

R9A06G037/ISL15102 Circuit Design Guideline

R30AN0454EJ0120

Rev.1.20

PCB Circuit Design Guide

March 1, 2025

Summary

This material is a guideline for PCB circuit when designing a PLC board using R9A06G037 as a PLC modem LSI by Renesas Electronics manufactured and ISL15102 as a Power Amp for transmission output. For the device and the power circuit design, follow guidelines and application notes of the target device.

Note that cautions on this material are based on general board design, and may not be applicable in some cases depending on the board size, parts, and layout.

Table of Contents

1. PLC Board Configuration Example	3
2. Cautions regarding peripheral circuits of R9A06G037	3
2.1 R9A06G037 Peripheral circuit	3
2.2 BOOT terminal setting	4
2.3 Reference clock setting	4
2.4 TEST terminal	5
2.5 RESETB terminal	5
2.6 Power supply circuit	6
2.6.1 DC-DC converter	6
2.6.2 LDO	7
2.7 LED	7
3. Cautions regarding AFE circuit and AC coupling circuit	8
3.1 AFE peripheral circuit	8
3.1.1 Setting the feedback resistance value of ISL15102	8
3.1.2 ISL15102 differential output balancing load circuit	9
3.2 Protection circuit	10
3.3 PLC Coupler	10
3.4 Zero cross detection circuit	11
3.5 RX-BPF	12
3.6 Step attenuator circuit	12
3.7 Measures for low impedance load (CENELEC-A band only)	14
3.8 EN50065-7 compatible impedance measures (CENELEC-A band only)	15
4. Cautions on the DC-DC Power Supply Circuit	16
5. Cautions on the AC-DC Power Supply Circuit	17
6. Circuit design example	18
6.1 Example of circuit design	18

6.2 Example of Bill of materials 22

Website and Support25

Revision History26

2.2 BOOT terminal setting

2.2.1 BOOT0 terminal

The BOOT0 is a terminal for setting the interface for downloading firmware for boot.

- Set to UART I/F BOOT: Open (High level)
- Set to SROM I/F BOOT: Connect to GND via 4.7kΩ or 5.1kΩ (Low level)

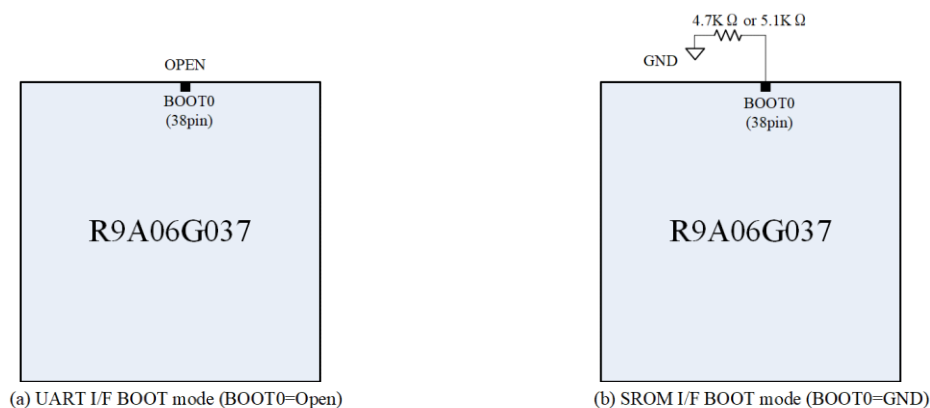


Figure 2-2 BOOT0 terminal connection example

2.2.2 BOOT1 terminal

BOOT1 is a terminal for selecting the clock supply mode.

- Use crystal oscillator: Open (High level) (default setting)
- Use external clock: Connect to GND via 4.7kΩ or 5.1kΩ (Low level)

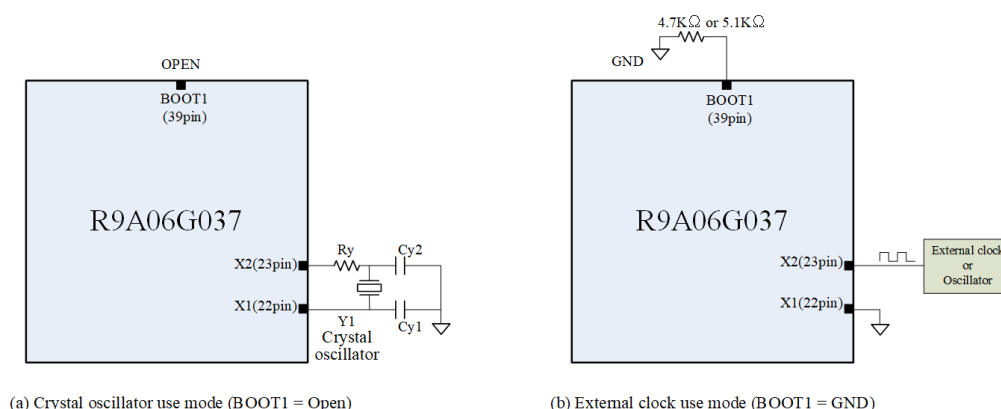


Figure 2-3 BOOT1 terminal connection example

2.3 Reference clock setting

For the reference clock, the G3-PLC standard recommends that the frequency deviation of the system clock be within ± 25 ppm across the full temperature range used. Therefore, it is recommended to select the reference clock so that the frequency tolerance (deviation) and frequency stability (temperature characteristics) are within ± 25 ppm.

2.3.1 Case using crystal oscillator circuit

- Figure 2-4 shows a connection example of the crystal oscillator circuit.
- Capacitor loads C_{in} and C_{out} are required for the X1 (22pin) and X2 (23pin) terminals in order for the 16MHz crystal oscillator to oscillate stably. In addition, R_d is required to adjust the negative resistance.
- Place the crystal oscillator connected to R9A06G037 and its peripheral parts as close to R9A06G037 as possible.
- The recommended specifications for the crystal oscillator are frequency: 16MHz, load capacitance: 8pF, frequency tolerance: ± 10 ppm, and frequency temperature characteristics: ± 15 ppm. Table 2-1 shows the recommended crystal oscillator devices and external circuit constants. Recommended devices: Daishinku DSX221SH (recommended specifications must be specified), NDK NX2520SA-16M-CHP-CSW-19 (note that the external circuit constants are different from those of the DSX221SH)

- Determine the final circuit constant in consideration of the specifications of the crystal oscillator to be used and the pattern capacitance of the PCB, and consult with the crystal oscillator manufacturer if necessary.

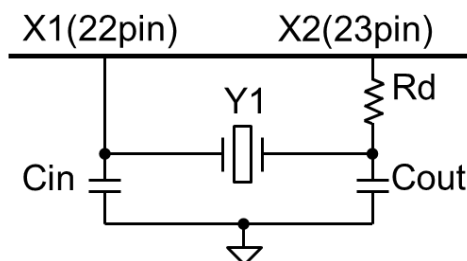


Figure 2-4 Crystal oscillator circuit connection example

Table 2-1 Recommended devices for crystal oscillator circuits and examples of external circuit constants

Recommended crystal oscillator device	Part No.	Cout	Cin	Rd
Using Daishinku DSX221SH		12pF	12pF	560Ω
Using NDK NX2520SA-16M-CHP-CSW-19		15pF	12pF	2.2kΩ

2.3.2 Case using an external clock

- When using an external clock, connect the X1 terminal to GND and input the external clock signal from the X2 terminal.
- Input 3.3V CMOS level signal to the X2 terminal.
- Place peripheral parts for the external clock connected to R9A06G037 as close to R9A06G037 as possible.

2.4 TEST terminal

- Connect to GND via 1kΩ to 5.1kΩ to prevent malfunction.

2.5 RESETB terminal

- An example of an external circuit for the RESETB terminal is shown in Figure 2-5, and an example of the circuit constants is shown in Table 2-2.
- Place Cx near the RESETB terminal to prevent malfunction due to noise.
- If surge noise such as ESD is expected and there is a concern about the operating environment such as malfunction or terminal destruction, it is recommended to add Dx near the terminal. (In the circuit constant example in Table 2-2, STMicro's BAT54SFILM is used, but determine the specifications such as current capacitor according to the assumed noise.)
- It is recommended to connect to GND via Rx (pull-down resistor). This is to keep the R9A06G037 in the reset state (RESETB = low) to prevent malfunctions while preparing to download the R9A06G037 firmware after a power-on reset. For the resistance value of Rx, consider the impedance of the reset signal output and set the optimum value. (In the circuit constant example in Table 2-2, it is set assuming that there is a pull-up resistance of 50 kΩ or more.)

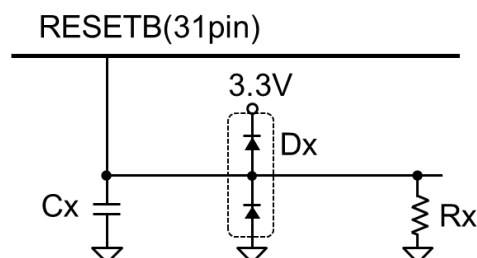


Figure 2-5 Example of an external circuit for the RESETB terminal

Table 2-2 Example of the circuit constants for the RESETB terminal

Component No.	Cx	Dx	Rx
Component value	0.1μF	BAT54SFILM (STMicro)	4.7kΩ or 5.1kΩ

2.6 Power supply circuit

2.6.1 DC-DC converter

- The built-in DC-DC converter of R9A06G037 generates a power supply voltage of 3.3V to 1.1V using the switching regulator method. This 1.1V is supplied to the 1.1V power supply of the digital circuit through the wiring of the PCB.
- For the frequency stability of the DC-DC converter, C2 and C3 should be a total of 20uF~60uF.
- Figure 2-6 shows an example of an external circuit for a DC-DC converter, and Table 2-3 shows an example of its circuit constants.
- Figure 2-7 shows an example of connecting the decoupling capacitor of the power supply terminal of the DC-DC converter. As shown in (a), place the decoupling capacitor in the immediate vicinity of the power supply terminal.

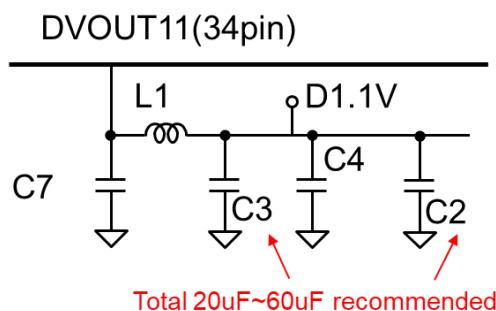


Figure 2-6 Example of an external circuit for a DC-DC converter

Table 2-3 Example of the circuit constants for a DC-DC converter

Component No.	C7	C3	C4	C2	L1
Component value	10pF	10uF	0.1uF	10uF	4.7uH

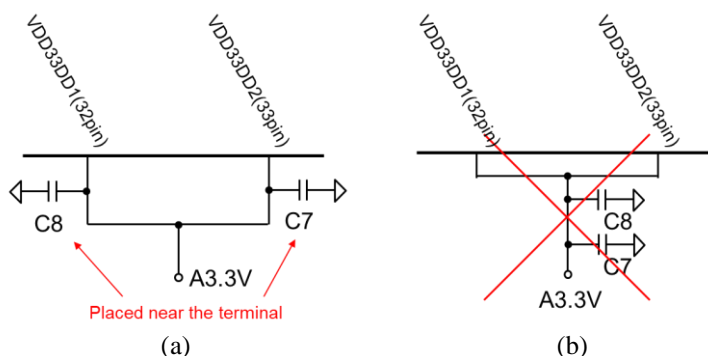


Figure 2-7 Example of connecting the decoupling capacitor of the power supply terminal of the DC-DC converter

2.6.2 LDO

- The built-in LDO of R9A06G037 generates a power supply voltage of 3.3V to 1.1V by the series regulator method. This 1.1V is supplied to the 1.1V power supply of the analog circuit (ADC and PLL) through the PCB wiring.
- Figure 2-8 shows an example of an external LDO circuit, and Table 2-4 shows an example of its circuit constants.
- As shown in Figure 2-8, place the decoupling capacitors in the immediate vicinity of the power supply terminal.

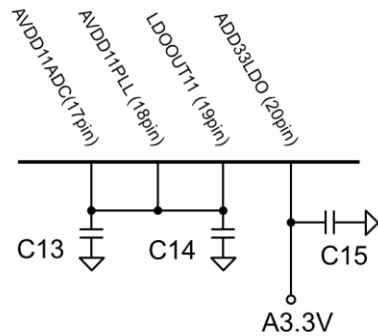


Figure 2-8 Example of an external LDO circuit

Table 2-4 Example of the circuit constants for a LDO circuit

Component No.	C17	C18	C19
Component value	0.1uF	4.7uF	1.0uF

2.7 LED

- Figure 2-9 shows an example of using the LED that shows the transmission / reception status of R9A06G037.
- In this example, it is assumed that LED1 indicates the state when the packet is sent and LED2 indicates the state when the packet is received. (The control of the LEDs is done based on the firmware that is downloaded during booting.)
- It is recommended to set the current flowing through the LED to about 1mA.
- For LEDs1 and R4, set R4 so that

$$I_{LED1} = \frac{(3.3V - V_{F_LED1})}{R4} \text{ makes } I_{LED1} \text{ about } 1mA.$$

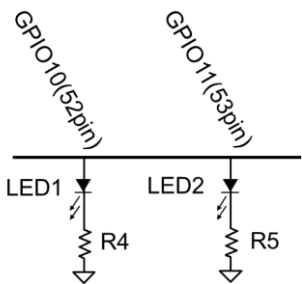


Figure 2-9 Example of using the LED that shows the TX/RX status of R9A06G037

3. Cautions regarding AFE circuit and AC coupling circuit

3.1 AFE peripheral circuit

- Place the decoupling capacitor of the AFE circuit (ISL15102 and RX circuit) near the terminal.
- Figure 3-1 shows an example of connecting the AFE peripheral circuit.

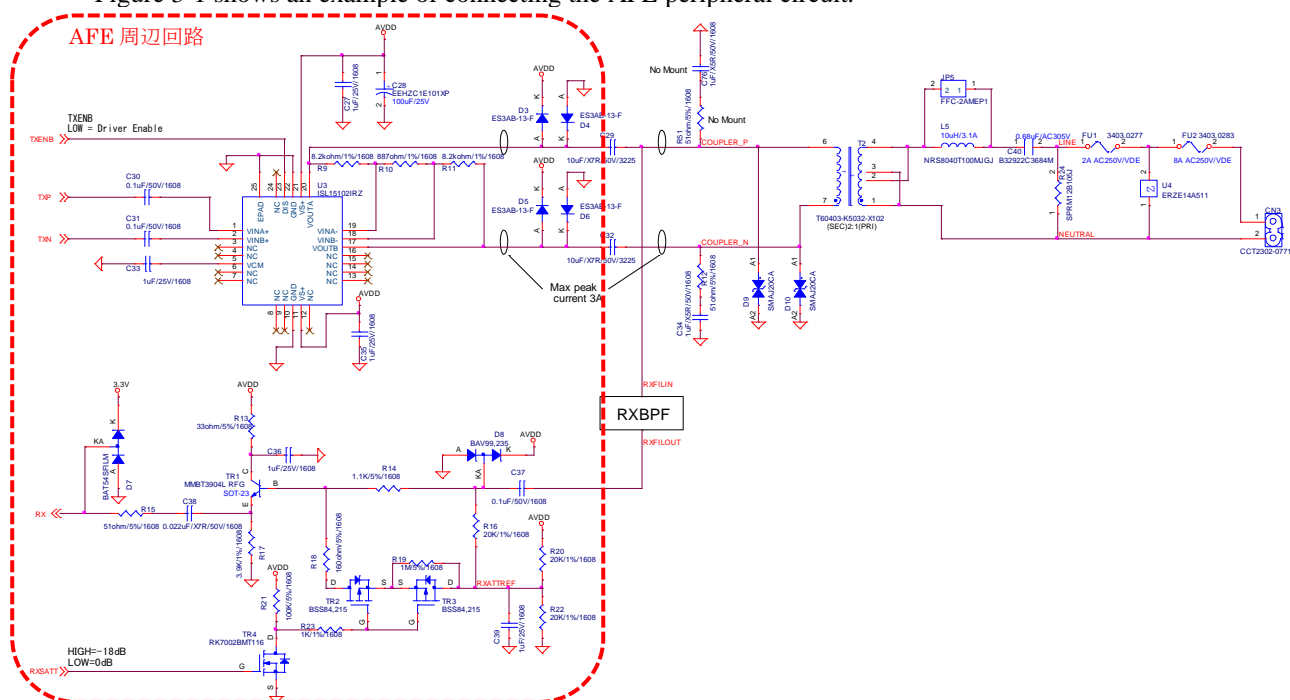
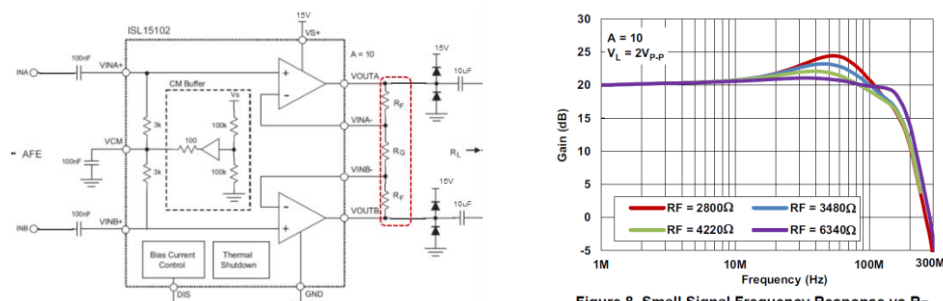


Figure 3-1 Example of connecting the AFE peripheral circuit

3.1.1 Setting the feedback resistance value of ISL15102

- As a tendency of the frequency characteristics of ISL15102 described in the data sheet of ISL15102, when the feedback resistance R_F of ISL15102 shown in the red circle in Figure 3-2 (a) becomes smaller, the peak near 70MHz of the frequency characteristic shown in Figure 3-2 (b) becomes large.
- To avoid the influence of this peak around 70MHz, we confirmed the R_F vs oscillation stability shown in Figure 3-4 and the effect on R_F and out-of-band noise shown in Figure 3-5.
- As a result, the relationship between R_F and oscillation stability is almost constant when $R_F=8.2k\Omega$ or higher, and the relationship between R_F and out-of-band noise is the lowest when $R_F=8.2k\Omega$.
- From this result, set the optimum value of $R_F (=R_9=R_{11})$ to $8.2k\Omega$, R_G to 887Ω so that the voltage gain of ISL15102 is 26dB. The formula for the voltage gain of the ISL15102 is shown below.

$$\frac{V_O}{V_I} = 1 + \left[2 \cdot \frac{R_F}{R_G} \right]$$



(a) ISL15102 block diagram

(b) ISL15102 frequency response vs R_F

Figure 3-2 Catalog data of ISL15102

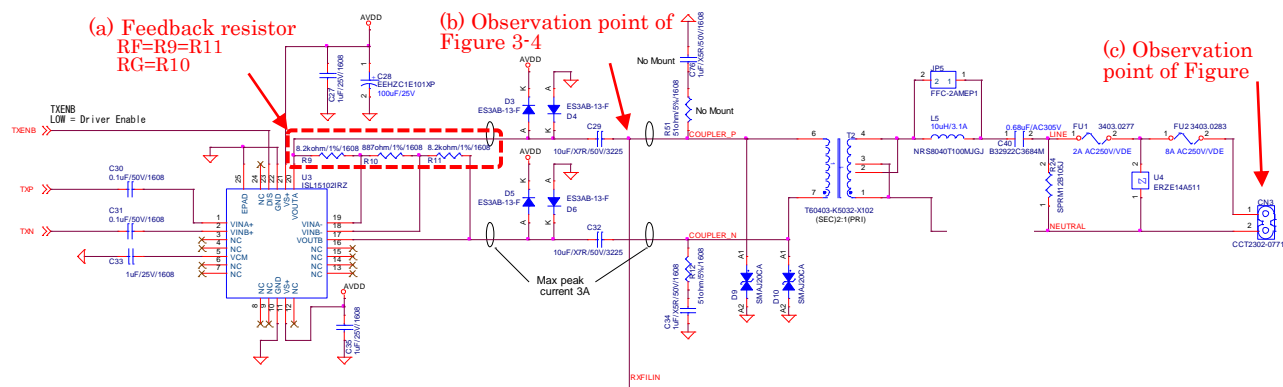


Figure 3-3 Setting the feedback resistor RF of ISL15102

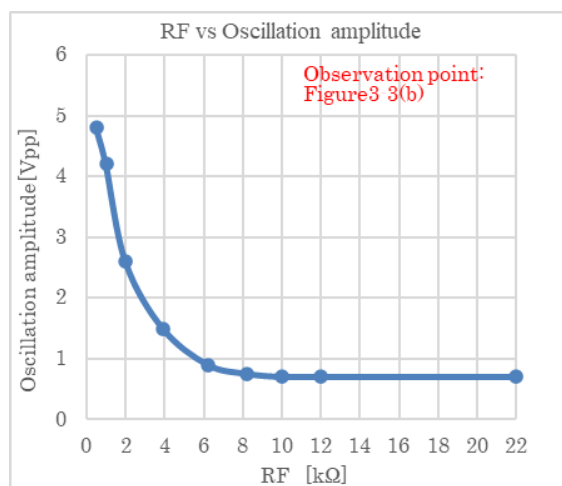


Figure 3-4 RF vs Oscillation Amplitude

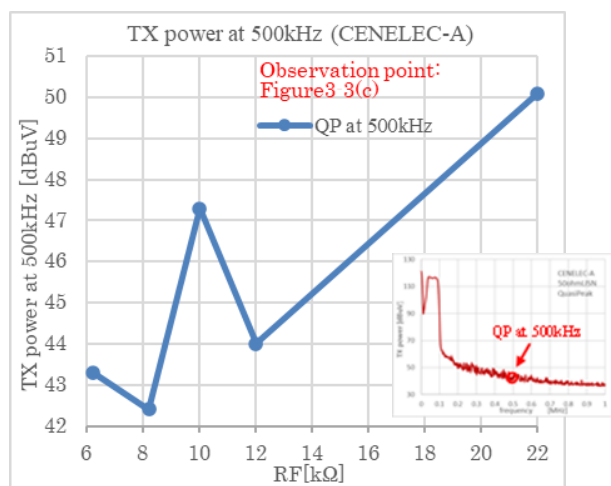


Figure 3-5 RF vs out-of-band noise (at 500kHz in CENELEC-A band)

3.1.2 ISL15102 differential output balancing load circuit

The differential output of the ISL15102 is connected to the RX section only on the positive phase output side. Therefore, place C34 = 1uF and R12 = 51Ω shown in Figure 3 6 (a) for the purpose of balancing the load on the negative phase output side.

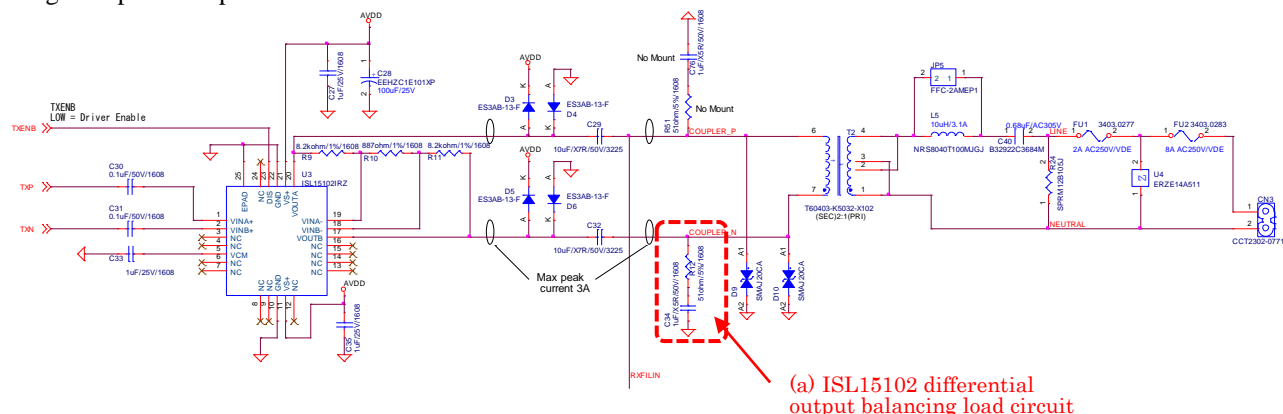


Figure 3-6 ISL15102 differential output balancing load circuit

3.2 Protection circuit

- Figure 3-7 shows an example of connecting a protection circuit that supports CE marking used for a PLC board.
- Select the protection element in consideration of the expected noise level.
- The FUSE used must be an element that complies with the laws and regulations of that country.

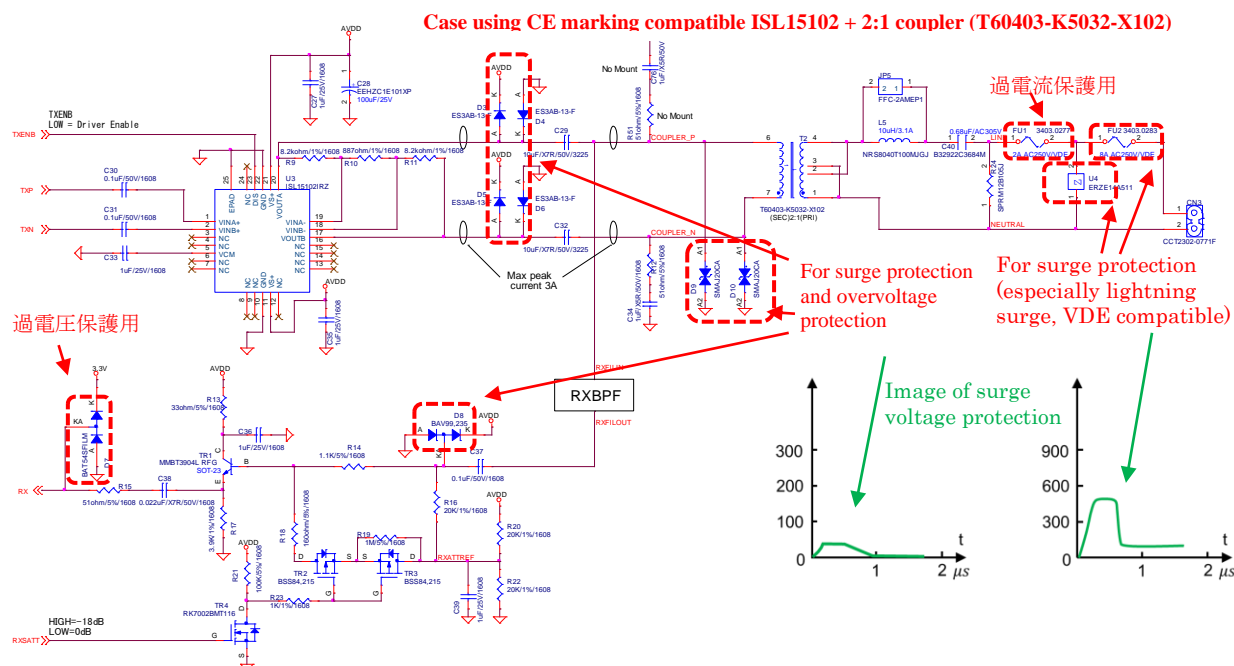


Figure 3-7 Example of connection of protection circuit used for PLC board (CE marking compatible)

3.3 PLC Coupler

This section describes the points to note about the PLC Coupler of the PLC board that uses ISL15102 for Power Amp.

- When using the ISL15102, use a 2:1 PLC coupler to supplement the drive capacity.
- The recommended PLC Coupler is T60403-5032-X102. Figure 3-8 shows a connection example when using the recommended PLC coupler (T60403-5032-X102) at 2:1.
- If for some reason you want to use a different component than the one above, choose the 2:1 PLC Coupler with the recommended specifications shown in Table 3-1.

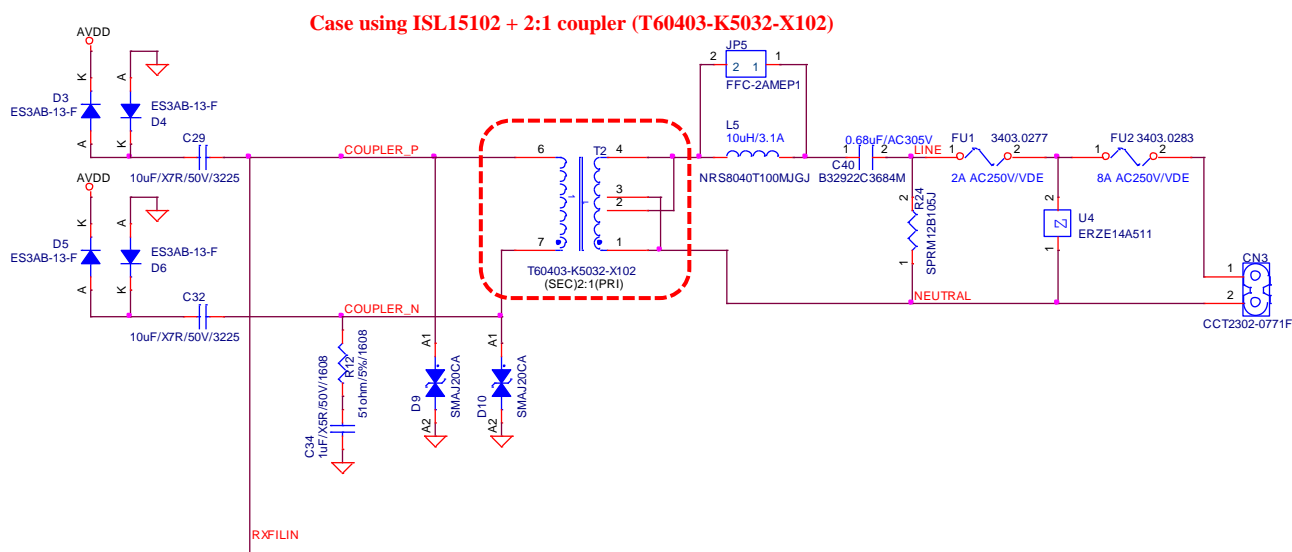


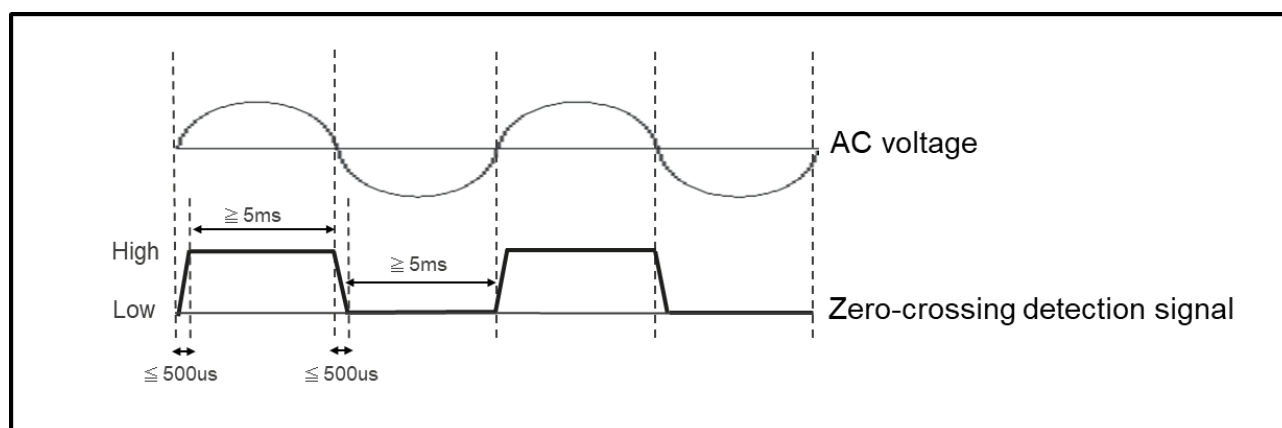
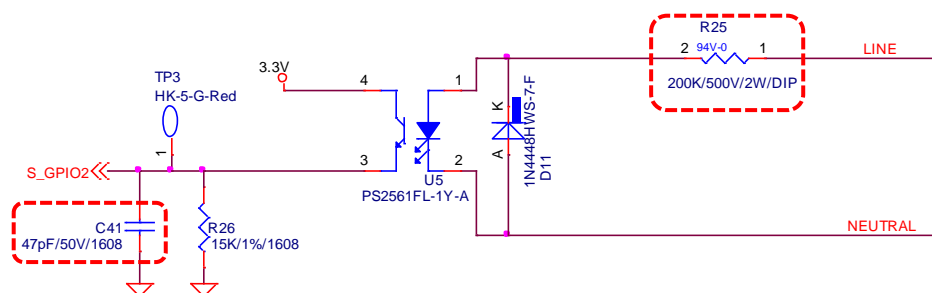
Figure 3-8 The recommended 2:1 PLC coupler (T60403-5032-X102) connection example

Table 3-1 The recommended specifications of the 2:1 PLC Coupler

	CENELEC A (35- 90 kHz)	CENELEC B (95-125 kHz)	ARIB (150-500 kHz)	FCC (150-500 kHz)	Global (35-500 kHz)
Inductance (Lp) @primary (secondary open)	> 0.2mH	> 0.2mH	> 0.2mH	> 0.2mH	> 0.2mH
Leakage Inductance (LI) @primary (secondary short)	< 1.25uH	< 1.25uH	< 0.3uH	< 0.3uH	< 0.3uH
DC Resistance (Rdc=Rdc(pri)+Rdc(sec))	< 0.50 Ohm	< 0.50 Ohm	< 0.50 Ohm	< 0.50 Ohm	< 0.50 Ohm
DC Bias current (I dc)	> 100 mA	> 100 mA	> 100 mA	> 100 mA	> 100 mA

3.4 Zero cross detection circuit

- When using the phase detection function, input the zero cross detection signal to GPIO of R9A06G037.
- Design the zero-cross detection circuit to be the zero-cross detection signal shown in Figure 3-9.
- Figure 3-10 shows an example of a zero-cross detection circuit used in a PLC board.
- As for the resistance value of R31, since the input current is assumed to be about 1-1.2mA_{AC}, set it to 200kΩ for 200-240V_{AC} and 100kΩ for 100-120V_{AC}.
- If necessary, adjust the rise / fall time of the zero cross detection signal with C38.

**Figure 3-9 The zero-cross detection signal****Figure 3-10 Example of a zero-cross detection circuit**

3.5 RX-BPF

- RX-BPF is used to suppress the noise which is outside the signal frequency band. When using ISL15102 for power amp of transmission, PLC Coupler needs to set the turns ratio of IC side: AC line side to 2: 1 due to the drive capacity of ISL15102. When using a 2: 1 PLC Coupler, the input impedance of the PLC board seen from the AC line side looks 1/4 compared to when using a 1: 1 PLC Coupler, so the input impedance drops. Therefore, in order to reduce the decrease in input impedance, select the RX-BPF constant for the frequency band used as shown in Figure 3-11.
- If you are considering a frequency band other than the CENELEC-A band and FCC / ARIB band, select the RX-BPF of the Global (35k-500kHz) band. (Please contact us if you would like the circuit constants of RX-BPF other than CENELEC-A band and FCC / ARIB band.)
- Figure 3-12 shows an example of the frequency characteristics of RX-BPF.
- If the noise outside the pass band is large, install C3 / L3. If you want to reduce the number of filter parts to reduce the parts cost, or if you judge that the influence of noise outside the pass band is small, do not install C3 / L3 and use it short-circuited.

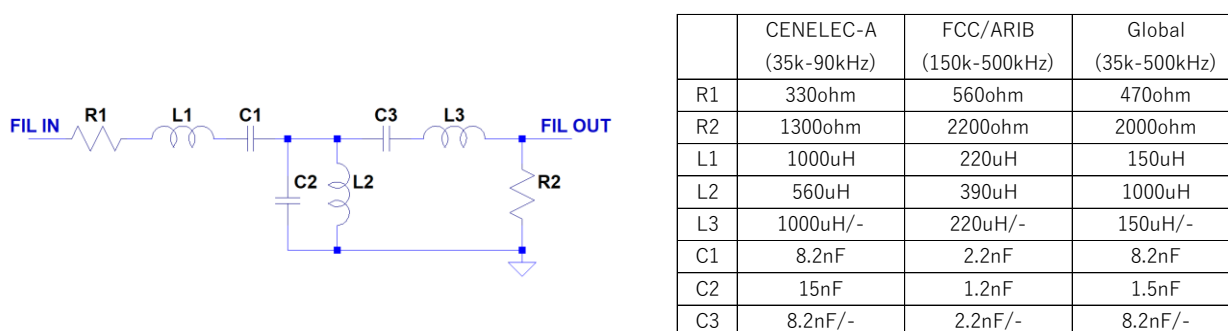


Figure 3-11 Configuration of RX-BPF and the circuit constant

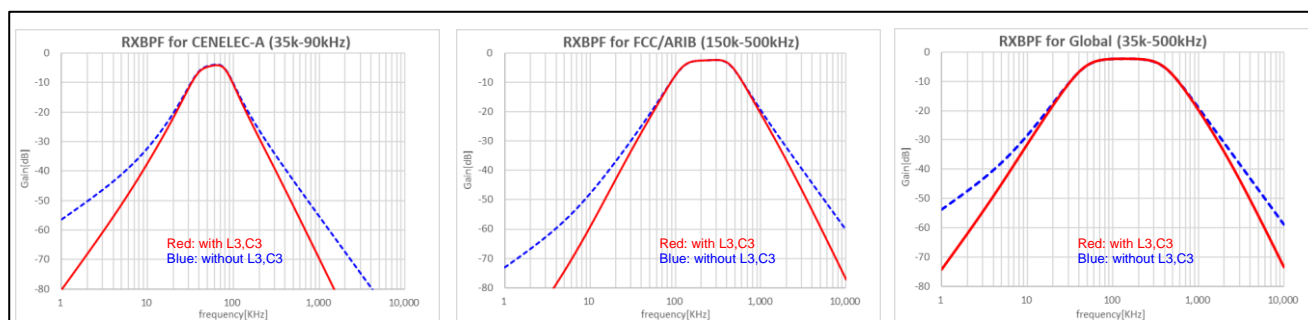


Figure 3-12 Frequency characteristics example of RX-BPF

3.6 Step attenuator circuit

This section describes the Step Attenuator (SATT).

- The function of SATT is to attenuate the received signal so that the receiving circuit can be demodulated without saturation when a signal with a large amplitude exceeding the input level of R9A06G037 or an interfering wave is input. If the received signal is smaller than the predetermined amplitude, the received signal will pass through without attenuation.
- When the receiving circuit is saturated, unnecessary harmonics are generated and it becomes difficult to distinguish it from the received signal. Therefore, insert a SATT circuit into the receiving circuit to prevent saturation of the receiving circuit.
- Figure 3-13 shows how to control SATT.
 - (1) Using the received preamble data, the level detection function of the digital baseband section determines whether the signal strength of the ADC output exceeds the signal level saturated in the receiving circuit.
 - (2) When the signal level saturated in the receiving circuit is exceeded, the received signal is attenuated by switching the RXSATT signal from 0 to 1 and switching the SATT gain from 0dB to -18dB.
- Figure 3-14 shows an example of the SATT circuit used for the PLC board.
- When the RXSATT signal is at low level, the gain of the SATT circuit is 0dB, and when it is at high level, the gain of the SATT circuit is -18dB.

- The resistance that determines the gain of the SATT circuit is calculated by the following formula for R14 and R18.

$$G_{\text{SATT}} = 20 \log \left(\frac{R18}{R14 + R18} \right) = 20 \log \left(\frac{160}{1100 + 160} \right) = -17.93[\text{dB}]$$

- When considering the insertion of a fixed attenuator circuit (fixed ATT) instead of the SATT circuit, the following precautions are required and are not recommended.
 - When a fixed ATT=-18dB is inserted, a signal with a large amplitude can be attenuated and demodulated without saturating the receiving circuit, as in the case of using the SATT circuit. However, the minimum reception sensitivity is 18dB worse than when using the SATT circuit.
 - When fixed ATT=-6dB is inserted, the signal amplitude that can be received without saturating the receiving circuit is about 1/4 (-12dB) compared to the case of -18dB. It is necessary to check the signal level that can be received. Also, the minimum reception sensitivity is 6dB worse than when using the SATT circuit.
 - When fixed ATT=0dB, the minimum reception sensitivity is the same as when using the SATT circuit. However, a signal with a large amplitude exceeding the input level of R9A06G037 will generate harmonics due to saturation, making it difficult to identify the received signal.

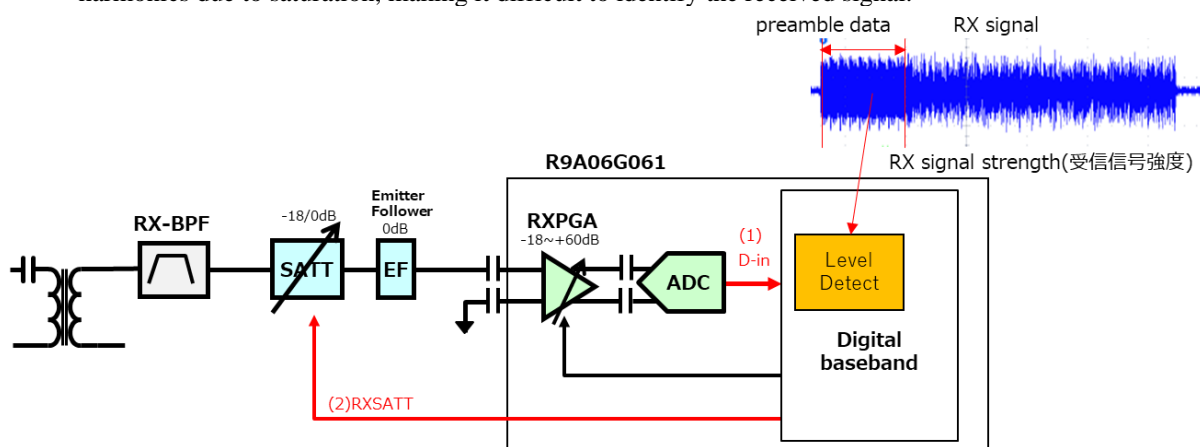


Figure 3-13 Step Attenuator (SATT) control method

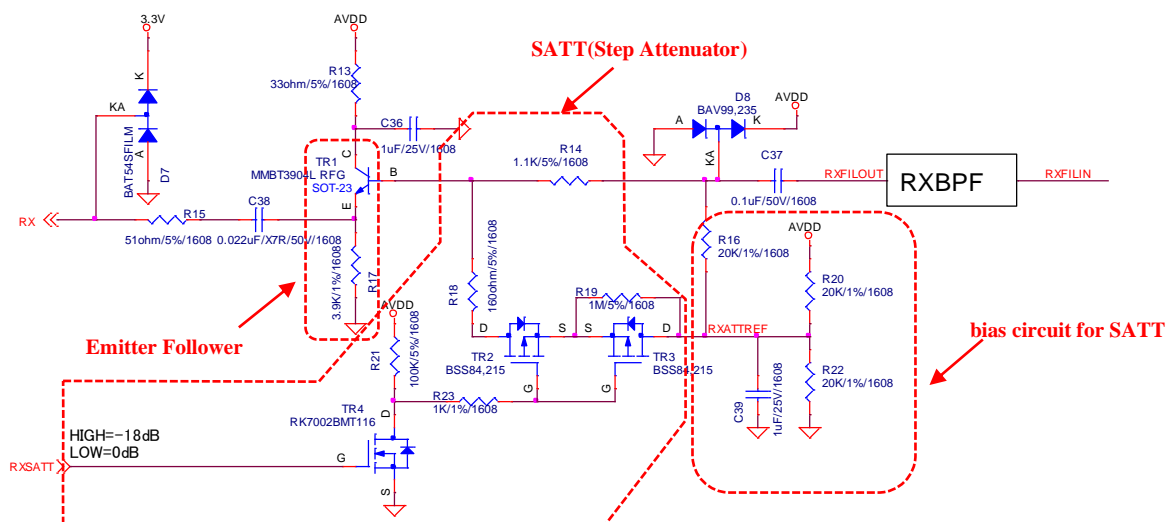


Figure 3-14 Example of Step Attenuator (SATT) circuit

3.7 Measures for low impedance load (CENELEC-A band only)

This section describes measures for low impedance load in the CENELEC-A band of the PLC board.

- For low impedance loads in the CENELEC-A band, the PLC transmission output power can be increased by inserting an L5 inductor in series with the transmission output.
- When inserting the L5, set the resonance frequency of the inductor L5 and the AC coupling capacitor C40 to be within the band of the CENELEC-A band, 35kHz-90kHz.

$$f_0 = \frac{1}{2\pi\sqrt{L5 \cdot C40}}$$

- In the case of ISL15102 + 2:1 PLC coupler configuration, by inserting L5=10uH for C40=0.68uF, it is possible to increase the transmission output under low impedance load compared to the case without L5.
- For the FCC/ARIB band and Global band, do not insert L5 because the transmission output will decrease if an inductor is inserted.
- Figure 3-15 shows an example of connection for low impedance load measures the CENELEC-A band, and Figure 3-16 shows the example of frequency characteristics.

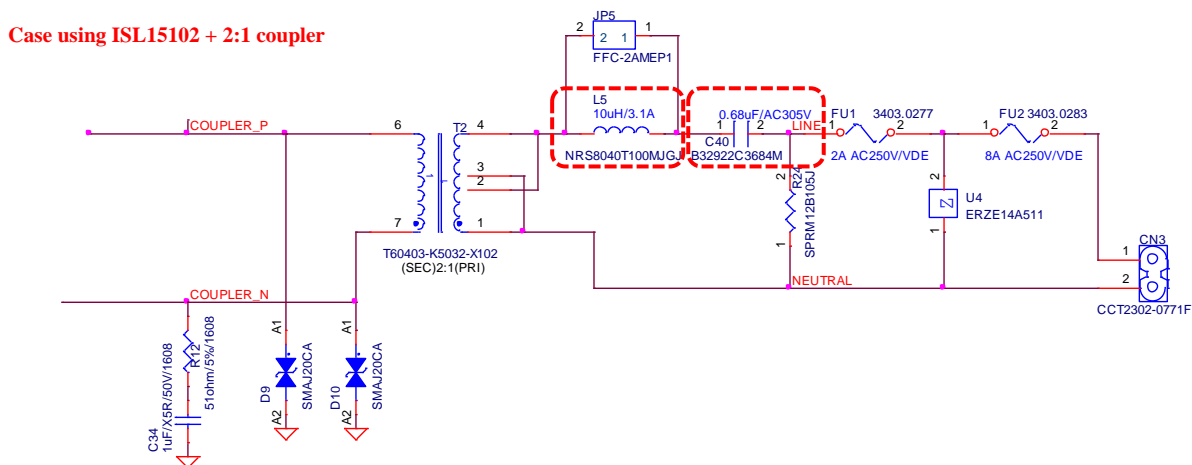


Figure 3-15 Example of connection for low impedance load measures in CENELEC-A band

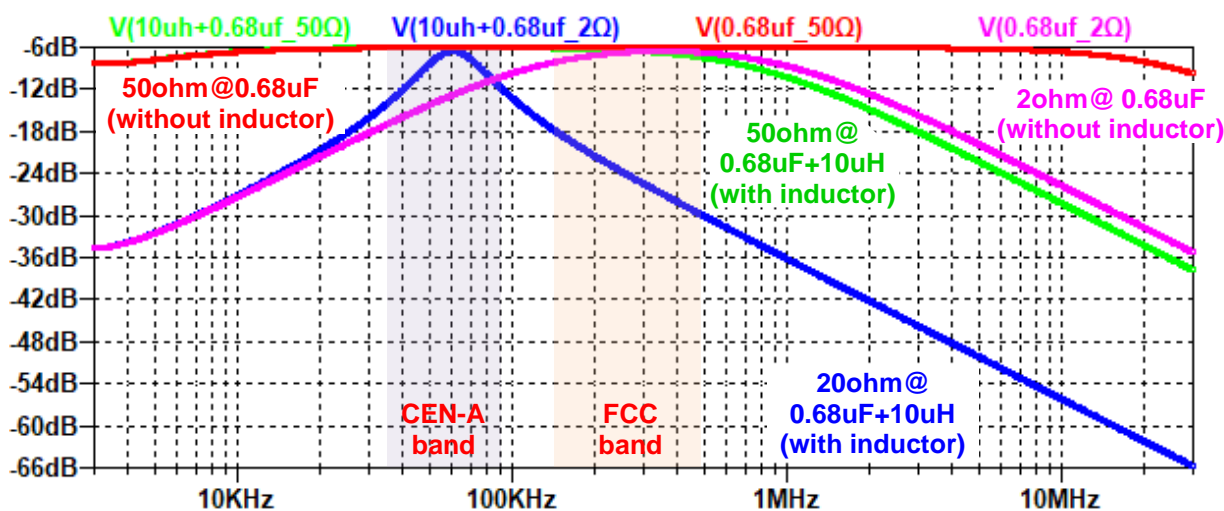


Figure 3-16 Example of frequency characteristics for low impedance load measures in CENELEC-A band

3.8 EN50065-7 compatible impedance measures (CENELEC-A band only)

In this section, the impedance measures for EN50065-7 in the CE marking of the CENELEC-A band of the PLC board are explained assuming the configuration of ISL15102 + 2:1 PLC coupler (T60403-5032-X102).

- The RX impedance at 3kHz-9kHz may not meet the EN50065-7 compatible impedance standard due to the resonance of C40 and T2 (main inductance). To move the peak due to the resonance to the outside of 3kHz-9kHz, it is recommended to set C40 = 0.68uF for the main inductance when using 2:1 of T2 in the part (a) of Figure 3-17.
- The TX impedance at 95kHz-148.5kHz may not meet the EN50065-7 compatible impedance standard due to the resonance frequency of C40 and (L5 + T2(leakage inductance)) in the part (b) of Figure 3-17. Set so that the resonance frequencies of L5 + T2 (leakage inductance) and C40 are within the band of CENELEC-A band. If C40=0.68uF, it is recommended to insert L5=6.8uH.
- If C40, L5 and T2 are changed, evaluate the impedance characteristics of EN50065-7 and determine the constants if necessary.

Case using ISL15102 + 2:1 coupler (T60403-5032-X102)

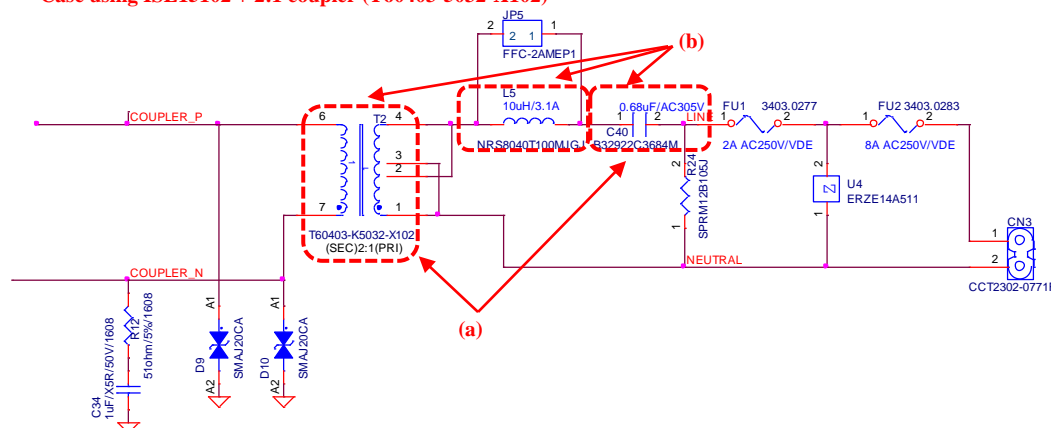


Figure 3-17 Example of impedance measures for EN50065-7 in CENELEC-A band

Table 3-2 EN50065-7:Minimum impedance value $|Z_e|$ of an equipment working in the frequency range 9 kHz to 95 kHz

95 kHz							
Frequency range	3kHz to 9kHz		9kHz to 95kHz			95kHz to 148.5kHz	
Operating mode	RX	TX	RX		TX	RX	TX
Ze	10ohm	Free	Out BW Free	In BW 50ohm	Free	5ohm	3ohm

4. Cautions on the DC-DC Power Supply Circuit

This section describes precautions when designing a DC-DC power supply circuit by mounting a DC-DC power supply IC on the PLC board.

- It is necessary to generate 3.3V to use R9A06G037 and 15V or 12V to use ISL15102 on the PLC board.
- When using a DC-DC power supply circuit, operating switching noise may affect the PLC signal and circuit.
- To avoid affecting the signal band (35kHz-500kHz) of the NB-PLC, use a DC-DC power supply IC that can select a switching frequency of 1MHz or higher.
- For the switching operation of the DC-DC power supply circuit, use a DC-DC power supply IC that has a PWM (Pulse Width Modulation) fixed operation function. The operation method of PFM (Pulse Frequency Modulation) and PSM (Pulse Skipping Modulation) may operate within the signal band of NB-PLC (35kHz-500kHz), which may affect the characteristics of PLC.
- To remove noise components contained in the input power supply supplied to the DC-DC power supply circuit, and to reduce the influence of switching noise generated in the DC-DC power supply circuit on other power supply circuits, it is recommended to insert a filter consisting of an LC circuit into the input section of the DC-DC power supply circuit. Table 4-1 shows an example of an input filter for a DC-DC power supply circuit, and Table 4-1 shows an example of its circuit constants.
- Figure 4-2 shows an example of a DC-DC power supply circuit that generates 3.3V from 15V using ISL85415.

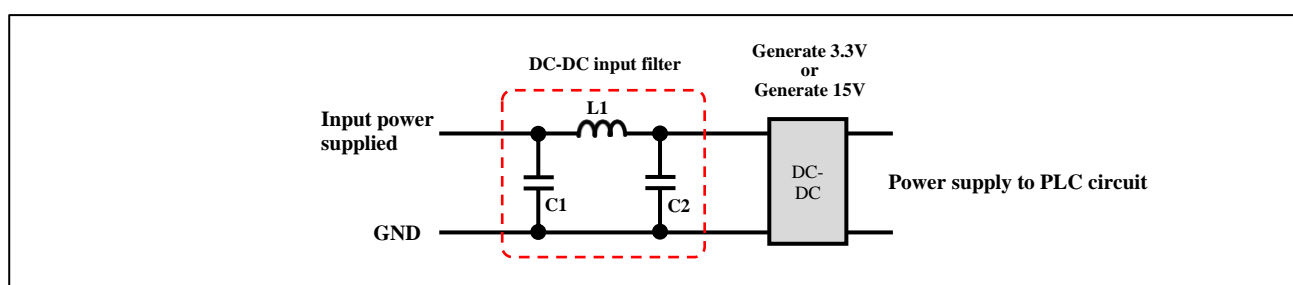


Figure 4-1 Example of input filter for DC-DC power supply circuit

Table 4-1 Example of circuit constants of input filter for DC-DC power supply circuit

	Circuit constant
L1	10uH
C1	10uF-22uF
C2 ¹⁾	10uF-22uF

Note.1) C2 can be omitted if the input capacitor of the DC-DC power supply circuit is 10uF or more.

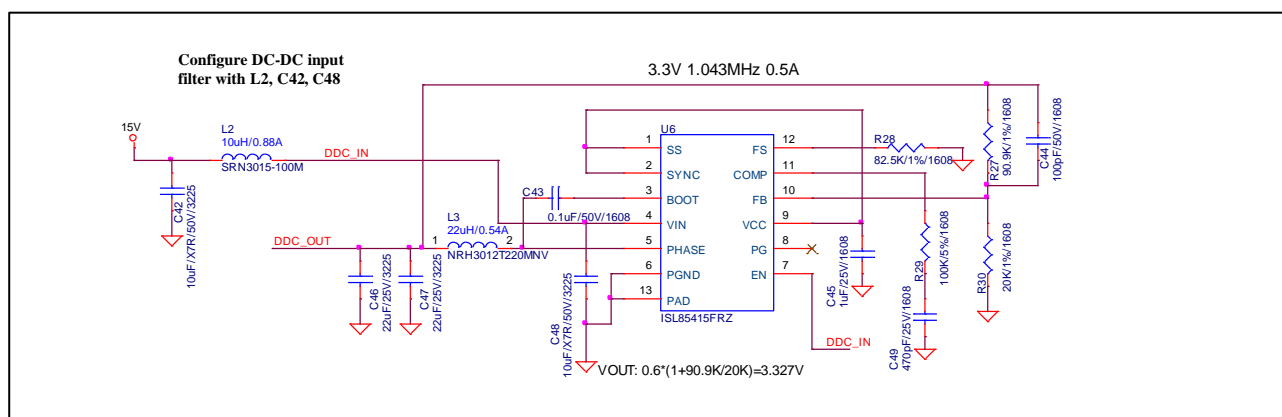


Figure 4-2 Example of DC-DC power supply circuit using ISL85415

5. Cautions on the AC-DC Power Supply Circuit

This section describes precautions when mounting the AC-DC power supply circuit on the PLC board. When installing an AC-DC power supply circuit, the switching noise of the AC-DC power supply circuit may affect the EMC standard and the transmission / reception characteristics of the PLC, so pay attention to the following items when designing.

- Separate the GND of the AC-DC circuit from the GND of other circuits.
- Insert L1 and L2 as an impedance upper between the AC-DC power supply circuit and the PLC signal. This is to prevent the input impedance of the AC-DC power supply circuit from affecting the load of the PLC output.
- Insert C1 between the AC-DC power circuit and the PLC signal as a measure against differential noise. (Recommendation) By combining L1, L2 and C1, it functions as a differential mode noise filter. If the input capacitor of AD-DC is 0.22uF or more, C1 can be omitted.
- Insert CM1 (common mode choke coil) as a countermeasure against common mode noise between the AC-DC power supply circuit and the PLC signal. (Recommendation)
- Figure 5-1 shows an example of an input filter for an AC-DC power supply circuit, and Table 5-1 shows an example of its circuit constants.

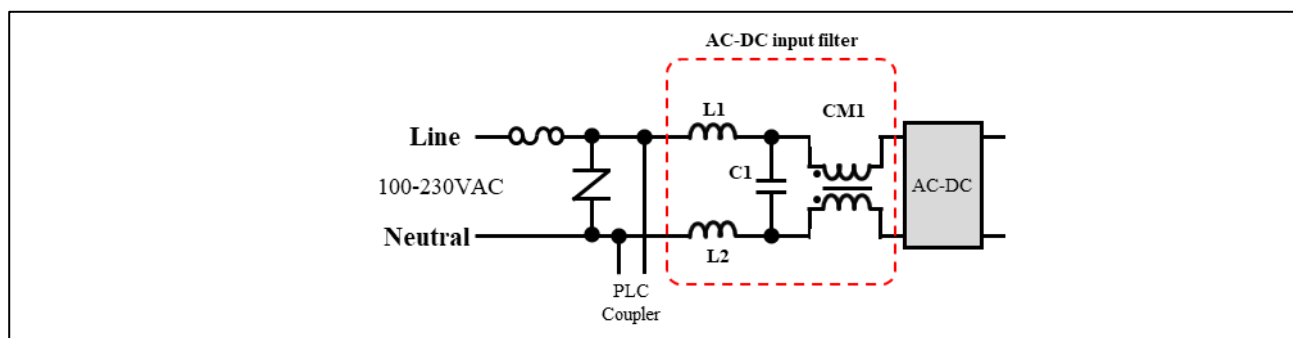


Figure 5-1 Example of input filter for AC-DC power supply circuit

Table 5-2 Example of circuit constant of input filter for AC-DC power supply circuit

	CENELEC-A	Global	FCC/ARIB
L1/L2	1mH or more		0.22mH or more
C1 ²⁾	0.22uF or more		
CM1	15mH or more		

Note.2) If the input capacitor of the AD-DC power supply circuit is 0.22uF or more, C1 can be omitted.

6. Circuit design example

- Regarding the contents explained in Chapters 2 to 4, this chapter provides a circuit design example for a PLC board (CENECLEC-A, FCC, Global compatible) using R9A06G037 and ISL15102 as a reference.
- Since Renesas Electronics does not prepare a PLC board equipped with an AC-DC power supply circuit, the AC-DC circuit in Chapter 5 is not included in the circuit design example in this chapter.
- If the contents of Chapters 2 to 4 differ from the circuit design examples in this chapter, give priority to the contents of Chapters 2 to 4.
- Section 6.1 shows an example of circuit design (Figure 6-1-Figure 6-8), and Section 6.2 shows an example of Bill of materials (Table 6.1-Table 6.5).

6.1 Example of circuit design

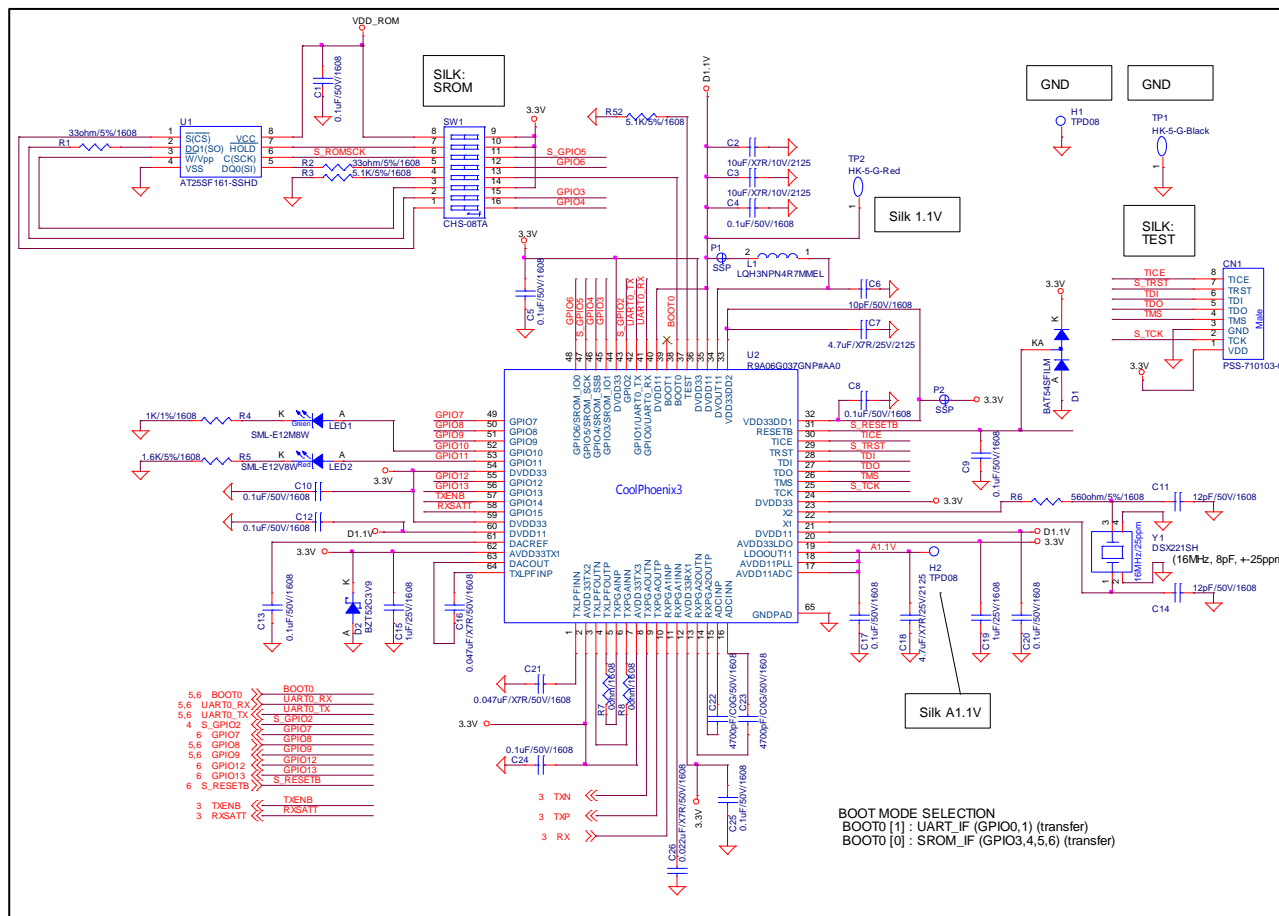


Figure 6-1 AC-PLC board (R9A06G037 peripheral circuit)

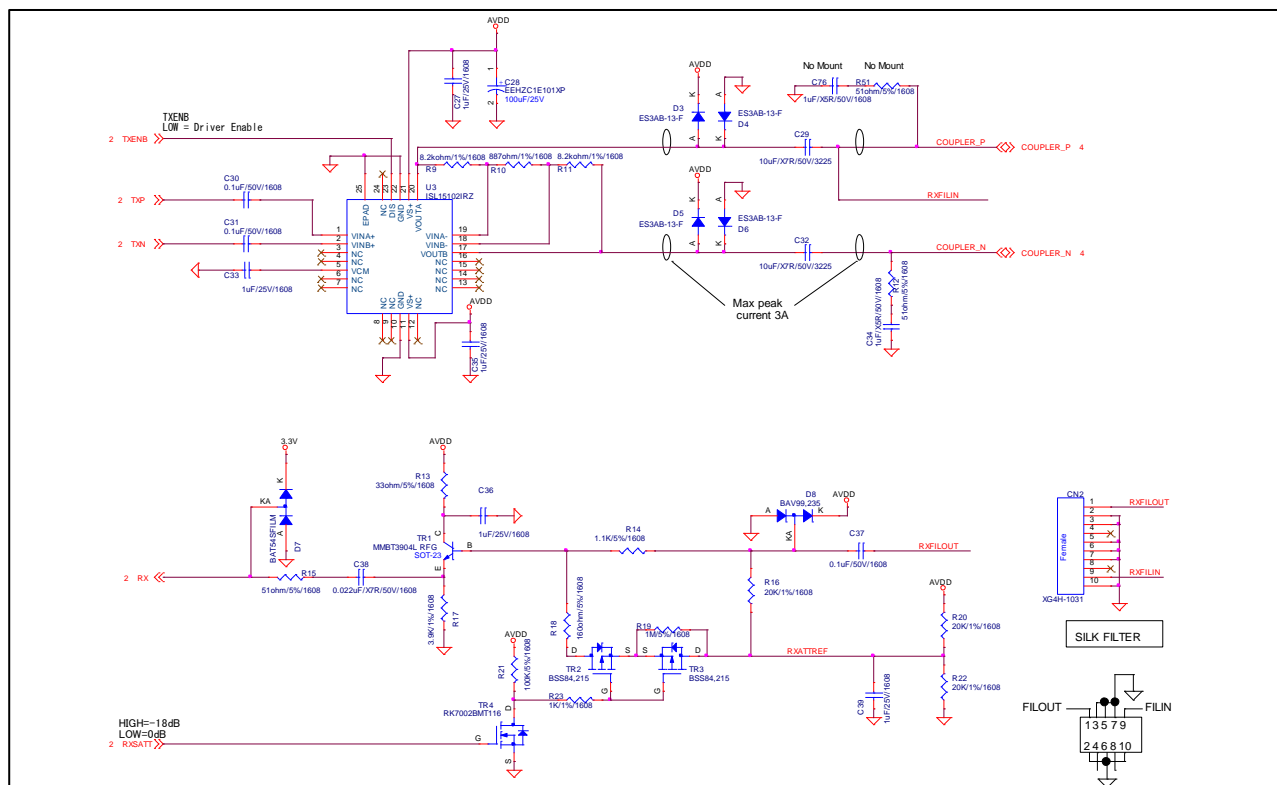


Figure 6-2 AC-PLC board (AFE peripheral circuit)

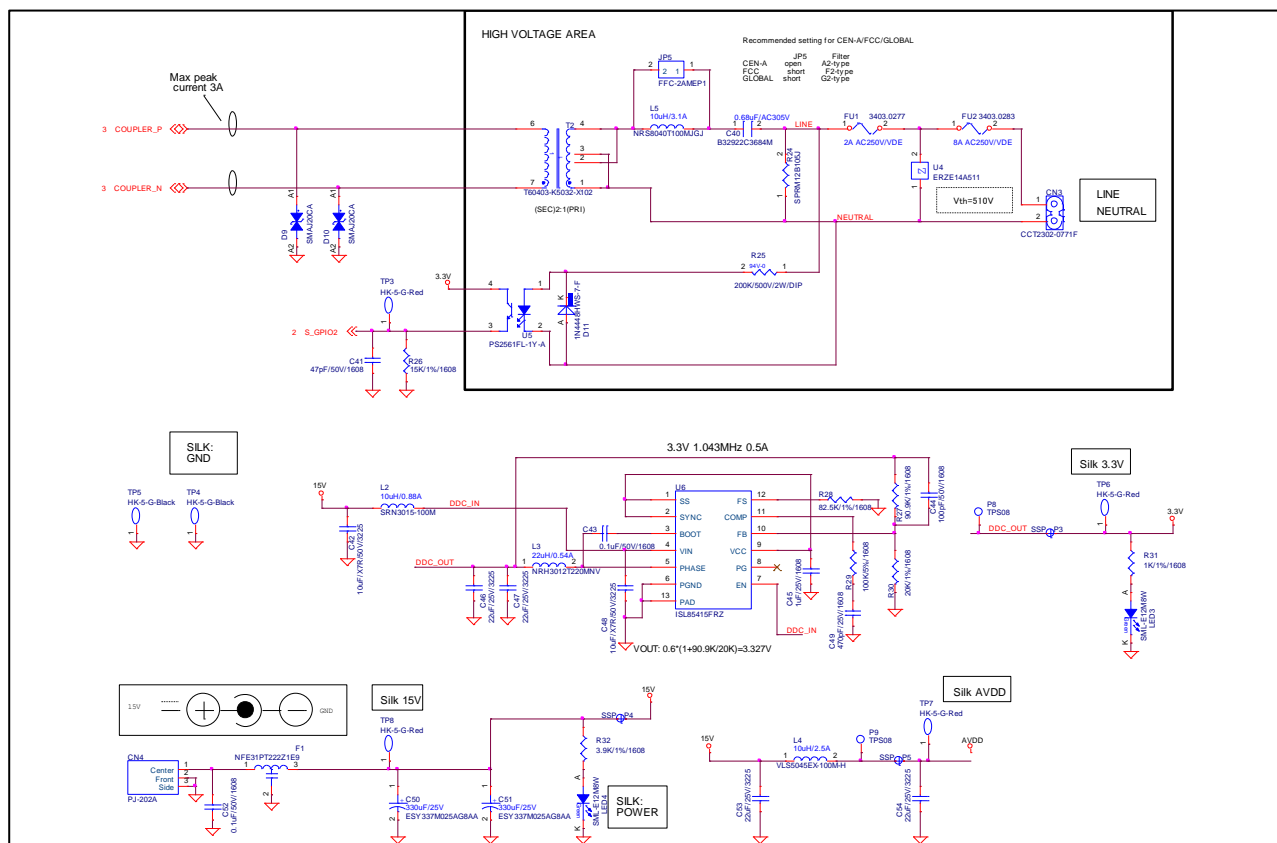
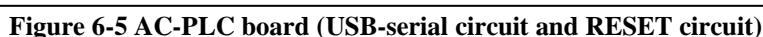
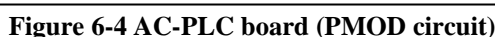
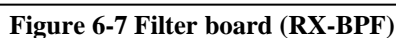


Figure 6-3 AC-PLC board (AC coupling circuit, DC-DC power supply circuit)





6.2 Example of Bill of materials

Table 6.1 AC-PLC board (1/2)

Quantity	Reference	KIND	Parts Name	Manufacturer	Remark
1	CN1	CONNECTOR	PSS-710103-08	HIROSUGI	
3	CN2,CN6,CN7	CONNECTOR	XG4H-1031	OMRON	
1	CN3	CONNECTOR	CCT2302-0771F	SMK	(2*) AC-M11PB73C(Echo Electric)
1	CN4	CONNECTOR	PJ-202A	CUI	
1	CN5	CONNECTOR	UX60SC-MB-5ST(82)	HIROSE	
38	C1,C4,C5,C8,C9,C10,C12,C13,C17,C20,C24,C25,C26,C30,C31,C37,C43,C52,C55,C56,C58,C59,C60,C61,C62,C63,C64,C65,C66,C67,C68,C69,C70,C71,C72,C73,C74,C75	CERAMIC CAPACITOR	CC0603KRX7R9BB104	Yageo	(1*) 0.1uF/X7R/50V/1608
2	C2,C3	CERAMIC CAPACITOR	GRM21BR71A106MA73L	Murata	(1*) 10uF/X7R/10V/2125
1	C6	CERAMIC CAPACITOR	C1608NP01H100D080AA	TDK	(1*) 10pF/COG/50V/1608
3	C7,C18,C57	CERAMIC CAPACITOR	TMK212AB7475KG-T	Taiyo Yuden	(1*) 4.7uF/X7R/25V/2125
2	C11,C14	CERAMIC CAPACITOR	CGA3E2C0G1H120J080AA	TDK	(1*) 12pF/COG/50V/1608
8	C15,C19,C27,C33,C35,C36,C39,C45	CERAMIC CAPACITOR	CGA3E1X7R1E105K080AC	TDK	(1*) 1uF/X7R/25V/1608
2	C16,C21	CERAMIC CAPACITOR	CC0603KRX7R9BB473	Yageo	(1*) 0.047uF/X7R/50V/1608
2	C22,C23	CERAMIC CAPACITOR	CGA3E2C0G1H472J	TDK	(1*) 4700pF/COG/50V/1608
1	C28	ALUM CAP	EEH2C1E101XP	Panasonic	
4	C29,C32,C42,C48	CERAMIC CAPACITOR	GRM32ER71H106KA12L	Murata	(1*) 10uF/X7R/50V/3225
1	C34	CERAMIC CAPACITOR	CGA3E3X5R1H105K080AB	TDK	(1*) 1uF/X5R/50V/1608
1	C38	CERAMIC CAPACITOR	C1608X7R1H223K	TDK	(1*) 0.022uF/X7R/50V/1608
1	C40	FILM CAPACITOR	B32922C3684M	EPCOS	
1	C41	CERAMIC CAPACITOR	CGA3E2C0G1H470J080AA	TDK	(1*) 47pF/COG/50V/1608
1	C44	CERAMIC CAPACITOR	C1608C0G1H101J080AA	TDK	(1*) 100pF/COG/50V/1608
4	C46,C47,C53,C54	CERAMIC CAPACITOR	TMK325B7226KMHT	Taiyo Yuden	(1*) 22uF/X7R/25V/3225
1	C49	CERAMIC CAPACITOR	C0603C471J3GACAUTO	KEMET	(1*) 470pF/COG/25V/1608
2	C50,C51	ELECTROLYTIC CAP	ESY337M025AG8AA	KEMET	(1*)
2	D1,D7	DIODE	BAT54SFLM	STMicroelectronics	
1	D2	DIODE	BZT52C3V9	Diodes Inc	
4	D3,D4,D5,D6	DIODE	ES3AB-13-F	Diodes Inc	
1	D8	DIODE	BAV99,235	NXP	
2	D9,D10	DIODE	SMAJ20CA	Bourns Inc.	
1	D11	DIODE	1N4448HWS-7-F	Diodes Inc	
1	D12	DIODE	RCLAMP0502BATCT	Semtech	
2	F1,F2	FILTER	NFE31PT222Z1E9	Murata	
1	FU1	FUSE	3403.0277	Schurter Inc	
1	FU2	FUSE	3403.0283	Schurter Inc	
3	JP1,JP3,JP5	CONNECTOR	FFC-2AMEP1	HONDA	
2	JP2,JP4	CONNECTOR	FFC-3AMEP1	HONDA	
1	L1	INDUCTOR	LQH3NPN4R7MMEL	Murata	
1	L2	INDUCTOR	SRN3015-100M	Bourns	
1	L3	INDUCTOR	NRH3012T220MNV	Taiyo Yuden	
1	L4	INDUCTOR	VLS5045EX-100M-H	TDK	(2*) VLS5045EX-100M
1	L5	INDUCTOR	NRS8040T100MJGJ	Taiyo Yuden	
3	LED1,LED3,LED4	LED	SML-E12M8W	ROHM	
1	LED2	LED	SML-E12V8W	ROHM	
1	PMOD1	CONNECTOR	PPPC062LJBN-RC	Sullins	
2	PMOD2,PMOD3	CONNECTOR	TSM-106-01-L-DV	Samtec	
3	R1,R2,R13	RESISTOR	RK73B1JTTDD330J	KOA	(1*) 33ohm/5%/0.125W/1608
5	R3,R39,R41,R42,R49	RESISTOR	RK73B1JTTDD512J	KOA	(1*) 5.1K/5%/0.125W/1608
3	R4,R23,R31	RESISTOR	RK73B1JTTD1001F	KOA	(1*) 1K/1%/0.125W/1608
1	R5	RESISTOR	RK73B1JTTDD162J	KOA	(1*) 1.6K/5%/0.125W/1608
1	R6	RESISTOR	RK73B1JTTDD561J	KOA	(1*) 560ohm/5%/0.125W/1608
2	R7,R8	RESISTOR	RK73Z1JTTD	KOA	(1*) 0ohm/1608
2	R9,R11	RESISTOR	RK73H1JTTD8201F	KOA	(1*) 8.2K/1%/0.125W/1608
1	R10	RESISTOR	RK73H1JTTD8870F	KOA	(1*) 887ohm/1%/0.125W/1608
2	R12,R15	RESISTOR	RK73B1JTTDD510J	KOA	(1*) 51ohm/5%/0.125W/1608
1	R14	RESISTOR	RK73B1JTTDD112J	KOA	(1*) 1.1K/5%/0.125W/1608
4	R16,R20,R22,R30	RESISTOR	RK73H1JTTD2002F	KOA	(1*) 20K/1%/0.125W/1608
2	R17,R32	RESISTOR	RK73H1JTTD3901F	KOA	(1*) 3.9K/1%/0.125W/1608
1	R18	RESISTOR	RK73B1JTTDD161J	KOA	(1*) 160ohm/5%/0.125W/1608
5	R19,R44,R45,R46,R47	RESISTOR	RK73B1JTTDD105J	KOA	(1*) 1M/5%/0.125W/1608
2	R21,R29	RESISTOR	RK73B1JTTDD104J	KOA	(1*) 100K/5%/0.125W/1608
1	R24	RESISTOR	SPRM12B105J	Akane Dengu	(2*) RCR50+CT52A105J, RCR50ENCT52A105J, RCR60CT52A105J(KOA), VR370000 01004J R500(Vishay)
1	R25	RESISTOR	FMP200JR-52-200K	Yageo	(1*) 200K/500V/2W/DIP
1	R26	RESISTOR	RK73H1JTTD1502F	KOA	(1*) 15K/1%/0.125W/1608
1	R27	RESISTOR	RK73H1JTTD9092F	KOA	(1*) 90.9K/1%/0.125W/1608
1	R28	RESISTOR	RK73H1JTTD8252F	KOA	(1*) 82.5K/1%/0.125W/1608
6	R33,R34,R35,R37,R38,R43	RESISTOR	RK73B1JTTDD513J	KOA	(1*) 51K/5%/0.125W/1608
1	R36	RESISTOR	RK73B1JTTDD103J	KOA	(1*) 10K/5%/0.125W/1608
2	R40,R48	RESISTOR	RK73B1JTTDD101J	KOA	(1*) 100ohm/5%/0.125W/1608

(1*)Equivalent product can be changed

(2*)Alternative product

Table 6.2 AC-PLC board (2/2)

Quantity	Reference	KIND	Parts Name	Manufacturer	Remark
1	SW1	Switch	CHS-08TA	COPAL	
2	SW2,SW3	Switch	SSSS222700	ALPS	
1	SW4	Switch	SKQMBBE010	ALPS	
1	T2	TRANS	T60403-K5032-X102	VAC Magnetic	
3	TP1,TP4,TP5	TEST PIN	HK-5-G-Black	MAC8	
5	TP2,TP3,TP6,TP7,TP8	TEST PIN	HK-5-G-Red	MAC8	
1	TR1	TRANSISTOR	MMBT3904L RFG	Taiwan Semiconductor	
2	TR2,TR3	TRANSISTOR	BSS84,215	Nexperia	
1	TR4	TRANSISTOR	RK7002BMT116	ROHM	
1	U1	IC	AT25SF321-SSHD	Adesto	
1	U11	IC	SN74LVC2G07DCKR	TI	
1	U12	IC	BD5228G	ROHM	(2*) BD52E28G
3	U13,U14,U15	IC	SN74LVC2T45DCUR	TI	
1	U2	IC	R9A06G037GNP#AA0	RENESAS	
1	U3	IC	ISL15102IRZ	Intersil	
1	U4	SURGE ABSORBER	ERZE14A511	Panasonic	(2*) ERZ-E14A471
1	U5	PHOTOCOUPLER	PS2561FL-1Y-A	RENESAS/CEL	(2*) PS2561FL-1Y-K-A
1	U6	IC	ISL85415FRZ	Intersil	
3	U7,U9,U10	IC	SN74LVC1T45DCK	TI	
1	U8	IC	FT232RL	FTDI	
1	Y1	CRYSTAL	DSX221SH	Daishinku	Specify the specifications (16MHz,CL:8pF, Frequency tolerance:±10ppm, Frequency characteristics over temperature:±15ppm) (2*)(3*)NX2520SA-16M-CHP-CSW- 19(NDK) (4*)

(2*) Alternative product

(3*) For NX2520SA-16M-CHP-CSW-19, it is necessary to change the constants of the external circuit (R6=2.2kΩ, C14=12pF, C11=15pF).

(4*) CX2520DB16000D0FLJCC (Kyocera) has been discontinued.

Table 6.3 RX651 MCU board

Quantity	Reference	KIND	Parts Name	Manufacturer	Remark
1	CN301	CONNECTOR	PPPC062LFBN-RC	SULLINS	
1	CN302	CONNECTOR	UX60SC-MB-5ST(82)	HIROSE	
2	CN303,CN304	CONNECTOR	XG4C-1031	OMRON	
1	CN305	CONNECTOR	XG4C-1431	OMRON	
1	C301	CERAMIC CAPACITOR	GCM188R71H224KA64	MURATA	(1*) 0.22uF/X7R/50V/1608
2	C302,C303	CERAMIC CAPACITOR	C0603C300J5GACTU	KEMET	(1*) 30pF/C0G/50V/1608
2	C304,C305	CERAMIC CAPACITOR	CGA3E1X7R1E105K080AC	TDK	(1*) 1uF/X7R/25V/1608
9	C306,C307,C308,C309,C310,C311,C312,C313,C314	CERAMIC CAPACITOR	CC0603KRX7R9B104	Yageo	(1*) 0.1uF/X7R/50V/1608
1	D301	DIODE	RCLAMP0502BATCT	Semtech	
1	F301	FILTER	NFE31PT222Z1E9	Murata	
1	JP301	CONNECTOR	FFC-2AMEP1	HONDA	(1*)
1	LED301	LED	SML-E12M8W	Rohm	
1	LED302	LED	SML-E12V8W	Rohm	
3	R302,R305,R310	RESISTOR	RK73Z1JTTD	KOA	(1*) 0ohm/1608
1	R303	RESISTOR	RK73B1JTTD1001F	KOA	(1*) 1K/1%/1608
1	R304	RESISTOR	RK73B1JTTD513J	KOA	(1*) 51K/5%/1608
9	R306,R315,R316,R317,R318,R319,R320,R321,R322	RESISTOR	RK73B1JTTD512J	KOA	(1*) 5.1K/5%/1608
2	R309,R314	RESISTOR	RK73B1JTTD103J	KOA	(1*) 10K/5%/1608
1	R311	RESISTOR	RK73B1JTTD2002F	KOA	(1*) 20K/1%/0.125W/1608
2	R312,R313	RESISTOR	RK73B1JTTD270J	KOA	(1*) 27ohm/5%/1608
2	SW301,SW302	SWITCH	CHS-04TA	COPAL	
1	U301	IC	R5F5651EHDFFP#30	Renesas	
1	Y301	CRYSTAL	ABM3C-24.000MHZ-D4Y	Abracon	

(1*) Equivalent product can be changed

Table 6.4 Filter board

Quantity	Reference	KIND	Parts Name	Manufacturer	Remark
4	C201,C202,C207,C208	Ceramic Capacitor	GRM1885C1H822JA01D	Murata	(1*) 8200pF/C0G/50V/1608
1	C203	Ceramic Capacitor	GRM3195C1H153JA01D	Murata	(1*) 0.015uF/C0G/50V/3216
2	C204,C205	Ceramic Capacitor	CGA3E2C0G1H222J080AA	TDK	(1*) 2200pF/C0G/50V/1608
1	C206	Ceramic Capacitor	GRM1885C1H122JA01D	Murata	(1*) 1200pF/C0G/50V/1608
1	C209	Ceramic Capacitor	GRM1885C1H152JA01J	Murata	(1*) 1500pF/C0G/50V/1608
3	CN201,CN202,CN203	Connector	XG4C-1031	OMRON	
1	JP201	Connector	FFC-2AMEP1	HONDA	(1*)
3	L201,L202,L210	Inductor	NL453232T-102J-PF	TDK	(2*) PM1812-102J-RC (Bourms)
1	L203	Inductor	NL453232T-561J-PF	TDK	(2*) PM1812-561J-RC (Bourms)
1	L204	Inductor	SRN5040-330M	Bourms Inc.	(2*) NR5040T330M (Taiyo Yuden)
2	L205,L206	Inductor	NL453232T-221J-PF	TDK	(2*) PM1812-221J-RC (Bourms)
1	L207	Inductor	NL453232T-391J-PF	TDK	(2*) PM1812-391J-RC (Bourms)
2	L208,L209	Inductor	NL453232T-151J-PF	TDK	(2*) PM1812-151J-RC (Bourms)
1	R201	Resistor	RK73B1JTTD331J	KOA	(1*) 330ohm/5%/0.125W/1608
1	R202	Resistor	RK73B1JTTD132J	KOA	(1*) 1.3K/5%/0.125W/1608
2	R203,R207	Resistor	RK73Z1JTTD	KOA	(1*) 0ohm/1608
1	R204	Resistor	RMCP2010JT100R	STACKPOLE	(1*) 100ohm/5%/1W
1	R205	Resistor	RK73B1JTTD561J	KOA	(1*) 560ohm/5%/0.125W/1608
1	R206	Resistor	RK73B1JTTD222J	KOA	(1*) 2.2K/5%/0.125W/1608
1	R209	Resistor	RK73B1JTTD202J	KOA	(1*) 2K/5%/0.125W/1608

(1*) Equivalent product can be changed

(2*) Alternative product

Table 6.5 PMOD conversion board

Quantity	Reference	KIND	Parts Name	Manufacturer	Remark
2	PMOD2,PMOD3	CONNECTOR	TSM-106-01-L-DV	SAMTEC	

Website and Support

Renesas Electronics Website

<https://www.renesas.com/us/en>

Inquiries

<https://www.renesas.com/us/en/contact-us>

All trademarks or registered trademarks are the property of their respective owners.

Revision History

Rev.	Date	Description	
		Page	Summary
1.00	2024.07.01		First Edition issued
1.10	2024.08.01	P2, 5, 6	Corrected errors (Section 2.1, 2.6.1, 2.6.2)
1.20	2025.03.01	P6	Changed the recommended value of the external capacitance C2 and C3 of the DC-DC converter

Notice

1. Descriptions of circuits, software and other related information in this document are provided only to illustrate the operation of semiconductor products and application examples. You are fully responsible for the incorporation or any other use of the circuits, software, and information in the design of your product or system. Renesas Electronics disclaims any and all liability for any losses and damages incurred by you or third parties arising from the use of these circuits, software, or information.
2. Renesas Electronics hereby expressly disclaims any warranties against and liability for infringement or any other claims involving patents, copyrights, or other intellectual property rights of third parties, by or arising from the use of Renesas Electronics products or technical information described in this document, including but not limited to, the product data, drawings, charts, programs, algorithms, and application examples.
3. No license, express, implied or otherwise, is granted hereby under any patents, copyrights or other intellectual property rights of Renesas Electronics or others.
4. You shall be responsible for determining what licenses are required from any third parties, and obtaining such licenses for the lawful import, export, manufacture, sales, utilization, distribution or other disposal of any products incorporating Renesas Electronics products, if required.
5. You shall not alter, modify, copy, or reverse engineer any Renesas Electronics product, whether in whole or in part. Renesas Electronics disclaims any and all liability for any losses or damages incurred by you or third parties arising from such alteration, modification, copying or reverse engineering.
6. Renesas Electronics products are classified according to the following two quality grades: "Standard" and "High Quality". The intended applications for each Renesas Electronics product depends on the product's quality grade, as indicated below.

"Standard": Computers; office equipment; communications equipment; test and measurement equipment; audio and visual equipment; home electronic appliances; machine tools; personal electronic equipment; industrial robots; etc.

"High Quality": Transportation equipment (automobiles, trains, ships, etc.); traffic control (traffic lights); large-scale communication equipment; key financial terminal systems; safety control equipment; etc.

Unless expressly designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not intended or authorized for use in products or systems that may pose a direct threat to human life or bodily injury (artificial life support devices or systems; surgical implantations; etc.), or may cause serious property damage (space system; undersea repeaters; nuclear power control systems; aircraft control systems; key plant systems; military equipment; etc.). Renesas Electronics disclaims any and all liability for any damages or losses incurred by you or any third parties arising from the use of any Renesas Electronics product that is inconsistent with any Renesas Electronics data sheet, user's manual or other Renesas Electronics document.

7. No semiconductor product is absolutely secure. Notwithstanding any security measures or features that may be implemented in Renesas Electronics hardware or software products, Renesas Electronics shall have absolutely no liability arising out of any vulnerability or security breach, including but not limited to any unauthorized access to or use of a Renesas Electronics product or a system that uses a Renesas Electronics product. RENESAS ELECTRONICS DOES NOT WARRANT OR GUARANTEE THAT RENESAS ELECTRONICS PRODUCTS, OR ANY SYSTEMS CREATED USING RENESAS ELECTRONICS PRODUCTS WILL BE INVULNERABLE OR FREE FROM CORRUPTION, ATTACK, VIRUSES, INTERFERENCE, HACKING, DATA LOSS OR THEFT, OR OTHER SECURITY INTRUSION ("Vulnerability Issues"). RENESAS ELECTRONICS DISCLAIMS ANY AND ALL RESPONSIBILITY OR LIABILITY ARISING FROM OR RELATED TO ANY VULNERABILITY ISSUES. FURTHERMORE, TO THE EXTENT PERMITTED BY APPLICABLE LAW, RENESAS ELECTRONICS DISCLAIMS ANY AND ALL WARRANTIES, EXPRESS OR IMPLIED, WITH RESPECT TO THIS DOCUMENT AND ANY RELATED OR ACCOMPANYING SOFTWARE OR HARDWARE, INCLUDING BUT NOT LIMITED TO THE IMPLIED WARRANTIES OF MERCHANTABILITY, OR FITNESS FOR A PARTICULAR PURPOSE.
8. When using Renesas Electronics products, refer to the latest product information (data sheets, user's manuals, application notes, "General Notes for Handling and Using Semiconductor Devices" in the reliability handbook, etc.), and ensure that usage conditions are within the ranges specified by Renesas Electronics with respect to maximum ratings, operating power supply voltage range, heat dissipation characteristics, installation, etc. Renesas Electronics disclaims any and all liability for any malfunctions, failure or accident arising out of the use of Renesas Electronics products outside of such specified ranges.
9. Although Renesas Electronics endeavors to improve the quality and reliability of Renesas Electronics products, semiconductor products have specific characteristics, such as the occurrence of failure at a certain rate and malfunctions under certain use conditions. Unless designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not subject to radiation resistance design. You are responsible for implementing safety measures to guard against the possibility of bodily injury, injury or damage caused by fire, and/or danger to the public in the event of a failure or malfunction of Renesas Electronics products, such as safety design for hardware and software, including but not limited to redundancy, fire control and malfunction prevention, appropriate treatment for aging degradation or any other appropriate measures. Because the evaluation of microcomputer software alone is very difficult and impractical, you are responsible for evaluating the safety of the final products or systems manufactured by you.
10. Please contact a Renesas Electronics sales office for details as to environmental matters such as the environmental compatibility of each Renesas Electronics product. You are responsible for carefully and sufficiently investigating applicable laws and regulations that regulate the inclusion or use of controlled substances, including without limitation, the EU RoHS Directive, and using Renesas Electronics products in compliance with all these applicable laws and regulations. Renesas Electronics disclaims any and all liability for damages or losses occurring as a result of your noncompliance with applicable laws and regulations.
11. Renesas Electronics products and technologies shall not be used for or incorporated into any products or systems whose manufacture, use, or sale is prohibited under any applicable domestic or foreign laws or regulations. You shall comply with any applicable export control laws and regulations promulgated and administered by the governments of any countries asserting jurisdiction over the parties or transactions.
12. It is the responsibility of the buyer or distributor of Renesas Electronics products, or any other party who distributes, disposes of, or otherwise sells or transfers the product to a third party, to notify such third party in advance of the contents and conditions set forth in this document.
13. This document shall not be reprinted, reproduced or duplicated in any form, in whole or in part, without prior written consent of Renesas Electronics.
14. Please contact a Renesas Electronics sales office if you have any questions regarding the information contained in this document or Renesas Electronics products.

(Note1) "Renesas Electronics" as used in this document means Renesas Electronics Corporation and also includes its directly or indirectly controlled subsidiaries.

(Note2) "Renesas Electronics product(s)" means any product developed or manufactured by or for Renesas Electronics.

(Rev.5.0-1 October 2020)

Corporate Headquarters

TOYOSU FORESIA, 3-2-24 Toyosu,
Koto-ku, Tokyo 135-0061, Japan
www.renesas.com

Trademarks

Renesas and the Renesas logo are trademarks of Renesas Electronics Corporation. All trademarks and registered trademarks are the property of their respective owners.

Contact information

For further information on a product, technology, the most up-to-date version of a document, or your nearest sales office, please visit:
www.renesas.com/contact/.