STDES-30KWVRECT test report

Introduction

The STDES-30KWVRECT reference design kit introduces a complete ST digital power solution for high-power three-phase active front end (AFE) rectifier applications based on the three-level Vienna topology.

This reference design topology is mostly used for electric vehicle (EV) DC fast charging applications and industrial high-power switch mode power supply (SMPS) applications.

This platform achieves a peak efficiency higher than 98.5% by using the SCTWA90N65G2V-4 650 V, 18 mohm SiC MOSFETs, and the STPSC40H12CWL 1200 V, 40 A SiC Schottky diodes.

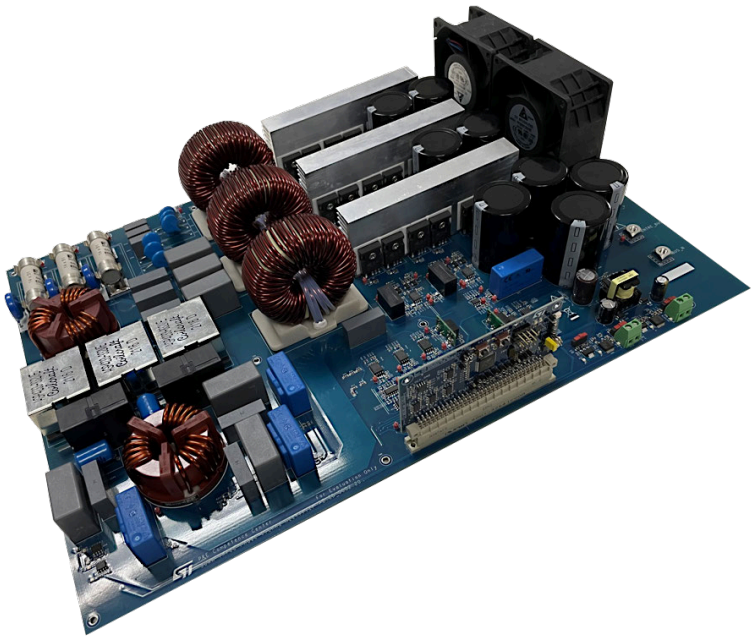
It features a fully digital control with the STM32G474RET3 mixed-signal high-performance microcontroller, which provides the full control of the PF, DC voltage, and soft startup procedure.

Providing high-bandwidth continuous conduction mode (CCM) current regulation, this platform achieves low total harmonic distortion (less than 5% THD at full load) and high-power factor (higher than 0.99 at full load).

The STDES-30KWVRECT is a fully assembled kit developed for performance evaluation only, not available for sale.

This document describes a summary of the test steps and experimental results.

Figure 1. STDES-30KWVRECT 30 kW Vienna PFC rectifier reference design kit



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

1 Safety instructions

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

Danger: *The high-voltage levels used to operate this reference design could provoke a serious electrical shock. This reference design 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 reference design as some of its components could reach a very high temperature.

2 Overview

2.1 Features

- Three-phase, three-level AC-DC power converter:
  - Nominal rate for DC voltage: 800 V_{DC}
  - Nominal rate for AC voltage: 400 V_{AC} at 50 Hz
  - Maximum power: 30 kW
  - Power factor: >0.99
  - Inrush current control and soft start-up
  - THD lower than 5% at nominal operation
- Power section based on SiC MOSFETs and SiC diodes:
  - High frequency operation (70 kHz)
  - High efficiency: >98.5%
  - Paralleled SiC MOSFETs for higher power with balanced sharing current
  - Passive element weight and size reduction
- Control section based on the STM32G474RE microcontroller:
  - Control and monitoring interfaces: SWD–UART, I²C, and DACs
  - 64-pin digital power connector
  - LED status as UI
  - Four integrated high-performance op-amps for additional features

2.2 Specifications

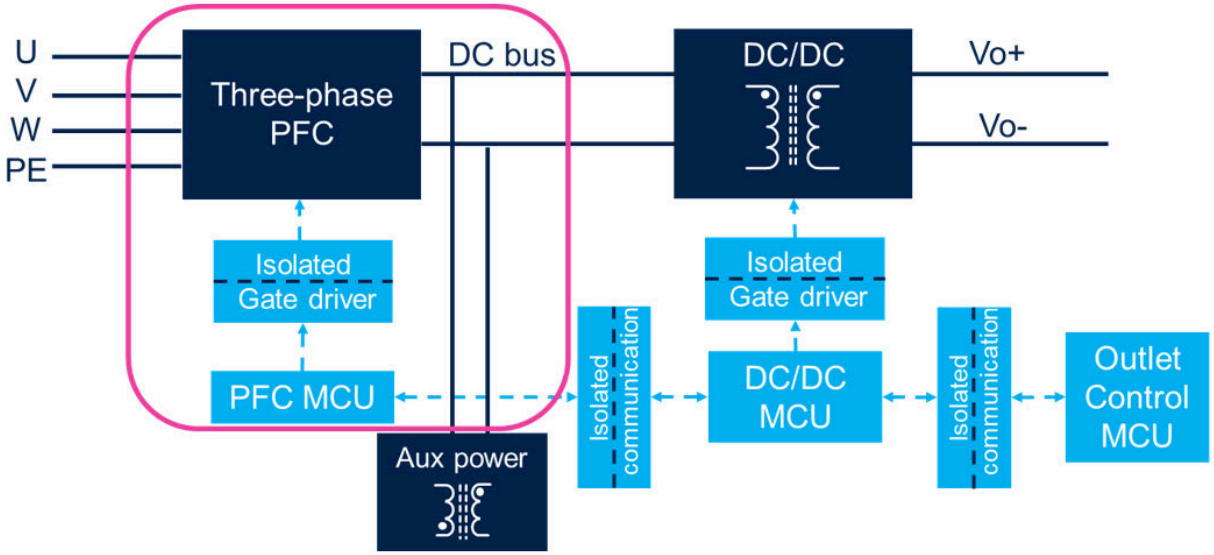
Table 1. Electrical characteristics

Symbol	Description	Min.	Typical	Max.	Units	Comments
$VAC_{(L-L)}$	Input line-line AC voltage	345	400	460	Vrms	
f_{AC}	Input AC frequency	47	50	63	Hz	
V_{out}	Output voltage	700	800	850	V	
P_{out}	Output power			30	kW	
I_{out}	Output current			37.5	A	VDC=800V
I_{in}	Input current			50	A	$VAC_{(L-L)}$ =350V
η	Peak efficiency			98.56	%	$VAC_{(L-L)}$ =400V, V_{out}=800V
				98.7	%	$VAC_{(L-L)}$ =450V, V_{out}=800V
iTHD	Total harmonic distortion			<5	%	At load >50%
PF	Power factor		0.99			At load >50%
I_{inrush}	Inrush current			30	A	$VAC_{(L-L)}$ =450V

2.3 Block diagram and simplified schematics

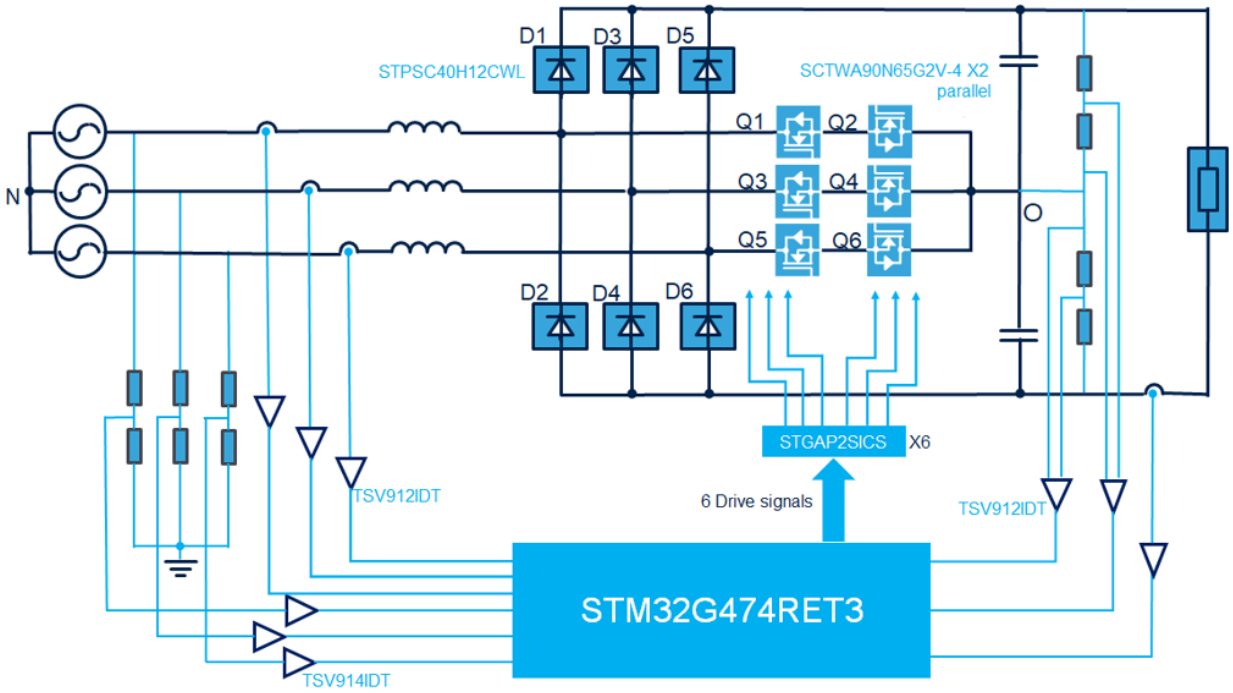
The DC fast charging supply consists of a three-phase active front end (AFE) rectifier, which provides a regulated DC link from a universal three-phase AC input, while it demands a high-quality current from the grid.

Figure 2. Block diagram of a DC fast charging application



The figure below shows the circuit configuration for the three-phase Vienna PFC.

Figure 3. Simplified schematic of the three-phase Vienna PFC



The Vienna rectifier works as a three-phase boost converter that steps up the AC mains input voltage to 800 V_{DC} output while forcing a sinusoidal input current that is in-phase with the input voltage on all three phases.

Each phase consists of a boost inductor, a pair of rectifiers (STPSC40H12C SiC Schottky diodes) and a set of series connected MOSFETs (each position uses two paralleled SCTWA90N65G2V-4 SiC MOSFET). The MOSFETs are connected to the center point of a capacitive divider, which reduces the voltage stress on the SiC MOSFETs. Two SiC Schottky diodes of each phase are used for boosting during the input AC voltage positive and negative alternation.

The driving circuit is an STGAP2SICS galvanic isolated driver IC for SiC MOSFETs. It provides 4 A driving current capability and a common mode transient immunity (CMTI) up to 100 V/ns.

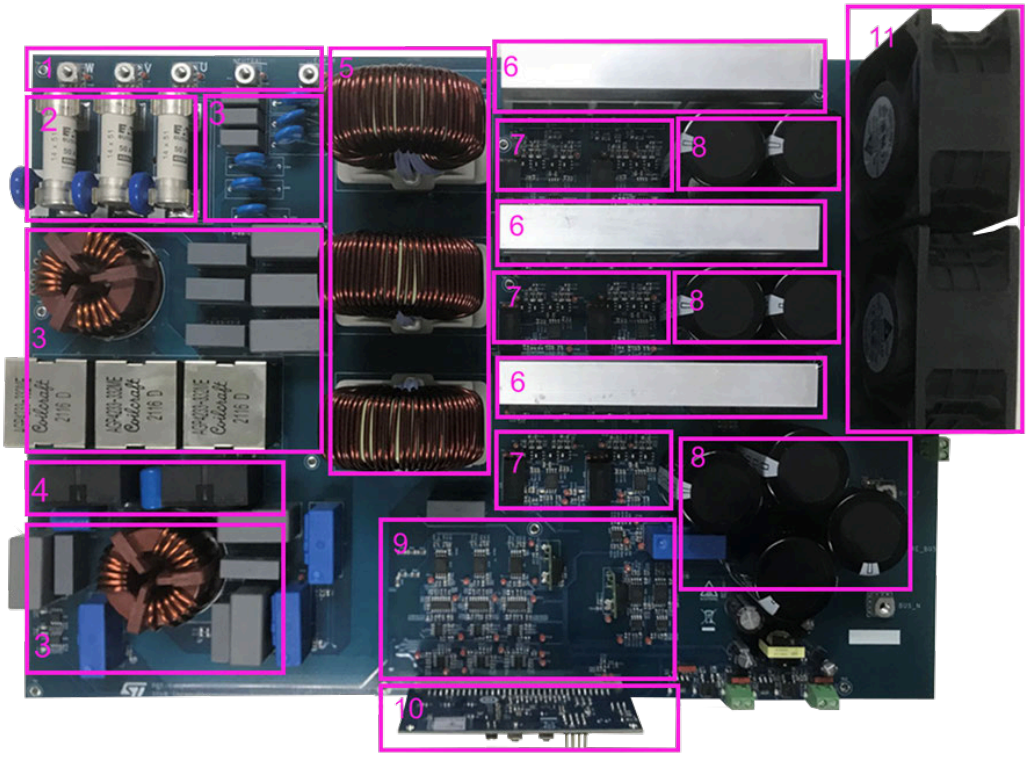
The control of the Vienna PFC is implemented with an STM32G474RE microcontroller, which includes PFC, THD, voltage regulation, input overcurrent protection (OCP), overvoltage protection (OVP), soft-start, and inrush current limit functions.

2.4 Kit component overview

2.4.1 Power board components

The figure below shows the power board of the STDES-30KWVRECT reference design.

Figure 4. Power board components



1. AC input connector
2. Fuse
3. EMI filter
4. Inrush current limiter
5. PFC choke
6. SiC MOSFET, diode, and heatsink
7. Drive circuit
8. PFC output capacitors
9. Sensing and amplifier circuit
10. Control board
11. Fans

2.4.2 LEDs

To check the auxiliary power supply status, several LEDs are used as indicators on the power board.

The D8 and D13 green LEDs show the external 7 V and 12 V power supply status. The D11 and D12 green LEDs show the status of VDD_5V and VDD_3.3V, which are used for sensing and control.

For each pair of paralleled MOSFETs, a LED indicates the driving power supply condition of the driving circuit. The LEDs of each phase have the same relative position with respect to the heatsink.

Figure 5. STDES-30KWVRECT power board LEDs (1 of 2)

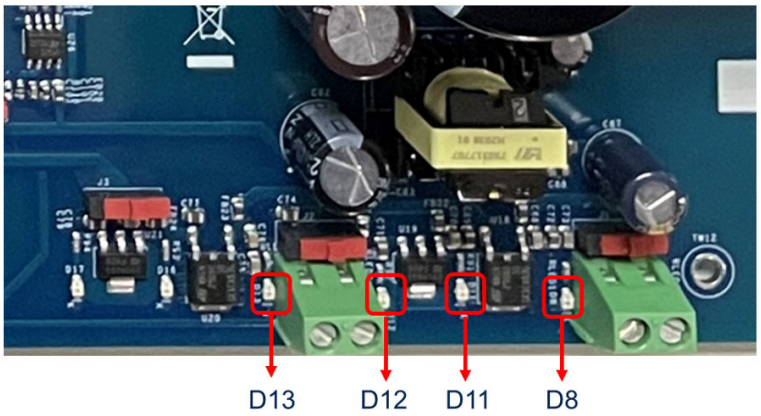


Figure 6. STDES-30KWVRECT power board LEDs (2 of 2)

Table 2. Power board LED definitions

Reference	Definition	Color	Comments
D8	External 7V	Green	On→normal Blink/off→abnormal
D13	External 12V	Green	
D11	VDD_5V	Green	
D12	VDD_3.3V	Green	
D25, D26	Phase A driving VDD	Green	
D29, D30	Phase B driving VDD	Green	
D33, D34	Phase C driving VDD	Green	

On the PFC control board, two LEDs (D13 and D15) indicate which is the state machine the reference design is working in.

The specific state can be observed on the online debugging interface.

Figure 7. **STDES-30KWVRECT control board LEDs**

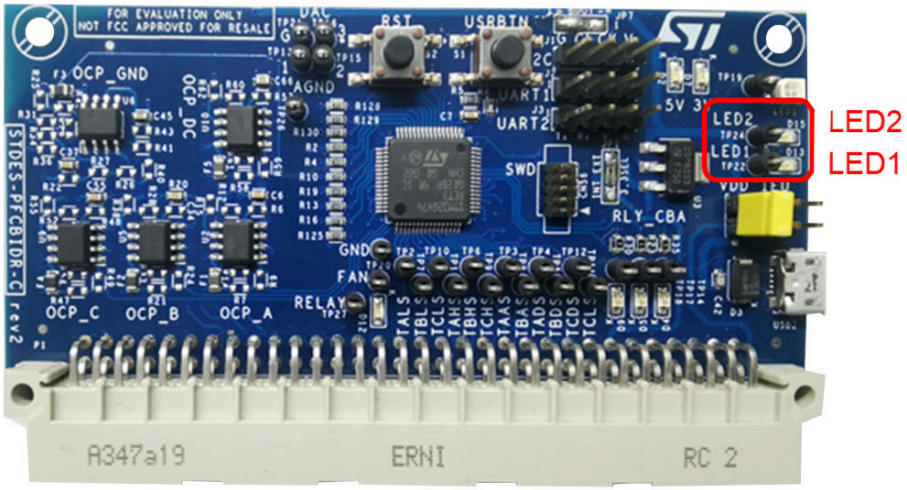


Table 3. **Control board LEDs and related state machine**

LED status	Definition
D13 on, D15 off	State machine = `Wait, Idle, Init, Start`
D13 on, D15 on	State machine = `Run`
D13 off, D15 off	State machine = `Stop, Error, Fault`

3 Test setup

3.1 Test conditions and equipment

Table 4. Test conditions

Symbol	Description	Min.	Typical	Max.	Units	Comments
$VAC_{(L-L)}$	Input line-line AC voltage	345	400	460	Vrms	
f_{AC}	Input AC frequency	47	50	63	Hz	
V_{out}	Output voltage	750	800	850	V	0 -50%- 0 Dynamic load
P_{out}	Output power			30	kW	
I_{out}	Output current			37.5	A	VDC = 800 V

Table 5. Test equipment

Items	Type	Description
1	Three-phase AC power source, 60 kVA	To be connected to the AC input.
2	Electrical DC load, 1000 V, 18 kVA*2	The two electronic DC loads need to be set in CC (constant current) mode with the current share setting. To be connected to the DC output.
3	Digital oscilloscope	To read the waveforms.
4	Differential voltage probe	To measure voltage waveforms.
5	Current probe	To measure current waveforms.
6	Multichannel power analyzer	To check input power quality and efficiency.
7	Optical isolation probe	To measure the MOSFET Vds.

3.2 AC input wire connection

Connect the line (U, V, W) and earth (PE) wires with J101 connectors as marked on the board to an unpowered main plug.

Figure 8. AC input wire connection

3.2.1 PFC bus connection

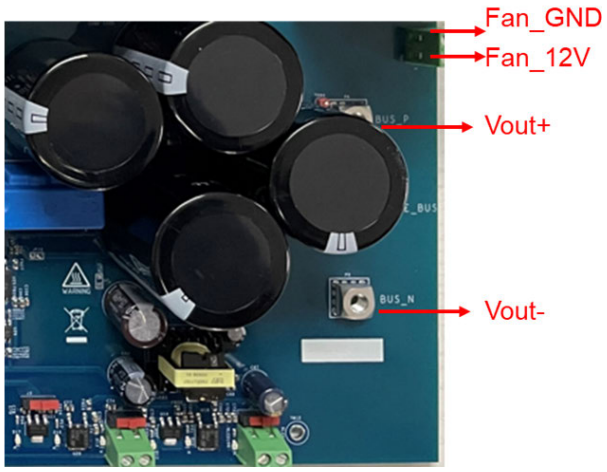
Connect the PFC Vout+ and Vout- output terminals to a resistance box or an electric load.

If using an electronic load, connect the positive and negative terminals of the electronic DC load to the Vout+ and Vout- connectors on the demo board.

3.2.2 External fan cooling

External fans should be used for cooling during the test (2pcs fans are recommended). The figure below shows the fan power supply wires.

Figure 9. Fan power wire connection



3.3 Preliminary test procedure

To ensure that each circuit on the power board is operating normally, verify before the signal on each of the test points described in the following sections.

3.3.1 AC sensing circuit check

To check the proper operation of the AC sensing (Figure 10), measure the test points for voltages (Figure 11) and currents (Figure 12).

Figure 10. AC sensing section on board

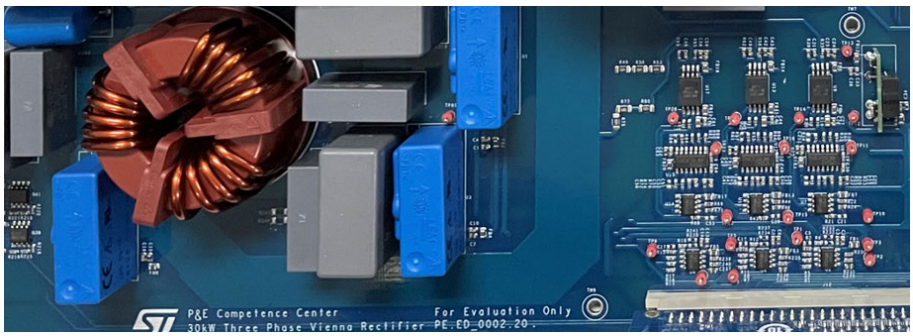


Figure 11. **Test procedure for AC voltage sensing**

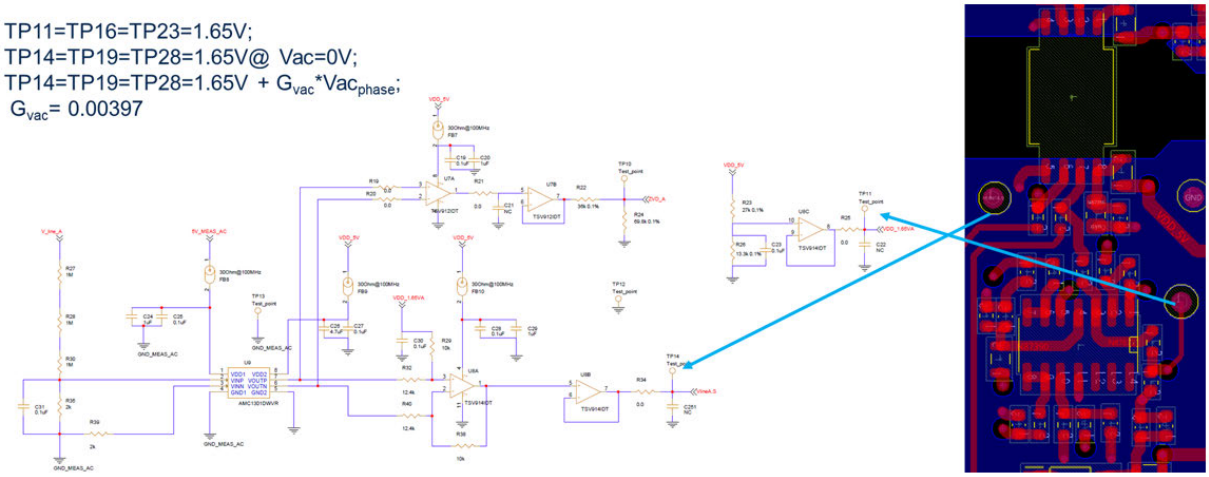
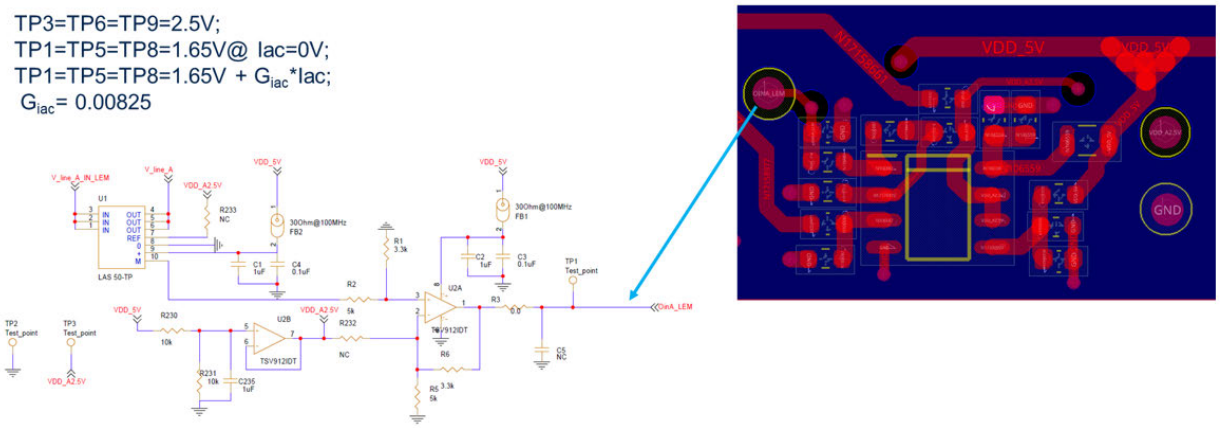


Figure 12. **Test procedure for AC current sensing**



3.3.2 DC sensing circuit check

To verify the proper operation of the DC sensing, analyze the test points for voltages (Figure 13) and currents (Figure 14).

Figure 13. **Testing procedure for DC voltage sensing**

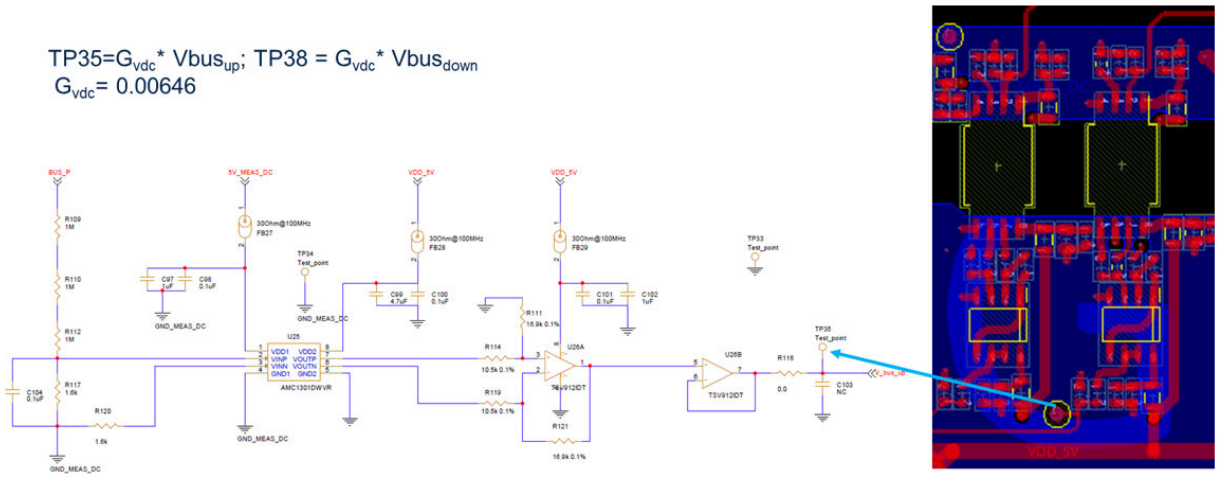
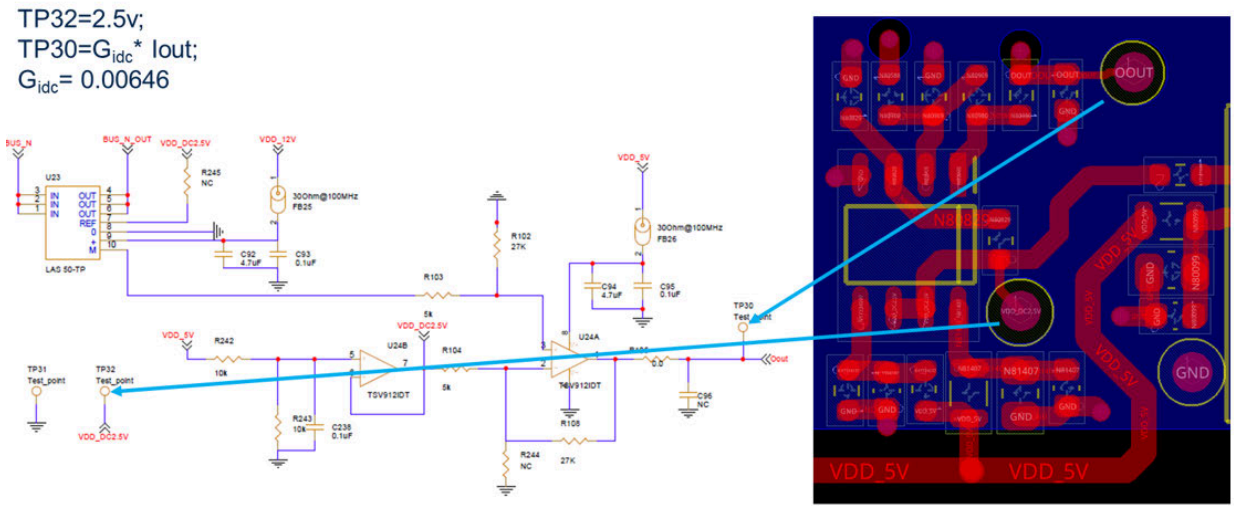


Figure 14. **Testing procedure for DC current sensing**



3.4 Power on/off sequence

3.4.1 Power on

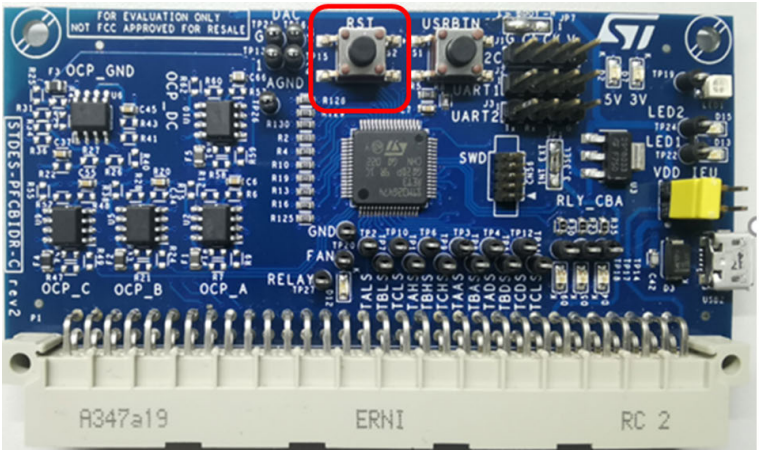
Step 1. Turn on the external auxiliary power supply. Check whether the control LEDs and drive LEDs are lit up.

Step 2. Set the AC source voltage to 20 V_{AC} 50 Hz and turn on. Measure all the sensing circuit test point voltage. Check whether they are operating normally.

Caution: The test probe should be placed before the external auxiliary power and AC source power-on. Do not remove the probe when the board is powered on, as this might cause short-circuit risk and damage the board.

Step 3. Turn off the AC source. Push the reset button on the control board to reset the MCU.
The reset button position is shown in the figure below.

Figure 15. **Reset button position on control board**



Step 4. The external fan is powered on.

Caution: The demo board might be damaged without fan cooling due to overheat under a heavy load condition.

Step 5. Set the AC source voltage between 350 V_{AC} ~ 450 V_{AC} and 47 Hz ~ 6 3Hz. Ensure that the output load is zero.

Step 6. Turn on the AC source.
Then, the output voltage gradually ramps up to 800 V_{DC}.

Step 7. According to the system specification, set the AC input voltage and the DC output load for test conditions.

Warning: *Do not touch any components when the board is powered on.*

3.4.2 Power off

After finishing the test, follow the steps below.

Step 1. Remove the load gradually to 0 A.

Step 2. Turn off the AC source.

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

Step 3. Turn off the power supply for the fans and the external power.

4 Measurements/waveforms/test data

This section is a summary of the experimental results of the 30 kW Vienna PFC rectifier.

The figures below shows the test waveforms in steady state at 400 V_{AC} at a load of 15 kW load. The yellow trace indicated the PFC bulk capacitor voltage or the AC input voltage. The blue, red, and green lines indicate each phase of the input current, which is smooth and aligned with the input voltage.

Figure 16. PFC steady state with V_{AC} = 400 V and P_{OUT} = 15 kW with bulk capacitor voltage

- Yellow trace: bulk capacitor voltage
- Blue trace: phase-U AC input current
- Red trace: phase-V AC input current
- Green trace: phase-W AC input current

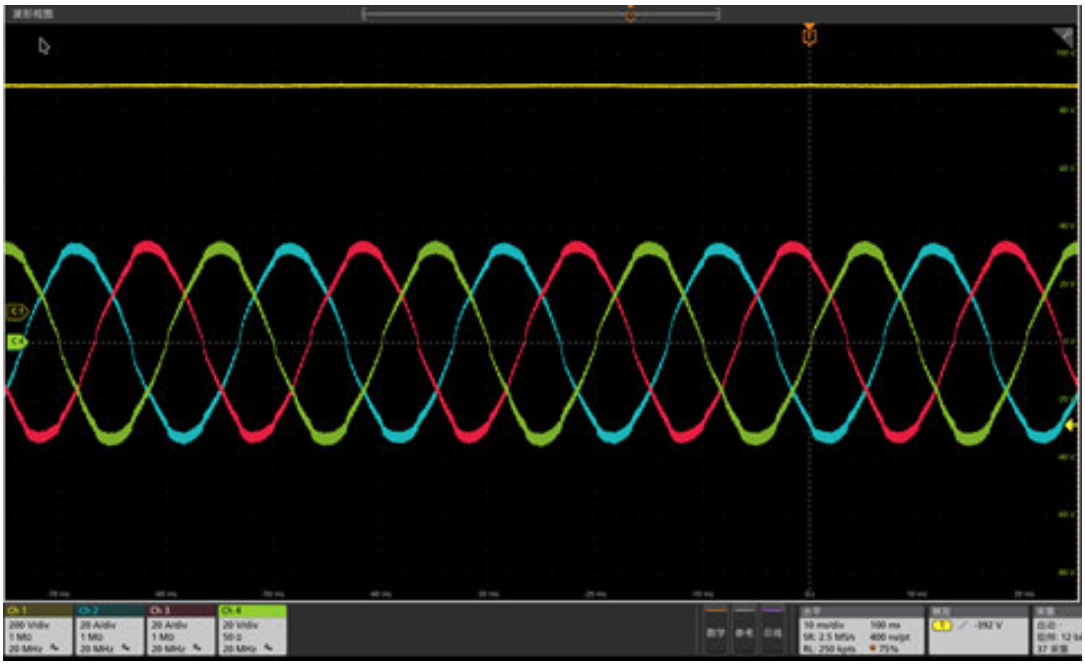
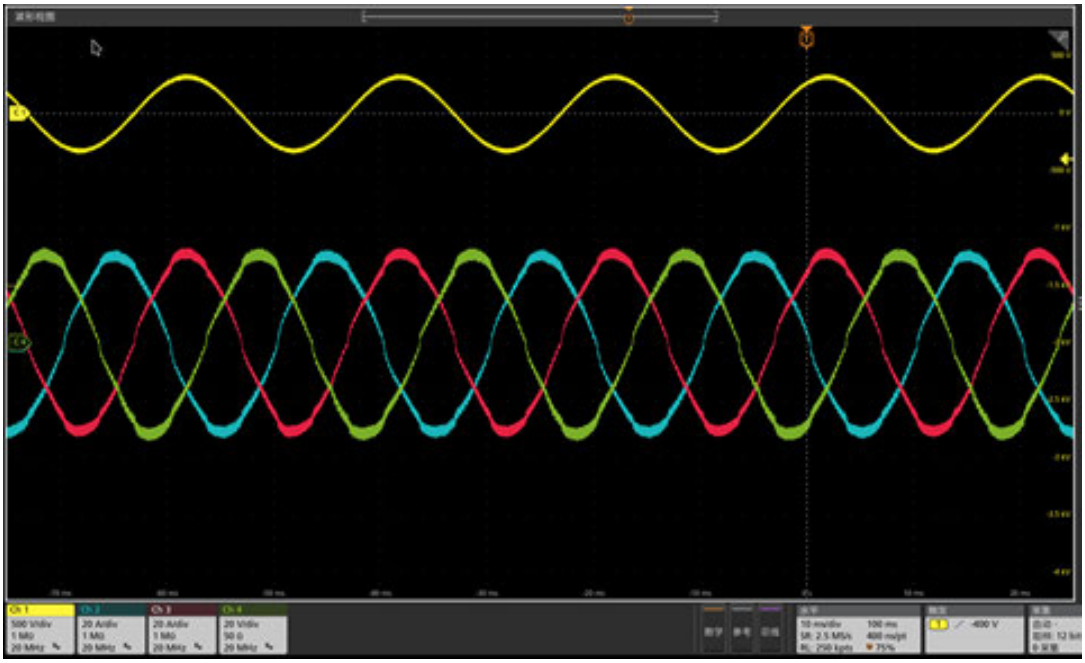


Figure 17. PFC steady state with V_{AC} = 400 V and P_{OUT} = 15 kW with AC input voltage

- Yellow trace: phase-V AC input current
- Blue trace: phase-U AC input current
- Red trace: phase-V AC input current
- Green trace: phase-W AC input current



The figure below shows the test waveform in steady state at 230 V_{AC} at a load of 30 kW.

Figure 18. PFC steady state with V_{AC} = 400 V and P_{OUT} = 30 kW

- Yellow trace: bulk capacitor voltage
- Blue trace: phase-U AC input current
- Red trace: phase-V AC input current
- Green trace: phase-W AC input current

The figure below shows the key waveforms of the voltage at phase-A bridge midpoint voltage and AC phase-A voltage.

Figure 19. Bridge midpoint voltage and AC line voltage (400 V_{AC}, 15 kW load)

- Blue trace: phase-A bridge midpoint voltage
- Red trace: AC phase-A voltage

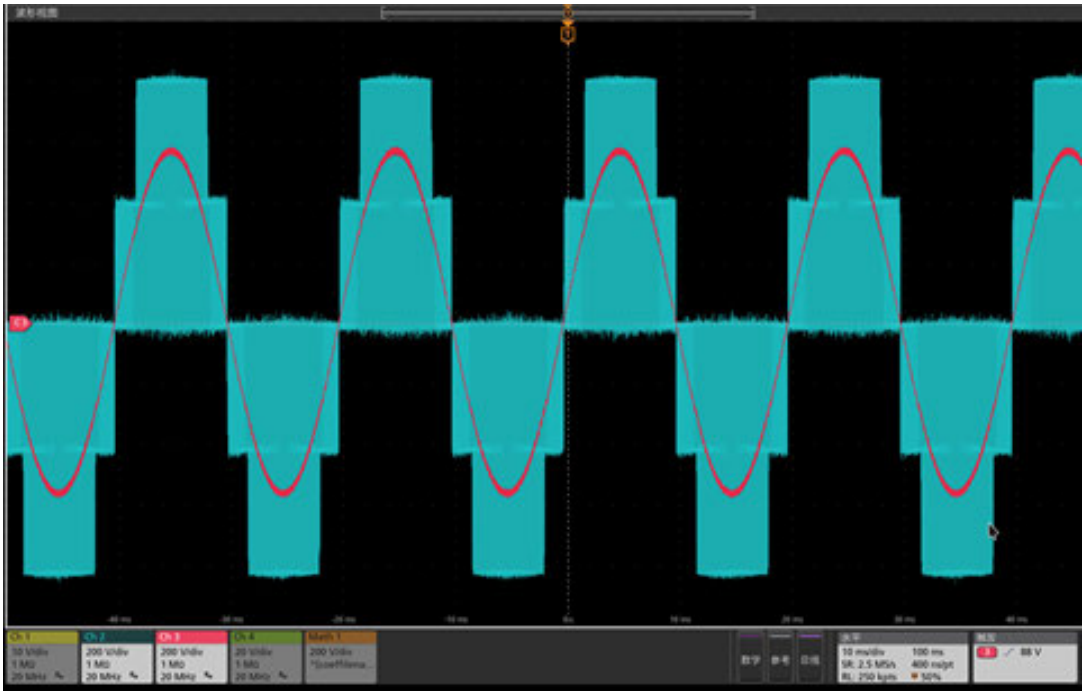


Figure 20. Load transient response at 400 V_{AC}, 0-15 kW load (1 of 2)

- Yellow trace: load current
- Blue trace: AC input current
- Green trace: PFC output voltage

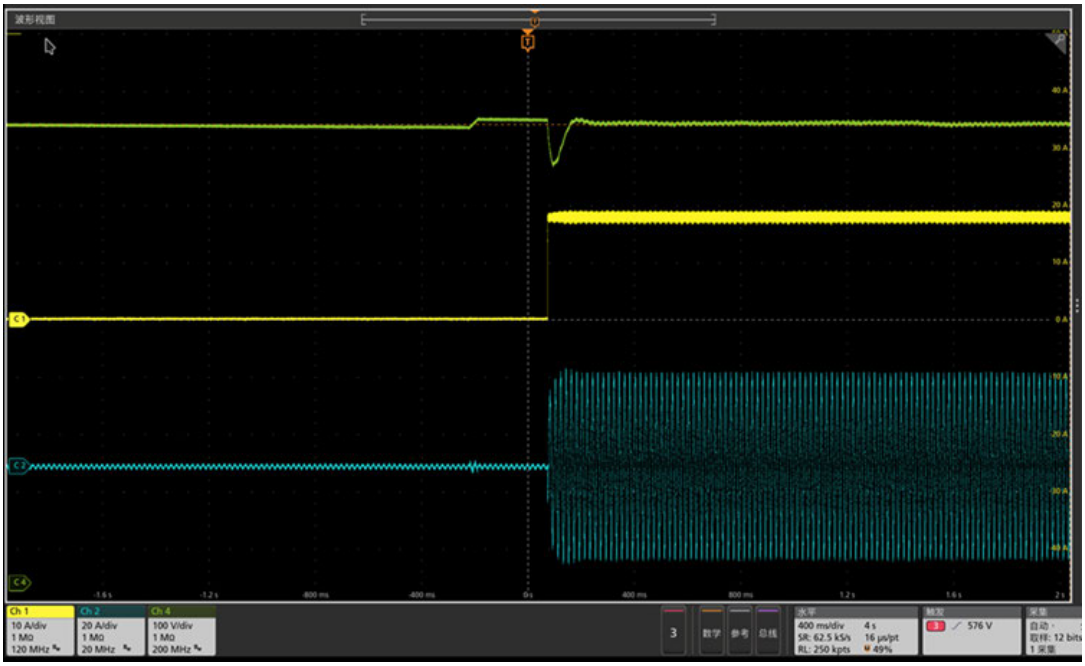
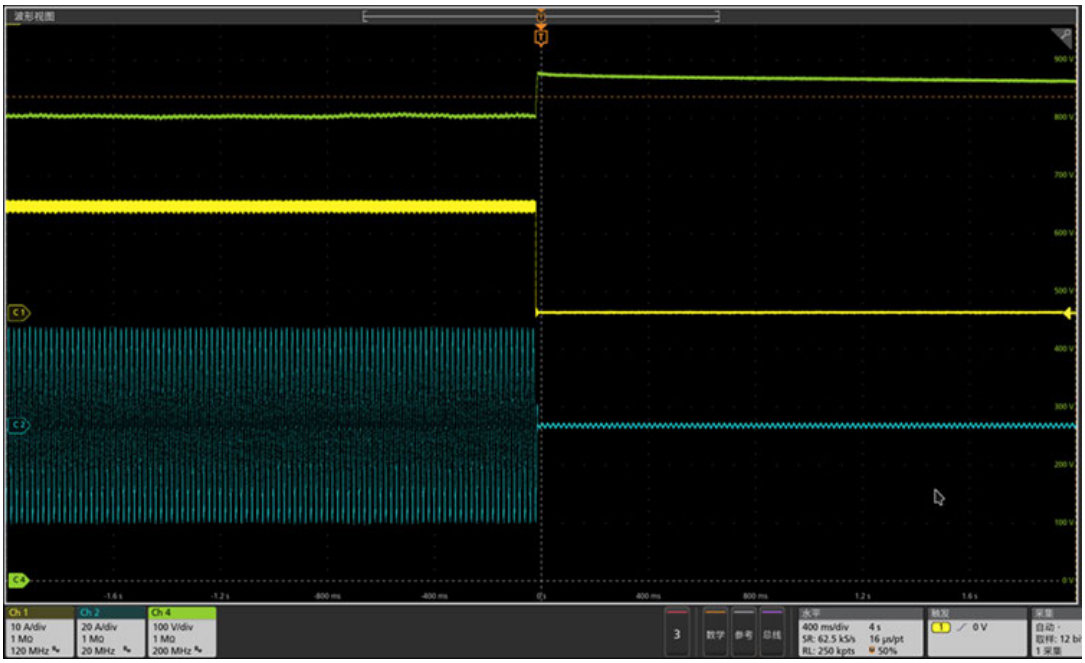


Figure 21. Load transient response at 400 V_{AC}, 0-15 kW load (2 of 2)

- Yellow trace: load current
- Blue trace: AC input current
- Green trace: PFC output voltage

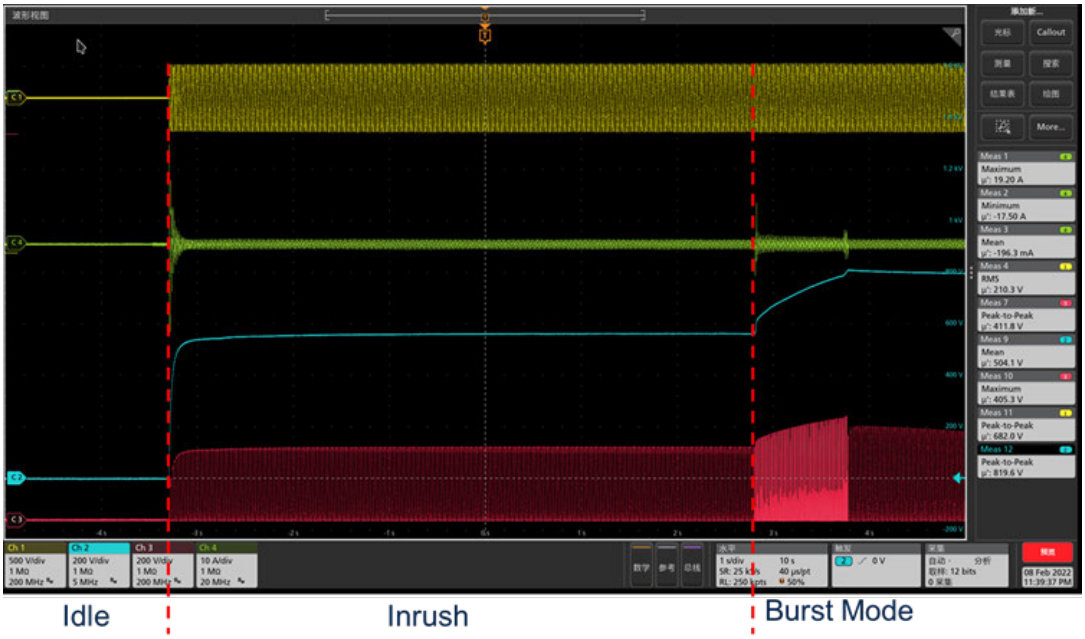


The figure below shows the PFC power-up procedure. When the AC voltage flows into the PFC converter, the inrush resistor limits the current, which is about 19.2 A in this case (400 V_{AC}).

Once the output voltage reaches the uncontrolled rectified voltage, the inrush relay actuates and keeps pulling in. Simultaneously, the PFC enters the burst mode, generating a fixed 70 kHz, open loop PWM until the output voltage rises to the target.

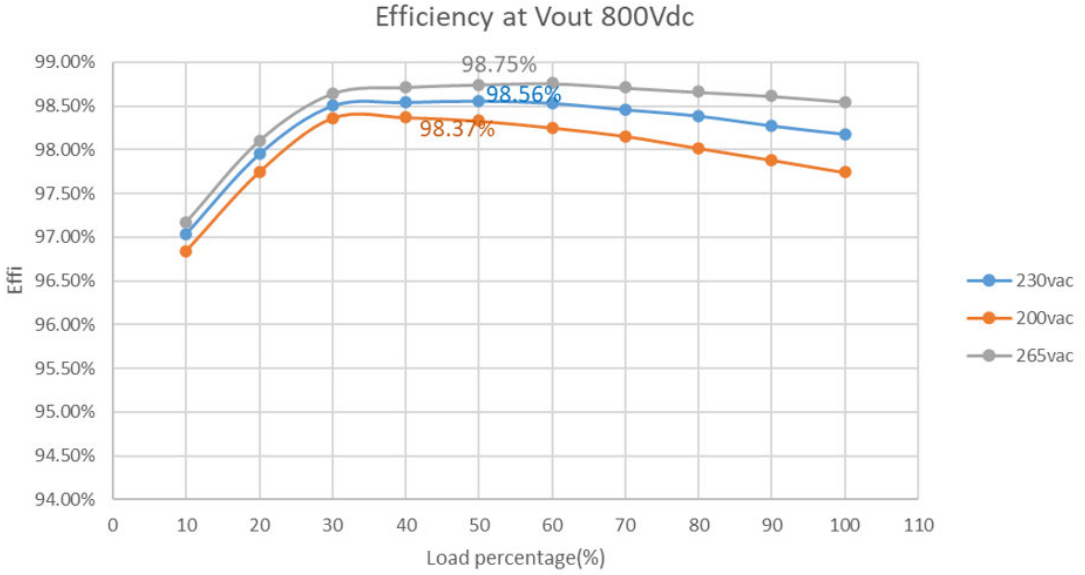
Figure 22. **PFC startup with V_{AC} = 400 V**

- Yellow trace: AC input voltage
- Blue trace: output voltage
- Red trace: V_{DS} of Q1
- Green trace: AC input current



The figure below shows the PFC efficiency measurement under various operating load conditions and different AC input voltage conditions. At 400 V_{AC} (L-L) condition, this reference design provides a 98.56% peak efficiency. At 450 V_{AC} (L-L) condition, the reference design can reach a 98.75% peak efficiency.

Figure 23. **PFC efficiency curve at different input conditions**



The following figures show the PFC iTHD and PF value results under various operating load conditions and different AC input voltage conditions. In the whole AC input voltage range, iTHD is less than 5% when the load is larger than 50%. The PF value reaches 0.998 when the load is larger than 50%.

Figure 24. **PFC iTHD curve at different input conditions (1 of 2)**

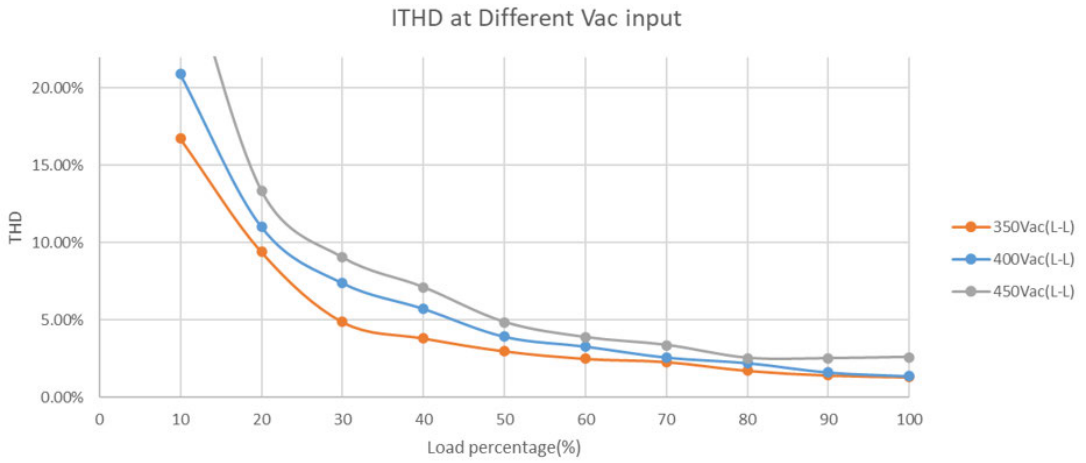
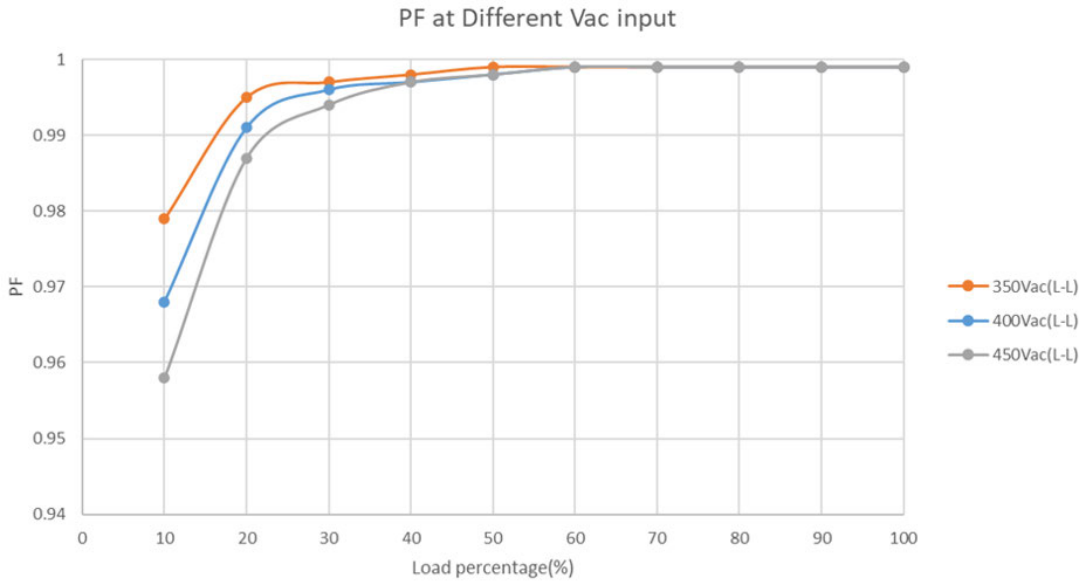


Figure 25. **PFC iTHD curve at different input conditions (2 of 2)**



The figure below shows the temperature of key components at an ambient temperature of 20.04°C. At 400 V_{AC} (L-L) and 30 kW condition, the SiC MOSFET case temperature is 67.12°C. The diode case temperature is 60.13°C.

Figure 26. **Overall thermal points at 30 kW**

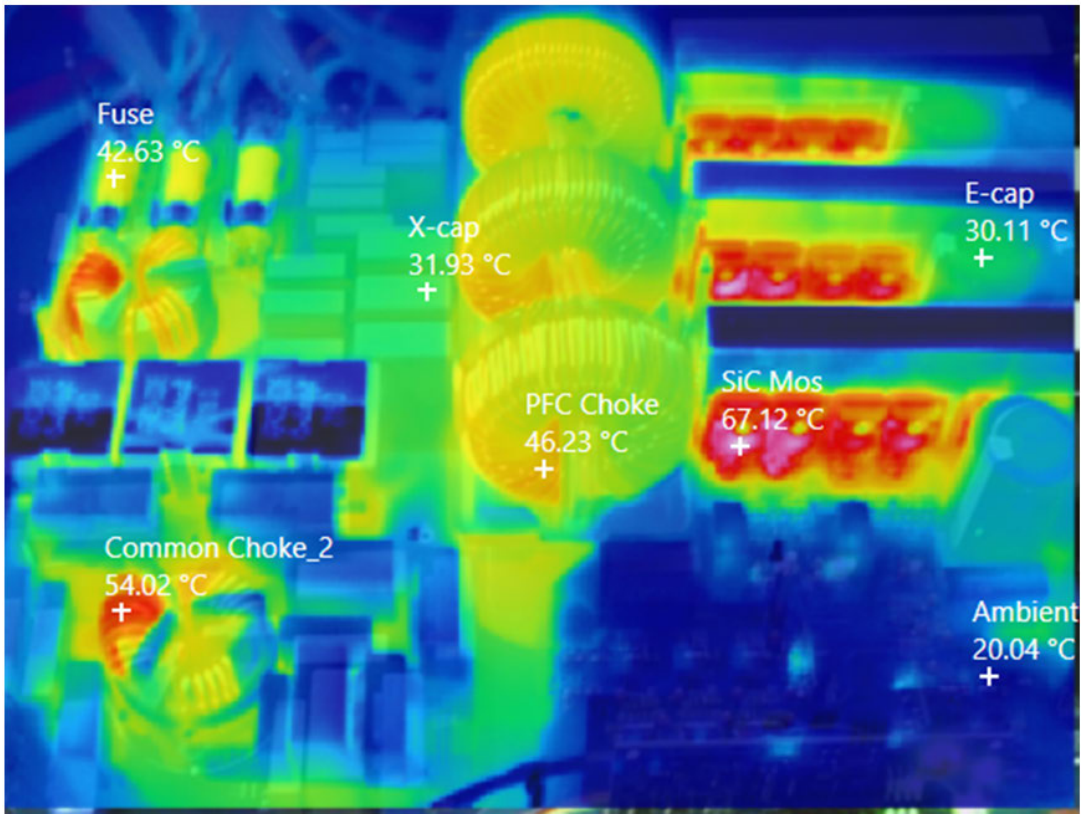


Figure 27. **EMI part and diode thermal results at 30 kW**

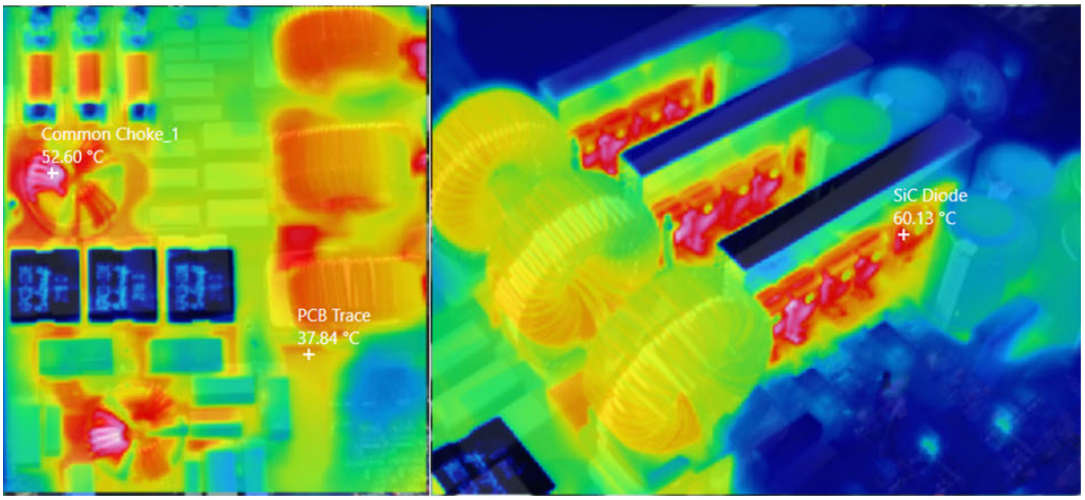


Table 6. **Overall thermal results at 30 kW**

Components	Temperature at 30 kW(°C)
Fuse	42.63
Common choke_1	52.6
Common choke_2	54.62
X capacitor	31.93
PFC choke	46.23

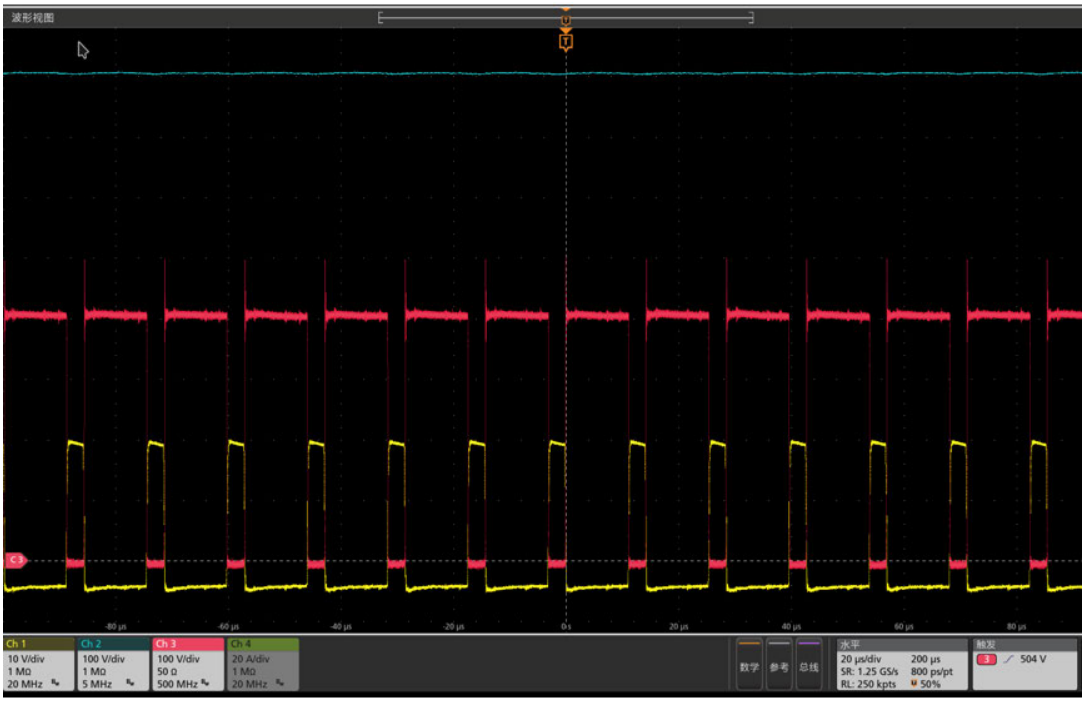
SiC MOSFET case	67.12
SiC diode case	60.13
Electrolytic capacitor	30.11
PCB trace	37.84
Ambient	20.04

To check the operation performance of the SiC MOSFET, we also measured the gate drive signal (V_{GS}) and the voltage stress (V_{DS}) at different loads.

The figure below shows the V_{DS} and V_{GS} of the SiC MOSFET working at 400 V_{AC} (L-L) and a load of 15 kW. The spike of V_{DS} is about 504 V, which corresponds to about 77.5% of the V_{DS} maximum rating (650 V).

Figure 28. V_{DS} spike of SiC MOSFET (400 V_{AC} (L-L), 15 kW load)

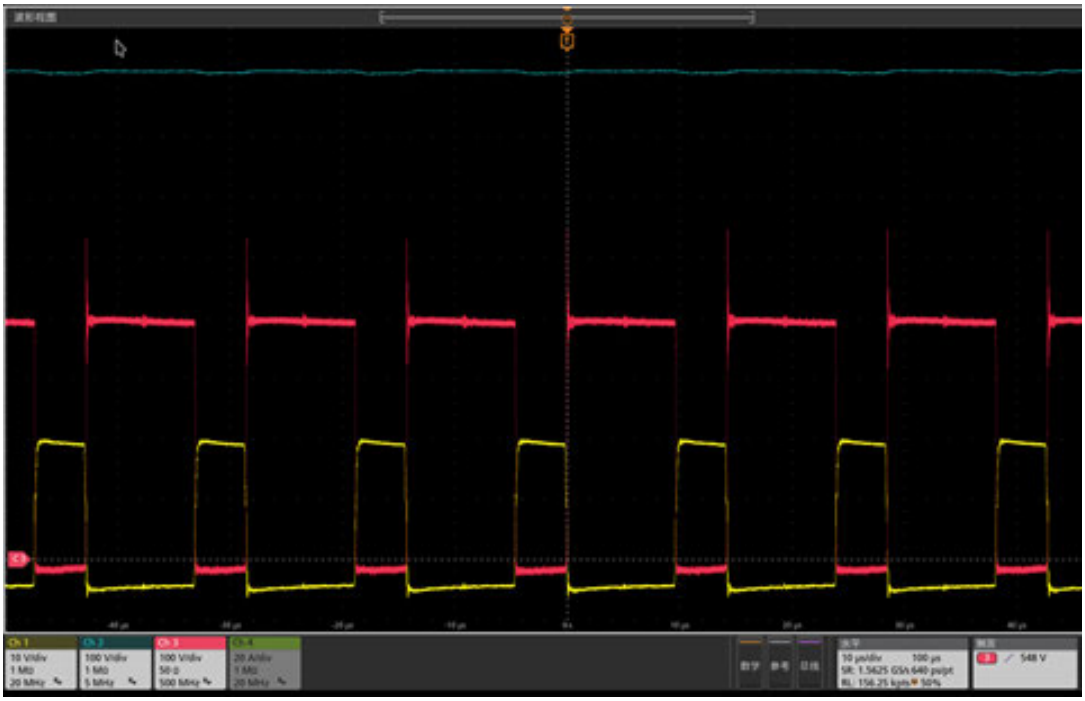
- Yellow trace: V_{GS} of SiC MOSFET
- Blue trace: bulk capacitor voltage
- Red trace: V_{DS} of SiC MOSFET



The figure below shows the V_{DS} and V_{GS} of SiC MOSFET working at 400 V_{AC} (L-L) and a load of 30 kW load. The spike of Vds is about 546V, nearly 85% of 650V Vds maximum rating.

Figure 29. V_{DS} spike of SiC MOSFET (400 V_{AC} (L-L), 30 kW load)

- Yellow trace: V_{GS} of SiC MOSFET
- Blue trace: bulk capacitor voltage
- Red trace: V_{DS} of SiC MOSFET

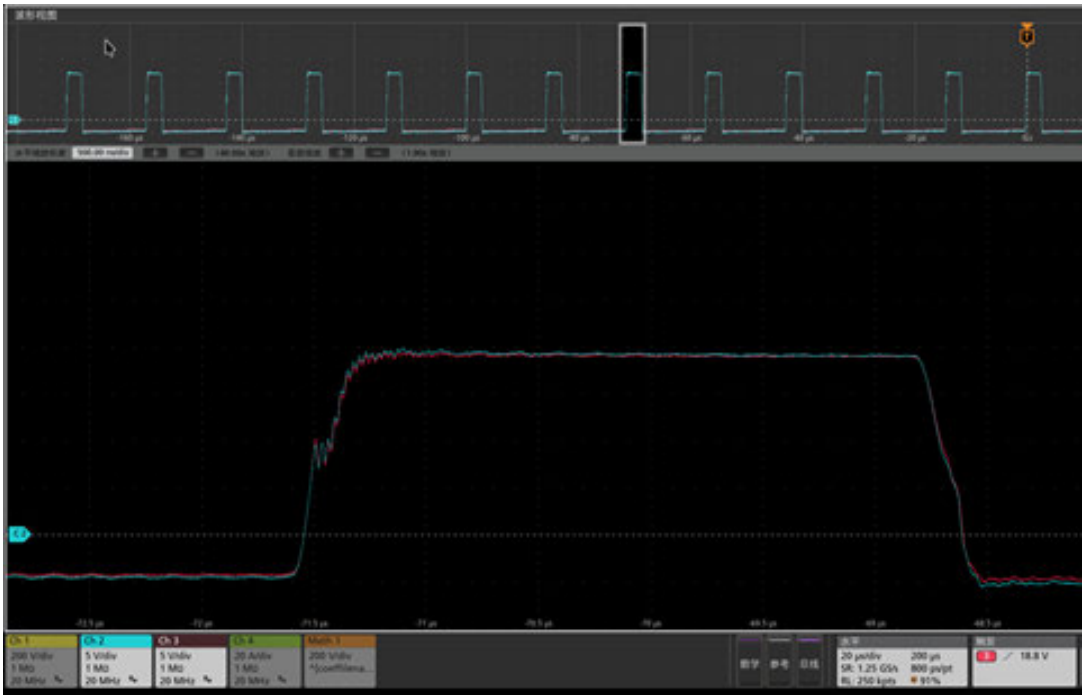


Note: In this reference design, the turn-on and turn-off gate drive resistances are both 5.1 Ohms. The gate drive resistances can be increased for a lower voltage spike or reduced for a higher switching speed.

The figure below shows the gate drive (V_{GS}) of two paralleled SiC MOSFETs. The rising and falling waveforms of each MOSFET are almost the same and the voltages of the Miller-platform are nearly overlapped. This means that the two paralleled MOSFETs are working at the same condition and the current is evenly distributed.

Figure 30. V_{GS} of the two paralleled SiC MOSFET (400 V_{AC} (L-L), 15 kW load)

- Blue trace: V_{GS} of Q1 SiC MOSFET
- Red trace: V_{GS} of Q2 SiC MOSFET



5 Schematic diagrams

Figure 31. STDES-30KWVRECT power board circuit schematic (1 of 9)

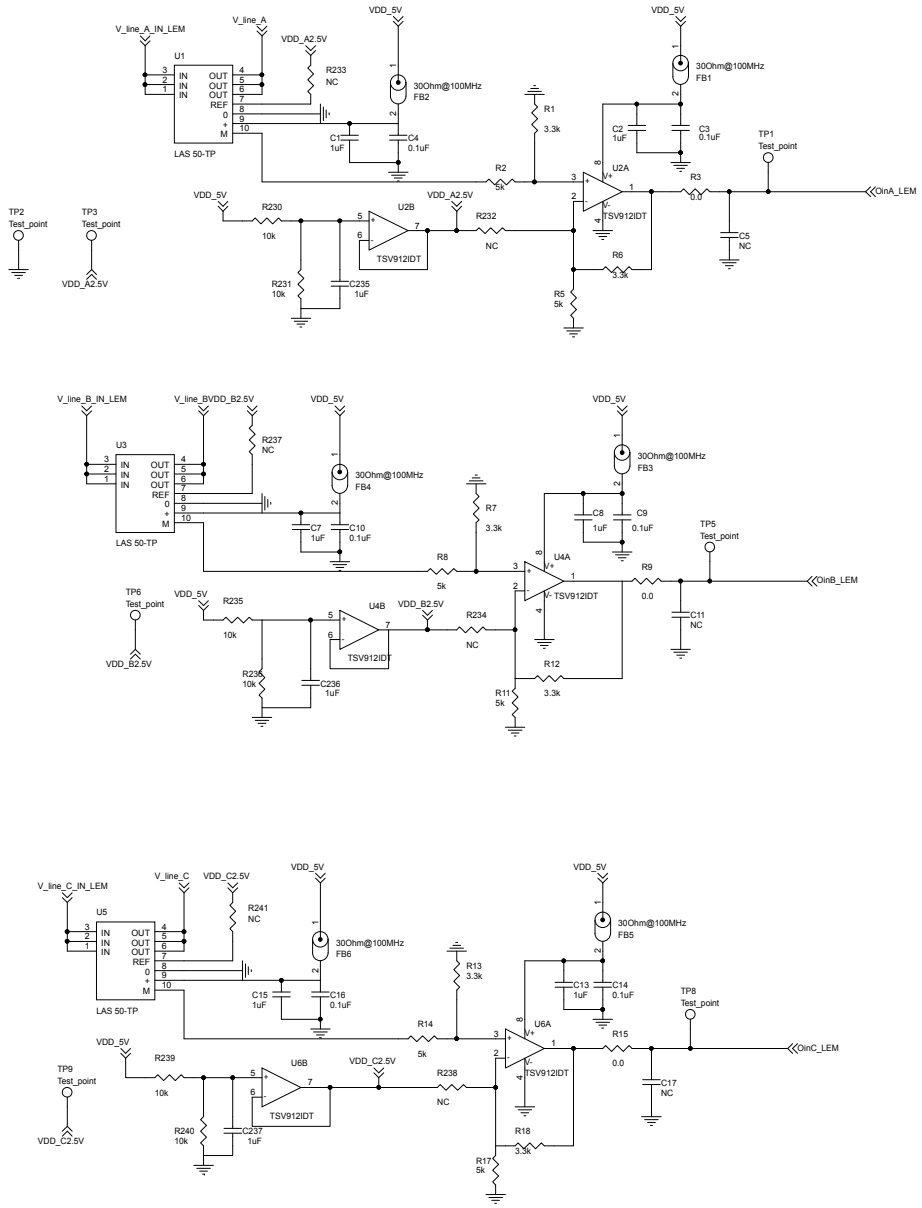


Figure 32. STDES-30KWVRECT power board circuit schematic (2 of 9)

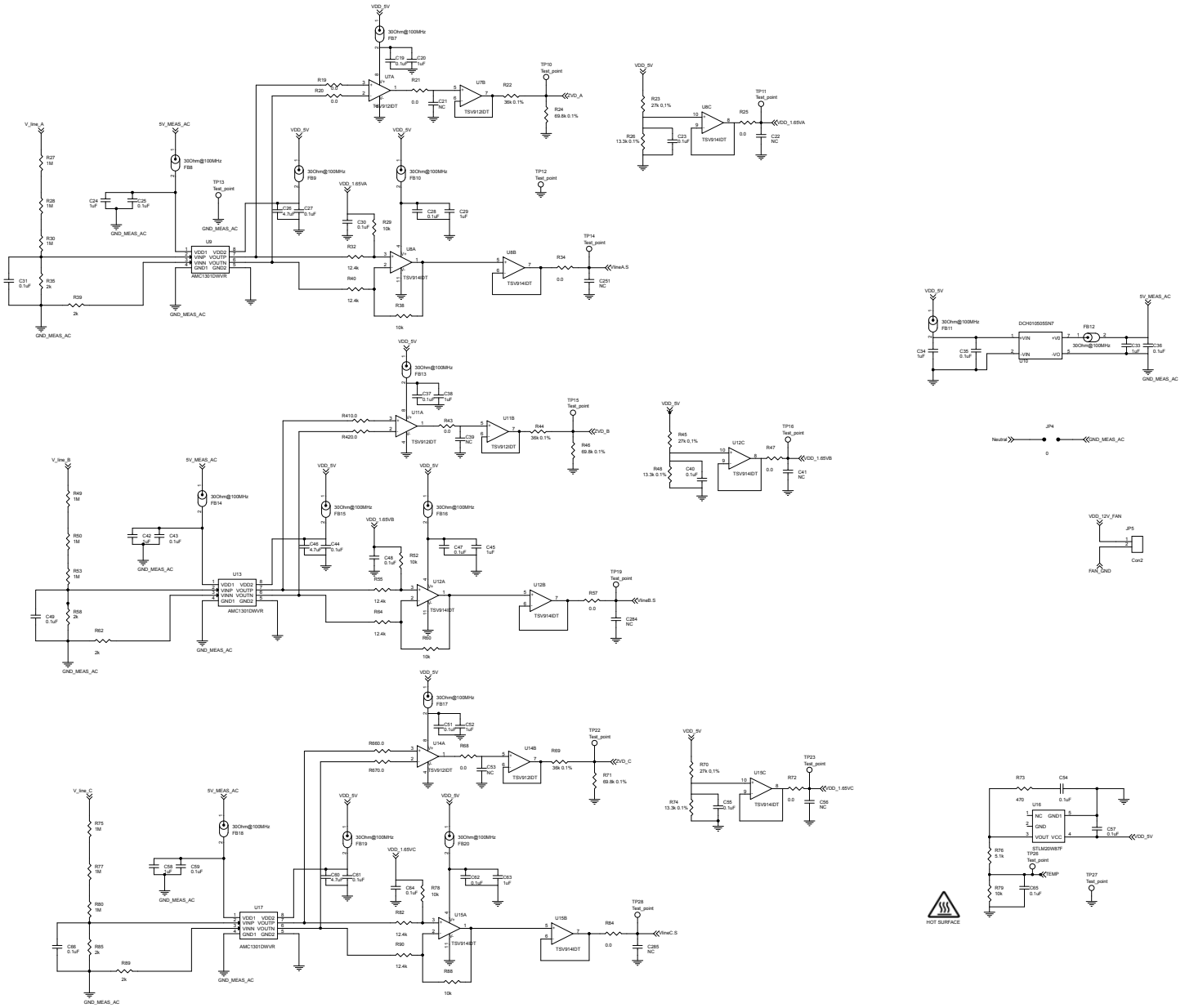


Figure 33. STDES-30KWVRECT power board circuit schematic (3 of 9)

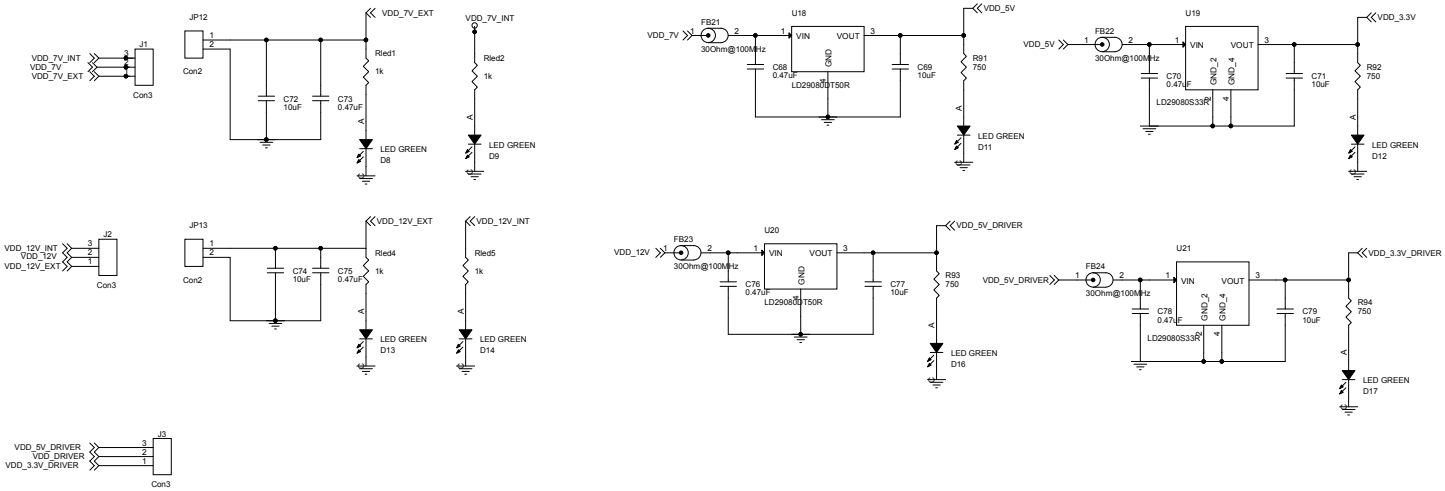


Figure 34. **STDES-30KWVRECT power board circuit schematic (4 of 9)**

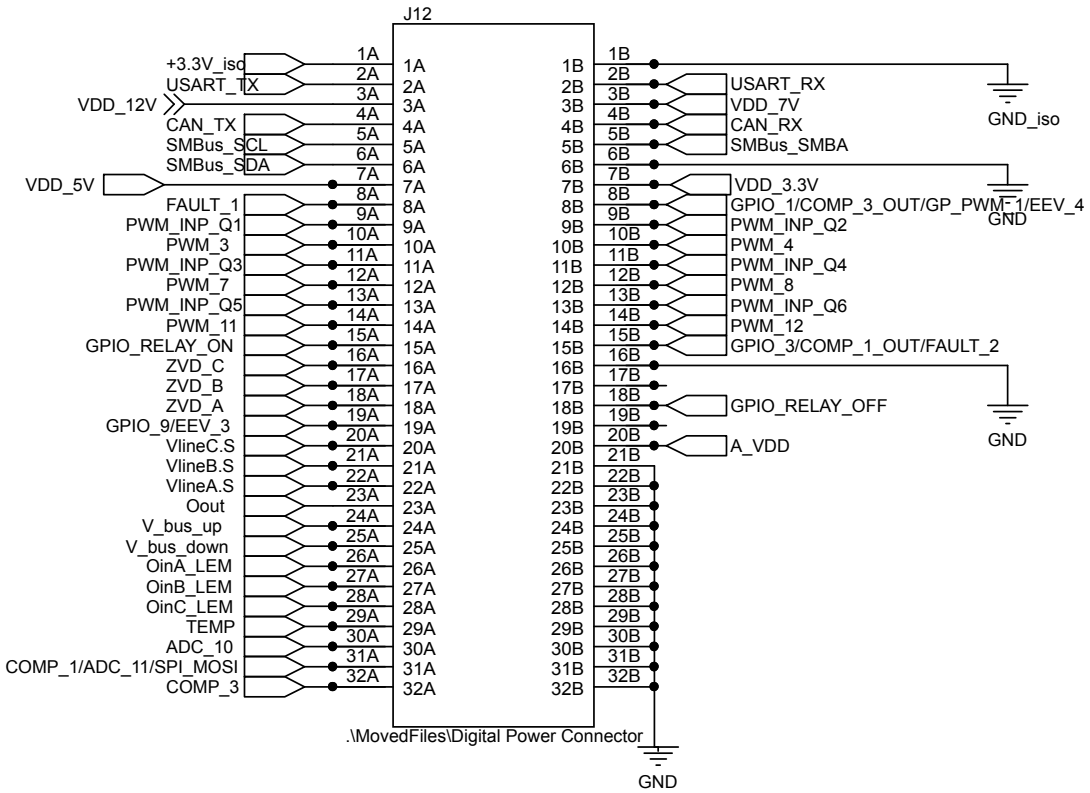


Figure 35. STDES-30KWVRECT power board circuit schematic (5 of 9)

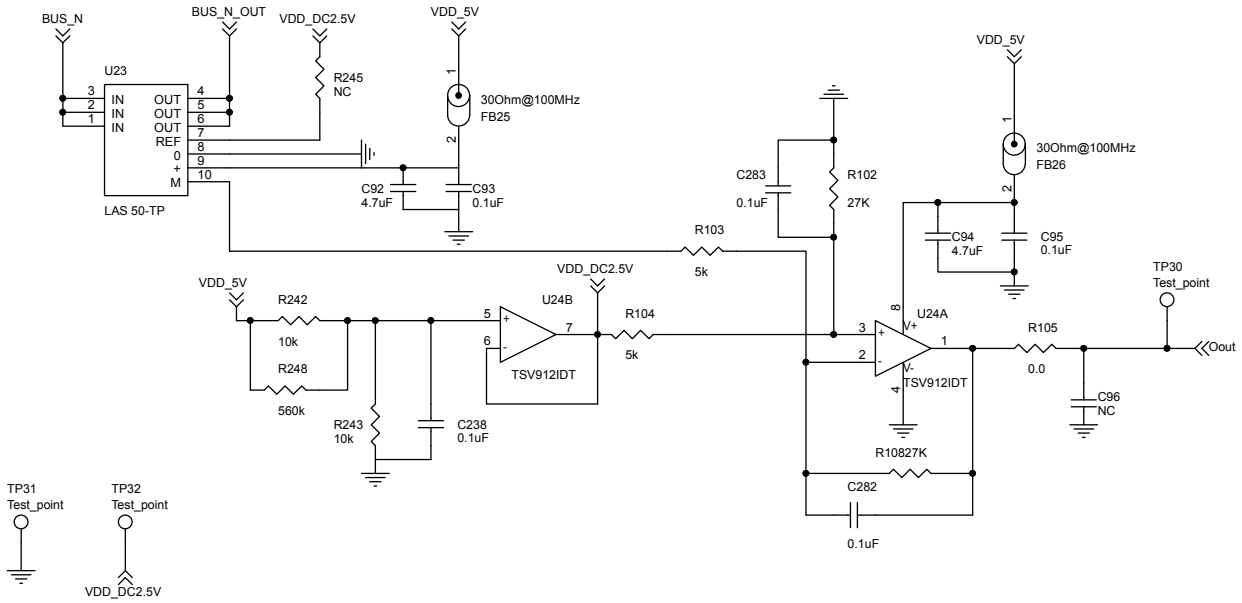
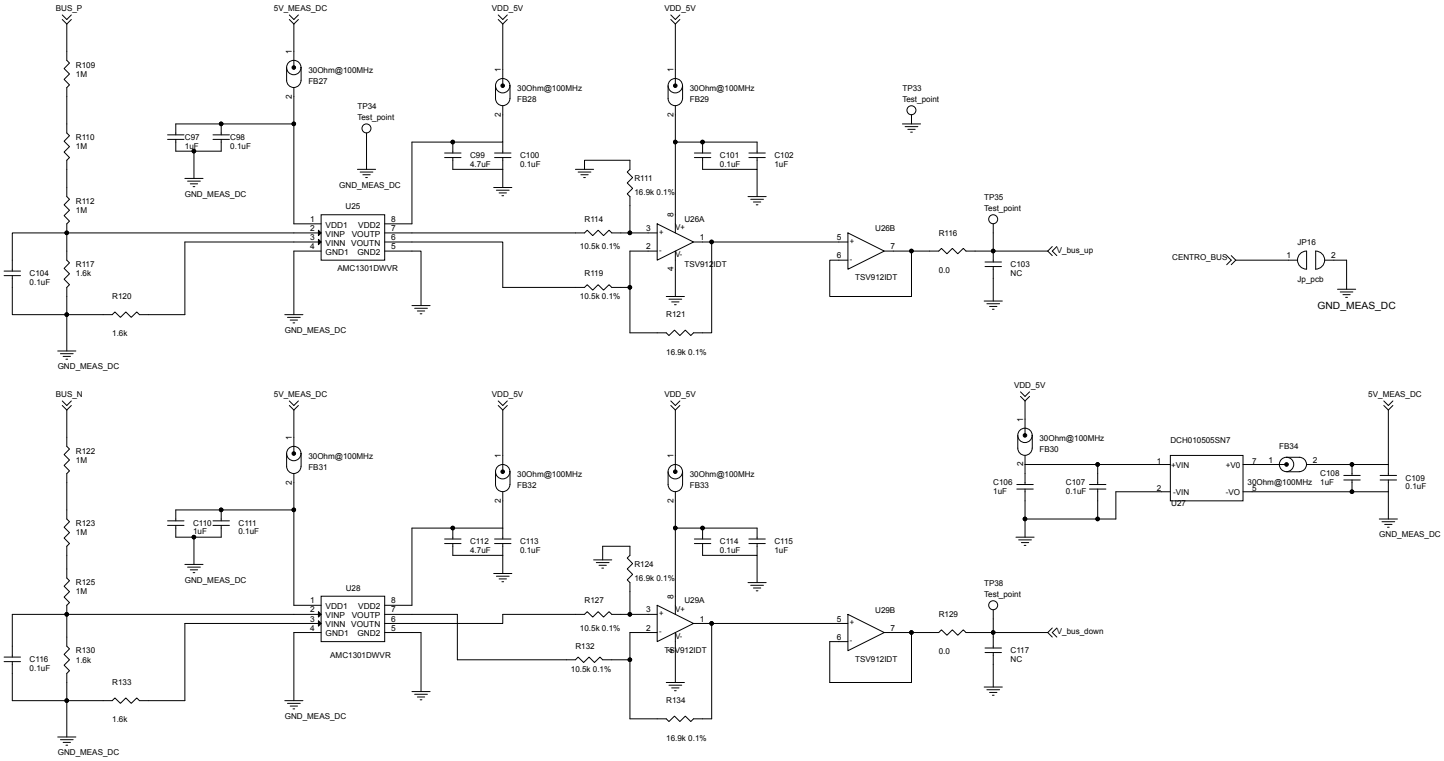


Figure 36. STDES-30KWVRECT power board circuit schematic (6 of 9)



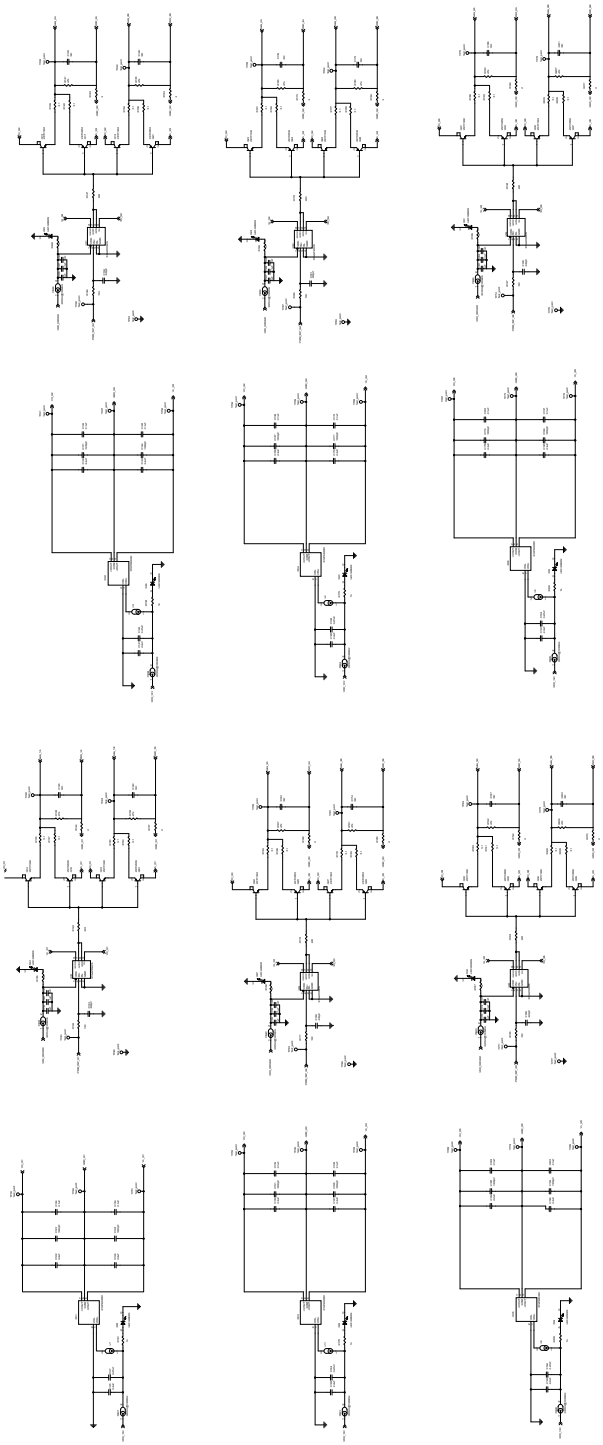


Figure 37. STDES-30KWVRECT power board circuit schematic (7 of 9)

Figure 38. STDES-30KWVRECT power board circuit schematic (8 of 9)

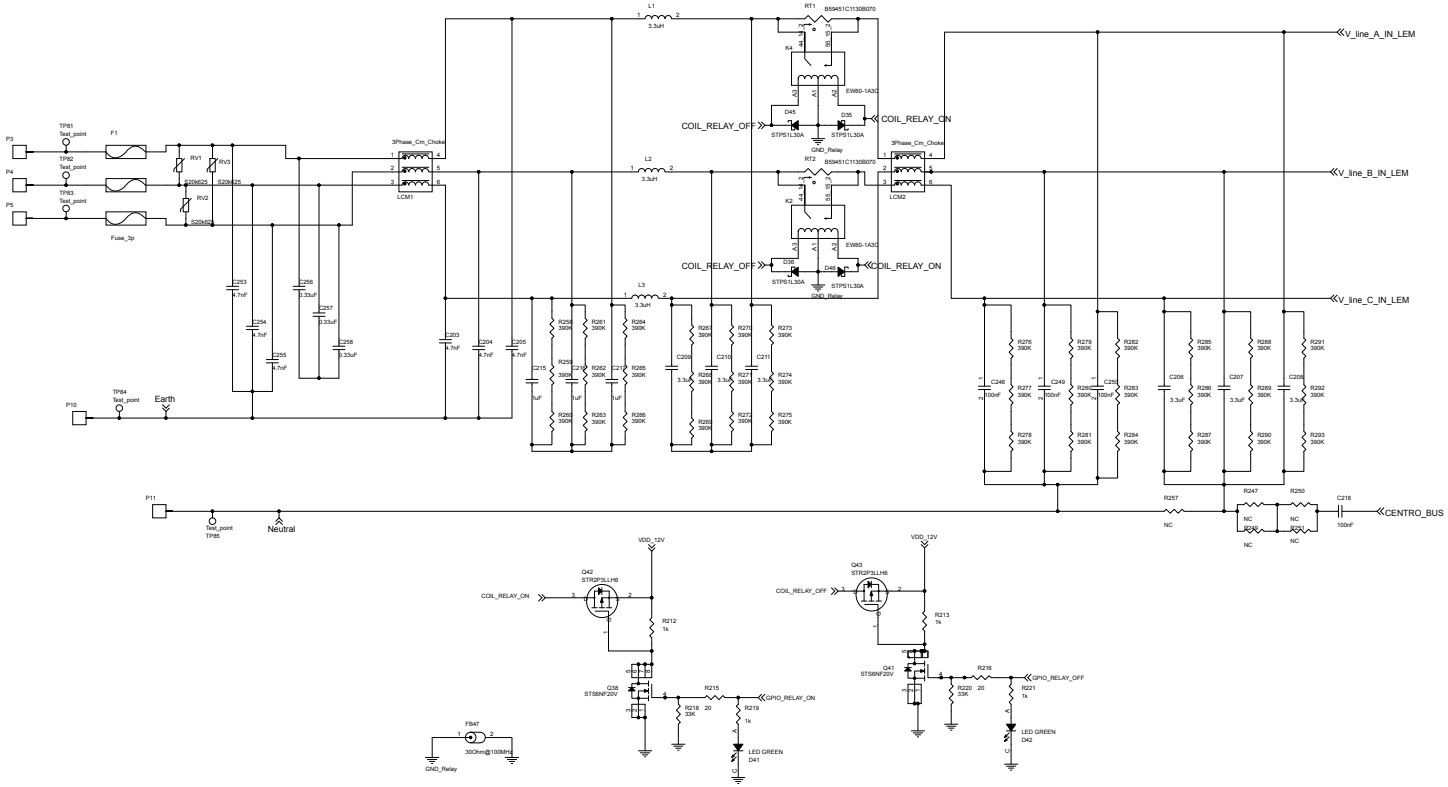


Figure 39. STDES-30KWVRECT power board circuit schematic (9 of 9)

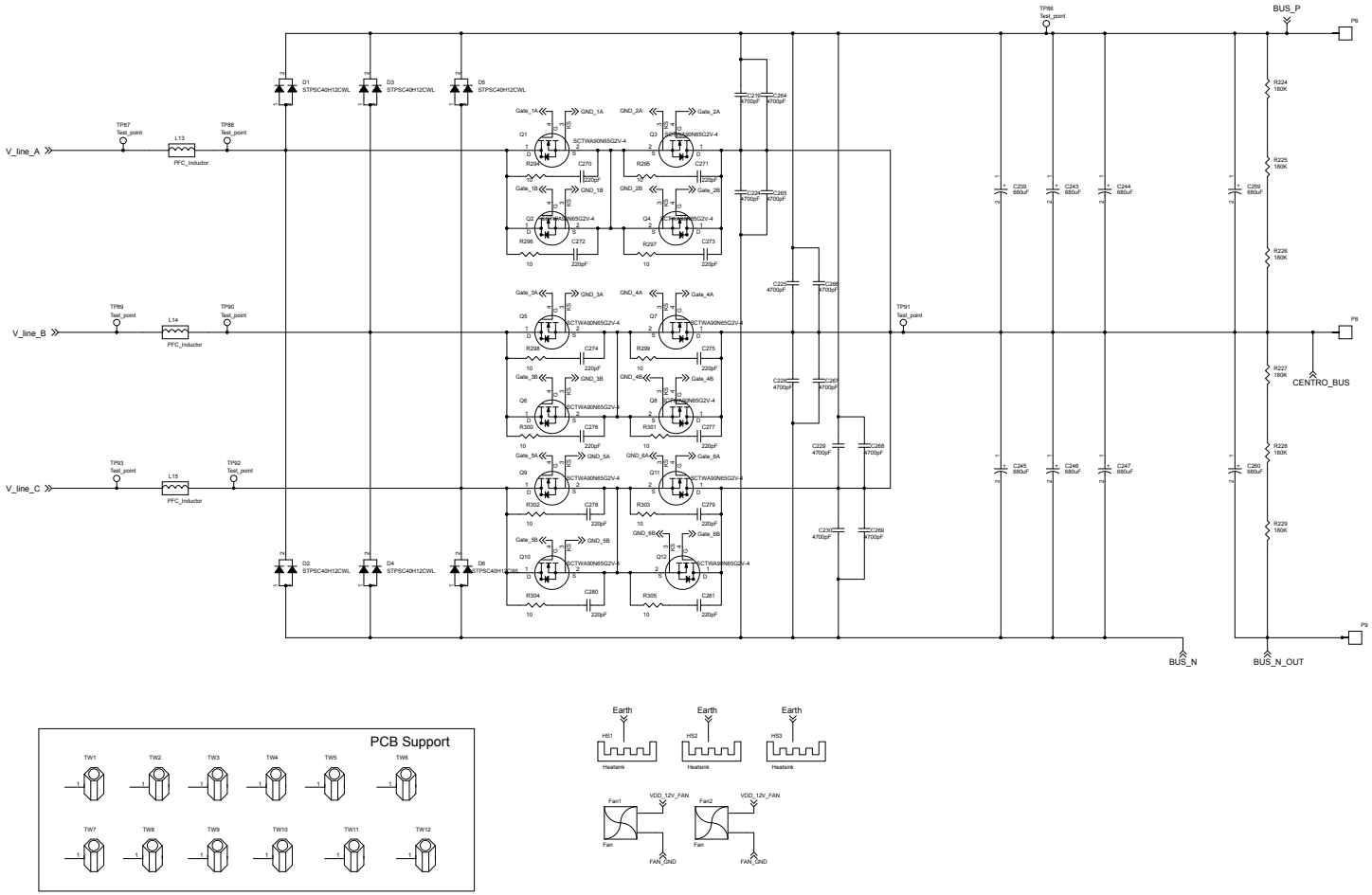
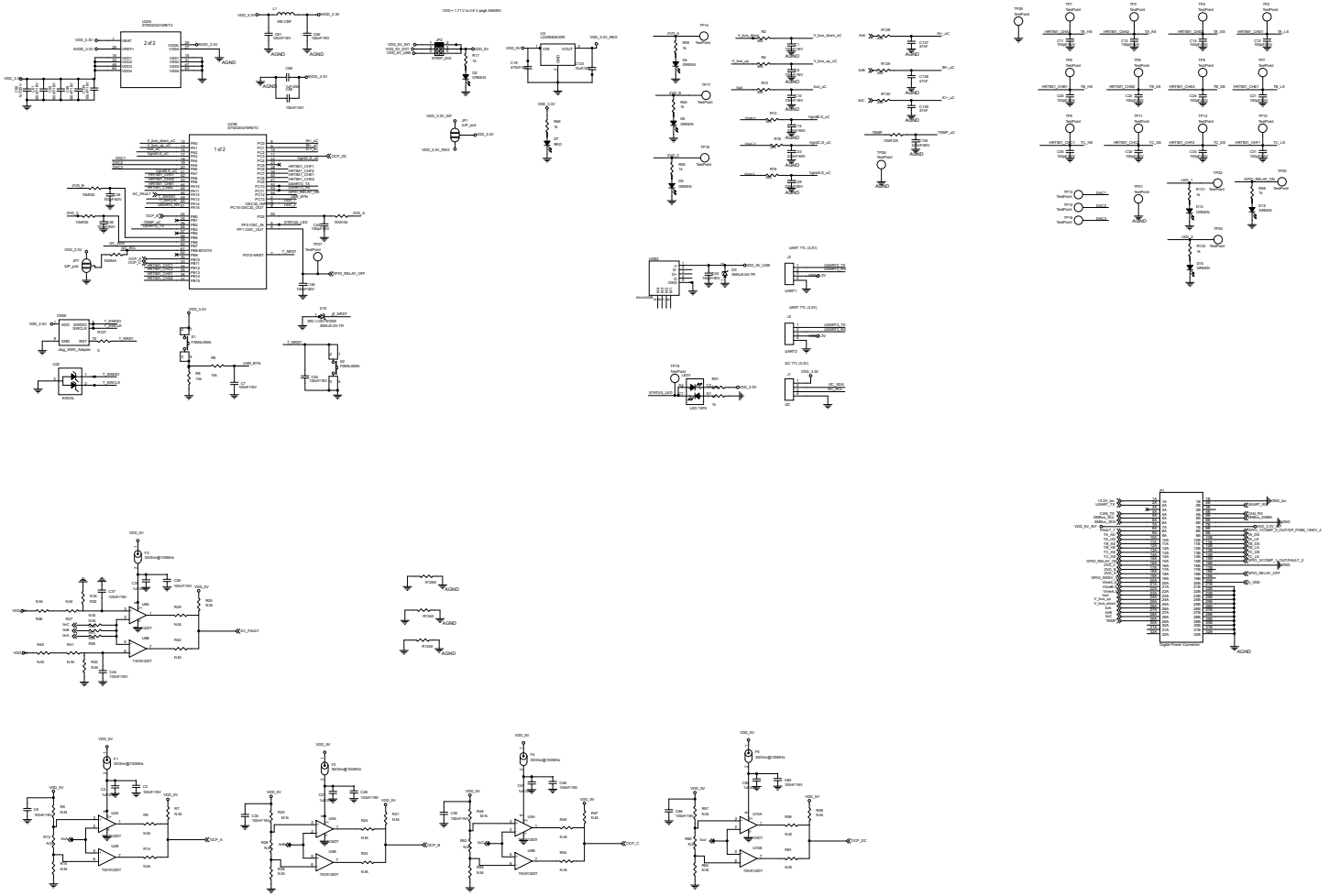


Figure 40. STDES-30KWVRECT control board circuit schematic



6 Bill of materials

Table 7. STDES-30KWVRECT bill of materials

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
1	1	Table 8. Power board bill of materials	-	Power board	ST	Not available for separate sale
2	1	Table 9. Control board bill of materials	-	Control board	ST	Not available for separate sale

Table 8. Power board bill of materials

Item	Qty.	Ref.	Part/value	Description	Manufacturer	Order code
1	32	C1,C2,C7, C8,C13,C15,C20,C24, C29,C33,C34,C38,C42,C45,C52, C58,C63,C97,C102,C106,C108, C110,C115,C119,C126,C147,C153,C175,C181,C235, C236,C237	1uF,0603 (1608 Metric),25V,10%	Ceramic capacitor	Wurth Electronics Inc.	885012206076
2	51	C3,C4,C9, C10,C14,C16,C19,C23,C25,C27, C28,C30,C31,C35,C36,C37,C40, C43,C44,C47,C48,C49,C51,C54, C55,C57,C59,C61,C62,C64,C65, C66,C93,C95,C98,C100,C101,C104,C107, C109,C111,C113,C114,C116,C120,C127,C148,C154, C176,C182,C238	0.1uF,0603 (1608 Metric),16V,10%	Ceramic capacitor	Wurth Electronics Inc.	885012206046
3	7	C26,C46,C60,C92,C94,C99,C112	4.7uF,0805 (2012 Metric),25V,10%	Ceramic capacitor	TDK Corporation	C2012X5R1E475K125AB
4	12	C68,C70,C73,C75,C76,C78,C137,C142,C164,C166,C192,C194	0.47uF,0805 (2012 Metric),50V,10%	Ceramic capacitor	AVX Corporation	08055C474KAT2A

Item	Qty.	Ref.	Part/value	Description	Manufacturer	Order code
5	7	C69,C71,C72,C74,C77,C79	10uF,0805 (2012 Metric),35V,10%	Ceramic capacitor	Taiyo Yuden	GMK212BBJ106KG-T
6	7	C133,C134,C161,C162,C189,C190	220pF,0603 (1608 Metric),50V,10%	Ceramic capacitor	Samsung Electro-Mechanics America, Inc.	CL10B221KB8NNNC
7	15	C124,C132,C139,C145,C152,C158,C169,C172,C180,C186,C197,C200,C282,C283	0.1uF,0603 (1608 Metric),50V,10%	Ceramic capacitor	Wurth Electronics Inc.	885012206095
8	6	C121,C128,C149,C155,C177,C183	1nF,0603 (1608 Metric),25V,10%	Ceramic capacitor	Samsung Electro-Mechanics	CL10B102KA8NNNC
9	18	C122,C130,C135,C136,C141,C143,C150,C156,C163,C165,C167,C170,C178,C184,C191,C193,C195,C198	2.2uF,0805 (2012 Metric),50V,10%	Ceramic capacitor	TDK Corporation	C2012X7R1H225K125AC
10	12	C123,C131,C138,C144,C151,C157,C168,C171,C179,C185,C196,C199	1000pF,0603 (1608 Metric),50V,10%	Ceramic capacitor	AVX Corporation	06035C102KAT2A
11	6	C203,C204,C205,C253,C254,C255	4.7nF,Radial, Disc, 440VAC Y5U	Ceramic capacitor	KEMET	ERK610Z472MCRU
12	6	C206,C207,C208,C209,C210,C211	3.3uF,Radial, Disc,305VAC,20%	Film capacitor	FARA	C42Q2335MBBC000
13	3	C215,C216,C217	1uF,Radial, Disc,305VAC,20%	Film capacitor	FARA	C42Q2105K9SC000
14	1	C218	100nF,Radial, Disc,1KVDC,10%	Film capacitor	KEMET	R474N310050A1K
15	12	C219,C224,C225,C228,C229,C230,C264,C265,C266,C267,C268,C269	4700pF, 1206 (3216 Metric), 630V C0G	Ceramic capacitor	TDK Corporation	CGA5F4C0G2J472J085AA
16	8	C239,C243,C244,C245,C246,C247,C259,C260	680uF,Radial, Can - Snap-In,450V,20%	Alum-electrolytic capacitor	EPCOS (TDK)	B43601A5687M000

Item	Qty.	Ref.	Part/value	Description	Manufacturer	Order code
17	3	C248,C249,C250	100nF,Radial, Disc,440VAC Y5U	Ceramic capacitor	KEMET	ERK610Z472MCRU
18	3	C256,C257,C258	0.33uF,Radial,305 VAC,20%	Film capacitor	EPCOS (TDK)	B32922C3334M000
19	12	C270,C271,C272,C273,C274,C275,C276,C277,C278,C279,C280,C281	220pF,1206 (3216 Metric),1KV C0G/NP0	Ceramic capacitor	Murata Electronics	GRM31A5C3A221JW01D
20	6	DC1,DC2, DC3,DC4, DC5,DC6	CONV DC/DC 2W ,0.77" L x 0.39" W x 0.49" H (19.5mm x 9.8mm x 12.5mm)	DC/DC Converter, 12VIN +20/-5VOUT	Recom Power	R12P22005D
21	6	D1,D2,D3, D4,D5,D6	STPSC40H12CWL, TO-247 long leads	1200 V, 40 A high surge silicon carbide power Schottky diode	ST	STPSC40H12CWL
22	22	D8,D9,D11, D12,D13,D14,D16,D17,D22,D23, D25,D26,D27,D28,D29,D30,D31, D32,D33,D34,D41,D42	SMD,0805 (2012 Metric)	Green Leds	Lite-On Inc.	LTST-C171GKT
23	4	D35,D36,D45,D46	STPS1L30A, SMA	30 V, 1 A low drop power Schottky rectifier	ST	STPS1L30A
24	53	FB1,FB2,FB3,L4,FB4, L5,FB5,L6, FB6,L7,FB7,FB8,L9,FB9,FB10,L11,FB11,FB12,FB13, FB14,FB15,FB16,FB17,FB18,FB19,FB20,FB21,FB22, FB23,FB24,FB25,FB26,FB27,FB28,FB29,FB30,FB31, FB32,FB33,FB34,FB35,FB36,FB37,FB38,FB39,FB40, FB41,FB42,FB43,FB44,FB45,FB46,FB47	Bead,0805,30Ohm	Ferrite beads	TDK Corporation	MPZ2012S300AT000
25	2	Fan1,Fan2	PFB0812DHE,12v,3.3a	FAN	Delta	PFB0812DHE

Item	Qty.	Ref.	Part/value	Description	Manufacturer	Order code
26	3	F1,F2,F3	50A 400VAC, 15mm x 51mm	Fuse	Eaton	C14G50
27	3	HS1,HS2,HS3	TO-247,130mm x 50mm x 18mm	Heatsink	-	-
28	3	JP5,JP12,JP13	CONN TERM BLOCK 2POS 5.08mm	Connector	Phoenix Contact	1715721
29	3	J1,J2,J3	Switch,SPDT,500 mA,12V,10mmx2.5mm,opposite side connect	Straight mini slide switch	Wurth Electronics Inc.	450301014042
30	1	J12	CON32x2, R/A 64POS 2.54 mm,	Digital power connector	Erni	284166
31	2	K2,K4	Relay,power latching, 60A,277VAC	Relay	TE Connectivity	EW60-1A3C
32	2	LCM1,LCM2	T60405-S6123-X140	Three-phase CM chock	VACUUMSCHMELZE	T60405-S6123-X140
33	3	L1,L2,L3	AGP4233-332ME	DM inductor	Coilcraft	AGP4233-332ME
34	3	L13,L14,L15	ARLDC724676C271N1B	PFC inductor	Sunloard	ARLDC724676C271N1B
35	8	P3,P4,P5,P6,P8,P9,P10,P11	PowerCon,9mmx 9.5mmx 3.5mm, M5	Power connector	Wurth	7460408
36	12	Q1,Q2,Q3,Q4,Q5,Q6,Q7,Q8,Q9,Q10,Q11,Q12	SCTWA90N65G2V-4, HiP247-4	Silicon carbide power MOSFET 650 V, 18 mOhm typ., 119 A in an HiP247-4 package	ST	SCTWA90N65G2V-4
37	12	Q14,Q15,Q18,Q19,Q22,Q23,Q26,Q27,Q30,Q31,Q34,Q35	2STF1360, SOT-89	Low voltage fast-switching NPN power transistor	ST	2STF1360
38	12	Q16,Q17,Q20,Q21,Q24,Q25,Q28,Q29,Q32,Q33,Q36,Q37	2STF2550, SOT-89	Low voltage high performance PNP power transistor	ST	2STF2550
39	2	Q38,Q41	STS6NF20V, SO-8	N-channel 20 V, 30 mOhm typ., 6 A, 2.7 V drive STripFET II power MOSFET in an SO-8 package	ST	STS6NF20V
40	2	Q42,Q43	STR2P3LLH6, SOT-23	P-channel 30 V, 0.048 Ohm typ., 2 A STripFET H6 power MOSFET in a SOT-23 package	ST	STR2P3LLH6
41	2	RT1,RT2	B59451C1130B070,±25%	PTC thermistors	TDK Electronics Inc.	B59451C1130B070

Item	Qty.	Ref.	Part/value	Description	Manufacturer	Order code
42	3	RV1,RV2,RV3	S20k625, DISC 14mm,625V,6.5KA	Varistor	EPCOS (TDK)	B72220S0621K101
43	16	Rled1,Rled2,Rled4,Rled5,R136,R151,R158,R160,R162,R178,R179,R187,R189,R204,R205,R246	1k,0603 (1608 Metric),1/10W,1%	Resistor	Yageo	RC0603FR-071KL
44	6	R1,R6,R7,R12,R13,R18	3.3k,0603 (1608 Metric),1/10W,1%	Resistor	Panasonic Electronic Components	ERA-3AEB332V
45	8	R2,R5,R8,R11,R14,R17,R103,R104,R76	5.1k,0603 (1608 Metric),1/10W,1%	Resistor	Yageo	RC0603FR-075K1L
46	21	R3,R9,R15,R19,R20,R21,R25,R34,R41,R42,R43,R47,R57,R66,R67,R68,R72,R84,R105,R116,R129	0,0603 (1608 Metric),1/10W,1%	Resistor	Yageo	RC0603JR-070RL
47	3	R22,R44,R69	36k,0603 (1608 Metric),1/10W,0.1%	Resistor	Yageo	RC0603BR-0736KL
48	3	R23,R45,R70	27k,0603 (1608 Metric),1/10W,0.1%	Resistor	Yageo	RT0603BRE0727KL
49	3	R24,R46,R71	69.8k,0603 (1608 Metric),1/10W,0.1%	Resistor	Yageo	RT0603BRE0769K8L
50	3	R26,R48,R74	13.3k,0603 (1608 Metric),1/10W,0.1%	Resistor	Yageo	RT0603BRE0713K3L
51	15	R27,R28,R30,R49,R50,R53,R75,R77,R80,R109,R110,R112,R122,R123,R125	1M,1206 (3216 Metric),1/4W,1%	Resistor	Yageo	RT1206FRE071ML
52	16	R29,R38,R52,R60,R78,R79,R88,R230,R231,R235,R236,R239,R240,R242,R243	10k,0603 (1608 Metric),1/10W,1%	Resistor	Yageo	RC0603FR-0710KL
53	6	R32,R40,R55,R64,R82,R90	12.4k,0603 (1608 Metric),1/10W,1%	Resistor	Yageo	RT0603FRE0712K4L

Item	Qty.	Ref.	Part/value	Description	Manufacturer	Order code
54	6	R35,R39,R58,R62,R85,R89	2k,0603 (1608 Metric),1/10W,1%	Resistor	Yageo	RC0603FR-072KL
55	1	R73	470,0603 (1608 Metric),1/10W,1%	Resistor	Yageo	RC0603FR-07470RL
56	4	R91,R92,R93,R94	750,0603 (1608 Metric),1/10W,1%	Resistor	Yageo	RC0603FR-07750RL
57	4	R102,R108	27K,0603 (1608 Metric),1/10W,1%	Resistor	Yageo	RC0603FR-0727KL
58	4	R111,R121,R124,R134	16.9k,0603 (1608 Metric),1/10W,0.1%	Resistor	Yageo	RT0603BRE0716K9L
59	4	R114,R119,R127,R132	10.5k,0603 (1608 Metric),1/10W,0.1%	Resistor	Yageo	RT0603BRE0710K5L
60	4	R117,R120,R130,R133	1.6k,0603 (1608 Metric),1/10W,1%	Resistor	Yageo	RC0603FR-071K6L
61	24	R135,R137,R139,R140,R150,R153,R154,R156,R161,R163,R164,R166,R176,R177,R182,R183,R186,R188,R191,R193,R202,R203,R208,R209	5.1,1210 (3225 Metric),1/2W,1%	Resistor	Yageo	RC1210FR-075R1L
62	12	R138,R141,R152,R155,R165,R167,R180,R181,R190,R192,R206,R207	47k,1206 (3216 Metric),1/4W,1%	Resistor	Yageo	RC1206FR-0747KL
63	6	R142,R146,R169,R171,R195,R197	100,0603 (1608 Metric),1/10W,1%	Resistor	Yageo	AT0603FRE07100RL
64	6	R143,R147,R170,R172,R196,R198	220,1210 (3225 Metric),1/2W,1%	Resistor	Yageo	RC1210FR-07220RL
65	12	R144,R148,R157,R159,R168,R173,R184,R185,R194,R199,R210,R211	2,1206 (3216 Metric),1/4W,1%	Resistor	Yageo	RC1206FR-072RL
66	4	R212,R213,R219,R221	1k,0603 (1608 Metric),1/10W,1%	Resistor	Yageo RC0603FR-071KL	RC0603FR-071KL
67	2	R215,R216	20,0603 (1608 Metric),1/10W,1%	Resistor	Yageo	RC0603FR-0720RL

Item	Qty.	Ref.	Part/value	Description	Manufacturer	Order code
68	3	R218,R220,R306	33K,0603 (1608 Metric),1/10W,1%	Resistor	Yageo	RC0603FR-0733KL
69	6	R224,R225,R226,R227,R228,R229	180K,1206 (3216 Metric),1/4W,0.1%	Resistor	Panasonic Electronic Components	ERA-8AEB184V
70	1	R248	560k,0603 (1608 Metric),1/10W,1%	Resistor	Yageo	RT0603FRE07560KL
71	36	R258,R259,R260,R261,R262,R263,R264,R265,R266,R267,R268,R269,R270,R271,R272,R273,R274,R275,R276,R277,R278,R279,R280,R281,R282,R283,R284,R285,R286,R287,R288,R289,R290,R291,R292,R293	390K,1206 (3216 Metric),1/4W,1%	Resistor	Yageo	RC1206FR-07390KL
72	12	R294,R295,R296,R297,R298,R299,R300,R301,R302,R303,R304,R305	10,1206 (3216 Metric),1/4W,0.1%	Resistor	Yageo	RT1206BRD0710RL
73	1	R307	330,0805 (2012 Metric),1/10W,0.01%	Resistor	Susumu	RG2012L-331-L-T05
74	82	TP1,TP2,TP3,TP5,TP6,TP8,TP9,TP10,TP11,TP12,TP13,TP14,TP15,TP16,TP19,TP22,TP23,TP26,TP27,TP28,TP30,TP31,TP32,TP33,TP34,TP35,TP38,TP39,TP40,TP41,TP42,TP43,TP44,TP45,TP46,TP47,TP48,TP49,TP50,TP51,TP52,TP53,TP54,TP55,TP56,TP57,TP58,TP59,TP	Test_point,0.100" Dia x 0.180" L (2.54mm x 4.57mm)	Test point	Keystone Electronics	5000

Item	Qty.	Ref.	Part/value	Description	Manufacturer	Order code
		60,TP61,TP62,TP63,TP64,TP65,TP66,TP67,TP68,TP69,TP70,TP71,TP72,TP73,TP74,TP75,TP76,TP77,TP78,TP79,TP80,TP81,TP82,TP83,TP84,TP85,TP86,TP87,TP88,TP89,TP90,TP91,TP92,TP93			
75	12	TW1,TW2,TW3,TW4,TW5,TW6,TW7,TW8,TW9,TW10,TW11,TW12	Support M3X40	PCB support M3 High 40mm	Essentra	TCBN-T1-M3-8-40
76	4	U1,U3,U5,U23	LAS 50-TP	Current Hall sensor	LEM	LAS 50-TP
77	9	U2,U4,U6,U7,U11,U14,U24,U26,U29	TSV912IDT, SO-8	Wide-bandwidth (8 MHz) rail to rail input/output 5 V CMOS op-amps, dual	ST	TSV912IDT
78	3	U8,U12,U15	TSV914IDT, SO-14	Wide-bandwidth (8 MHz) rail to rail input/output 5 V CMOS op-amps, quad	ST	TSV914IDT
79	5	U9,U13,U17,U25,U28	AMC1301DWVR, 8-SOIC (0.295", 7.50mm Width)	IC amplifier	Texas Instruments	AMC1301DWVR
80	2	U10,U27	DCH010505SN7, 7-SIP Module, 4 Leads	DC/DC Converter,5V,1W	Texas Instruments	DCH010505SN7
81	1	U16	STLM20W87F, SOT323-5L	Analog temperature sensor, ultra-low current 2.4 V, high precision	ST	STLM20W87F
82	2	U18,U20	LD29080DT50R, DPAK	800 mA fixed and adjustable output very low drop voltage regulator	ST	LD29080DT50R
83	2	U19,U21	LD29080S33R, SOT-223	800 mA fixed and adjustable output very low drop voltage regulator	ST	LD29080S33R
84	6	U30,U31,U32,U33,U34,U35	STGAP2SICS, SO 8 WIDE 300	Galvanically isolated 4 A single gate driver for SiC MOSFETs	ST	STGAP2SICS

Table 9. **Control board bill of materials**

Item	Qty.	Ref.	Part/value	Description	Manufacturer	Order code
1	1	CN56	Jtag_SWD_Adapter,10 Way, 2 Row,1.27mm	10 Way, 2 Row, Vertical Pin Header	-	-
2	23	C1,C3,C5,C6,C7,C10,C28,C34,C36,C37,C45,C48,C49,C51,C52,C53,C55,C59,C61,C62,C65,C66,C134	100nF,0603 (1608 Metric),16V,10%	Ceramic capacitor	Wurth	885012206046
3	7	C2,C27,C35,C47,C50,C58,C64	1uF,0603 (1608 Metric),25V,10%	Ceramic capacitor	Wurth	885012206076
4	17	C11,C12,C13,C14,C20,C21,C22,C24,C30,C31,C32,C33,C38,C40,C42,C43,C140	100pF,0603 (1608 Metric),50V,10%	Ceramic capacitor	Wurth	885012006057
5	3	C15,C23,C135	220nF,0603 (1608 Metric),50V,10%	Ceramic capacitor	TDK	CGA3E3X7R1H224K080AE
6	1	C18	470nF,0603 (1608 Metric),50V,10%	Ceramic capacitor	Wurth	885012207102
7	1	C29	220pF,0603 (1608 Metric),50V,10%	Ceramic capacitor	Wurth	885012206079
8	1	C133	10uF,0805 (2012 Metric),25V,10%	Ceramic capacitor	Samsung Electro-Mechanics America, Inc.	CL21A106KAYNNNG
9	3	C137,C138,C139	47nF,0603 (1608 Metric),50V,10%	Ceramic capacitor	Murata Electronics	GCM188R71H473KA55D
10	7	D2,D4,D5,D9,D12,D13,D15	Green,SMD,0805 (2012 Metric)	Green LED diode	Wurth	150080GS75000
11	2	D3,D10	SMAJ5.0A-TR, SMA	400 W TVS in SMA	ST	SMAJ5.0A-TR
12	1	D7	Red,SMD,0805 (2012 Metric)	Red LED diode	Wurth	150080RS75000
13	5	F1,F2,F3,F4,F5	Bead,0805 (2012 Metric),30Ohm	Ferrite Bead	Wurth	742792021
14	2	JP1,JP7	Solder Jumper Selector	Solder Jumper Selector	ANY	ANY
15	1	JP2	Solder Jumper Selector	Solder Jumper Selector	ANY	ANY
16	1	J1	4 Way, 1 Row, Straight Pin Header,2.54mm	Straight Pin Header	Wurth	61300411121
17	1	J2	4 Way, 1 Row, Straight Pin Header,2.54mm	Straight Pin Header	Wurth	61300411121

Item	Qty.	Ref.	Part/value	Description	Manufacturer	Order code
18	1	J3	4 Way, 1 Row, Straight Pin Header,2.54mm	Straight Pin Header	Wurth	61300411121
19	1	LED1	Green & Red,SMD,0805 (2012 Metric)	Green and red LED PLCC	OSRAM	LSG T676
20	1	L1	Bead,0603 (1608 Metric),120Ohm	Ferrite bead	WE	74279262
21	1	P1	CON32x2, R/A 64POS 2.54 mm,male	Digital power connector	ERNI	533406
22	9	R2,R4,R10 ,R13,R16, R19,R128, R129,R130	390,0603 (1608 Metric),1/10W,1%	Resistors	Yageo	RC0603FR-07390RL
23	7	R5,R8,R23 ,R30,R35, R44,R125	10k,0603 (1608 Metric),1/10W,1%	Resistors	Yageo	RC0603FR-0710KL
24	10	R17,R39,R 45,R46,R5 0,R51,R53, R56,R131, R133	1k,0603 (1608 Metric),1/10W,1%	Resistors	Yageo	RC0603FR-071KL
25	4	R126,R127 ,R134,R13 5	0,0603 (1608 Metric),1/10W,1%	Resistors	Yageo	RC0603JR-070RL
26	2	S1,S2	SWITCH TACTILE SPST-NO 0.05A 24V	Tactile SPST switch	TE Connectivity	FSM4JSMATR
27	26	TP1,TP2,T P3,TP4,TP 5,TP6,TP7, TP8,TP9,T P10,TP11, TP12,TP13 ,TP14,TP1 5,TP16,TP 17,TP18,T P19,TP20, TP21,TP22 ,TP24,TP2 5,TP26,TP 27	TestPoint	TestPoint	Keystone Electronics	5001
28	1	USB2	Micro USB 2.0 Molex tipo B	Micro USB 2.0	MOLEX	47346-0001
29	5	U2,U5,U6, U9,U10	TSV912IDT, SO-8	Wide-bandwidth (8 MHz) rail to rail input/output 5 V CMOS op-amps, dual	ST	TSV912IDT
30	1	U3	LD29080S33R, SOT-223	800 mA fixed and adjustable output very low drop voltage regulator	ST	LD29080S33R
31	1	U22	ESDA6V1, SOT23-3L	Dual Transil array for ESD protection	ST	ESDA6V1L

Item	Qty.	Ref.	Part/value	Description	Manufacturer	Order code
32	1	U23	STM32G474RET3, LQFP 64 10x10x1.4 mm	Mainstream Arm® Cortex®-M4 MCU 170 MHz with 512 Kbytes of flash memory, math accelerator, HR timer, high analog level integration	ST	STM32G474RET3

7 Conclusions

The test results shown demonstrate the good performance achieved by the STDES-30KWVRECT.

This reference design achieves a peak efficiency higher than 98.5% by using the ST 650 V, 18 mohm SiC MOSFETs (SCTWA90N65G2V-4), and the 1200 V, 40 A SiC Schottky diodes (STPSC40H12C).

Thanks to the STM32G474RET3, this platform achieves low total harmonic distortion (less than 5% THD at full load) and high-power factor (higher than 0.99 at full load).

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 10. **Document revision history**

Date	Revision	Changes
13-Apr-2022	1	Initial release.

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