1.6kW LLC Resonant
AC-DC Converter for Servers

Reference Guide

RD212-RGUIDE-01

Toshiba Electronic Devices & Storage Corporation

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1. Introduction

This Reference Guide describes the specifications and operation procedure of the 1.6kW LLC Resonant AC-DC Converter for Servers (hereinafter referred to as "this design").

With the increase in the amount of information handled daily, the number of data centers is increasing, and the size of data centers is also increasing. Therefore, reducing the power consumption of data centers has become a global issue. Various measures are being considered to reduce power consumption in data centers, and one of them is the use of 48V bus voltages in servers used in data centers, and 48V servers have become increasingly popular in recent years. This design is an AC-DC converter that takes 100V/200V AC input and outputs 54.5V DC to a 48V server.

In order to improve power supply efficiency, following topologies have been used, an active bridge circuit that uses MOSFETs instead of a diode bridge, an interleaved PFC circuit, and a 3-phase LLC resonant DC-DC converter. This allowed to achieve an efficiency that exceeds the Titanium standard of 80 PLUS* at 230V input condition.

Toshiba's latest power MOSFETs like TK024N60Z1 mounted on the active bridge section, TK080N60Z1 mounted on the interleaved PFC section, TK125A60Z1 mounted on the primary side of the 3-phase LLC resonant DC-DC converter, and TPH2R408QM mounted on the secondary side of the 3-phase LLC resonant DC-DC converter and ORing section, and 650V SiC Schottky barrier diodes TRS8E65H mounted on the interleaved PFC contributes to reduced losses and high-efficiency operation.

Toshiba's TMPM372FWUG microcontroller is used to generate the 3-phase control signal for the LLC resonant DC-DC converter.

*80 PLUS: It is the efficiency standard for power supply units for computers such as servers, and Titanium is the name of the highest standard.

2. Appearance and Specifications

2.1. Specifications

Table 2.1 lists the main specifications of this design.

Table 2.1 Specifications of This Design

Item	Conditions	Min.	Typ.	Max.	Unit
Input characteristics					
AC input voltage (rms)		90		264	V
AC input current (rms)	Vin = AC 90V, Iout = 20A			12	A
Input frequency		47		63	Hz
Internal characteristics (Interleaved PFC circuit)					
Output voltage			390		V
Maximum output power	Vin = AC 230V			1.77	kW
	Vin = AC 115V			0.89	kW
Switching frequency			62.5		kHz
Output characteristics (3-phase LLC resonant DC-DC converter circuit)					
Output voltage		51.7	54.5	57.3	V
Output current	Vin = AC 230V			29.4	A
	Vin = AC 115V			14.7	A
Maximum output power	Vin = AC 230V			1.6	kW
	Vin = AC 115V			0.8	kW
Output ripple voltage	Ta = 25℃			2180	mV
Other					
Protective functions	Output overvoltage protection, output overcurrent protection, output short-circuit protection, and overheat protection				
Board layer configuration	Main board: FR-4 4-layer structure, copper foil thickness 70μm (all layers) Active bridge circuit board: FR-4 2-layer configuration, copper foil thickness 70μm PFC control board, LLC control board: FR-4 2-layer configuration, copper foil thickness 35μm				

2.2. Block Diagram

Fig. 2.2 shows the block diagram of this design.

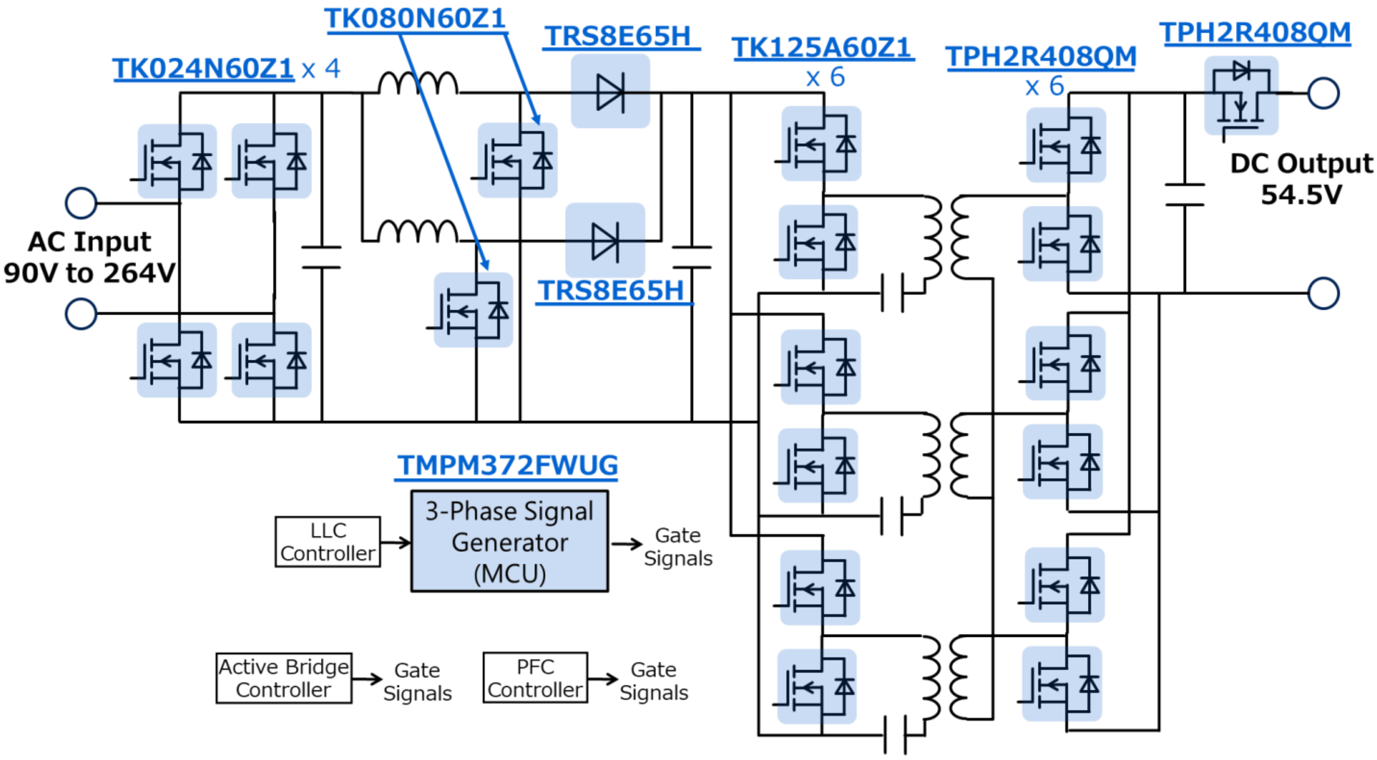


Fig. 2.1 Block Diagram

This design outputs DC 54.5V from AC input via the full wave rectifier of active bridge circuit with MOSFET, interleaved PFC circuit, 3-phase LLC resonant DC-DC converter and ORing circuit.

2.3. Appearance

The appearance of this design is shown in Fig. 2.2 and 2.3. This design consists of a main board and an active bridge circuit board, a PFC control board, and LLC control board, on a main board. Fig. 2.4 and 2.5 show the appearance of the PFC control board, Fig. 2.6 and 2.7 show the appearance of the LLC control board, and Fig. 2.8 and 2.9 show the appearance of the active bridge circuit board.

Fig. 2.2 Appearance of This Design (Side View)

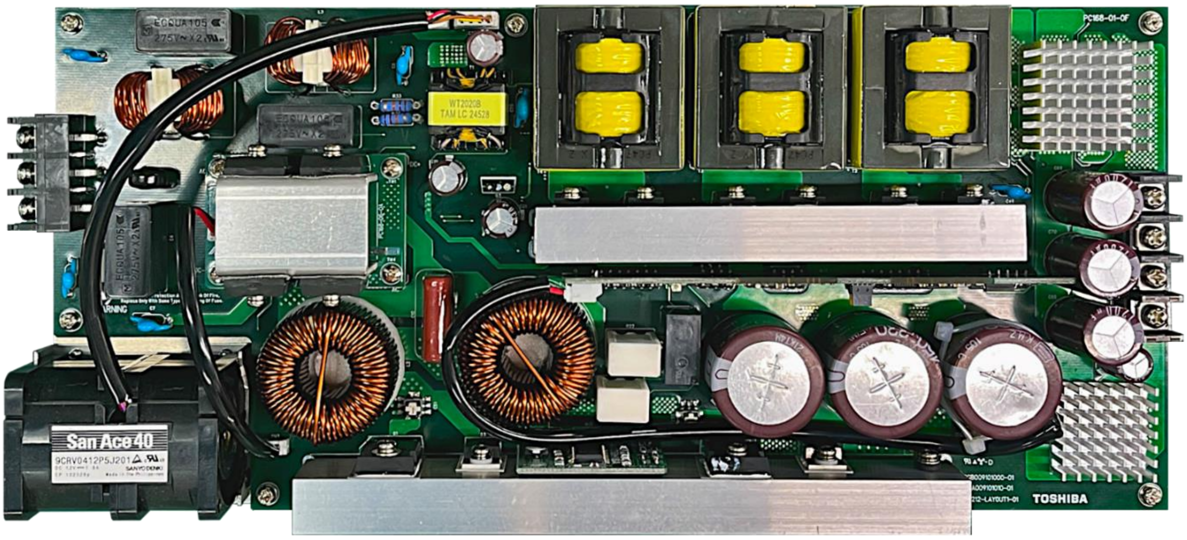


Fig. 2.3 Appearance of This Design (Front View)

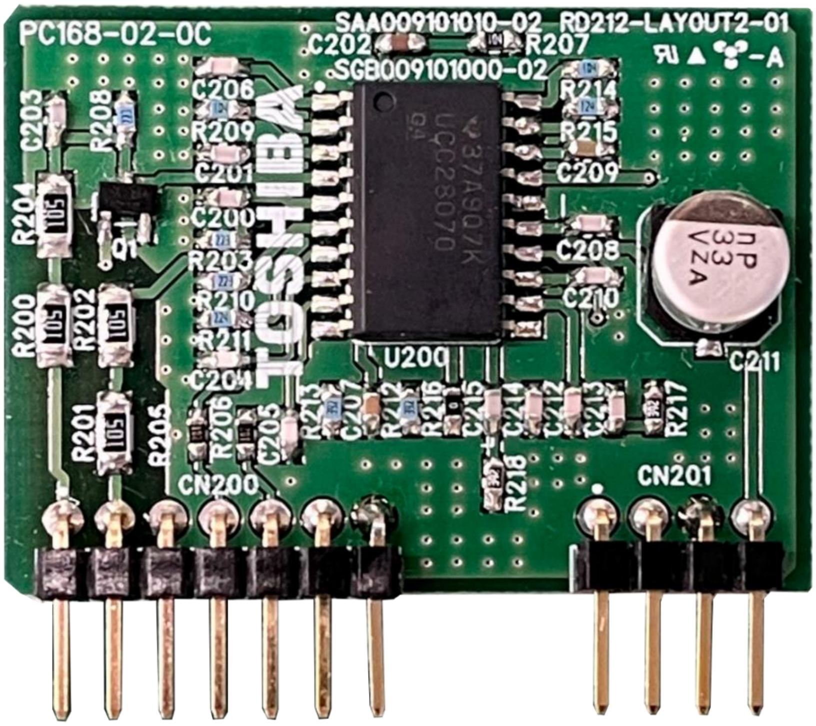


Fig. 2.4 Front View of PFC Control Board

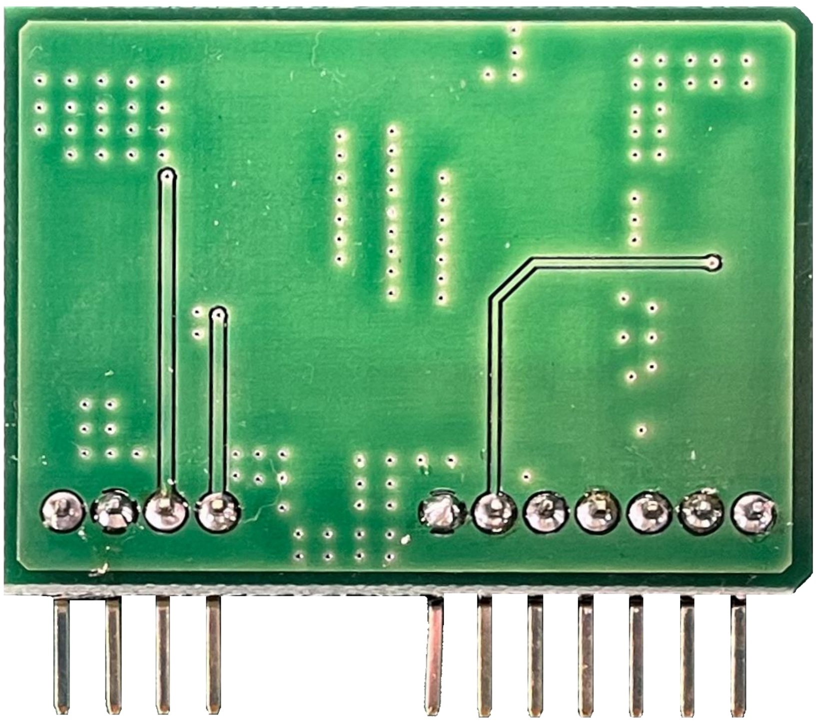


Fig. 2.5 Back View of PFC Control Board

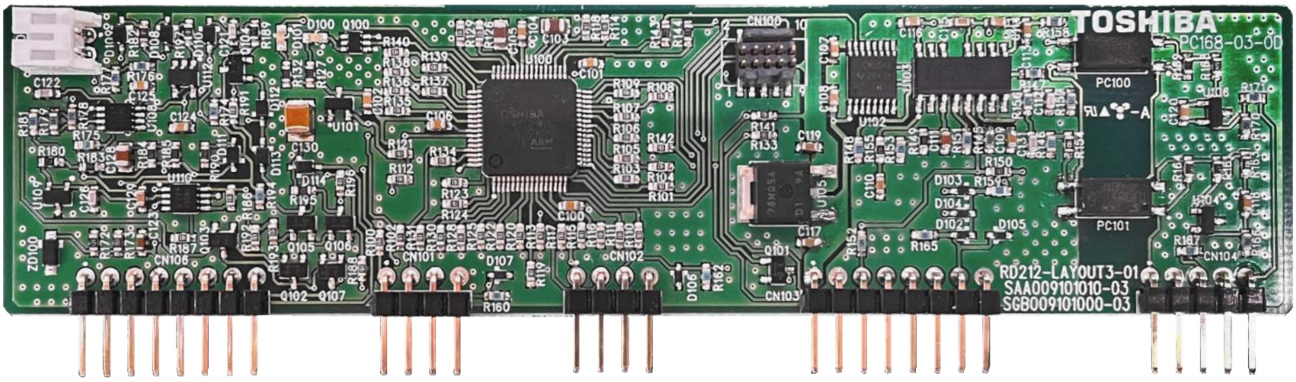


Fig. 2.6 Front View of LLC Control Board

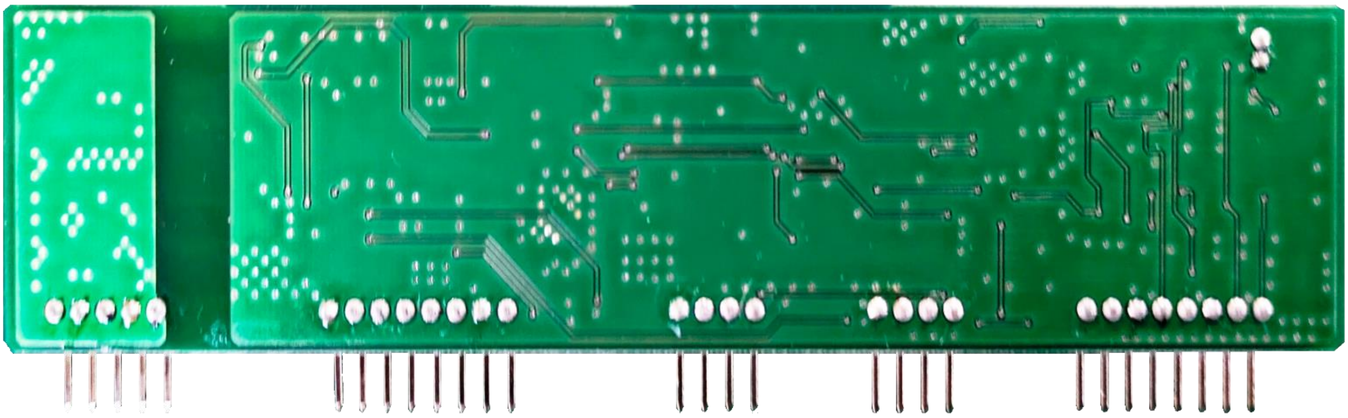


Fig. 2.7 Back View of LLC Control Board

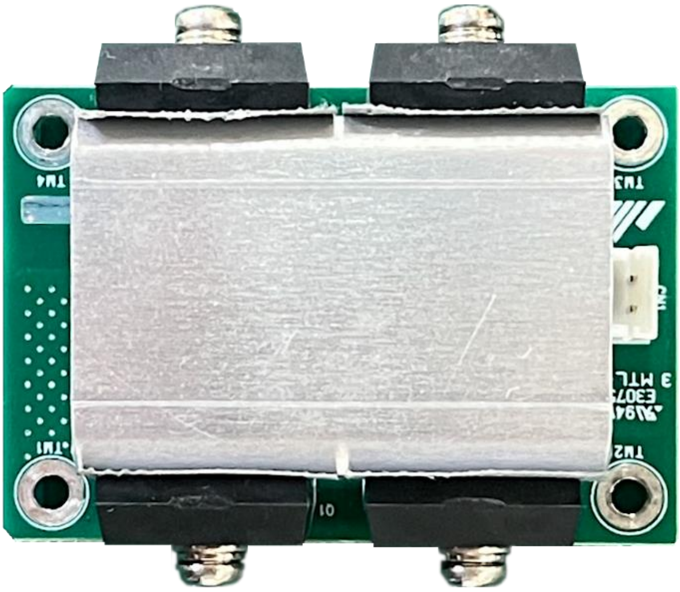


Fig. 2.8 Front View of Active Bridge Circuit Board

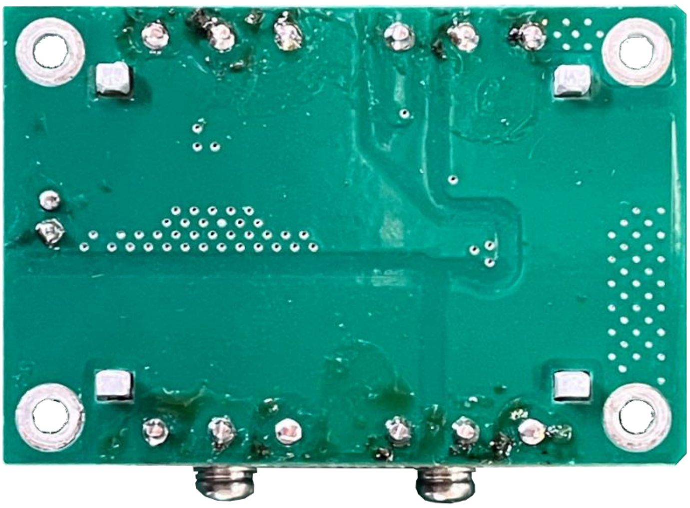
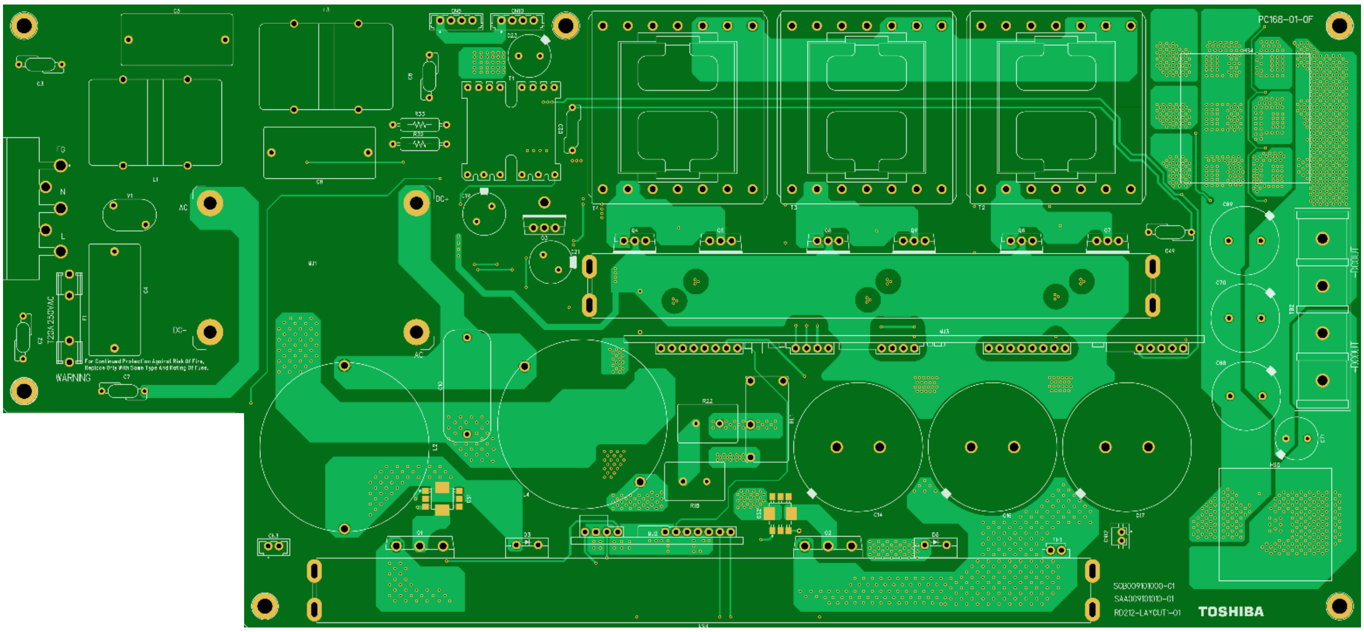


Fig. 2.9 Back View of Active Bridge Circuit Board

2.4. PCB Component Layout

Fig. 2.10 shows the component layout of the main board, Fig. 2.11 shows the component layout of the PFC control board, Fig. 2.12 shows the component layout of the LLC control board, and Fig. 2.13 shows the component layout of the active bridge circuit board.



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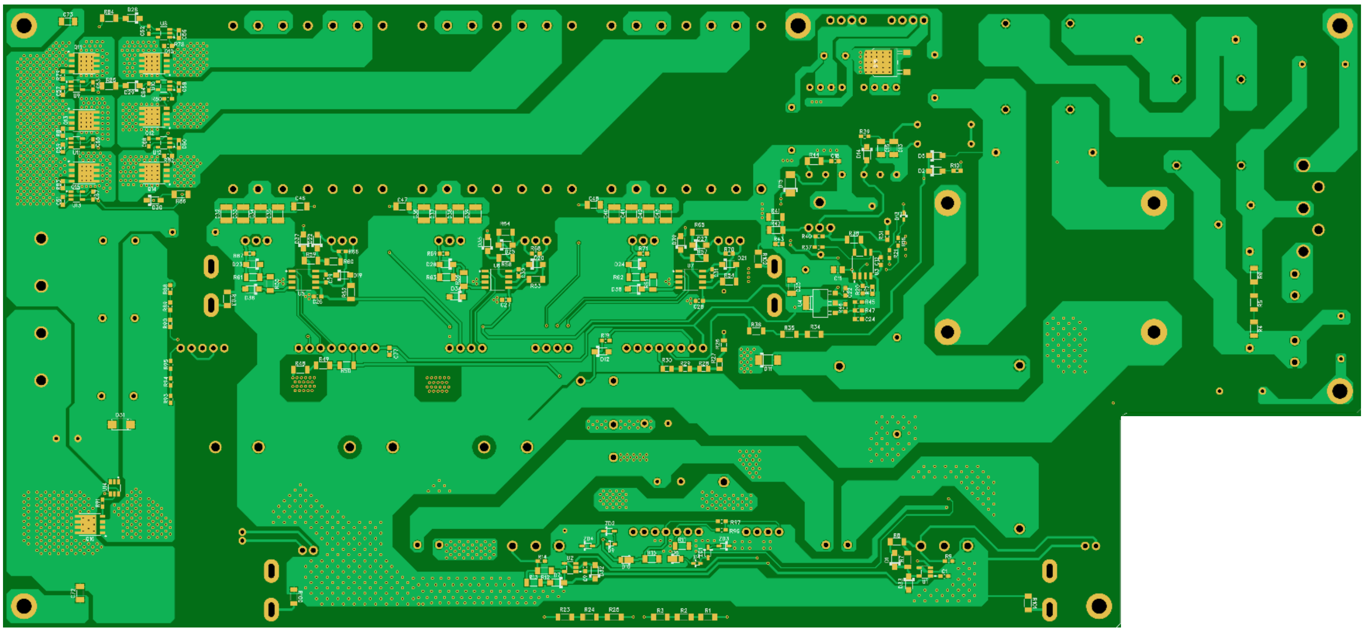

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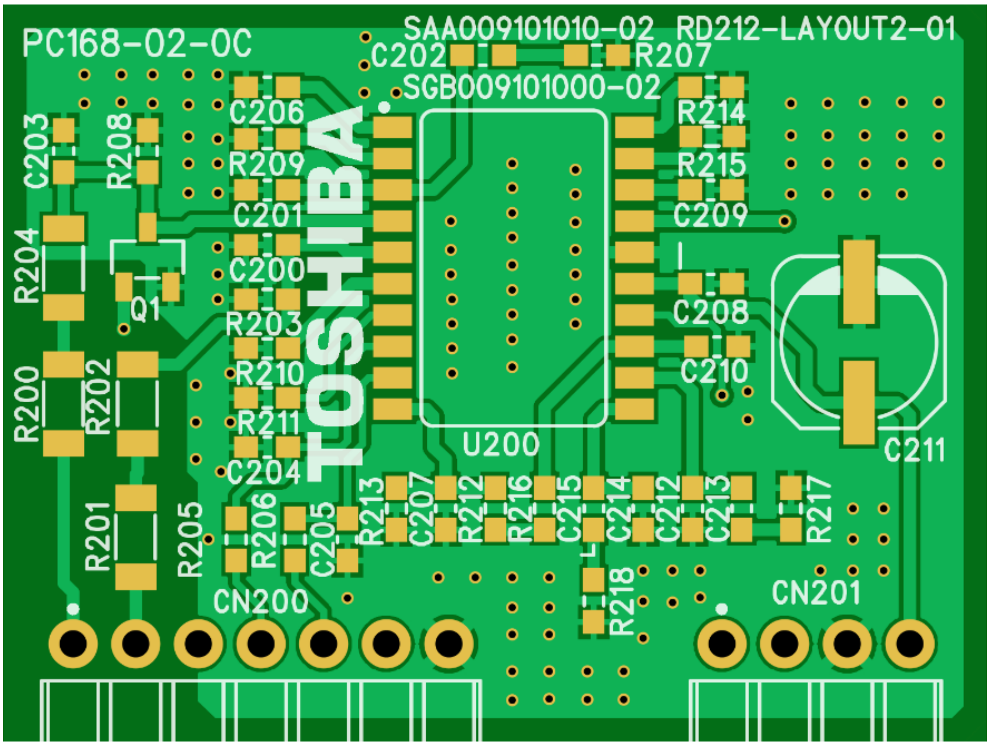
Fig. 2.10 Component Layout of Main Board



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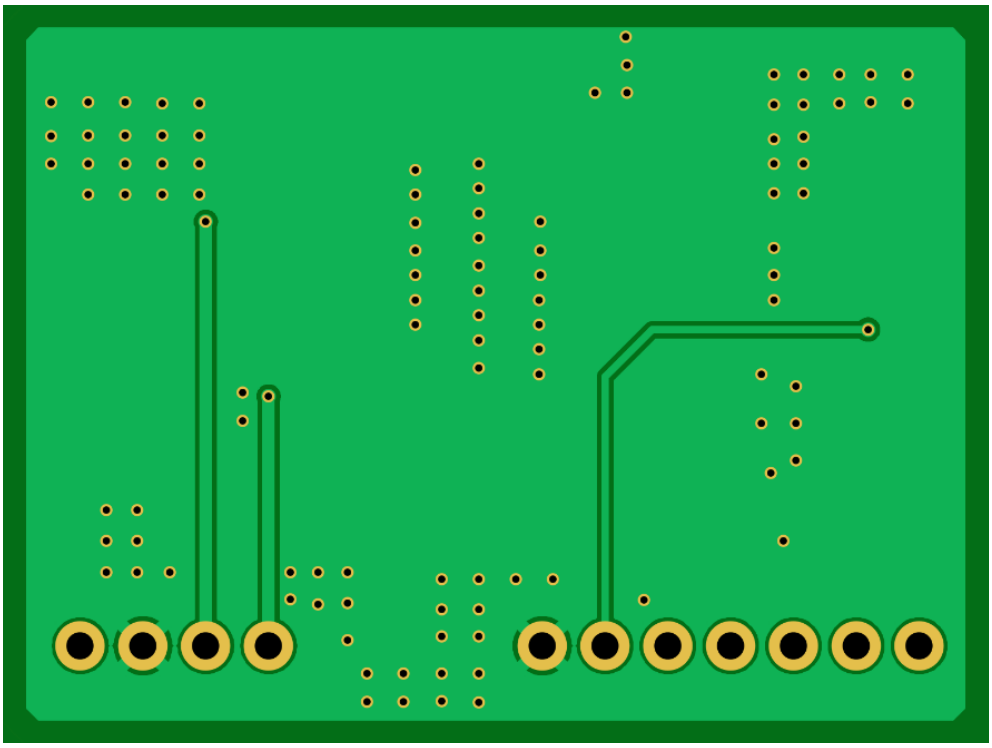

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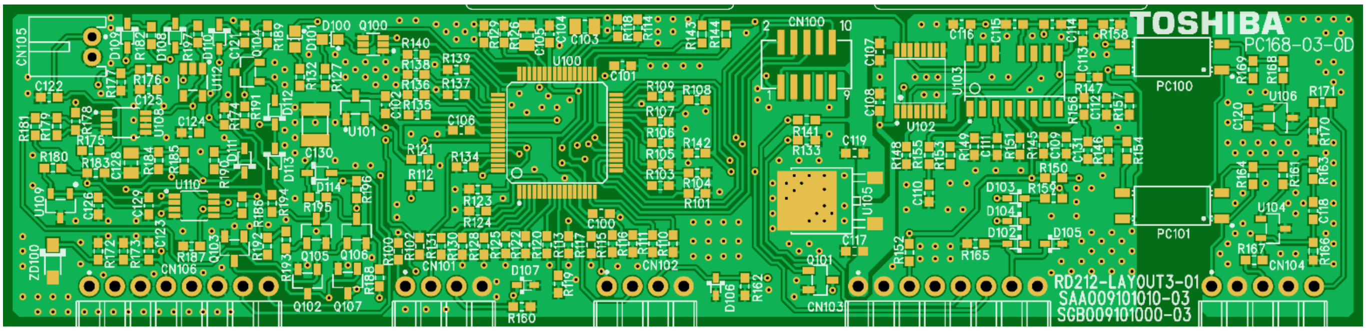
Fig. 2.11 Component Layout of PFC Control Board



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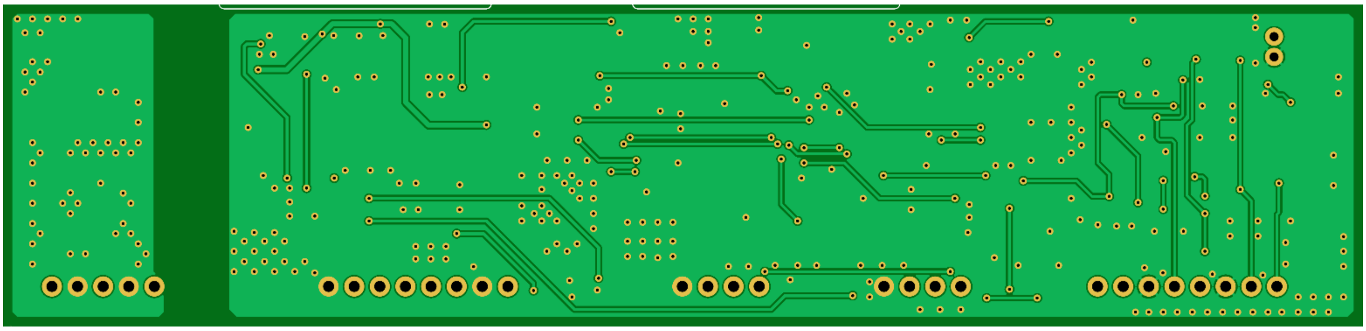

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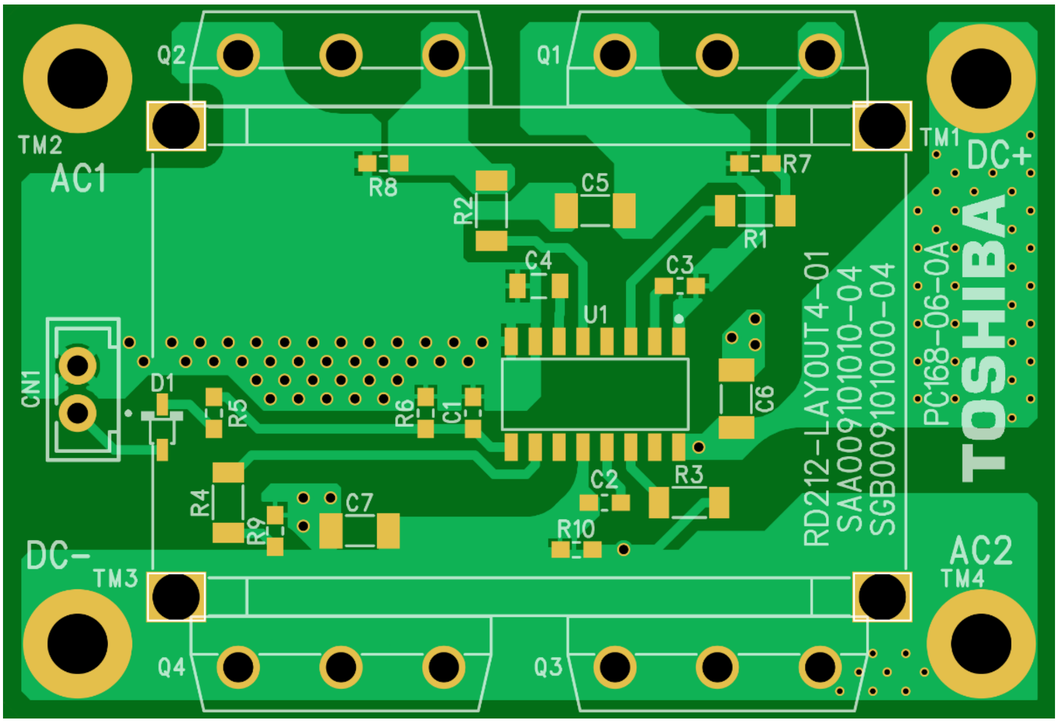
Fig. 2.12 Component Layout of LLC Control Board



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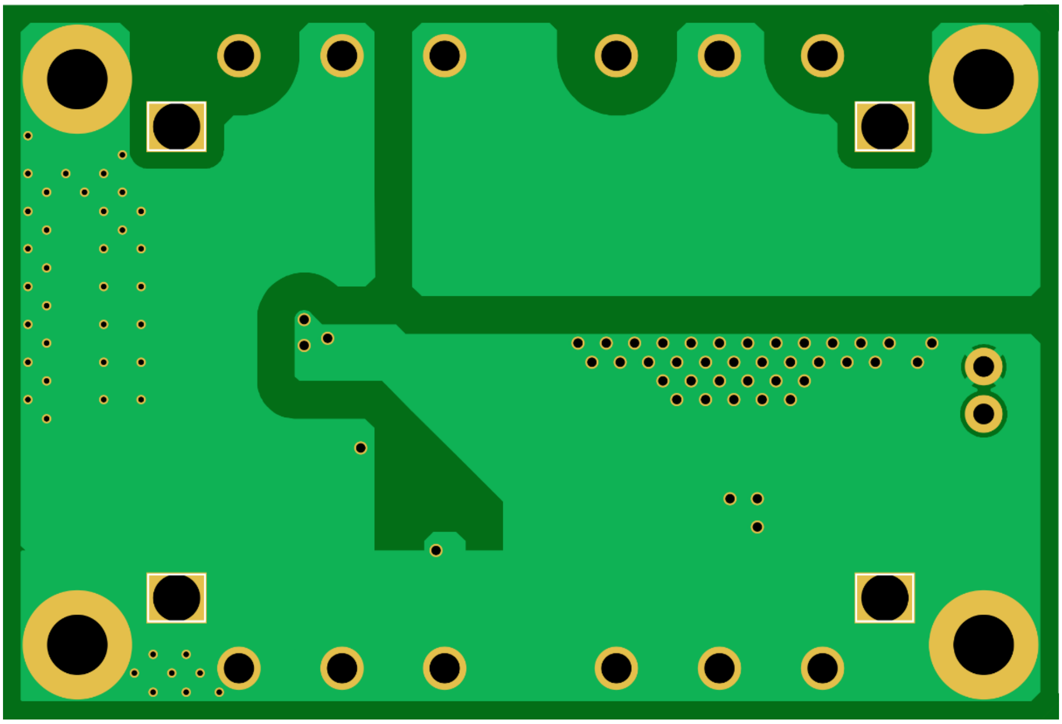

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Fig. 2.13 Component Layout of Active Bridge Circuit Board

3. Schematic, Bill of Materials, and PCB Pattern Diagram

3.1. Schematic

Refer to following files:

Main board: RD212-SCHEMATIC1-xx.pdf
PFC control board: RD212-SCHEMATIC2-xx.pdf
LLC control board: RD212-SCHEMATIC3-xx.pdf
Active bridge circuit board: RD212-SCHEMATIC4-xx.pdf
(xx is the revision number.)

3.2. Bill of Materials

Refer to following files:

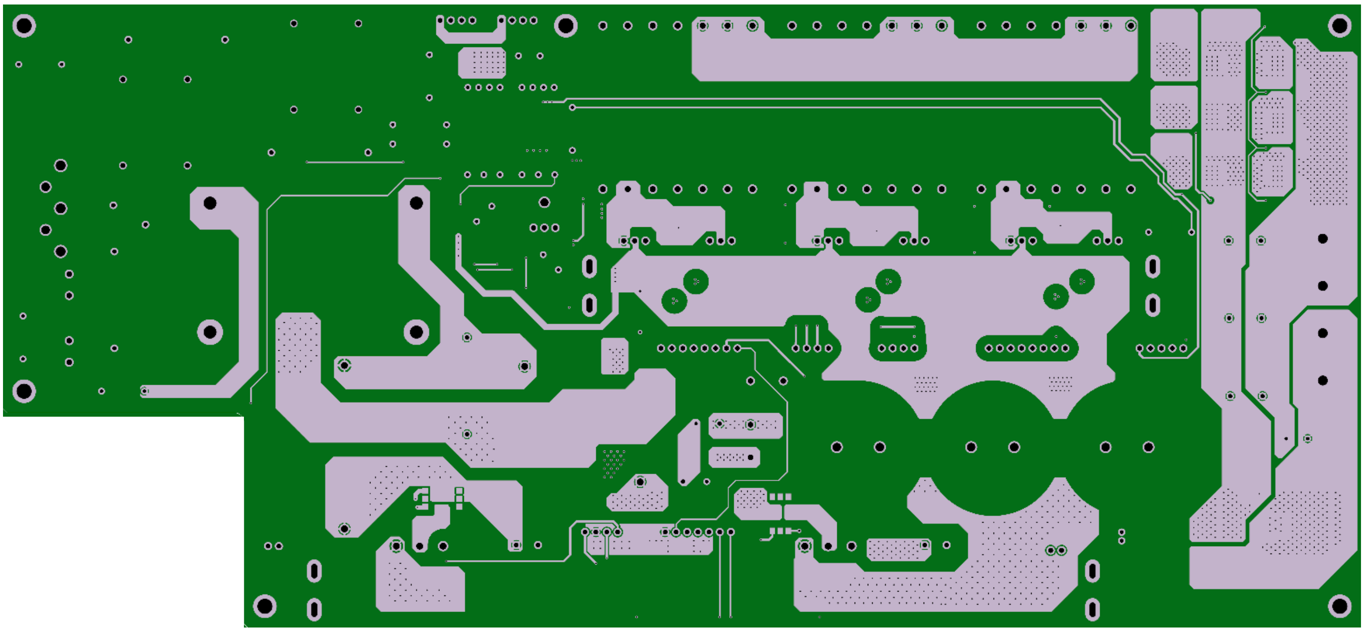
Main board: RD212-BOM1-xx.pdf
PFC control board: RD212-BOM2-xx.pdf
LLC control board: RD212-BOM3-xx.pdf
Active bridge circuit board: RD212-BOM4-xx.pdf
(xx is the revision number.)

3.3. PCB Pattern Diagram

Fig. 3.1 shows PCB pattern diagram of the main board, Fig. 3.3 shows PCB pattern diagram of the PFC control board, Fig. 3.3 shows PCB pattern of the LLC control board, and Fig. 3.4 shows PCB pattern of the active bridge circuit board.

Refer to following files:

Main board: RD212-LAYER1-xx.pdf
PFC control board: RD212-LAYER2-xx.pdf
LLC control board: RD212-LAYER3-xx.pdf
Active bridge circuit board: RD212-LAYER4-xx.pdf
(xx is the revision number.)



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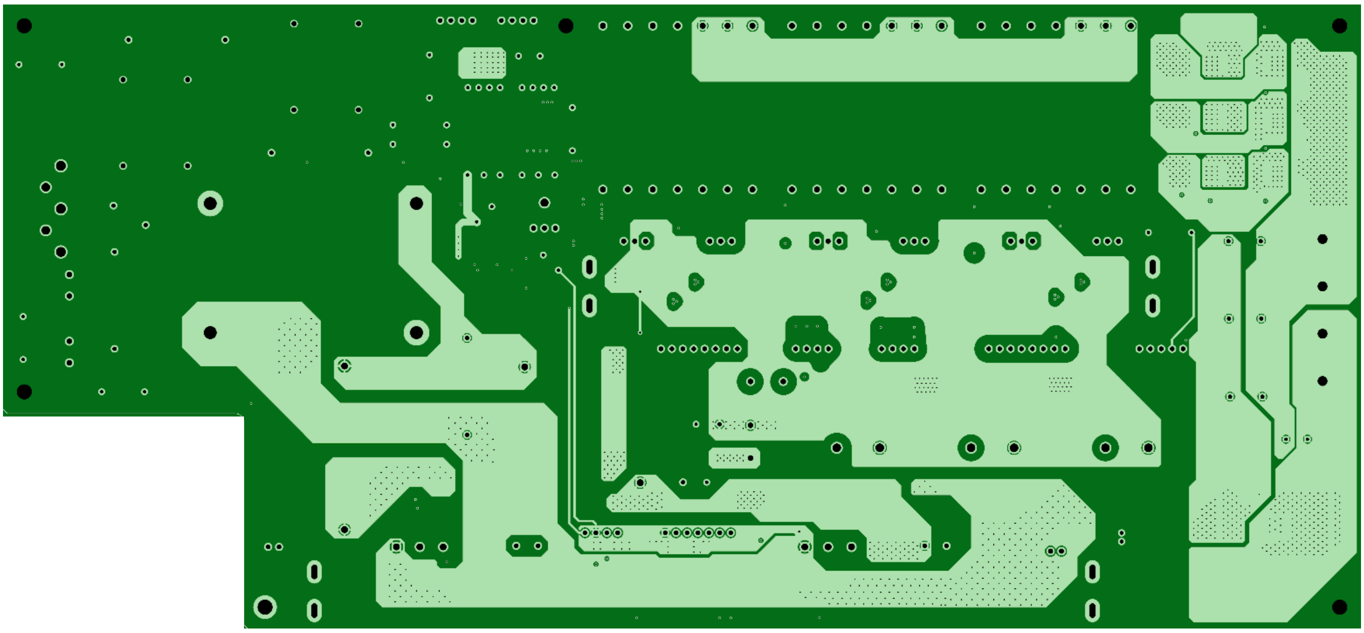

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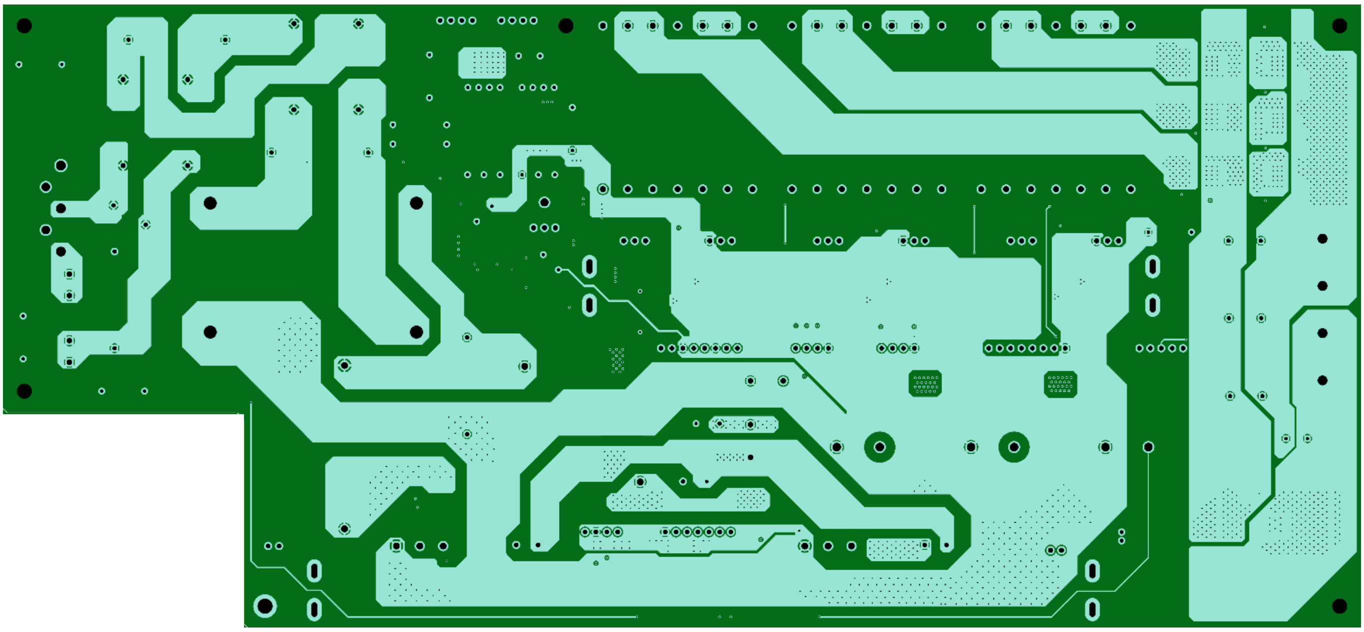

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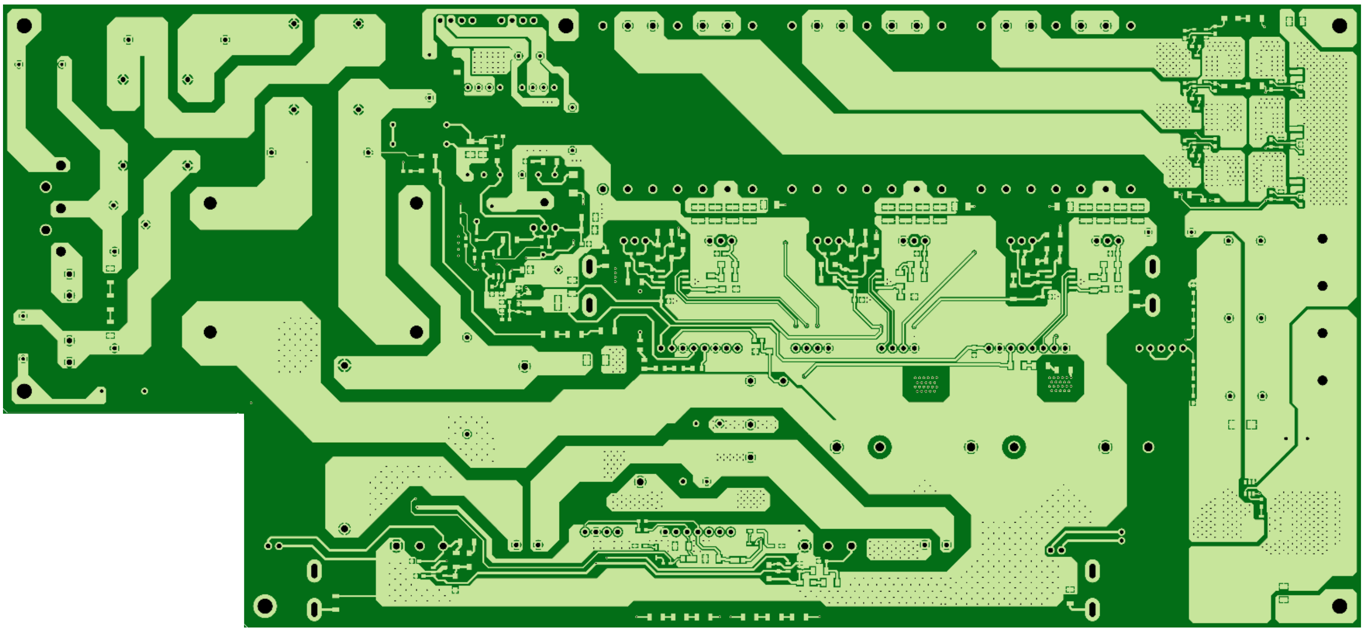

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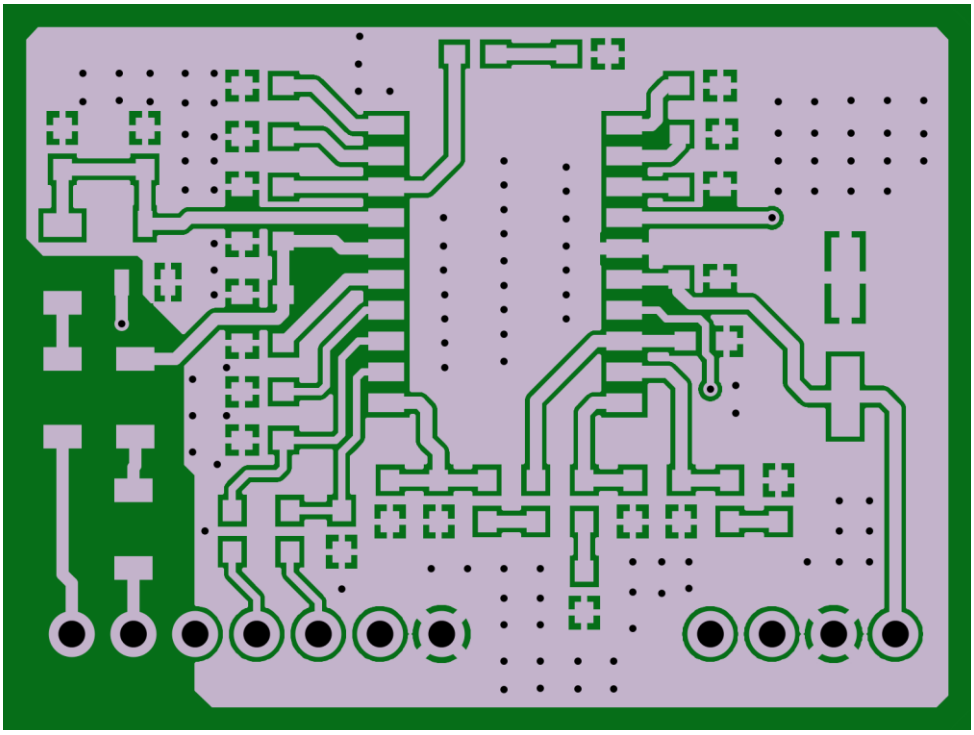
Fig. 3.1 Main Board Pattern Diagram (Top View)



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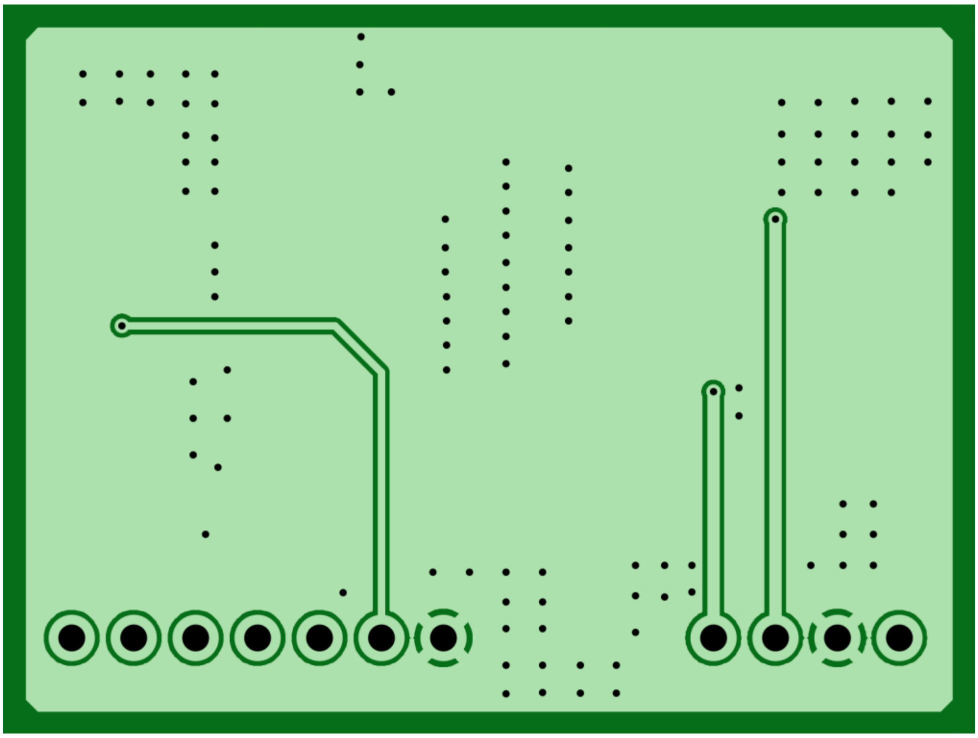

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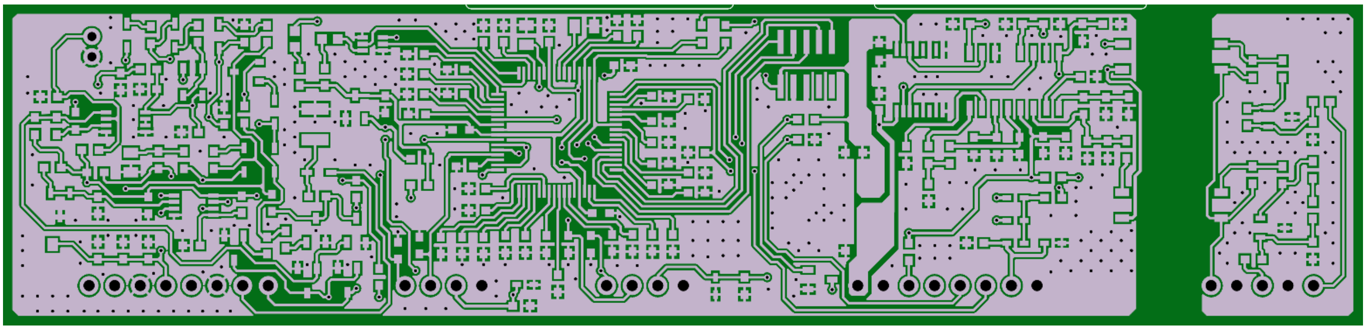
Fig. 3.2 PFC Control Board Pattern Diagram (Top View)



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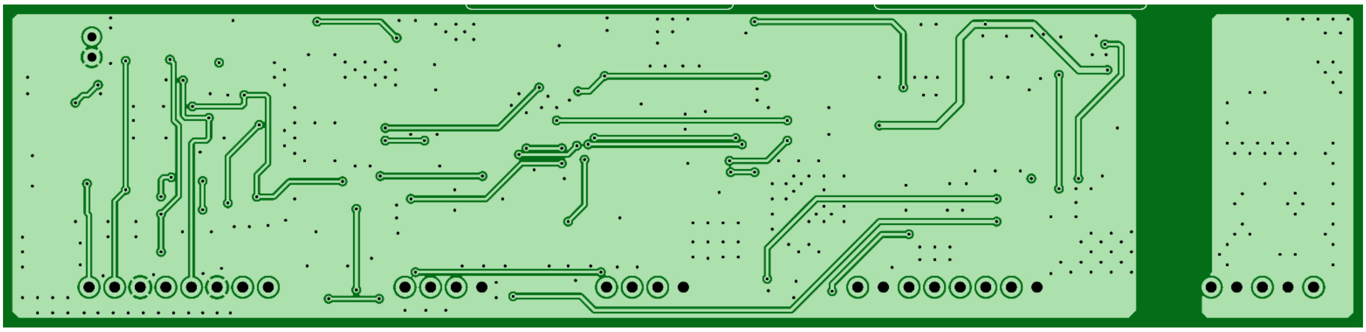

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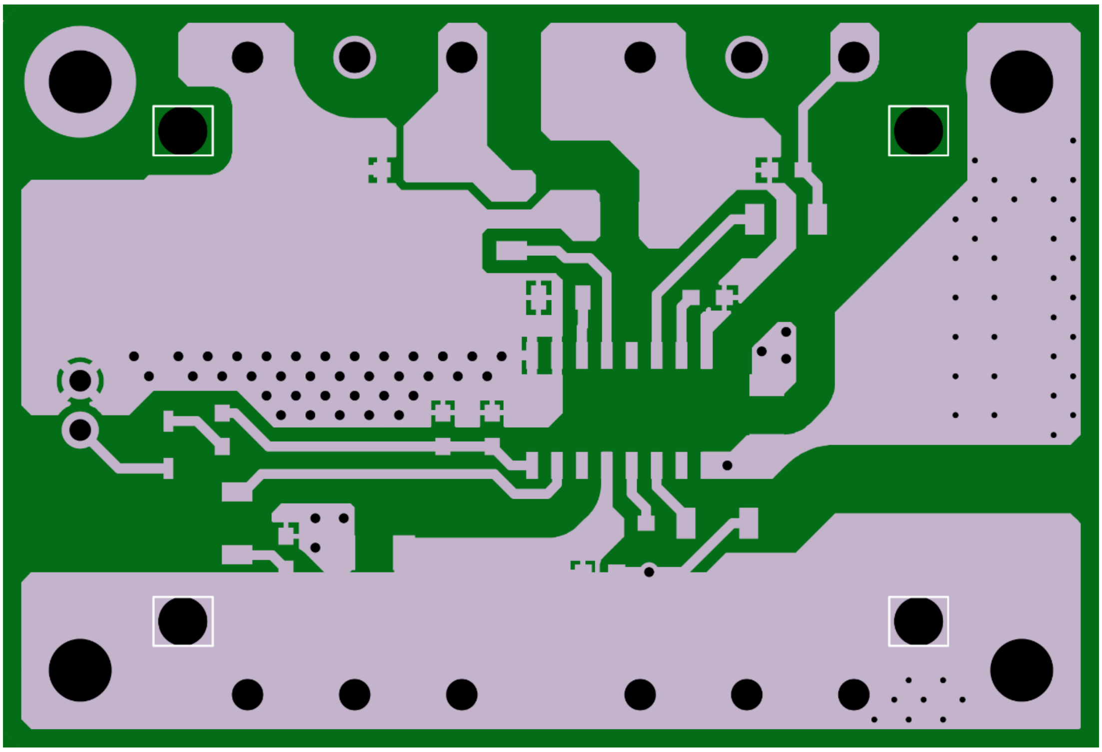
Fig. 3.3 LLC Control Board Pattern Diagram (Top View)



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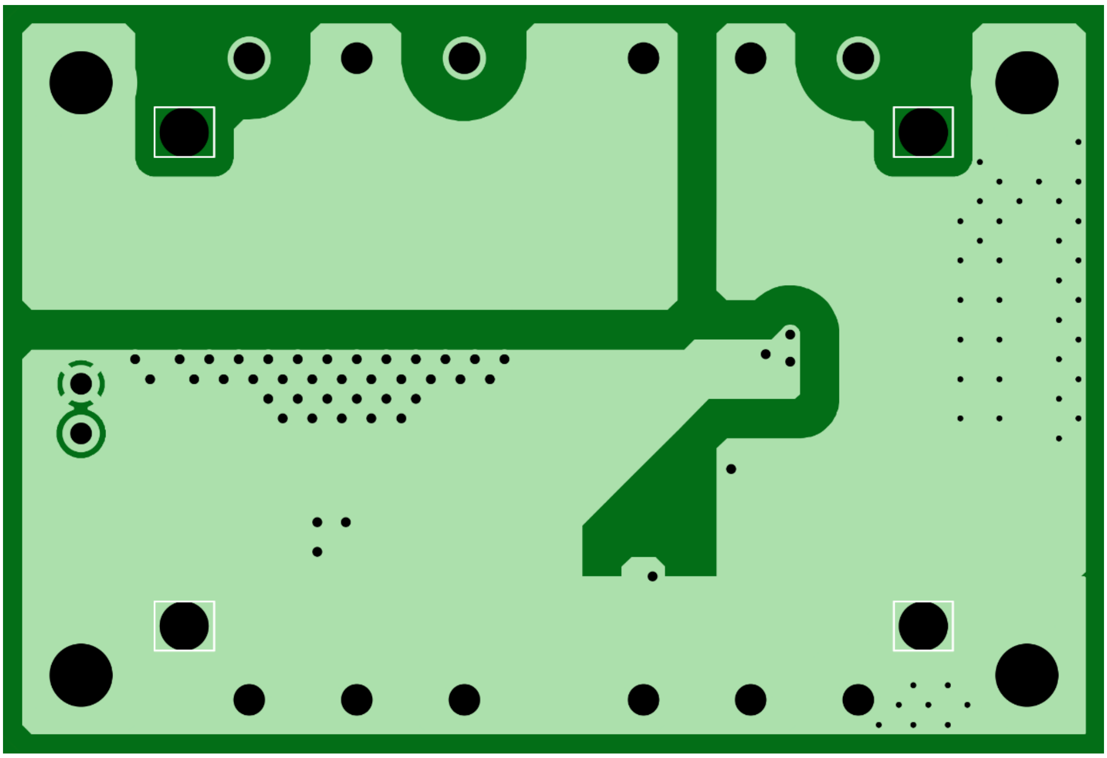

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Fig. 3.4 Active Bridge Circuit Board Pattern Diagram (Top View)

4. Operating Procedure

4.1. Connection to External Devices

Fig. 4.1 shows the external connection terminals of this design. The component enclosed in the red box is the AC IN terminal (TB1) and the component enclosed in the blue box is the DC OUT terminal (TB2).

Connect the N (Neutral) of the AC stabilized power supply to pin 2 of TB1, connect the L of the AC stabilized power supply to pin 3 of TB1, and connect the ground (frame ground) to pin 1 if required. Connect the positive side of the DC load to pin 1 and 2 of TB2, connect the negative side of the DC load (GND potential) to pin 3 and 4 of TB2. Use a power supply, a load, and cables, which satisfy the power specifications.

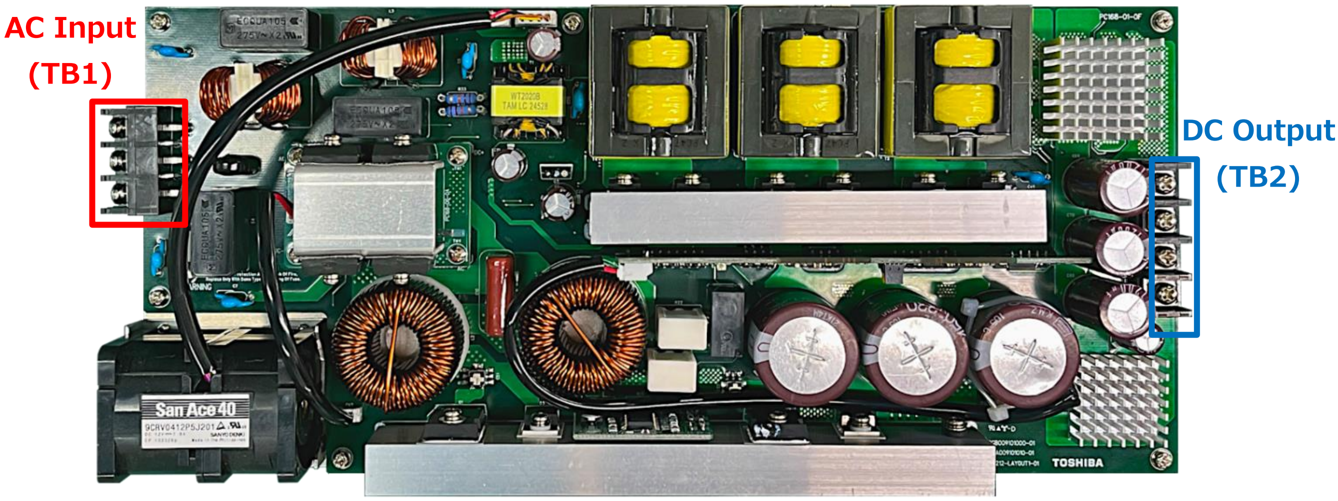

Fig. 4.1 External Connections

4.2. Start and Stop Procedure

Make sure all external terminals are 0V before starting.

[Starting Procedure]

1. Turn on the AC stabilized power supply.

[Stopping Procedure]

1. Turn off the AC stabilized power supply.

4.3. Evaluation Precautions (To Prevent Electric Shocks, Burns, etc.)

Be careful of electric shock when connecting the power supply. Do not touch any component of the power supply directly while it is energized. Be very careful when observing waveforms. Even after this power supply is shut down, there is a danger of electric shock due to residual charge of various capacitors. Make sure that the voltage of each component has dropped sufficiently before touching the BOARD.

In addition, the semiconductor devices and inductors of this power supply may generate heat according to the load current. This power supply assumes forced air cooling. Use an air-cooling device that enables heat-generating components to stay within the rated temperature range under high load. Do not touch any component of the power supply while the power supply is in operation as it may cause burns.

5. Power Supply Characteristics

This section describes the power supply efficiency result of this design.

5.1. Efficiency

Fig. 5.1 shows the measured efficiency of this design. The measurement is done with AC input (Vin) is 115V and 230V.

The maximum output power of this design is 0.8kW at Vin = 115V, and 1.6kW at Vin = 230V. The high efficiency of 96.1% is achieved at 0.8kW output in Vin = 115V, and the high efficiency of 96.7% is achieved at 1.6kW output in Vin = 230V.

The efficiency measurement at this time is performed with the cooling FAN driven by an external power supply. The measurement result changes when the cooling FAN is driven by the internal power supply. In addition, this design equipped with the ORing circuit at the output section. When ORing circuit is removed, the power supply efficiency of this design will be improved.

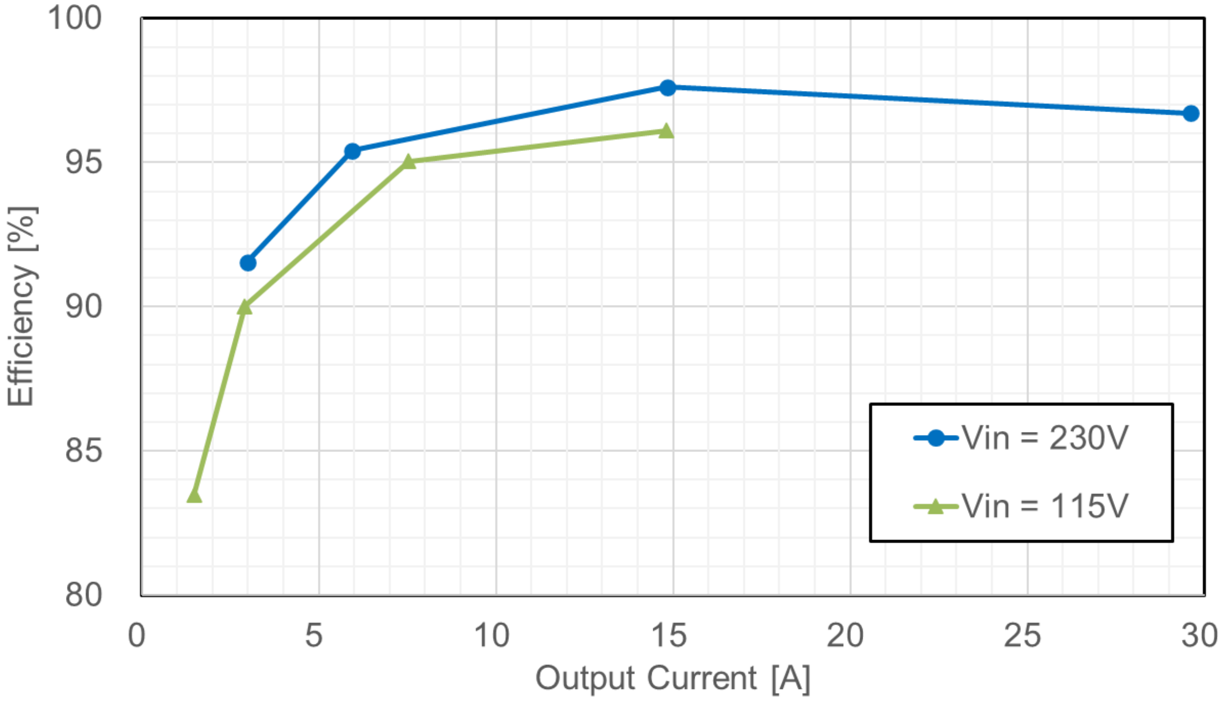

Fig. 5.1 Efficiency Measurement Result (Vin = 115V, Vin = 230V)

For reference, Fig. 5.2 to Fig. 5.5 show the measurement efficiency of this design and the standard of 80 PLUS. It is confirmed that the efficiency of this design in Vin = 230V meets Titanium standard (in Vin = 115V case it meets Platinum standard.).

The 80 PLUS standards in the chart are as of March 2025. The standard values may be updated. Please check them every time.

This design is not certified for 80 PLUS. It is necessary to measure the power supply efficiency using the equipment that will be the final product and acquire the certification.

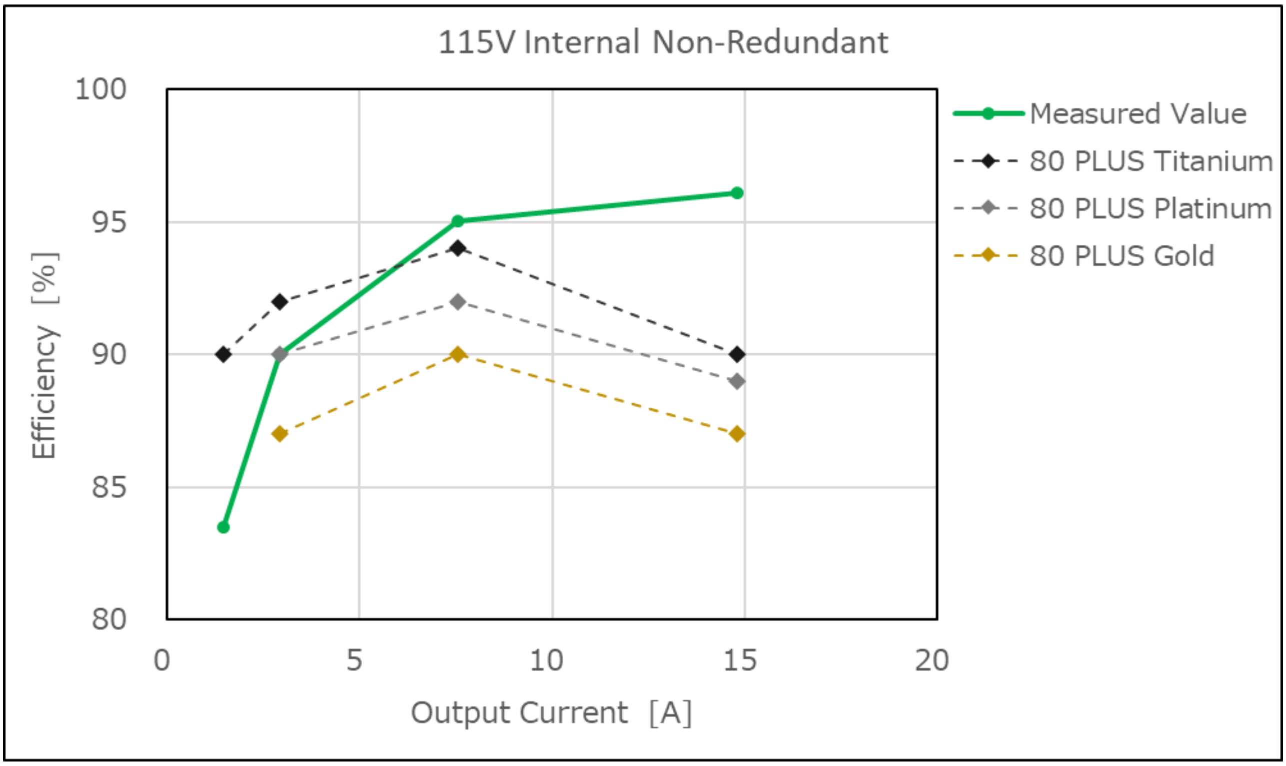

Fig. 5.2 Efficiency Measurement Result (80 PLUS 115V Internal Non-Redundant)

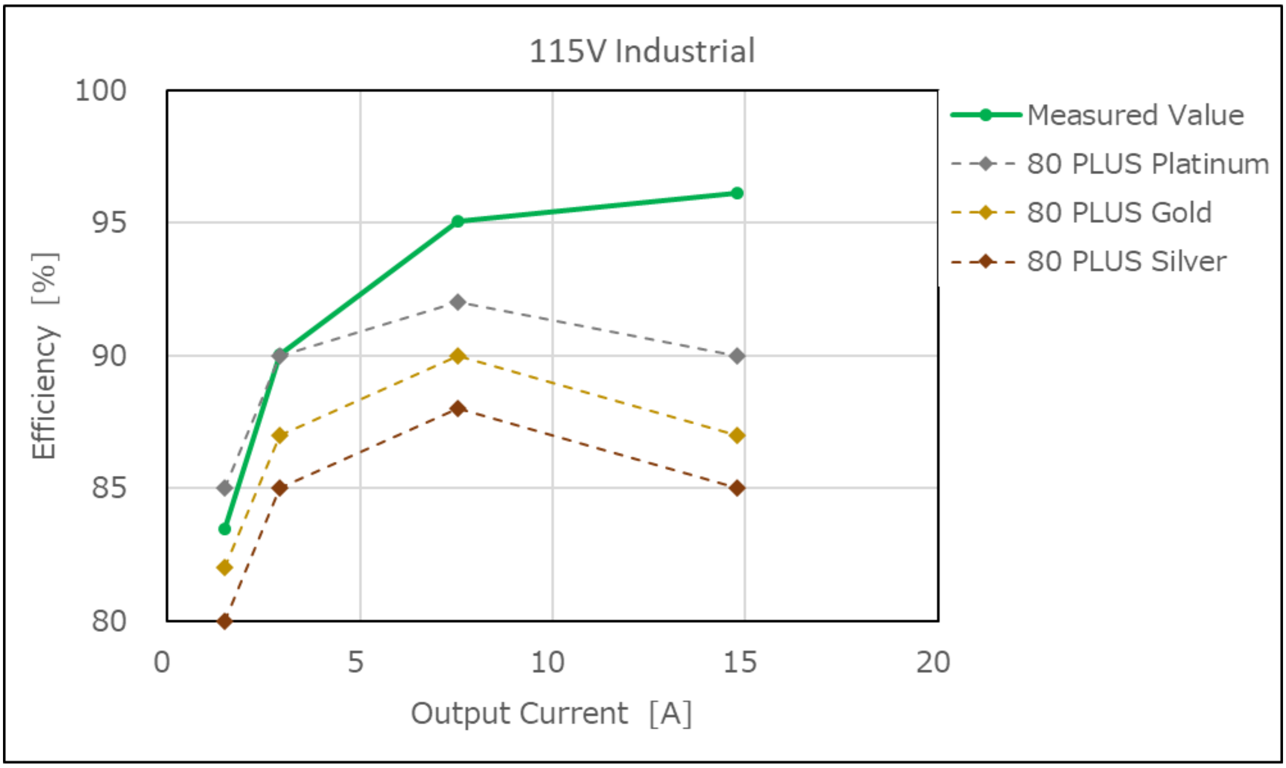

Fig. 5.3 Efficiency Measurement Result (80 PLUS 115V Industrial)

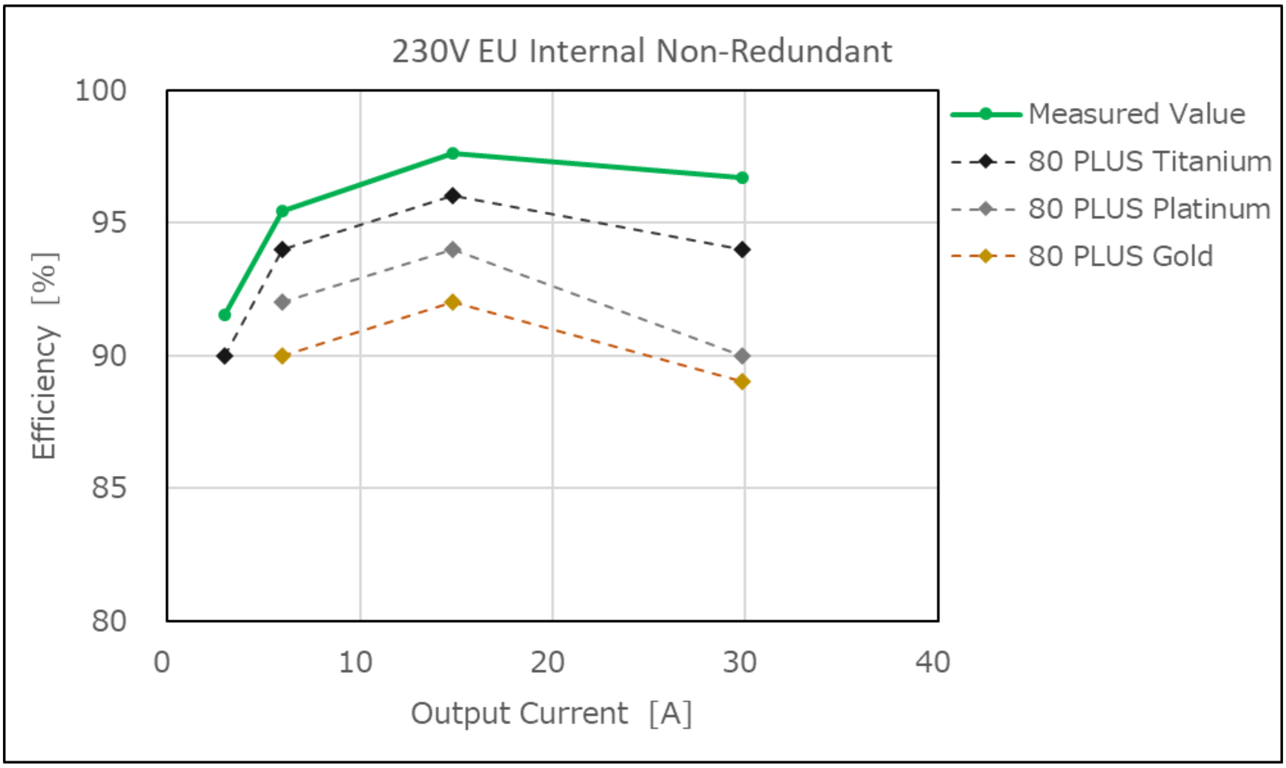

Fig. 5.4 Efficiency Measurement Result (80 PLUS 230V EU Internal Non-Redundant)

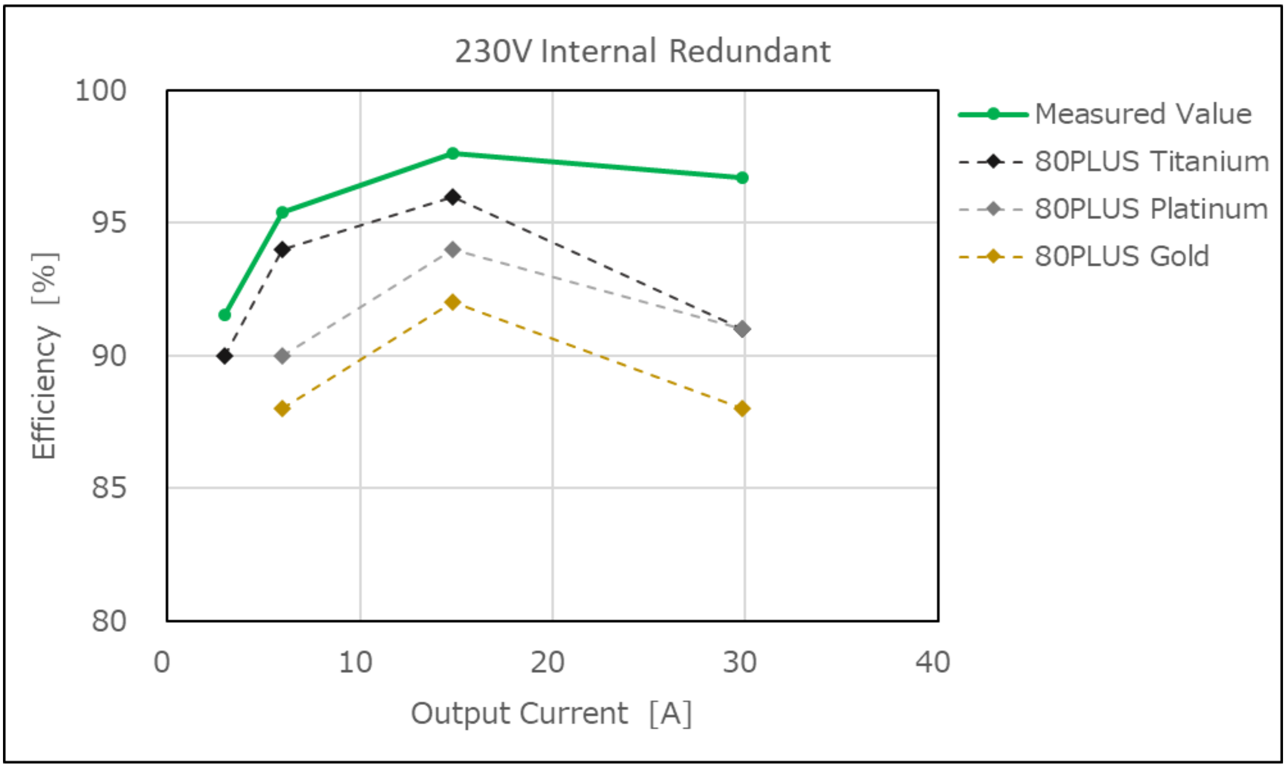

Fig. 5.5 Efficiency Measurement Result (80 PLUS 230V Internal Redundant)

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