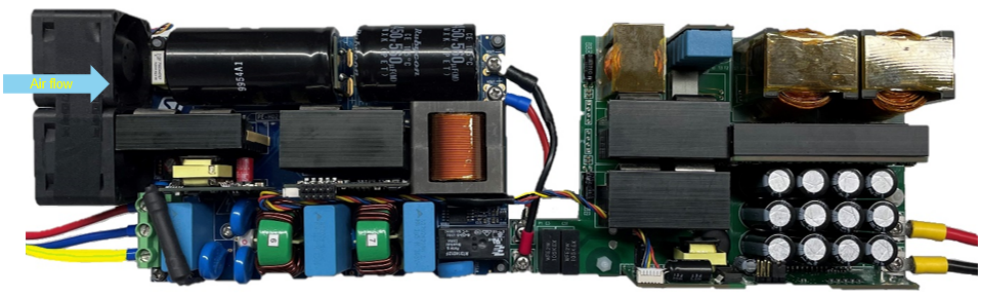


Step 6. Use an external fan for cooling (2pcs fans recommended).

Step 7. Power the external fan on.

Note: If you do not use a fan cooling, you might damage the reference design due to overheat at heavy load condition.

Figure 18. Setup overview



Step 8. Set the AC source voltage between 90 V_{AC}~264 V_{AC} and 47 Hz~63 Hz.

Step 9. Set the output load to zero.

Step 10. Turn the AC source on.
The output voltage gradually ramps up to 53.5 V_{DC}.

Step 11. Refer to the system specifications to set AC input voltage and DC output load for test conditions.

Danger: *Do not touch any components when the reference design is powered on.*

Step 12. When finishing the test, remove the load or reduce it to 0 A.

Step 13. Turn the AC source off.

Caution: Ensure that the bus capacitors are discharged and the voltage is lower than 60 V before touching the components or metal parts.

Step 14. Turn off the power supply for fans.

5 Measurements/waveforms/test data

5.1 Totem pole PFC experimental results

The figures below show, respectively, the test waveforms in steady state at 230 V_{AC} and 115 V_{AC} at full load conditions.

The input current is smooth and aligned with the input voltage by using the digital control on the totem pole PFC. Moreover, there is no current spike at AC zero-crossing.

Figure 19. PFC steady state with V_{AC} = 115 V and P_{OUT} = 1.5 kW

- Yellow trace: bulk capacitor voltage
- Blue trace: AC input voltage
- Green trace: PFC inductor current

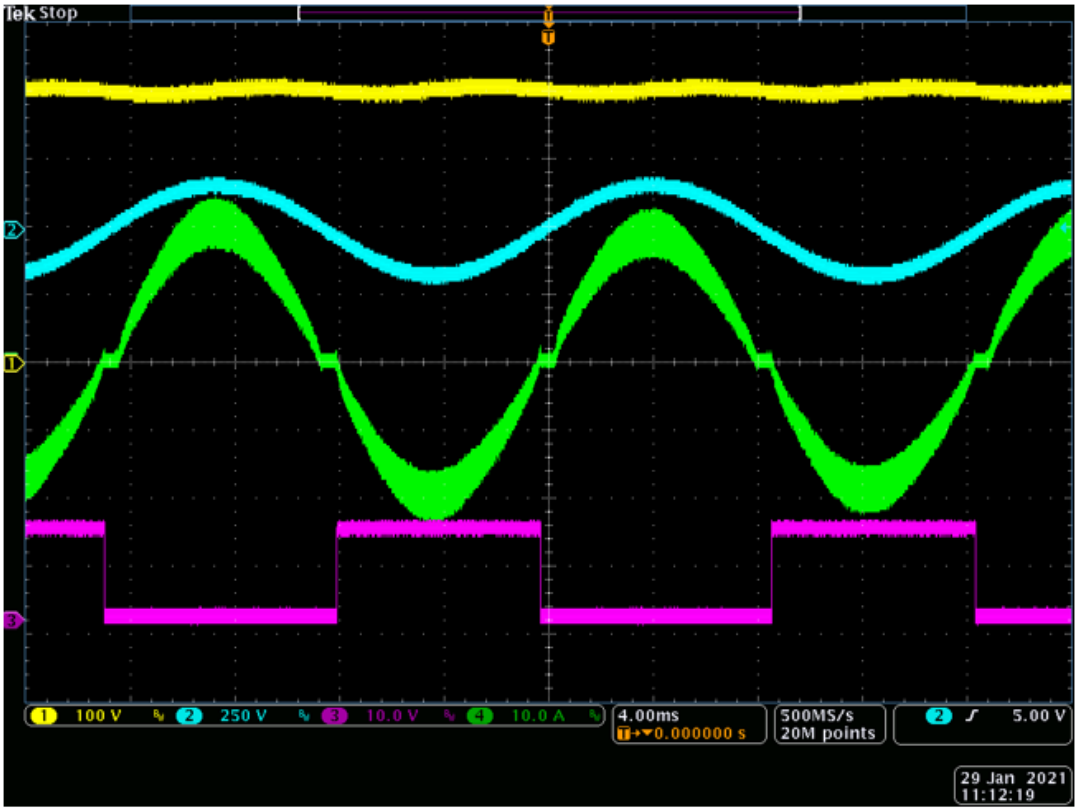
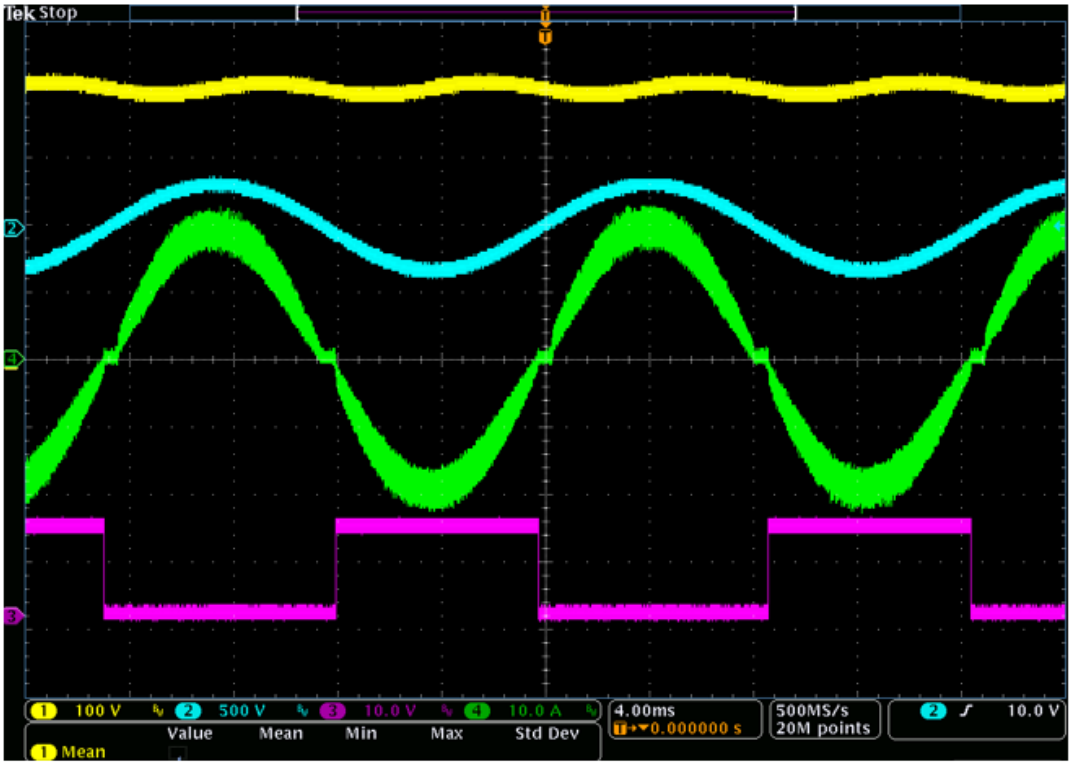


Figure 20. PFC steady state with V_{AC} = 230 V and P_{OUT} = 3 kW

- Yellow trace: bulk capacitor voltage
- Blue trace: AC input voltage
- Green trace: PFC inductor current



The following figures show an example of the drain to source voltage stress of the totem pole PFC. The maximum drain overshoot is 496 V at 230 V_{AC}/3 kW and 452 V at 115 V_{AC}/1.5 kW conditions, well within the rated limits of the devices.

Figure 21. Drain to source voltage stress on Q1 SiC MOSFET (230 V_{AC}, 3 kW load)

- Yellow trace: high-side (Q1) PWM signal
- Blue trace: AC input voltage
- Pink trace: high-side (Q1) of drain to source voltage

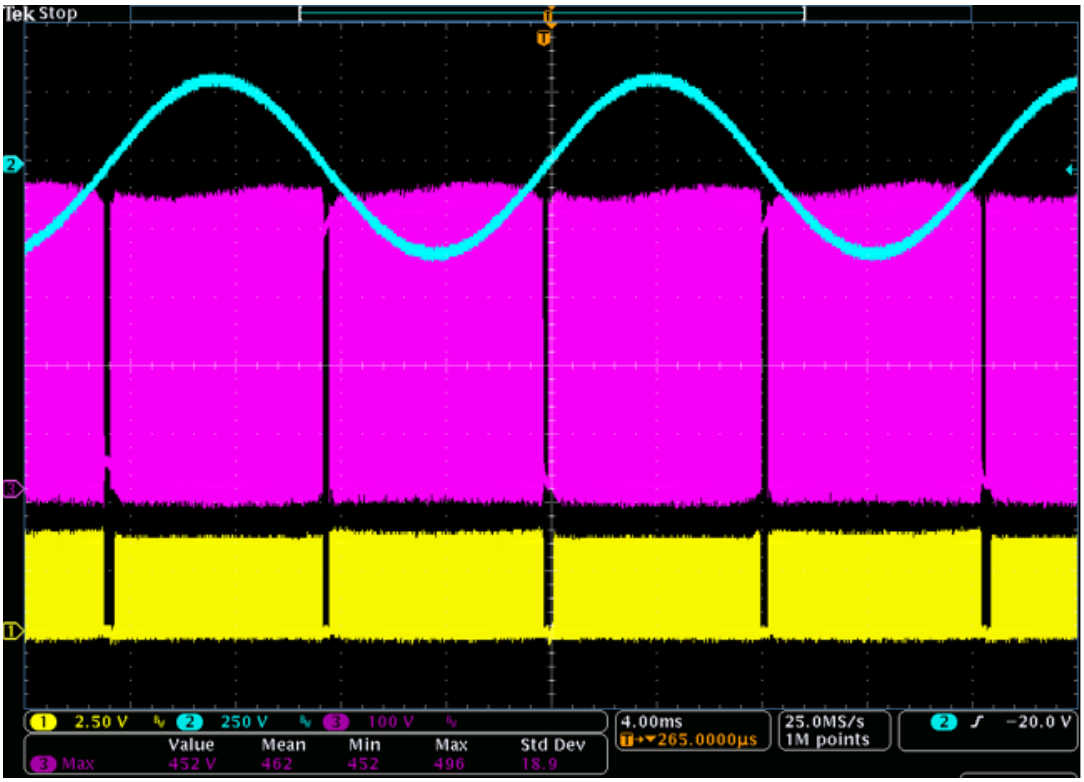
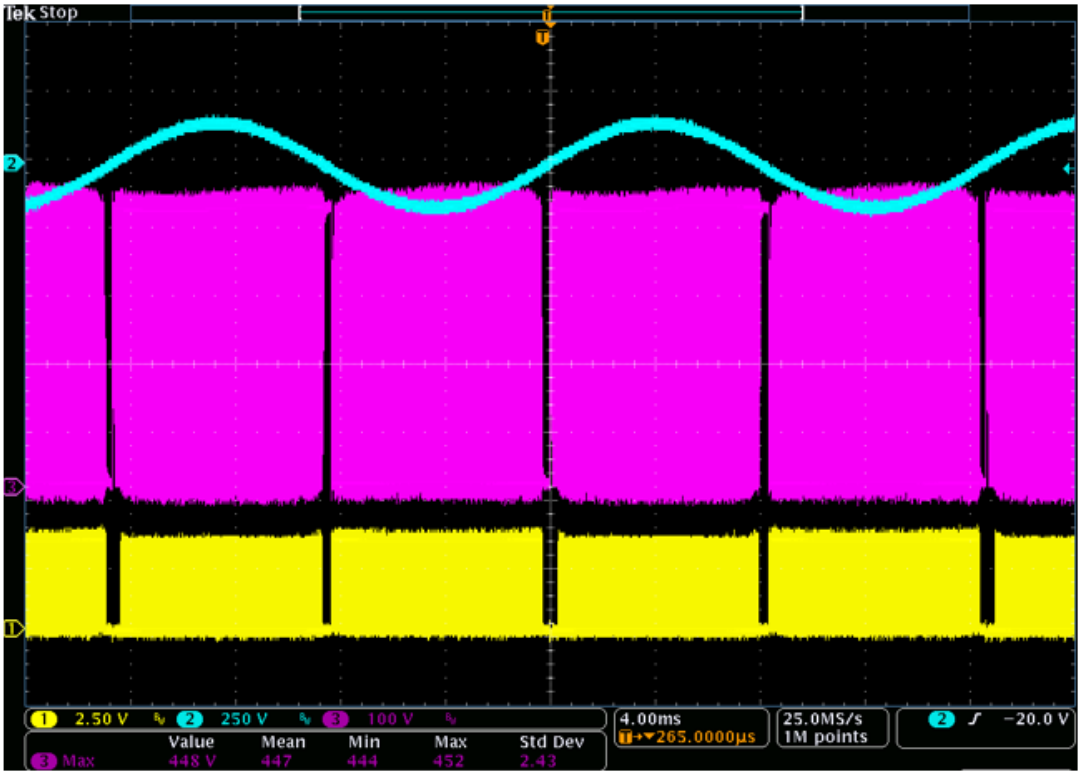


Figure 22. Drain to source voltage stress on Q1 SiC MOSFET (115 V_AC, 1.5 kW load)

- Yellow trace: high-side (Q1) PWM signal
- Blue trace: AC input voltage
- Pink trace: high-side (Q1) of drain to source voltage



The figures below show the AC input voltage transient response between 200 V and 240 V. Thanks to the input voltage, the feed-forward causes power input to remain constant at a specified level regardless of line voltage changes.

Figure 23. AC input voltage transient response (200 V_{AC} to 240 V_{AC}, 3 kW load)

- Yellow trace: bulk capacitor voltage
- Blue trace: AC input voltage
- Pink trace: AC input current

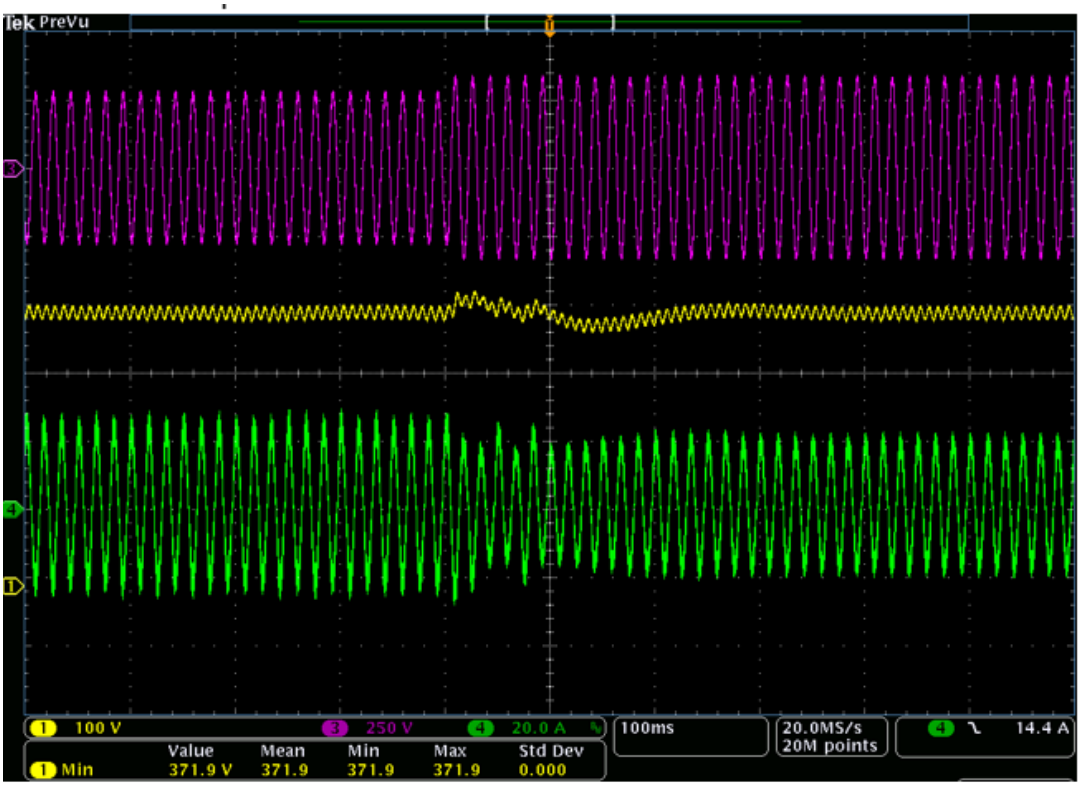
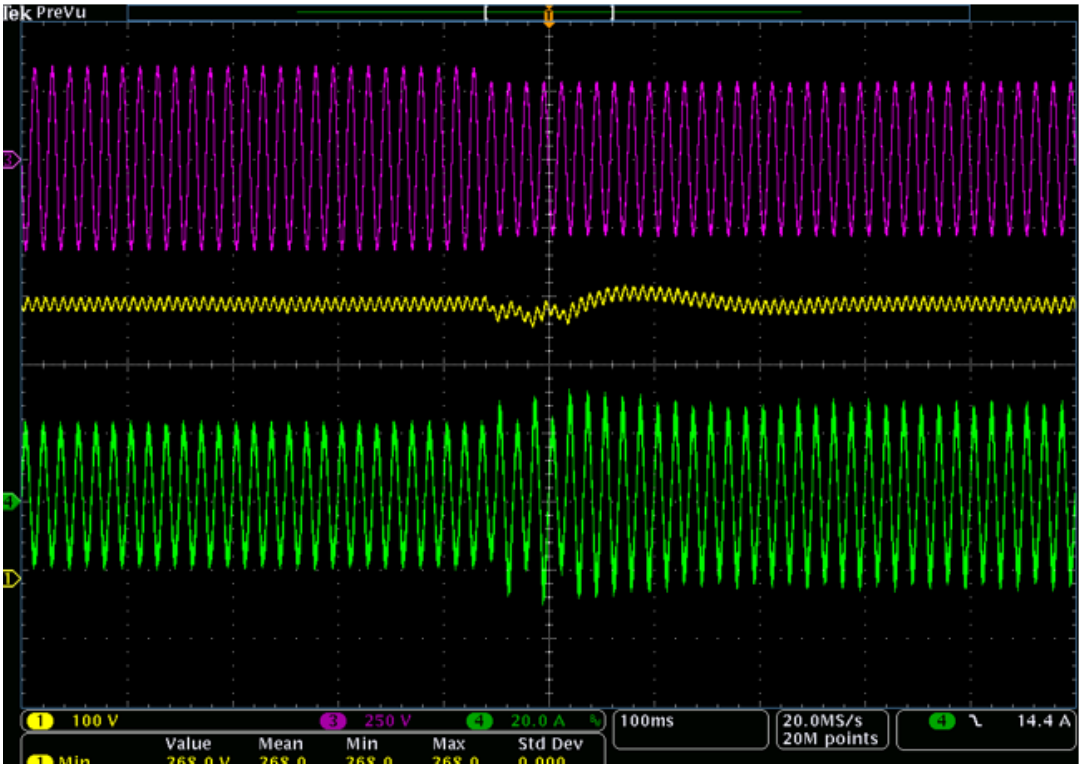


Figure 24. AC input voltage transient response (240 V_{AC} to 200 V_{AC}, 3 kW load)

- Yellow trace: bulk capacitor voltage
- Blue trace: AC input voltage
- Pink trace: AC input current



The figures below show the AC input frequency transient response between 63 Hz and 47 Hz. Thanks to the phase lock loop, it provides a quick and accurate AC zero-crossing detection. The digital control loop can be well aligned with the input voltage frequency. ZCD detection can be corrected within few cycles.

Figure 25. AC input frequency transient response (47 Hz to 63 Hz, 115 V_{AC}, 1.5 kW load)

- Yellow trace: bulk capacitor voltage
- Blue trace: AC input voltage
- Pink trace: AC input current

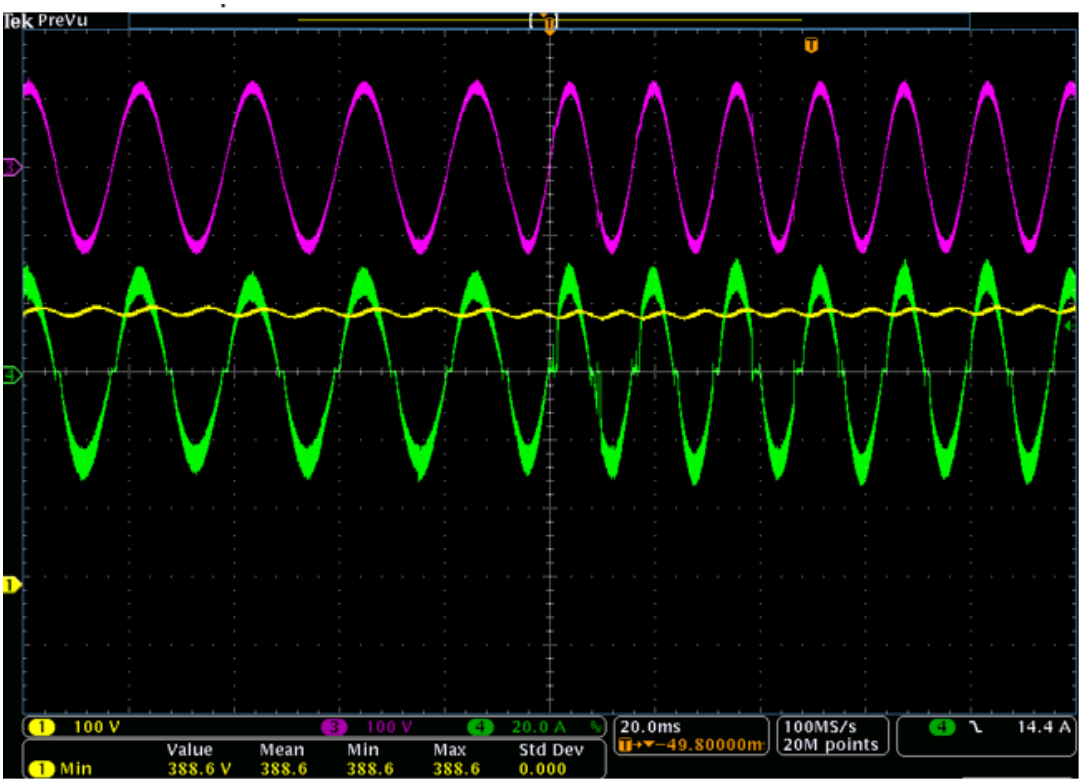


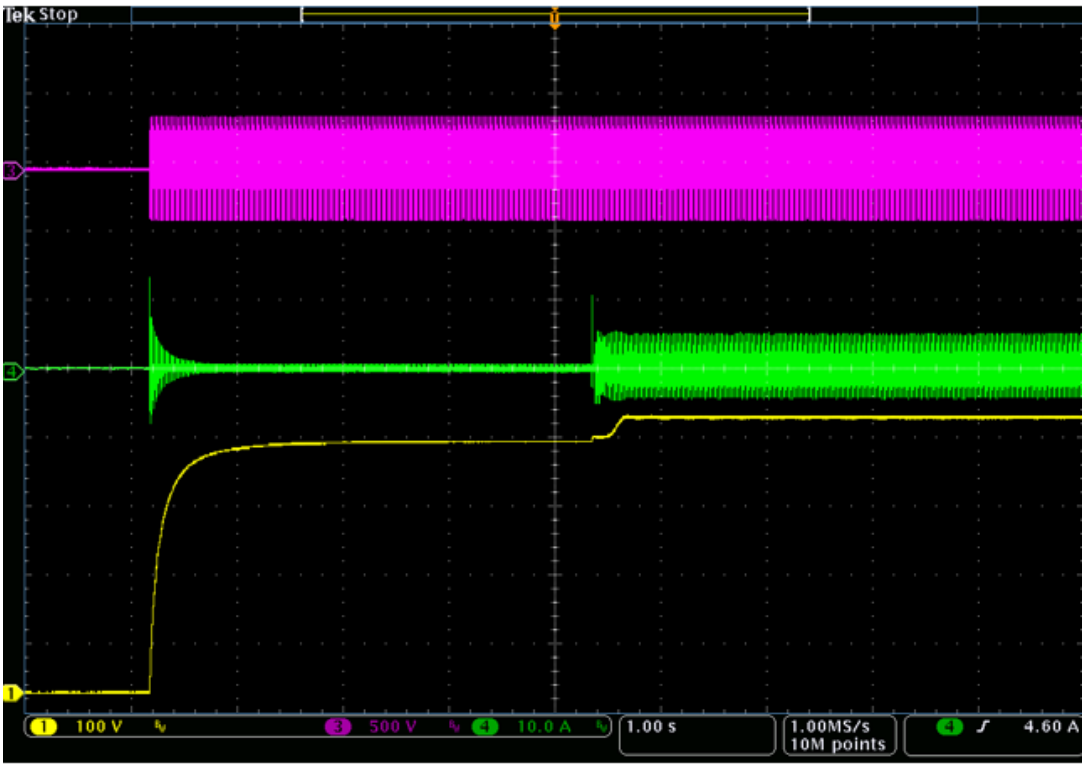
Figure 26. AC input frequency transient response (63 Hz to 47 Hz, 115 V_{AC}, 1.5 kW load)

- Yellow trace: bulk capacitor voltage
- Blue trace: AC input voltage
- Pink trace: AC input current

The figure below shows the input inrush current when the PFC is powered up. When the AC voltage is fed into the PFC converter, the PTC resistor limits the inrush current. The peak inrush current is around 14 A in this case (264 V_{AC}).

Figure 27. **PFC startup with V_{AC} = 264 V**

- Yellow trace: bulk capacitor voltage
- Blue trace: AC input voltage
- Pink trace: AC input current



An input current spike is generated at each AC line zero crossing. This issue is related to the totem pole topology. For example, during the negative AC line cycle, Q3 is always on and Q4 is always off. The PFC output voltage (400 V_{DC}) is applied across Q4.

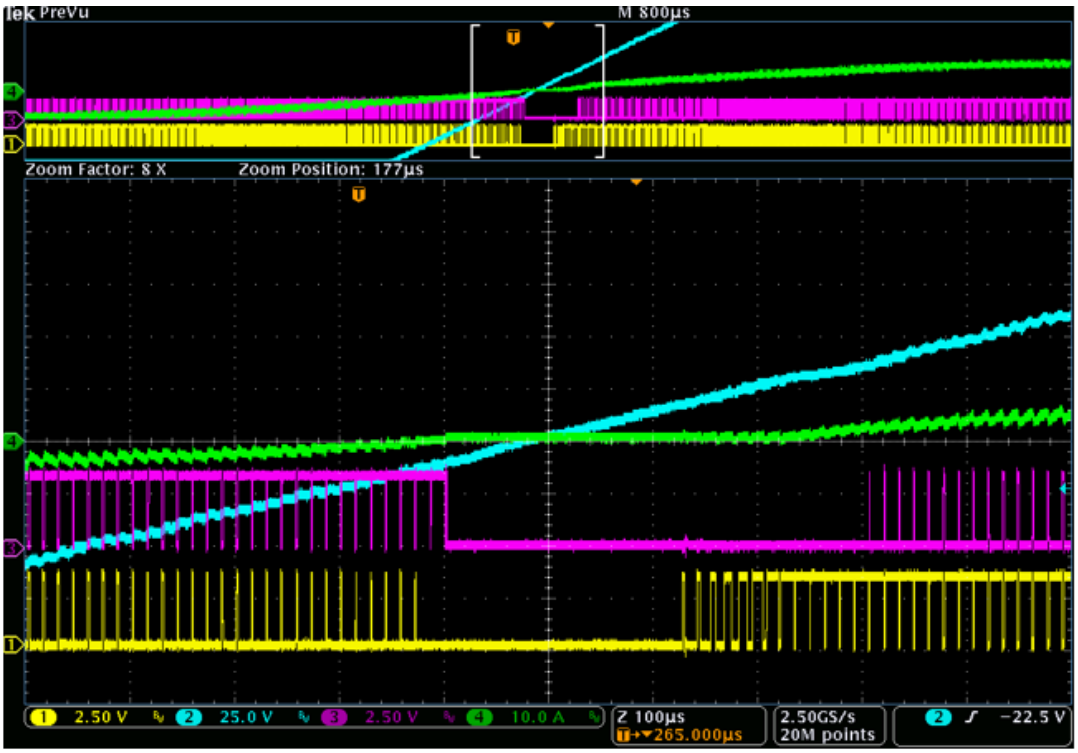
Q1 SiC MOSFET switch increases the boost inductor current and S2 SiC MOSFET acts as a freewheeling boost diode. When the AC line voltage polarity is changing from negative to positive AC line cycle, the duty cycle of the Q1 SiC MOSFET changes from 100% to zero and the active Q2 SiC MOSFET changes from zero to 100%. The Q4 voltage is then applied across the boost inductor and the current spike is generated.

In order to solve this issue, this reference design provides an additional mechanism through the digital control. To limit the current spike, in PWM control, we added a blanking time at around zero-crossing point, adding soft-start to improve the current wave shape.

The figure below shows the PWM signal for Q1 and Q2 SiC MOSFETs. There is a blanking time that turns off Q1 and Q2 simultaneously. Once the AC input enters the positive cycle, Q2 implements the duty cycle soft-start to limit the current spike.

Figure 28. Blanking time and soft-start mechanism to deal with current spike in AC zero-crossing (V_{AC} = 230 V and P_{OUT} = 3 kW)

- Yellow trace: low side(Q2) PWM signal for the high-speed leg
- Blue trace: AC input voltage
- Pink trace: high-side(Q1) PWM signal for the high-speed leg
- Green trace: AC input current



The figures below show the PFC efficiency measurement under various operating load conditions and different AC input voltage conditions. At 230 V_{AC}, this reference design provides a 98.5% peak efficiency for the totem pole PFC stage.

Figure 29. PFC efficiency curve at AC high-line condition

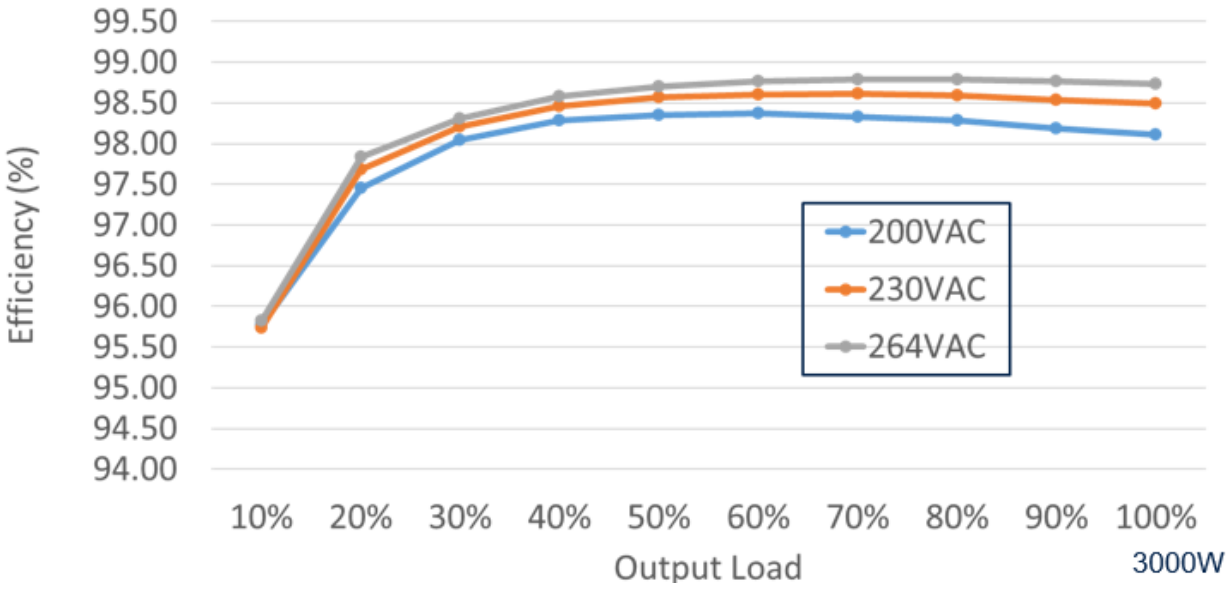
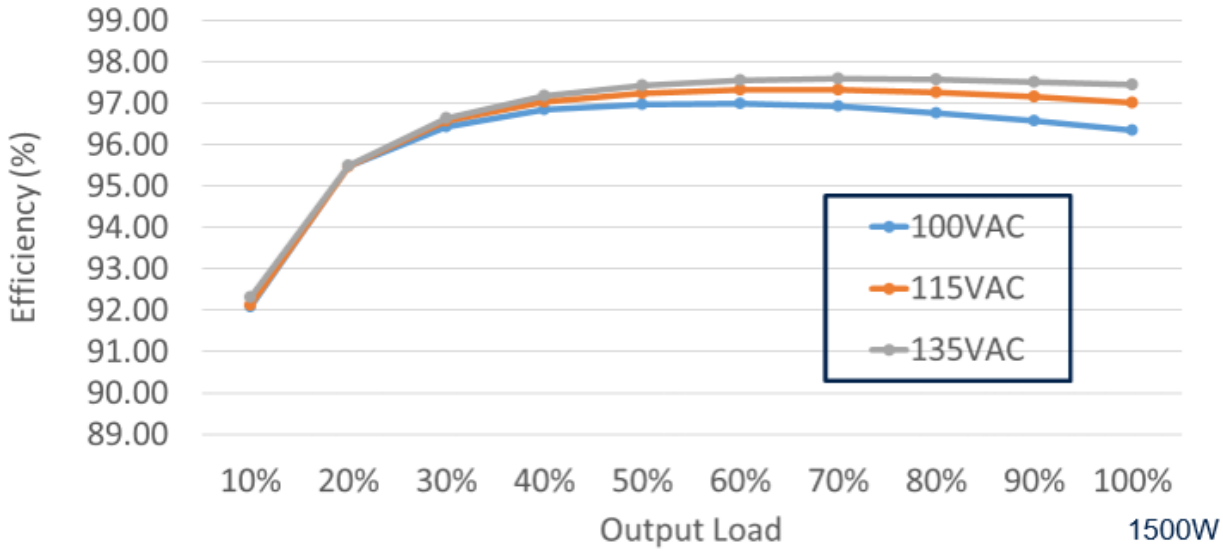


Figure 30. **PFC efficiency curve at AC low line condition**



5.2 Full bridge LLC experimental results

The next four figures show the LLC operation waveforms at steady state and full load conditions.

Figure 31. **Primary resonant tank current at full load condition**

- Yellow trace: Vgs of low side MOSFET
- Pink trace: Vgs of high-side MOSFET
- Green trace: resonant tank current

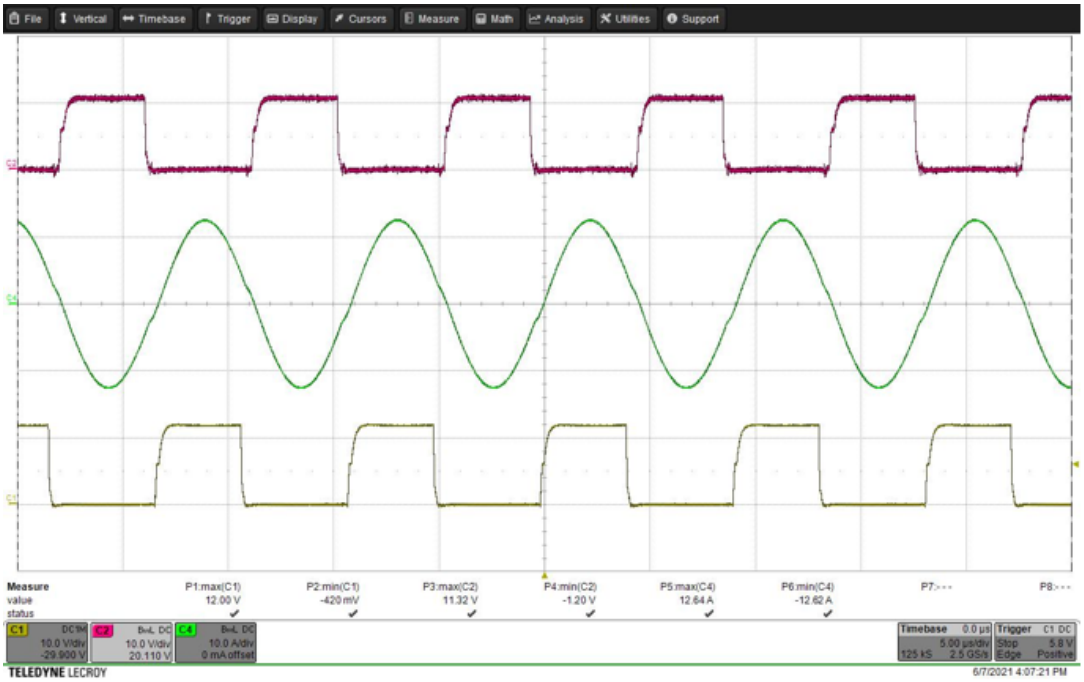


Figure 32. Drain to source stress of primary MOSFET at full load condition

- Yellow trace: Vgs of low side MOSFET
- Pink trace: Vgs of high-side MOSFET
- Green trace: resonant tank current

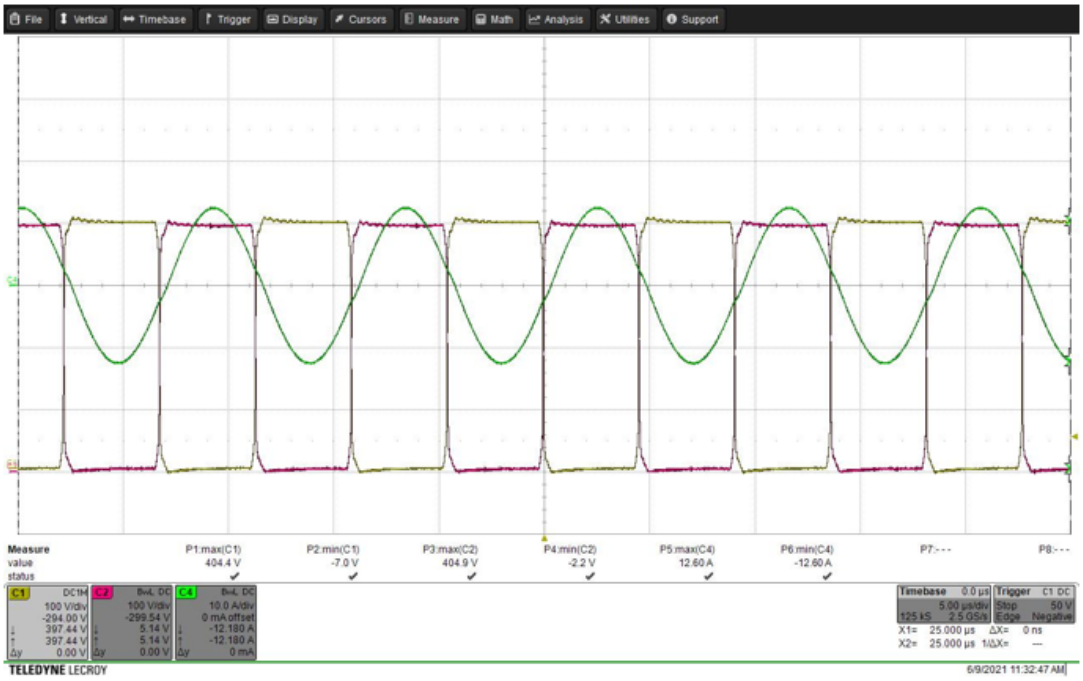


Figure 33. Gate to source waveform for SR MOSFET at full load

- Yellow trace: Vgs of SR MOSFET
- Pink trace: Vgs of SR MOSFET
- Green trace: resonant tank current

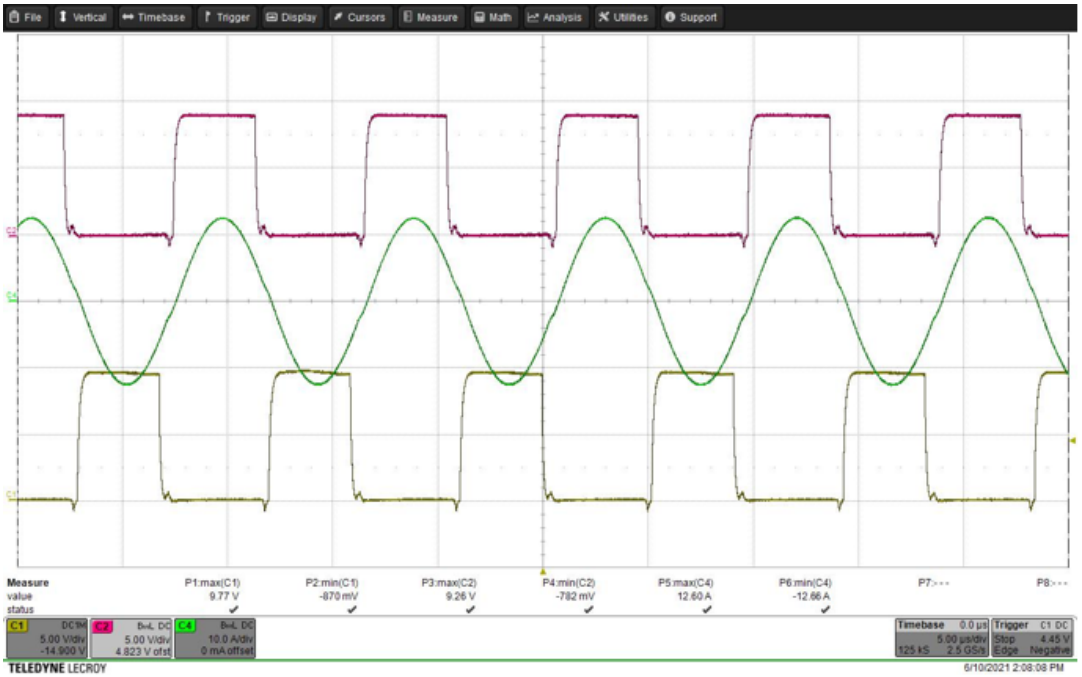
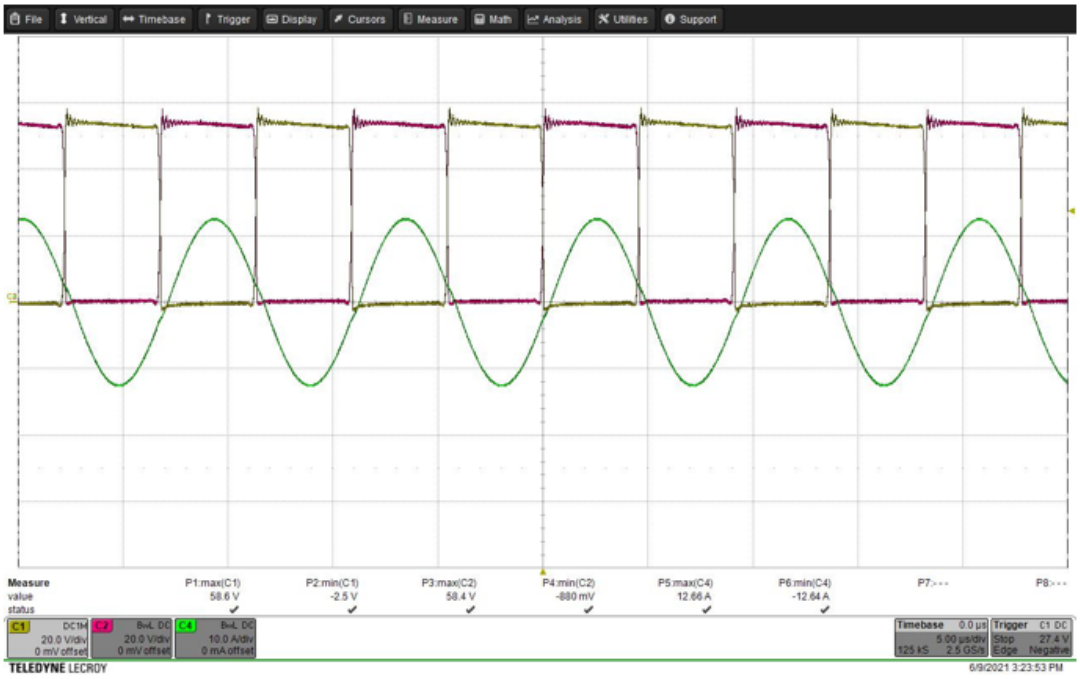


Figure 34. Drain to source stress of SR MOSFET at full load condition

- Yellow trace: Vds of SR MOSFET
- Pink trace: Vds of SR MOSFET
- Green trace: resonant tank current



The next three figures show the LLC startup waveforms at different load conditions. The output voltage is built up monotonically.

Figure 35. **LLC startup waveform at zero load**

- Yellow trace: output voltage
- Pink trace: resonant tank current
- Green trace: Vgs of the primary MOSFET
- Blue trace: Vgs of the primary MOSFET

Figure 36. **LLC startup waveform at half load**

- Yellow trace: output voltage
- Pink trace: resonant tank current
- Green trace: Vgs of the primary MOSFET
- Blue trace: Vgs of the primary MOSFET

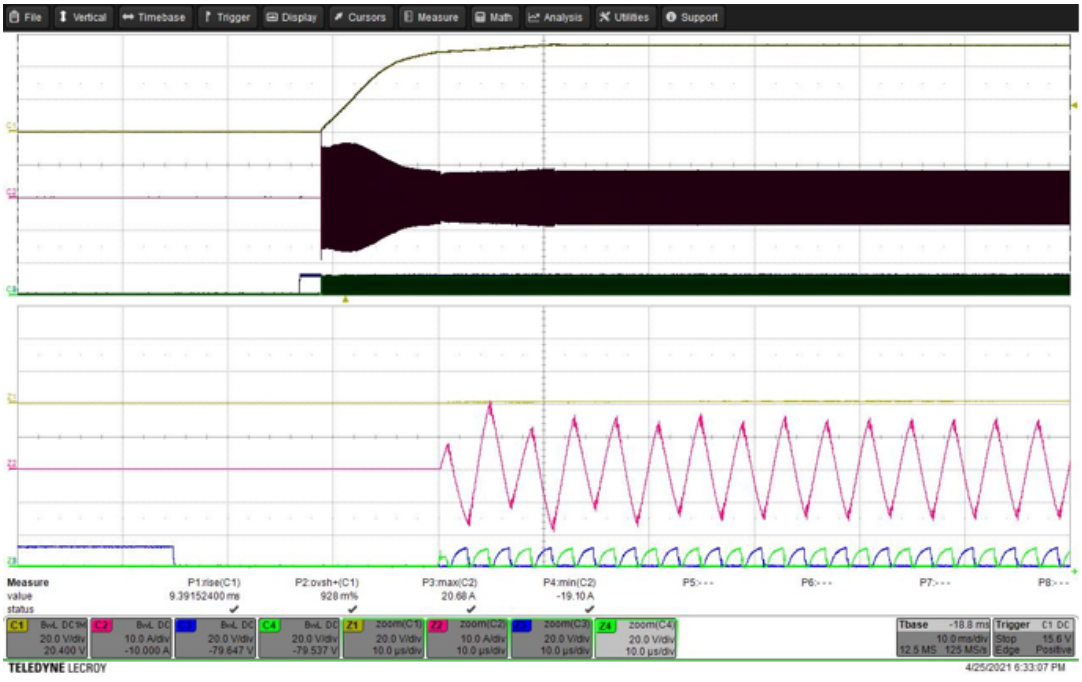
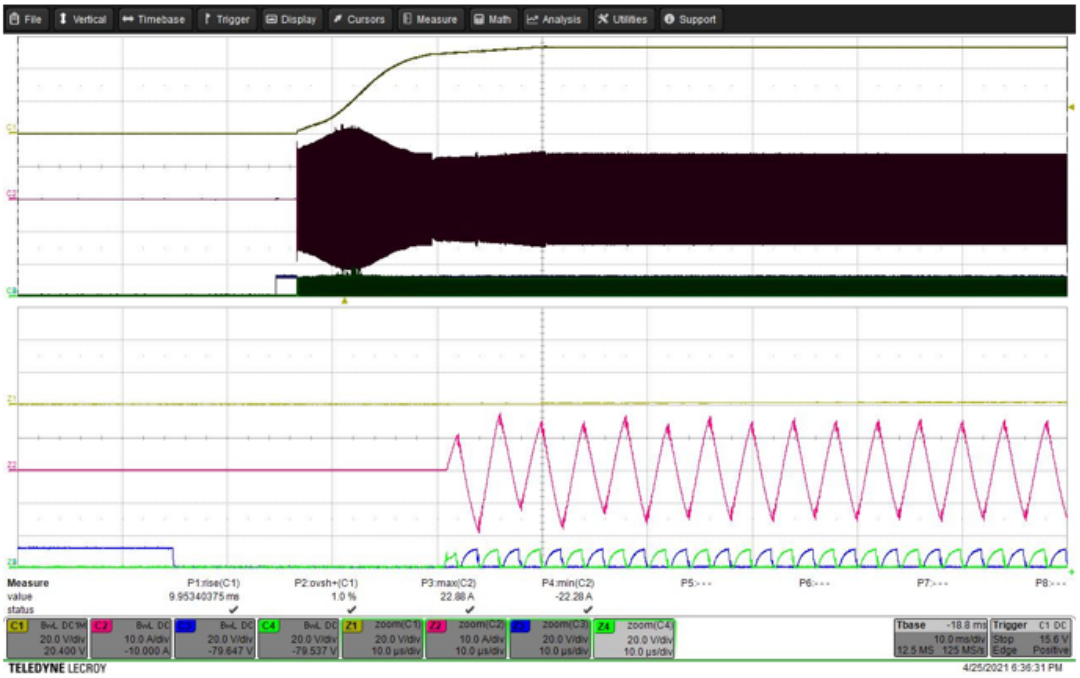


Figure 37. LLC startup waveform at full load

- Yellow trace: output voltage
- Pink trace: resonant tank current
- Green trace: Vgs of the primary MOSFET
- Blue trace: Vgs of the primary MOSFET



The figures below show the LLC waveforms at load transient conditions.

Figure 38. Load transient between 25% and 50% load

- Yellow trace: output voltage
- Pink trace: resonant tank current
- Blue trace: output current

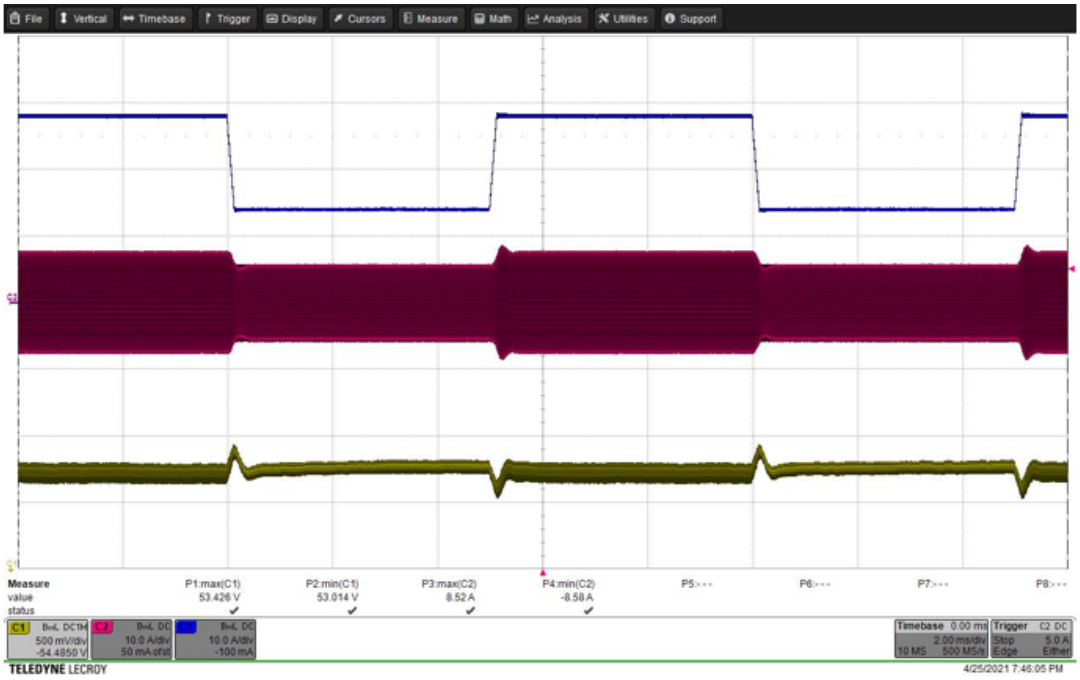
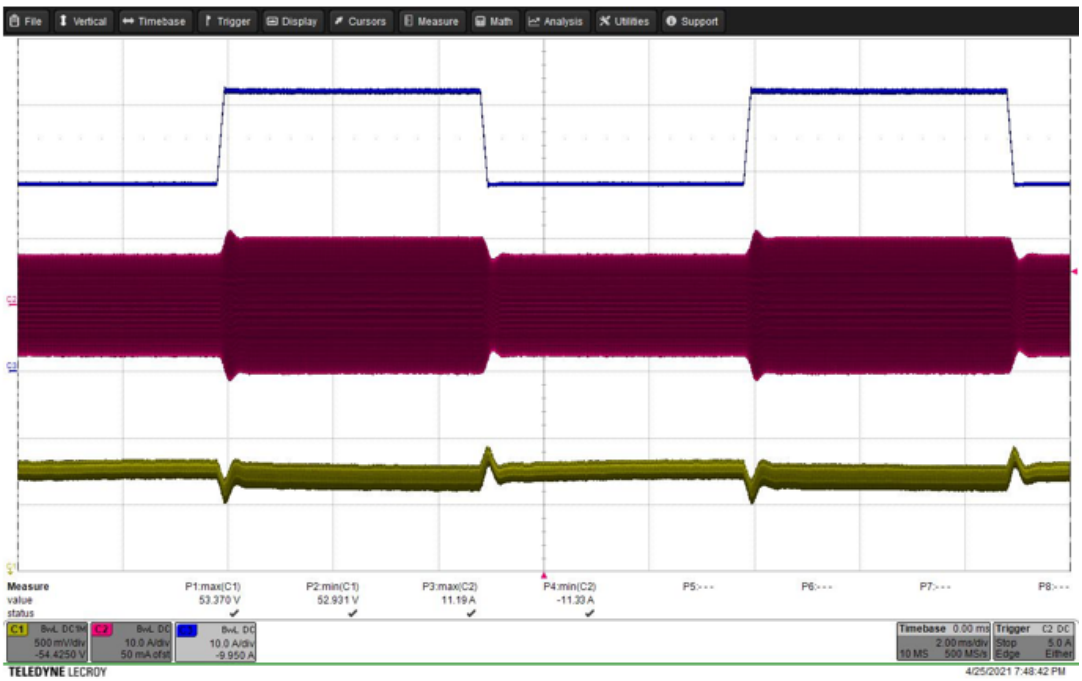


Figure 39. Load transient between 50% and 75% load

- Yellow trace: output voltage
- Pink trace: resonant tank current
- Blue trace: output current



The next three figures show the LLC output voltage ripple waveforms, which are tested at 400 V_{DC} input. The oscilloscope bandwidth was set to 20 MHz. We also added external 47 µF/100V electrolytic and 1 µF ceramic capacitors to the output probe.

Figure 40. Output voltage ripple at zero load

- Yellow trace: output voltage
- Pink trace: resonant tank current

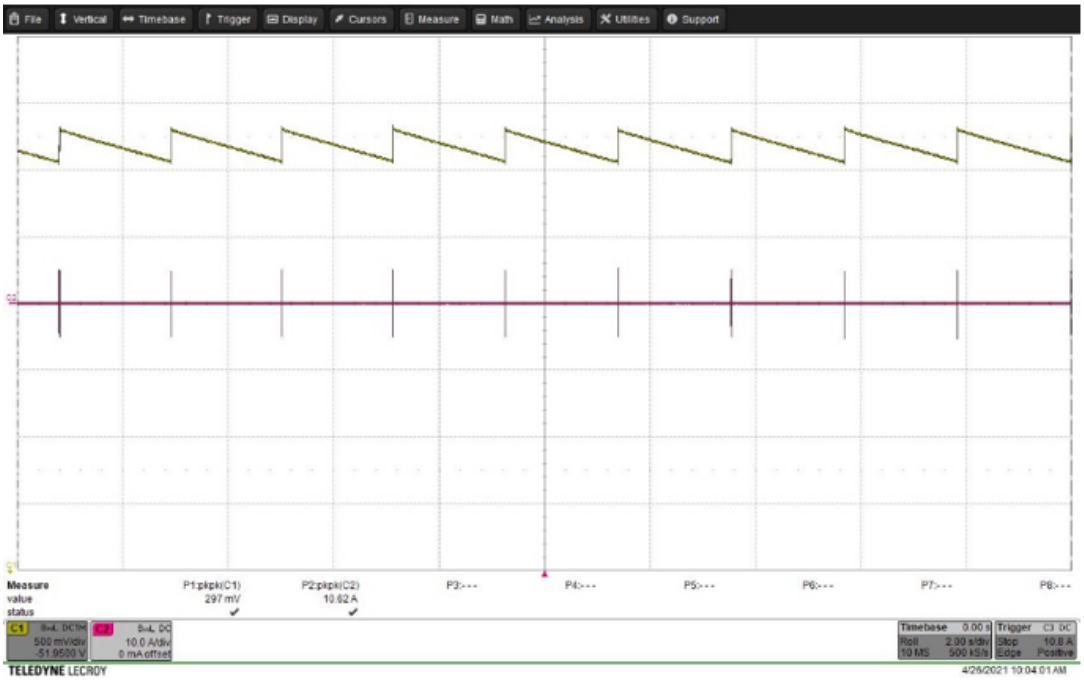


Figure 41. Output voltage ripple at half load

- Yellow trace: output voltage
- Pink trace: resonant tank current

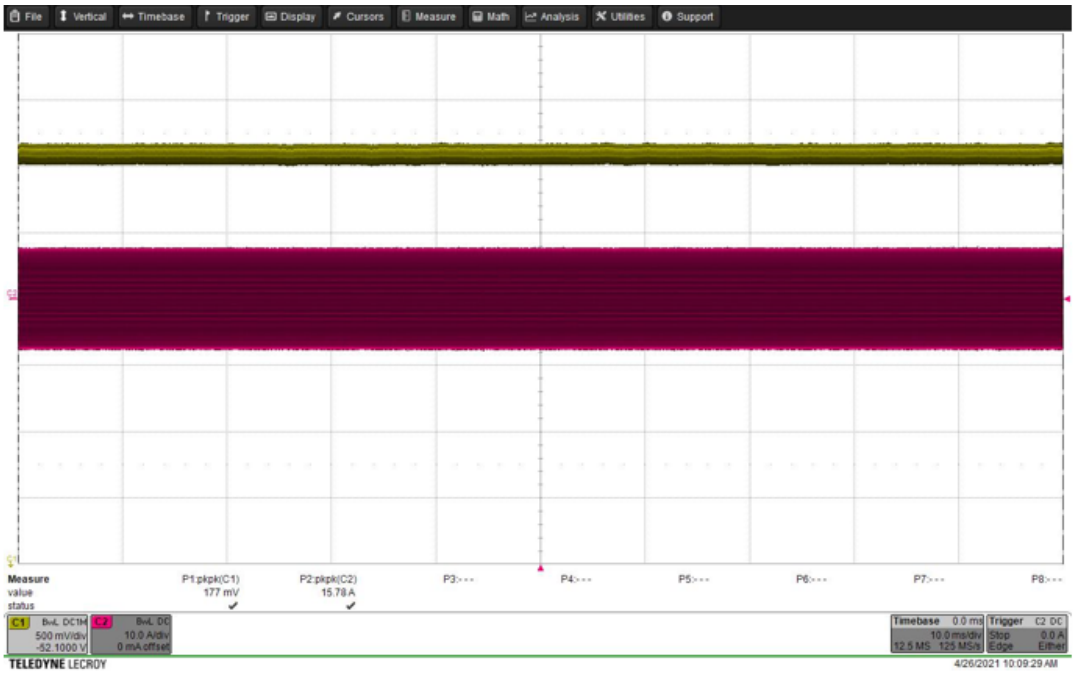
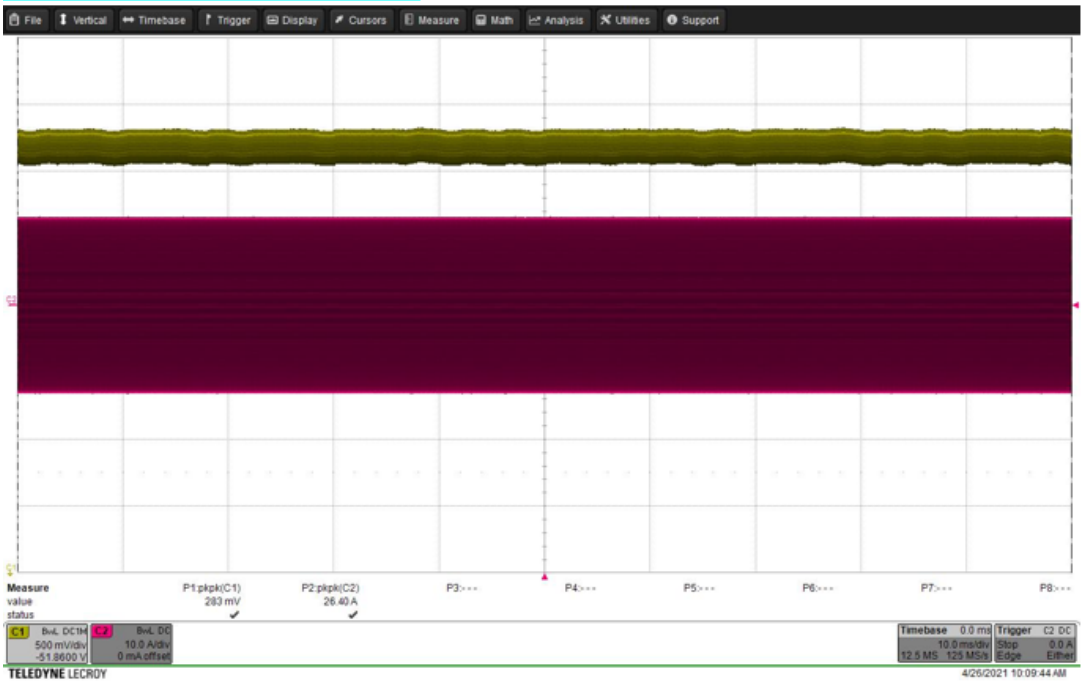


Figure 42. **Output voltage ripple at full load**

- Yellow trace: output voltage
- Pink trace: resonant tank current



The following figure shows the loop-gain stability of the LLC converter, which is tested at 400 V_{DC} input.

Figure 43. **LLC loop-gain stability**

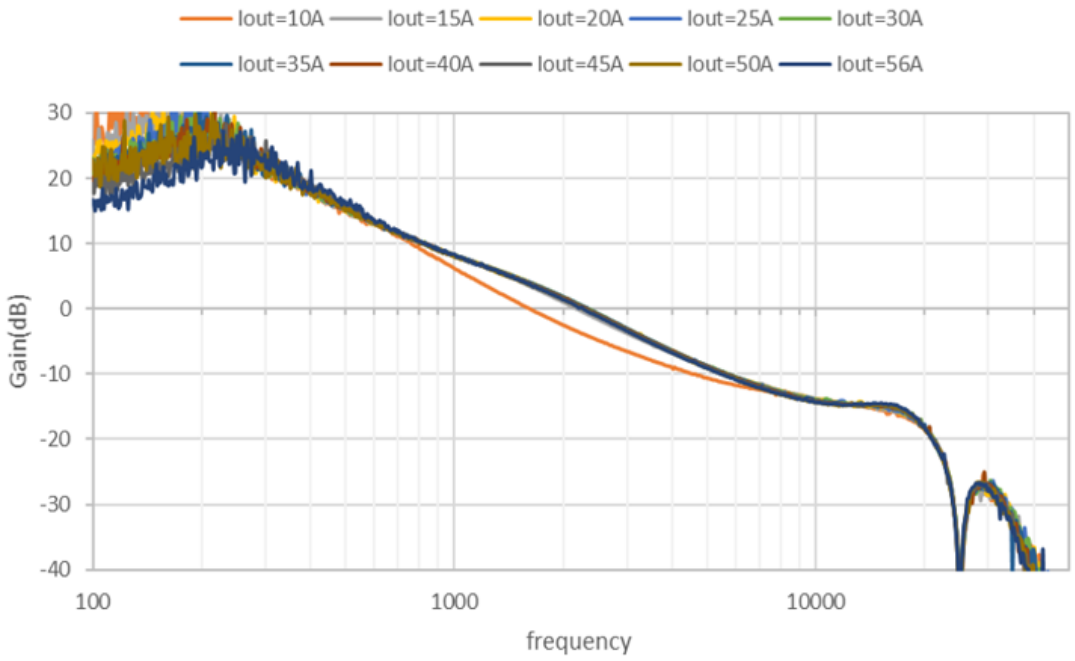
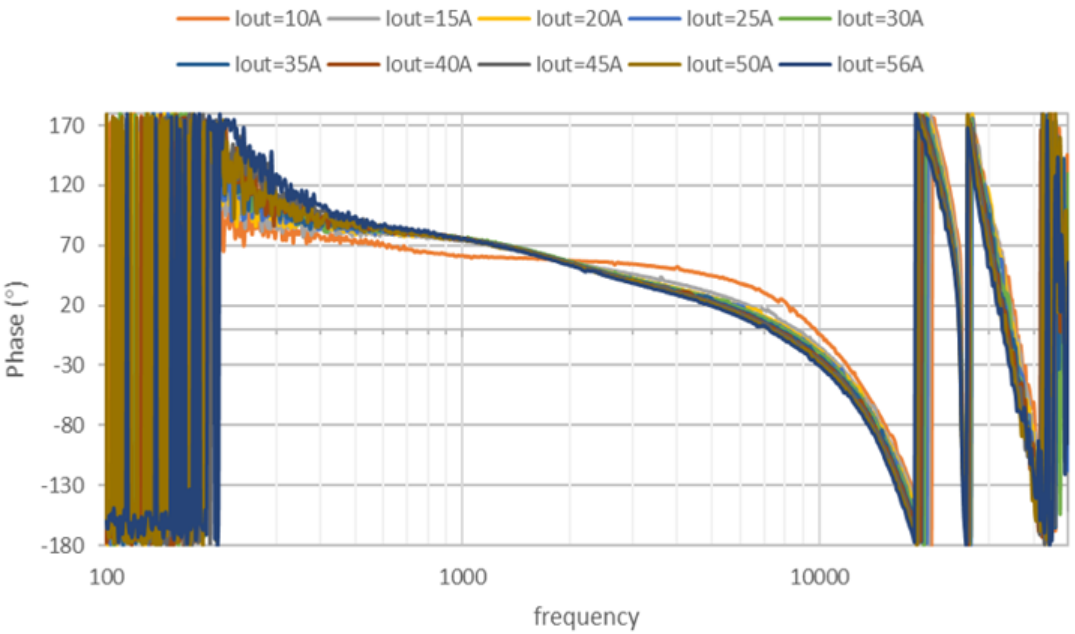


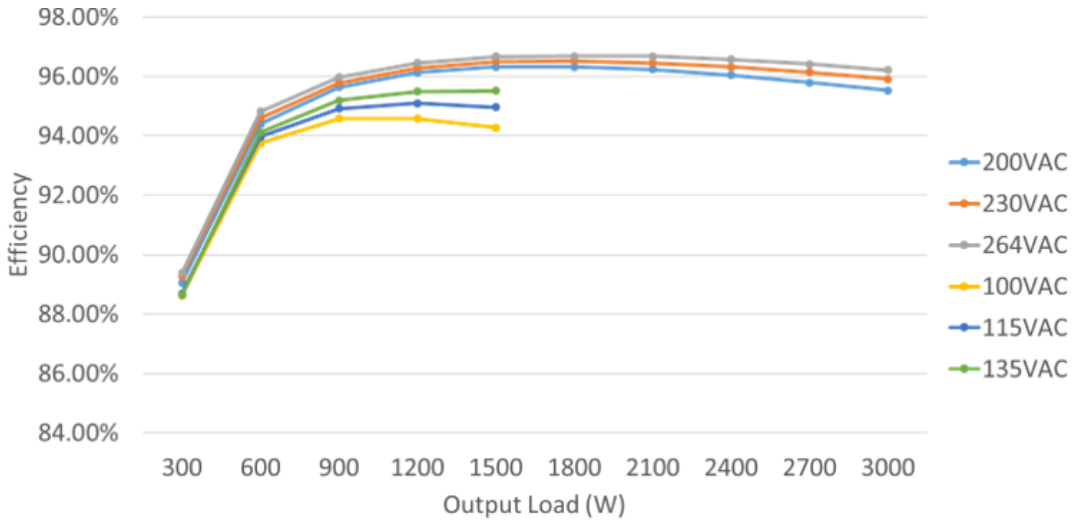
Figure 44. **LLC loop-phase stability**



5.3 PSU overall performance

The figure below shows the efficiency curve for the complete power supply unit. There is a 96.3% peak efficiency at 230 V_{AC}.

Figure 45. **PSU efficiency curve**



The figures below show power factor and iTHD test data at different loads and high-line conditions.

Figure 46. **PSU power factor**

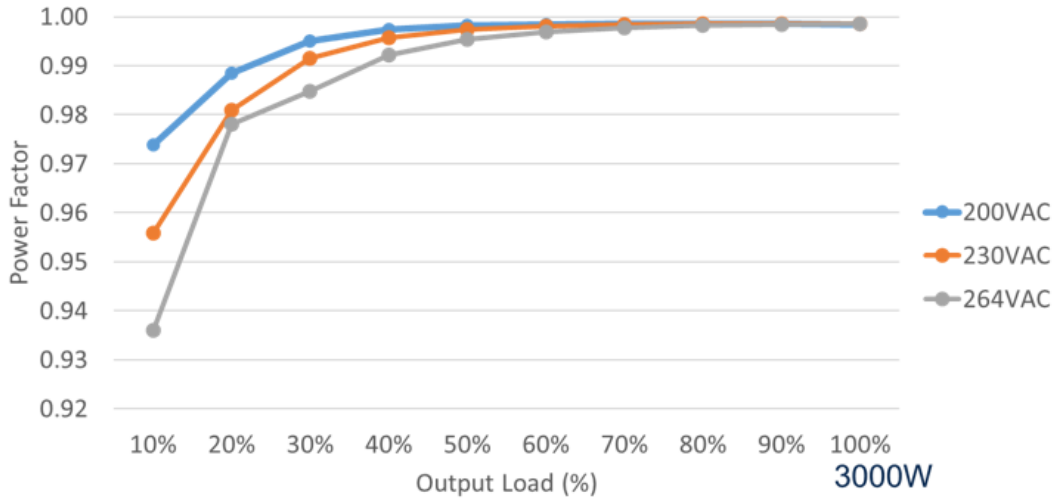
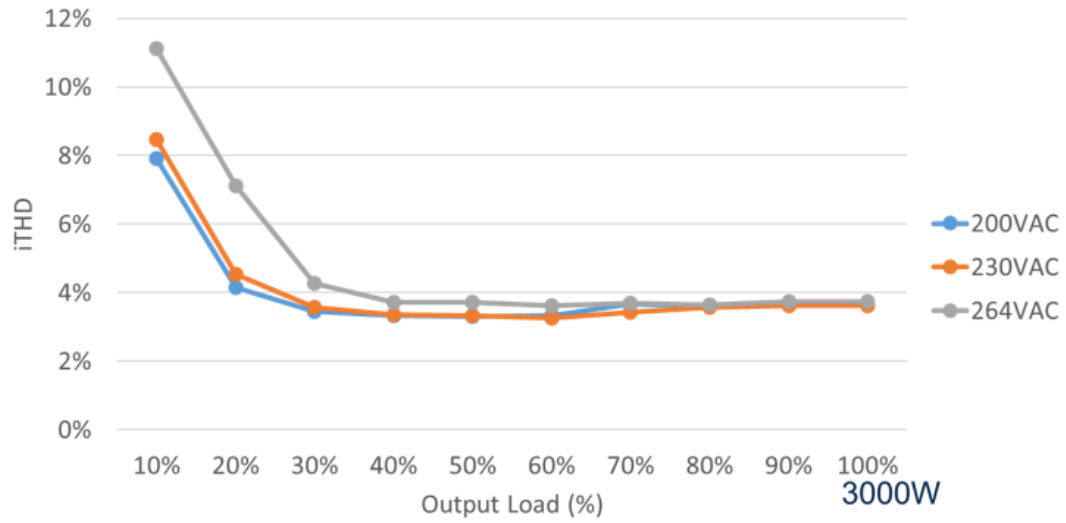


Figure 47. **PSU iTHD**



The figure below show the startup sequence when the PFC integrates the LLC to build a complete power supply. When the AC input applies to the PSU, the PFC controller starts operating and the bulk capacitor voltage ramps up to 400 V. Then, the bulk_ok signal enables the LLC controller to build up the output voltage.

Figure 48. **PSU startup sequence at 115 V_{AC}/1.5 kW load**

- Black trace: AC input current
- Blue trace: AC input voltage
- Red trace: PFC bulk capacitor voltage
- Green trace: LLC output voltage

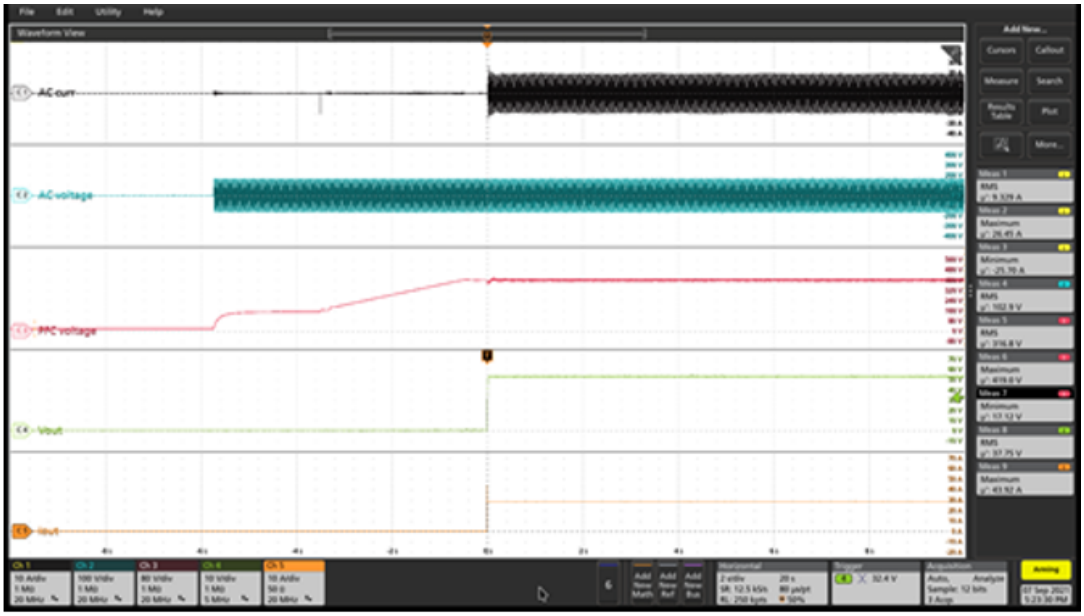
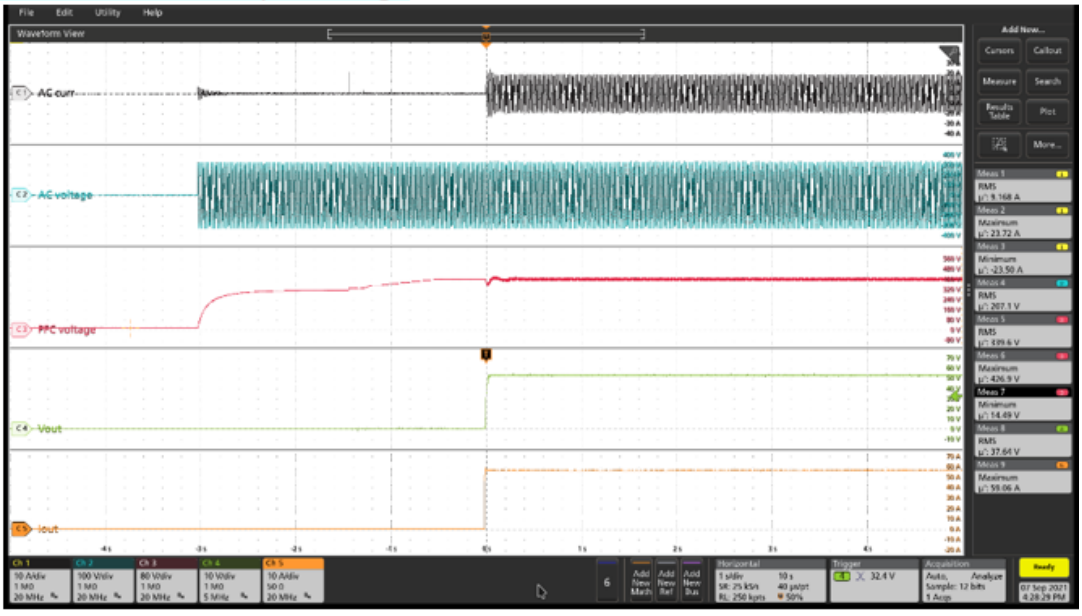


Figure 49. **PSU startup sequence at 230 V_{AC}/3 kW load**

- Black trace: AC input current
- Blue trace: AC input voltage
- Red trace: PFC bulk capacitor voltage
- Green trace: LLC output voltage



The figures below show the load transient response between 0 W to 1500 W at 115 V_{AC} and 0 W to 3000 W at 230 V_{AC} conditions. During the dynamic load jumps, the peak-to-peak voltage variation is approximately 3.3 V at 115 V_{AC} and 7.4 V at 230 V_{AC}.

Figure 50. Load transient response at 115 V_{AC}: 0 W to 1.5 kW

- Black trace: AC input current
- Blue trace: AC input voltage
- Red trace: PFC bulk capacitor voltage
- Green trace: LLC output voltage

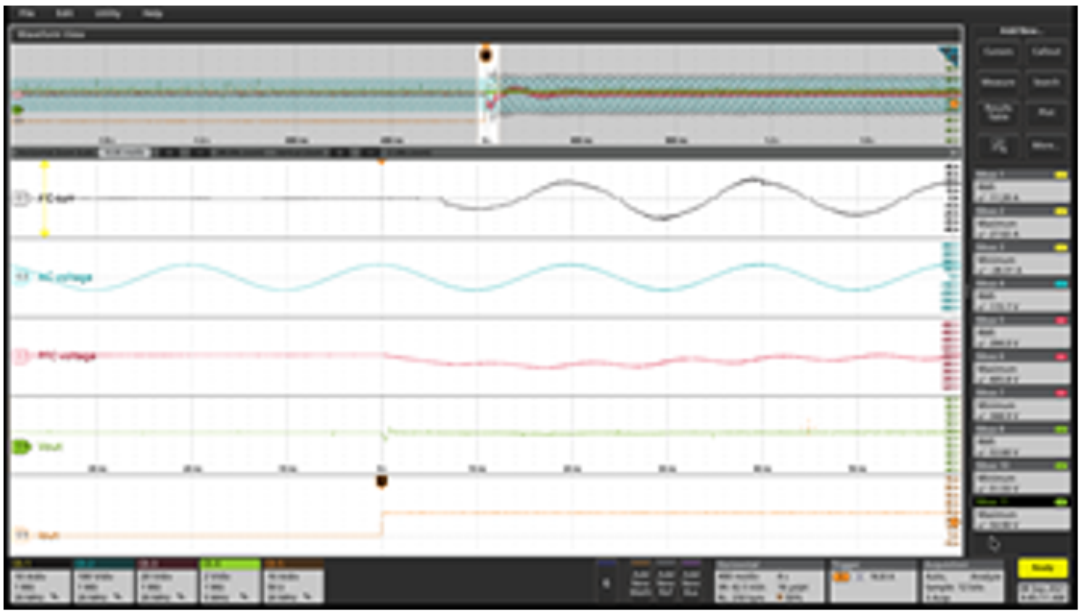
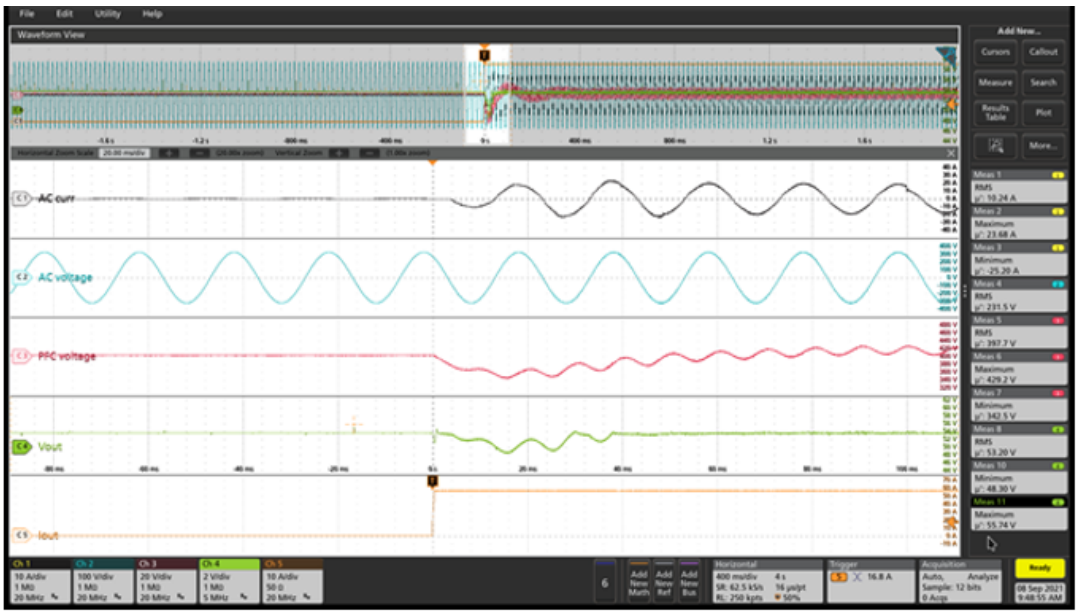


Figure 51. Load transient response at 230 V_{AC}: 0 W to 3 kW

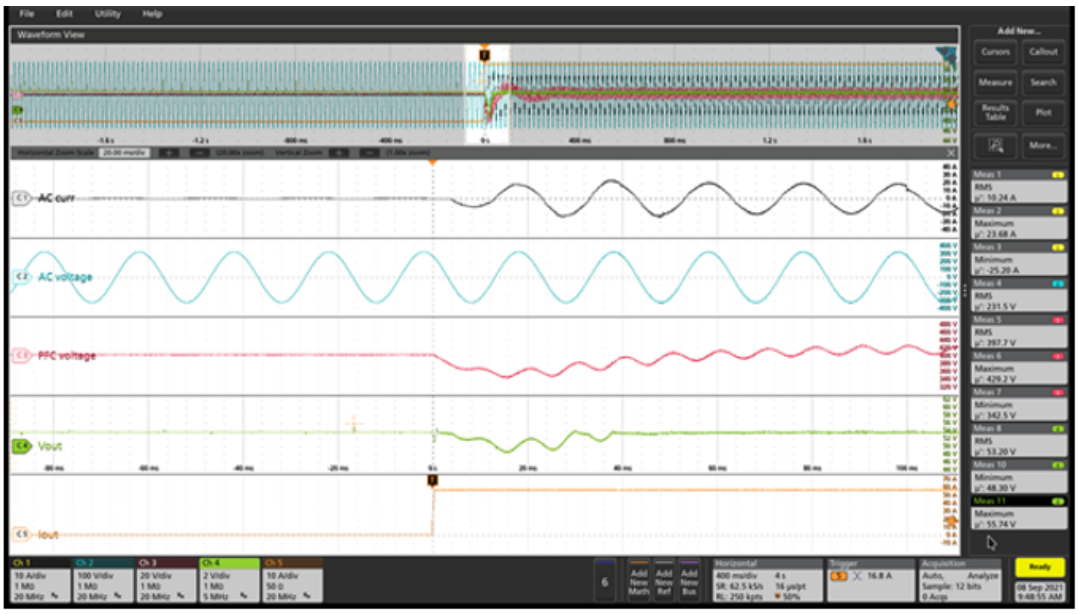
- Black trace: AC input current
- Blue trace: AC input voltage
- Red trace: PFC bulk capacitor voltage
- Green trace: LLC output voltage



The hold-up time specification requires up to 10 ms at full power, although the output voltage of the PSU is allowed to drop down to 48 V. The figure below shows the hold-up time measurement when the 230 V_{AC} input voltage drops to zero at 3 kW. There are 11 ms from the AC off to the output voltage drop to 48 V.

Figure 52. **Hold-up time measurement at 3 kW load**

- Green trace: LLC resonant current
- Blue trace: AC input voltage
- Red trace: PFC bulk capacitor voltage
- Yellow trace: LLC output voltage
- Pink trace: LLC output current



The table below shows the key component temperature at an ambient temperature of 28°C.
At 230 V_{AC} and 3 kW, the temperature of the high-speed leg (SiC MOSFET) for the totem pole is 62.1°C.
The temperature of the low-speed leg (SJ MOSFET) for the totem-pole is 31.4°C.
For the LLC stage, the primary side MOSFET temperature is 45.3°C and the secondary side SR MOSFET temperature is 67.2°C.

Table 5. **Thermal test results**

Item	Function	Order code	115 V_{AC}/1500 W	230 V_{AC}/3000 W
			Temperature	
PFC stage	High-speed leg: SiC MOSFET	SCTW35N65G2V	58.9	54.9
	Low speed leg: SJ MOSFET	STY139N65M5	33.6	31.4
	Driver IC	STGAP2D	43.4	40.0
	PFC choke		77.4	72.6
	Bulk capacitor		40.5	40.4
LLC stage	Primary side: SJ MOSFET	STW70N65DM6-4	40.3	45.3
	Primary side driver IC	STGAP2HS	39.2	40.8
	Main transformer		58.2	91.4
	Secondary side: SR MOSFET	STL130N8F7	45.2	67.2
	Secondary side driver IC		48.8	64.6
Auxiliary power	Auxiliary power control IC	VIPER38LD	45.8	42.8
	Flyback transformer		40.2	38.0
	Ambient		28	28

6 Schematic diagrams

Figure 53. **STDES-3KWTLCPT totem-pole PFC board circuit schematic (1 of 7)**

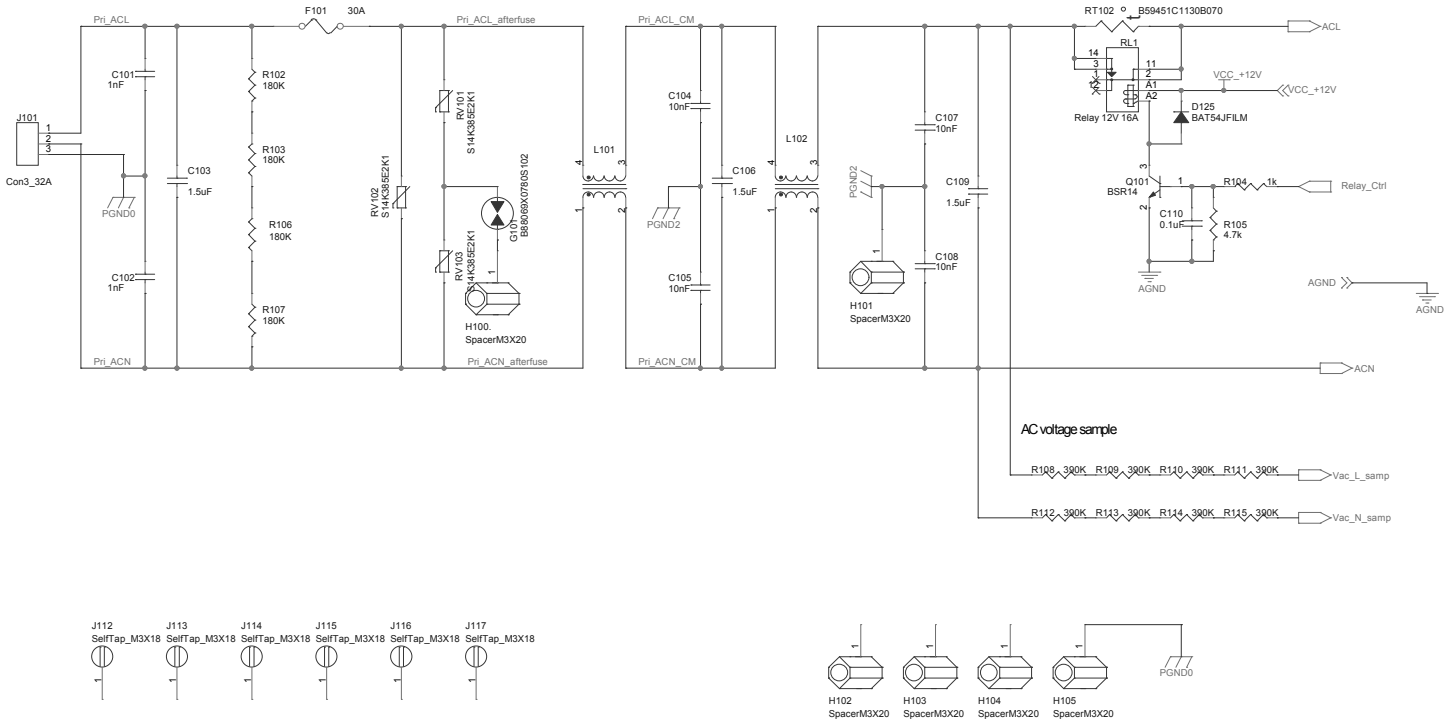


Figure 54. STDES-3KWTLCPT totem-pole PFC board circuit schematic (2 of 7)

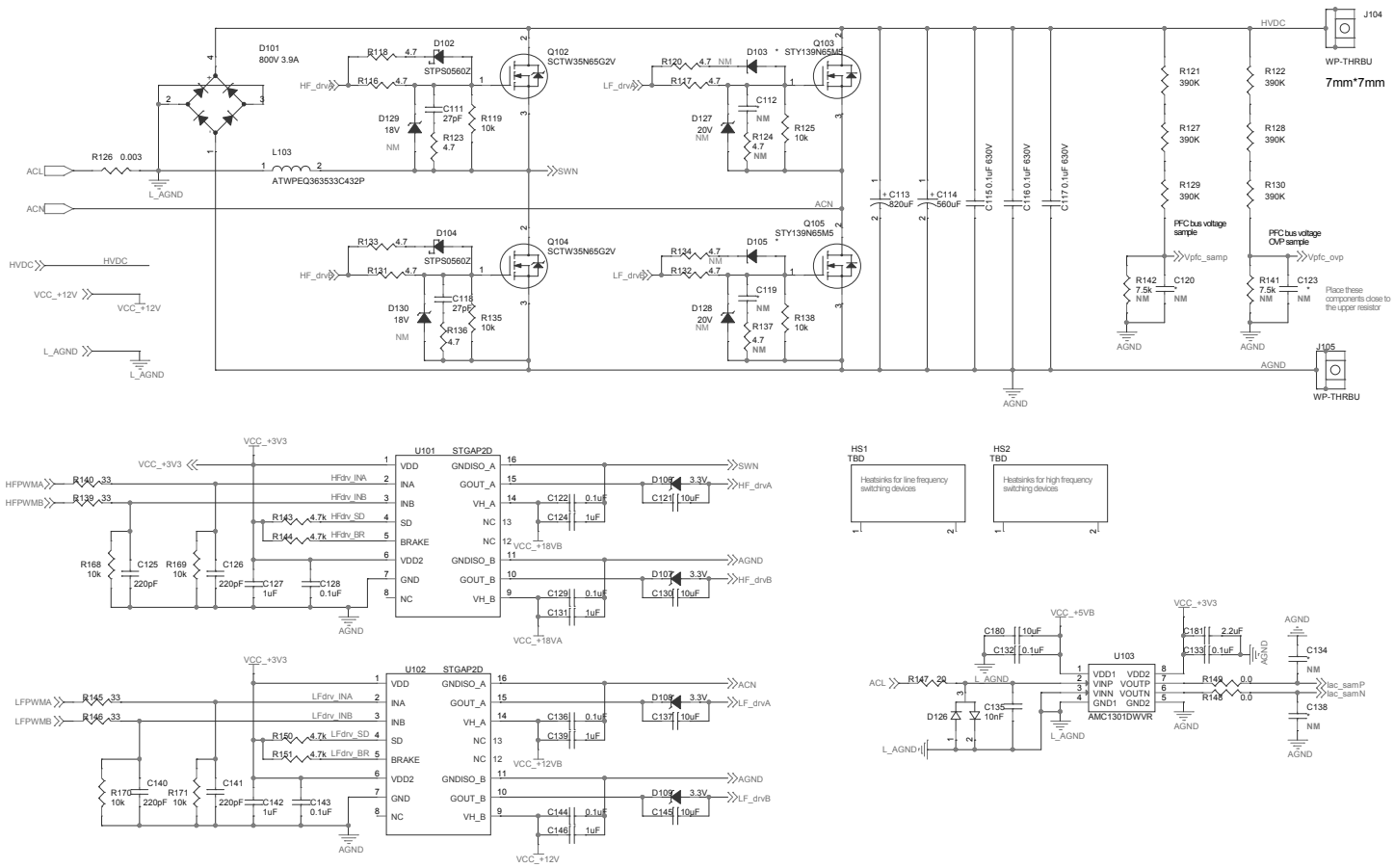


Figure 55. STDES-3KWTLCPT totem-pole PFC board circuit schematic (3 of 7)

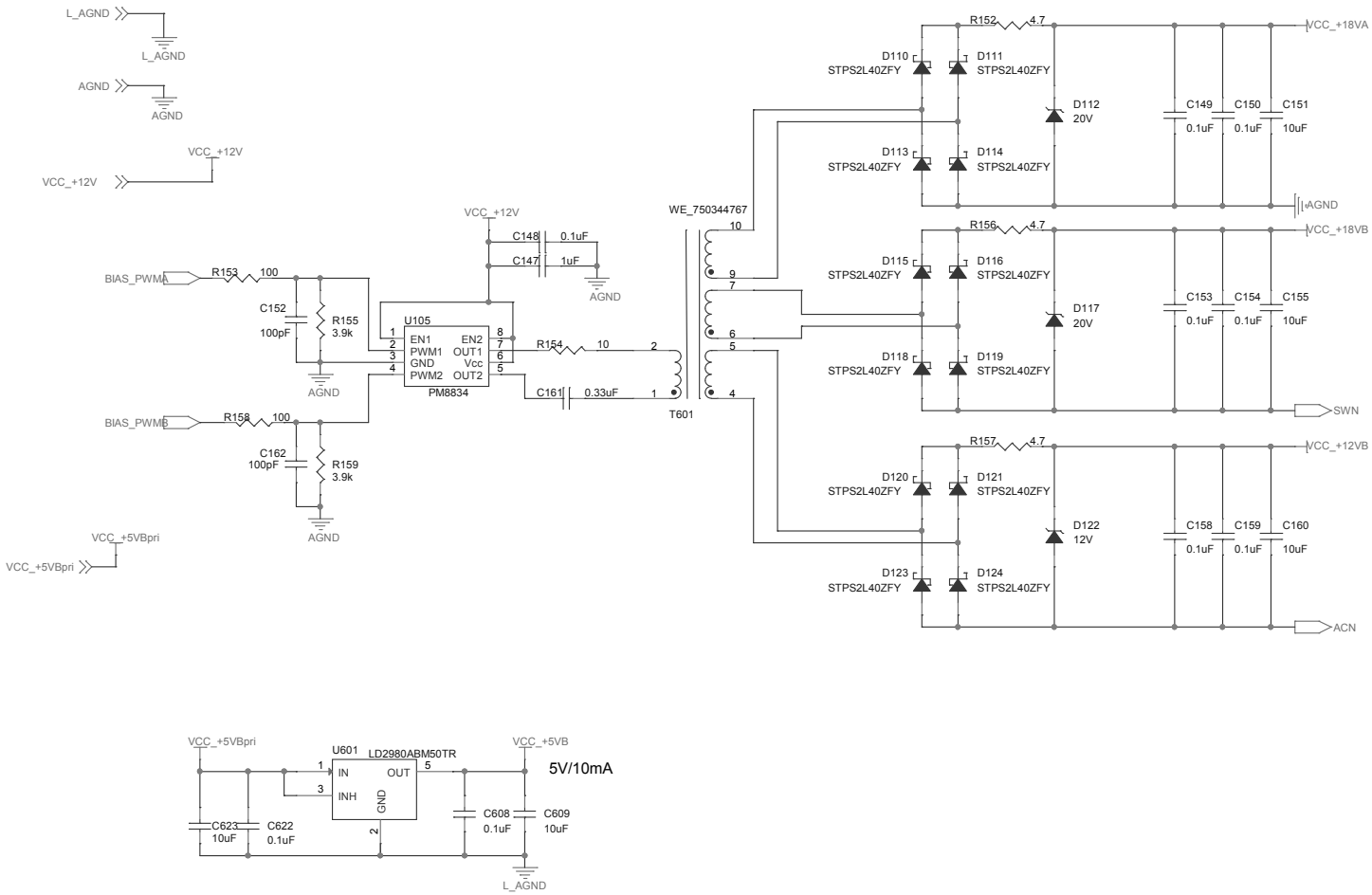


Figure 56. STDES-3KWTLCPT totem-pole PFC board circuit schematic (4 of 7)

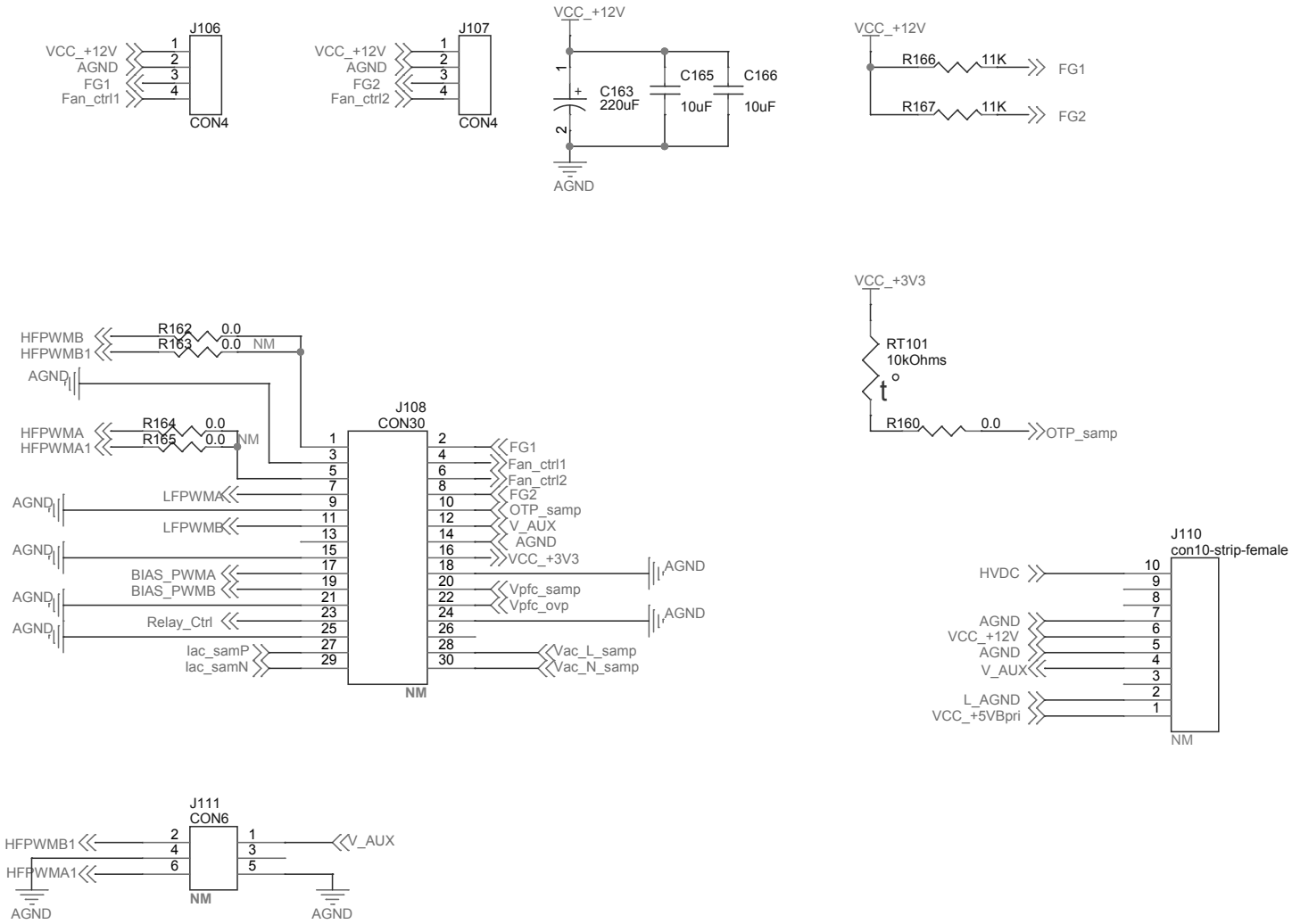


Figure 57. STDES-3KWTLCPT totem-pole PFC board circuit schematic (5 of 7)

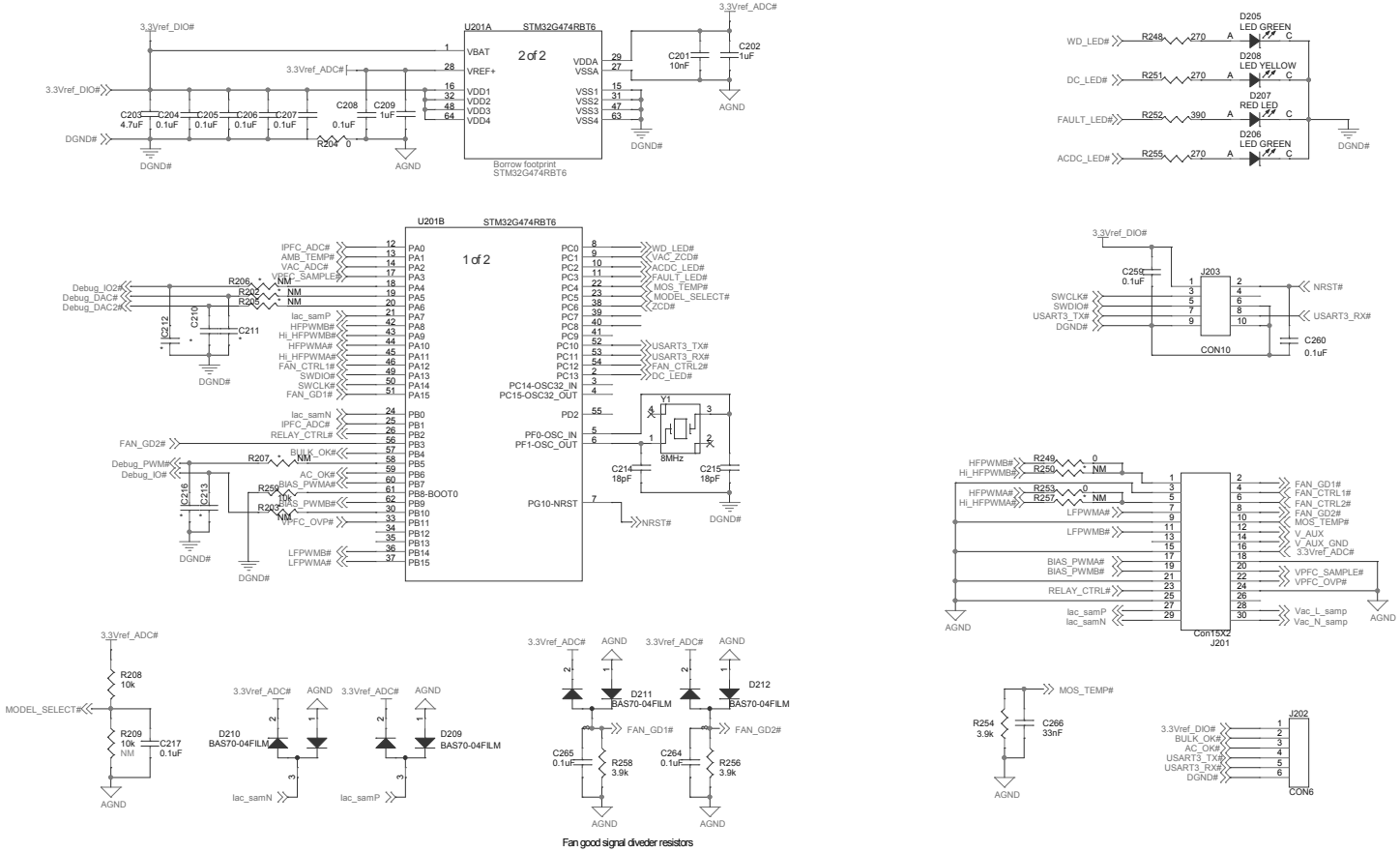


Figure 58. STDES-3KWTLCPT totem-pole PFC board circuit schematic (6 of 7)

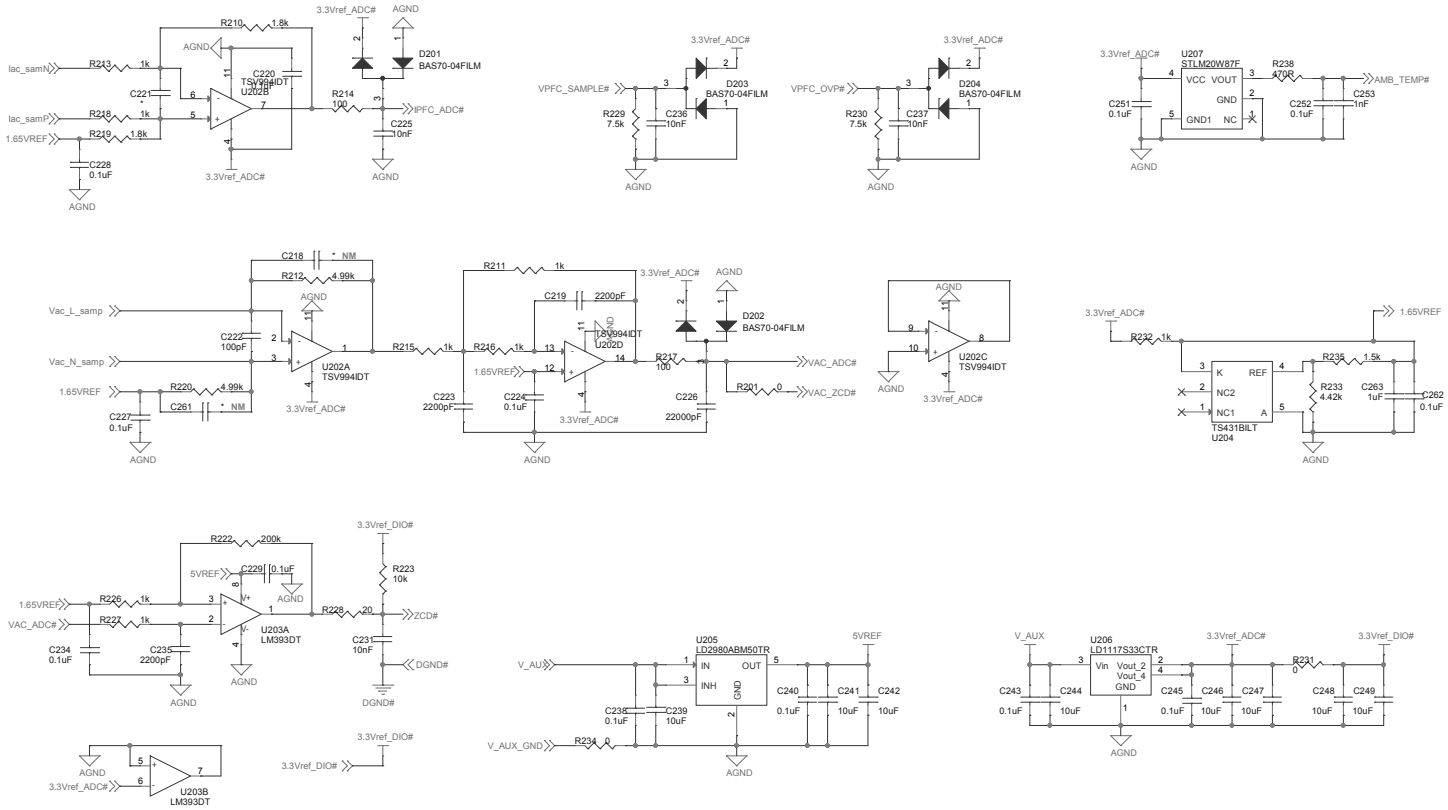


Figure 59. STDES-3KWTLCPT totem-pole PFC board circuit schematic (7 of 7)

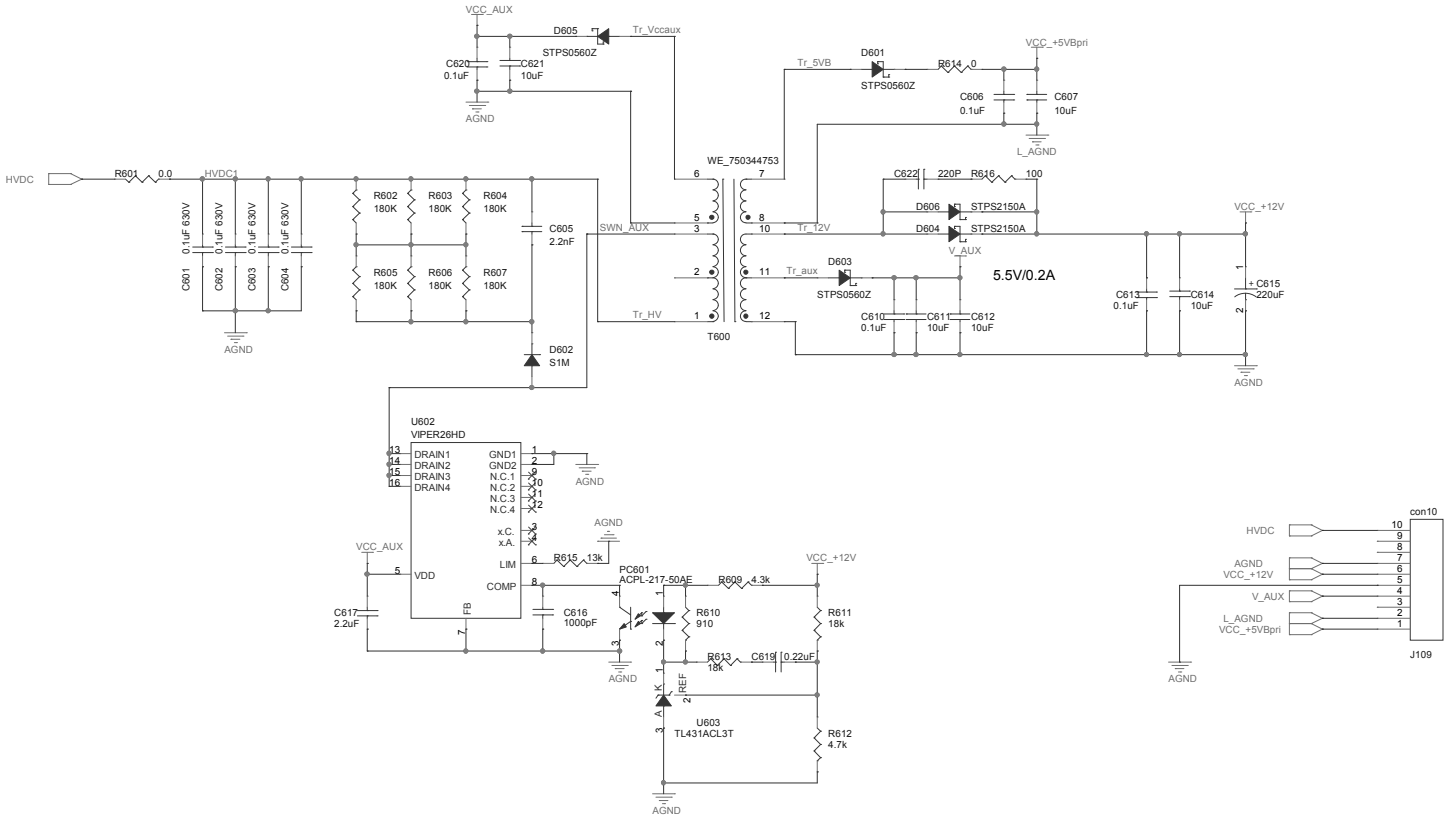


Figure 60. STDES-3KWTLCPL LLC resonant converter board circuit schematic (1 of 5)

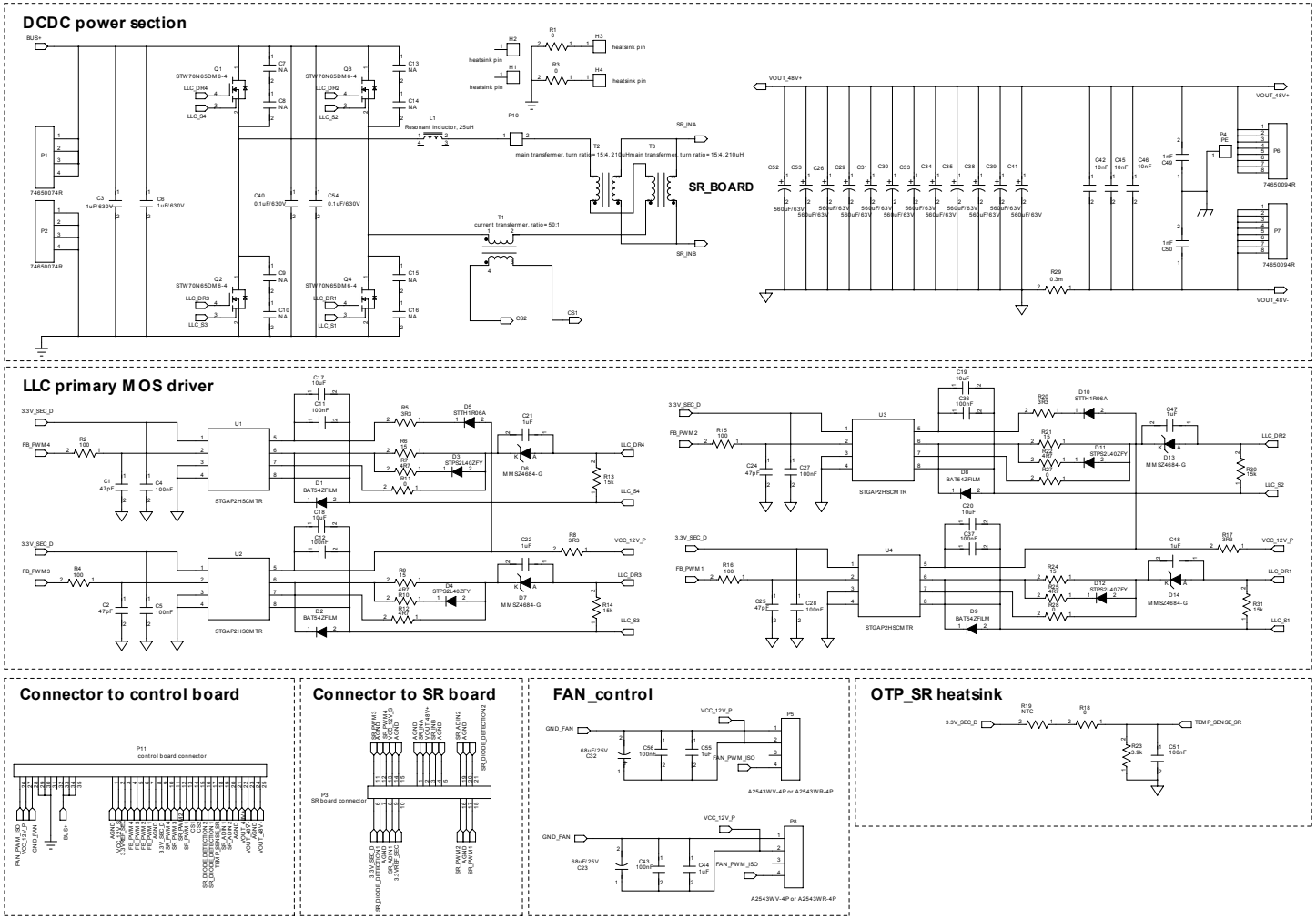


Figure 61. STDES-3KWTLCPL LLC resonant converter board circuit schematic (2 of 5)

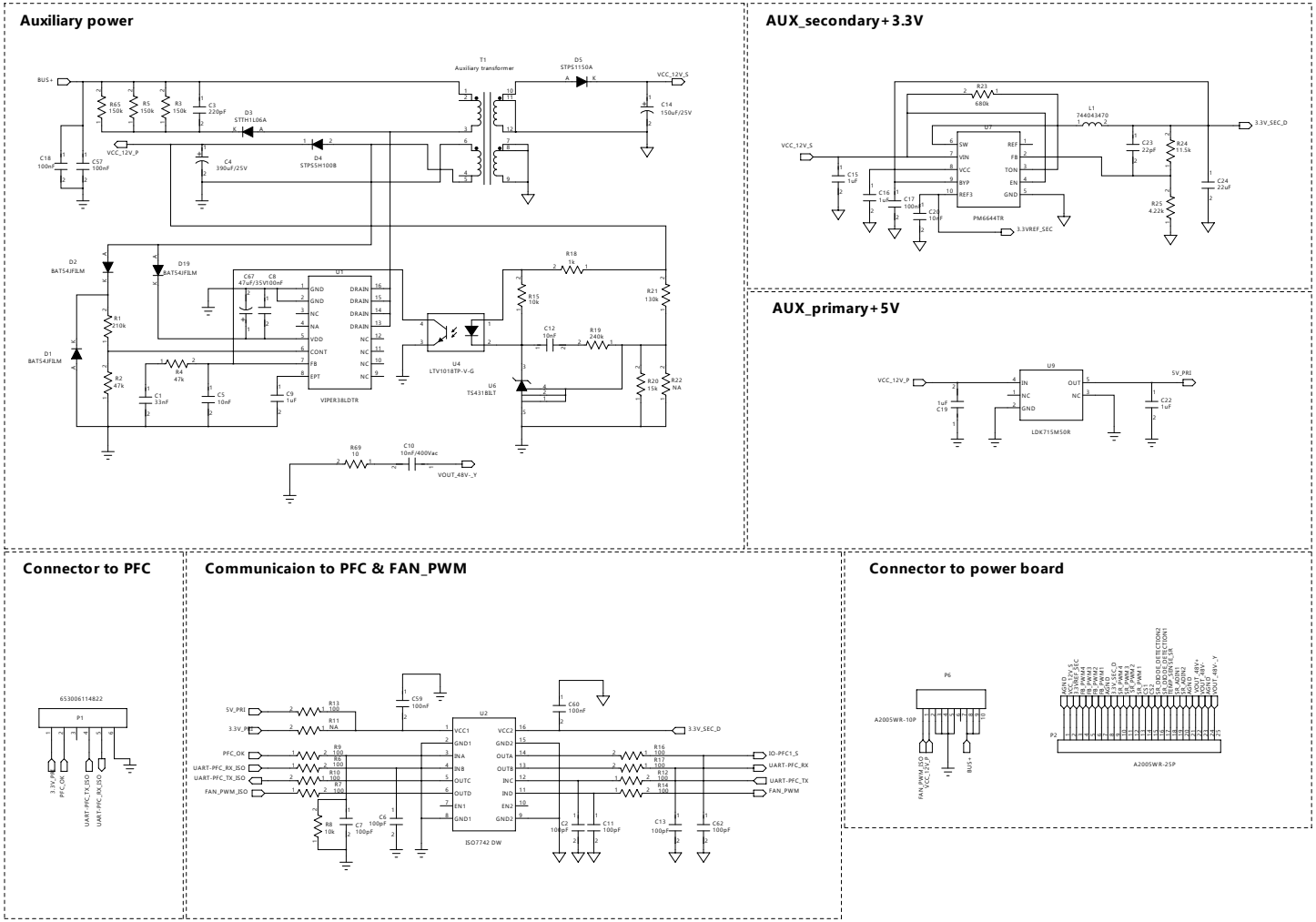


Figure 62. STDES-3KWTLCPL LLC resonant converter board circuit schematic (3 of 5)

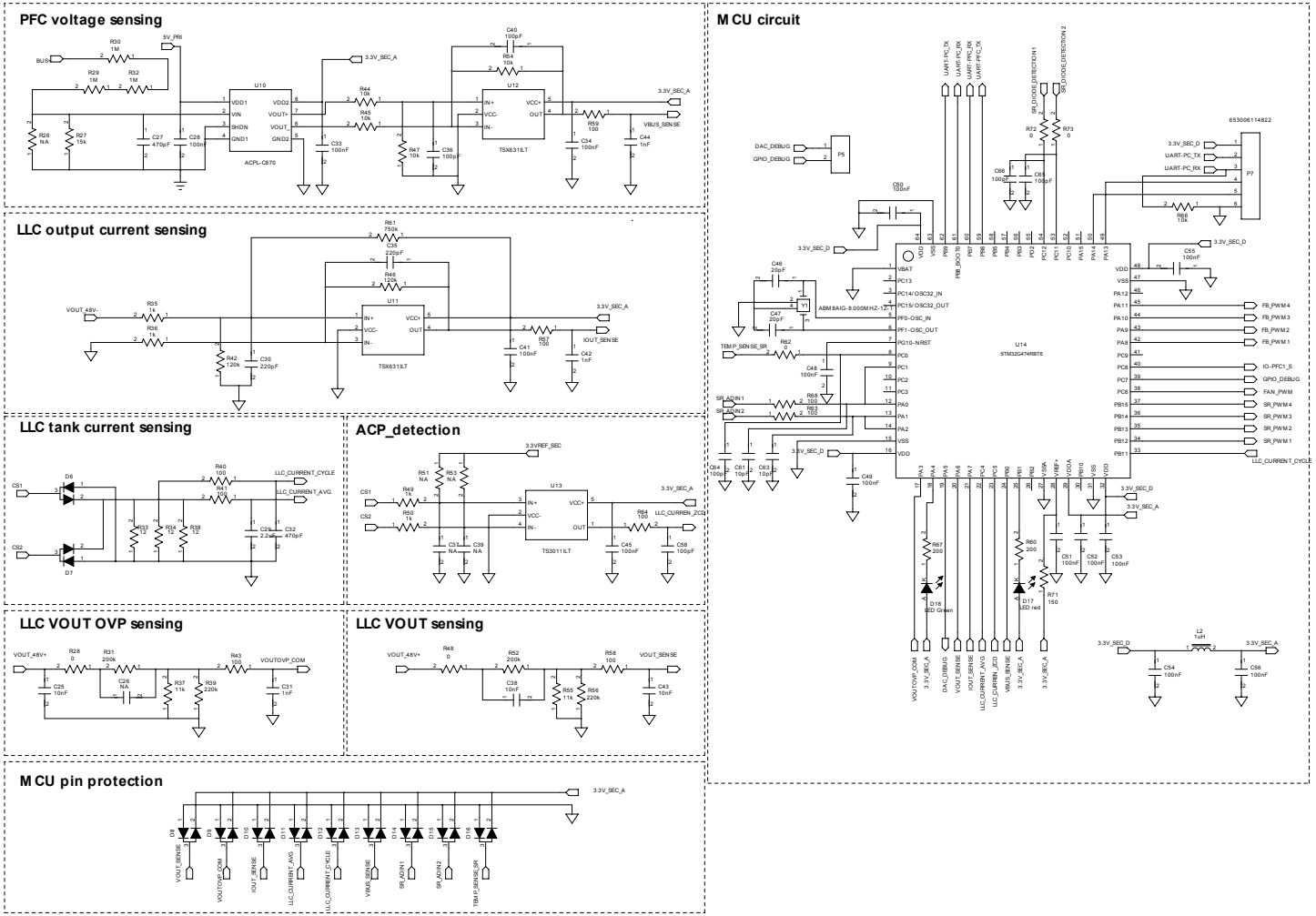


Figure 63. STDES-3KWTLCPL LLC resonant converter board circuit schematic (4 of 5)

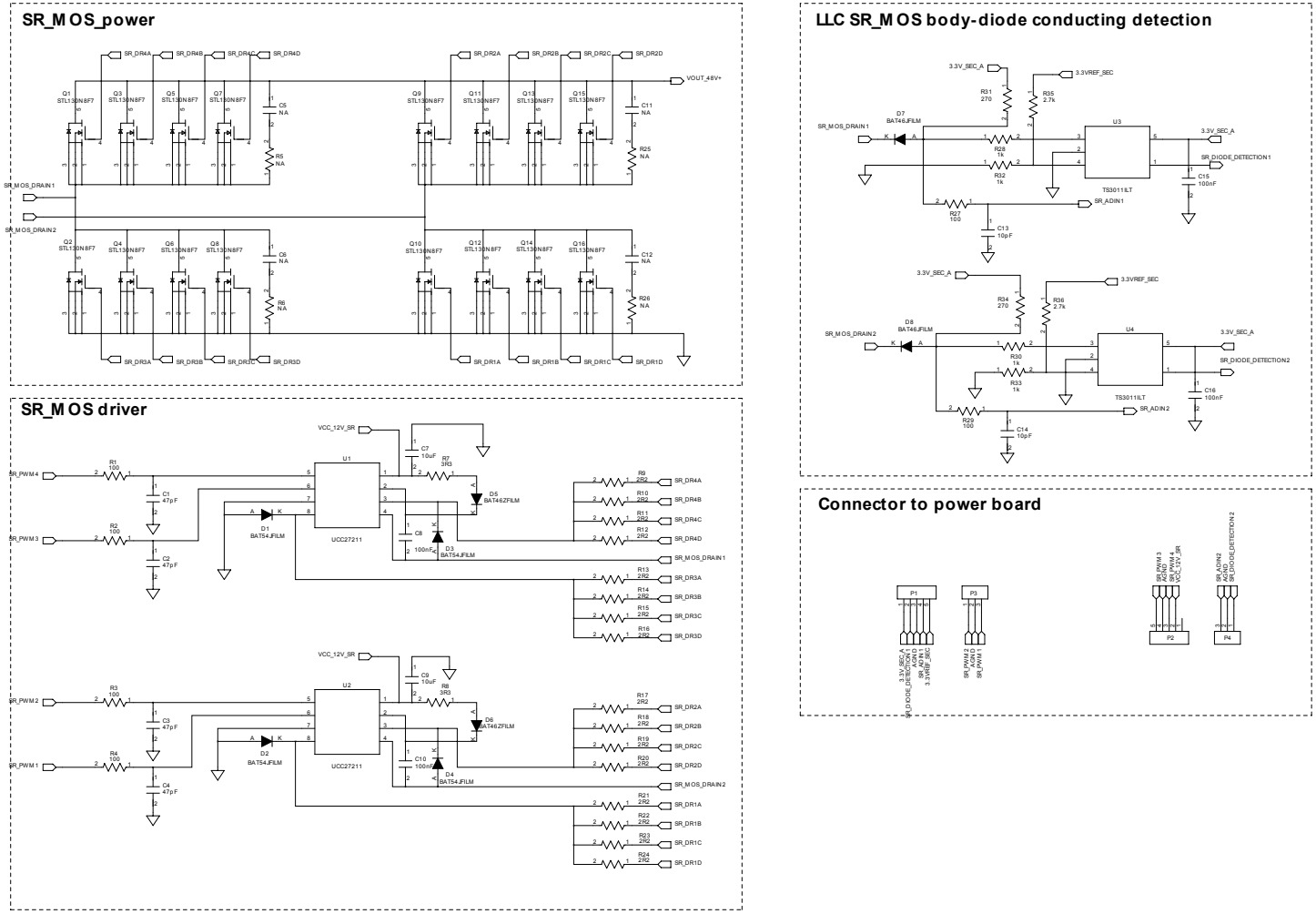
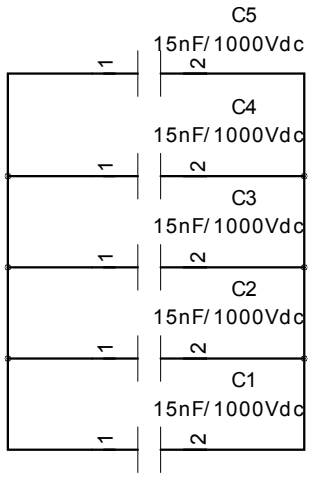


Figure 64. **STDES-3KWTLCPL LLC resonant converter board circuit schematic (5 of 5)**



7 Bill of materials

Table 6. STDES-3KWTLCP bill of materials

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
1	1	Table 7. Totem pole PFC	-	Totem pole PFC	ST	Not available for separate sale
2	1	Table 8. Full bridge LLC	-	Full bridge LLC	ST	Not available for separate sale

Table 7. Totem pole PFC bill of materials

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
1	2	C101, C102	1 nF, radial, disc, 400 V_{AC}, ±20%	Ceramic capacitors	Kemet	C907U102MYVDBA7317
2	1	C103	1.5 µF, radial, 305 V_{AC}, ±20%	Ceramic capacitor	TDK Electronics Inc.	B32923C3155M000
3	4	C104, C105, C107, C108	10 nF, radial, 1500 Vdc, ±10%	Ceramic capacitors	TDK Electronics Inc.	B32022A3103K000
4	2	C106, C109	1.5 µF, radial, 305 V_{AC}, ±20%	Ceramic capacitors	TDK Electronics Inc.	B32923C3155M000
5	18	C110, C122, C128, C129, C132, C133, C136, C143, C144, C148, C149, C150, C153, C154, C158, C159, C608, C622	0.1 µF, 0603 (1608 metric), 25 V, ±10%	Ceramic capacitors	Kemet	C0603C104K3RACTU
6	2	C111, C118	27 pF, 0603 (1608 metric), 50 V, ±5%	Ceramic capacitors	Murata Electronics North America	GCM1885C1H270JA16D
7	6	C112, C119, C120, C123,C134, C138	0603 (1608 metric), SMD	Ceramic capacitors (not mounted)	-	-
8	1	C113	820 µF, radial, can - snap-in, 450 V, ±20%	Ceramic capacitor	Rubycon	450MXK820MEFCSN30X60
9	1	C114	560 µF, radial, can - snap-in, 450 V, ±20%	Ceramic capacitors	Rubycon	450MXK560MEFCSN30X45
10	3	C115, C116, C117	0.1 µF 630V, 1812 (4532 metric), 630 V, ±10%	Ceramic capacitors	Würth Elektronik	885342211006
11	5	C121, C130, C180, C609, C623	10 µF, 0805 (2012 metric), 16 V, ±20%	Ceramic capacitors	Wurth Electronics Inc.	885012107014
12	7	C124, C127, C131, C139, C142, C146, C147	1 µF, 0603 (1608 metric), 25 V, ±10%	Ceramic capacitors	Wurth Electronics Inc.	885012206076
13	4	C125, C126, C140, C141	220 pF, 0603 (1608 metric), 50 V, ±10%	Ceramic capacitors	Samsung Electro-Mechanics America, Inc.	CL10B221KB8NNNC

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
14	1	C135	10 nF, 0603 (1608 metric), 50 V, ±10%	Ceramic capacitor	Murata Electronics North America	GRM188R71H103KA01D
15	5	C151, C155, C160, C165, C166	10 µF, 1206 (3216 metric), 50 V, ±10%	Ceramic capacitors	Samsung Electro-Mechanics America, Inc.	CL31B106KBHNNNE
16	2	C152, C162	100 pF, 0603 (1608 metric), 50 V, ±5%	Ceramic capacitors	Murata Electronics North America	GRM1885C1H101JA01D
17	1	C161	0.33 µF, 0603 (1608 metric), 50 V, ±10%	Ceramic capacitor	TDK Corporation	C1608X5R1H334K080AB
18	1	C163	220 µF, radial, can, 16 V, ±20%	Ceramic capacitor	Wurth Electronics Inc.	860020373010
19	1	C181	2.2 µF, 0603 (1608 metric), 25 V, ±10%	Multilayer ceramic capacitors	Murata Electronics	GRM188B31E225KA12D
20	1	D101	800 V 3.9 A, 4-SIP, GBU	Bridge rectifier	Vishay Semiconductor Diodes Division	GBU8K-E3/45
21	2	D102, D104	STPS0560Z, SOD-123, 60 V, 0.5 A	60 V, 0.5 A power Schottky rectifier	ST	STPS0560Z
22	2	D103, D105	SOD123	Diodes	Any	Any
23	2	D106, D107	3.3 V, SOD-123	Zener diodes	ON Semiconductor	MMSZ4684T1G
24	12	D110, D111, D113, D114, D115, D116, D118, D119, D120, D121, D123, D124	STPS2L40ZFY, SOD-123F, 40 V, 2 A,	Automotive 40 V, 2 A low drop power Schottky rectifier	ST	STPS2L40ZFY
25	2	D112, D117	20 V, SOD-123, 20 V, 0.5 W	Zener diodes	ON Semiconductor	MMSZ5250BT1G
26	1	D122	12V, SOD-123, 12 V, 0.5 W	Zener diode	ON Semiconductor	MMSZ5242BT1G
27	1	D125	BAT54JFILM, SOD-323	40 V, 300 mA general purpose signal Schottky diode	ST	BAT54JFILM
28	1	D126	BAR43SFILM, SOT-23-3	30 V, 100 mA Vf 0.33 V at 2 mA SMD general purpose signal Schottky diode	ST	BAR43SFILM
29	2	D127, D128	20 V, SOD-123, 0.5 W	Zener diodes (not mounted)	ON Semiconductor	MMSZ5250BT1G
30	2	D129, D130	18 V, SOD-123, 0.5 W	Zener diodes (not mounted)	ON Semiconductor	MMSZ5248BT1G
31	1	F101	30 A, 3AB, 3AG, 1/4" x 1-1/4" (axial), 250 V	Fuse	Littelfuse Inc.	0324030.HXP
32	1	G101	B88069X0780S102, axial cylinder	GDT	EPCOS (TDK)	B88069X0780S102

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
33	1	HS1	TO-218,TO-220,TO-247	Heatsink	Taiwan Microloops Corp	TSM-001979-NN2
34	1	HS2	TO-218,TO-220,TO-247	Heatsink	Taiwan Microloops Corp	TSM-001979-NN1
35	6	H100, H101, H102, H103, H104, H105	SpacerM3X20	Brass spacers	Würth Elektronik	970200324
36	1	J101	Con3_32A, 3P 9.52 mm 90DEG	Fixed terminal blocks	Phoenix Contact	1714984
37	2	J104, J105	WP-THRBU, M4 4-pin PCB	Terminals	Würth Elektronik	74650074R
38	2	J106, J107	CON4, WR-WTB 1.50 mm	Male vertical shrouded headers	Wurth Electronics	64800411622
39	1	J108 NM	CON30, AMPMODU 2 mm, PCB mount receptacle, vertical, board-to-board, 30 position, 2 mm	Jumper (not mounted)	Te Connectivity	3-2314823-0
40	1	J110	con10-strip-female,	Jumper (not mounted)	-	-
41	1	J111	CON6, AMPMODU 2 mm, PCB mount receptacle, vertical, board-to-board, 6 position, 2 mm	Jumper (not mounted)	Te Connectivity	2314823-6
42	6	J112, J113,J114, J115, J116, J117	SelfTap_M3X18, self-tapping, M3,18 mm	Screws	TR fastenings	3.018PRST30TC1D
43	2	L101, L102	ARCDC341831E202N2B, 34.00 mm x 18.00 mm, 10 KHz, 1.0 V	Common mode choke	Sunlord	ARCDC341831E202N2B
44	1	L103	ATWPEQ363533C432P	PFC inductor	Sunlord	ATWPEQ363533C432P
45	1	Q101	BSR14, SOT-23-3, 40 V, 0.8 A	Transistor	ON Semiconductor	BSR14
46	2	Q102, Q104	SCTW35N65G2V, HIP247 full pack	Silicon carbide power MOSFET 650 V, 55 mOhm typ., 45 A in an HIP247 package	ST	SCTW35N65G2V
47	2	Q103, Q105	STY139N65M5, TO-247-3	N-channel 650 V, 0.014 Ohm typ., 130 A MDmesh M5 Power MOSFET in Max247 package	ST	STY139N65M5
48	1	RL1	Relay 12 V 16 A	Relay	TE Connectivity Potter & Brumfield relays	RT314012F
49	1	RT101	10 kOhms, ±1%	NTC thermistor	Vishay/BC Components	NTCLE213E3103FLT1
50	1	RT102	B59451C1130B070, ±25%	ICL	TDK Electronics Inc.	B59451C1130B070

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
51	3	RV101, RV102, RV103	S14K385E2K1, disc 14 mm	Varistors	EPCOS (TDK)	B72214P2381K101
52	4	R102,R103, R106, R107	180 K, 1206 (3216 metric), 1/4 W, ±0.10%	Resistors	Panasonic Electronic Components	ERA-8AEB184V
53	1	R104	1 k, 0603 (1608 metric), 1/10 W, ±1%	Resistors	Yageo	RC0603FR-071KL
54	5	R105, R143, R144, R150, R151	4.7 k, 0603 (1608 metric), 1/10 W, ±1%	Resistors	Yageo	RC0603FR-074K7L
55	14	R108, R109, R110, R111, R112, R113, R114, R115, R121, R122, R127, R128, R129, R130	390K, 1206 (3216 metric), 1/4 W, ±1%	Resistors	Yageo	RC1206FR-07390KL
56	9	R116, R117, R118, R131, R132, R133, R152, R156, R157	4.7, 1206 (3216 metric), 1/4 W, ±1%	Resistors	Yageo	RC1206FR-074R7L
57	8	R119, R125, R135, R138,R168, R169, R170, R171	10 k, 0603 (1608 metric), 1/10 W, ±1%	Resistors	Yageo	RC0603FR-0710KL
58	2	R120, R134	4.7, 1206 (3216 metric), 1/4 W, ±1%	Resistors (not mounted)	Yageo	RC1206FR-074R7L
59	2	R123, R136	4.7, 0805 (2012 metric), 1/8 W, ±1%,	Resistors	Yageo	RC0805FR-074R7L
60	2	R124, R137	4.7, 0805 (2012 metric), 1/8 W, ±1%	Resistors (not mounted)	Yageo	RC0805FR-074R7L
61	1	R126	0.003, 2512 (6432 metric), 3 W, ±1%	Resistor	TE Connectivity Passive Product	TLR3A30DR003FTDG
62	4	R139, R140, R145, R146	33, 0603 (1608 metric), 1/10 W, ±1%	Resistors	Yageo	9C06031A33R0FKHFT
63	2	R141, R142	7.5k, 0603 (1608 metric), 1/10 W, ±1%	Resistors (not mounted)	Panasonic Electronic Components	ERJ-3EKF7501V
64	1	R147	20, 0603 (1608 metric), 1/10 W, ±1%	Resistor	Yageo	RC0603FR-0720RL
65	5	R148, R149, R160, R162, R164	0, 0603 (1608 metric), 1/10 W	Resistors	Yageo	RC0603JR-070RL
66	2	R153, R158	100, 0603 (1608 metric), 1/10 W, ±1%	Resistors	Yageo	RC0603FR-07100RP
67	1	R154	10, 1210 (3225 metric), 1/2 W, ±1%	Resistor	Stackpole Electronics Inc.	RMCF1210FT10R0
68	2	R155, R159	3.9 k, 0603 (1608 metric), 1/10 W, ±1%	Resistors	Yageo	RC0603FR-073K9L
69	2	R163, R165	0, 0603 (1608 metric), 1/10 W	Resistors (not mounted)	Yageo	RC0603JR-070RL

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
70	2	R166, R167	11 K, 0603 (1608 metric), 1/10 W, ±1%	RES SMD 11K OHM 1% 1/10W 0603	Yageo	RC0603FR-0711KL
71	1	T601	WE_750344767	Transformer	Wurth Electronics	750344767
72	2	U101, U102	STGAP2DMTR, 16-SOIC (0.154", 3.90 mm width)	Galvanically isolated 4 A half-bridge dual channel gate driver	ST	STGAP2DMTR
73	1	U103	AMC1301DWVR, 8-SOIC (0.295", 7.50 mm width)	IC amplifier	Texas Instruments	AMC1301DWVR
74	1	U105	PM8834, 8-SOIC (0.154", 3.90mm width)	4 A dual low side MOSFET driver	ST	PM8834
75	1	U601	LD2980ABM50TR, SC-74A, SOT-753, SOT23-5L	Ultra low drop voltage regulators compatible with low ESR output capacitors	ST	LD2980ABM50TR
76	5	C201, C225, C231, C236, C237	10 nF, 0603 (1608 Metric), ±10 % X7R	Ceramic capacitors	Murata Electronics North America	GRM188R71H103KA01D
77	3	C202, C209, C263	1 µF, 0603 (1608 Metric), ±10 %	Ceramic capacitors	Wurth Electronics Inc.	885012206076
78	1	C203	4.7 µF, 0603 (1608 Metric), ±20%	Ceramic capacitor	Wurth Electronics Inc.	885012106012
79	23	C204, C205, C206,C207, C208, C217, C220, C224, C227, C228, C229, C234, C238, C240, C243, C245, C251, C252, C259, C260, C262, C264, C265	0.1 µF, 0603 (1608 Metric), ±10 %	Ceramic capacitors	Kemet	C0603C104K3RACTU
80	6	C210, C211, C212, C213, C216, C221	SMD 0603 (1608 metric)	Ceramic capacitors	Any	Any
81	2	C214,C215	18 pF, 0402 (1005 metric), ±5% C0G/NPO	Ceramic capacitors	Yageo	CC0402JRNPO9BN180
82	2	C218,C261	0603 (1608 metric)	Ceramic capacitors		
83	3	C219, C223, C235	2200 pF, 0603 (1608 Metric), ±10% X7R	Ceramic capacitors	TDK Corporation	CGA3E2X7R1H222K080AD
84	1	C222	100 pF, 0603 (1608 metric), ±5%	Ceramic capacitor	Murata Electronics North America	GRM1885C1H101JA01D
85	1	C226	22000 pF, 0603 (1608 metric), ±10% X7R	Ceramic capacitor	Wurth Electronics Inc.	885012206067

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
86	8	C239, C241, C242, C244, C246, C247, C248, C249	10 µF, 0805 (2012 metric), ±20% X5R	Ceramic capacitors	Wurth Electronics Inc.	885012107014
87	1	C253	1 nF, 0603 (1608 metric), ±10%	Ceramic capacitor	Samsung Electro-Mechanics	CL10B102KA8NNNC
88	1	C266	33 nF, 0603 (1608 Metric), ±10%	CAP CER 0.033UF 50V X7R 0603	Wurth Electronics Inc.	885012206092
89	8	D201, D202, D203, D204, D209, D210, D211, D212	BAS70-04FILM, SOT-23-3	70 V, 70 mA RF and ultrafast switching signal Schottky diode	ST	BAS70-04FILM
90	2	D205,D206	SMD 0603 (1608 metric),	Green LEDs	Wurth Electronics Inc.	150060VS75000
91	1	D207	SMD, 0603 (1608 metric)	Red LED	Wurth Electronics Inc.	150060RS75000
92	1	D208	SMD, 0603 (1608 metric)	Yellow LED	Wurth Electronics Inc.	150060YS75000
93	1	J201	Con15X2, 30 P, 2 mm, BRK HDR DRRT, 2.8, SN, TB	Board-to-board and mezzanine connectors	TE Connectivity	1-2842149-5
94	1	J202	CON6, WR-WTB 1.25 mm	Male horizontal shrouded header	Wurth Electronics	653006117322
95	1	J203	CON10, R/A 10POS 2.54 mm	Connector header	Samtec Inc.	TSW-105-08-T-D-RA
96	6	R201, R204, R231, R234, R249, R253	0, 0603 (1608 metric)	Resistors	Panasonic Electronic Components	ERJ-3GEY0R00V
97	7	R202, R203, R205, R206, R207, R250, R257 NM	SMD, 0603 (1608 metric), ±1%,	Chip resistors (not mounted)		
98	3	R208, R223, R259	10 k, 0603 (1608 metric), ±1%	Resistors	Yageo	RC0603FR-0710KL
99	1	R209	10 k, 0603 (1608 metric), ±1%	Resistor (not mounted)	Yageo	RC0603FR-0710KL
100	2	R210, R219	1.8 k, 0603 (1608 metric), ±1%	Resistors	Vishay Beyschlag	MCT06030C1801FP500
101	8	R211, R213, R215, R216, R218, R226, R227, R232	1 k, 0603 (1608 metric), ±1%	Resistors	Yageo	RC0603FR-071KL
102	2	R212, R220	4.99 k, 0603 (1608 metric), ±1%	Resistors	Vishay Dale	CRCW06034K99FKEA
103	2	R214, R217	100, 0603 (1608 metric), ±1%	Resistors	Yageo	RC0603FR-07100RP
104	1	R222	200 k, 0603 (1608 metric), ±1%	Resistor		

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
105	1	R228	20, 0603 (1608 metric), ±1% SMD	Resistor	Yageo	RC0603FR-0720RL
106	2	R229, R230	7.5 k, 0603 (1608 metric), ±1% SMD	Resistors	Panasonic Electronic Components	ERJ-3EKF7501V
107	1	R233	4.42 k, 0603 (1608 metric), ±1% SMD	Chip resistor	Any	Any
108	1	R235	1.5 k, 0603 (1608 metric), ±1% SMD	Resistor	Yageo	RC0603FR-071K5L
109	1	R238	470 R, 0603 (1608 metric), ±1% SMD	Chip resistor	Any	Any
110	3	R248, R251, R255	270, 0603 (1608 metric), ±1% SMD	Resistors	Yageo	9C06031A2700FKHFT
111	1	R252	390, 0603 (1608 metric), ±1% SMD	Resistor	Yageo	RC0603FR-07390RL
112	3	R254, R256, R258	3.9 k, 0603 (1608 Metric), ±1% SMD	Resistors	Yageo	RC0603FR-073K9L
113	1	U201	STM32G474RBT6, LQFP64 (10 x 10 mm)	Mainstream Arm® Cortex®-M4 MCU 170 MHz with 128 Kbytes of Flash memory, math accelerator, HR timer, high analog level integration	ST	STM32G474RBT6
114	1	U202	TSV994IDT, 14-SOIC (0.154", 3.90 mm width)	Wide bandwidth (20 MHz) rail-to-rail input/ output 5 V CMOS op-amps, quad	ST	TSV994IDT
115	1	U203	LM393DT, 8-SOIC (0.154", 3.90 mm width)	Low power dual voltage comparator	ST	LM393DT
116	1	U204	TS431BILT, SOT23-5	Adjustable shunt voltage reference IC	ST	TS431BILT
117	1	U205	LD2980ABM50TR, SOT23-5L	Ultra low drop voltage regulators compatible with low ESR output capacitors	ST	LD2980ABM50TR
118	1	U206	LD1117S33CTR, SOT223	Adjustable and fixed low drop positive voltage regulator	ST	LD1117S33CTR

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
119	1	U207	STLM20W87F, SOT-323-5	Analog temperature sensor, ultra-low current 2.4 V, high precision	ST	STLM20W87F
120	1	Y1	8 MHz, 4-SMD, no lead, 18 pF	Crystal	Abracon LLC	ABM8AIG-8.000MHZ-1Z-T
121	4	C601, C602, C603, C604	0.1 µF 630 V, 1812 (4532 metric), ±10 % X7R	Capacitors	Würth Elektronik	885342211006
122	1	C605	2.2 nF, 1206 (3216 metric), 1000 V, ±10%	Capacitor	Murata Electronics North America	GRM31BR73A222KW01L
123	4	C606, C610, C613, C620	0.1 µF, 0603 (1608 Metric), 25 V, ±10%	Capacitors	KEMET	C0603C104K3RACTU
124	3	C607, C611, C612	10 µF, 0805 (2012 Metric), 16 V, 20 %	Capacitors	Wurth Electronics Inc.	885012107014
125	2	C614, C621	10 µF, 1206 (3216 Metric), 50 V, ±10%	Capacitors	Samsung Electro-Mechanics America, Inc.	CL31B106KBHNNNE
126	1	C615	220 µF, Radial, Can, 16 V, ±20%,	Capacitor	Wurth Electronics Inc.	860020373010
127	1	C616	1000 pF, 0603 (1608 metric), 50 V, ±5%,C0G/NP0	Capacitor	Murata Electronics North America	GRM1885C1H102JA01J
128	1	C617	2.2 µF, 0603 (1608 Metric), 25 V, ±10%	Multilayer ceramic capacitor	Murata Electronics	GRM188B31E225KA12D
129	1	C619	0.22 µF, 0603 (1608 Metric), 50 V, ±10%	Capacitor	TDK Corporation	CGA3E3X7R1H224K080AD
130	1	C622	220P, 0805 (2012 metric), ±5%	Capacitor	Any	Any
131	3	D601, D603, D605	STPS0560Z, SOD-123, 60 V, 500 mA	60 V, 0.5 A power Schottky rectifier	ST	STPS0560Z
132	1	D602	S1M, DO-214AC, SMA, 1000 V, 1 A	General purpose diode	Diodes Incorporated	S1M-13-F
133	2	D604, D606	STPS2150A, DO-214AC, SMA, 150 V, 2 A	150 V, 2 A power Schottky rectifier	ST	STPS2150A
134	1	PC601	ACPL-217-50AE, 4-SOIC (0.173", 4.40 mm width)	Optoisolator	Broadcom Limited	ACPL-217-50AE
135	1	R601	0, 0603 (1608 metric), 1/10 W	Resistor	Yageo	RC0603JR-070RL
136	6	R602, R603, R604, R605, R606, R607	180K, 1206 (3216 Metric), 1/4 W, ±0.10 %	Resistors	Panasonic Electronic Components	ERA-8AEB184V
137	1	R609	4.3 k, 0603 (1608 metric), 1/10 W, ±1%	Resistor	Yageo	RC0603FR-074K3L
138	1	R610	910, 0603 (1608 metric), 1/10 W, ±1%,	Resistor	Yageo	9C06031A9100FKHFT
139	2	R611, R613	18 k, 0402 (1005 metric), 1/16 W, ±1%	Resistors	Yageo	RC0402FR-0718KL

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
140	1	R612	4.7k, 0603 (1608 metric), 1/10 W, ±1%	Resistor	Yageo	RC0603FR-074K7L
141	1	R614	0, 0805 (2012 metric), 1/8 W	Resistor	Yageo	RC0805JR-070RL
142	1	R615	13 k, 0603 (1608 metric), 1/10 W, ±1%	Resistor	Yageo	RC0603FR-0713KL
143	1	R616	100, 1206 (3216 metric), 1/4 W, ±5%,	Chip resistor	Any	Any
144	1	T600	WE_750344753,	Wurth-Trasformer ratio	Wurth Electronics	750344753
145	1	U602	VIPER26HD, 16-SOIC (0.154", 3.90 mm width)	Fixed frequency VIPer plus family	ST	VIPER26HD
146	1	U603	TL431ACL3T, SOT-23-3	Adjustable micropower shunt voltage reference	ST	TL431ACL3T

Table 8. Full bridge LLC bill of materials

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
1	4	C1-2 C24-25	47 pF, 0603, ±5%	Film capacitors	Murata	GRM1885C1H470JA01
2	2	C3 C6	1 µF/630 V, 7.0 mm*12.5 mm*17.5 mm, ±10%	Metallized polypropylene film capacitors	Panasonic	ECWFE2W105K
3	9	C4-5 C11 C27-28 C36-37 C43 C56	100 nF, 0603, ±10%,	SMD. Film cap 0603, 100nF/25V X7R	Murata	GRM188R71E104KA01
4	8	C7-10 C13-16	1206	Capacitors	-	-
5	2	C12 C51	100 nF, 0603, ±10 % SMD X7R	Film capacitors	Murata	GRM188R71E104KA01
6	4	C17-20	10 µF, 1206, ±10% X7R	Film capacitors	Murata	GRM31CR71E106KA12
7	4	C21-22 C47-48	1 µF, 0805, ±10%	Film capacitors	Murata	GCM21BR71E105KA56
8	2	C23 C32	68 µF/25 V, 5 mm*11 mm, ±20%	Aluminium electrolytic capacitors	Rubycon	25ZLH68MEFC5X11
9	12	C26 C29-31 C33-35 C38-39 C41 C52-53	560 µF/63 V, 12.5 mm*30 mm, ±20%	Aluminium electrolytic capacitors	Rubycon	63ZLH560MEFC12.5X30
10	2	C40 C54	0.1 µF/630 V, 2220, ±10% X7R	Film capacitors	Murata	GC355DD72J104KX01
11	3	C42 C45-46	10 nF, 1206, ±10% X7R	Film capacitors	Murata	GRM319R72A103KA01
12	2	C44 C55	1 µF, 0603, ±10%	Film capacitors	Murata	GRM185B31E105KA12
13	2	C49-50	1 nF, 1206, ±10% X7R	Film capacitors	Murata	GRM31BR73A102KW01
14	4	D1-2 D8-9	BAT54ZFILM, SOD-123	40 V, 300 mA general purpose signal Schottky diode	ST	BAT54ZFILM

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
15	4	D3-4 D11-12	STPS2L40ZFY, SOD-123	Automotive 40 V, 2 A low drop power Schottky rectifier	ST	STPS2L40ZFY
16	2	D5 D10	STTH1R06A, SMA,	Turbo 2 ultrafast high voltage rectifier, SMA	ST	STTH1R06A
17	4	D6-7 D13-14	MMSZ4684-G, SOD123, 3.3 V, 0.5 W	Small signal Zener diodes	Vishay	MMSZ4684-G
18	2	H1/2, H3/4		Primary MOSFET heatsink	-	-
19	1	L1	PQ2620 core, Lr = 25 µH	Resonant inductor	-	-
20	2	P1-2	74650074R, 7 mm*7 mm, 50 A	WP-THRBU	Wurth	74650074R
21	1	P3	-	SR board connector	-	-
22	1	P4	-	PE	-	-
23	2	P5 P8	A2543WV-4P or A2543WR-4P, 2.54 mm, 4Pin,	Board-to-board connector	CJT	A2543WV-4P or A2543WR-4P
24	2	P6-7	74650094R, 10 mm*10 mm	WP-THRBU	Wurth	74650094R
25	1	P10	-	Resonant capacitor connector	-	-
26	1	P11	-	Control board connector	-	-
27	4	Q1-4	STW70N65DM6-4, TO247-4	N-channel 650 V, 36 mOhm typ., 68 A MDmesh DM6 Power MOSFET in a TO247-4 package	ST	STW70N65DM6-4
28	3	R1 R3 R18	0, 0603, ±1% SMD	Film resistors	Vageo	RC0603FR-070RL
29	4	R2 R4 R15-16	100, 0603, ±1% SMD	Film resistors	Vageo	RC0603FR-07100RL
30	4	R5 R8 R17 R20	3R3, 0805, ±1% SMD	Film resistors	Vageo	RC0805FR-073R3L
31	4	R6 R9 R21 R24	15, 0805, ±1% SMD	Film resistors	Vageo	RC0805FR-0715RL
32	5	R7 R10 R12 R22 R25	4R7, 0805, ±1% SMD	Film resistors	Vageo	AC0805FR-074R7L
33	3	R11 R27-28	0, 0805, ±1% SMD	Film resistors	Vageo	RC0805FR-070RL
34	5	R13-14 R23 R30-31	15k, 0603, ±1% SMD	Film resistors	Vageo	RC0603FR-0715KL
35	1	R19	NTC, ±1% SMD	NTC thermistor	Vishay	NTCLE213E3103FLT1
36	1	R23	3.9 k, 0603, ±1% SMD	Film resistor	Vageo	RC0603FR-073K9L
37	1	R29	0.3 mohms, 2512, 6 W, 2512, ±1% SMD	Current sensing resistor	shenzhenzhanye	ASR-M-3-0.3F
38	1	T1	Turn ratio = 50:1, EP10 core, Lm = 210 µH	Current transformer	Sunlord	-
39	2	T2-3	Turn ratio = 18:5, PQ3535 core	Main transformer	-	-

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
40	4	U1-4	STGAP2HSCMTR, SO-8W	Galvanically isolated 4 A single gate driver	ST	STGAP2HSCMTR
41	2	Thermal insulating pad of Q1, Q2, Q3, Q4 heatsinks	SP800-0.005-AC-1212, 45 mm*23 mm, 0.127 mm thickness	Isolation materials	Bergquist	SP800-0.005-AC-1212
42	4	Clips TO247	MAX03N, Clips TO247	Clips for TO247 MOSFET	AAVID Thermalloy	MAX03N
43	2	\	FFB03812HHN, PWM fan 12 V 0.57 A	PWM DC brushless fan	Delta	FFB03812HHN
44	1	C1	33 nF, 0603, ±10% X7R SMD	Capacitor	Murata	GRM188R71E333KA01
45	12	C2 C6-7 C11 C13 C36 C40 C58 C62 C64-66	100 pF, 50 V C0G, 0603, ±5%	Film capacitors	Murata	GRM1885C1H101JA01
46	1	C3	220 pF, 1206, ±5%, SMDC0G	Film capacitor	Murata	GRM31A5C2J221JW01
47	1	C4	390 µF/25 V, 8 mm*16 mm, ±20%	Aluminium electrolytic capacitor	Rubycon	25ZLH390MEFC8X16
48	4	C5 C12 C20 C43	10 nF, 0603, ±5%	Film capacitors	Murata	GRM1885C1H103JA01
49	18	C8 C17 C28 C33-34 C41 C45 C48-56 C59-60	100 nF, 0603, ±10%, SMD	Film capacitors	Murata	GRM188R71E104KA01
50	5	C9 C15-16 C19 C22	1 µF, 0603, ±10% SMD X5R	Film capacitors	Murata	GRM185B31E105KA12
51	1	C10	10 nF/400 V_{AC}, 5 mm for bulk, ±20%	High voltage ceramic capacitors CS45-F2GA103M-NKA	TDK	CS45-F2GA103M-NKA
52	1	C14	150 µF/25 V, 6.3 mm*11 mm, ±20%	Aluminium electrolytic capacitor	Rubycon	25ZLH150MEFC6.3X11
53	2	C18 C57	100 nF, 1210, ±10%	Film capacitors	Murata	GRM32DR7LV104KW01
54	1	C23	22 pF, 50 V, 0603, ±5%, C0G	Film capacitor	Murata	GRM1885C1H220JA01
55	1	C24	22 µF, 6.3 V, 0805, ±20%, X7R	Film capacitor	Murata	GRM21BZ70J226ME44
56	1	C25	10 nF, 1206, ±10%, X7R	SMD. Film cap 1206, 10nF/100V	Murata	GRM319R72A103KA01
57	3	C26 C37 C39	-	Capacitors	Any	Any
58	2	C27 C32	470 pF, 0603, ±5%, C0G	Film capacitors	Murata	GRM1885C1H471JA01
59	1	C29	2.2µF, 0603, ±10%, X7R	Film capacitor	Murata	GRM188Z71C225KE43
60	2	C30 C35	220 pF, 0603, ±5%, C0G	Film capacitors	Murata	GRM1885C1H221JA01
61	3	C31 C42 C44	1 nF, 0603, ±5%, C0G	Film capacitors	Murata	GRM1885C1H102JA01
62	1	C38	10 nF, 0603, ±10%, X7R	Film capacitors	Murata	GRM188R72A103KA01

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
63	2	C46-47	20 pF, 0603, ±5%, C0G	Film capacitors	Murata	GRM1885C1H200JA01
64	2	C61 C63	10pF, 0603,±5%, C0G	Film capacitors	Murata	GRM1885C1H100JA01
65	1	C67	47µF/35 V, 5 mm*11 mm, ±20%,	Aluminium electrolytic capacitor	Rubycon	35ZLH47MEFC5X11
66	3	D1-2 D19	BAT54JFILM, SOD323	40 V, 300 mA general purpose signal Schottky diode	ST	BAT54JFILM
67	1	D3	STTH1L06A, SMA	600 V, 1 A low drop ultrafast diode	ST	STTH1L06A
68	1	D4	STPS5H100B, DPAK	100 V, 5 A power Schottky rectifier	ST	STPS5H100B
69	1	D5	STPS1150A, SMA	150 V, 1 A power Schottky rectifier	ST	STPS1150A
70	11	D6-16	BAT54SWFILM, SOT323	40 V, 300 mA general purpose signal Schottky diode	ST	BAT54SWFILM
71	1	D17	0603	Red LED	Wurth Elektronik	150060RS75000
72	1	D18	LED Green, 0603, SMD	Green LED	Wurth Elektronik	150060VS75000
73	1	L1	744043470, 4.8 mm*4.8 mm, ±30%	47µH shielded power inductor	Wurth Elektronik	744043470
74	1	L2	1 µH, 0805, 25.2 MHz 3 0.18 A 2.13 Ohm DCR 0805 T/R	5Q-factor ferrite	Vishay	IMC0805ER1R0J01
75	2	P1 P7	653006114822, 1.25 mm, 6Pin	Male vertical shrouded headers	Wurth	653006114822
76	1	P2	A2005WR-25P, 2 mm*25Pin,	Board-to-board connector	CJT	A2005WR-25P
77	1	P5	-	Connector	-	-
78	1	P6	A2005WR-10P, 2 mm, 10Pin	Board-to-board connector	CJT	A2005WR-10P
79	1	R1	210 k, 0603, ±1%	Film resistor	Vageo	RC0603FR-07210KL
80	2	R2 R4	47 k, 0603, ±1%	Film resistors	Vageo	RC0603FR-0747KL
81	3	R3 R5 R65	150 k, 1210, ±5%	Film resistors	Vageo	RC1210JR-07150KL
82	18	R6-7 R9 R10 R12-14 R16-17 R40-41 R43 R57-59 R63-64 R68	100, 0603, ±1%	Film resistors	Vageo	RC0603FR-07100RL
83	7	R8 R15 R44-45 R47 R54 R66	10 k, 0603, ±1%, SMD, 1/16 W	Film resistors	Vageo	RC0603FR-0710KL
84	5	R11 R22 R26 R51 R53	-	Resistors	-	-
85	5	R18 R35-36 R49-50	1 k, 0603, ±1%, 1/16 W	Film resistors	Vageo	RC0603FR-071KL
86	1	R19	240 k, 0603, ±1%	Film resistor	Vageo	RC0603FR-07240KL
87	1	R20	15 k, 0603, ±1%	Film resistor	Vageo	RC0603FR-0715KL

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
88	1	R21	130 k, 0603, ±1%	Film resistor	Vageo	RC0603FR-07130KL
89	1	R23	680 k, 0603, ±1%, SMD	Film resistor	Vageo	RC0603FR-07680KL
90	1	R24	11.5 k, 0603, ±1%, SMD, 1/16 W	Film resistor	Vageo	RC0603FR-0711K5L
91	1	R25	4.22k, 0603, ±1%, SMD, 1/16 W	Film resistor	Vageo	RC0603FR-074K22L
92	1	R27	15 k, 0603,SMD, 1/16 W ±0.5%	Film resistor	Vageo	RC0603DR-0715KL
93	5	R28 R48 R62 R72-73	0, 0603, 1/16 W, ±1%	Film resistors	Vageo	RC0603FR-070RL
94	3	R29-30 R32	1M, 1206, 1/4 W, ±0.5%	Film resistors	Vageo	RC1206DR-071ML
95	2	R31 R52	200 k, 0603, 1/16 W, ±1%	Film resistors	Vageo	RC0603FR-07200KL
96	3	R33-34 R38	12, 0603, 1/4 W, ±0.5%	Film resistors	Vageo	SR0603DR-7T12RL
97	2	R37 R55	11 k, 0603, 1/16 W, ±0.5%	Film resistors	Vageo	RC0603DR-0711KL
98	2	R39 R56	220 k, 0603, 1/16 W, ±0.5%	Film resistors	Vageo	RC0603DR-07220KL
99	2	R42 R46	120k, 0603,1/16 W, ±1%, SMD	Film resistors	Vageo	RC0603FR-07120KL
100	2	R60 R67	200, 0603, 1/16 W, ±1%, SMD	Film resistors	Vageo	RC0603FR-07200RL
101	1	R61	750 k, 0603, 1/16 W, ±1%, SMD	Film resistor	Vageo	RC0603FR-07750KL
102	1	R69	10, 1210, 1 W, ±1%, SMD	Film resistor	Vageo	AC1210FR-7W10RL
103	1	R71	150, 0603,1/16 W, ±1%, SMD	Film resistor	Vageo	RC0603FR-07150RL
104	1	T1	-	Auxiliary transformer	Wurth Elektronik	350344830
105	1	U1	VIPER38LDTR, SO16N	VIPerPlus family: peak power fixed frequency high voltage converter	ST	VIPER38LDTR
106	1	U2	ISO7742 DW, SOIC (DW)	High-speed, robust-EMC reinforced and basic quad-channel digital isolator	TI	ISO7742 DW
107	1	U4	LTV1018TP-V-G, SMD-4, 5300 Vrms, CTR 100-200	Photocoupler	Liteon	LTV1018TP-V-G
108	1	U6	TS431BILT, SOT23-5	Adjustable shunt voltage reference IC	ST	TS431BILT
109	1	U7	PM6644TR, DFN10	350 mA adjustable step-down regulator	ST	PM6644TR
110	1	U9	LDK715M50R, SOT23-5L,	High input voltage 85 mA LDO linear regulator	ST	LDK715M50R
111	1	U10	ACPL-C870	Precision optically isolated voltage sensor	Avago	ACPL-C870

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
112	2	U11-12	TSX631ILT, SOT23-5	Micropower (60 µA), rail-to-rail 16V CMOS op-amp, single, GBP 200 kHz	ST	TSX631ILT
113	1	U13	TS3011ILT, SOT23-5,	Rail-to-rail high-speed comparator, SOT23-5	ST	TS3011ILT
114	1	U14	STM32G4474RBT6, LQFP64,	Mainstream Arm Cortex-M4 MCU 170 MHz with 128 Kbytes of Flash memory, math accelerator, HR timer, high analog level integration	ST	STM32G474RBT6
115	1	Y1	ABM8AIG-8.000MHZ-1Z-T, 2.5 mm*3.2 mm, SMD crystal	Automotive and industrial grade ceramic base	ABRACON	ABM8AIG-8.000MHZ-1Z-T
116	4	C1-4	47 pF, 50 V C0G, 0603, SMD	Film capacitors	Murata	GRM1885C1H470JA01
117	4	C5-6 C11-12	0805	Capacitors	-	-
118	2	C7 C9	10 µF, 0805, 25 V X7R	Film capacitors	Murata	GRM21BZ71E106KE15
119	4	C8 C10 C15-16	100 nF, 0603, X7R	SMD. Film cap 0603, 100nF/25V	Murata	GRM188R71E104KA01
120	2	C13-14	10 pF, 0603, 50 V C0G	Film capacitors	Murata	GRM1885C1H100JA01
121	4	D1-4	BAT54JFILM, SOD323	40 V, 300 mA general purpose signal Schottky diode	ST	BAT54JFILM
122	2	D7-8	BAT46JFILM, SOD323	100 V, 200 mA surface mount general purpose signal Schottky diode	ST	BAT41JFILM
123	2	D5-6	BAT46ZFILM, SOD123	100 V, 200 mA surface mount general purpose signal Schottky diode	ST	BAT41ZFILM
124	16	Q1-16	STL130N8F7, PowerFLAT 5*6,	N-channel 80 V, 3.0 mOhm typ., 120 A STripFET F7 Power MOSFET in PowerFLAT 5x6 package	ST	STL130N8F7
125	6	R1-4 R27 R29	100, 0603, 1/16 W, ±1%	Film resistors	Vageo	RC0603FR-07100RL
126	4	R5-6 R25-26	0805	Film resistors	-	-
127	2	R7-8	3R3, 0805, 1/8 W, ±1%	Film resistors	Vageo	RC0805FR-073R3L
128	16	R9-24	2R2, 0603, 1/4 W, ±5%	Film resistors	Vageo	SR0603JR-7T2R2L
129	4	R28 R30 R32-33	1 k, 0603, 1/16 W, ±1%	Film resistors	Vageo	RC0603FR-071KL
130	2	R31 R34	270, 0603, 1/16 W, ±1%	Film resistors	Vageo	RC0603FR-07270RL
131	2	R35-36	2.7k, 0603, 1/16 W, ±1%	Film resistors	Vageo	RC0603FR-072K7L

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
132	2	U1-2	UCC27211, VSON (8)	4 A, 120 V half bridge gate driver with 8 V UVLO and TTL inputs	TI	UCC27211
133	2	U3-4	TS3011ILT, SOT23-5	Rail-to-rail high-speed comparator	ST	TS3011ILT
134	1	Thermal insulating pad of heatsink	SP800-0.005-AC-1212, 72 mm*35 mm, 0.127 mm thickness	Isolation materials	Bergquist	SP800-0.005-AC-1212
135	1	Heatsink	SR MOSFET heatsink	SR MOSFET heatsink	-	-
136	5	C1-5	15 nF/1000 Vdc, 5.0 mm *10.5 mm* 18.0 mm, P-P=15 mm	Metallized polypropylene film capacitors	Epcos	B32652A0153J

8 Conclusions

The STDES-3KWTLCP is a complete solution to meet the latest 5G telecom system requirements.

This reference design provides a compact solution (40 W/inch^3), offering a high peak efficiency (96.3%), a low THD distortion (less than 5% THD at full load), and a reduced bill of materials.

The fully digital control demonstrates high flexibility on the power management, high-performance input power quality (iTHD and PF), and accurate output regulation to deal with the fast transient of the input/output conditions.

Appendix A Reference design warnings, restrictions and disclaimer

Important: *The reference design is not a complete product. It is intended exclusively for evaluation in laboratory/ development environments by technically qualified electronics experts who are familiar with the dangers and application risks associated with handling electrical/mechanical components, systems and subsystems.*

Danger: *Exceeding the specified reference design ratings (including but not limited to input and output voltage, current, power, and environmental ranges) may cause property damage, personal injury or death. If there are questions concerning these ratings, contact an STMicroelectronics field representative prior to connecting interface electronics, including input power and intended loads. Any loads applied outside of the specified output range may result in unintended and/or inaccurate operation and/or possible permanent damage to the reference design and/or interface electronics. During normal operation, some circuit components may reach very high temperatures. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors which can be identified in the reference design schematic diagrams.*

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Revision history

Table 9. **Document revision history**

Date	Revision	Changes
11-Jan-2022	1	Initial release.

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