Design precautions for AC-PLC with AC-DC

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Abstract

This document summarizes the precautions for circuit design and PCB layout design when mounting an AC-DC power supply circuit on an AC-PLC board or module that uses a Renesas Electronics power line communication (PLC) modem LSI.

When designing an AC-DC power supply circuit, please follow the guidelines in the application notes of the device to be used.

Note that the precautions explained in this document are general information for board design and may not necessarily be appropriate depending on the size, mounted components, and layout of your board.

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1. Board Design Precautions

This chapter explains the precautions for board design when mounting an AC-DC power supply circuit in an AC-PLC.

1.1 GND design for AC-DC power supply circuits

There are two types of AC-DC power supply circuits: isolated AC-DC and non-isolated AC-DC.
The GND design for each AC-DC power supply circuit is a very important element related to operational stability, noise countermeasures, and safety. Therefore, please pay attention to the following points when designing the board.
Also, be sure to select an isolated or non-isolated AC-DC power supply circuit appropriately depending on the usage environment.
When designing an AC-DC power supply circuit, be sure to follow the application notes and guidelines for the device being used.

1.1.1 Precautions when designing GND in an isolated AC-DC power supply circuit

- An isolated AC-DC power supply circuit such as a flyback converter is electrically isolated by an insulating element such as a transformer, and there are two GNDs: a primary GND and a secondary GND.
- The primary GND is the high-voltage GND immediately after rectification from the AC line, and requires special attention because it poses a risk of electric shock. On the other hand, the secondary GND is the low-voltage GND via a transformer or isolation element, and there is no risk of electric shock.
- Be sure to separate the primary GND and secondary GND and do not mix them. From a safety perspective, it is important to protect the high-voltage circuit area on the primary side with an insulating cover.
- The secondary GND of the AC-DC power supply circuit and the GND of the low-voltage circuit including the PLC circuit are shared, but to suppress noise interference in the AC-DC power supply circuit, connect the two at a single point (single-point earth).
- The DC power supply circuit (3.3V power supply circuit and AFE power supply line) that supplies power to the PLC circuit is located close to the AC-DC power supply circuit, so it is susceptible to noise from the AC-DC power supply circuit. For this reason, in order to suppress noise interference from the GND of the DC power supply circuit, we recommend that the GND of the DC power supply circuit and the GND of the PLC circuit are also connected at a single point (single point earth).
- Figure 1-1 shows an AC-PLC block diagram using an isolated AC-DC power supply circuit, Figure 1-2 shows an example of an isolated AC-DC power supply circuit using the RAA223021 manufactured by Renesas Electronics.

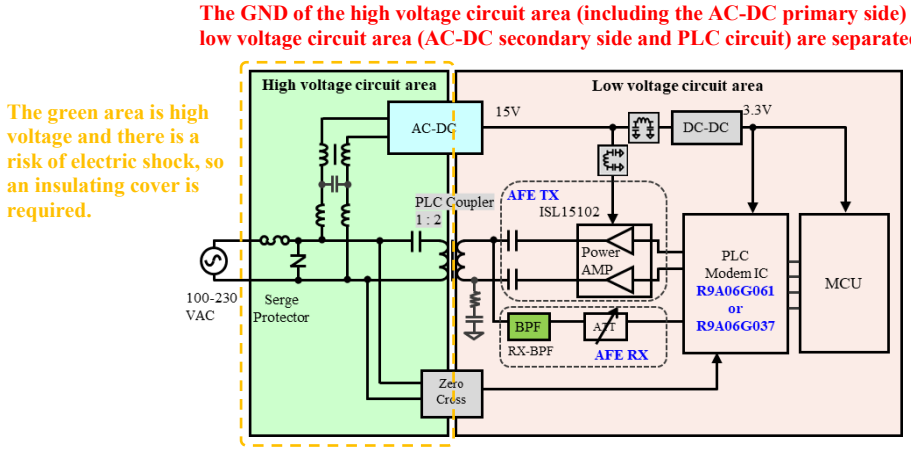


Figure 1-1 AC-PLC block diagram using an isolated AC-DC power supply circuit

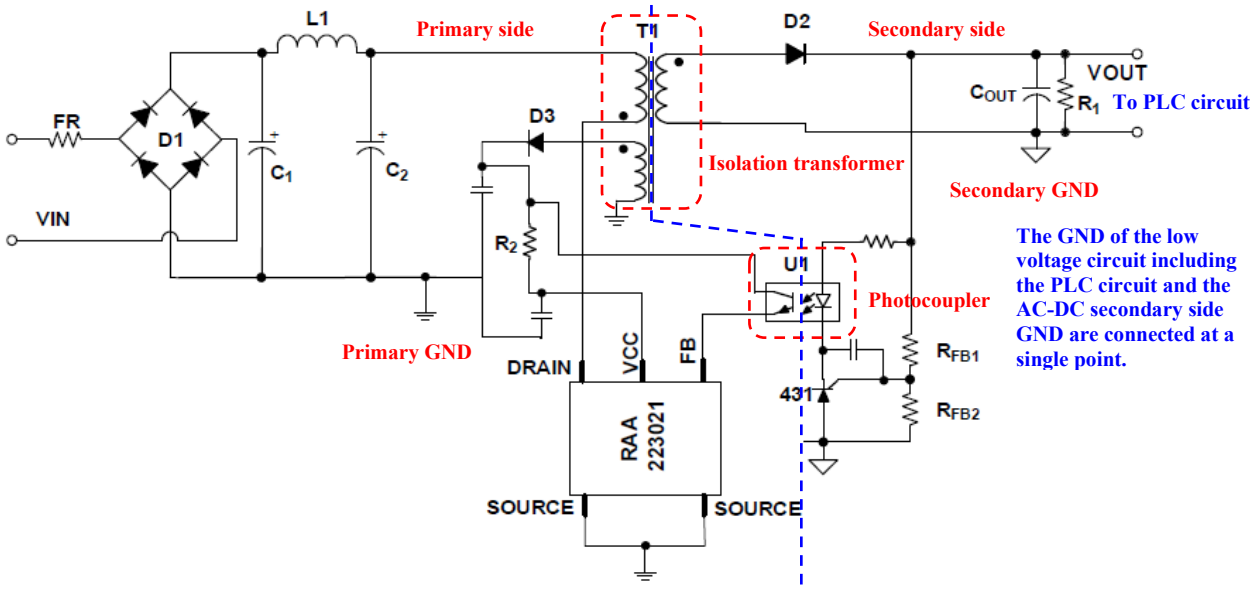


Figure 1-2 Example of an isolated AC-DC power supply circuit using Renesas Electronics RAA223021

1.1.2 Precautions for GND design in non-isolated AC-DC power supply circuits

- In a non-isolated AC-DC power supply circuit such as a non-isolated buck converter, the primary side GND and secondary side GND are common, so there is no need to separate the GND as in an isolated type.
- However, this common GND includes the primary side GND (the high voltage side GND immediately after rectification from the AC line), so there is a risk of electric shock. To ensure safety, it is necessary to protect the entire board with an insulating cover.
- We recommend that the GND path of the switching loop consisting of noise sources (switching FET, flywheel diode, inductor, output capacitor) in a non-isolated AC-DC power supply circuit be designed to be as short and wide as possible.
- The GND of the non-isolated AC-DC power supply circuit and the GND of the low-voltage circuit including the PLC circuit are common, but to suppress noise interference in the AC-DC power supply circuit, connect the two at a single point (single-point earth).
- The DC power supply circuit (3.3 V power supply circuit and AFE power line) that supplies power to the PLC circuit is placed close to the AC-DC power supply circuit, so it is susceptible to noise from the AC-DC power supply circuit. For this reason, we recommend that the GND of the DC power supply circuit and the GND of the PLC circuit be connected at a single point (single point earth) to suppress noise interference from the GND of the DC power supply circuit.
- Figure 1-3 shows an AC-PLC block diagram using a non-isolated AC-DC power supply circuit, and Figure 1-4 shows an example of a non-isolated AC-DC power supply circuit using the Renesas Electronics RAA223021.

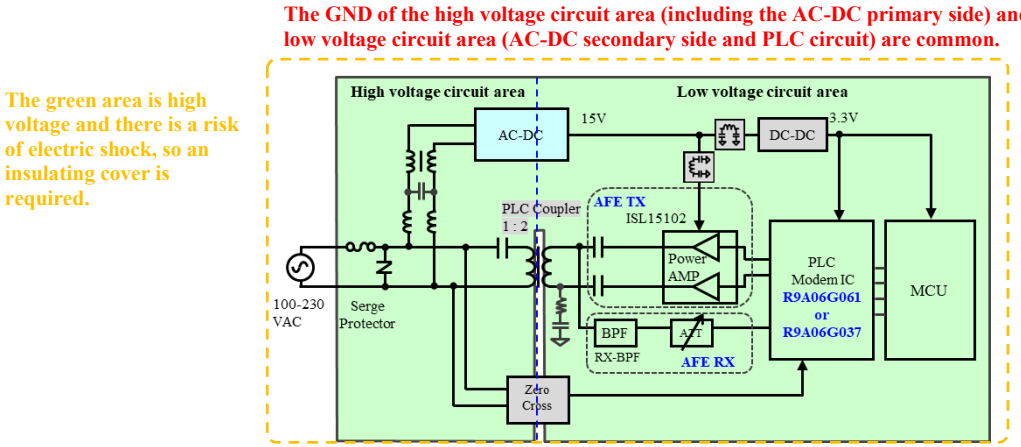


Figure 1-3 AC-PLC block diagram using a non-isolated AC-DC power supply circuit

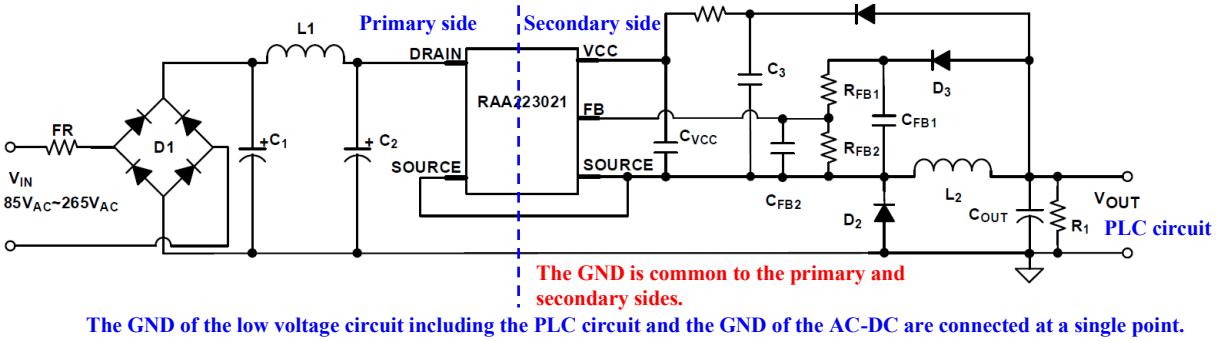


Figure 1-4 Example of a non-isolated AC-DC power supply circuit using Renesas Electronics RAA223021

1.2 Output smoothing inductor

- Among the components in an AC-DC power supply circuit, the output smoothing inductor (the output smoothing inductor in the case of a non-isolated AC-DC, or the isolation transformer in the case of an isolated AC-DC) is likely to generate a lot of electromagnetic noise. Therefore, be sure to select a shielded inductor element for the output smoothing inductor element.

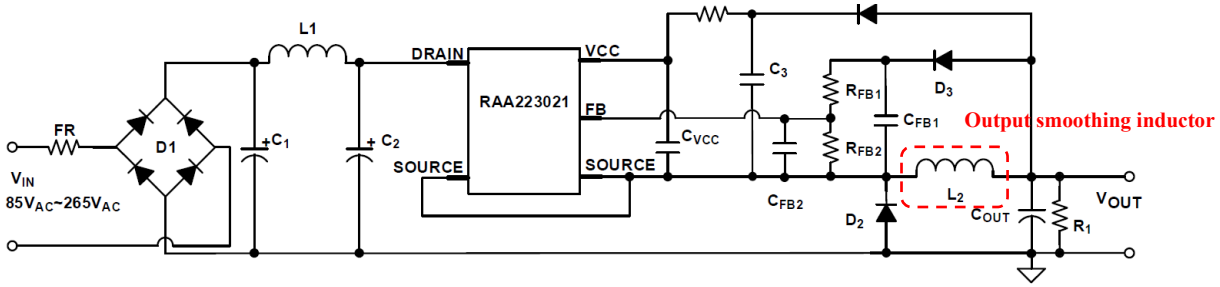


Figure 1-5 Example of a non-isolated AC-DC power supply circuit using Renesas Electronics RAA223021

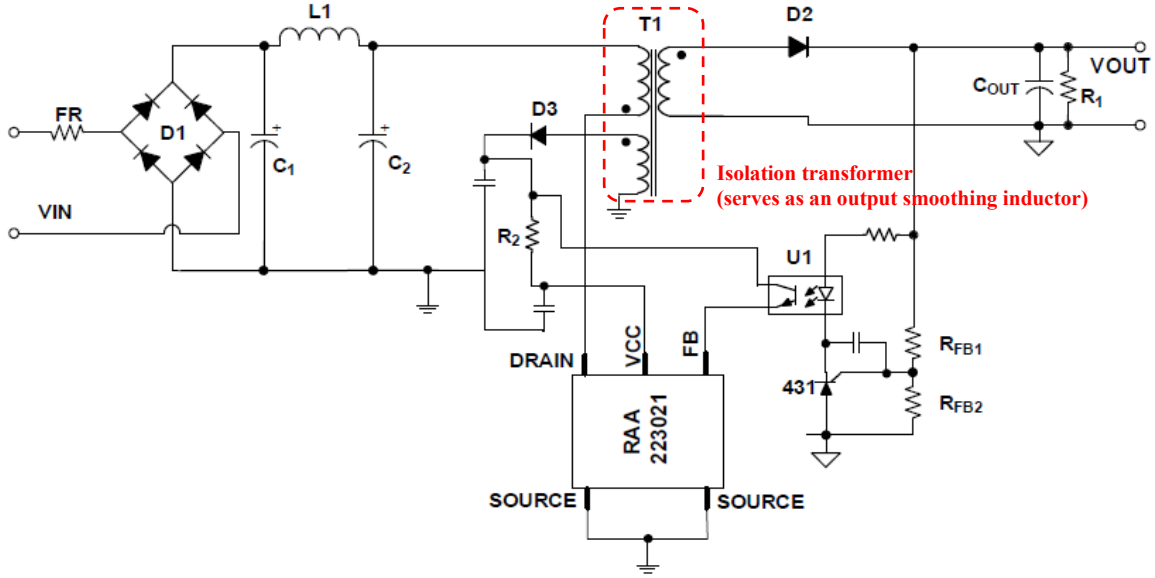


Figure 1-6 Example of an isolated AC-DC power supply circuit using Renesas Electronics RAA223021

1.3 Insertion of Impedance upper circuit

- To prevent the input impedance of the AC-DC power supply circuit from affecting the PLC input/output, insert an impedance upper between the PLC signal and the AC-DC power supply circuit. An example of impedance upper insertion is shown in Figure 1-7, and examples of impedance upper circuit constants are shown in Table 1-1.

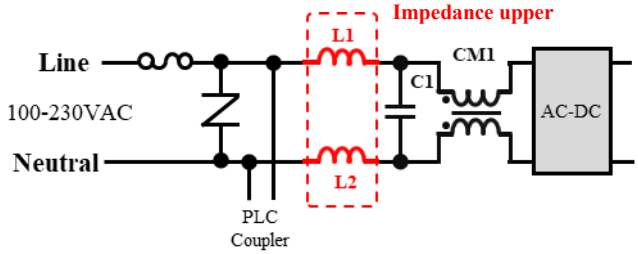


Figure 1-7 Example of impedance upper insertion

Table 1-1 Example of circuit constants of impedance upper for AC-DC power supply circuit

	CENELEC-A 35kHz-90kHz	Global 35kHz-500kHz	FCC/ARIB 150kHz-500kHz
L1/L2	1mH or more		0.22mH or more

1.4 Insertion of Noise filter

1.4.1 AC-DC power supply circuit input section

- LC filter: To prevent PLC signals from affecting the AC-DC power supply circuit, we recommend inserting an LC LPF by combining the impedance upper inductor with a capacitance.
- Common mode filter: To prevent noise from the AC-DC power supply circuit from affecting the AC line, we recommend inserting a common mode filter.
- An example of inserting a noise filter at the input section of the AC-DC power supply circuit is shown in Figure 1-8, and an example of the noise filter circuit constants is shown in Table 1-2.

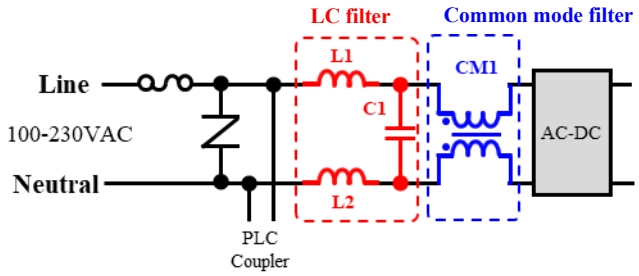


Figure 1-8 Example of inserting noise filters at the input section of an AC-DC power supply circuit

Table 1-2 Example of circuit constants of noise filter at the input part of the AC-DC power supply circuit

	CENELEC-A 35kHz-90kHz	Global 35kHz-500kHz	FCC/ARIB 150kHz-500kHz
C1 [1)]	0.22uF or more		
CM1	15mH or more		

Note.1) If the input capacitance of the AD-DC power supply circuit is 0.22uF or more, C1 can be omitted.

1.4.2 DC power supply circuit input section

- To remove noise from the AC-DC power supply circuit and to reduce the influence of switching noise generated on the DC power supply circuit on other power supply circuits, we recommend inserting a noise filter consisting of an LC circuit at the DC power supply circuit input section of the 3.3V generation DC-DC power supply circuit and the AFE power supply line (15V or 12V). An example of a circuit for an input filter for a DC power supply circuit is shown in Figure 1-9, and an example of circuit constants for a noise filter at the input section of a DC power supply circuit is shown in Table 1-3.

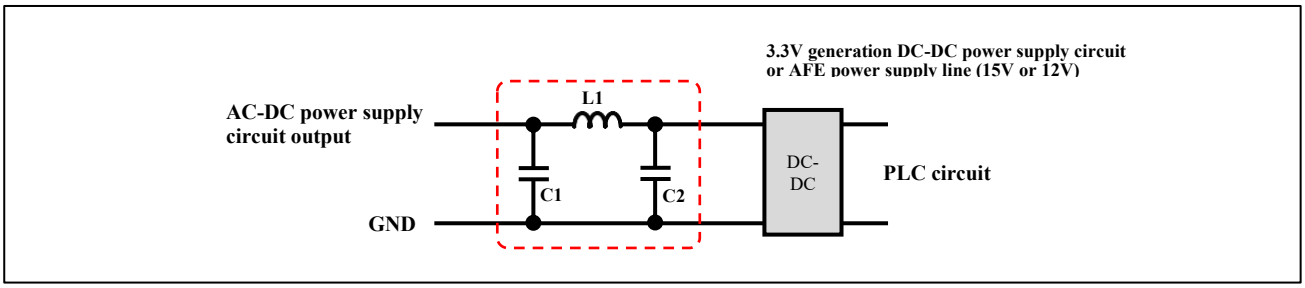


Figure 1-9 Example of input noise filter for DC power supply circuit

Table 1-3 Example of circuit constants for noise filter at the input section of a DC power supply circuit

	Circuit constants
L1	10uH
C1	10uF-22uF
C2 [2)]	10uF-22uF

Note.2) If the input capacitance of the DC power supply circuit is 10uF or more, C2 can be omitted.

2. Precautions regarding distance between AC-DC power supply circuit and other circuits

This chapter explains the precautions concerning the distance between the AC-DC power circuit and other circuits in the PCB layout of the AC-PLC board when an AC-DC power circuit is mounted.

2.1 Creepage and Clearance Distances in Accordance with Safety Standards

- In the AC-PLC board with an AC-DC power circuit, the AC coupling circuit and the primary side of the AC-DC power circuit involve high voltage. Therefore, the creepage and clearance distances between electrodes within the high-voltage circuit, as well as between high-voltage and low-voltage circuits, must be designed in accordance with the safety standards applicable in the region of use. As a reference, examples of creepage and clearance distances from EN50065-4-2 (CE marking) are shown in Table 2-1.
- For areas such as insulation components where creepage distance must be ensured, it is recommended to add slits on the PCB as necessary.

Table 2-1 Examples of creepage distances and clearance distances in EN50065-4-2 (CE marking)
Creepage distances and clearances

Description	Rated impulse voltage 4 kV (mm)	Rated impulse voltage 6 kV (mm)
Creepage distances		
1. Between live parts of different polarity, including parts for looping-in of external conductors	4[1)]	5,5
2. Between live parts, including parts for looping-in of external conductors, and:		
- accessible metal parts,	5,5	8
- earthed metal parts, including the earthing circuits	3	5,5
- screws or other devices for fixing bases, covers or cover plates	3	5,5
Clearances		
3. Between live parts of different polarity, including parts for looping-in of external conductors	3	5,5
4. Between live parts, including parts for looping-in of external conductors, and		
- accessible metal parts,	5,5	8
- earthed metal parts, including the earthing circuits	3	5,5
- screws or other devices for fixing bases, covers or cover plates	3	5,5
5. Between live parts, including parts for looping-in of external conductors, and the surface on which the base of surface-type equipment is mounted	5,5	8
Distances through insulating sealing compound		
6. Between live parts covered with at least 2 mm of sealing compound and the surface on which the base of surface-type equipment is mounted	4	5,5

1) The value is reduced to 3 mm for nominal voltage up to and including 250 V

2.2 Suppression of Power Noise Interference from the AC-DC Power Circuit

Among the components of the AC-DC power circuit, the output smoothing inductor or the isolation transformer are highly likely to be sources of electromagnetic noise. Therefore, maintaining sufficient distance from these components is an effective measure to suppress noise interference.

2.2.1 PLC Input/Output Lines

- The PLC input/output lines, which connect the LINE and NEUTRAL terminals to the PLC coupler, are laid out near the AC-DC power circuit. For this reason, it is recommended to maintain a distance of at least 40 mm between these lines and noise-generating components such as the output smoothing inductor or isolation transformer.
- As an example, results of near electromagnetic field analysis are shown for Renesas' prototype AC-PLC board using a non-isolated AC-DC power supply. A comparison was made between the PCB layout before improvement (Prototype #0014) and after improvement (Prototype #0004), focusing on noise interference from the output smoothing inductor to the nearest PLC LINE pattern. The results confirmed that, after layout improvement, the electric field strength around 900 kHz was suppressed by approximately 12 dB compared to the previous layout (see Figure 2-1). Furthermore, as shown in Figure 2-2, this layout improvement also reduced transmission spurious emissions around 900 kHz and in the 1.5 MHz to 4 MHz range, resulting in compliance with the CENELEC-A standard. These results demonstrate that maintaining a distance of at least 40 mm between the output smoothing inductor of the AC-DC power circuit and the PLC input/output lines connected from the LINE and NEUTRAL terminals to the PLC coupler is effective in suppressing noise interference.

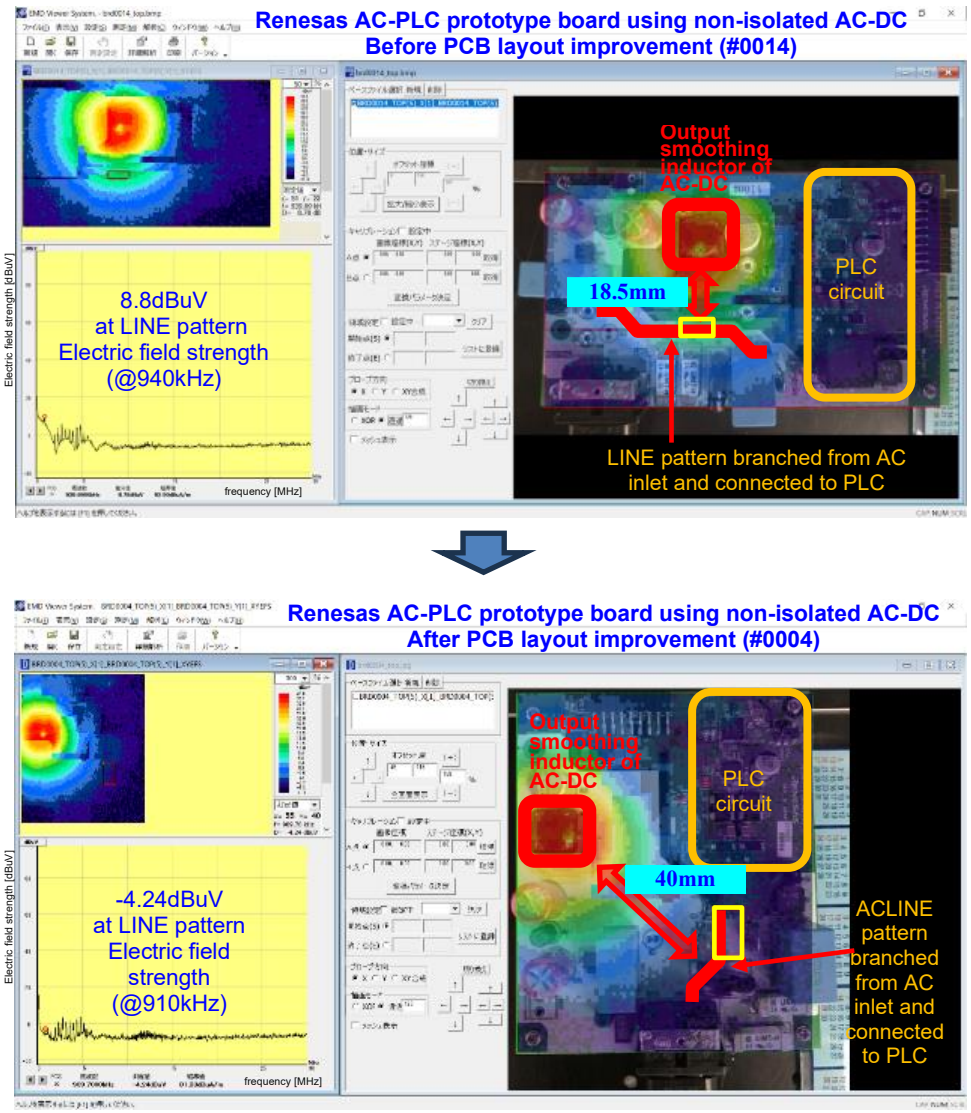
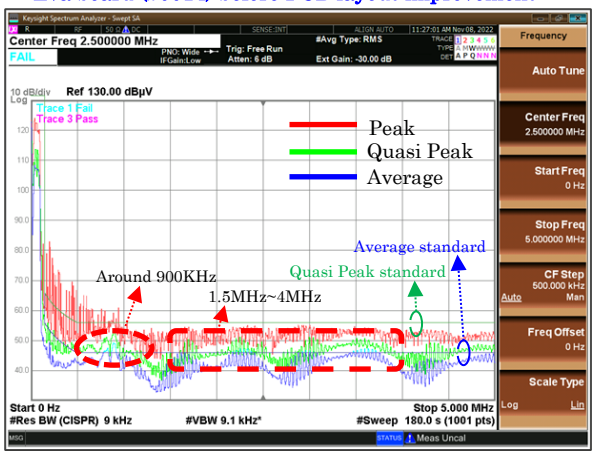


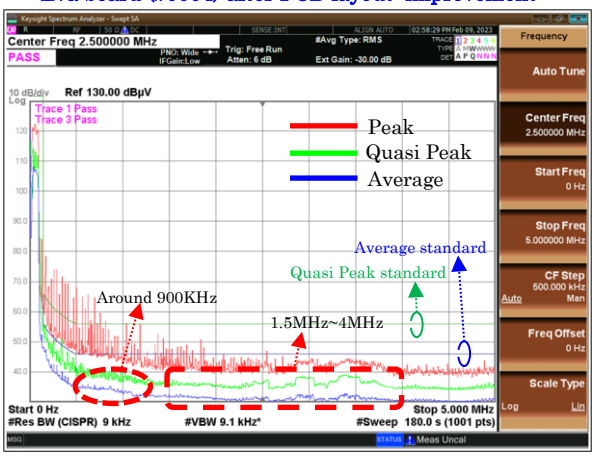
Figure 2-1 Example of noise interference based on the distance between the AC-DC output smoothing inductor and the PLC line pattern

Eva board (#0014) before PCB layout improvement



Due to the influence of interference noise from the AC-DC power supply circuit, the Eva board (#0014) does not satisfy the CENELEC-A standard for transmission spurious around 900 kHz and 1.5 MHz to 4 MHz.

Eva board (#0004) after PCB layout improvement



By changing the PCB layout, the influence of interference noise from the AC-DC power supply was reduced, and the transmission spurious around 900 kHz and 1.5 MHz to 4 MHz was suppressed. As a result, the CENELEC-A standard is satisfied.

Figure 2-2 Example of transmission spurious based on the distance between the AC-DC output smoothing inductor and the PLC line pattern

2.2.2 DC Power Circuit Section

- The DC-DC power circuit section (including the 3.3V power supply and the 15V or 12V power supply line for the AFE, along with the noise filters placed at each input) may be adversely affected by noise coupling from the AC-DC power circuit if placed too close to the output smoothing inductor or isolation transformer. This noise can degrade the reception performance of the PLC circuit. Therefore, it is recommended to maintain a distance of at least 30 mm between the DC-DC power circuit section and the output smoothing inductor or isolation transformer. If layout constraints make this difficult, ensure a minimum distance of at least 20 mm.
- As an example, results of near electromagnetic field analysis are shown for Renesas' prototype AC-PLC board using a non-isolated AC-DC power supply. A comparison was made between the PCB layout before improvement (#0004) and after improvement (#0005). The analysis focused on noise interference from the output smoothing inductor of the AC-DC circuit to the nearest 15V noise filter. The results confirmed that, after layout improvement, the electric field strength caused by noise around 70 kHz in the CENELEC-A band was reduced by approximately 3.4 dB compared to the previous layout (see Figure 2-2). In addition, this reduction in AC-DC power circuit noise led to an improvement in reception sensitivity by approximately 3 to 4 dB within the CENELEC-A band. These results demonstrate that maintaining a distance of at least 30 mm between the output smoothing inductor of the AC-DC circuit and the DC power circuit (in this case, the 15V noise filter) is effective in suppressing noise interference.

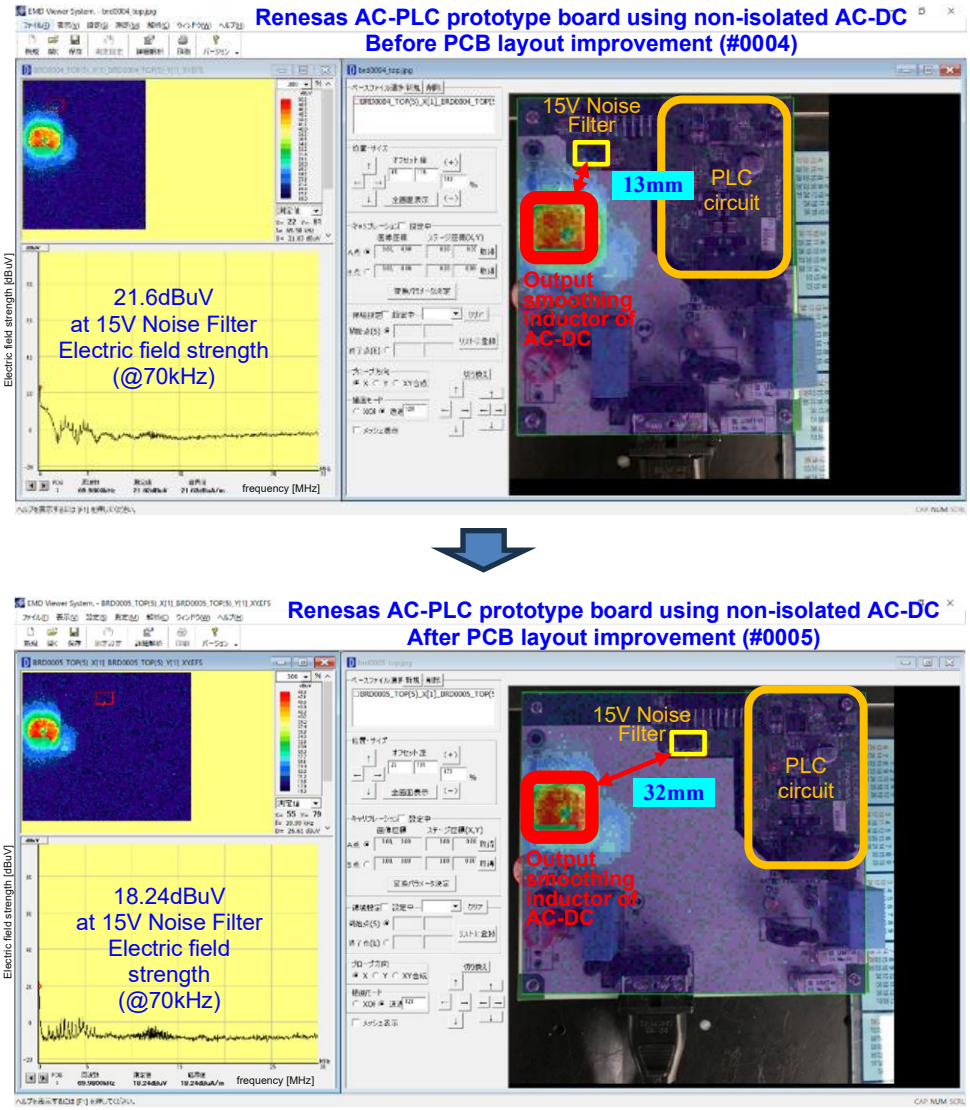


Figure 2-3 Example of noise interference based on the distance between the AC-DC output smoothing inductor and the 15V noise filter

2.2.3 RX-BPF

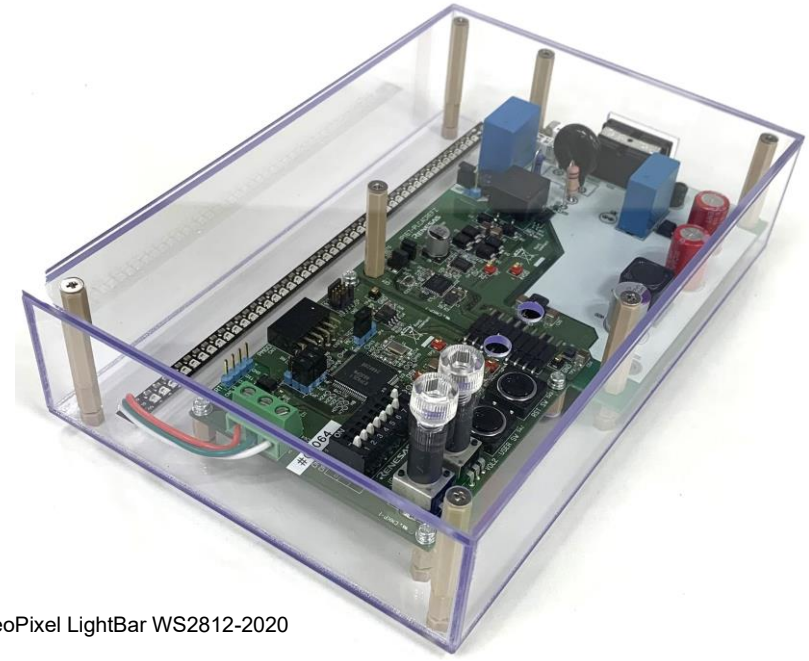
- Since the RX-BPF is particularly susceptible to noise, it is recommended to maintain a distance of at least 40 mm from the AC-DC power circuit's output smoothing inductor or isolation transformer, and to separate them with a GND pattern. If maintaining this distance is difficult due to layout constraints, placing the RX-BPF on a different layer from the AC-DC power circuit is advised.
- Regarding the RX-BPF, there is no near electromagnetic field analysis data available as shown in the previous section. However, based on Renesas' experience in evaluation board development, it has been confirmed that maintaining a distance of at least 40 mm between the RX-BPF and the AC-DC power circuit's output smoothing inductor or isolation transformer is effective in suppressing noise interference and preventing degradation of reception sensitivity.

3. Example of AC-PLC Board with AC-DC Power Circuit

This chapter introduces an example of an AC-PLC demo kit developed by Renesas Electronics, featuring a non-isolated AC-DC power circuit.

The demo kit consists of a PLC board, an MCU board, and an LED bar. The PLC board includes a PLC circuit using Renesas Electronics' modem LSI "R9A06G061GNP" and a non-isolated AC-DC power circuit. The MCU board controls the LED bar, enabling demonstration of LED lighting system control via power line communication (PLC) over AC power lines.

Since the kit uses a non-isolated AC-DC power circuit, safety measures have been implemented, such as enclosing the entire kit in an insulated cover and using an insulating knob for the dimming variable resistor.



LED bar : Mini NeoPixel LightBar WS2812-2020

Figure 3-1 Example of AC-PLC demo kit by Renesas Electronics with non-isolated AC-DC power supply

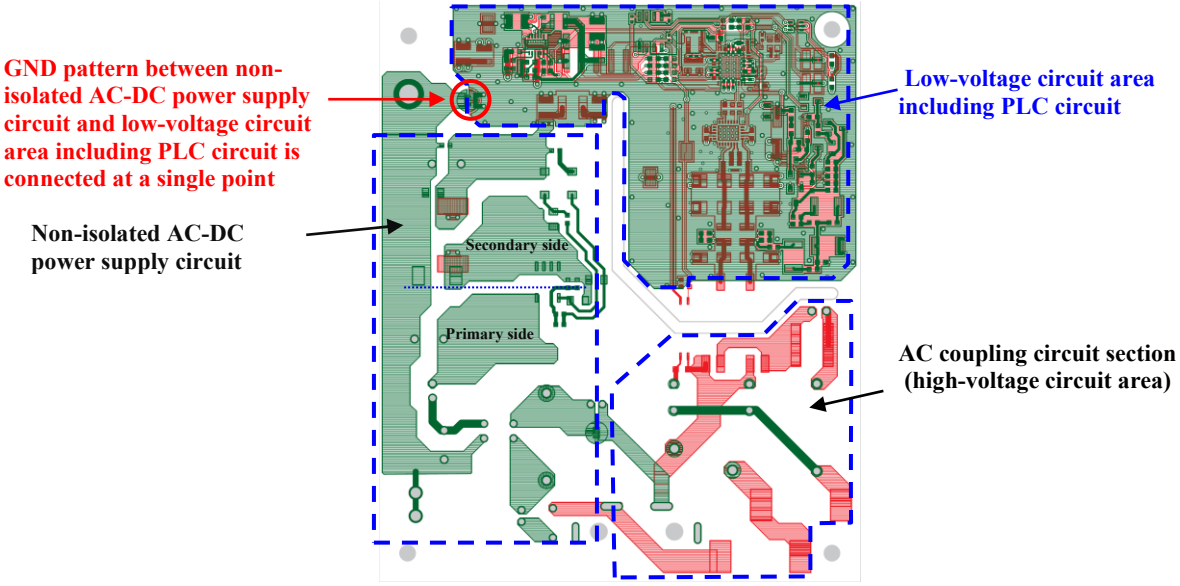


Figure 3-2 Example of GND pattern of AC-PLC demo kit with non-isolated AC-DC power supply

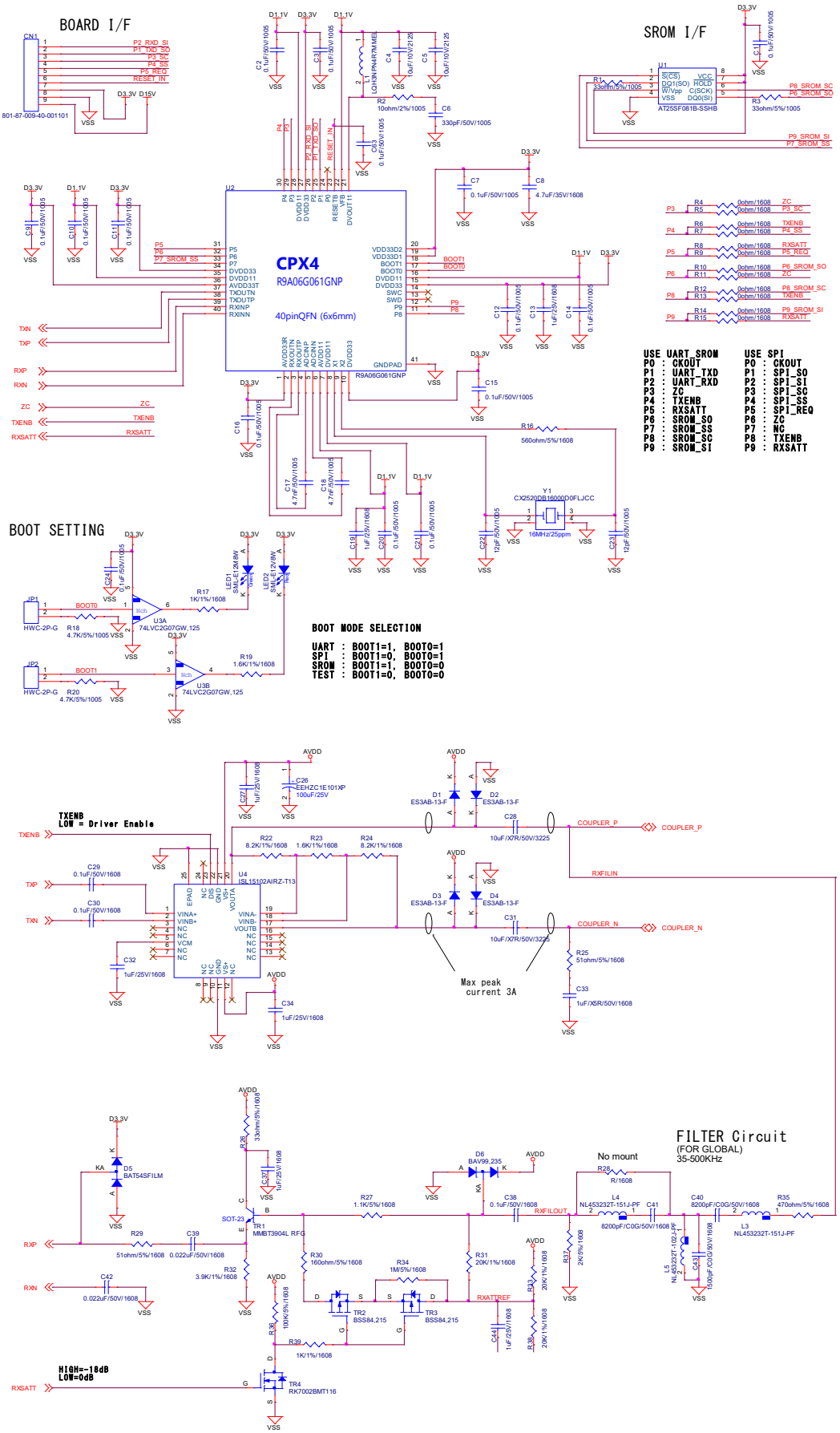


Figure 3-3 Schematic of PLC board of AC-PLC demo kit (1)

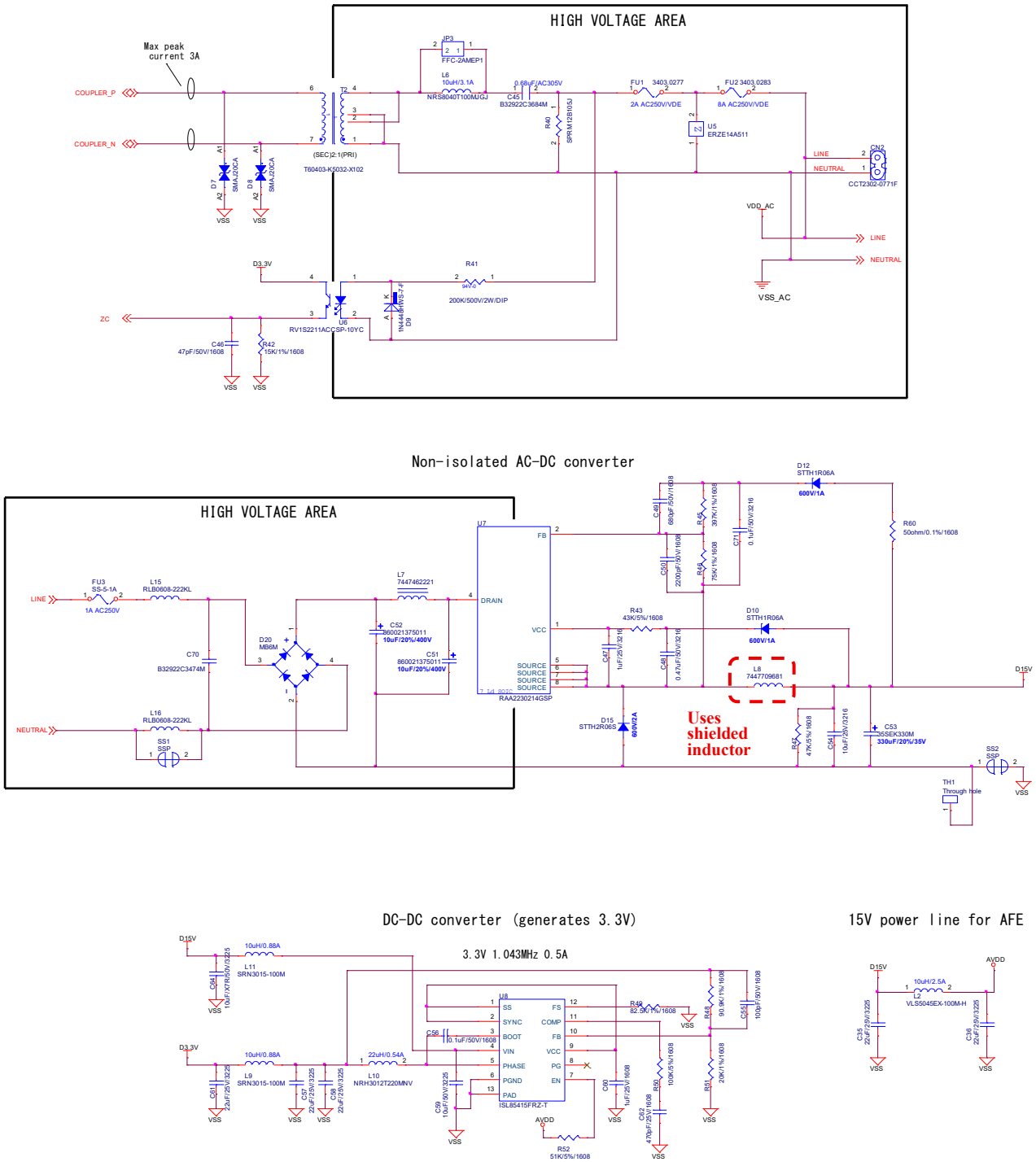


Figure 3-4 Schematic of PLC board of AC-PLC demo kit (2)

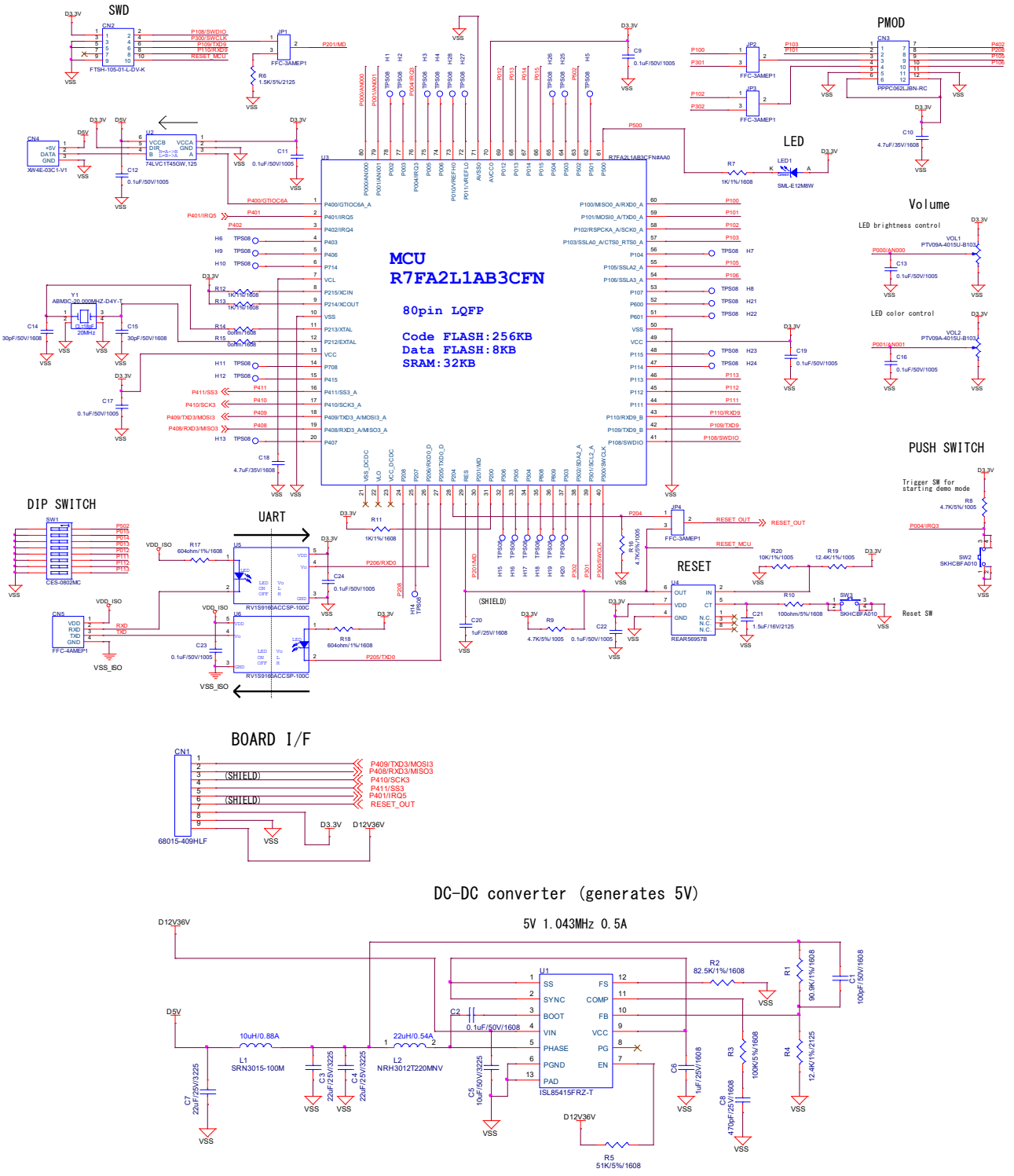
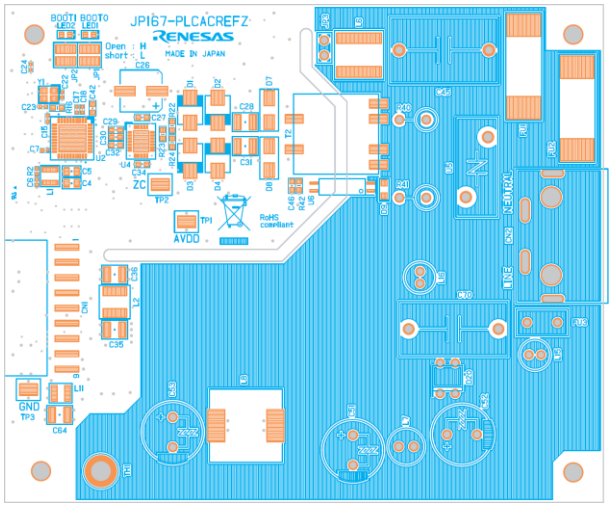
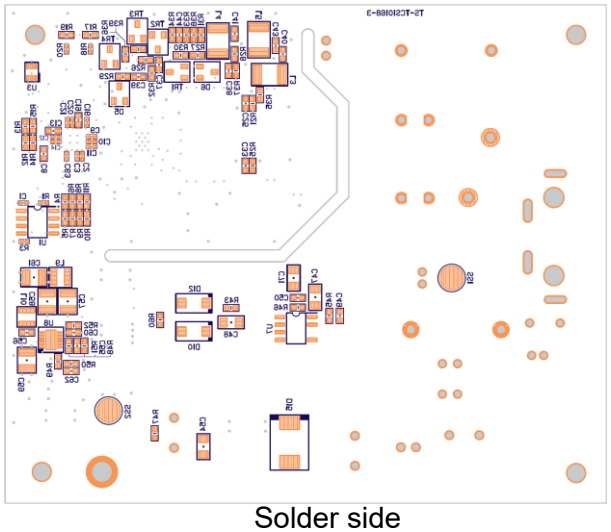


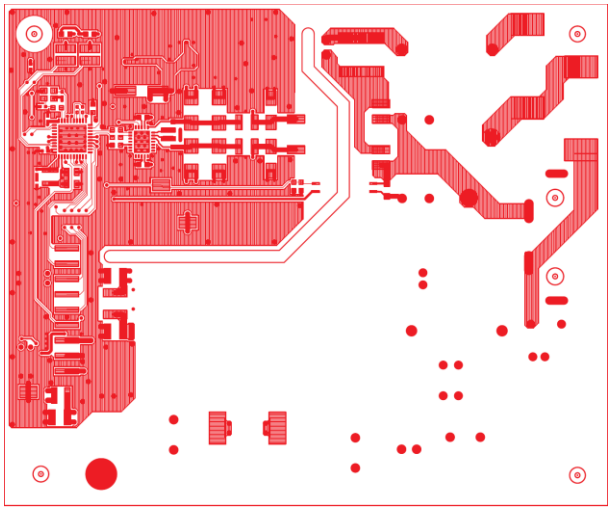
Figure 3-5 Schematic of MCU board of AC-PLC demo kit



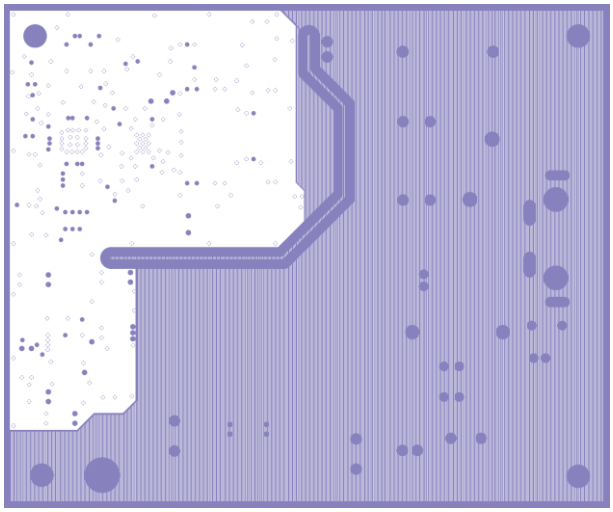
Component side



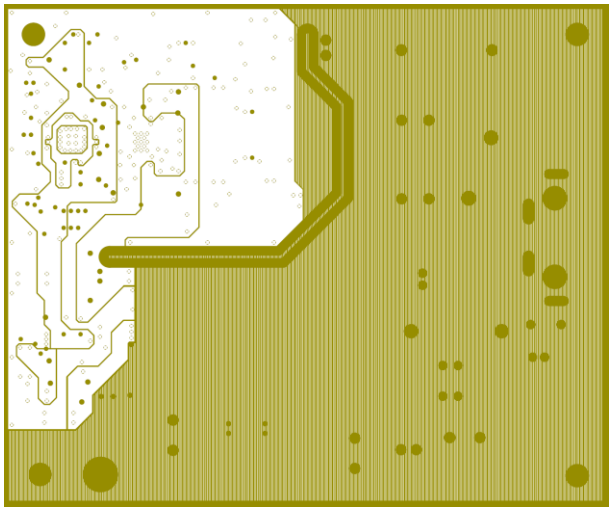
Solder side



Layer 1



Layer 2



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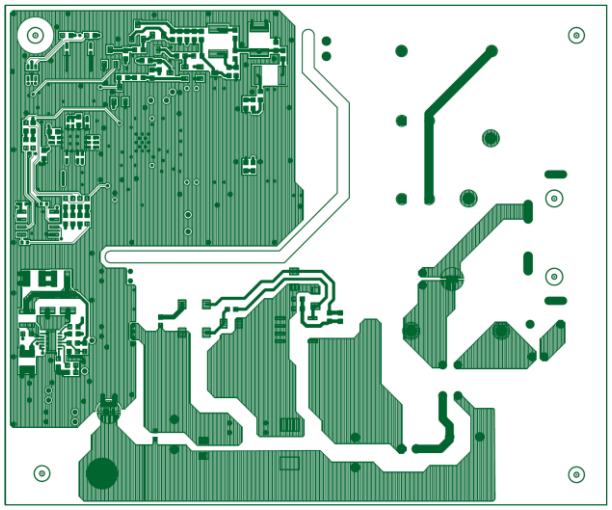
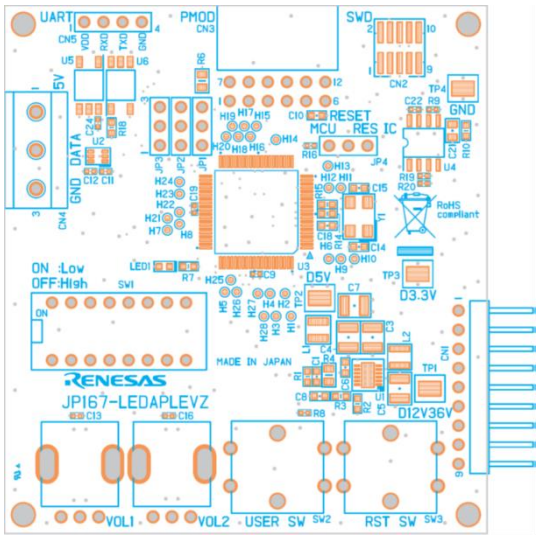
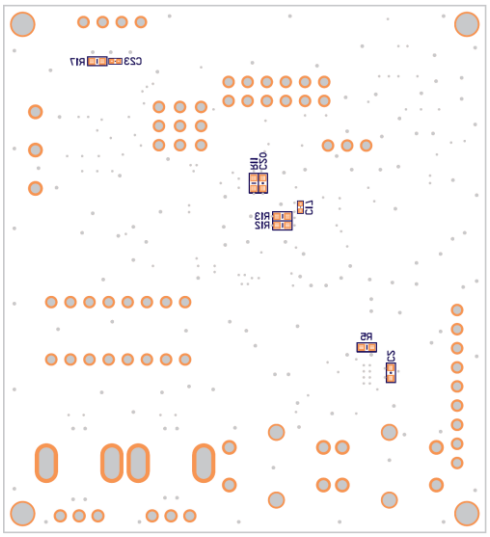


Layer 4

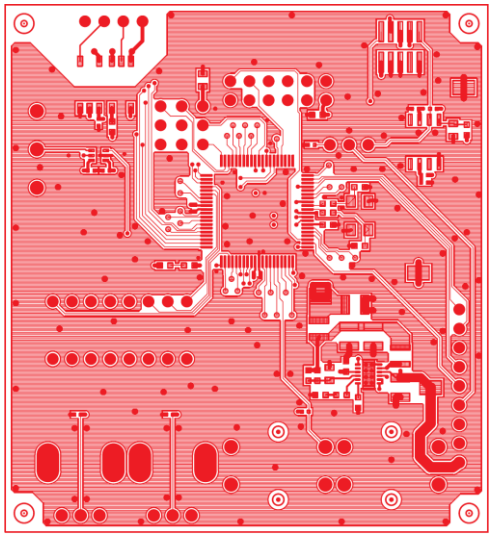
Figure 3-6 PCB layout of PLC board of AC-PLC demo kit



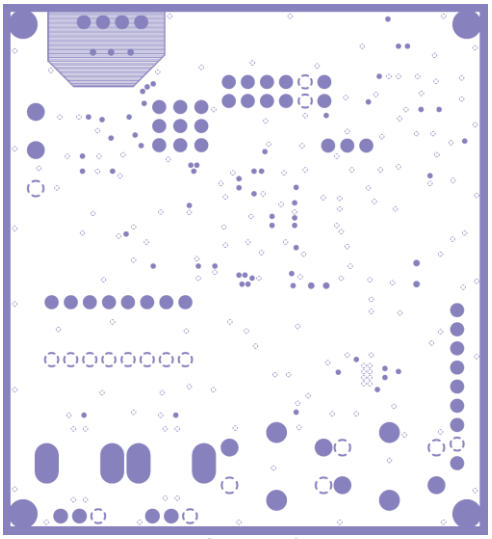
Component side



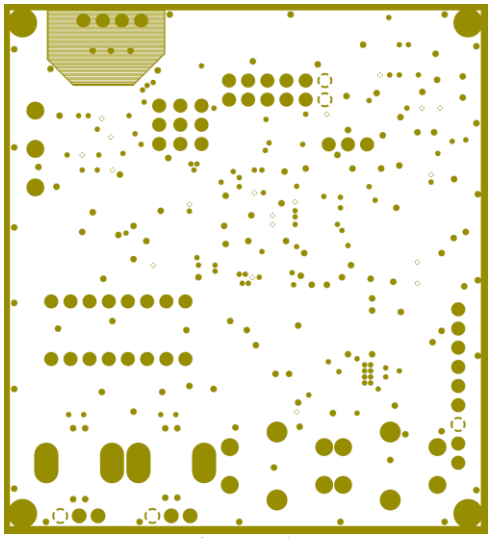
Solder side



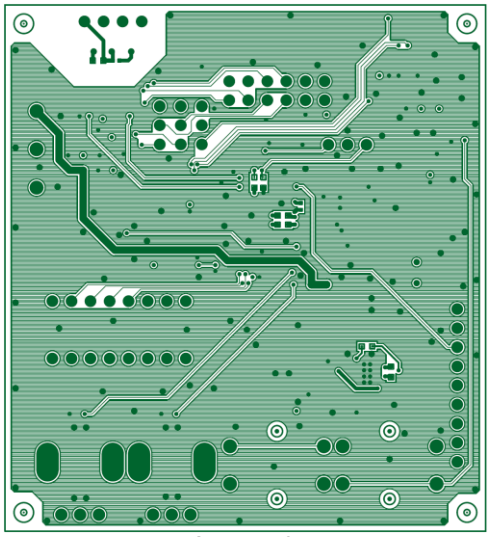
Layer 1



Layer 2



Layer 3



Layer 4

Figure 3-7 PCB layout of MCU board of AC-PLC demo kit

Website and Support

Renesas Electronics Website
https://www.renesas.com/jp/en

Inquiries
https://www.renesas.com/jp/en/contact-us

Revision History

Rev.	Date	Description	
		Page	Summary
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