1.3 kW Half-Bridge LLC Evaluation Board HBLLC-TSB-001

User's Guide

<High Voltage Safety Precautions>

◇ Read all safety precautions before use

Please note that this document covers only the 1.3 kW Half-Bridge LLC Evaluation Board (HBLLC-TSB-001) and its functions. For additional information, please refer to the datasheet.

To ensure safe operation, please carefully read all precautions before handling the evaluation board.

Depending on the configuration of the board and voltages used,

Potentially lethal voltages may be generated.

Therefore, please make sure to read and observe all safety precautions described in the box below.

Before Use

[1] Verify that the parts/components are not damaged or missing (e.g. due to the drops).
[2] Check that there are no conductive foreign objects on the board.
[3] Exercise caution when soldering the module and/or evaluation board to prevent solder splash.
[4] Check that there are no condensation or water droplets on the circuit board.

During Use

[5] Do not allow conductive objects to come into contact with the board.
[6] **Brief accidental contact or even bringing your hand close to the board may result in discharge and lead to severe injury or death.**

Therefore, DO NOT touch the board with your bare hands or bring them too close to the board.
In addition, as mentioned above, please exercise extreme caution when using conductive tools such as tweezers and screwdrivers.

[7] If used under conditions beyond its rated voltage, it may cause defects such as short-circuit or depending on the circumstances, explosion or other permanent damage.
[8] During operation, proceed with work while paying attention to discoloration or fluid leakage of the board and components due to heat, as well as condensation during low-temperature evaluations.

After Use

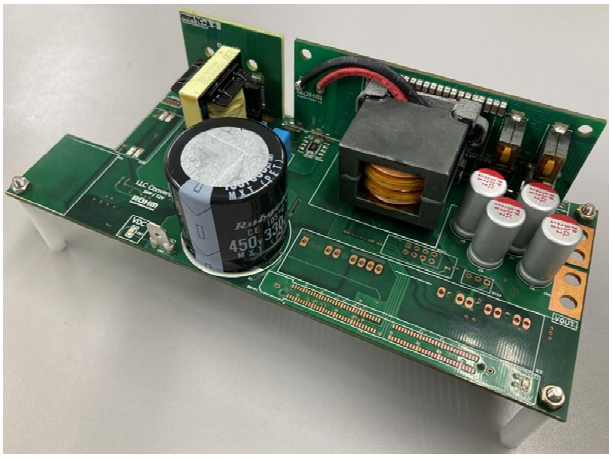
[9] The ROHM Evaluation Board may contain circuits that store high voltage. Because electrical charges remain even after the power supply is disconnected, be sure to discharge the board after use and verify the discharge before handling it.
[10] Be careful of burns caused by contact with overheated components.

This evaluation board is intended for use only in research and development facilities and should be handled **only by qualified personnel familiar with all safety and operating procedures.**
We recommend carrying out operation in a safe environment that includes the use of high voltage signage at all entrances, safety interlocks, and protective glasses.

HBLLC-TSB-001

1.3 kW Half-Bridge LLC Evaluation Board

This document is the user's guide for the 1.3 kW Half-Bridge LLC Resonant Converter Evaluation Board "HBLLC-TSB-001". This evaluation board provides a reference design for a high-efficiency, high-power-density isolated DC/DC converter designed for data center server power supplies, BBUs, and industrial high-power systems. This document describes the specifications and evaluation results of the evaluation board.



Description

The HBLLC-TSB-001 is a 1.3 kW LLC resonant converter evaluation board featuring 4th generation SJ-MOSFETs on the primary side and 7th generation Synchronous Rectification (SR) MOSFETs on the secondary side. This board operates with a 390 V DC input, assuming power supply from a preceding PFC (Power Factor Correction) circuit, and outputs a regulated 12 V DC. The board delivers a continuous output current of 83 A, and up to 108 A.

By adopting an LLC resonant topology, ZVS (Zero Voltage Switching) of the primary-side switching devices and ZCS (Zero Current Switching) of the secondary-side rectifying devices are achieved across the entire load range. This significantly reduces switching losses, achieving a peak efficiency of 97.0%.

The primary-side MOSFETs are mounted on the removable daughter board to allow device replacement evaluation. Note that the components generating the most heat on this evaluation board are the LLC transformer and the secondary-side board. If you are considering extending the power beyond the rated specification, redesigning these components for improved thermal performance will be necessary.

Features

Topology: Half-Bridge LLC Resonant Converter + Center-tapped Synchronous Rectification

Input Voltage: 390 V DC (Assumed PFC output)

Output Voltage: 12 V DC

Rated Output Power: 1000 W

Maximum Output Power: 1300 W

Peak Efficiency: >97.0 %

Switching Frequency: 42 kHz to 105 kHz

Primary Side MOSFET: R6050WNJ2 (600 V 50 A, TOLL, PrestoMOS™ Super Junction MOSFET)

Secondary Side Synchronous Rectification (SR) MOSFET: RS6G120CH (Nch 40 V 300 A, HSOP8, Power MOSFET)

Protections: Under Voltage Lock Out (UVLO), Output Over Current Protection (OCP)

Board Size: 170 mm × 70 mm × 37 mm

Applications

Data Center / Server Power Supplies

Battery Backup Unit (BBU)

Industrial Equipment / FA

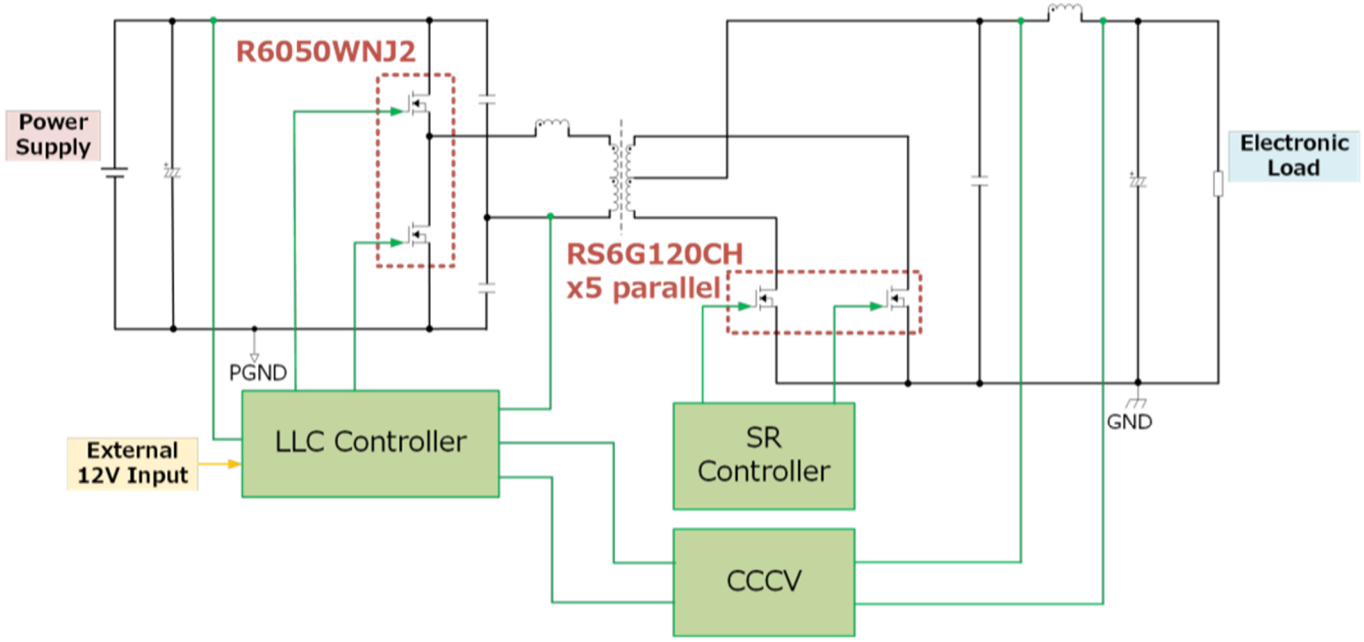


Figure 1. Block Diagram

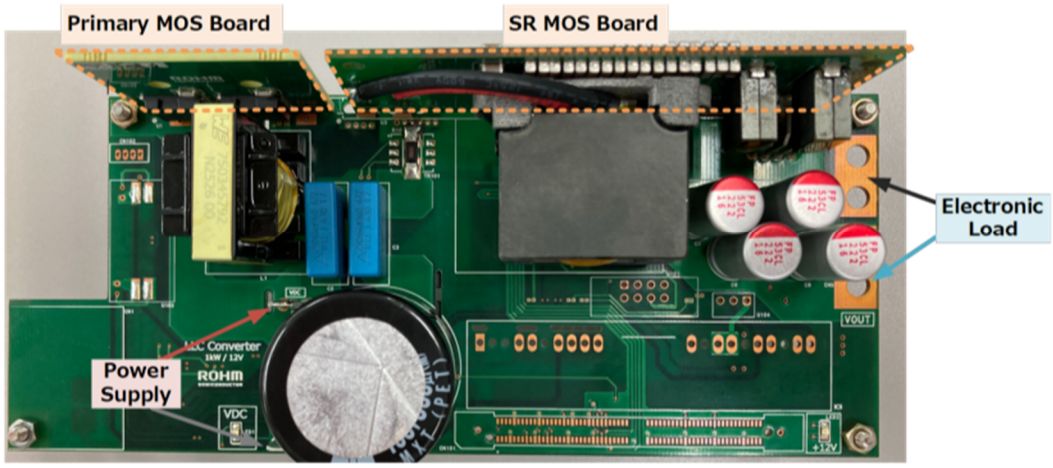


Figure 2. Board Top View Image

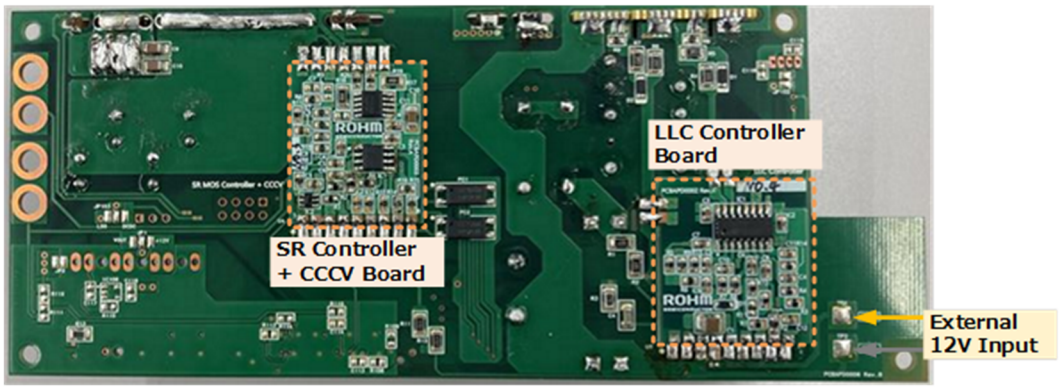


Figure 3. Board Bottom View Image

Figure 4. Primary-side MOSFET Daughter Board

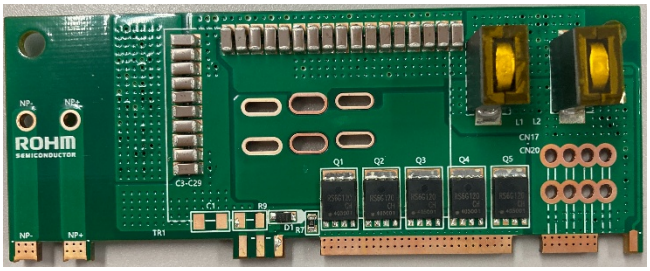


Figure 5. Secondary-side SR MOSFET Daughter Board (without transformer)

1. Performance Specifications

Table 1. Board Performance Specifications

Parameter	Specification
DC Input Voltage	390 V
Efficiency	97.0% peak
Leakage Current	0.61 mA
Output Voltage	12 V
Rated Output Power	1000 W
Max Output Power	1300 W
Output Current	108 A
Output Over Current Protection	150 A
Ripple Voltage *1	65 mV Ripple
Under Voltage Lock Out	300 V
Start up Voltage	330 V
Operating Temperature Range	25 °C

*1: Excluding spike noise.

2. Efficiency Evaluation Results

The efficiency measurement results under an ambient temperature (Ta) of 25 °C are shown below. This evaluation board achieved a peak efficiency of 97.0%. Furthermore, efficiencies of 95.9% at the rated power of 1000W and 94.4% at full load (1300 W) were obtained.

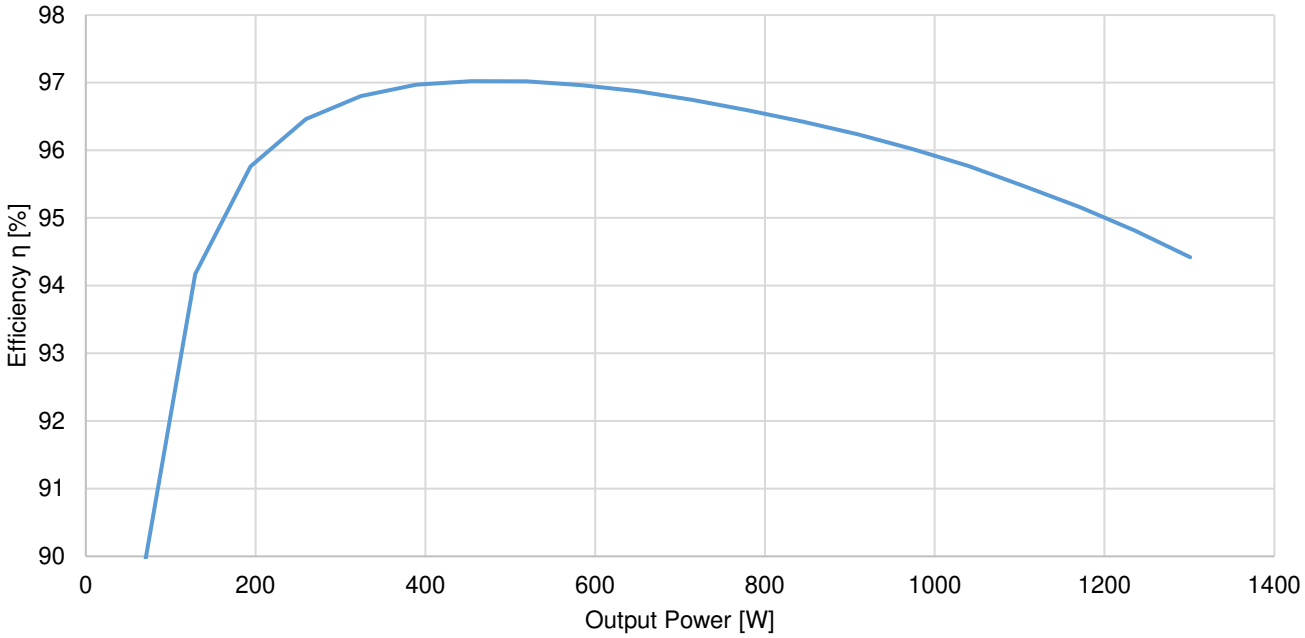


Figure 6. Efficiency Measurement Results

3. Operating Waveforms

Figure 7 and Figure 8 show the operating waveforms of each part at full load (1300 W). The measurement targets for each channel in Figure 7 are as follows:

- CH1: Primary Side Low-side MOSFET Vds
- CH2: Primary Side High-side MOSFET Vds
- CH5: Primary Side Resonant Current Ir
- CH7: Secondary Side SR MOSFET1 Vds
- CH8: Secondary Side SR MOSFET2 Vds

Figure 8 shows the output voltage Vout.

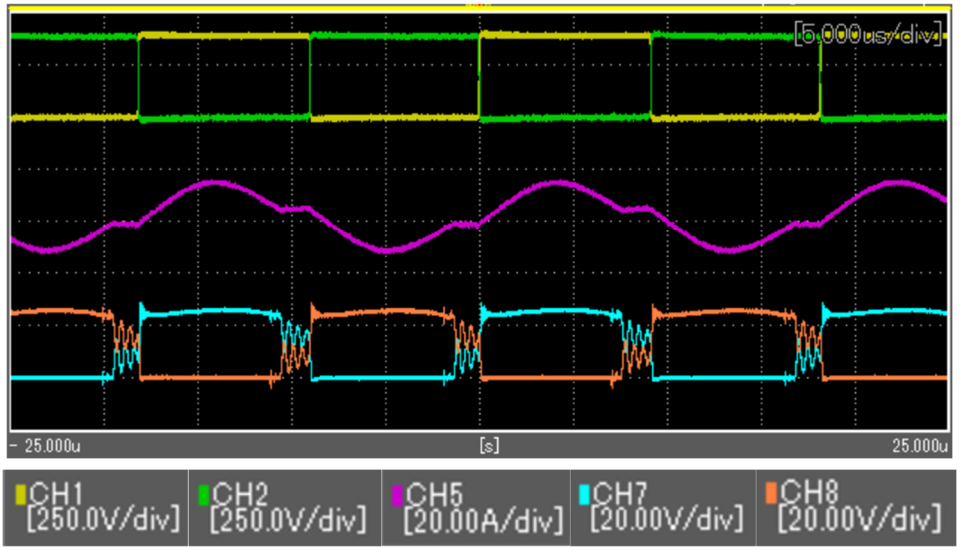


Figure 7. LLC Operating Waveforms (at Full Load)

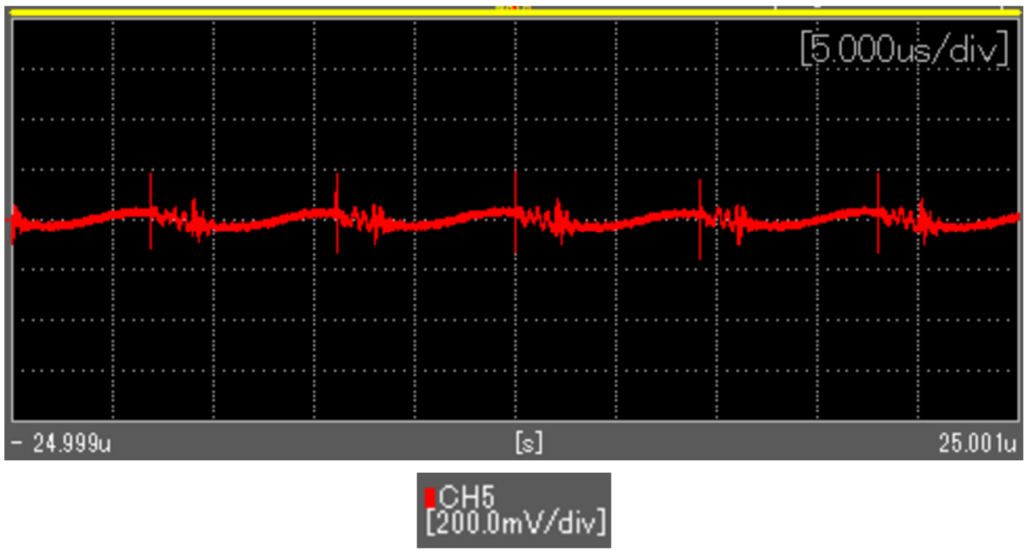


Figure 8. LLC Output Voltage Waveform (at Full Load)

4. Thermal Characteristics (Temperature Evaluation Results)

The thermal characteristic evaluation results when operated continuously for 30 minutes at the rated power (1000 W) condition are shown (Ta=25 °C). Figure 9 shows the surface temperature distribution using a thermography camera, and Table 2 details the temperature at each measurement point (MP). Note that this measurement was conducted under forced air cooling using an external fan, with a heat sink attached to the secondary board. The part generating the highest temperature on this evaluation board is the secondary winding (foil winding) of the transformer. If considering operation at higher power, it is necessary to redesign the transformer as the thermal design margin may become insufficient.

Figure 9. Surface Temperature Distribution (at Rated Load)

Table 2. Temperature at Each Measurement Point

Point	Description	Temp.(°C)
MP1	Transformer	59.4 °C
MP2	Secondary MOSFET	58.9 °C
MP3	Primary MOSFET	36.9 °C
MP-MAX	Transformer secondary winding	81.1 °C

5. Transformer Specifications

This evaluation board utilizes an LLC transformer manufactured by Würth Elektronik. Table 3 shows the main electrical characteristics and constants of the transformer.

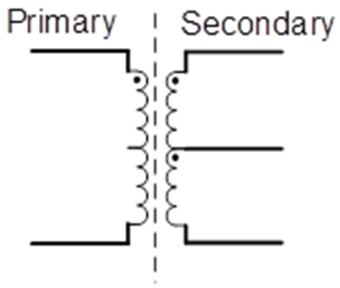


Figure 10. Transformer Model Diagram

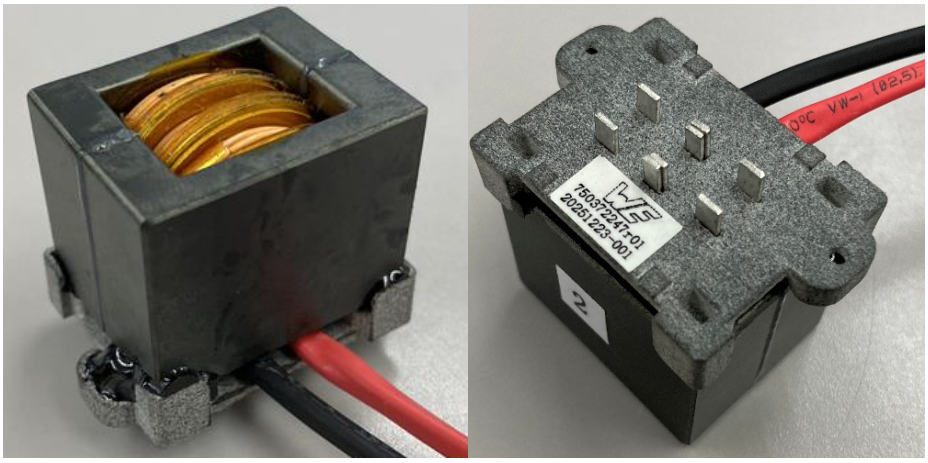


Figure 11. Transformer External View

Table 3. Transformer Constants

Parameter	Specification
Inductance	240 µH
Leakage Inductance	2.4 µH
D.C. Resistance Pri	45 mΩ
D.C. Resistance Sec	0.33 mΩ
Turn ratio	16:1

6. Loss Calculation Results

Figure 12 shows a comparison between the calculated and measured efficiency values of this LLC converter. A strong correlation with an error of less than 0.5% over the entire load range has been obtained, and this calculation model can be used to estimate loss trends at any given load point.

Additionally, Figure 13 shows the breakdown of losses by device at each load point. It can be confirmed that the main loss factors in this evaluation are the conduction loss of the board patterns and the LLC transformer (core loss and copper loss).

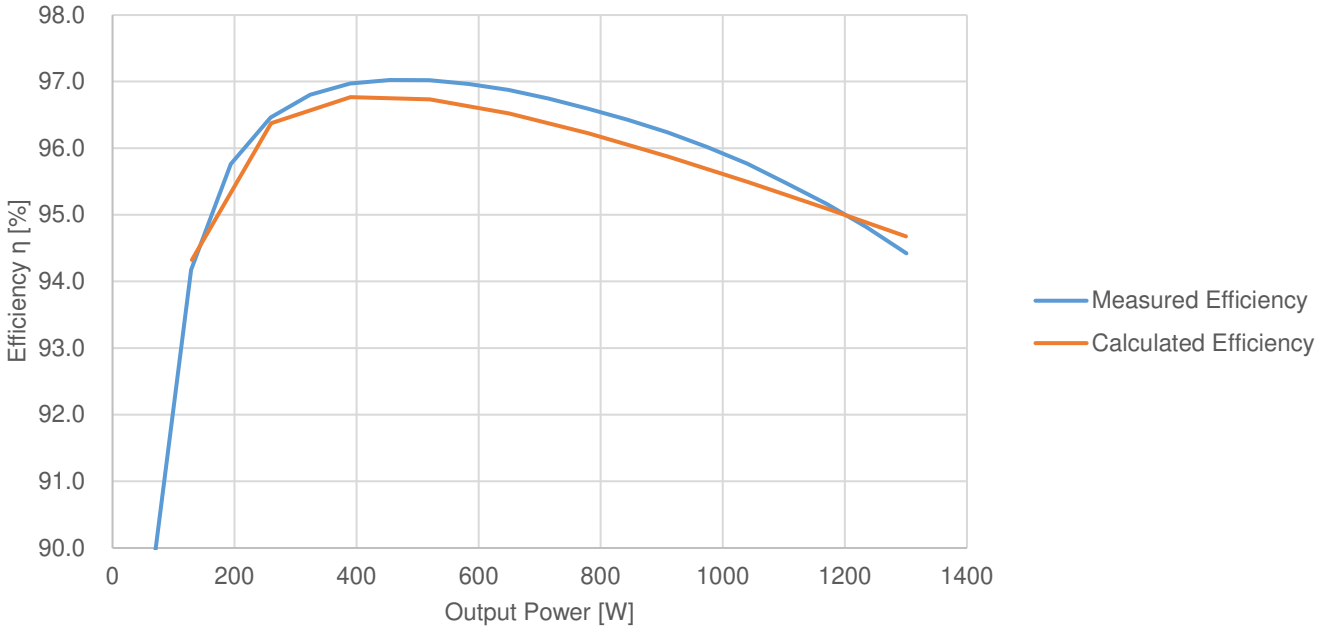


Figure 12. Measured vs. Calculated Efficiency Comparison

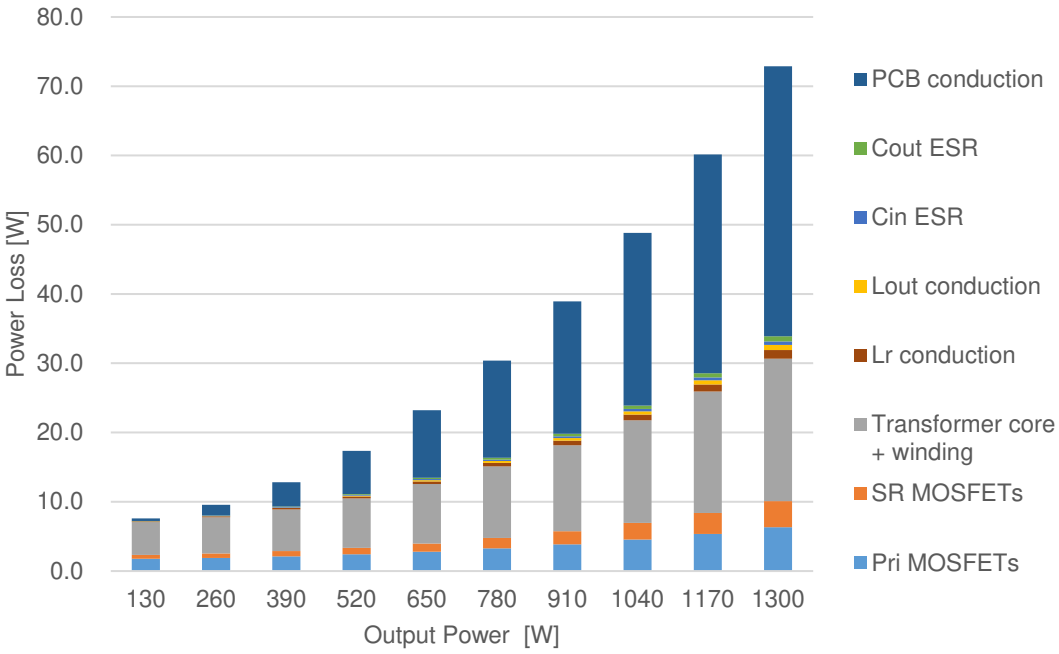


Figure 13. Breakdown of Loss Calculations

7. Bill of Materials

Table 4. Main board BOM

Part Reference	Description	Part Number	Manufacture	Qty.
C1	CAP Electrolytic 390µF ±20% 450V Φ30x30mm SMT	450MXT390MEFCSN30X30	Rubycon	1
C2,C3	CAP Film 0.12µF ±5% 630V Class - SMT	B32672Z6124J	TDK	2
C4	CAP CER 220pF ±5% 630Vdc U2J 3216 SMD	GRM31A7U2J221J	Murata	1
C5,C6,C7,C8	CAP Electrolytic 2200µF ±20% 16V Φ10×20mm SMT	RNL1C222MDS1	Nichicon	4
C9,C10	CAP CER 1µF ±10% 50Vdc X7R 3216 SMD	MSASU31LSB7105KTNA01	Taiyo Yuden	2
CN1	CONNECTOR 2pin 250V AC Inlet C14	6100-4	schurter	1
CN2,CN3	CONNECTOR 1pin -V -mm pitch SMT	7471287	Würth	2
CN4	CONNECTOR 1pin -V -mm pitch SMD	9775046360R	Würth	4
D1,D2	DIODE SHOTTKEY BARRIER 40V 1A VF:0.52V PMDU SMD	RBR1MM40A	ROHM	2
L1	COIL 24µH±10% 25mΩ 7A 28x20.3mm x 28.6mm SMD	750345792	Würth	1
LED1	LED RED 20mA VF 2.2V SMD	SML-H12U8TT86	ROHM	1
LED2	LED Green 20mA VF 2.2V SMD	SML-H12M8T	ROHM	1
PC1,PC2	RES 1MΩ J(±5%) 3216 0.25W 500V SMD	TCLT1008	ROHM	2
R1,R2	RES 1MΩ J(±5%) 3216 0.25W 500V SMD	KTR18EZPJ105	ROHM	2
R3	RES 47Ω J(±5%) 3216 0.25W 200V SMD	MCR18EZPJ470	ROHM	1
R4,R6	RES 10Ω J(±5%) 3216 0.5W 200V SMD	ESR18EZPJ100	ROHM	2
R5,R7	RES 3.3Ω J(±5%) 3216 0.5W 200V SMD	ESR18EZPJ3R3	ROHM	2
R8,R9	RES 10kΩ J(±5%) 1608 0.1W 50V SMD	MCR03EZPJ103	ROHM	2
R10	RES 100kΩ FX(±1%) 1608 0.1W 50V SMD	PMR50HZPJ000	ROHM	1
R11,R12	RES 470kΩ F(±1%) 3216 0.25W 500V SMD	KTR18EZPF4703	ROHM	2
R13	RES 2.2kΩ F(±1%) 3216 0.25W 200V SMD	MCR18EZPF2201	ROHM	1
U1	Daughter Board (MOSFET for LLC)	LLCMOS_REV2504	ROHM/EVK	1
U2	Daughter Board (Controller Circuit for LLC 1.3kW)	LLCCONT_Rev2504_A	ROHM/EVK	1
U3	Daughter Board (SR MOS+Trans, etc for LLC 1.3kW)	SRMOS_Rev2504_B	ROHM/EVK	1
U4	Daughter Board (CCCV Controller Circuit for LLC 1.3kW)	CCCV_Rev2504_A	ROHM/EVK	1
U5	Daughter Board (Auxialliry Power Supply for Server PC)	AUXPS_Rev2510_A	ROHM/EVK	1

Table 5. LLCMOS board BOM

Part Reference	Description	Part Number	Manufacture	Qty.
C1,C2	CAP CER 100pF ±5% 630Vdc C0G 3216 SMD	GRM31A5C2J101J	Murata	2
Q1,Q2	TRANSISTOR MOSFET Nch 600V Id:50A 0.099Ω SMD	R6050WNJ2	ROHM	2

Table 6. LLCCONT board BOM

Part Reference	Description	Part Number	Manufacture	Qty.
C1	CAP CER 10µF ±10% 50Vdc X7R 3225 SMD	MSASU32MAB7106KPNA01	Taiyo Yuden	1
C2,C12	CAP CER 0.1µF ±20% 100Vdc X7R 1608 SMD	MSASH168SB7104MTNA01	Taiyo Yuden	2
C3,C7,C9	CAP CER 0.22µF ±10% 50Vdc X7R 1608 SMD	MSASU168SB7224KTNB25	Taiyo Yuden	3
C4	CAP CER 4700pF ±20% 100Vdc X7R 1608 SMD	MSASH168SB7472MTNA01	Taiyo Yuden	1
C5	CAP CER 47nF ±20% 100Vdc X7R 1608 SMD	MSASH168SB7473MTNA01	Taiyo Yuden	1
C6,C8	CAP CER 1000pF ±20% 100Vdc X7R 1608 SMD	MSASH168SB7102MTNA01	Taiyo Yuden	2
C10	CAP CER 330pF ±10% 100Vdc undefined 1608 SMD	MSASH168SSD331KTNA01	Taiyo Yuden	1
C11	CAP CER 10nF ±10% 100Vdc X7R 1608 SMD	MSASH168SB7103KTNA01	Taiyo Yuden	1
D1	DIODE SWITCHING 80V 0.1A VF:1.2V UMD2 SMD	1SS355VM	ROHM	1
IC1	IC Resonat controller SMD	L6699D	ST	1
R1	RES 100kΩ FX(±1%) 1608 0.1W 50V SMD	MCR03EZPFX1003	ROHM	1
R2	RES 0Ω J(±5%) 1608 0.1W 50V SMD	MCR03EZPJ000	ROHM	1
R3	RES 8.2kΩ FX(±1%) 1608 0.1W 50V SMD	MCR03EZPFX8201	ROHM	1
R4	RES 10Ω J(±5%) 1608 0.1W 50V SMD	MCR03EZPJ100	ROHM	1
R5	RES 27kΩ FX(±1%) 1608 0.1W 50V SMD	MCR03EZPFX2702	ROHM	1
R6	RES 5.6kΩ FX(±1%) 1608 0.1W 50V SMD	MCR03EZPFX5601	ROHM	1
R7	RES 56Ω FX(±1%) 1608 0.1W 50V SMD	MCR03EZPFX56R0	ROHM	1
R8	RES 270kΩ FX(±1%) 1608 0.1W 50V SMD	MCR03EZPFX2703	ROHM	1
R9	RES 15kΩ FX(±1%) 1608 0.1W 50V SMD	MCR03EZPFX1502	ROHM	1
R10	RES 39Ω FX(±1%) 1608 0.1W 50V SMD	MCR03EZPFX39R0	ROHM	1
R11	-	N.C.	-	0
R12	RES 150Ω J(±5%) 1608 0.1W 50V SMD	MCR03EZPJ151	ROHM	1
R13	RES 470kΩ J(±5%) 1608 0.1W 50V SMD	MCR03EZPJ474	ROHM	1
R14	RES 100Ω J(±5%) 1608 0.1W 50V SMD	MCR03EZPJ101	ROHM	1

Table 7. SRMOS board BOM

Part Reference	Description	Part Number	Manufacture	Qty.
C1	-	N.C.	-	0
C2	-	N.C.	-	0
C3~C50	CAP CER 10µF ±10% 35Vdc X7R 3216 SMD	C3216X7R1V106	TDK	48
CN17,CN18, CN19,CN20	CONNECTOR 1pin -V -mm pitch SMT	7474966	Würth	4
D1,D2	TVS 40V PMDE SMD	VS40VUA1VWM	ROHM	2
L1,L2	COIL 0.1µH±15% 0.125mΩ 125A φ-mm x 12mm SMD	74431012010	Wurth	2
Q1~Q5, Q7~Q11	TRANSISTOR MOSFET Nch 40V Id:300A 0.00125Ω SMD	RS6G120CH	ROHM	10
R7,R8	RES 100kΩ J(±5%) 1608 0.1W 50V SMD	MCR03EZPJ104	ROHM	2
R9,R10	RES T.B.D 3216 SMD	NON-MCR18	ROHM	2
TR1	TRANSFORMER 16:1 Lm:240µF Lr:2.4µF SMT	750372247	Würth	1

Table 8. CCCV board BOM

Part Reference	Description	Part Number	Manufacture	Qty.
C1,C2,C5, C9	CAP CER 1µF ±10% 25Vdc X7R 1608 SMD	MSAST168SB7105KTNA01	Taiyo Yuden	4
C3,C8,C11	CAP CER 0.1µF ±20% 100Vdc X7R 1608 SMD	MSASH168SB7104MTNA01	Taiyo Yuden	3
C4,C6	CAP CER 1000pF ±20% 100Vdc X7R 1608 SMD	MSASH168SB7102MTNA01	Taiyo Yuden	2
C7	-	N.C.	-	0
C10	CAP CER 10µF ±20% 25Vdc X7R 3216 SMD	MSAST31LAB7106MTNA01	Taiyo Yuden	1
IC1	IC CCCV Controller - - SO-8 SMD	TSM1014A	ST	1
IC2	IC Current Sense AMP SMD	BD14210G-C	ROHM	1
IC3	IC Synchronous rectification controller for LLC SMD	SRK2001	ST	1
R1	RES 10kΩ FX(±1%) 1608 0.1W 50V SMD	MCR03EZPFX1002	ROHM	1
R2	RES 100kΩ FX(±1%) 1608 0.1W 50V SMD	MCR03EZPFX1003	ROHM	1
R3	RES 15kΩ FX(±1%) 1608 0.1W 50V SMD	MCR03EZPFX1502	ROHM	1
R4,R5	RES 3.3kΩ FX(±1%) 1608 0.1W 50V SMD	MCR03EZPFX3301	ROHM	2
R6	RES 82kΩ FX(±1%) 1608 0.1W 50V SMD	MCR03EZPFX8202	ROHM	1
R7	RES 4.3kΩ FX(±1%) 1608 0.1W 50V SMD	MCR03EZPFX4301	ROHM	1
R8	RES 10kΩ FX(±1%) 1608 0.1W 50V SMD	MCR03EZPFX1002	ROHM	1
R9,R21	RES Ω 1608 W V SMD	NON-MCR03	ROHM	2
R10	RES 47kΩ FX(±1%) 1608 0.1W 50V SMD	MCR03EZPFX4702	ROHM	1
R11	RES 56Ω FX(±1%) 1608 0.1W 50V SMD	MCR03EZPFX56R0	ROHM	1
R12	RES 3.9kΩ FX(±1%) 1608 0.1W 50V SMD	MCR03EZPFX3901	ROHM	1
R13	RES 6.8kΩ FX(±1%) 1608 0.1W 50V SMD	MCR03EZPFX6801	ROHM	1
R14	RES 0Ω J(±5%) 1608 0.1W 50V SMD	MCR03EZPJ000	ROHM	1
R15	RES 15kΩ FX(±1%) 1608 0.1W 50V SMD	MCR03EZPFX1502	ROHM	1
R16	RES 820kΩ FX(±1%) 1608 0.1W 50V SMD	MCR03EZPFX8203	ROHM	1
R17,R18	RES 1Ω J(±5%) 3216 0.5W 200V SMD	ESR18EZPJ1R0	ROHM	2
R19,R20	RES 220Ω J(±5%) 1608 0.1W 50V SMD	MCR03EZPJ221	ROHM	2

8. Schematic Diagrams

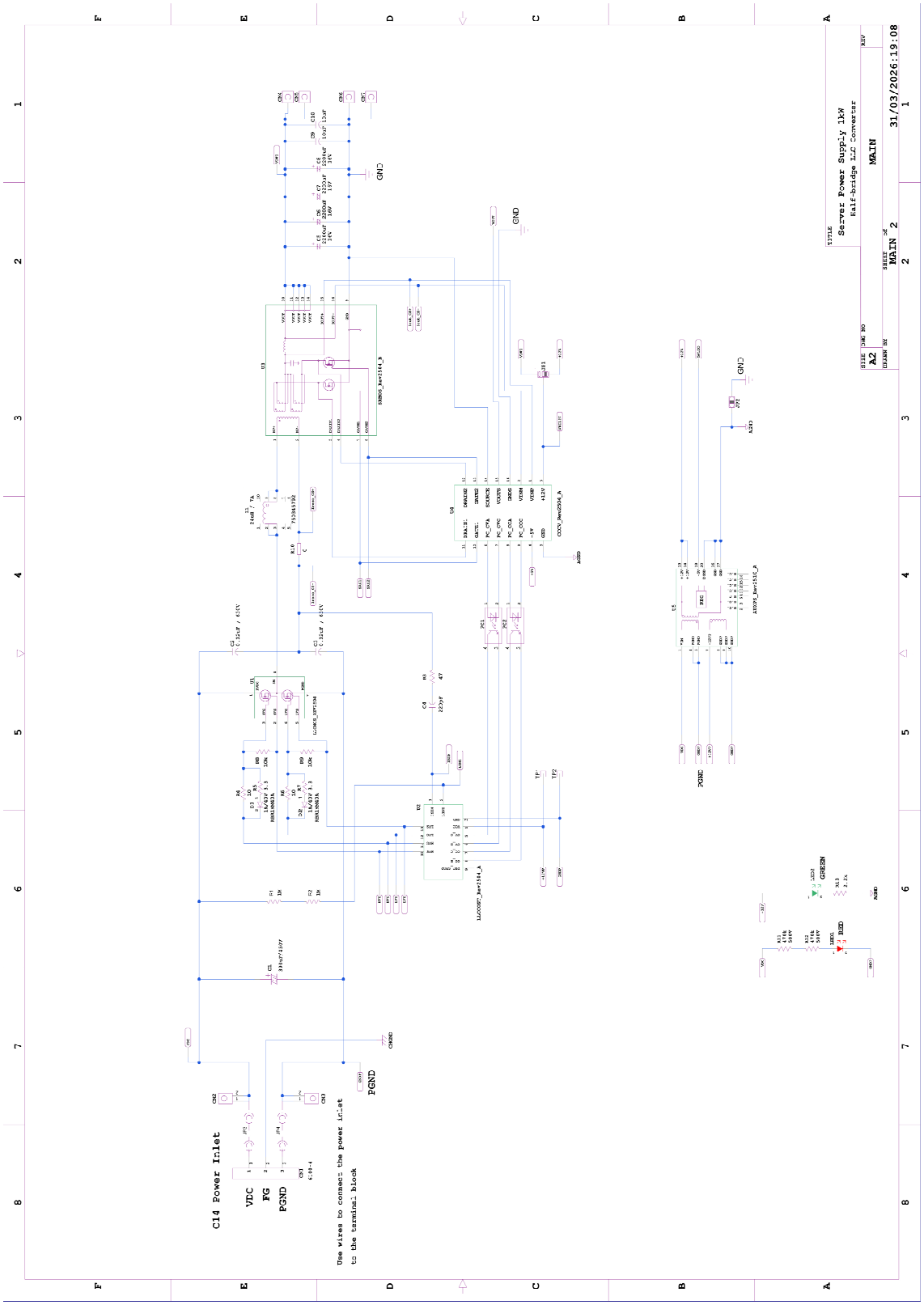


Figure 14. Main board schematic

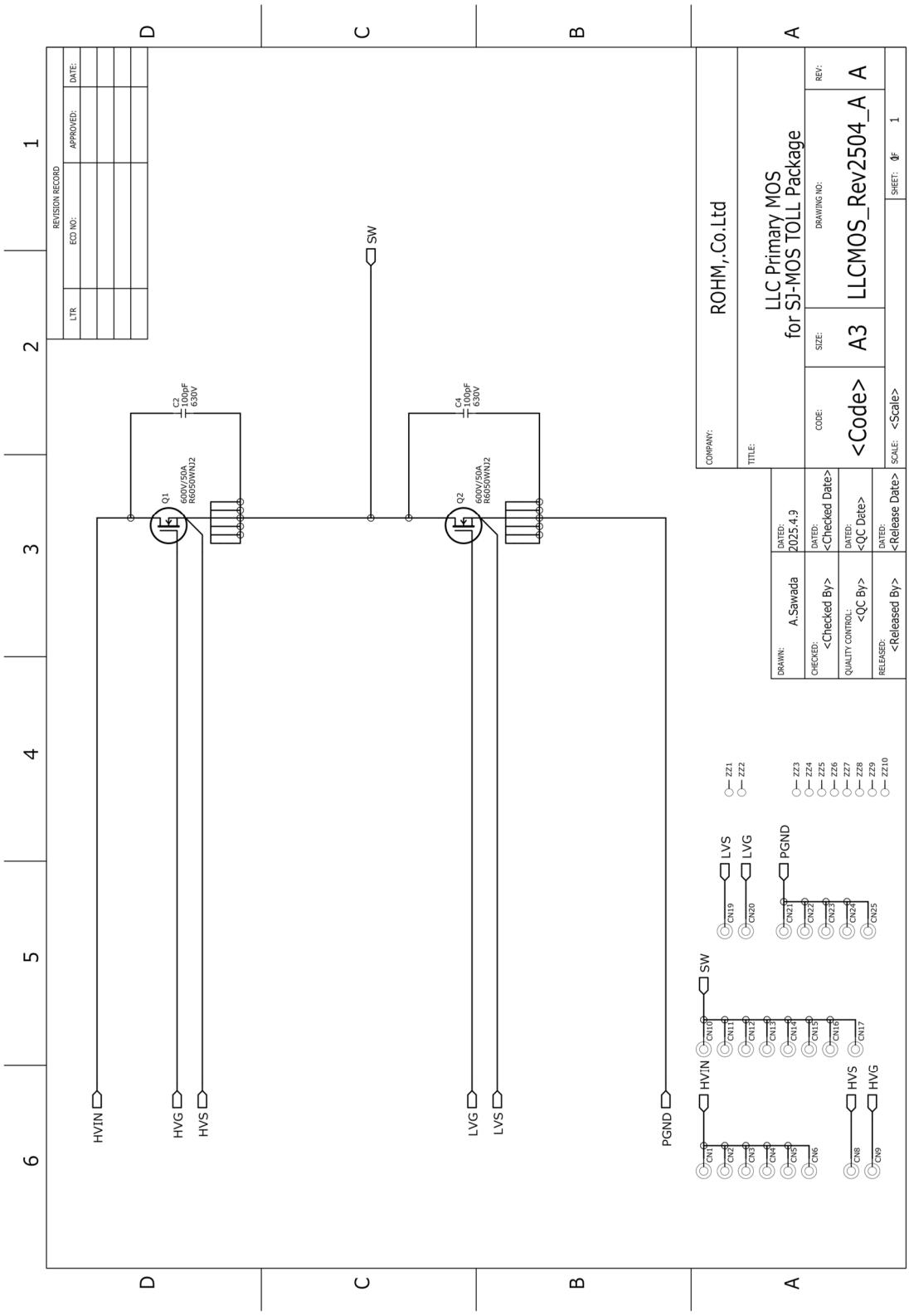


Figure 15. LLCMOS board schematic

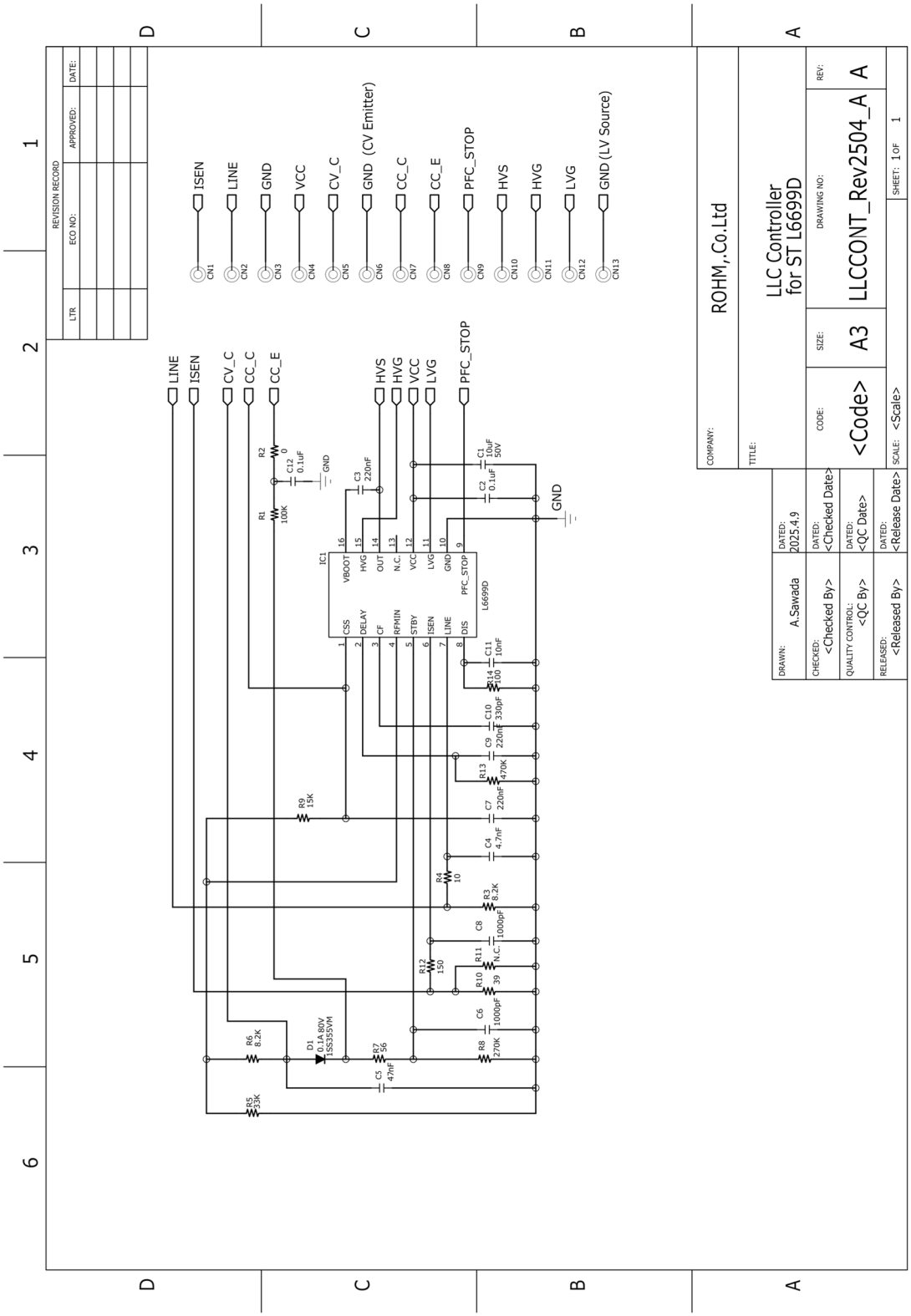


Figure 16. LLCCONT board schematic

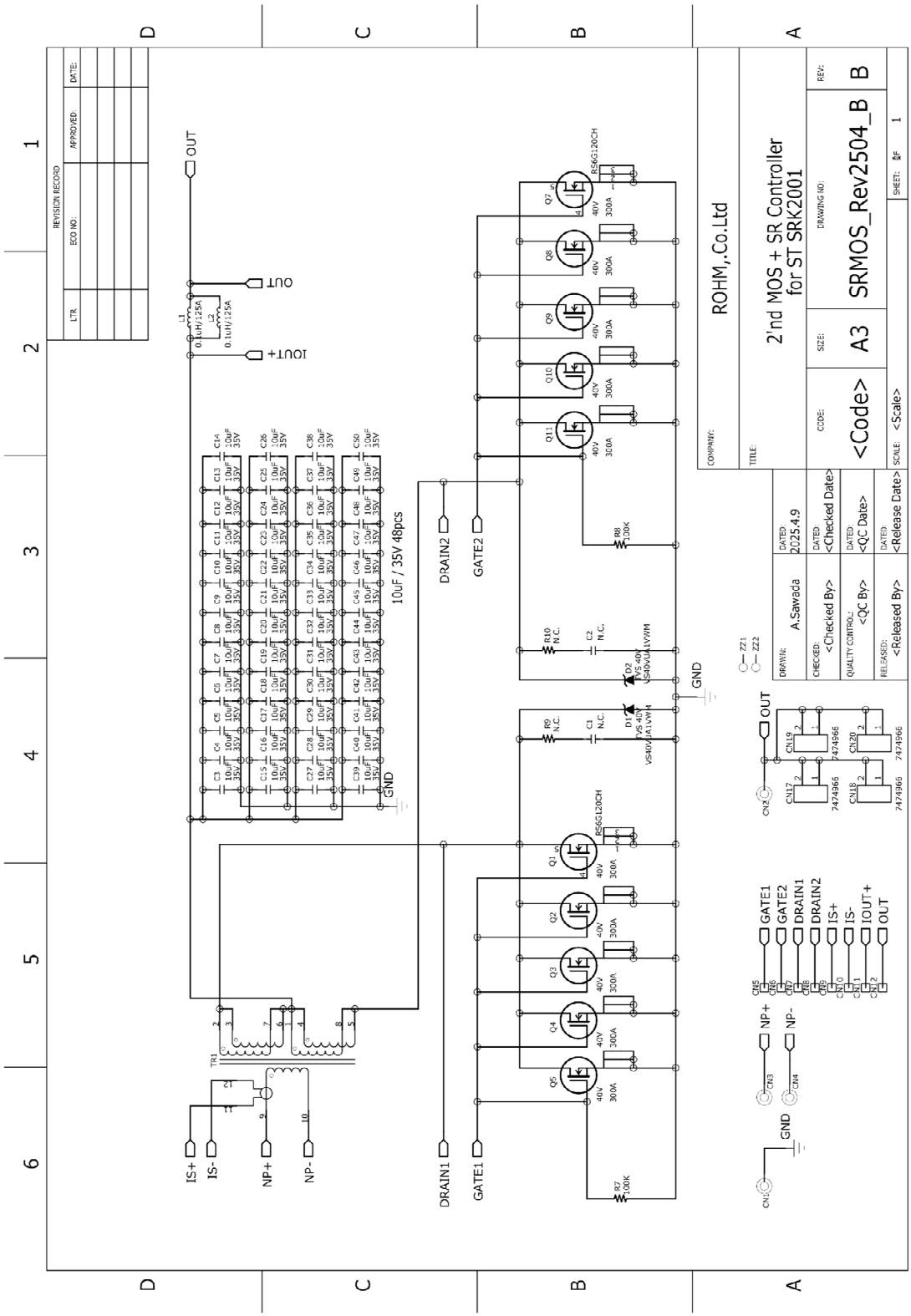


Figure 17. SRMOS board schematic

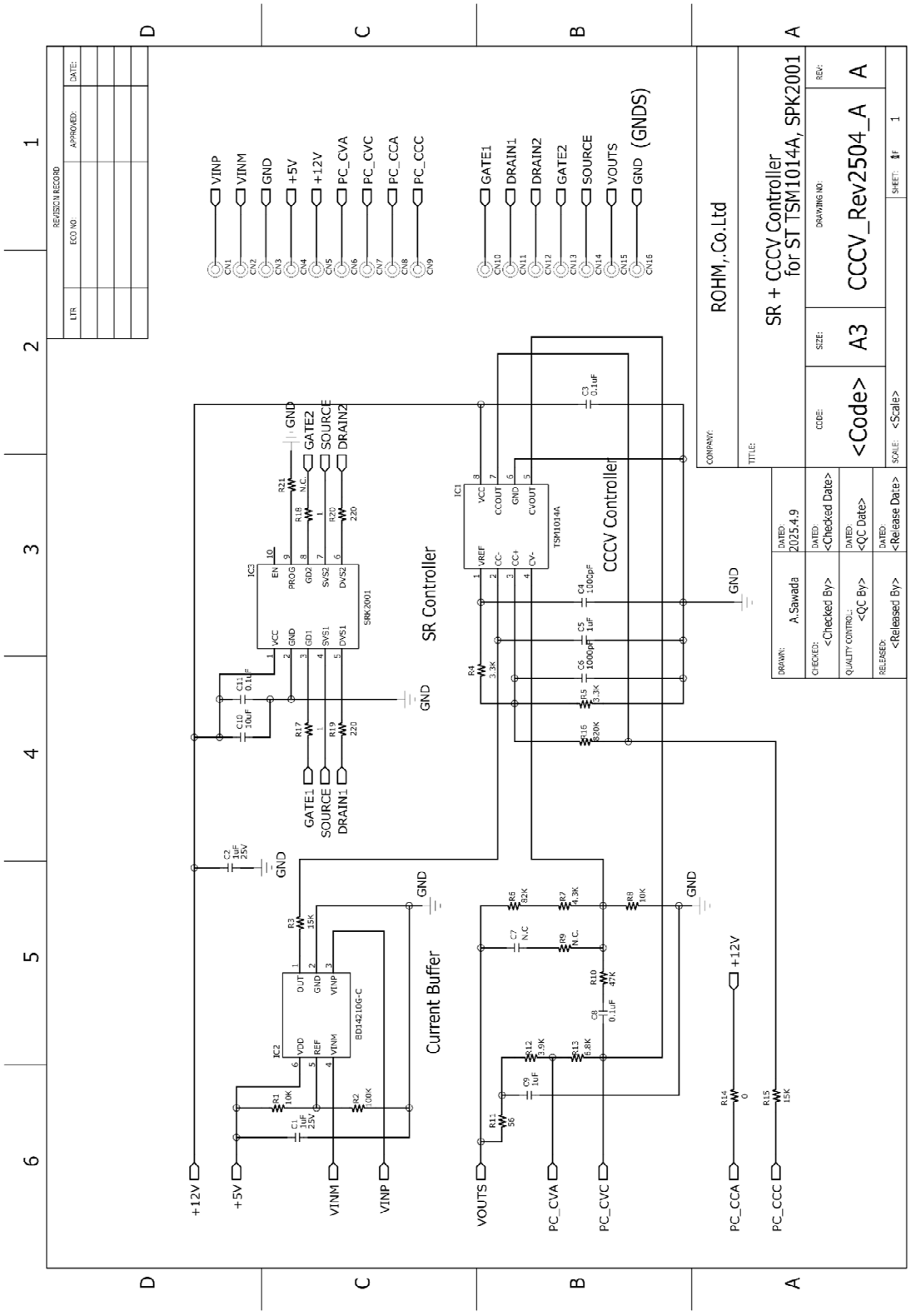
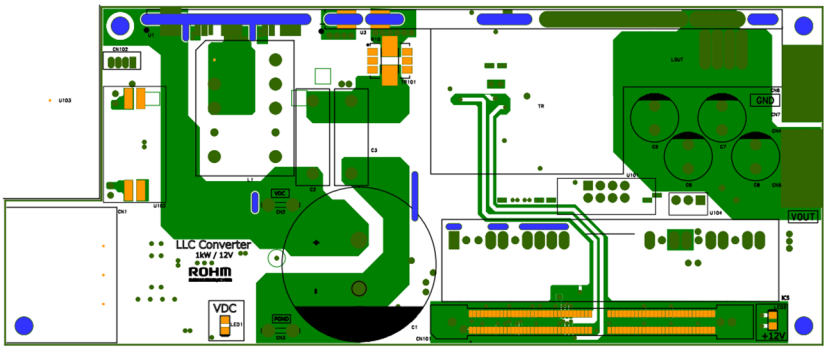


Figure 18. CCCV board schematic

9. Layout Diagrams



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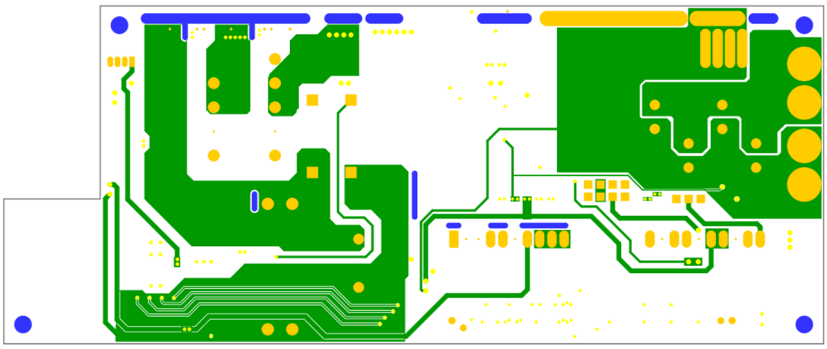

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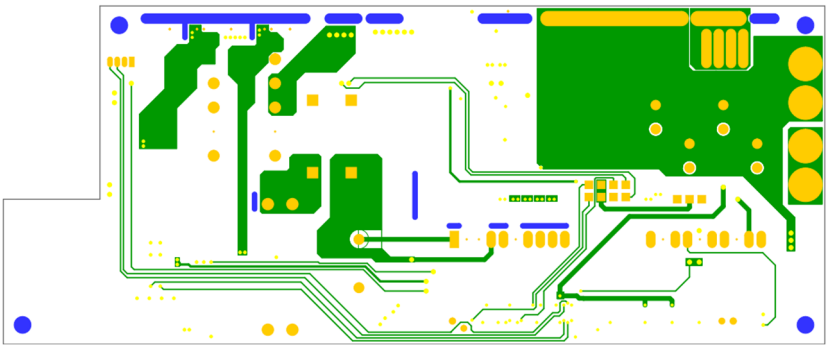
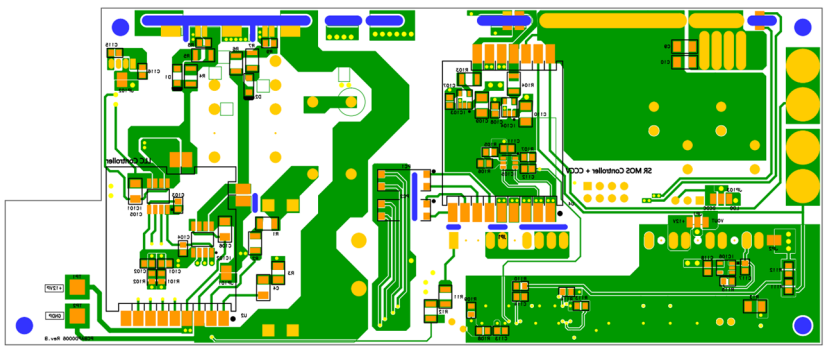
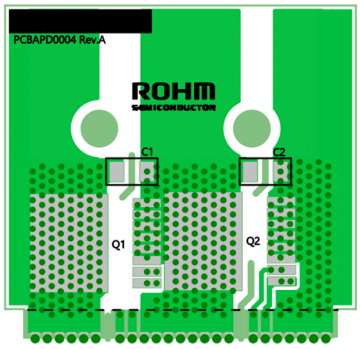


[3rd layer]



[Bottom layer]

Figure 19. Main board layout



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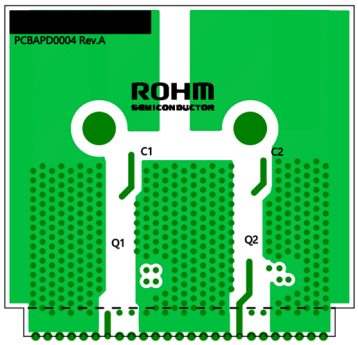

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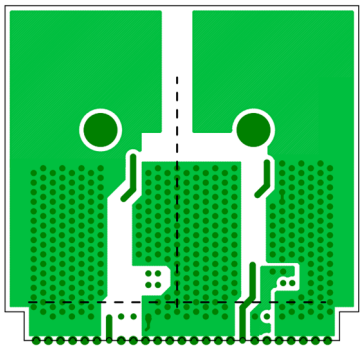

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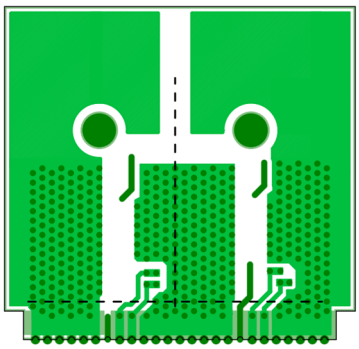
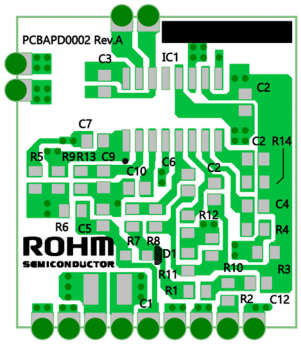
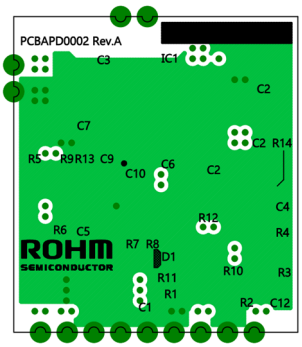


[Bottom layer]

Figure 20. LLCMOS board layout



[Top layer]



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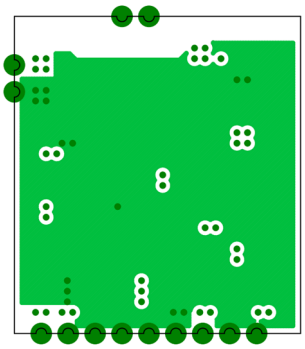

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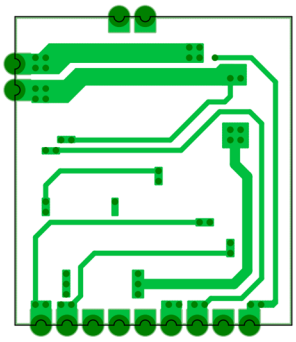
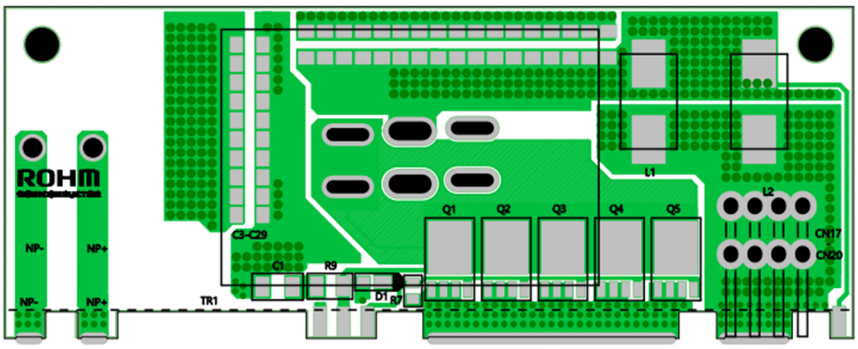


[Bottom layer]

Figure 21. LLCCONT board layout



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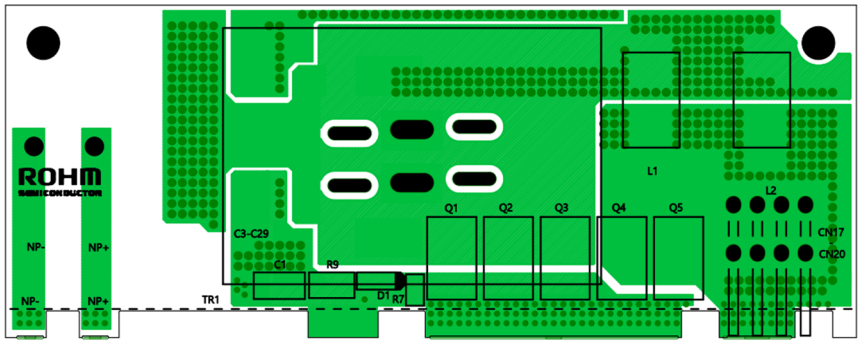

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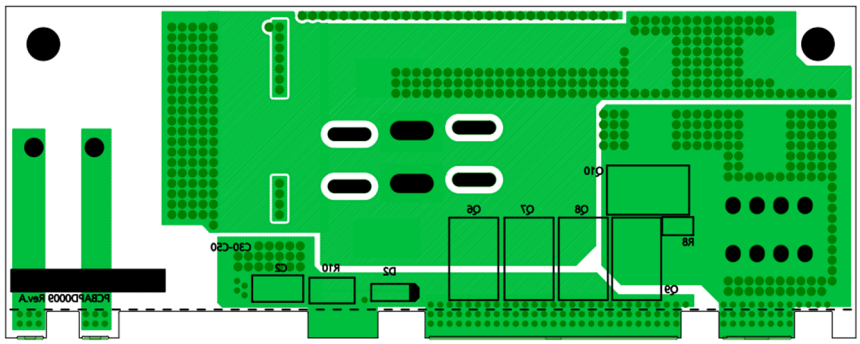
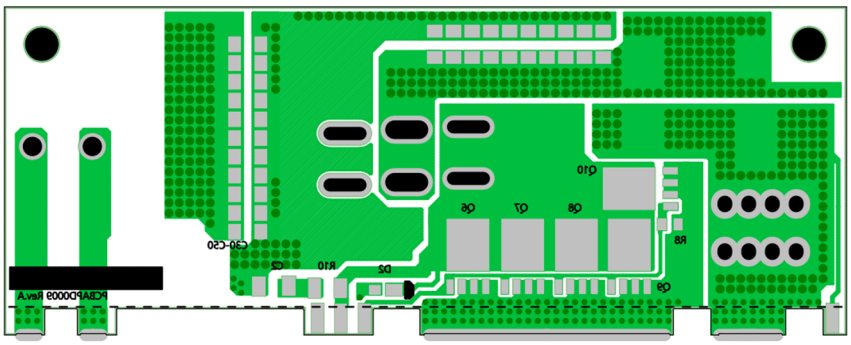
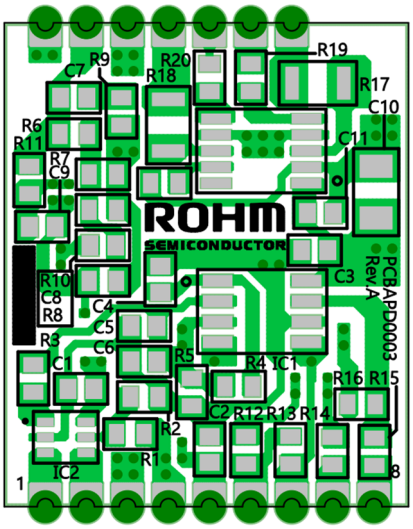


[3rd layer]

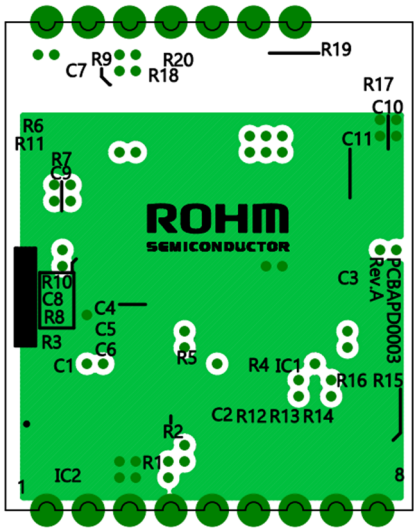


[Bottom layer]

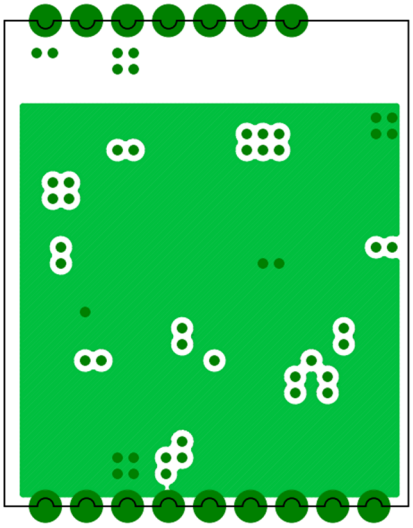
Figure 22. SRMOS board layout



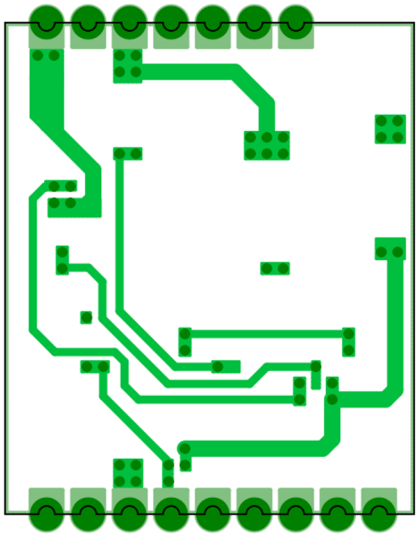
[Top layer]



[2nd layer]



[3rd layer]



[Bottom layer]

Figure 23. CCCV board layout

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