
STDES-7KWOBC test report

Introduction

This document reports the functional and efficiency measurements results for the [STDES-7KWOBC](#) 7 kW on-board charger reference design for electric vehicles. This on-board charger (OBC) reference design allows charging the battery of an electric vehicle through your home AC mains plug or a private/public outlet (AC charging station).

The reference design embeds two sections: an interleaved totem pole PFC with SiC and a dual galvanic isolated LLC DC-DC ZVS resonant converter, based on MDmesh DM6 super-junction power MOSFETs.

The power platform is a 7 kW module able to deliver a constant current (CC) or constant voltage (CV) on the output to be used as standalone (1 PH+ N), in parallel or in 3-phase mode (3Ph + N) to reach 21 kW.

The underlying insulated metal substrate on aluminum base plate enables very effective heat dissipation, forced or liquid cooling.

Each module composing the reference design allows an easy interconnection among modules of the same type through wires or bus bar connection, reaching a higher output power.

This reference design key factor is the efficiency and high-power density gained thanks to SiC and SJ power MOSFETs, silicon and SiC diodes, gate drivers, the [SPC58NN84E7](#) power architecture automotive-grade microcontroller, and SCR thyristors for inrush current limitation.

The [STDES-7KWOBC](#) is a fully assembled kit developed for performance evaluation only, not available for sale.

1 Overview

The [STDES-7KWOBC](#) features:

- Front-end PFC stage using 2-channel interleaved totem pole topology operating at 70 kHz
- Digital inrush current control
- DC-DC stage using FB LLC resonant topology with 140 kHz resonant frequency
- Constant current and constant voltage mode
- Control stage based on [SPC58NN84E7RMHBR](#) MCU
- 12 V input supply voltage galvanically isolated from output voltage GND (high voltage battery)
- Bus bar interconnection possibility
- PFC stage:
 - Key products: [TN3050H-12GY-TR](#) SCRs, [STBR3012G2Y](#) bypass diodes, [SCTH35N65G2V-7AG](#) SiC power MOSFET
 - Input: 85 to 265 V_{AC}, 45 to 65 Hz
 - Digital inrush current limiter
 - Max. input current: 32 A_{rms}
 - Switching frequency: 70 kHz
 - Average current mode control in continuous conduction mode (CCM)
 - PID or 2p2z 2x independent current loop regulators
 - PID or 2p2pz voltage regulator
 - [SPC58NN84E7RMHBR](#) MCU controller
- DC-DC stage:
 - Key products: [STB47N60DM6AG](#) power MOSFET, [STPSC20065GY-TR](#) output diodes, [A6387](#) gate driver
 - Output voltage: 250 to 450 V_{DC}
 - Switching frequency: 92 to 250 kHz with start-up at 350 kHz
 - Two independent current loops (CC)
 - One voltage loop plus current balancing (CV)
 - PID regulators
 - [SPC58NN84E7RMHBR](#) MCU controller

Figure 1. STDES-7KWOBBC architecture block diagram

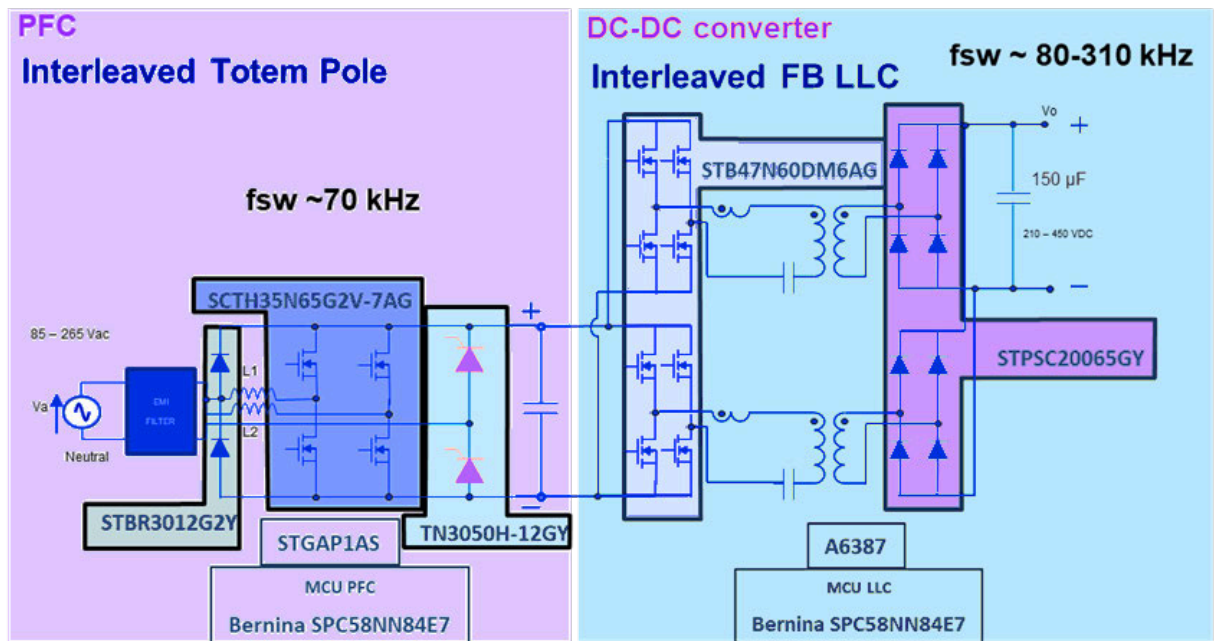
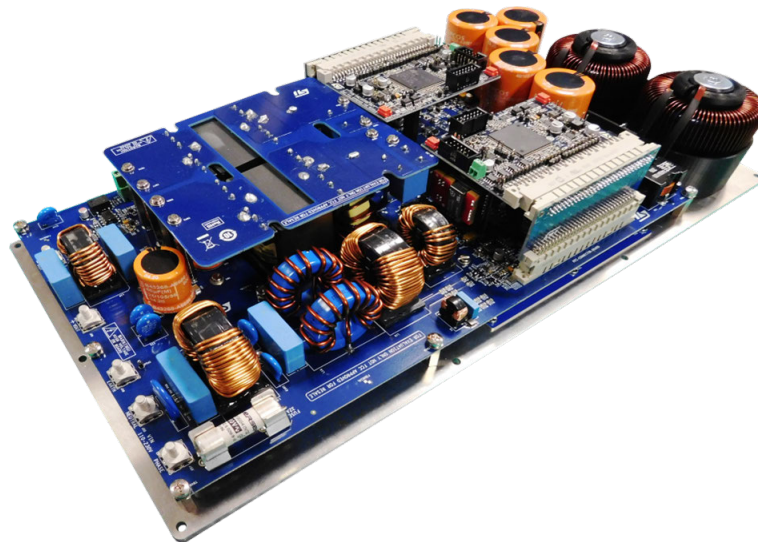


Figure 2. STDES-7KWOBBC reference design



Fully assembled board developed for
performance evaluation only,
[not available for sale](#)

2 Specifications

Table 1. STDES-7KW0BC electrical specifications

Parameter	Value
Input voltage	85 to 265 V _{AC}
Input frequency	45 to 65 Hz
Max. input current	32 A _{rms}
PFC switching frequency	70 kHz
Output voltage	250 to 450 V _{DC}
DC-DC switching frequency	92 to 250 kHz with start-up at 350 kHz
Resonant frequency	140 kHz
DC-DC input	400 V
External input supply voltage	12 V

3 Test setup

3.1 Test conditions and equipment

- 1 x [STDES-7KWOB](#)
- 1 x 7 kW DC-DC 600 V 24 A (for DC-DC test only) by Magna-Power Electronics
- 1 x 7.5 kW programmable AC-AC power source by Adaptive Power System
- 1 x 800 V, 90 A max. electronic DC load (CC and CV mode) by ZS Electronic load H&H
- 1 x HD08108A multi-channel digital oscilloscope by Teledyne Lecroy
- 2 x 34401A digital multi-meters by Agilent
- 1 x 20 mV/A CWT18 Rogowski current transducer
- 2 x HVD3206A differential voltage probes (galvanically insulated) by Teledyne Lecroy
- 1 x [ST-LINK](#) programmer (or [J-Link](#))
- 1 x STEVAL-DPSADP01 adapter board
- 1 x 30 A current probe by Teledyne Lecroy
- 1 x cooling free air base plate (20x42x6 mm)
- Ambient temperature = 25 °C

3.2 Procedure

Step 1. Connect the programmed control board to the proper 64-pin connector. Different firmware packages are used for the PFC section and the LLC section.
 To program a new control board (based on [STM32F334R8T6](#) MCU or [SPC58NN84E7](#) MCU), power it through an external 5 V through the supply connector.

Note: Do not connect the control board to the power board for this operation.

Step 2. Connect the programmable AC voltage source to the control board AC input voltage through cable, taking into account the proper cross-section gauge able to sustain 32 A.
 The output load must be connected to J28-J29 connectors with a cable with an appropriate cross-section to carry the desired load current (28 A max.).

Note: Always connect the earth to the input connector.

Step 3. Verify that the [STDES-7KWOB](#) is not powered.

Step 4.

Step 4a. To update or debug the firmware for the [STM32F334R8T6](#), connect a 10-wire flat cable to the control board J7 and to the adapter board J1, then connect a programmer ([ST-LINK](#) or [J-Link](#)) through the J3 standard 20-pin JTAG connector of the adapter board.

Step 4b. To reprogram or update the firmware for the [SPC58NN84E7](#), directly connect a programmer to the J6 14-pin JTAG connector of the control board.

Note: Do not apply any voltage to the power board for these operations.

4 Measurements/waveforms/test data

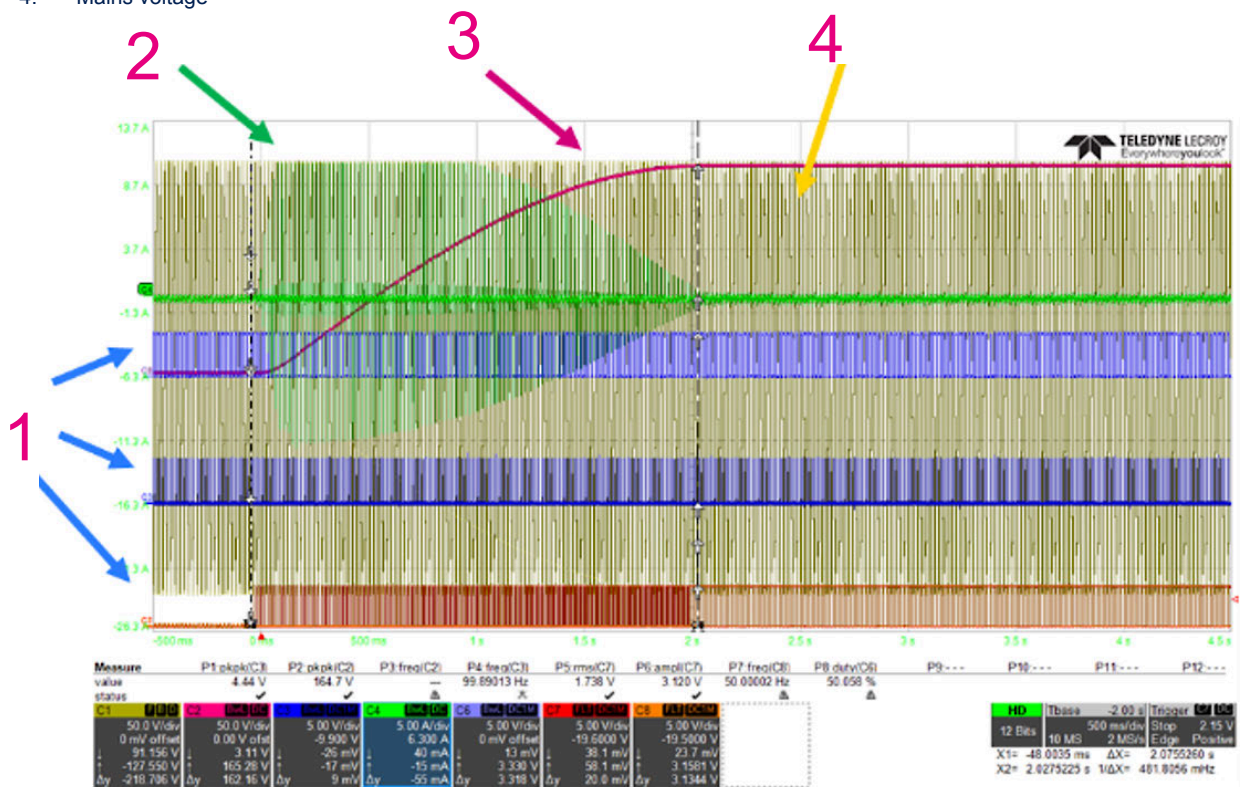
4.1 PFC section

4.1.1 Inrush current limiter (ICL) and PFC start-up waveforms

Once the platform is supplied, at start-up, you can check the limitation of the input current and the evolution of the bulk capacitor voltage thanks to the presence of the inrush current limiter circuit.

Figure 3. Input current and bus voltage evolution during start-up

1. HF (blue and light blue waveforms) and SCR (red and orange waveforms) PWM driving signals
2. ICL - input current limited at a peak of 11 A
3. Smooth bulk capacitor charging
4. Mains voltage

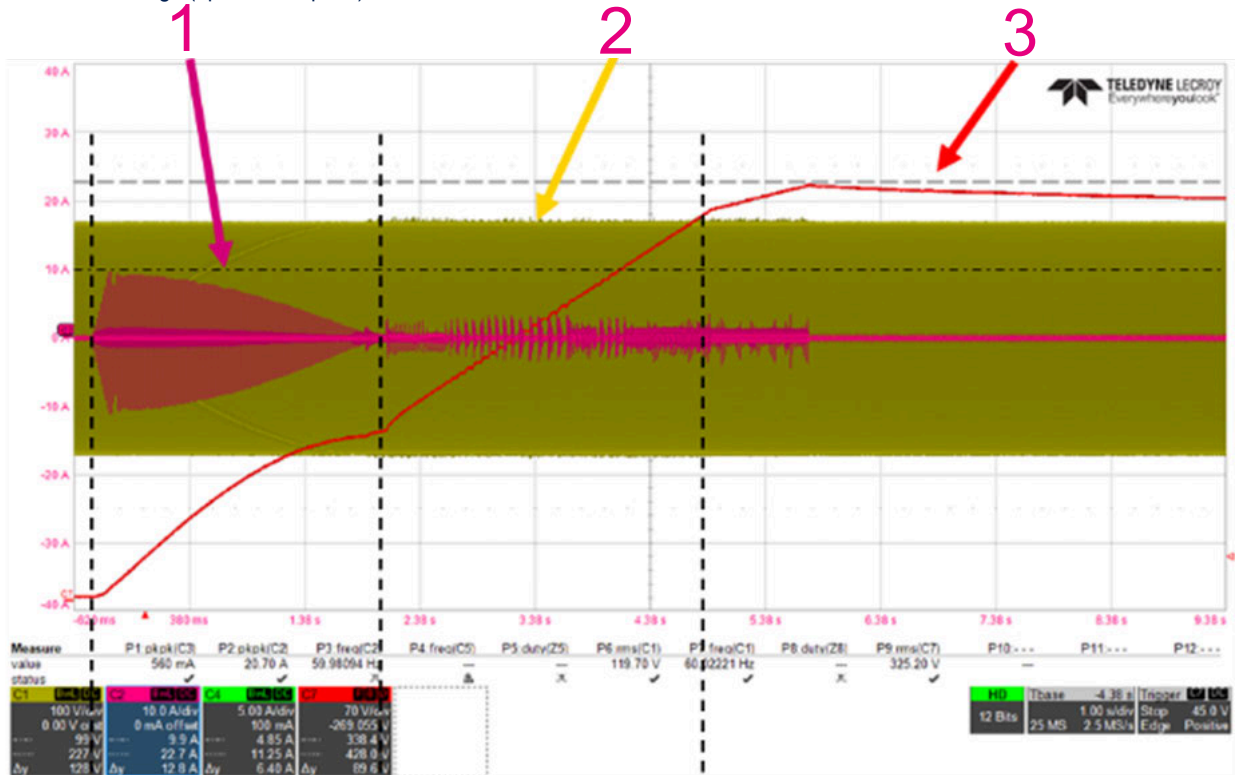


After the inrush phase, if no load is applied:

- the line current is close to zero
- a max. voltage input bus voltage level is reached ($V_{\text{input}} \cdot 1.41$), different from the ICL phase
- the PFC start-up phase begins
- the bus voltage increases up to 430 V
- the closed loop and burst mode controls are triggered

Figure 4. Start-up waveforms

1. Inrush current (below 10 A)
2. Mains voltage
3. Bus voltage (up to 430 V peak)



ICL

PFC start-up

Closed loop and burst mode

Applying a load on the PFC output bus or on the DC-DC output section, we obtain the waveforms shown in the figures below (at 120 V – 60 Hz and 220 V 50 Hz, 32.5 A and 20 A, respectively).

Figure 5. Waveform example of mains voltage and current and inductor current at 120 V_{AC}

1. Mains voltage - 120 V, 60 Hz at 32.5 A_{rms} line current, P = 4.255 W
2. inductor1 current
3. Mains current - 32.5 A
4. inductor2 current

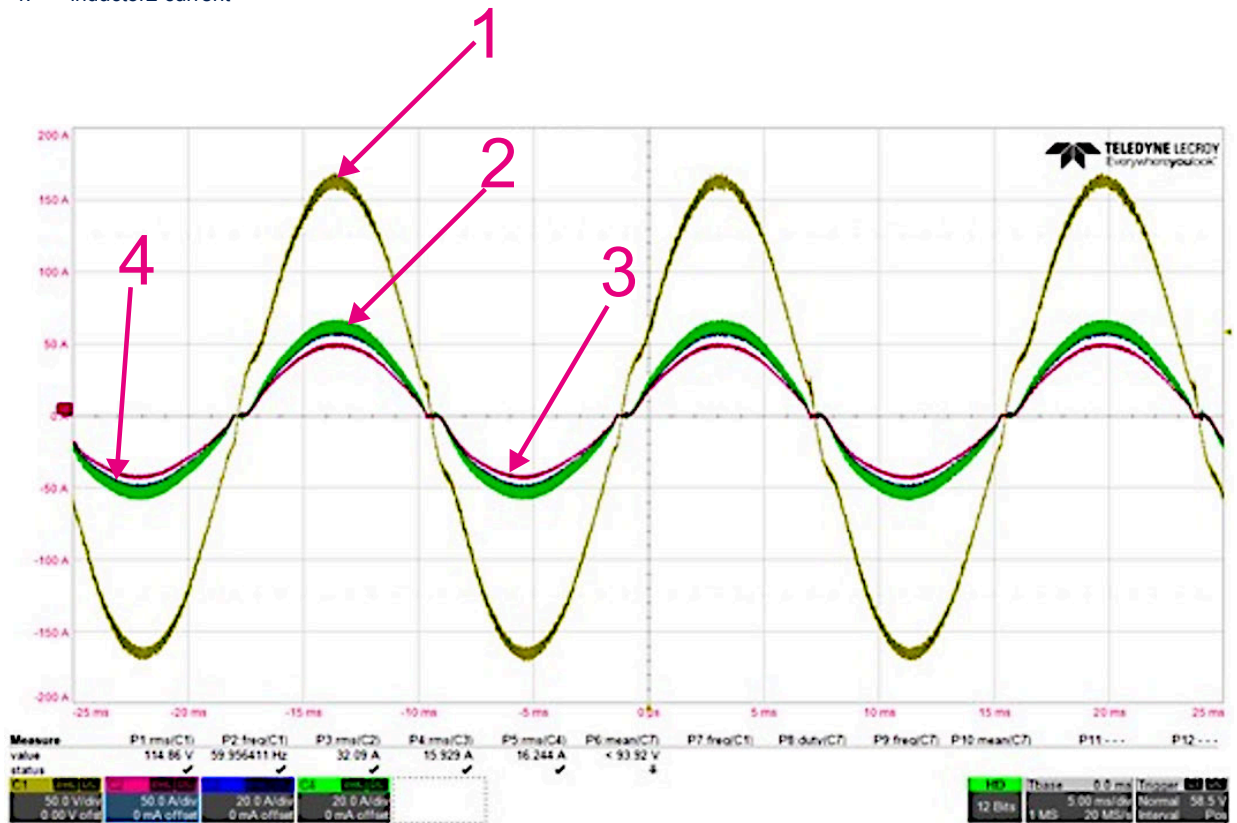
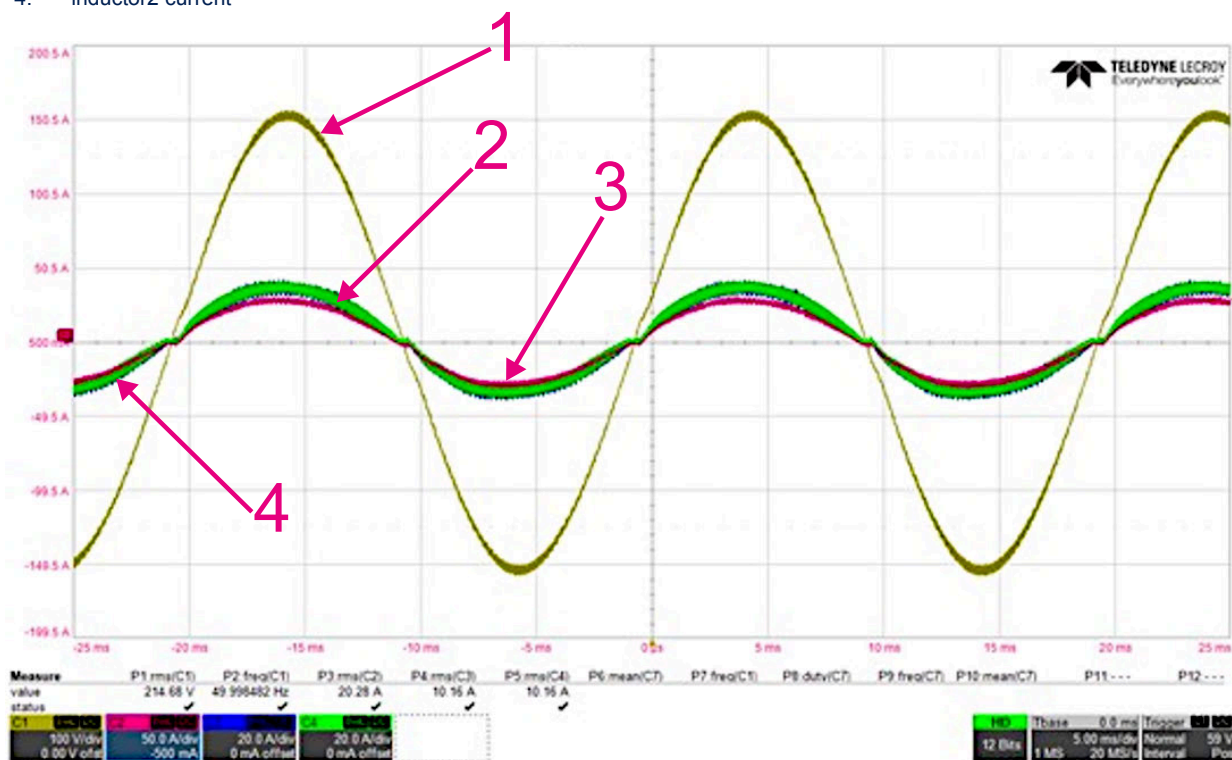


Figure 6. Waveform example of mains voltage and current and inductor current at 220 V_{AC}

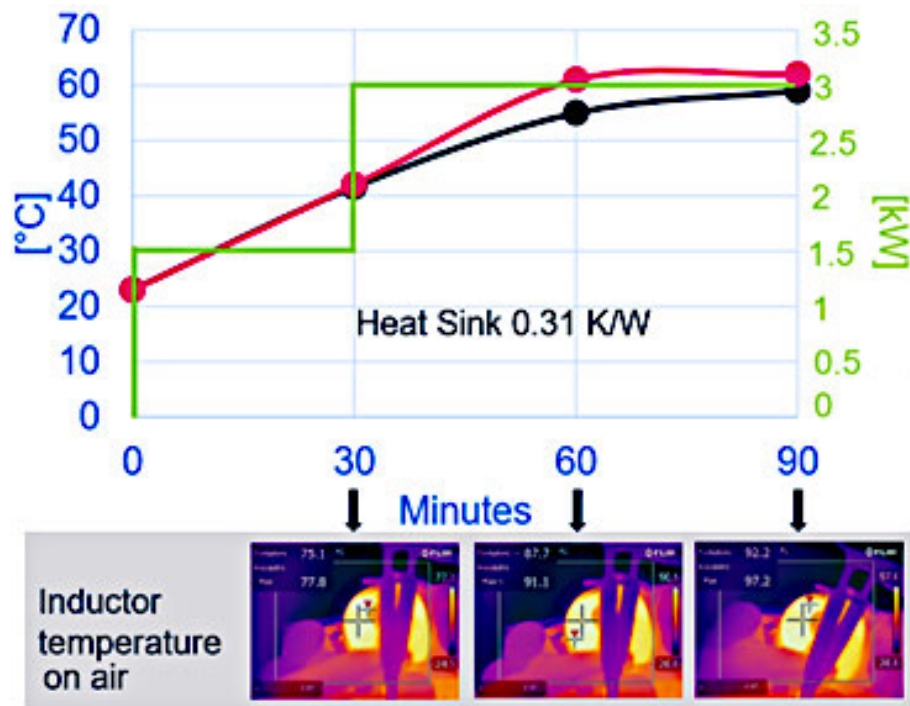
1. Mains voltage - 220 V, 50 Hz at 20 A_{rms} line current, P = 4.400 W
2. inductor1 current
3. Mains current - 20 A
4. inductor2 current



4.1.2 Thermal measurements

Figure 7. PFC - low side and high side SiC device (1-channel) thermal measurements

Pink line = HS
 Blue line = LS
 Green line = P_{OUT}



4.1.3 Efficiency

The table below lists the PFC efficiency measurement preliminary results with the following working conditions:

- $V_{IN} = 230 \text{ V}$, 50 Hz
- $V_{OUT} = 400 \text{ V}_{DC}$, 7.5 A

Table 2. PFC efficiency measurements

Time lapse (minutes)	P_{IN} [kW]	P_{OUT} [kW]	%	PF	Low side temperature [°C]	High side temperature [°C]
0-30	1.531	1.5	98	0.982	42	42
30-60	3.058	3	98.5	0.995	55	61
60-90	3.058	3	98.5	0.995	59	62

4.2 LLC section

4.2.1 Waveforms

The DC-DC LLC section is supplied by the PFC interleaved totem pole section regulated at 400 V.

This dual LLC section can reach high current capabilities and phase-shading operation in case of low load current for greater efficiency.

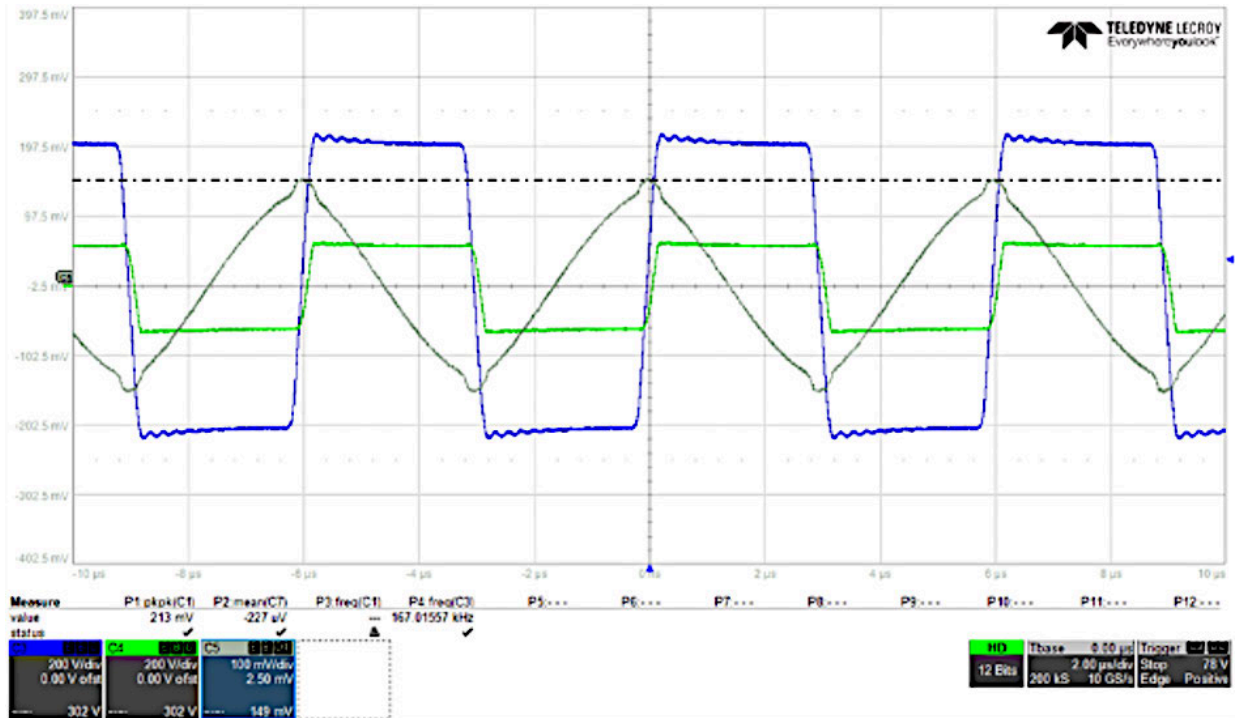
The section is also able to work in constant current and constant voltage modes. The operation is established by the voltage trigger set at 375 V as default value.

Figure 8. LLC waveform - output load = 5 A

Grey = resonant current on the LLC channel

Blue = tank voltage applied

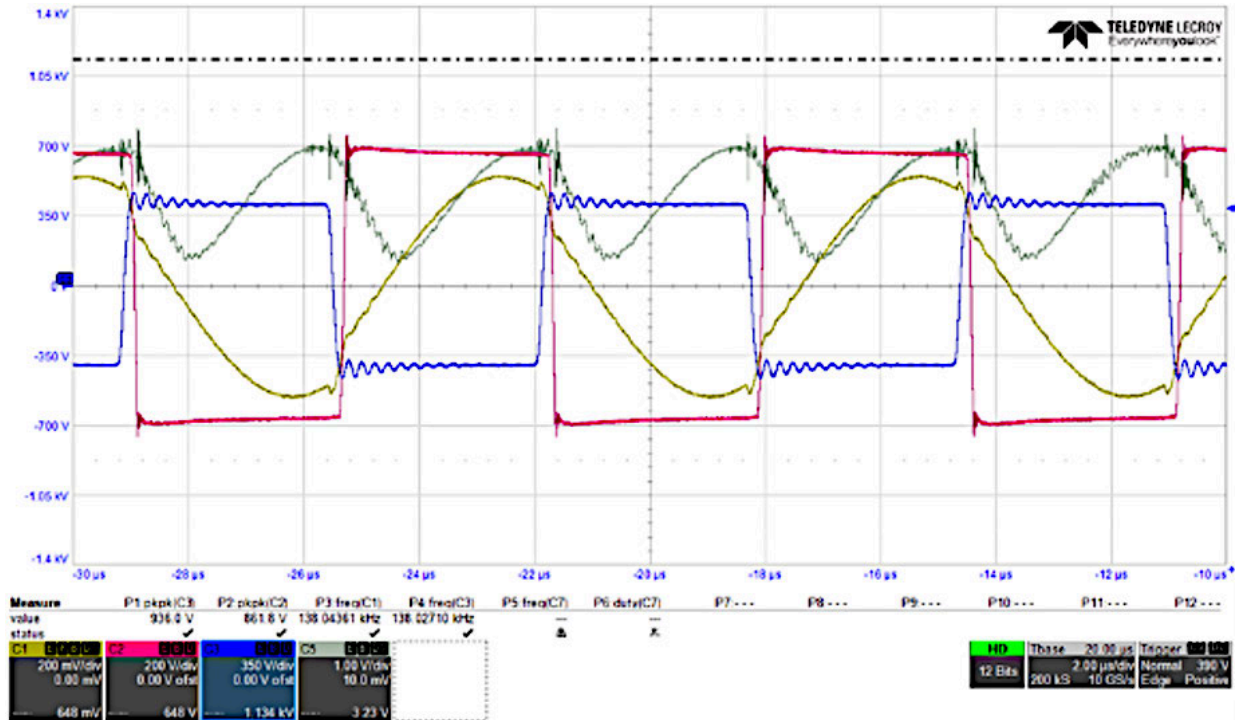
Green = secondary transformer voltage at 167 Hz, 6 A on primary current



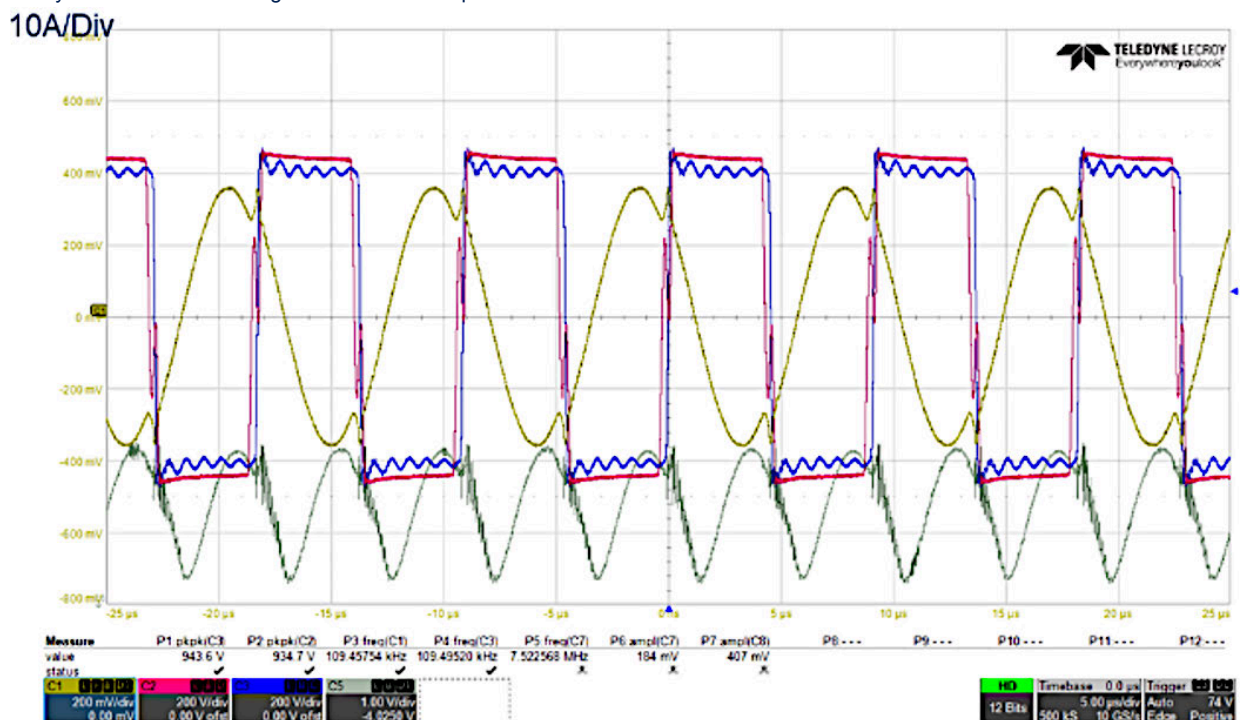
A dedicated signal for the overcurrent protection is continuously monitored for each LLC phase resonant current (grey trace in the figure below). These signals are sent to the fast comparators for fast shutdown in case of overcurrent.

Figure 9. LLC waveform - output load = 10 A

Dark yellow = resonant current of one LLC
 Grey = current feedback signal
 Pink = transformer primary voltage (15 A, 375 V output voltage)
 Blue = transformer secondary voltage (15 A, 375 V output voltage)


Figure 10. LLC waveform - overcurrent protection

Dark yellow = current on single LLC channel below the resonance
 Pink and blue = primary and secondary voltage below the resonance
 Grey = feedback current signal for overcurrent protection



The control algorithm of the LLC resonant DC-DC converter guarantees the output current balance either when the **STDES-7KW0BC** works in CC mode (two independent current control loops) or in CV mode (a voltage control loop and an internal current balance loop).

Moreover, the balancing of the output currents allows a similar amplitude of the resonant currents on the transformer primary side, even if with a different frequency.

Figure 11 shows unbalanced currents when the current balance feature is not activated: in this case the working frequencies are the same but with different current levels. **Figure 12** shows balanced currents when the current balance loop control is active.

Figure 11. LLC waveform - unbalanced currents

Pink and blue = tank voltages shifted of 90 degrees

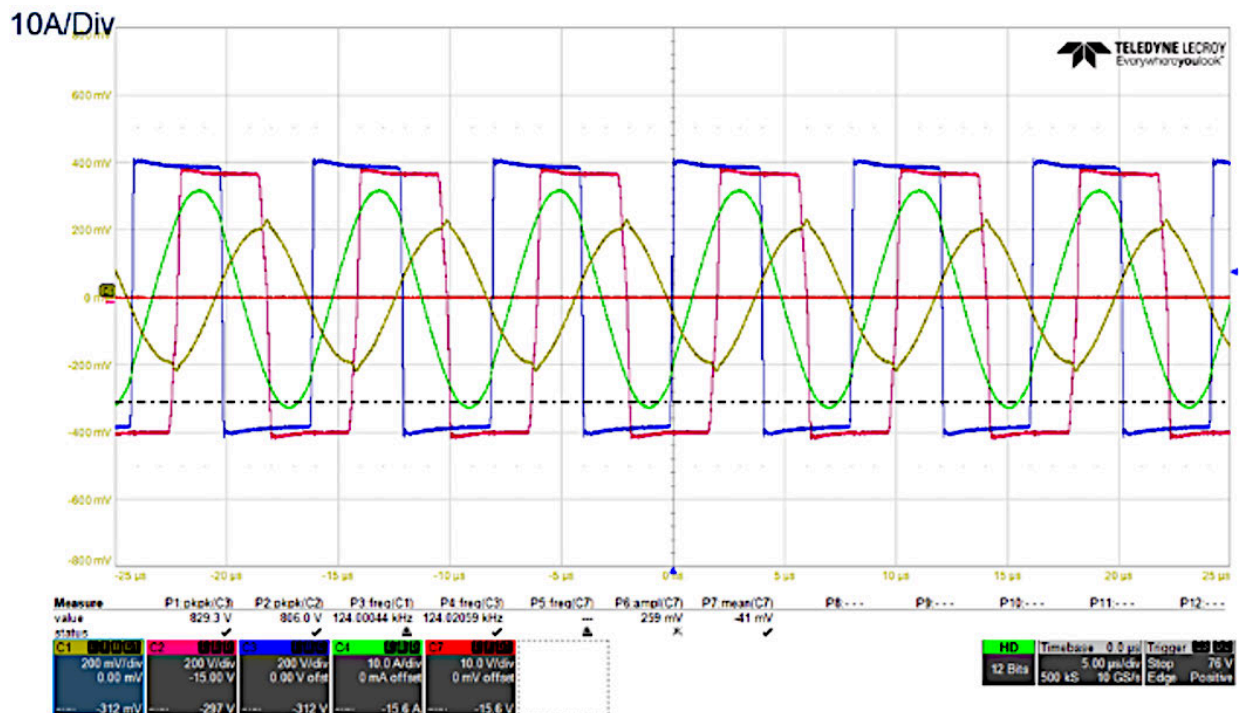
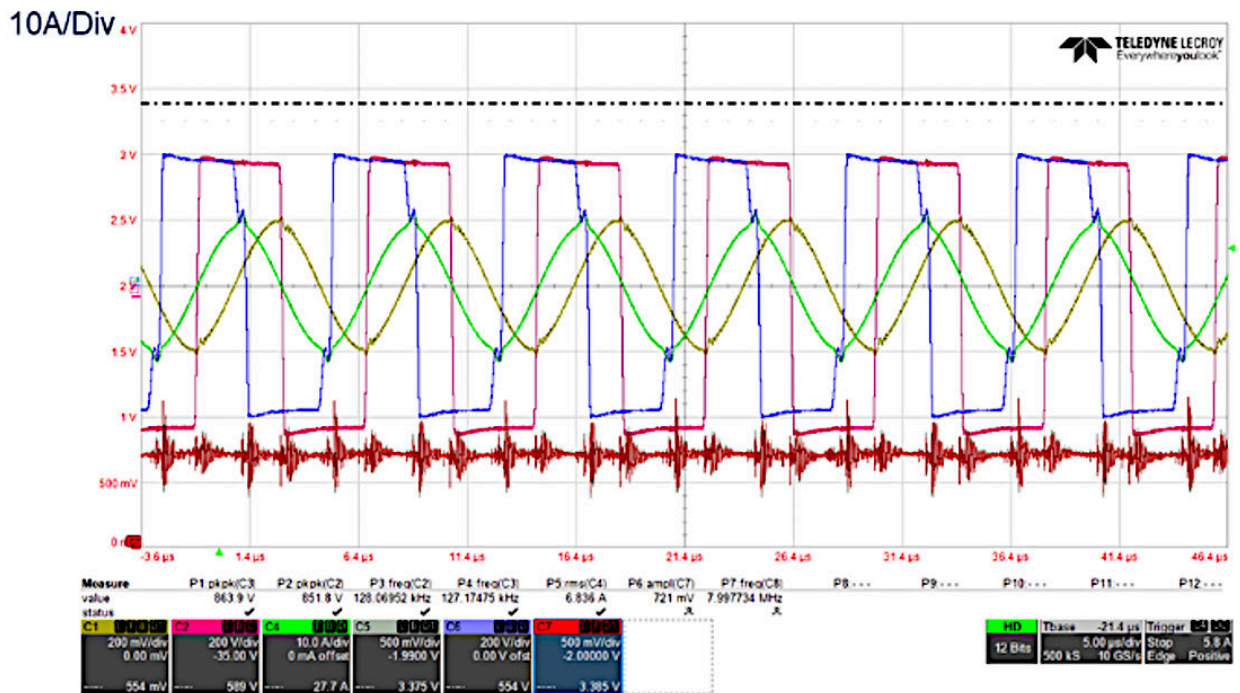
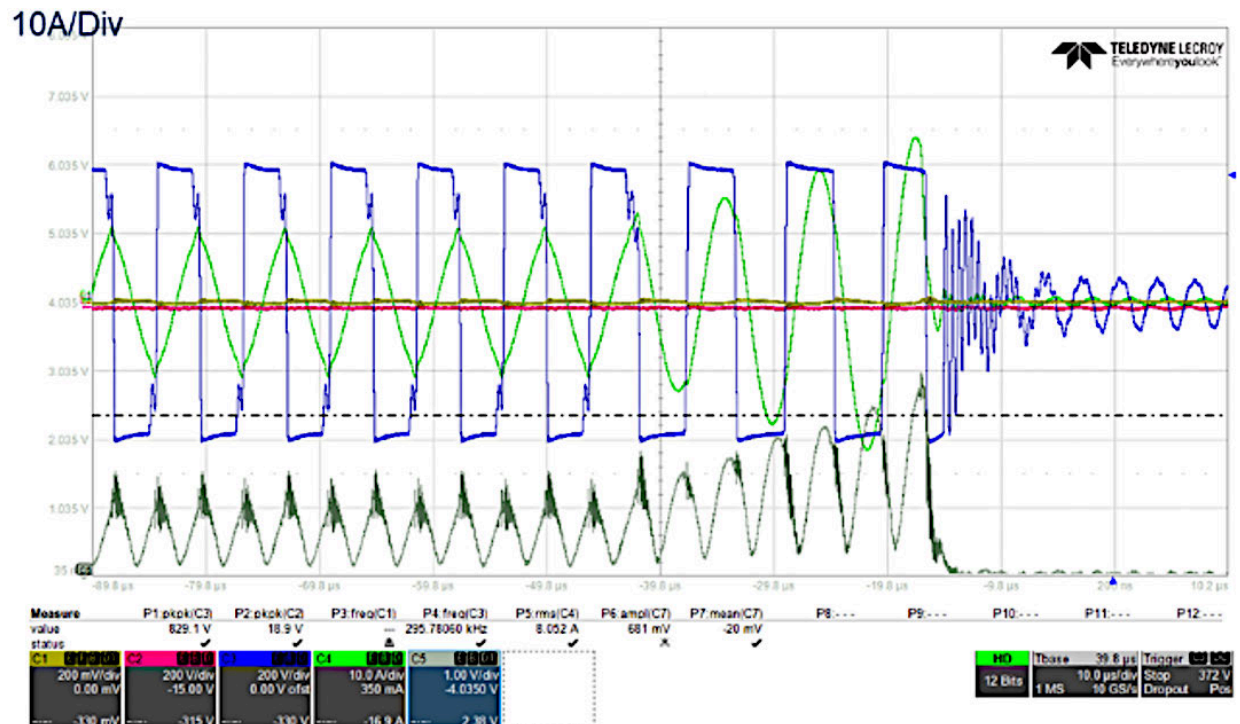


Figure 12. LLC waveform - balanced currents (current balance loop control activated)


The LLC DC-DC converter is protected against overcurrent. The MCU detects overcurrent issues thanks to the feedback signals from current transformers and puts the MOSFETs PWM signals low with very short latency, protecting the leg's switches from further current increase.

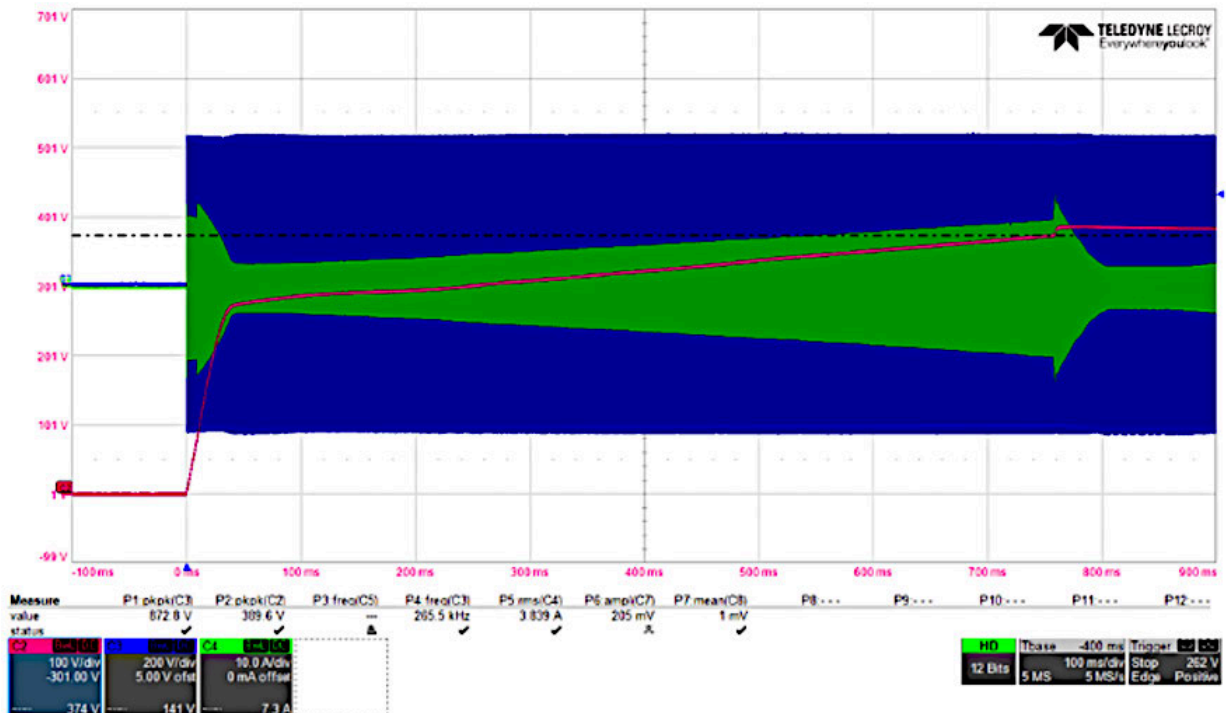
Figure 13. LLC waveform - overcurrent protection


4.2.2 Start-up

When the bus voltage starts increasing, thanks to the PFC stage, the LLC performs the start-up procedure at the maximum switching frequency (350 kHz). The voltage increases up to 400 V and the tank resonant current increases as well. When the output voltage reaches the minimum set value (250 V), the current loop or the voltage loop with the current balance loop are closed according to the selected operation mode (CC or CV). The closed control loop is then activated to maintain the output voltage constant.

Figure 14. LLC start-up

Pink = bus voltage
 Green = resonant tank current
 Blue = square wave applied



4.2.3 Voltage reference change

You can change the output voltage by changing the voltage reference on the firmware voltage loop.

Attention: *This procedure has to be very slow (approximately 5-10 ms) to avoid overcurrent.*

In case of load variation, the voltage tends to change: the control voltage loop maintains the output voltage constant after a short transient related to the PID parameter.

Figure 15. Voltage reference change test

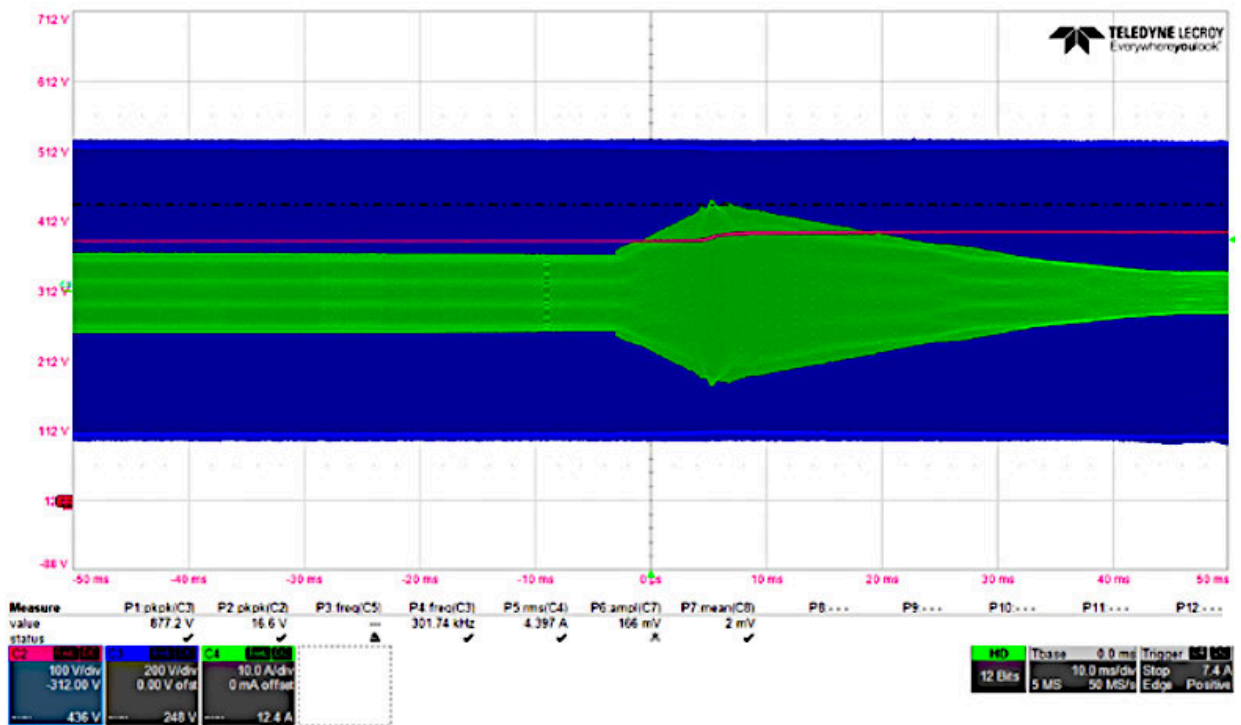


Figure 16. Output voltage transient (in pink) during steady-state

Green = resonant current

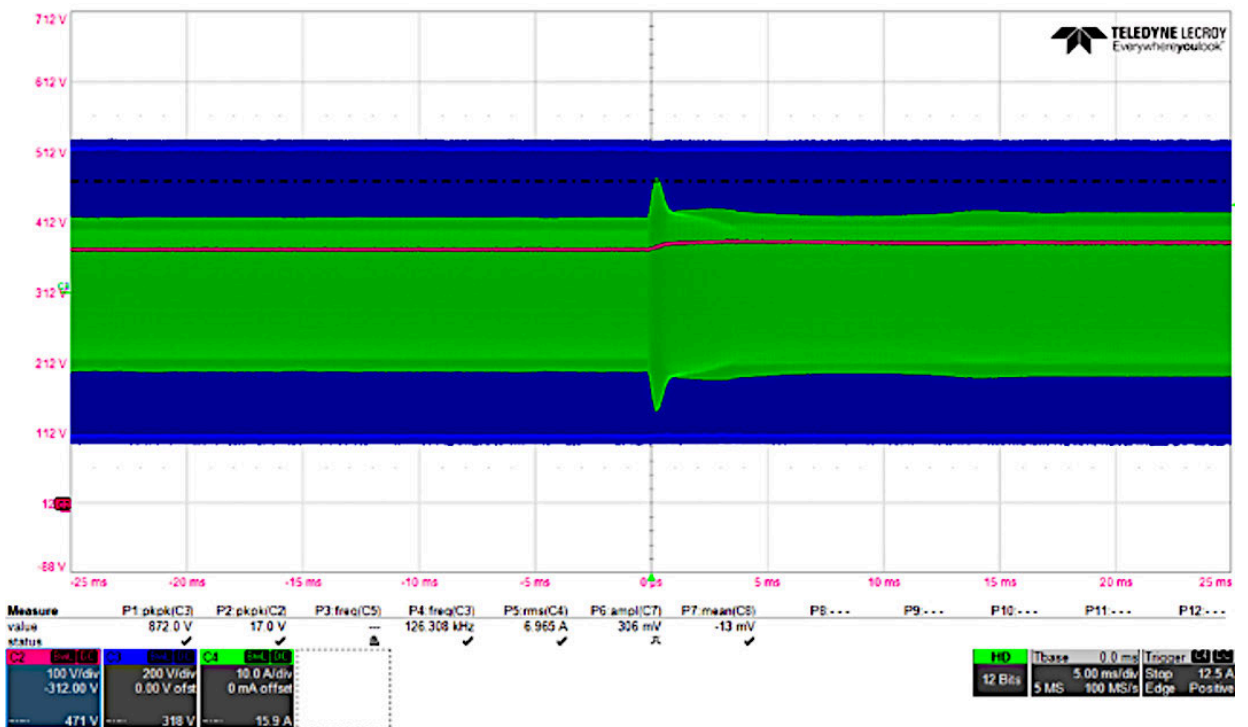


Figure 17. Interleaved mode LLC current balanced control

Dark yellow and green = LLC stages driven by a different frequency to balance tank resonant currents
 Blue and pink = voltage applied to resonant tanks

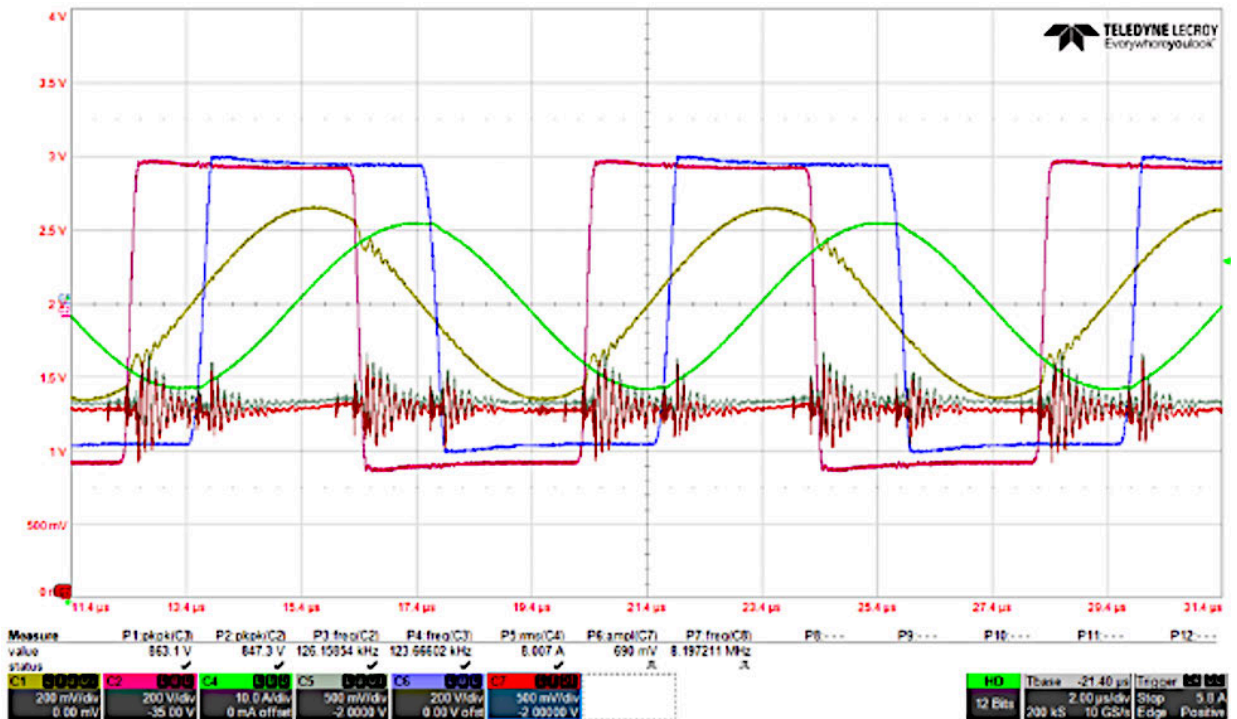


Figure 18. Mother board circuit schematic - AUX PS

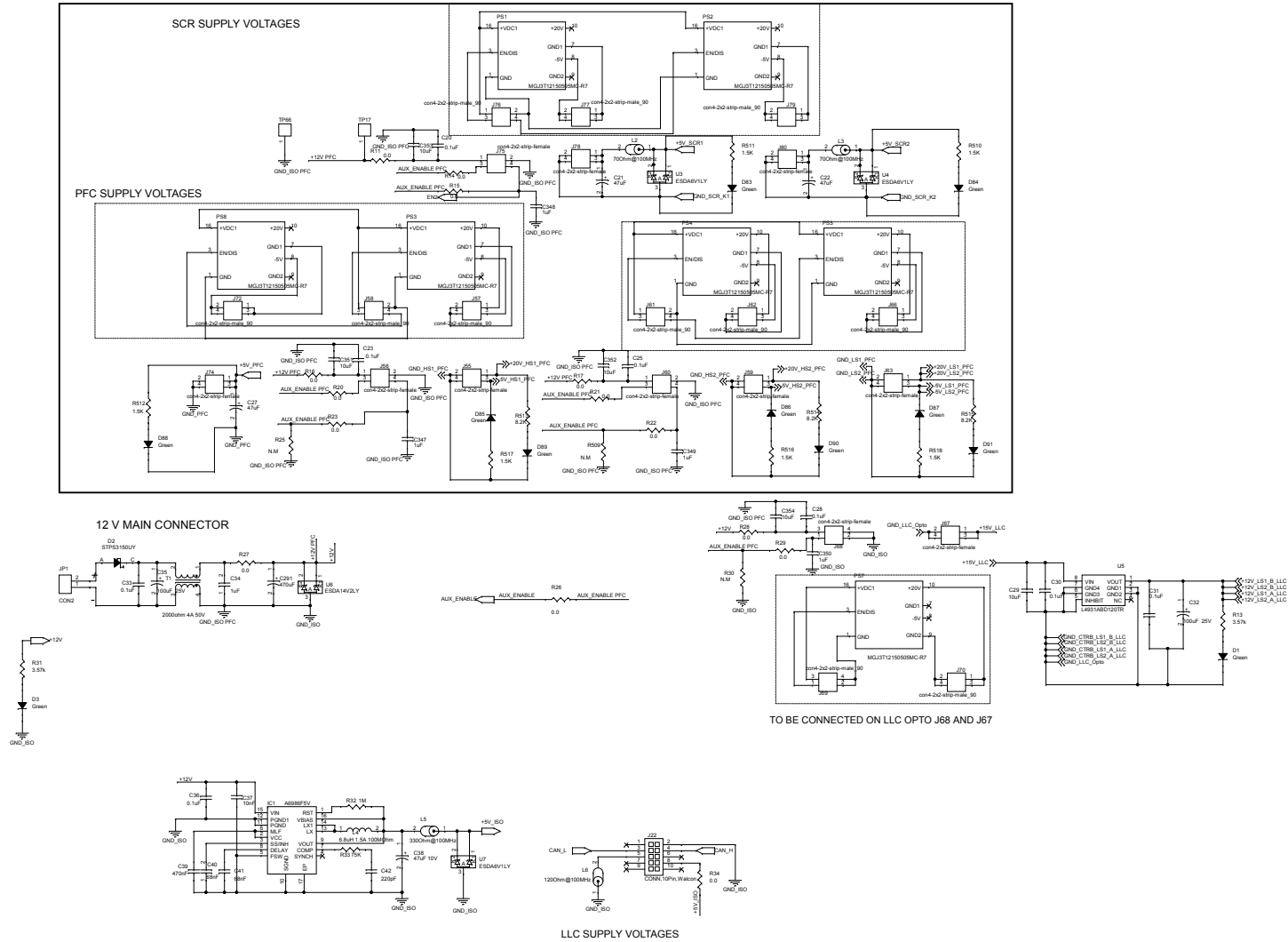


Figure 19. Mother board circuit schematic - bus monitoring

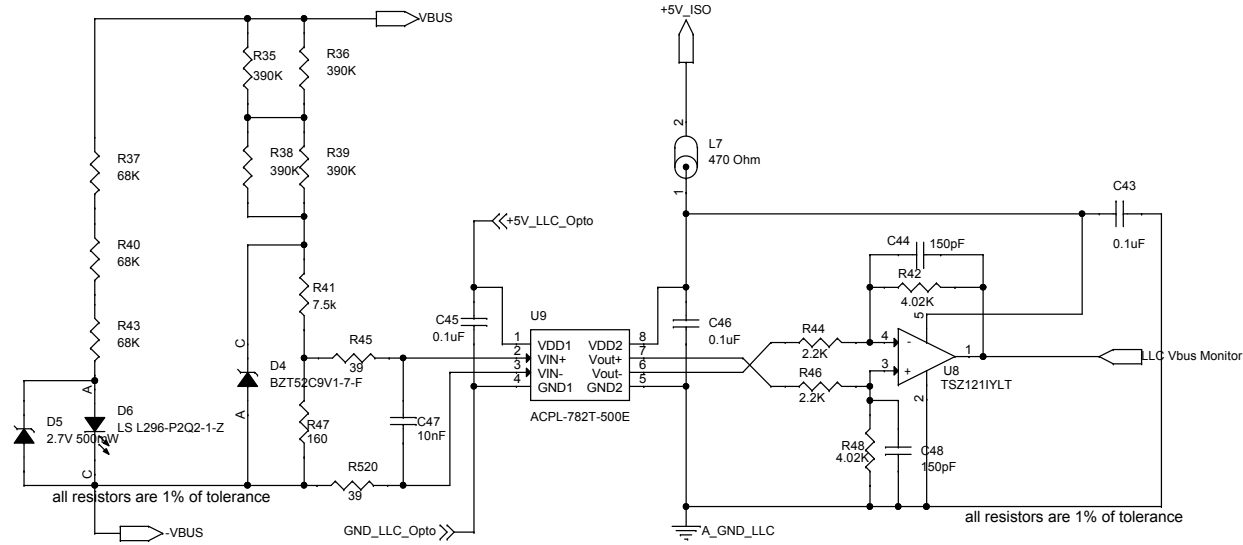


Figure 20. Mother board circuit schematic - HV discharge circuit

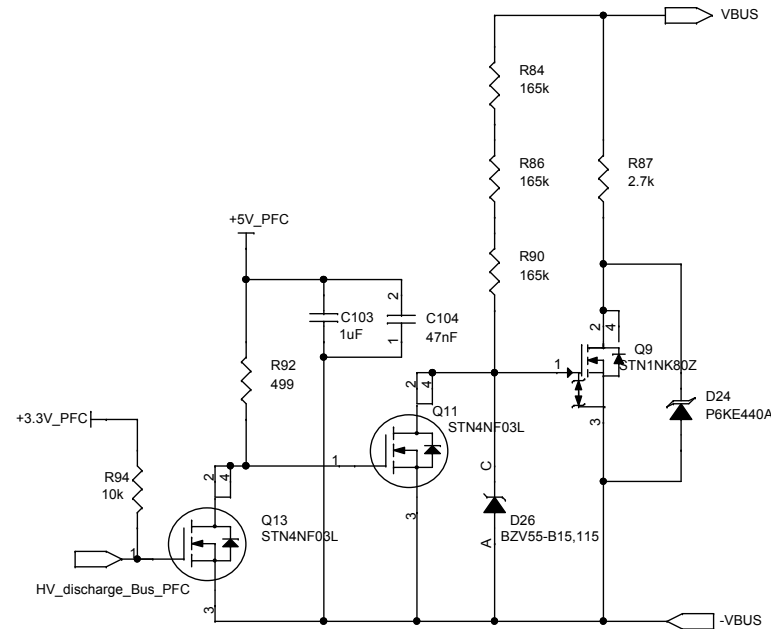


Figure 21. Mother board circuit schematic - input section

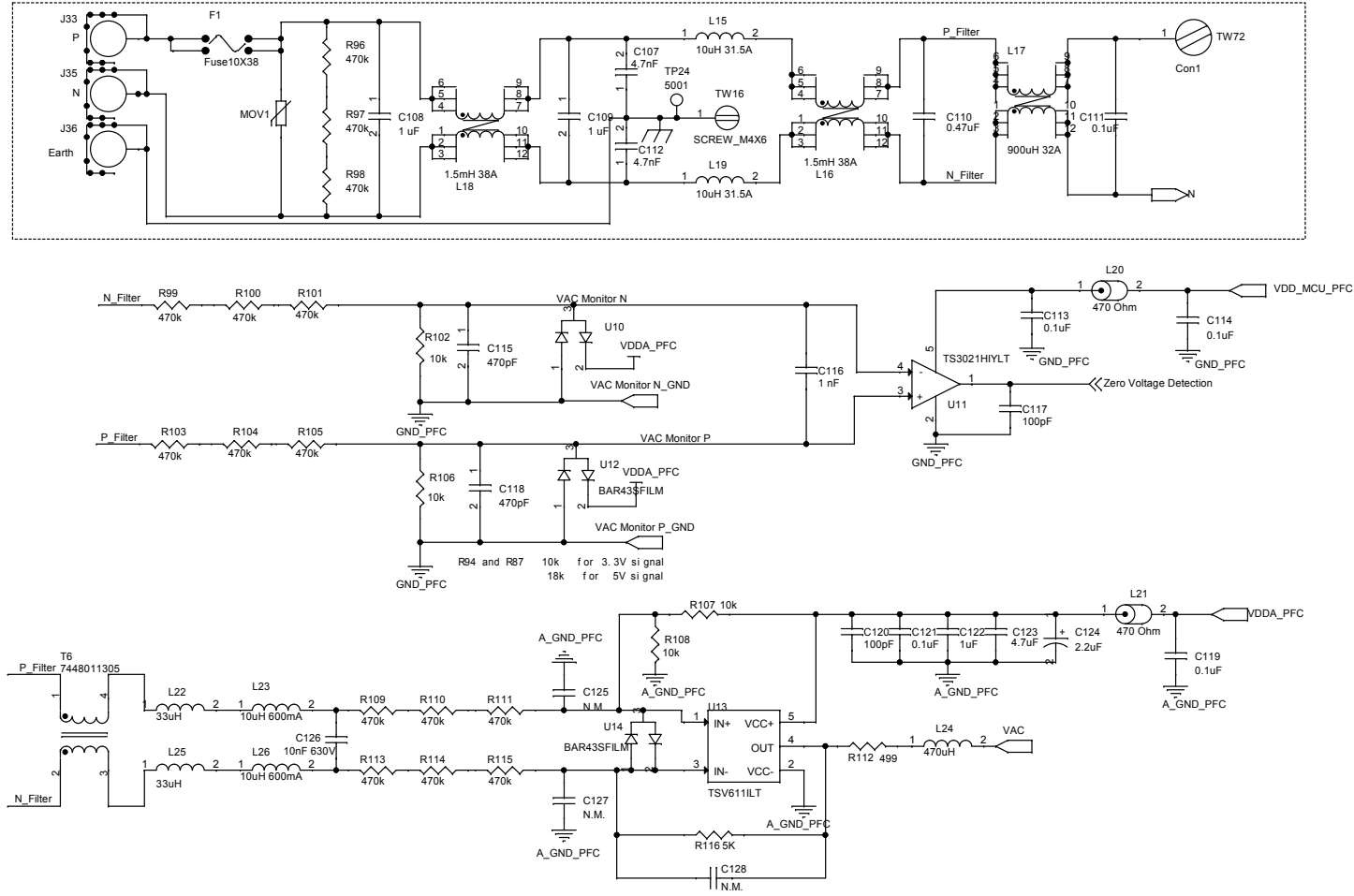


Figure 22. Mother board circuit schematic - LLC control

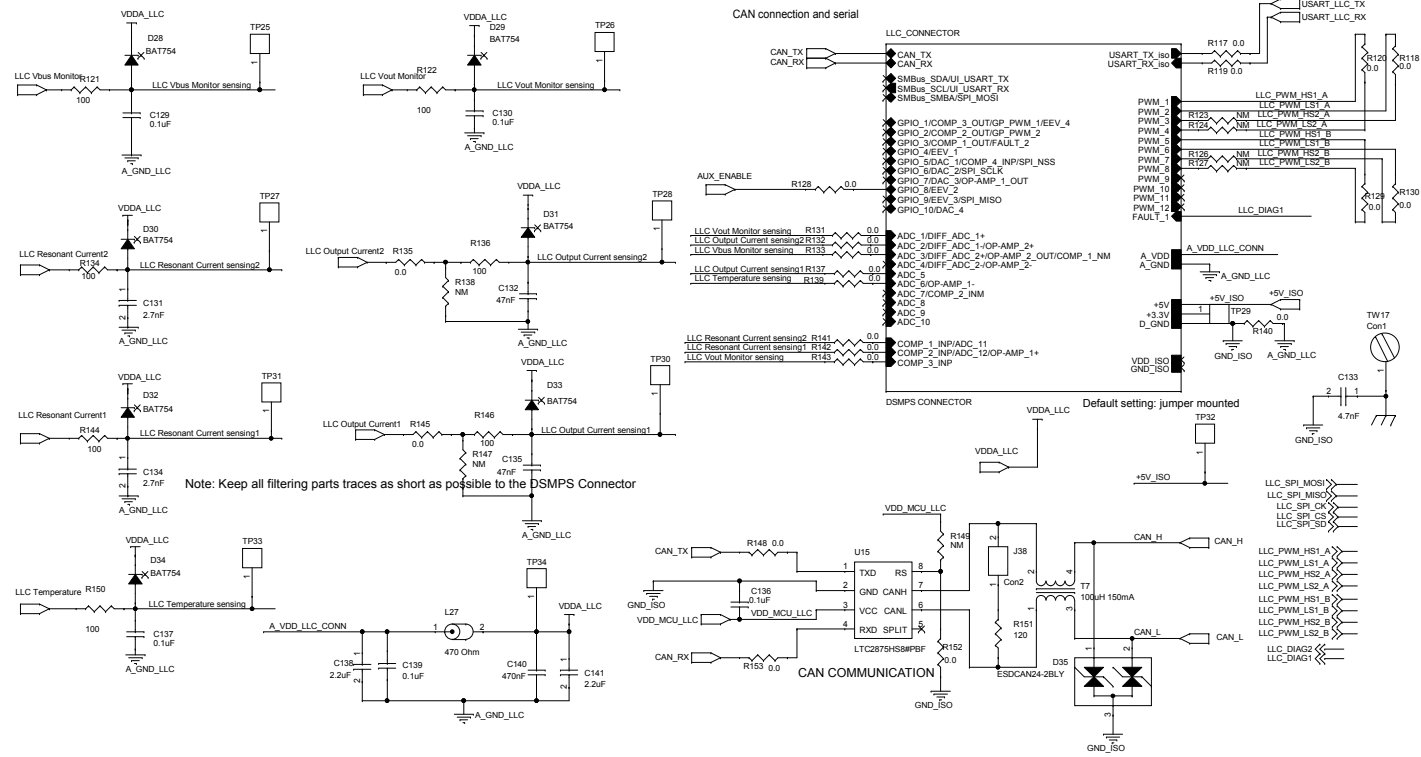


Figure 23. Mother board circuit schematic - PFC control

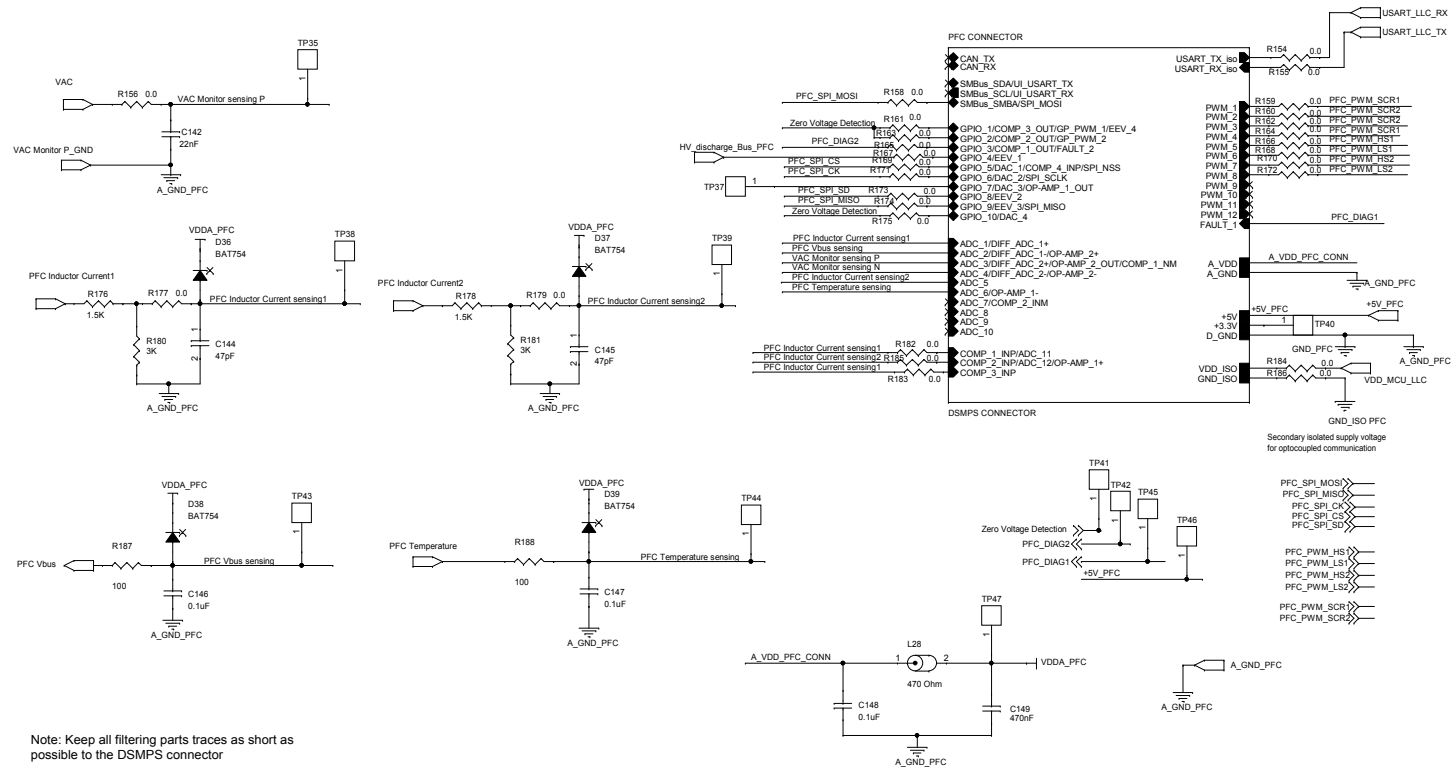
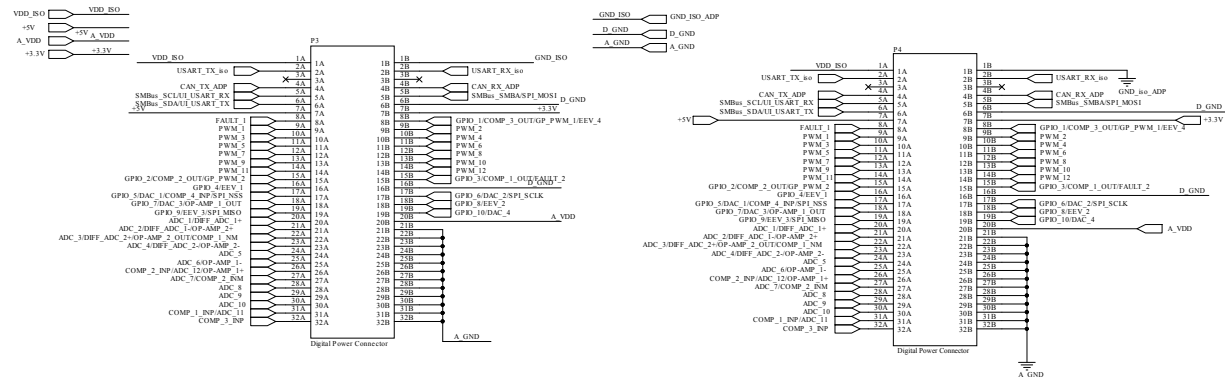
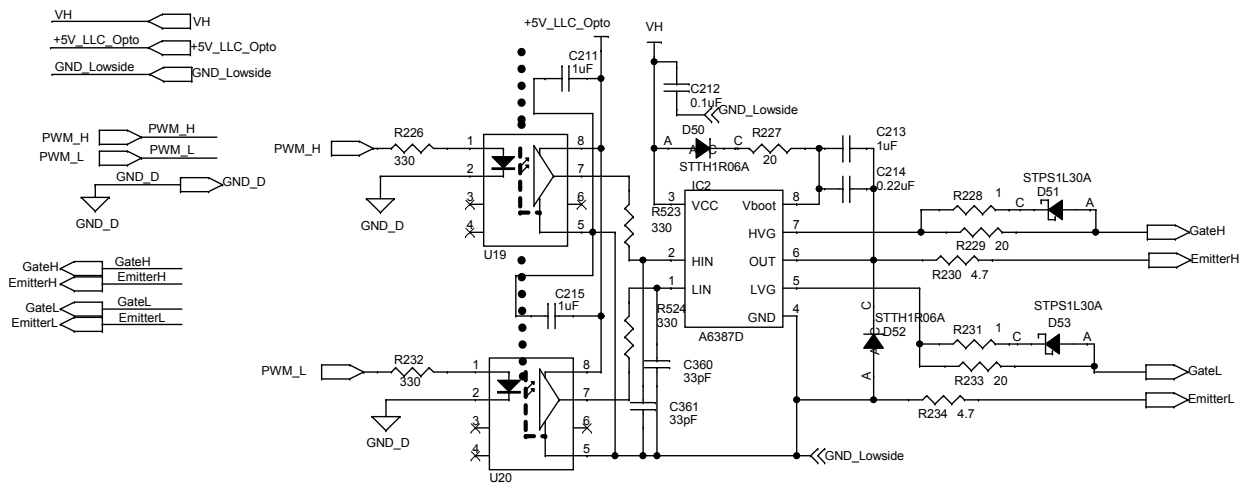


Figure 24. Mother board circuit schematic - vertical adapter





TN1373



Schematic diagrams



TN1373

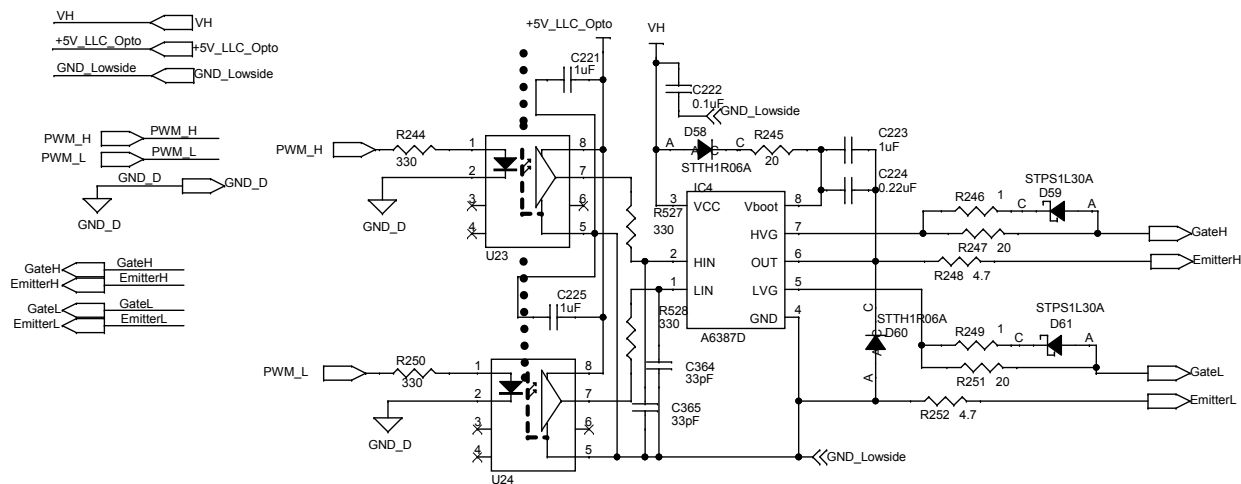


Figure 29. Mother board circuit schematic - A6387 LLC (4 of 4)

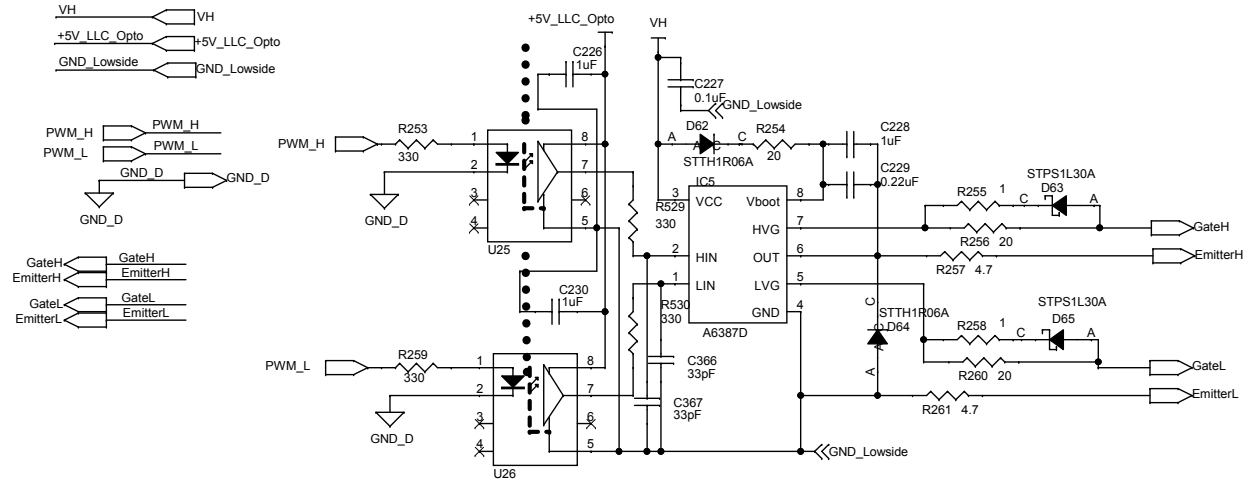


Figure 30. Mother board circuit schematic - STGAP1AS PFC (1 of 4)

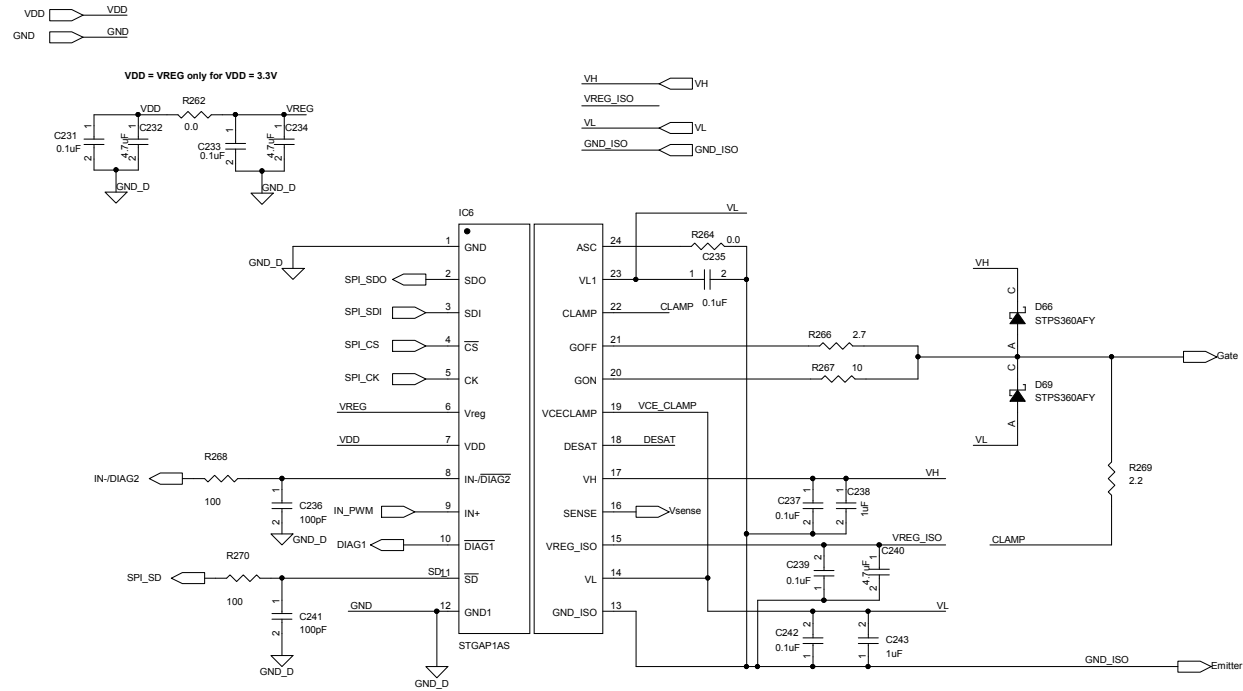


Figure 31. Mother board circuit schematic - STGAP1AS PFC (2 of 4)

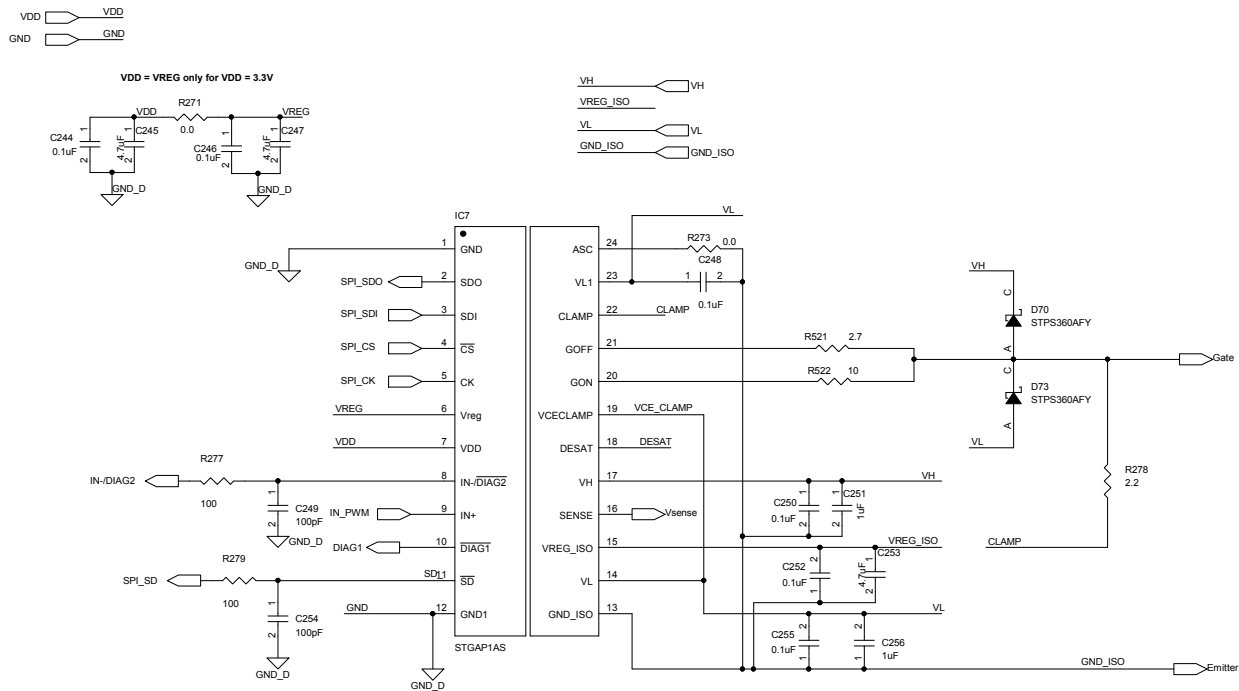


Figure 32. Mother board circuit schematic - STGAP1AS PFC (3 of 4)

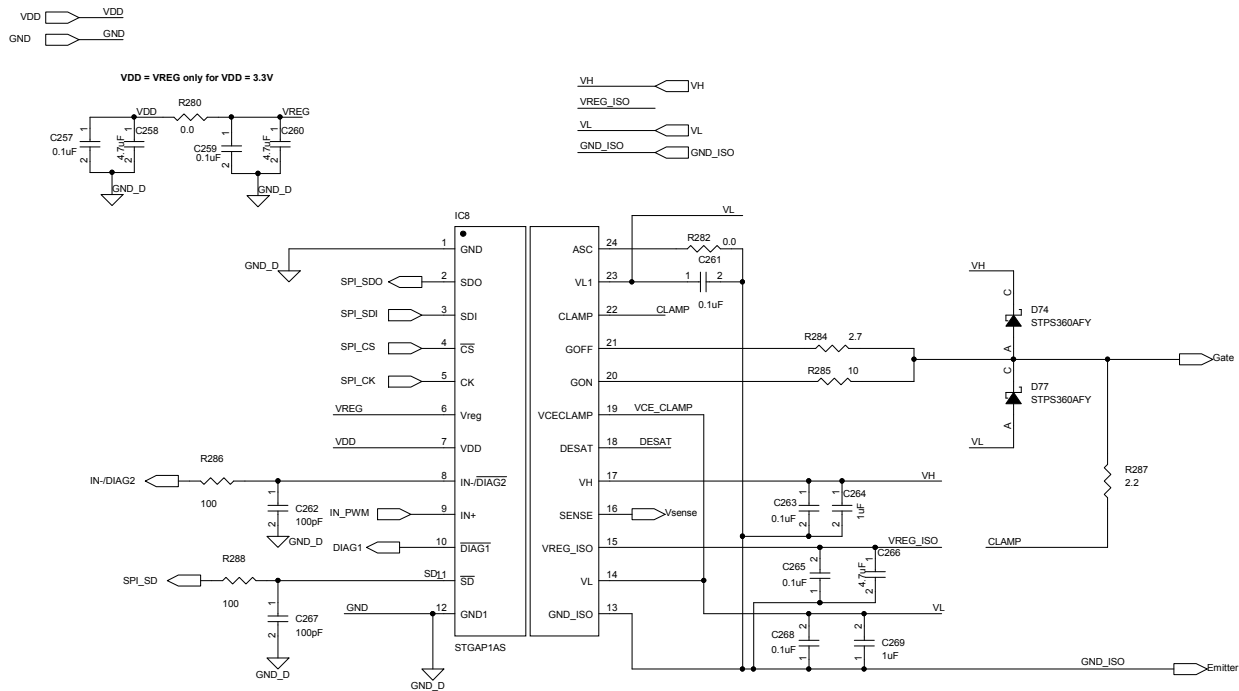


Figure 33. Mother board circuit schematic - STGAP1AS PFC (4 of 4)

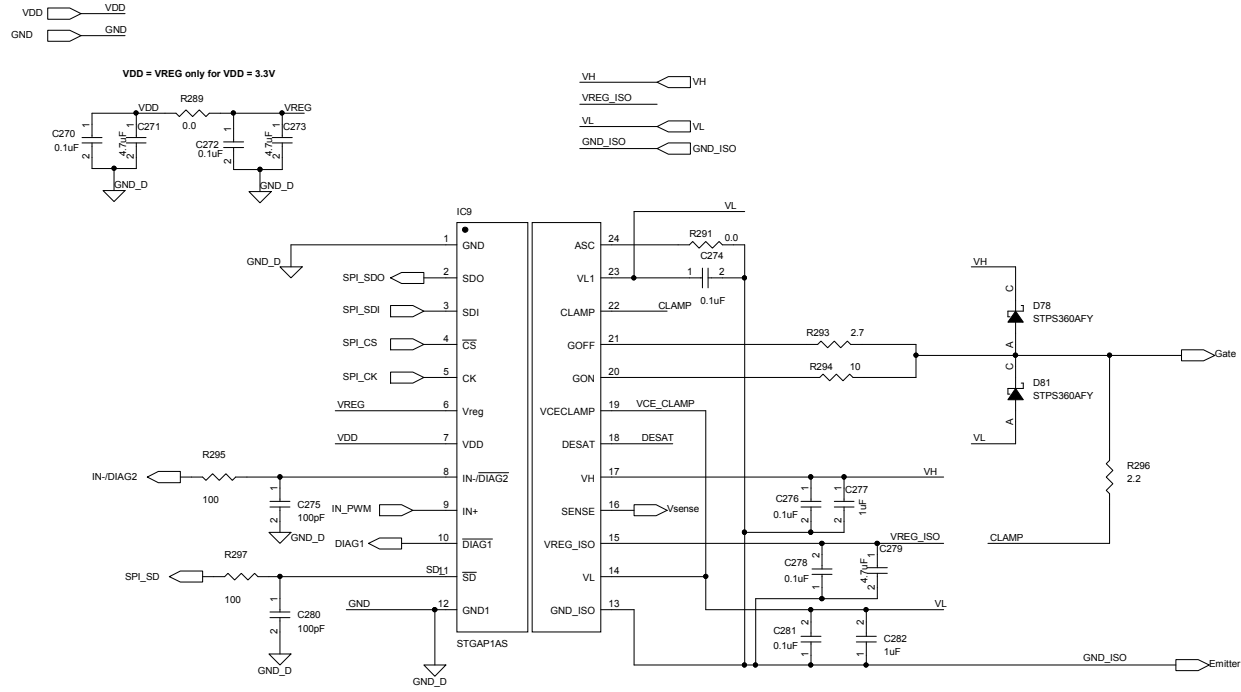


Figure 34. Mother board circuit schematic - A6387 drivers plus IMS connector

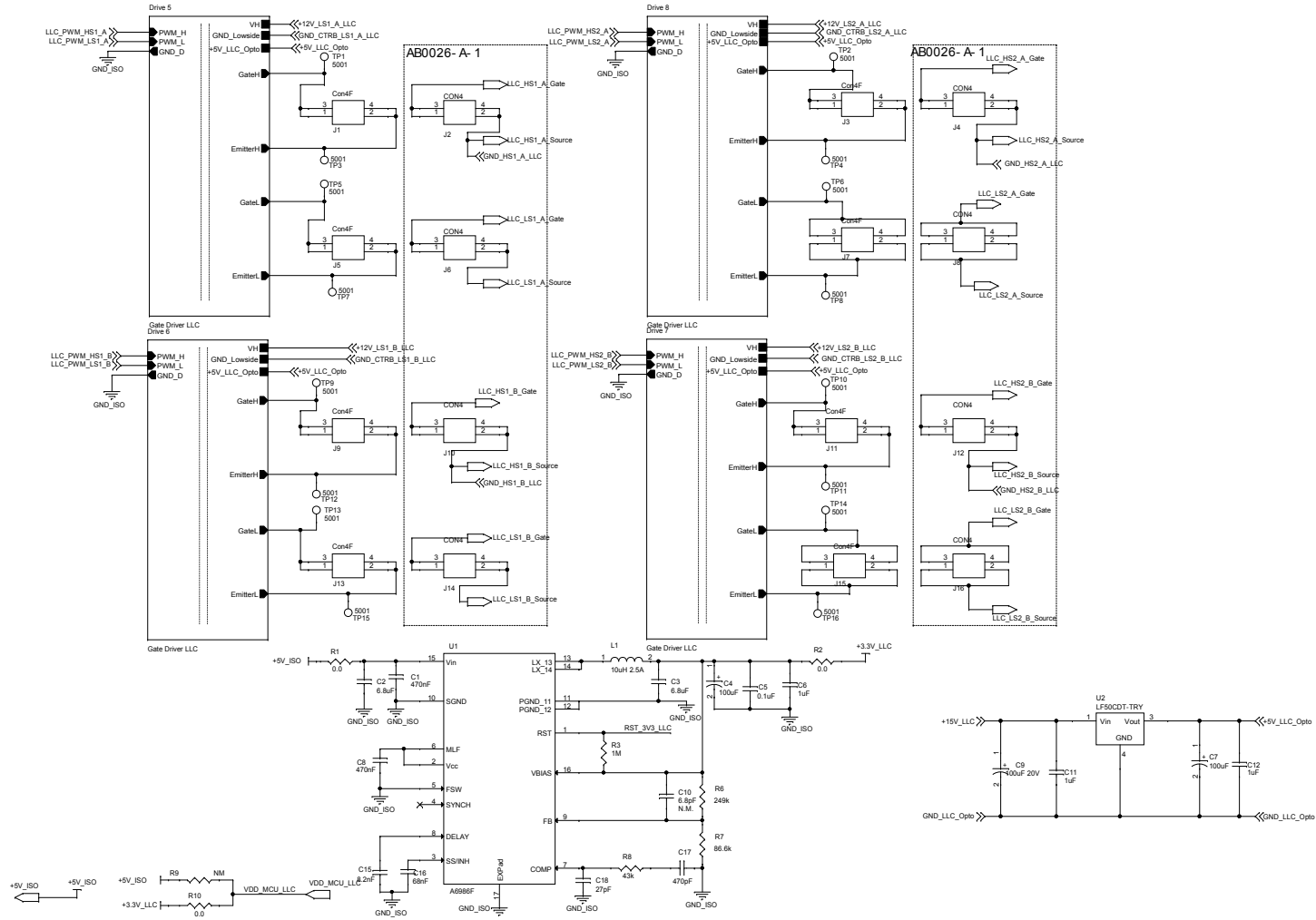


Figure 35. Mother board circuit schematic - full bridge LLC plus diodes on IMS

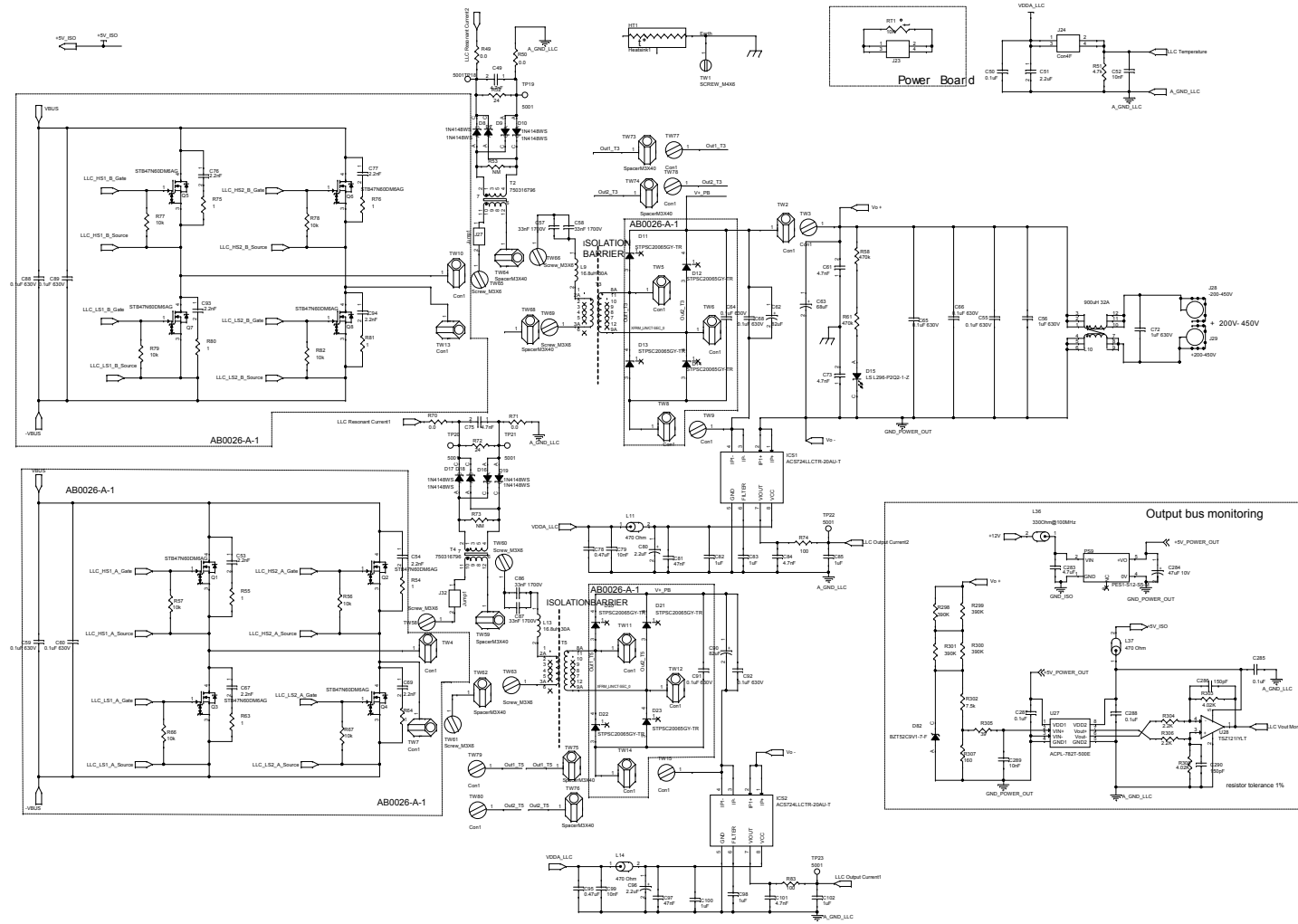
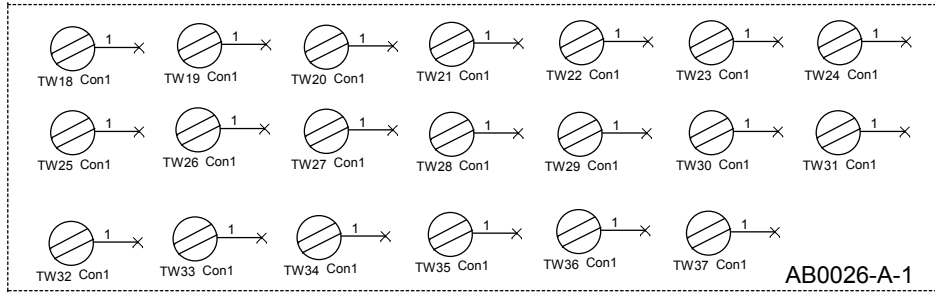


Figure 36. IMS board and mother board mechanical parts



Clips 455-2522-1-ND

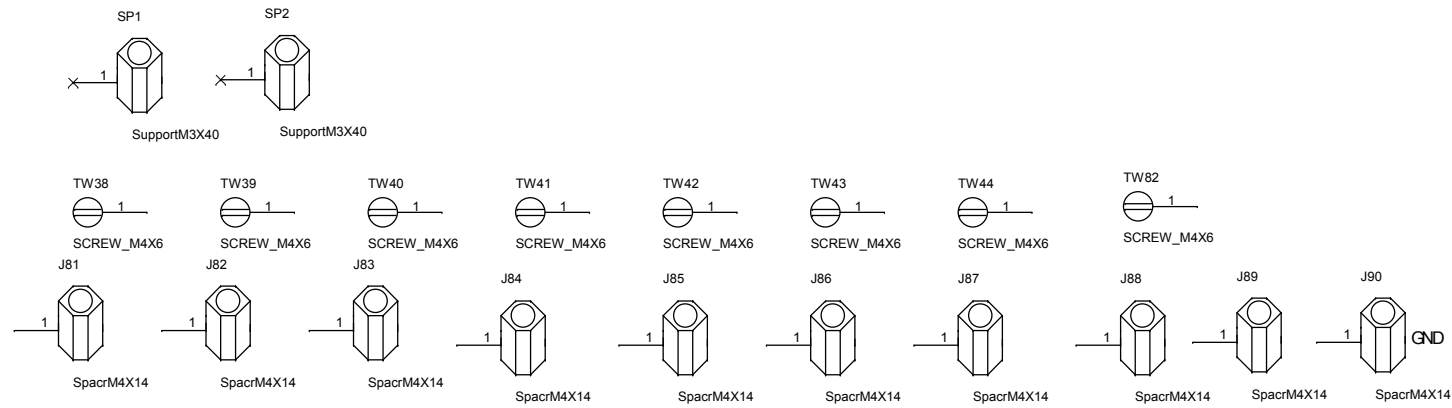


Figure 37. Mother board circuit schematic - PFC GAP drivers plus IMS connector

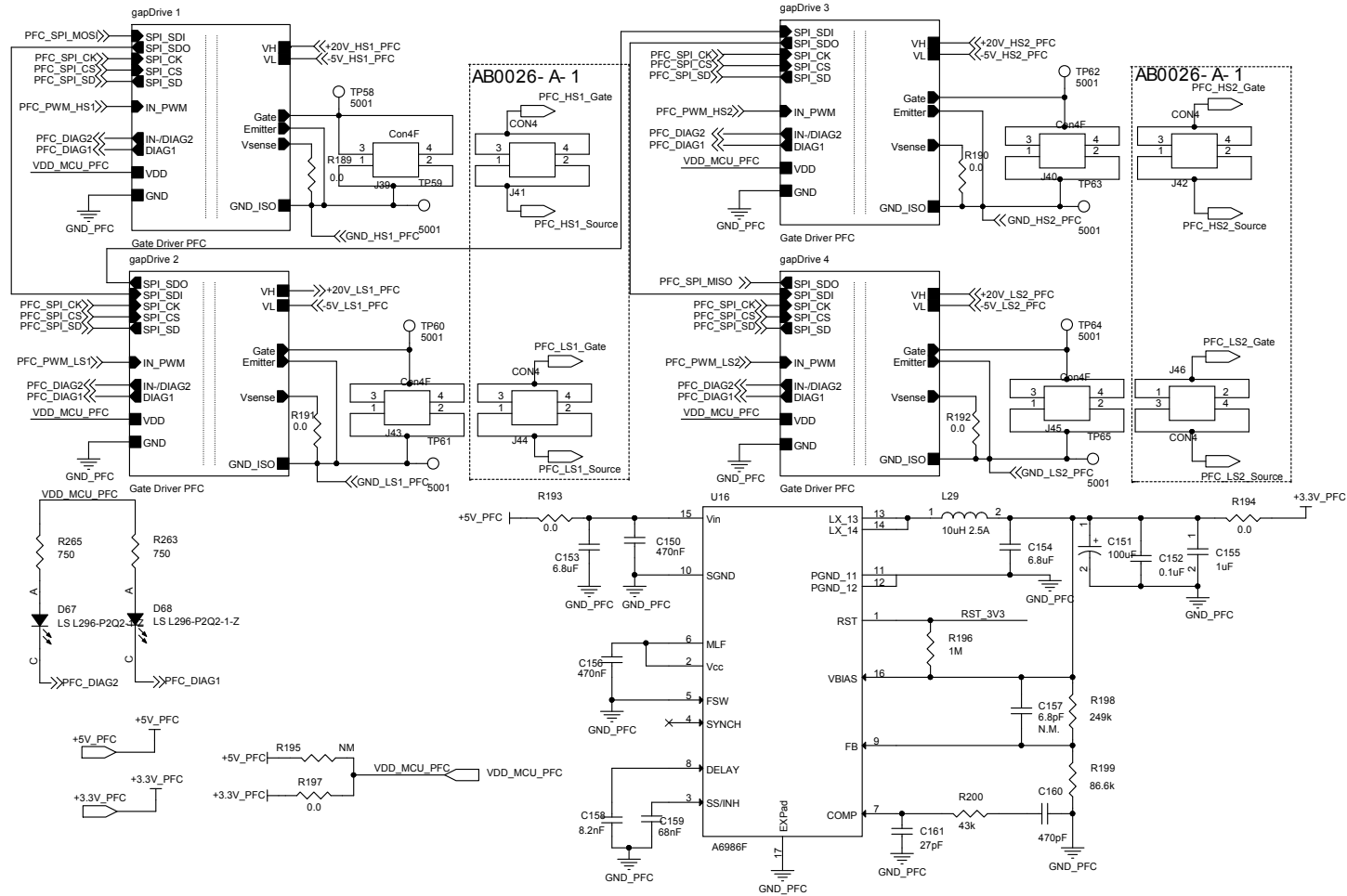
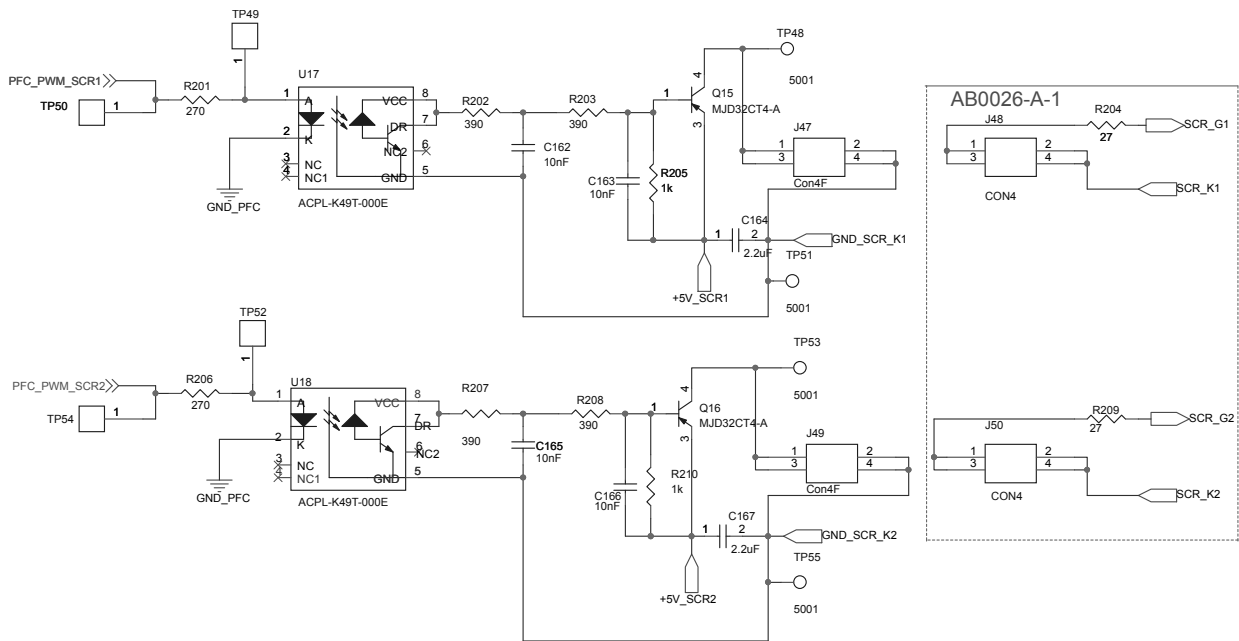
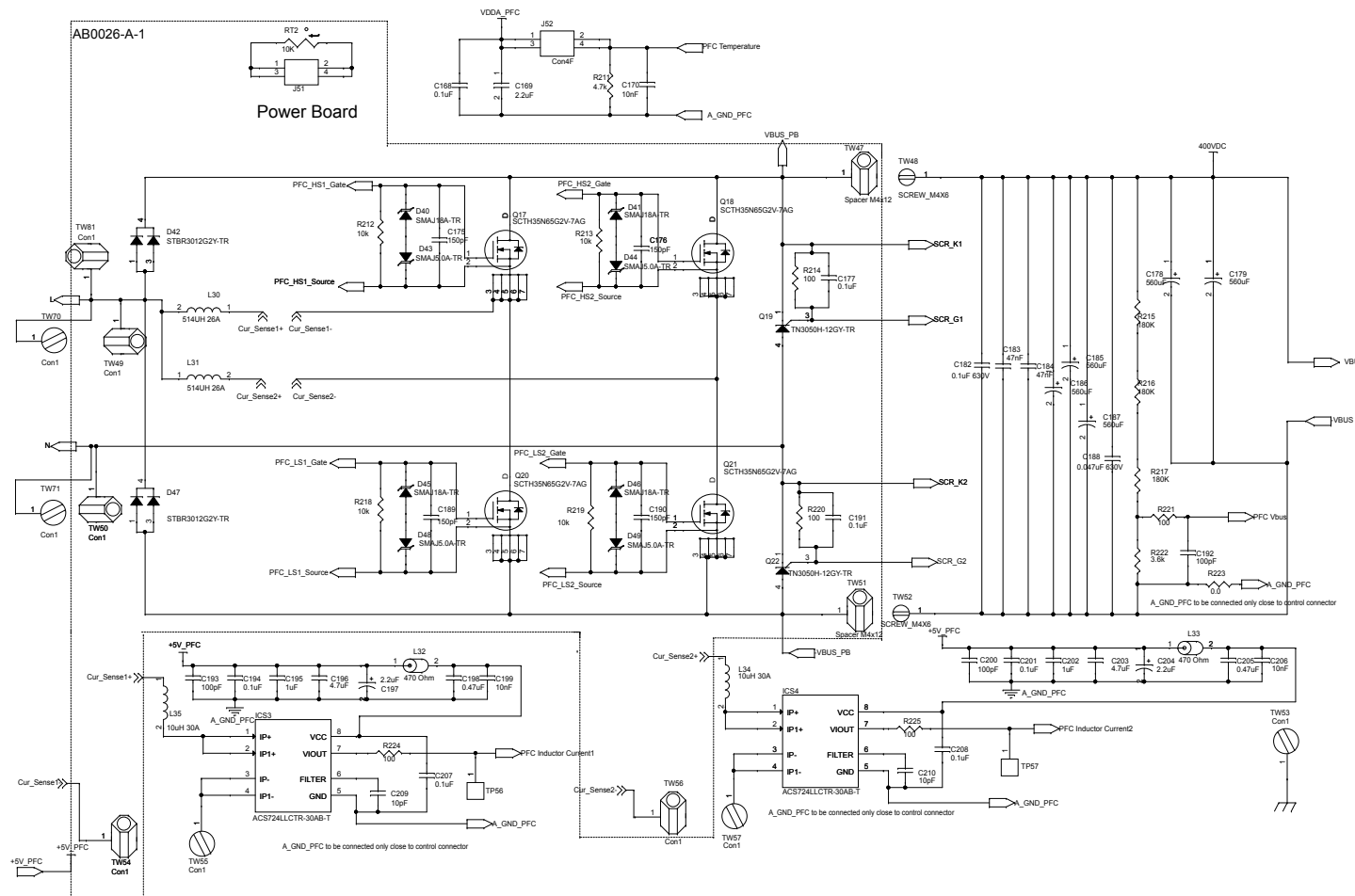


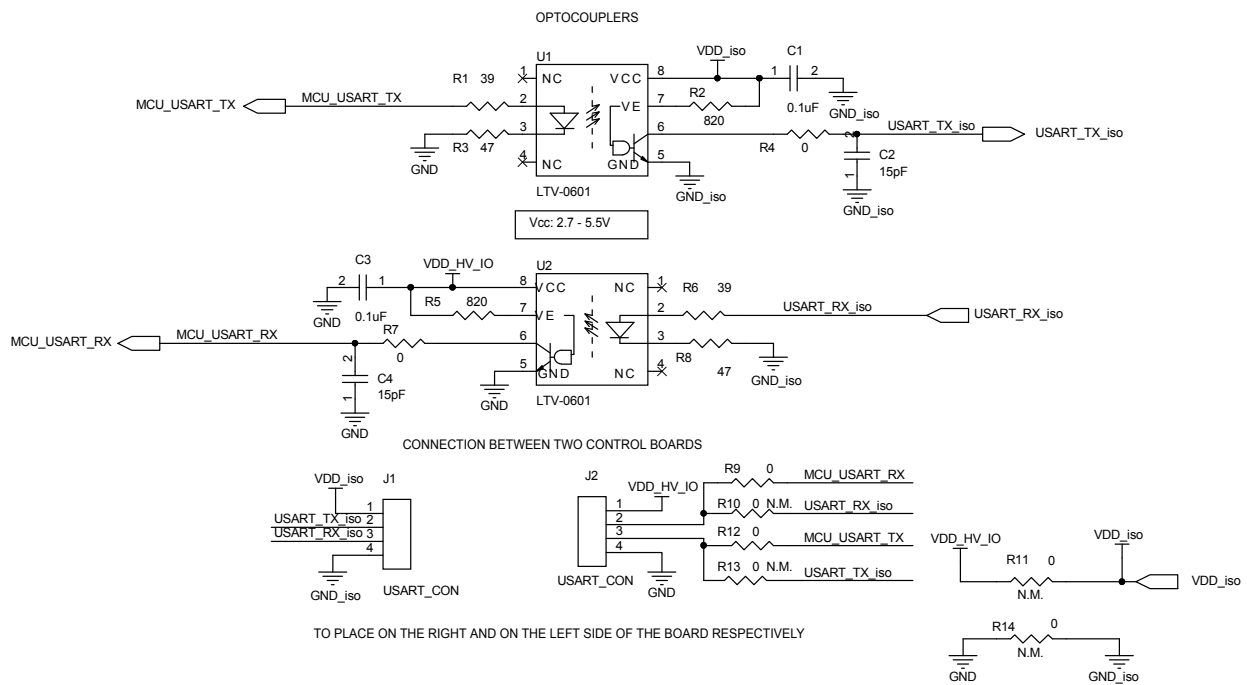
Figure 38. IMS board circuit schematic - SCR drivers plus IMS connectors



Schematic diagrams



VDD_HV_IO VDD_HV_IO



TO PLACE ON THE RIGHT AND ON THE LEFT SIDE OF THE BOARD RESPECTIVELY

Figure 41. Control board circuit schematic - comparators

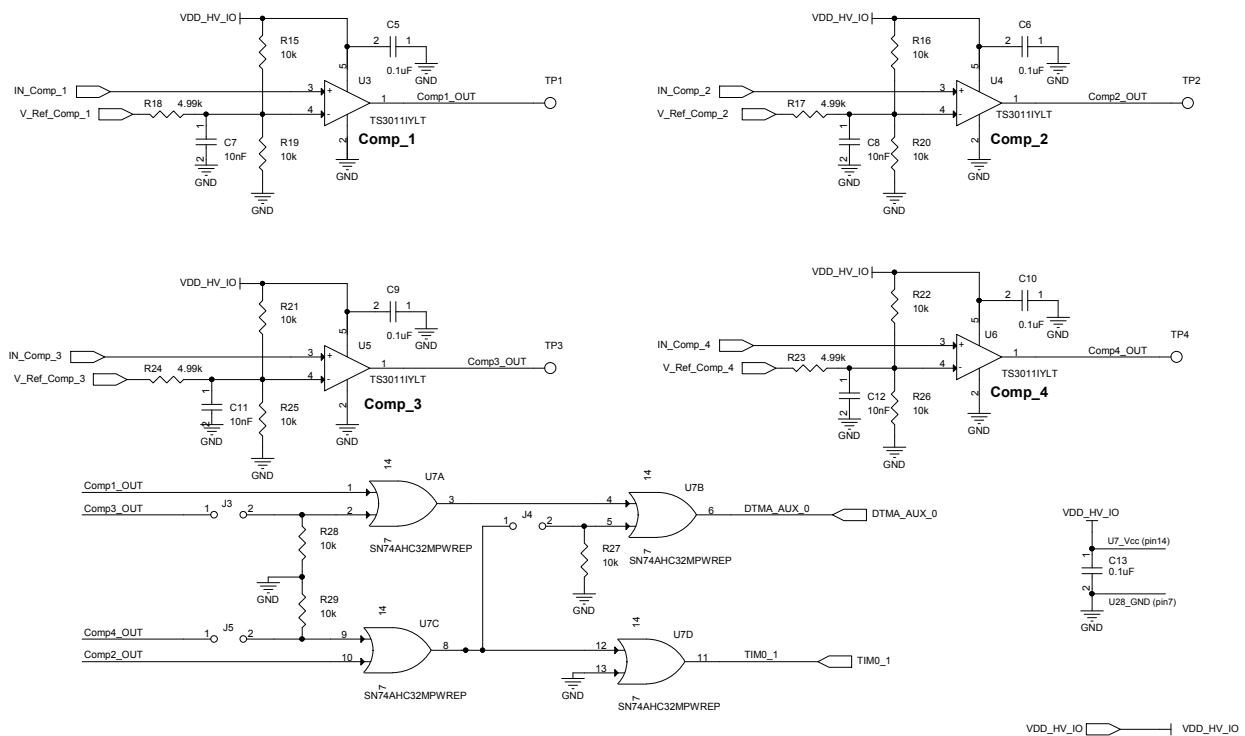


Figure 42. Control board circuit schematic - DSMPS connector

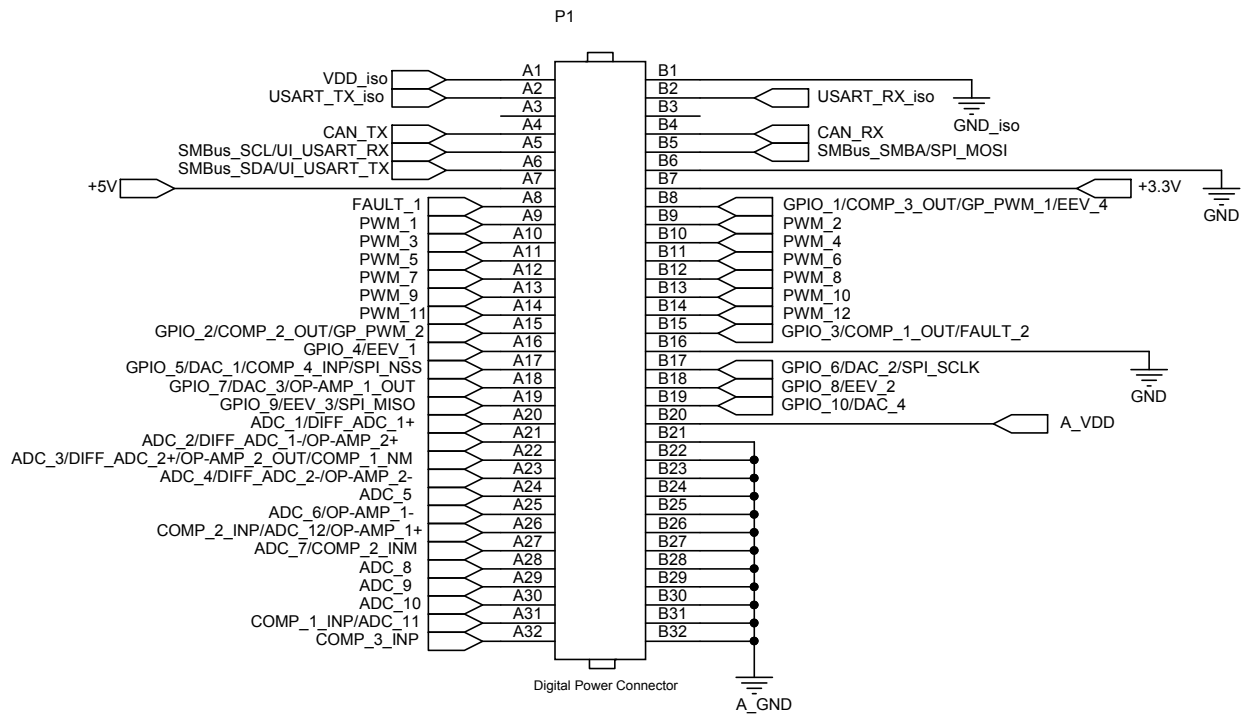
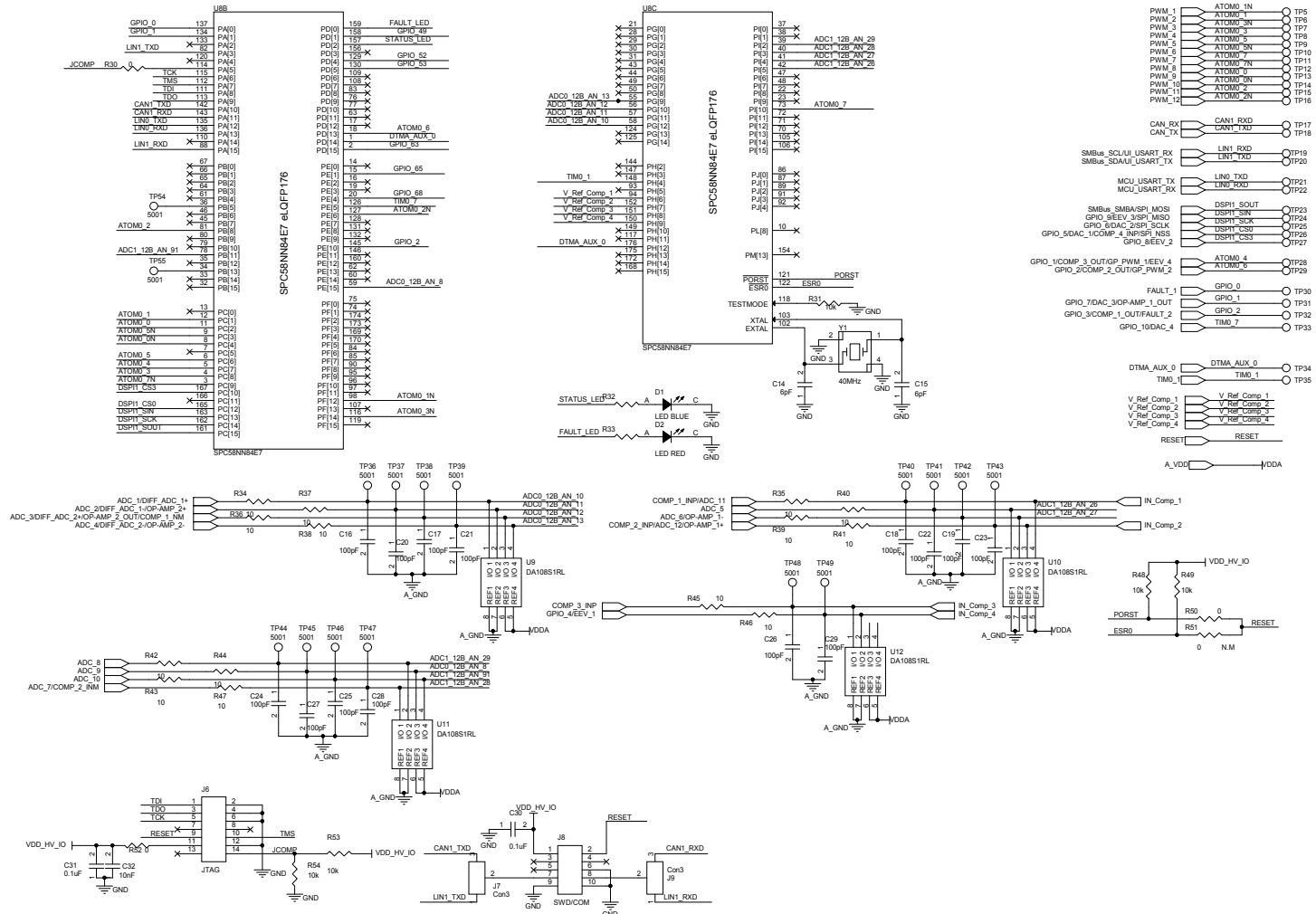


Figure 43. Control board circuit schematic - SPC58NN84E7 MCU IO



Schematic diagrams

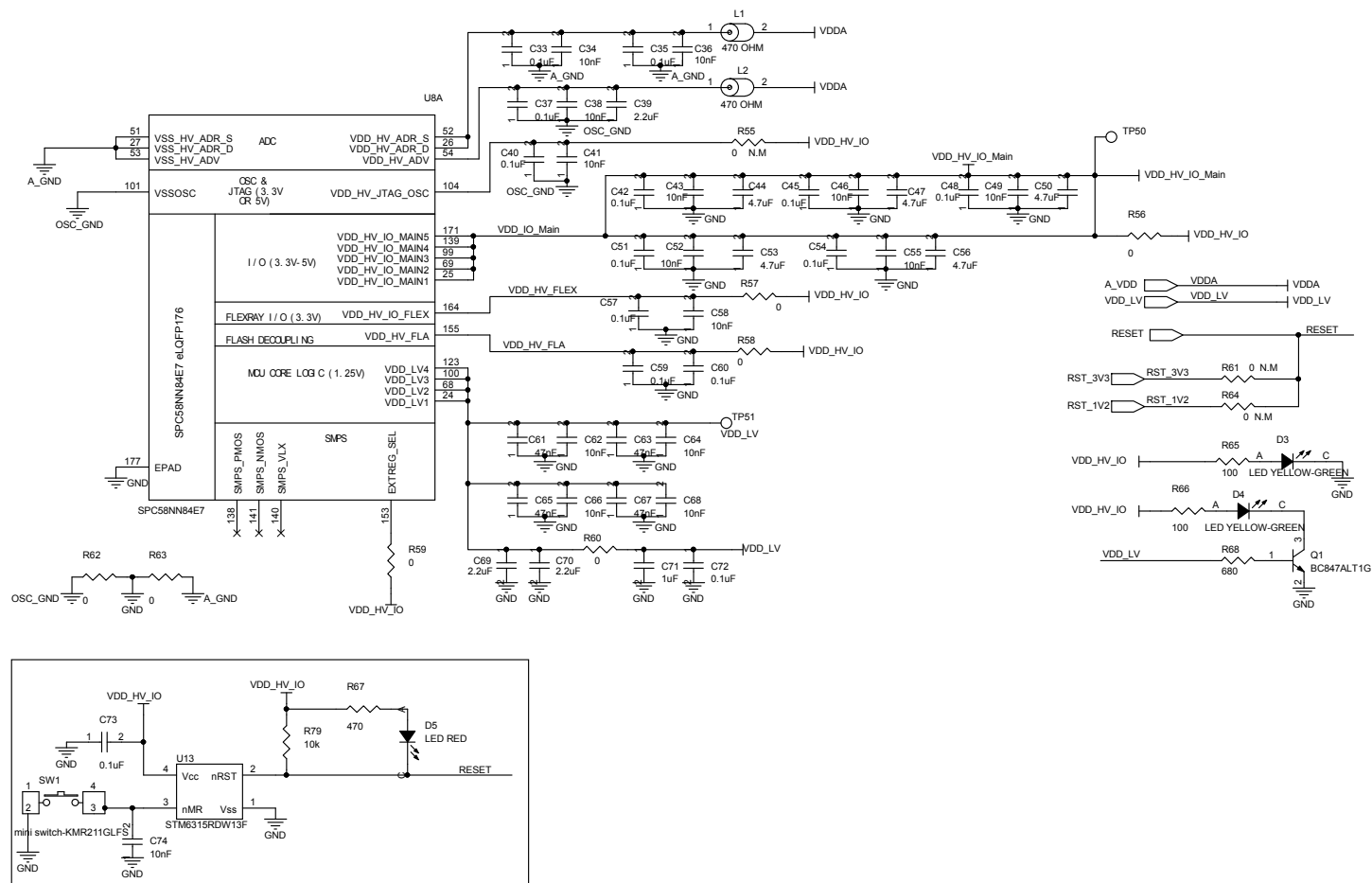
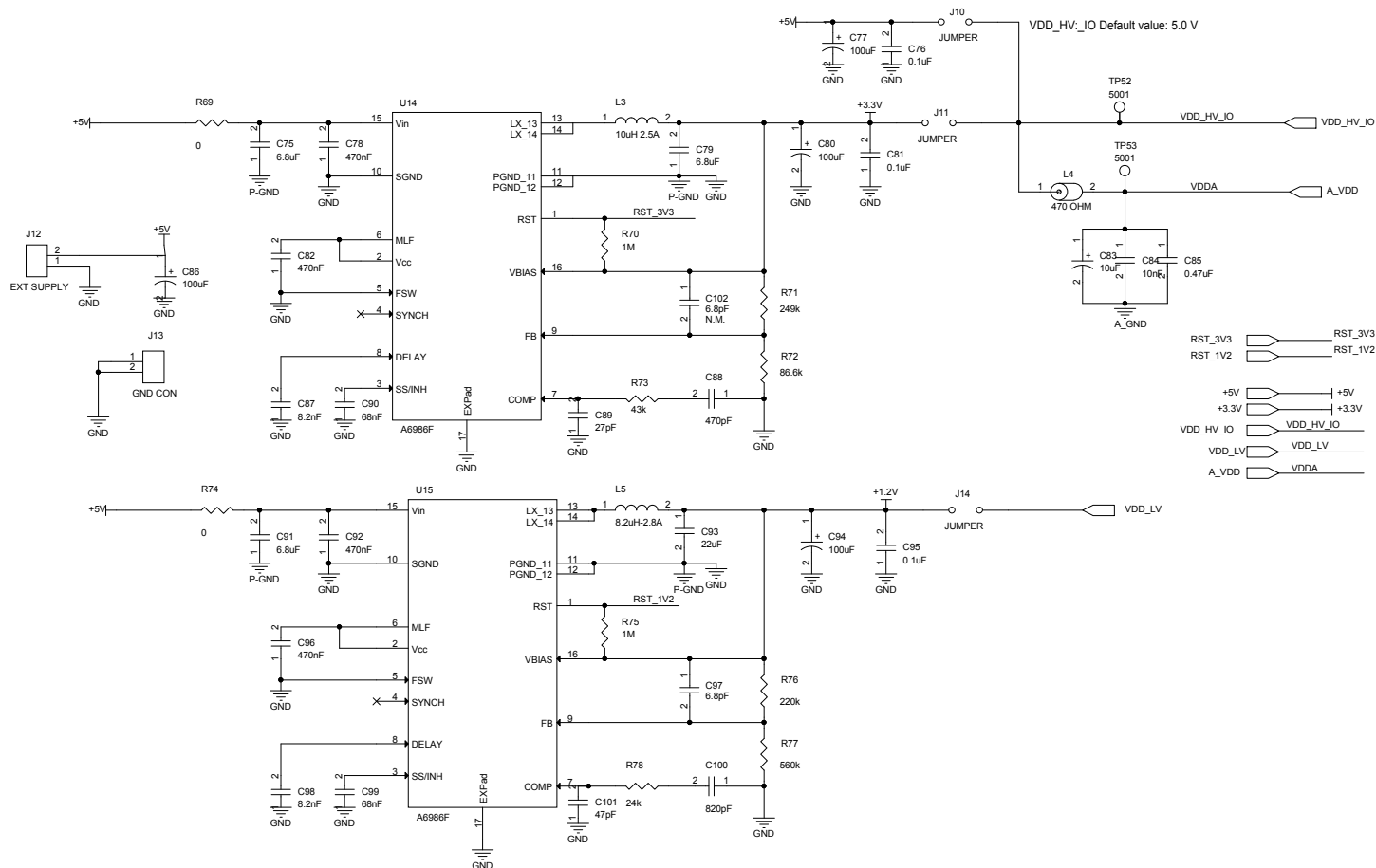


Figure 45. Control board circuit schematic - power supply



6 Bill of materials

Table 3. STDES-7KWOBc bill of materials

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
1	1	-	-	Table 4. Mother board	ST	Not available for separate sale
2	1	-	-	Table 5. IMS board	ST	Not available for separate sale
3	1	-	-	Table 6. Control board	ST	Not available for separate sale

Table 4. Mother board bill of materials

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
1	6	C1, C8, C39, C149, C15, C156	470 nF 0603 (1608 Metric) 25V ±10% X7R	Ceramic capacitors	Würth Electronics Inc.	885012206075
2	2	C2, C153	6.8 µF 1206 (3216 Metric) 16 V ±20% X7R	Ceramic capacitors	TDK Corporation	CGA5L1X7R1C685M160AC
3	2	C3, C154	6.8 µF 1206 (3216 Metric) 16 V ±20% X7R	Ceramic capacitors	TDK Corporation	CGA5L1X7R1C685M160AC
4	3	C4, C7, C151	100 µF Radial, Can - SMD 16 V ±20%	Aluminium capacitors	Panasonic Electronic Components	EEE-FT1C101AR
5	1	C5	0.1 µF 0603 (1608 Metric) 50 V ±10% X7R	Ceramic capacitor	Würth Electronics Inc.	885012206095
6	29	C6, C11, C12, C82, C83, C85, C98, C100, C102, C103, C122, C195, C202, C211, C213, C215, C216, C218, C220, C221, C223, C225, C226, C228, C230, C347, C348, C349, C350	1 µF 0805 (2012 Metric) 50 V ±10%	Ceramic capacitors	Würth Elektronik	885012207103
7	1	C9	100 µF 20 V 2917 (7343 Metric) 20 V ±20%	Capacitor	AVX Corporation	TAJE107M020RNJ
8	2	C10, C157	6.8 pF 0603 (1608 Metric) 50 V 0.5 pF C0G/NP0	Capacitors (not mounted)	Würth Electronics Inc.	885012006050
9	2	C15, C158	8.2 nF 0603 (1608 Metric) 50 V ±10%	Ceramic capacitors	Kemet	C0603C822K5RACTU

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
10	3	C16, C41, C159	68 nF 0603 (1608 Metric) 50 V $\pm 10\%$ X7R	Ceramic capacitors	Würth Electronics Inc.	885012206094
11	1	C17	470pF 0603 (1608 Metric) 50 V $\pm 10\%$ C0G	Ceramic capacitor	Würth Electronics Inc.	885012206081
12	1	C18	27 pF 0603 (1608 Metric) 50 V $\pm 5\%$ C0G/NP0	Ceramic capacitor	Murata Electronics North America	GCM1885C1H270JA16 D
13	32	C20, C23, C25, C28, C30, C31, C33, C36, C43, C45, C46, C50, C113, C114, C119, C121, C146, C147, C148, C152, C168, C194, C201, C207, C208, C212, C217, C222, C227, C285, C287, C288	0.1 μ F 0603 (1608 Metric) 50 $\pm 10\%$	Ceramic capacitors	Würth Elektronik	885012206095
14	2	C21, C22	47 μ F 2917 (7343 Metric) $\pm 10\%$	Ceramic capacitors	AVX Corporation	TAJD476K025RNJ
15	1	C27	47 μ F 2917 (7343 Metric) $\pm 10\%$	Ceramic capacitor	AVX Corporation	TAJD476K010RNJ
16	5	C29, C351, C352, C353, C354	10 μ F 0805 (2012 Metric) 25 V $\pm 10\%$	Ceramic capacitors	Samsung Electro-Mechanics America, Inc.	CL21A106KAYNNNG
17	2	C32, C35	100 μ F 25 V Radial-SMD, 6.3x5.4 mm	Aluminium capacitors	Würth	865080445010
18	1	C34	1 μ F 1206 (3216 Metric) 50 V $\pm 20\%$	Ceramic capacitor	Kemet	C1206C105M3RACTU
19	11	C37, C47, C79, C99, C162, C163, C165, C166, C199, C206, C289	10 nF 0603 (1608 Metric) 50 $\pm 10\%$	Ceramic capacitors	Würth Elektronik	885012206089
20	2	C38, C284	47 μ F radial-SMD, 5x5.4 mm 10 V $\pm 20\%$	Aluminium capacitors	Würth	875105242006
21	1	C40	68 nF 0603 (1608 Metric) 50 V $\pm 10\%$	Ceramic capacitor	Würth	885012206094
22	1	C42	220pF 0603 (1608 Metric) 50 V $\pm 10\%$	Ceramic capacitor	Würth	885012206079
23	4	C44, C48, C286, C290	150 pF 0603 (1608 Metric) 50 $\pm 10\%$	Ceramic capacitors	Würth Elektronik	885012206103
24	2	C49, C75	4.7 nF 0805 (2012 Metric) 50 V $\pm 10\%$	Ceramic capacitors	KEMET	C0805C472K5RACTU

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
25	4	C51, C164, C167, C169	2.2 μ F 0805 (2012 Metric) 50 V \pm 10% X7R	Ceramic capacitors	TDK Corporation	C2012X7R1H225K125A C
26	2	C52, C170	10 nF 0603 (1608 Metric) 50 \pm 10%	Ceramic capacitors	Würth Elektronik	885012206089
27	8	C53, C54, C67, C69, C76, C77, C93, C94	2.2 nF 1812 (4532 Metric) 1000 V (1kV) \pm 5% C0G/NP0	Ceramic capacitors	KEMET	C1812C222JDGACTU
28	5	C55, C65, C66, C68, C92	0.1 μ F 630V 1812 (4532 Metric) 630 V \pm 10%	Ceramic capacitors	WURTH	885342211006
29	2	C56, C72	1 μ F 630 V radial \pm 20%	Ceramic capacitors	TDK Electronics Inc.	B32923C3105M000
30	4	C57, C58, C86, C87	33 nF 1600 V radial \pm 5%	Ceramic capacitors	Kemet	R75TI2330AA30J
31	6	C59, C60, C64, C88, C89, C91	0.1 μ F 630 V 1812 (4532 Metric) 630 V \pm 10%	Ceramic capacitors	WURTH	885342211006
32	5	C61, C73, C107, C112, C133	4.7 nF radial, disc 440 V _{AC} \pm 20%	Ceramic capacitors	KEMET	ERK610Z472MCRU
33	2	C62, C90	82 μ F radial, 22x35 mm 500	Ceramic capacitors	Nichicon	LGN2H820MELZ35
34	1	C63	68 μ F radial, 22x30 mm 500	Ceramic capacitors	Cornell Dubilier	380LX680M500H032
35	4	C78, C95, C198, C205	0.47 μ F 0603 (1608 Metric) 25 \pm 10%	Ceramic capacitors	Würth Elektronik	885012206075
36	5	C80, C96, C124, C197, C204	2.2 μ F SMD, 3216-18 10 V	Ceramic capacitors	Kemet	T491A225M010ATT
37	2	C81, C97	47 nF 0603 (1608 Metric) 50 \pm 10%	Ceramic capacitors	Murata Electronics North America	GCM188R71H473KA55 D
38	2	C84, C101	4.7 nF 0603 (1608 Metric) 50 \pm 10% X7R	Ceramic capacitors	Würth Elektronik	885012206063
39	1	C104	47 nF 0603 (1608 Metric) 50 V \pm 10% X7R	Ceramic capacitors	Murata Electronics North America	GCM188R71H473KA55 D
40	2	C108, C109	1 μ F radial \pm 20%	Ceramic capacitors	EPCOS (TDK)	B32924C3105K000
41	1	C110	0.47 μ F 305 V _{AC} X2 \pm 20%	Ceramic capacitor	TDK	B32922H3474M
42	1	C111	0.1 μ F radial 305 V _{AC} \pm 20%	Ceramic capacitor	EPCOS (TDK)	B32921C3104M000
43	2	C115, C118	470 pF 0603 (1608 metric) 50 V \pm 5% C0G/NP0	Ceramic capacitors	Würth Electronics Inc.	885012006061

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
44	1	C116	1 nF 0805 (2012 metric) 100 V $\pm 10\%$	Ceramic capacitor	Würth Elektronik	885012207116
45	4	C117, C120, C193, C200	100 pF 0603 (1608 metric) 50 $\pm 10\%$	Ceramic capacitors	Würth Elektronik	885012206077
46	4	C123, C196, C203, C283	4.7 μ F 0805 (2012 Metric) 25 V $\pm 20\%$	Ceramic capacitors	Würth Elektronik	885012107018
47	3	C125, C127, C128	N.M. 0603 (1608 metric) 50 $\pm 10\%$	Ceramic capacitors		
48	1	C126	10 nF 630 V radial $\pm 20\%$	Ceramic capacitors	EPCOS (TDK)	B32921C3103M289
49	5	C129, C130, C136, C137, C139	0.1 μ F 0603 (1608 metric) 50 V $\pm 10\%$	Ceramic capacitors	Würth	885012206095
50	2	C131, C134	2.7 nF 0603 (1608 metric) 50 V $\pm 10\%$	Ceramic capacitors	Samsung Electro-Mechanics	CL10B272KB8NNNC
51	2	C132, C135	47 nF 0603 (1608 metric) 50 V $\pm 10\%$	Ceramic capacitors	Murata Electronics North America	GCM188R71H473KA55D
52	2	C138, C141	2.2 μ F 0805 (2012 metric) 50 V $\pm 10\%$	Ceramic capacitors	TDK Corporation	C2012X7R1H225K125A C
53	1	C140	470 nF 0603 (1608 metric) 25 V $\pm 10\%$	Ceramic capacitor	Würth	885012206075
54	1	C142	22 nF 0603 (1608 metric) 50 V $\pm 10\%$ X7R	Ceramic capacitor	Würth Elektronik	885012206091
55	2	C144, C145	47 pF 0603 (1608 metric) 50 V $\pm 5\%$ C0G	Ceramic capacitors	TDK Corporation	C1608C0G1H470J080A A
56	1	C155	1 μ F 0603 (1608 Metric) 50 V $\pm 10\%$	Ceramic capacitor	Samsung Electro-Mechanics America, Inc.	CL10A105KB8NNNC
57	1	C160	470 pF 0603 (1608 metric) 50 V $\pm 5\%$ C0G	Ceramic capacitor	TDK Corporation	CGA3E2C0G1H471J080 AD
58	1	C161	27 pF 0603 (1608 metric) 50 V $\pm 5\%$ C0G/NP0	Ceramic capacitor	Murata Electronics North America	GCM1885C1H270JA16 D
59	4	C175, C176, C189, C190	150 pF 0805 (2012 metric) 50 V $\pm 5\%$	Ceramic capacitors	Würth Elektronik	885012007058
60	2	C177, C191	0.1 μ F 0805 (2012 metric) 50 V $\pm 10\%$	Ceramic capacitors	Würth Elektronik	885012207098
61	5	C178, C179, C185, C186, C187	560 μ F radial, 35X45 pitch 10 450 $\pm 20\%$	Aluminum electrolytic capacitors	EPCOS (TDK)	B43268A5567M060
62	1	C182	0.1 μ F 630 V radial $\pm 20\%$	Ceramic capacitor	TDK Electronics Inc.	B32921C3104M000

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
63	2	C183, C184	47 nF 1210 (3225 metric) 630 V ±20% X7R	Ceramic capacitors	TDK	CGA6M4X7R2J473M20 0AA
64	1	C188	0.047 µF 630 V radial ±20%	Ceramic capacitor	TDK Electronics Inc.	B32921C3473M189
65	1	C192	100 pF 0603 (1608 metric) 50 ±10%	Ceramic capacitor	Würth Elektronik	885012206077
66	2	C209, C210	10 pF 0603 (1608 metric) 25 V ±5%	Ceramic capacitors	Würth Elektronik	885012006032
67	4	C214, C219, C224, C229	0.22 µF 0805 (2012 metric) 50 V ±10%	Ceramic capacitors	Würth Elektronik	885012207100
68	24	C231, C233, C235, C237, C239, C242, C244, C246, C248, C250, C252, C255, C257, C259, C261, C263, C265, C268, C270, C272, C274, C276, C278, C281	0.1 µF 0603 (1608 metric) 50 V ±10%	Ceramic capacitors	Würth Elektronik	885012206095
69	12	C232, C234, C240, C245, C247, C253, C258, C260, C266, C271, C273, C279	4.7 µF 0603 (1608 metric) 10 V ±20%	Ceramic capacitors	Würth Electronics Inc.	885012106012
70	8	C236, C241, C249, C254, C262, C267, C275, C280	100 pF 0603 (1608 metric) 50 V ±10% C0G/NP0	Ceramic capacitors	Würth Electronics Inc.	885012206077
71	8	C238, C243, C251, C256, C264, C269, C277, C282	1 µF 0603 (1608 metric) 50 V ±10%	Ceramic capacitors	Samsung Electro-Mechanics America, Inc.	CL10A105KB8NNNC
72	1	C291	470 µF radial-SMD, 10x10 mm 25 V ±20%	Aluminium electrolytic capacitor	Würth Elektronik	865060457009
73	8	C360, C361, C362, C363, C364, C365, C366, C367	33 pF 0603 (1608 metric) 25 ±5%	Ceramic capacitors	Würth Elektronik	885012006035
74	11	D1, D3, D83, D84, D85, D86, D87, D88, D89, D90, D91	Green 0603 (1608 metric)	Green LED diode	Würth Elektronik	150060VS55040
75	1	D2	STPS3150UY DO-214AA, SMB 820 mV 3A	Automotive 150 V, 3 A power Schottky rectifier	ST	STPS3150UY

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
76	2	D4, D82	BZT52C9V1-7-F SOD-123 9.1 V 500 MW SOD123	Zener diodes	Diodes Incorporated	BZT52C9V1-7-F
77	1	D5	2.7 V 500 mW DO-213AC, MINI-MELF, SOD-80 1.5V @ 200 mA 10 μ A @ 1 V 500 mW	Zener diode	Vishay Semiconductor Diodes Division	TZMB2V7-GS08
78	4	D6, D15, D67, D68	LS L296-P2Q2-1-Z 0603 (1608 metric)	Red LED diode	OSRAM Opto Semiconductor Inc.	LS L296-P2Q2-1-Z
79	8	D7, D8, D9, D10, D16, D17, D18, D19	1N4148WS SC-90, SOD-323F 1V @ 10 mA 150 mA 75 V	General purpose diodes	Fairchild/ON Semiconductor	1N4148WS
80	8	D11, D12, D13, D14, D20, D21, D22, D23	STPSC20065GY-TR D2PAK, TO-263AB	Automotive 650 V, 20 A SiC power Schottky diode	ST	STPSC20065GY-TR
81	1	D24	P6KE440A DO-204AC, DO-15, Axial 600 W	600 W TVS in DO-15	ST	P6KE440A
82	1	D26	BZV55-B15,115 DO-213AC, MINI-MELF, SOD-80 900 mV @ 10mA 50 nA @ 10.5 V 500 mW	Zener diode	Nexperia USA Inc.	BZV55-B15,115
83	11	D28, D29, D30, D31, D32, D33, D34, D36, D37, D38, D39	BAT754 SOT-23-3 200 mA (DC) 200 MA	Schottky diodes	Nexperia USA Inc.	BAT754,215
84	1	D35	ESDCAN24-2BLY TO-236-3, SC-59, SOT-23-3	Automotive dual-line TVS in SOT23-3L for CAN bus (12 V system)	ST	ESDCAN24-2BLY
85	4	D40, D41, D45, D46	SMAJ18A-TR DO-214AC, SMA 400 W	400 W TVS in SMA	ST	SMAJ18A-TR
86	2	D42, D47	STBR3012G2Y-TR TO-263-3, D ² Pak (2 Leads + Tab), TO-263AB 1.3 V @ 30 A	Automotive 1200 V, 30 A bridge rectifier diode	ST	STBR3012G2Y-TR
87	4	D43, D44, D48, D49	SMAJ5.0A-TR DO-214AC, SMA 400 W	400 W TVS in SMA	ST	SMAJ5.0A-TR
88	8	D50, D52, D54, D56, D58, D60, D62, D64	STTH1R06A DO-214AC, SMA 1.7 V @ 1 A	600 V, 1 A Turbo 2 ultra-fast diode	ST	STTH1R06A

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
89	8	D51, D53, D55, D57, D59, D61, D63, D65	STPS1L30A DO-214AC, SMA 1 A	30 V, 1 A low drop power Schottky rectifier	ST	STPS1L30A
90	8	D66, D69, D70, D73, D74, D77, D78, D81	STPS360AFY SOD-128 3 A	Automotive 60 V, 3 A power Schottky rectifier	ST	STPS360AFY
91	1	F1	Fuse10X38 2XClips	Fuse	Eaton+Mersen	BK/1A3400-09- R+A214107
92	1	HT1	Heatsink1	Heat-sink	AAVID THERMALLO Y	
93	1	IC1	A6986F5V 16- TSSOP (0.173", 4.40 mm width) exposed pad	Automotive 38 V, 1.5 A synchronous step-down switching regulator with 30 μ A quiescent current	ST	A6986F5V
94	4	IC2, IC3, IC4, IC5	A6387D	High-voltage high and low side driver for automotive applications	ST	A6387D
95	4	IC6, IC7, IC8, IC9	STGAP1AS SMD SO24	Galvanically isolated single gate driver	ST	STGAP1S
96	2	ICS1, ICS2	ACS724LLCTR-2 0AU-T 8-SOIC (0.154", 3.90 mm width)	Hall current sensors	Allegro MicroSystems, LLC	ACS724LLCTR-20AU-T
97	2	ICS3, ICS4	ACS724LLCTR-3 0AB-T 8-SOIC (0.154", 3.90 mm width)	Hall current sensors	Allegro MicroSystems, LLC	ACS724LLCTR-30AB-T
98	16	J1, J3, J5, J7, J9, J11, J13, J15, J24, J39, J40, J43, J45, J47, J49, J52	Con4F	Connector headers	Sullins Connector Solutions	PPTC022LFBN-RC
99	16	J2, J4, J6, J8, J10, J12, J14, J16, J23, J41, J42, J44, J46, J48, J50, J51	CON4	Connector headers	Molex Connector Corporation	0015912040
100	1	J22	CONN, 10-pin	Connector header	Sullins Connector Solutions	SBH11-PBPC-D05-ST- BK
101	2	J27, J32	Jump1	Uninsulated shorting plug	Harwin Inc.	D3080-05

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
102	1	J28	-200-450 V	Shank, THR	Würth Electronics Inc.	74651195R
103	1	J29	+200-450 V	Shank, THR	Würth Electronics Inc.	74651195R
104	1	J33	P	Shank, THR	Würth Electronics Inc.	74651195R
105	1	J35	N	Shank, THR	Würth Electronics Inc.	74651195R
106	1	J36	Earth	Shank, THR	Würth Electronics Inc.	74651195R
107	1	J38	Con2	Connector header	Amphenol FCI	77311-118-02LF
108	11	J55, J56, J59, J60, J63, J67, J68, J74, J75, J78, J80	con4-2x2-strip-female, female, 100 dual str, 4pos	Connector headers	Sullins Connector Solutions	PPTC022LFBN-RC
109	9	J57, J58, J61, J62, J66, J72, J76, J77, J79	con4-2x2-strip-male_90	Connector headers	Würth Elektronik	61300421021
110	2	J69, J70	con4-2x2-strip-male_90	Connector headers	Würth Elektronik	61300421021
111	10	J81, J82, J83, J84, J85, J86, J87, J88, J89, J90	SpacrM4X14	Tower	Harwin Inc.	R40-1001402
112	1	JP1	CON2	Terminal block	Würth Electronics	691253510002
113	2	L1, L29	10 μ H 2.5 A non-standard $\pm 20\%$	Fixed inductors	TDK Corporation	VLS5045EX-100M-CA
114	2	L2, L3	70 Ohm@100 MHz 0603 (1608 metric)	Ferrite beads	Murata Electronics North America	BLM18SG700TN1D
115	1	L4	6.8 μ H 1.5 A 100 MOhm 1919 (4848 metric) $\pm 30\%$	Fixed inductor	Würth Electronics Inc.	744042006
116	2	L5, L36	330 Ohm@100 MHz 0603 (1608 metric)	Ferrite beads	Murata Electronics North America	BLM18SG331TN1D
117	1	L6	120 Ohm@100 MHz 0603 (1608 metric)	Ferrite bead	Murata Electronics North America	BLM18AG121SN1D
118	10	L7, L11, L14, L20, L21, L27, L28, L32, L33, L37	470 Ohm 0603 (1608 metric)	Ferrite beads	Würth Electronics Inc.	742792643

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119	2	L9, L13	16.8 μ H 30 A	Inductors	Würth	750344211
120	2	L10, L17	900 μ H 32 A vertical, 12 PC pin	CMC	Würth Electronics Inc.	7448053201
121	2	L15, L19	10 μ H 31.5 A non-standard $\pm 15\%$	Fixed inductors	WURTH ELEKTRONIK	S20100037
122	2	L16, L18	1.5 mH 38 A vertical, 12 PC pin 38 A	CMC	Würth Elektronik	7448063801
123	2	L22, L25	33 μ H 1210 (3225 metric) $\pm 10\%$	Fixed inductors	Würth Elektronik	744764133
124	2	L23, L26	10 μ H 600 mA 1008 (2520 metric) $\pm 20\%$	Fixed inductors	Würth Elektronik	74438323100
125	1	L24	470 μ H 1812 (4532 metric) $\pm 10\%$	Fixed inductors	Würth Elektronik	74476624
126	2	L30, L31	514 μ H 26 A radial, D 70 mm x H 56 mm	Inductors	Würth Electronics Inc.	750344522
127	2	L34, L35	10 μ H 30 A non-standard $\pm 15\%$	Fixed inductors	Würth Electronics Inc.	7443641000
128	1	MOV1	250 V disc 20 mm	Varistor	EPCOS (TDK)	B72220S0251K101
129	2	P1, P2	CON64AB	Connector Erni 284166 32X2	ERNI	284166
130	1	P3	CON64AB	Connector Erni 284166 32X2	ERNI	284166
131	1	P4	CON64AB	Connector ERNI 533406 32X2 male 90 grade	ERNI	384241
132	7	PS1, PS2, PS3, PS4, PS5, PS7, PS8	MGJ3T12150505 MC-R7 0.91" L x 0.89" W x 0.58" H (23.0mm x 22.6 mm x 14.7 mm)	DC-DC converters	Murata Power Solutions Inc.	MGJ3T12150505MC-R7
133	1	PS9	PES1-S12-S5-M 8-SMD module, 5 leads 1 W	DC-DC converter	CUI Inc.	PES1-S12-S5-M-TR
134	8	Q1, Q2, Q3, Q4, Q5, Q6, Q7, Q8	STB47N60DM6A G D2PAK	Automotive-grade N-channel 600 V, 70 mOhm typ., 36 A MDmesh DM6 Power MOSFET in a D2PAK package	ST	STB47N60DM6AG

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
135	1	Q9	STN1NK80Z TO-261-4, TO-261AA 2.5 W (Tc)	N-channel 800 V, 13 Ohm typ., 0.25 A SuperMESH Zener protected Power MOSFET in a SOT-223 package	ST	STN1NK80Z
136	2	Q11, Q13	STN4NF03L TO-261-4, TO-261AA 3.3W (Tc)	N-Channel 30V - 0.039 Ohm - 4A - SOT-223 STripFET power MOSFET	ST	STN4NF03L
137	2	Q15, Q16	MJD32CT4-A TO-252-3, DPak (2 leads + tab), SC-63	Automotive-grade low voltage PNP power transistor	ST	MJD32CT4-A
138	4	Q17, Q18, Q20, Q21	SCTH35N65G2V- 7AG H2PAK-7	Automotive-grade silicon carbide power MOSFET 650 V, 45 A, 55 mOhm (typ. T _J = 25 C) in an H2PAK-7 package	ST	SCTH35N65G2V7AG
139	2	Q19, Q22	TN3050H-12GY- TR TO-263-3, D ² Pak (2 leads + tab), TO-263AB	1200 V, 30 A automotive-grade AEC-Q101 SCR thyristor	ST	TN3050H-12GY-TR
140	12	R1, R2, R10, R11, R16, R17, R28, R140, R193, R194, R197, R223	0.0 0805 (2012 metric) 0.125 W, 1/8 W jumper	Resistors	Yageo	RC0805JR-070RL
141	2	R3, R32	1 M 0603 (1608 metric) 0.1 W, 1/10 W ±1%	Resistors	TE Connectivity	CRGCQ0603F1M0
142	2	R6, R198	249 k 0603 (1608 metric) 0.1 W, 1/10 W ±1%	Resistors	Vishay	MCT06030C2493FP500
143	2	R7, R199	86.6 k 0603 (1608 metric) 0.1 W, 1/10 W ±1%	Resistors	Stackpole	RMCF0603FT86K6
144	1	R8	43 k 0603 (1608 metric) 0.1 W, 1/10 W ±1%	Resistors	Panasonic	ERJ-3EKF4302V
145	2	R9, R195	NM 0805 (2012 metric) 0.125 W, 1/8 W ±1%	Resistors (not mounted)	Any	Any
146	2	R13, R31	3.57 k 0603 (1608 metric) 0.1 W, 1/10 W ±1%	Resistors	Yageo	RC0603FR-073K57L

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
147	62	R14, R15, R20, R23, R26, R29, R34, R49, R50, R70, R71, R117, R118, R119, R120, R128, R129, R130, R131, R132, R133, R135, R137, R139, R141, R142, R143, R145, R148, R153, R154, R155, R156, R158, R159, R160, R161, R162, R163, R164, R165, R166, R167, R168, R169, R170, R171, R172, R173, R174, R175, R177, R179, R182, R183, R184, R185, R186, R189, R190, R191, R192	0.0 0603 (1608 metric) 0.1 W, 1/10 W jumper	Resistors	Yageo	RC0603JR-070RL
148	3	R21, R22, R152	0.0 0603 (1608 metric) 0.1 W, 1/10 W jumper	Resistors	Yageo	RC0603JR-070RL
149	2	R25, R509	N.M 0603 (1608 Metric) 0.1 W, 1/10 W jumper	Resistors	Yageo	RC0603JR-070RL
150	1	R27	0.0 1206 (3216 metric) 0.25 W, ¼ W jumper	Resistor	Yageo	RC1206JR-070RL
151	1	R30	N.M 0603 (1608 metric) 0.1 W, 1/10 W jumper	Resistor (not mounted)	Yageo	RC0603JR-070RL
152	1	R33	75 K 0603 (1608 metric) 0.1 W, 1/10 W ±1%	Resistor	Yageo	RC0603FR-0775KL
153	8	R35, R36, R38, R39, R298, R299, R300, R301	390 K 1206 (3216 metric) 0.25 W, 1/4 W ±1%	Resistors	Yageo	RC1206FR-07390KL
154	3	R37, R40, R43	68K 2512 (6432 metric) 2 W ±1%	Resistors	TE Connectivity Passive Product	352168KFT
155	2	R41, R302	7.5 k 005 (2012 metric) 0.125 W, 1/8 W ±1%	Resistors	Yageo	RC0805FR-077K5L
156	4	R42, R48, R303, R308	4.02 K 0603 (1608 Metric) 0.1 W, 1/10 W ±0.1%	Resistors	Panasonic Electronic Components	ERA-3AEB4021V

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
157	4	R44, R46, R304, R306	2.2 K 0603 (1608 metric) 0.1 W, 1/10 W $\pm 1\%$	Resistors	Yageo	RC0603FR-072K2L
158	3	R45, R305, R520	39 0603 (1608 metric) 0.1 W, 1/10 W $\pm 1\%$	Resistors	Panasonic Electronic Components	ERJ-3EKF39R0V
159	2	R47, R307	160 0603 (1608 metric) 0.1 W, 1/10 W $\pm 1\%$	Resistors	Yageo	RC0603FR-07160RL
160	2	R51, R211	4.7 k 0603 (1608 metric) 0.1 W, 1/10 W $\pm 1\%$	Resistors		
161	1	R52	24 Ohm 1206 (3216 Metric) 0.25 W, 1/4 W $\pm 1\%$	Resistor	Yageo	RC1206FR-0724RL
162	2	R53, R73	NM 1206 (3216 metric) 0.25 W, 1/4 W $\pm 1\%$	Resistors (not mounted)	Any	Any
163	8	R54, R55, R63, R64, R75, R76, R80, R81	1 2512 (6432 metric) 1 W $\pm 1\%$	Resistors (not mounted)	Vishay Dale	CRCW25121R00FKEG
164	8	R56, R57, R66, R67, R77, R78, R79, R82	10 k 0805 (2012 metric) 0.1 W, 1/10 W $\pm 1\%$	Resistors	Yageo	RC0805FR-0710KL
165	2	R58, R61	470 k 2512 (6432 metric) 1 W $\pm 5\%$	Resistors	Vishay Dale	CRCW2512470KJNEG
166	1	R72	24 1206 (3216 Metric) 0.25 W, 1/4 W $\pm 1\%$	Resistor	Yageo	RC1206FR-0724RL
167	6	R74, R221, R268, R277, R286, R295	100 0603 (1608 metric) 0.1 W, 1/10 W $\pm 1\%$	Resistors	Yageo	RC0603FR-07100RP
168	12	R83, R121, R122, R134, R136, R144, R146, R150, R187, R188, R224, R225	100 0603 (1608 metric) 0.1 W, 1/10 W $\pm 1\%$	Resistors	Yageo	RC0603FR-07100RP
169	3	R84, R86, R90	165 k 1206 (3216 metric) 0.25 W, 1/4 W $\pm 1\%$	Resistors	Yageo	RC1206FR-07165KL
170	1	R87	2.7 k 5329 5 W $\pm 5\%$	Power resistor	TE CONNECTIVITY	SMF52K7JT
171	1	R92	499 0805 (2012 metric) 0.125 W, 1/8 W $\pm 1\%$	Resistor	Stackpole	RNCP0805FTD499R
172	2	R94, R107	10 k 0603 (1608 metric) 0.1 W, 1/10 W $\pm 1\%$	Resistors	Yageo	RC0603FR-0710KL

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
173	15	R96, R97, R98, R99, R100, R101, R103, R104, R105, R109, R110, R111, R113, R114, R115	470 k 1206 (3216 metric) 0.25 W, 1/4W ±1%	Resistors	Yageo	RC1206FR-07470KL
174	3	R102, R106, R108	10 k 0805 (2012 metric) 0.1 W, 1/10 W ±1%	Resistors	Yageo	RC0805FR-0710KL
175	1	R112	499 Ohm 0603 (1608 metric) 0.1 W, 1/10 W ±1%	Resistors	Stackpole	RNCP0603FTD499R
176	1	R116	4.99K Ohm 0603 (1608 metric) 0.1 W, 1/10 W ±1%	Resistors	Panasonic	RC0603FR-074K99L
177	4	R123, R124, R126, R127	NM 0603 (1608 metric) 0.1W, 1/10W 1%	Chip resistors (not mounted)	Any	Any
178	3	R138, R147, R149	NM 0603 (1608 metric) 0.1 W, 1/10 W ±1%	Chip resistors (not mounted)	Any	Any
179	1	R151	120 0603 (1608 metric) 0.125 W, 1/8 W ±1%	Resistor	Vishay Beyschlag	MCT06030C1200FP500
180	8	R176, R178, R510, R511, R512, R516, R517, R518	1.5 K 0603 (1608 metric) 0.1 W, 1/10 W ±1%	Chip resistors	TE Connectivity	CRGCQ0603F1K5
181	2	R180, R181	3 K 0603 (1608 metric) 0.1 W, 1/10 W ±1%	Chip resistors	Vishay	MCT06030C3001FP500
182	1	R196	1 M 0603 (1608 metric) 0.1 W, 1/10 W ±1%	Resistor	Vishay	CRCW06031M00FKEA
183	1	R200	43 k 0603 (1608 metric) 0.1 W, 1/10 W ±1%	Resistor	Panasonic	ERA-3AEB433V
184	2	R201, R206	270 Ohm 0603 (1608 metric) 0.1 W, 1/10 W ±1%	Resistors	Vishay	RMCF0603FT270R
185	4	R202, R203, R207, R208	390 0603 (1608 metric) 0.1 W, 1/10 W ±1%	Resistors	Yageo	RC0603FR-07390RL
186	2	R204, R209	27 2512 (6432 metric) 1 W ±1%	Resistors	Yageo	AC2512FK-0727RL
187	2	R205, R210	1 k 0603 (1608 metric) 0.1 W, 1/10 W ±1%	Resistors	Yageo	RC0603FR-071KL
188	4	R212, R213, R218, R219	10 k 0805 (2012 metric) 0.1 W, 1/10 W ±1%	Resistors	Vishay Foil Resistors (Division of Vishay Precision Group)	Y162910K0000F9R

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
189	2	R214, R220	100 0805 (2012 metric) 0.125 W, 1/8 W $\pm 1\%$	Resistors		
190	3	R215, R216, R217	180 K 1206 (3216 metric) 0.25 W, 1/4 W $\pm 0.1\%$	Resistors	Panasonic Electronic Components	ERA-8AEB184V
191	1	R222	3.6 k 0805 (2012 metric) 0.125 W, 1/8 W $\pm 1\%$	Resistors	Yageo	RC0805FR-073K6L
192	16	R226, R232, R235, R241, R244, R250, R253, R259, R523, R524, R525, R526, R527, R528, R529, R530	330 0805 (2012 metric) 0.1 W, 1/10 W $\pm 0.01\%$	Resistors	TE Connectivity	CRG0805F330R
193	4	R227, R236, R245, R254	20 1210 (3225 Metric) 0.5 W, 1/2 W $\pm 1\%$	Resistors	Stackpole Electronics Inc.	RMCF1210FT20R0
194	8	R228, R231, R237, R240, R246, R249, R255, R258	1 2010 (5025 metric) 1 W $\pm 1\%$	Resistors	Vishay Dale	CRCW20101R00FKEFH P
195	8	R229, R233, R238, R242, R247, R251, R256, R260	20 2010 (5025 metric) 1 W $\pm 1\%$	Resistors	Stackpole Electronics Inc.	RMCP2010FT20R0
196	8	R230, R234, R239, R243, R248, R252, R257, R261	4.7 2010 (5025 metric) 1 W $\pm 5\%$	Resistors	Bourns Inc.	CRM2010-JW-4R7ELF
197	8	R262, R264, R271, R273, R280, R282, R289, R291	0.0 0603 (1608 metric) 0.1 W, 1/10 W jumper	Resistors	Yageo	RC0603JR-070RL
198	2	R263, R265	750 0603 (1608 metric) 0.1 W, 1/10 W $\pm 1\%$	Resistors	Yageo	RC0603FR-07750RL
199	4	R266, R284, R293, R521	2.7 Ohm 2010 (5025 metric) 1 W $\pm 1\%$	Resistors	Panasonic	ERJ-12ZYJ2R7U
200	4	R267, R285, R294, R522	10 Ohm 2010 (5025 metric) 1 W $\pm 1\%$	Resistors	Stackpole Electronics Inc.	ERJ-12ZYJ100U
201	4	R269, R278, R287, R296	2.2 1206 (3216 metric) 0.25 W, 1/4W $\pm 1\%$	Resistors	Bourns Inc.	CRM1206-JW-2R2ELF
202	4	R270, R279, R288, R297	100 0603 (1608 metric) 0.1 W, 1/10 W $\pm 1\%$	Resistors	Yageo	RC0603FR-07100RP
203	3	R513, R514, R515	8.2 K 0603 (1608 metric) 0.1 W, 1/10 W $\pm 1\%$	Resistors	Panasonic	RC0603FR-078K2L
204	2	RT1, RT2	10 K 0805 (2012 metric) 210 mW	Thermistor	Vishay BC Components	NTCS0805E3103FLT
205	2	SP1, SP2	SupportM3X40	Support	Essentra	TCBN-T1-M3-8-40

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
206	1	T1	2000 ohm 4 A 50 V	Filter	Würth	744237151
207	2	T2, T4	750316796 0.560" L x 0.530" W (14.22 mm x 13.46 mm)	Current sense filters	Würth Electronics Inc.	750316796
208	2	T3, T5	XFRM_LIN/CT-SEC_0 375-425 V $\pm 10\%$	Transformer	WURTH	750317867
209	1	T6	7448011305 vertical, 4 PC pin 1.3 A	CMC	Würth Elektronik	7448011305
210	24	TP1, TP2, TP3, TP4, TP5, TP6, TP7, TP8, TP9, TP10, TP11, TP12, TP13, TP14, TP15, TP16, TP58, TP59, TP60, TP61, TP62, TP63, TP64, TP65	5001 0.100" Dia x 0.180" L (2.54mm x 4.57mm)	Test points	Keystone Electronics	5001
211	1	T7	100 μ H 150 mA horizontal, 4 L-Lead	CMC	EPCOS (TDK)	B82789C0104N002
212	30	TP17, TP25, TP26, TP27, TP28, TP29, TP30, TP31, TP32, TP33, TP34, TP35, TP37, TP38, TP39, TP40, TP41, TP42, TP43, TP44, TP45, TP46, TP47, TP49, TP50, TP52, TP54, TP56, TP57, TP66	ALERT 0.079" L x 0.047" W (2.00 mm x 1.20 mm)	Test points	Harwin Inc.	S2751-46R
213	11	TP18, TP19, TP20, TP21, TP22, TP23, TP24, TP48, TP51, TP53, TP55	5001 0.100" diameter x 0.180" L (2.54 mm x 4.57 mm)	Test points	Keystone Electronics	5001
214	9	TW1, TW38, TW39, TW40, TW41, TW42, TW43, TW44, TW82	SCREW_M4X6	Screws	RS Pro	483-0158

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
215	16	TW2, TW4, TW5, TW6, TW7, TW8, TW10, TW11, TW12, TW13, TW14, TW49, TW50, TW54, TW56, TW81	Con1	Towers	RS	222-402
216	10	TW3, TW9, TW15, TW17, TW53, TW55, TW57, TW70, TW71, TW72	Con1	Screws	RS	482-8515
217	3	TW16, TW48, TW52	SCREW_M4X6	Screws	RS Pro	483-0158
218	20	TW18, TW19, TW20, TW21, TW22, TW23, TW24, TW25, TW26, TW27, TW28, TW29, TW30, TW31, TW32, TW33, TW34, TW35, TW36, TW37	Con1	Screws	RS	482-8515
219	2	TW47, TW51	Spacer M4x12	Spacers	Würth Elektronik	970120474
220	3	TW58, TW61, TW65	Screw_M3X6	Screws	RS	482-8515
221	8	TW59, TW62, TW64, TW68, TW73, TW74, TW75, TW76	SpacerM3X40	Spacers	Würth Elektronik	971400324
222	4	TW60, TW63, TW66, TW69	Screw_M3X6	Screws	RS	482-8515
223	4	TW77, TW78, TW79, TW80	Con1	Screws	RS	482-8515

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
224	2	U1, U16	A6986F 16-TSSOP (0.173", 4.40 mm width) exposed pad	Automotive 38 V, 1.5 A synchronous step-down switching regulator with 30 μ A quiescent current	ST	A6986F
225	1	U2	LF50CDT-TRY TO-252-3, DPak (2 leads + tab), SC-63	Very low drop voltage regulator with inhibit	ST	LF50CDT-TRY
226	3	U3, U4, U7	ESDA6V1LY TO-236-3,SC-59, SOT-23-3	Automotive dual Transil array for ESD protection	ST	ESDA6V1LY
227	1	U5	L4931ABD120TR 8-SOIC (0.154", 3.90 mm width)	Very low drop voltage regulators with inhibit	ST	L4931ABD120TR
228	1	U6	ESDA14V2LY TO-236-3,SC-59, SOT-23-3	Automotive dual Transil array for ESD protection	ST	ESDA14V2LY
229	2	U8, U28	TSZ121IYLT SC-74A, SOT-753	Very high accuracy (5 μ V) zero drift 5 V CMOS Op-Amp, single, GBP = 400 kHz	ST	TSZ121IYLT
230	2	U9, U27	ACPL-782T-500E 8-SMD, Gull Wing	Opamp	Broadcom Limited	ACPL-782T-500E
231	3	U10, U12, U14	BAR43SFILM TO-236-3, SC-59, SOT-23-3 100 mA	30 V, 100 mA Vf 0.33 V @ 2 mA SMD general purpose signal Schottky diode	ST	BAR43SFILM
232	1	U11	TS3021HIYLT SC-74A, SOT-753	Rail-to-rail 1.8 V high-speed comparator, 150°C extended temperature range	ST	TS3021HIYLT
233	1	U13	TSV611ILT SC-74A, SOT-753, SOT23-5L	Rail to rail input/output 5 V CMOS Op-Amp, micro-power (10 μ A), GBP = 120 kHz	ST	TSV611ILT
234	1	U15	LTC2875HS8#PBF 8-SOIC (0.154", 3.90mm Width)	IC TXRX CAN	Linear Technology	LTC2875HS8#PBF
235	2	U17, U18	ACPL-K49T-000E 8-SOIC (0.268", 6.81mm Width)	Optoisolator transistors	Broadcom Limited	ACPL-K49T-000E

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
236	8	U19, U20, U21, U22, U23, U24, U25, U26	ACPL-K72T-060E	High speed automotive optocouplers	Broadcom/ Avago	ACPL-K72T-060E

Table 5. IMS board bill of materials

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
1	8	C53, C54, C67, C69, C76, C77, C93, C94	2.2 nF 1812 (4532 metric) 1000 V (1 kV) $\pm 5\%$	Capacitors (not mounted)	KEMET	C1812C222JDGACT U
2	6	C59, C60, C64, C88, C89, C91	0.1 μ F 630 V 1812 (4532 metric) 630 $\pm 10\%$	Ceramic capacitors	Wurth Elektronik	885342211006
3	4	C175, C176, C189, C190	150 pF 0805 (2012 metric) 50 V $\pm 5\%$	Ceramic capacitors	Wurth Elektronik	88501207058
4	2	C177, C191	0.1 μ F 0805 (2012 Metric) 50 V $\pm 10\%$	Ceramic capacitors	Wurth Elektronik	885012207098
5	8	D11, D12, D13, D14, D20, D21, D22, D23	STPSC20065GY- TR D2PAK	Automotive 650 V, 20 A SiC power Schottky diode	ST	STPSC20065GY-TR
6	4	D40, D41, D45, D46	SMAJ18A-TR DO-214AC, SMA 400 W	400 W TVS in SMA	ST	SMAJ18A-TR
7	2	D42, D47	STBR3012G2Y- TR TO-263-3, D ² Pak (2 leads + tab), TO-263AB 1.3 V @ 30 A	Automotive 1200 V, 30 A bridge rectifier diode	ST	STBR3012G2Y-TR
8	4	D43, D44, D48, D49	SMAJ5.0A-TR DO-214AC, SMA 400W	400 W TVS in SMA	ST	SMAJ5.0A-TR
9	2	BX1, BX2	BOX	Aluminium boxes (not mounted)	HAMMOND	1550P
10	16	J2, J4, J6, J8, J10, J12, J14, J16, J23, J41, J42, J44, J46, J48, J50, J51	CON4	Connector headers	Molex Connector Corporation	0015912040
11	8	Q1, Q2, Q3, Q4, Q5, Q6, Q7, Q8	STB47N60DM6A G D2PACK	Automotive- grade N- channel 600 V, 70 mOhm typ., 36 A MDmesh DM6 Power MOSFET in a D2PAK package	ST	STB47N60DM6AG

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
12	4	Q17, Q18, Q20, Q21	SCTH35N65G2V- 7AG H2PAK-7	Automotive- grade silicon carbide Power MOSFET 650 V, 45 A, 55 mOhm (typ. T _J = 25 C) in an H2PAK-7 package	ST	SCTH35N65G2V7AG
13	2	Q19, Q22	TN3050H-12GY- TR TO-263-3, D ² Pak (2 leads + tab), TO-263AB	1200 V, 30 A automotive- grade AEC- Q101 SCR thyristor	ST	TN3050H-12GY-TR
14	8	R54, R55, R63, R64, R75, R76, R80, R81	1 2512 (6432 metric) 1 W ±1%	Resistors	Vishay Dale	CRCW25121R00FKE G
15	12	R56, R57, R66, R67, R77, R78, R79, R82, R212, R213, R218, R219	10k 0805 (2012 metric) 0.1 W, 1/10 W ±1%	Resistors	Yageo	RC0805FR-0710KL
16	2	R204, R209	27 2512 (6432 Metric) 1W 1%	Resistors	Yageo	AC2512FK-0727RL
17	2	R214, R220	100 0805 (2012 Metric) 0.125W, 1/8W 1%	Resistors		
18	2	RT1, RT2	10K 0805 (2012 Metric) 210mW	Thermistors	Vishay BC Components	NTCS0805E3103FLT
19	16	TW2, TW4, TW5, TW6, TW7, TW8, TW10, TW11, TW12, TW13, TW14, TW49, TW50, TW54, TW56, TW81	Con1	Towers	RS	222-402
20	20	TW18, TW19, TW20, TW21, TW22, TW23, TW24, TW25, TW26, TW27, TW28, TW29, TW30, TW31, TW32, TW33, TW34, TW35, TW36, TW37	Con1	Screws	RS	482-8515
21	2	TW47, TW51	Spacer M4x12 M4x12	Spacers	Würth Elektronik	970120474
22	1	IMS PCB	(90.4x63.8mm + 203x138.5 mm) x 1.63mm	IMS PCB	-	-

Table 6. Control board bill of materials

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
1	24	C1, C3, C5, C6, C9, C10, C13, C30, C31, C33, C35, C37, C40, C42, C45, C48, C51, C57, C59, C60, C72, C73, C76, C81	0.1 μ F 0603 (1608 Metric) 50 V \pm 10%	Ceramic capacitors	KEMET	C0603C104K5RACTU
2	2	C2, C4	15 pF 0603 (1608 Metric) 25 V \pm 10%	Ceramic capacitors	Any	Any
3	21	C7, C8, C11, C12, C32, C34, C36, C38, C41, C43, C46, C49, C52, C55, C58, C62, C64, C66, C68, C74, C84	10 nF 0603 (1608 metric) 50 V \pm 5%	Ceramic capacitors	AVX Corporation	06035C103JAT2A
4	2	C14, C15	6 pF 0603 (1608 metric) 50 V \pm 10%	Ceramic capacitors	Any	Any
5	14	C16, C17, C18, C19, C20, C21, C22, C23, C24, C25, C26, C27, C28, C29	100 pF 0603 (1608 metric) 50 V \pm 5%	Ceramic capacitors	Murata Electronics North America	GRM1885C1H101JA01 D
6	3	C39, C69, C70	2.2 μ F 0603 (1608 metric) 16 V \pm 20%	Ceramic capacitors	TDK Corporation	CGA3E1X7S1C225M08 0AC
7	5	C44, C47, C50, C53, C56	4.7 μ F 0805 (2012 metric) 10 V \pm 10%	Ceramic capacitors	Murata Electronics North America	GCM21BC71A475KA73 L
8	1	C54	0.1 μ F 0603 (1608 metric) 16 V \pm 10%	Ceramic capacitor	Wurth Electronics Inc.	885012206046
9	4	C61, C63, C65, C67	47 nF 0603 (1608 metric) 50 V \pm 10%	Ceramic capacitors	Murata Electronics North America	GCM188R71H473KA55 D
10	1	C71	1 μ F 0603 (1608 metric) 50 V \pm 10%	Ceramic capacitors	Samsung Electro-Mechanics America, Inc.	CL10A105KB8NNNC
11	3	C75, C79, C91	6.8 μ F 1206 (3216 metric) 16 V \pm 20%	Ceramic capacitors	TDK Corporation	CGA5L1X7R1C685M16 0AC
12	4	C77, C80, C86, C94	100 μ F radial, Can - SMD 16 V \pm 20%	Aluminium capacitors	Panasonic Electronic Components	EEE-FT1C101AR
13	4	C78, C82, C92, C96	470 nF 0603 (1608 metric) 25 V \pm 10%	Ceramic capacitors	Wurth Electronics Inc.	885012206075
14	1	C83	10 μ F 1206 (3216 metric) 16 V \pm 10%	Ceramic capacitor	AVX Corporation	TAJA106K016RNJ

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
15	1	C85	0.47 μ F 1206 (3216 metric) 50 V \pm 10%	Ceramic capacitor	Wurth Electronics Inc.	885012208091
16	2	C87, C98	8.2 nF 0603 (1608 metric) 50 V \pm 5%	Ceramic capacitors	TDK Corporation	CGA3E2NP01H822J080AA
17	1	C88	470 pF 0603 (1608 metric) 50 V \pm 5%	Ceramic capacitor	TDK Corporation	CGA3E2C0G1H471J080AD
18	1	C89	27 pF 0603 (1608 metric) 50 V \pm 5%	Ceramic capacitor	Murata Electronics North America	GCM1885C1H270JA16D
19	2	C90, C99	68 nF 0603 (1608 metric) 50 V \pm 10%	Ceramic capacitors	KEMET	C0603C683K5RACTU
20	1	C93	22 μ F 1206 (3216 metric) 6.3 V \pm 20%	Ceramic capacitor	TDK Corporation	CGA5L1X7R0J226M160AC
21	1	C95	0.1 μ F 0603 25 V \pm 10%	Ceramic capacitor	Kemet	C0603C104K3RAC
22	1	C97	6.8 pF 0603 (1608 metric) 50 V 0.5 pF	Ceramic capacitor	Wurth Electronics Inc.	885012006050
23	1	C100	820 pF 0603 (1608 metric) 50 V \pm 10%	Ceramic capacitor		
24	1	C101	47 pF 0603 (1608 metric) 50 V \pm 5%	Ceramic capacitor	TDK Corporation	C1608C0G1H470J080AA
25	1	C102	6.8 pF 0603 (1608 metric) 50 V 0.5 pF	Ceramic capacitor (not mounted)	Wurth Electronics Inc.	885012006050
26	1	D1	LED BLUE 0402 (1005 metric) 5 mA	Blue LED	Vishay Semiconductor Opto Division	VLMB1500-GS08
27	2	D2, D5	LED RED 0402 (1005 metric) 20 mA	Red LED	Vishay Semiconductor Opto Division	VLMS1500-GS08
28	2	D3, D4	LED YELLOW-GREEN 0402 (1005 metric) 20 mA	Yellow-green LED	Vishay Semiconductor Opto Division	VLMG1500-GS08
29	2	J1, J2	USART_CON	Connectors	TE Connectivity AMP Connectors	215079-4
30	3	J3, J4, J5	JUMPER-con2-strip-male	Jumpers	Any	Any
31	1	J6	JTAG	Connector header	Sullins Connector Solutions	SBH11-PBPC-D07-ST-BK
32	2	J7, J9	Con3	Headers	Harwin Inc.	M20-9990345
33	1	J8	SWD/COM	Connector header	Any	Any
34	1	J10	JUMPER	Connector header	Any	Any
35	2	J11, J14	JUMPER	Jumpers	Any	Any
36	1	J12	EXT SUPPLY	Terminal block	Phoenix Contact	1725656
37	1	J13	GND CON	Connector header		

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
38	7	J15, J16, J17, J18, J19, J20, J21	Jumper_Female	Jumpers	Sullins Connector Solutions	QPC02SXGN-RC
39	3	L1, L2, L4	470 OHM 0402 (1005 metric)	Ferrite beads	Würth Electronics Inc.	7427927141
40	1	L3	10 μ H 2.5A non-standard \pm 20%	Fixed inductor	TDK Corporation	VLS5045EX-100M-CA
41	1	L5	8.2 μ H-2.8A non-standard \pm 20%	Fixed inductor	Würth Electronics Inc.	78438357082
42	1	P1	Digital power connector	Connector Erni 90° 384241 32X2 male	ERNI	384241
43	1	Q1	BC847ALT1G TO-236-3, SC-59, SOT-23-3	Transistor	ON Semiconductor	BC847ALT1G
44	2	R1, R6	39 0603 (1608 metric) 0.1 W, 1/10 W \pm 1%	Resistors	Panasonic Electronic Components	ERJ-3EKF39R0V
45	2	R2, R5	820 0603 (1608 metric) 0.1 W, 1/10 W \pm 1%	Resistors	Yageo	RC0603FR-07820RL
46	2	R3, R8	47 0603 (1608 metric) 0.1 W, 1/10 W \pm 1%	Resistors	Yageo	RC0603FR-0747RL
47	8	R4, R7, R9, R12, R30, R59, R62, R63	0 0603 (1608 metric) 0.1 W, 1/10 W jumper	Resistors	Panasonic Electronic Components	ERJ-3GEY0R00V
48	4	R10, R11, R13, R14	0 2512 (6432 metric) 1 W jumper	Resistors (not mounted)	Yageo	RC2512JK-070RL
49	17	R15, R16, R19, R20, R21, R22, R25, R26, R27, R28, R29, R31, R48, R49, R53, R54, R79	10 k 0603 (1608 metric) 0.1 W, 1/10 W \pm 1%	Resistors	Yageo	RC0603FR-0710KL
50	4	R17, R18, R23, R24	4.99 k 0603 (1608 metric) 0.1 W, 1/10 W \pm 1%	Resistors	Vishay Dale	CRCW06034K99FKEA
51	1	R32	470 0603 (1608 metric) 0.1 W, 1/10 W \pm 1%	Resistor		
52	1	R33	390 0603 (1608 metric) 0.1 W, 1/10 W \pm 1%	Resistor	Yageo	RC0603FR-07390RL
53	14	R34, R35, R36, R37, R38, R39, R40, R41, R42, R43, R44, R45, R46, R47	10 0603 (1608 metric) 0.1 W, 1/10 W \pm 1%	Resistors		

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
54	2	R50, R52	0 0603 (1608 metric) 0.1 W, 1/10 W $\pm 1\%$	Resistors		
55	1	R51	0 0603 (1608 metric) 0.1 W, 1/10 W $\pm 1\%$	Resistor (not mounted)		
56	1	R55	0 0603 (1608 metric) 0.1 W, 1/10 W jumper	Resistor (not mounted)	Panasonic Electronic Components	ERJ-3GEY0R00V
57	4	R56, R57, R58, R60	0 0603 (1608 metric) 0.1 W, 1/10 W $\pm 1\%$	Resistors		
58	2	R61, R64	0 0603 (1608 metric) 0.1 W, 1/10 W $\pm 1\%$	Resistor (not mounted)		
59	2	R65, R66	100 0603 (1608 metric) 0.1 W, 1/10 W $\pm 1\%$	Resistors	Yageo	RC0603FR-07100RP
60	1	R67	470 0603 (1608 metric) 0.1 W, 1/10 W $\pm 1\%$	Resistor		
61	1	R68	680 0603 (1608 metric) 0.1 W, 1/10 W $\pm 1\%$	Resistor		
62	2	R69, R74	0 1206 (3216 metric) 0.25 W, 1/4W jumper	Resistors	Yageo	RC1206JR-070RL
63	2	R70, R75	1M 0603 (1608 metric) 0.1 W, 1/10 W $\pm 1\%$	Resistors	Vishay Dale	CRCW06031M00FKEA C
64	1	R71	249 k 0603 (1608 metric) 0.1 W, 1/10 W $\pm 1\%$	Resistor		
65	1	R72	86.6 k 0603 (1608 metric) 0.1 W, 1/10 W $\pm 1\%$	Resistor		
66	1	R73	43 k 0603 (1608 metric) 0.1 W, 1/10 W $\pm 1\%$	Resistor		
67	1	R76	220 k 0603 (1608 metric) 0.1 W, 1/10 W $\pm 1\%$	Resistor		
68	1	R77	560 k 0603 (1608 metric) 0.1 W, 1/10 W $\pm 1\%$	Resistor		
69	1	R78	24 k 0603 (1608 metric) 0.1 W, 1/10 W $\pm 1\%$	Resistor		
70	1	SW1	Miniswitch-KMR211GLFS 4.60 mm x 2.80 mm	Switch	C&K	KMR211GLFS

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
71	54	TP1, TP2, TP3, TP4, TP5, TP6, TP7, TP8, TP9, TP10, TP11, TP12, TP13, TP14, TP15, TP16, TP17, TP18, TP19, TP20, TP21, TP22, TP23, TP24, TP25, TP26, TP27, TP28, TP29, TP30, TP31, TP32, TP33, TP34, TP35, TP36, TP37, TP38, TP39, TP40, TP41, TP42, TP43, TP44, TP45, TP46, TP47, TP48, TP49, TP50, TP52, TP53, TP54, TP55	5001 0.100" Dia x 0.180" L (2.54 mm x 4.57 mm)	Test points	Keystone Electronics	5001
72	1	TP51	VDD_LV 0.100" Dia x 0.180" L (2.54 mm x 4.57 mm)	Test point	Keystone Electronics	5001
73	2	U1, U2	LTV-0601 8-SOIC (0.154", 3.90 mm width)	Optoisolators	Lite-On Inc.	LTV-0601
74	4	U3, U4, U5, U6	TS3011IYLT SC-74A, SOT-753	Rail-to-rail high-speed comparators	ST	TS3011IYLT
75	4	U9, U10, U11, U12	DA108S1RL 8-SOIC (0.154", 3.90 mm width)	Diode arrays	ST	DA108S1RL
76	1	U13	STM6315RDW13F TO-253-4, TO-253AA	Open drain microprocessor reset	ST	STM6315RDW13F
77	2	U14, U15	A6986F 16-TSSOP (0.173", 4.40 mm width) exposed pad	Automotive 38 V, 1.5 A synchronous step-down switching regulator with 30 μ A quiescent current	ST	A6986F
78	1	U7	SN74AHC32MPWR EP 14-TSSOP (0.173", 4.40 mm width)	IC gate	Texas Instruments	SN74AHC32MPWREP
79	1	U8	SPC58NN84E7RM HBR LQFP 176 24x24x1.4	32-bit power architecture MCU for high performance applications	ST	SPC58NN84E7RMHBR

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
80	1	Y1	40 MHz 0.098" L x 0.079" W (2.50 mm x 2.00 mm)	Crystal	ECS Inc.	ECS-400-8-36CKM

7 Conclusions

The test results shown demonstrate the good performances achieved by the [STDES-7KW0BC](#).

The reference design consists of two separate sections: an interleaved dual stage totem pole PFC and a dual stage galvanic isolated LLC DC-DC ZVS resonant converter, whose power devices allow achieving high levels of efficiency and optimal thermal management.

The interleaved totem pole block switching element is implemented using 650 V STPOWER SiC MOSFETs. The 55 mΩ [SCTH35N65G2V-7AG](#) SiC power MOSFET is available in H2PAK-7L surface mount package. Junction temperatures of 175°C are thus attainable.

The rectifier stage is implemented using a combination of diodes and thyristors (SCR). SCRs offer inrush protection when the filter capacitors are charged at power-on and are an alternative to a relay and inrush resistor combination that is not as compact. A suitable device is the 1200 V, 30 [TN3050H-12GY-TR](#) that is AEC-Q101 qualified and available in a D2PAK package. The diode selected is the 30 A, 1200 V [STBR3012G2Y-TR](#) low-drop ultra-fast diode that is also available in the same package.

In the final stage, an interleaved full-bridge LLC resonant DC-DC converter incorporates classic silicon MOSFETs together with SiC Schottky diodes. Here the AEC-Q101 qualified [STPSC20065-Y](#) SiC Schottky is well suited to the application. It offers a 20 A/650 V rating, has no or negligible reverse recovery, and also comes in a D2PAK package. This matches with the [STB47N60DM6AG](#) N-channel silicon MOSFET, part of the MDmesh DM6 series in STMicroelectronics STPOWER MOSFET family. With a fast-recovery body diode and 70 mΩ typical $R_{DS(on)}$, they are well suited to zero-voltage switching (ZVS) topologies and come in a surface mount D2PAK package. The total peak efficiency is greater than 94%.

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.

STMicroelectronics reference designs are solely intended to assist designers ("buyers") who are developing systems that incorporate STMicroelectronics semiconductor products (herein, also referred to as "components"). The buyer understands and agrees that he/she is the only responsible for independent analysis, evaluation and judgment in designing his/her own systems and products. STMicroelectronics has conducted only the measurements and tests specifically described in the published documentation for the specified reference design. STMicroelectronics may correct, enhance, improve its reference designs for future development.

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Revision history

Table 7. Document revision history

Date	Revision	Changes
05-Aug-2021	1	Initial release.
10-Feb-2022	2	Updated Section 6 Bill of materials.

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