R9A06G061/ISL15102 Circuit Design Guideline

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PCB Circuit Design Guide

Summary

This material is a guideline for PCB circuit when designing a PLC board using R9A06G061 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.

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1. PLC Board Configuration Example

Figure 1-1shows a PLC board configuration example using R9A06G061 as a PLC modem LSI by Renesas Electronics manufactured and ISL15102 as a power amp for transmission output. This material explains cautions on PCB layout for PLC board design based on the configuration below.

(Renesas Electronics can provide a reference board with the PLC board configuration shown in Figure 1-1 except for the AC-DC circuit.)

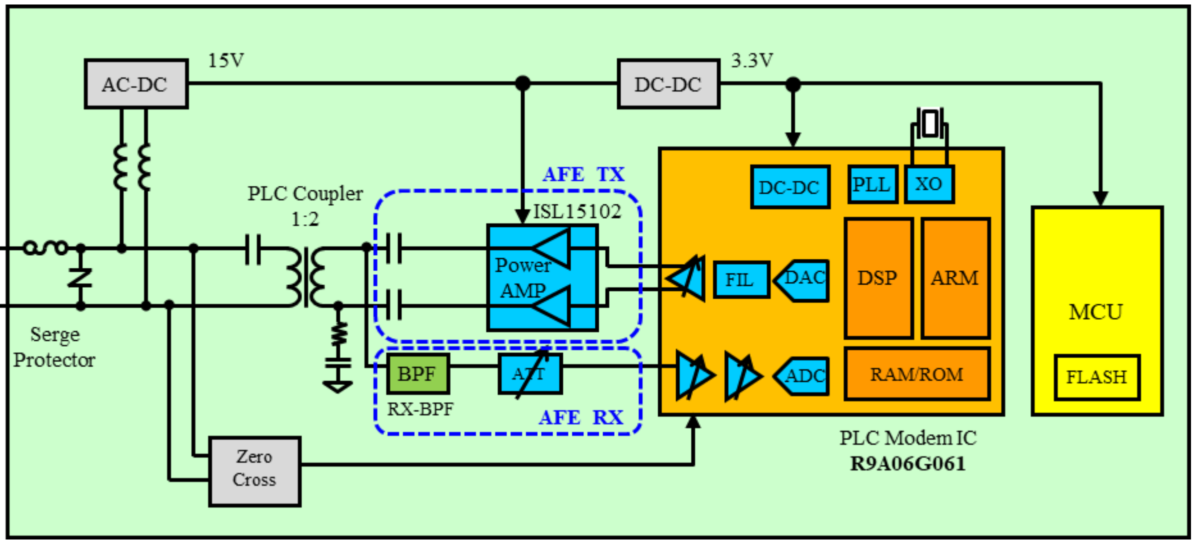


Figure 1-1 PLC board configuration example to which R9A06G061 / ISL15102 are applied

2. Cautions regarding peripheral circuits of R9A06G061

2.1 R9A06G061 Peripheral circuit

Place the decoupling capacitor of R9A06G061 near the terminal. In particular, AVDD33R(1pin) and AVDD33T(36pin) affect the transmission and reception characteristics, so place them near the terminals.

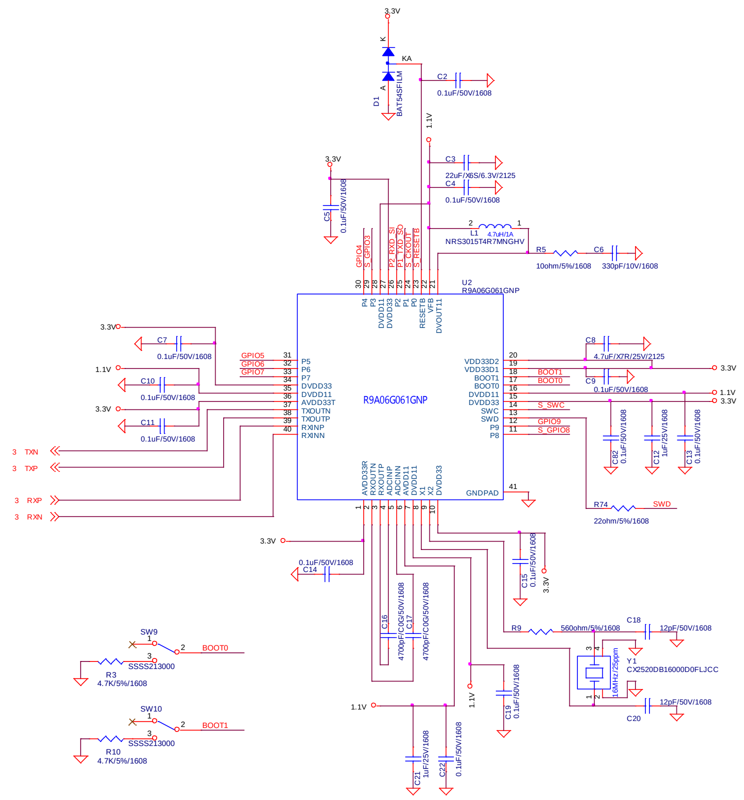


Figure 2-1 R9A06G061 Peripheral circuit

2.2 BOOT terminal setting

The BOOT0 and BOOT1 are terminals for setting the interface for downloading firmware for boot. Figure 2-2 shows the settings for the BOOT0 and BOOT1 terminals.

- Set to UART I/F BOOT : BOOT0, BOOT1=Open (High)
- Set to SPI I/F BOOT : BOOT0=Open (High), BOOT1=Connect to GND via 4.7kΩ or 5.1kΩ (Low)
- Set to SROM I/F BOOT : BOOT0=Connect to GND via 4.7kΩ or 5.1kΩ (Low), BOOT1=Open (High)
- TEST mode (Setting prohibited) : BOOT0, BOOT1=Connect to GND via 4.7kΩ or 5.1kΩ (Low)

Note) The BOOT0 terminal has a built-in pull-up resistor of 50kΩ.

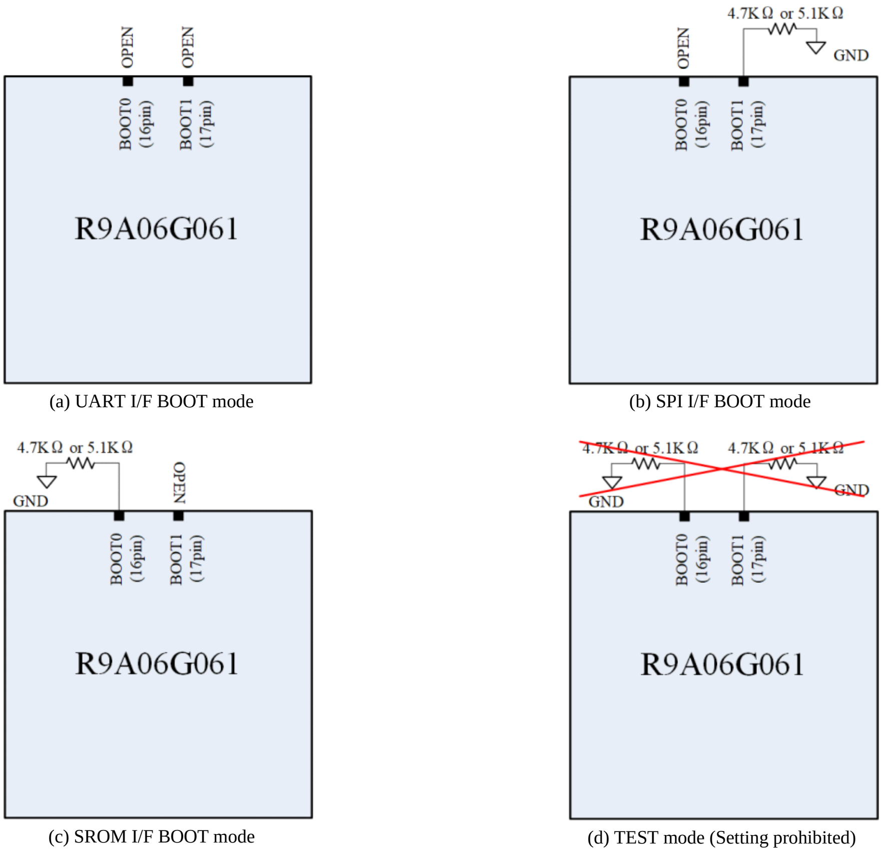


Figure 2-2 BOOT0, BOOT1 terminal settings

2.3 Reference clock setting

- Figure 2-3 shows a connection example of the crystal oscillator circuit.
- Capacitor loads C18 and C20 are required for the X1(8pin) and X2(9pin) terminals in order for the 16MHz crystal oscillator to oscillate stably. In addition, R9 is required to adjust the negative resistance.
- 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.
- Place the crystal oscillator connected to R9A06G061 and its peripheral parts as close to R9A06G061 as possible.
- Table 2-1 shows an example of circuit constants when the crystal oscillator Y1: Kyocera CX2520DB16000D0FLJCC or Daishinku DSX221SH is used. (Crystal oscillator specifications: Frequency: 16MHz, Load capacitor: 8pF, Frequency tolerance: ± 10ppm, Frequency temperature characteristics: ± 15ppm)
- 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.
- R9A06G061 does not have a mode that uses an external clock.

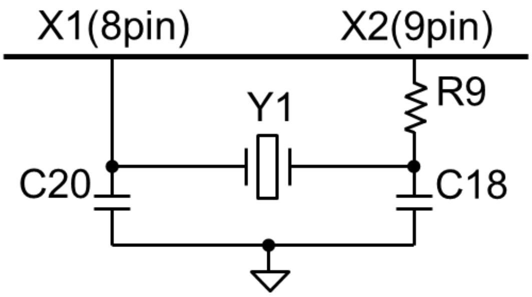


Figure 2-3 Crystal oscillator circuit connection example

Table 2-1 Example of circuit constant of crystal oscillator circuit
(When using crystal oscillator Y1: Kyocera CX2520DB16000D0FLJCC Daishinku DSX221SH)

Component No.	C18	C20	R9
Component value	12pF	12pF	560Ω

2.4 RESETB terminal

- An example of an external circuit for the RESETB terminal is shown in Figure 2-4, 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 R9A06G061 in the reset state (RESETB = low) to prevent malfunctions while preparing to download the R9A06G061 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.)

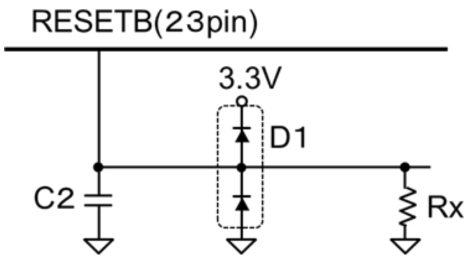


Figure 2-4 Example of an external circuit for the RESETB terminal

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

Component No.	C2	D1	Rx
Component value	0.1uF	BAT54SFILM (STMicro)	4.7kΩ or 5.1kΩ

2.5 DC-DC converter

- The built-in DC-DC converter of R9A06G061 generates a power supply voltage of 3.3V to 1.1V by the switching regulator method. This 1.1V is supplied to the 1.1V power supply of R9A06G061 through the PCB wiring.
- For the frequency stability of the DC-DC converter, set the total to 20uF or more for C3.
- Figure 2-5 shows an example of an external circuit for a DC-DC converter, and Table 2-3 shows an example of its circuit constants.
- Figure 2-6 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.

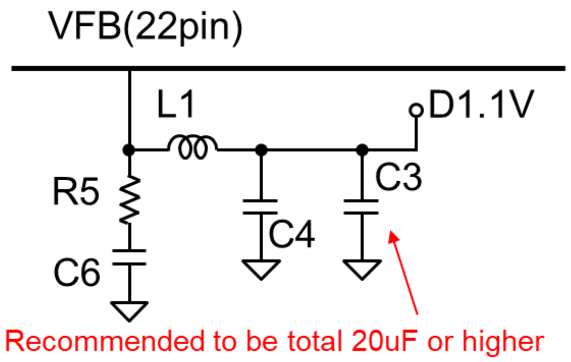


Figure 2-5 Example of an external circuit for a DC-DC converter

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

Component No.	R5	C6	C3	C4	L1
Component value	10Ω	330pF	22uF	0.1uF	4.7uH

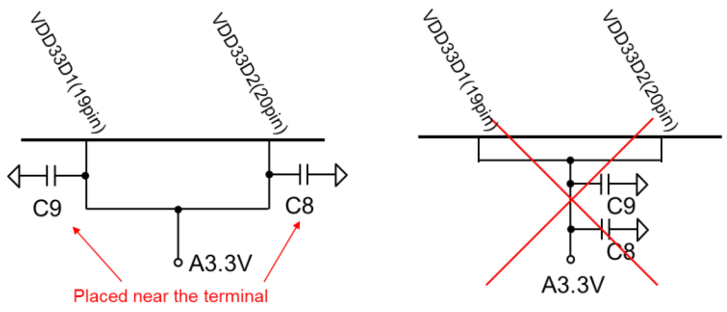


Figure 2-6 Example of connecting the decoupling capacitor of the power supply terminal of the DC-DC converter

2.6 LED

- Figure 2-7 shows an example of using the LED that shows the transmission / reception status of R9A06G061.
- 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.) However, due to the limitation of the GPIO terminal of R9A06G061, the connection terminal to the LED becomes a terminal that can be used as both the BOOT0 terminal and the BOOT1 terminal.
- It is recommended to set the current flowing through the LED to about 1mA.
- For LEDs1 and R7, set R7 so that

$$I_{LED1} = \frac{(3.3V - V_{F\_LED1})}{R7} \text{ makes } I_{LED1} \text{ about 1mA.}$$

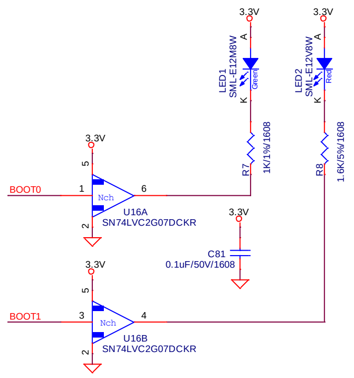


Figure 2-7 Example of using the LED that shows the TX/RX status of R9A06G061

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.

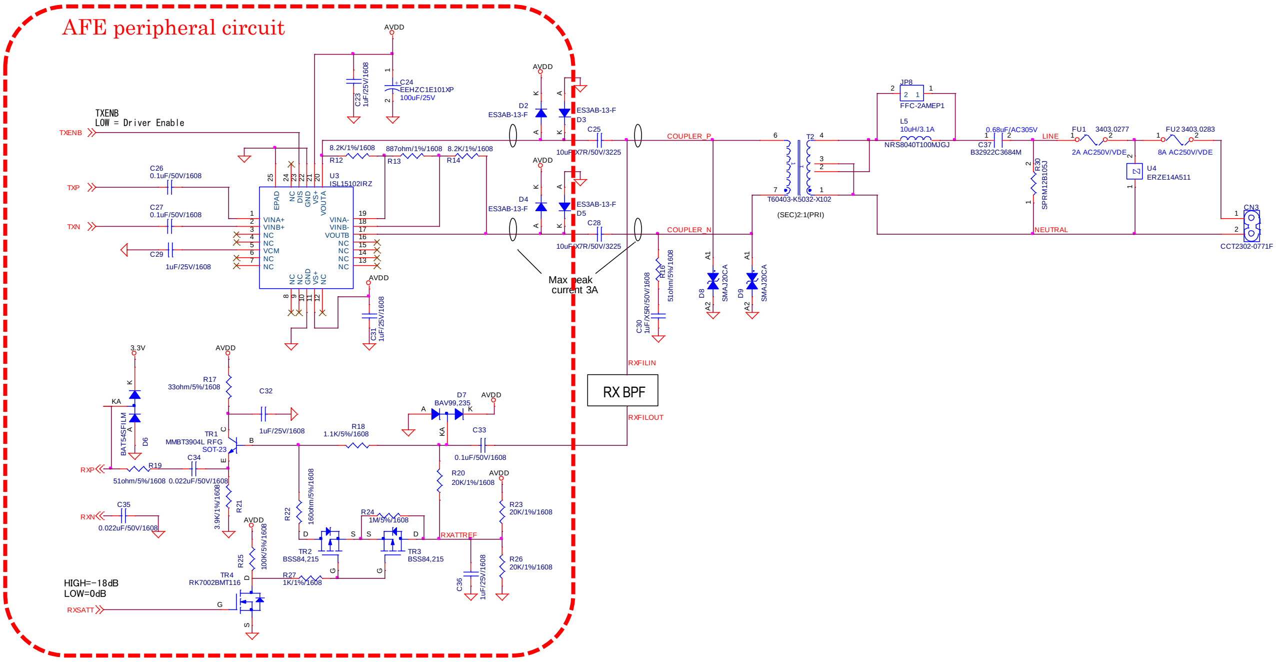
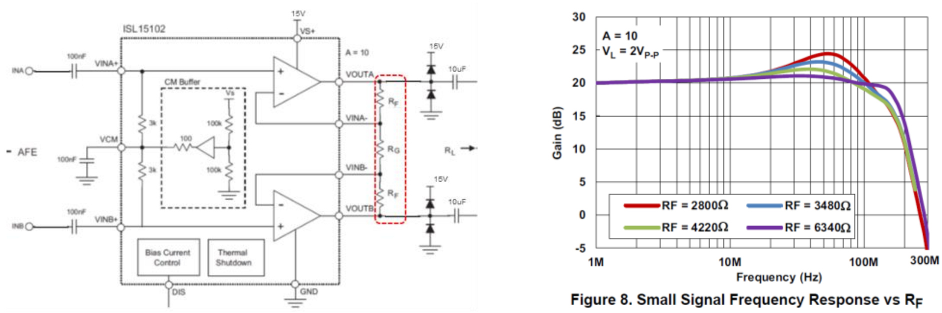


Figure 3-1 Example of connecting the AFE peripheral circuit

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 RF 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 RF vs oscillation stability shown in Figure 3-4 and the effect on RF and out-of-band noise shown in Figure 3-5.
- As a result, the relationship between RF and oscillation stability is almost constant when RF=8.2kΩ or higher, and the relationship between RF and out-of-band noise is the lowest when RF=8.2kΩ.
- From this result, set the optimum value of RF(=R12=R14) to 8.2kΩ, RG 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 RF

Figure 3-2 Catalog data of ISL15102

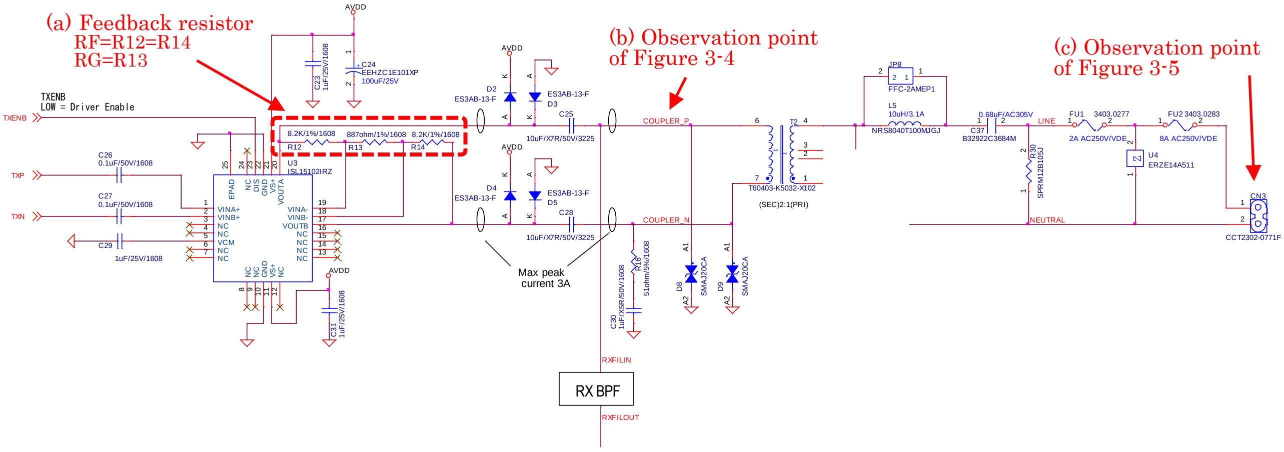


Figure 3-3 Setting the feedback resistor RF of ISL15102

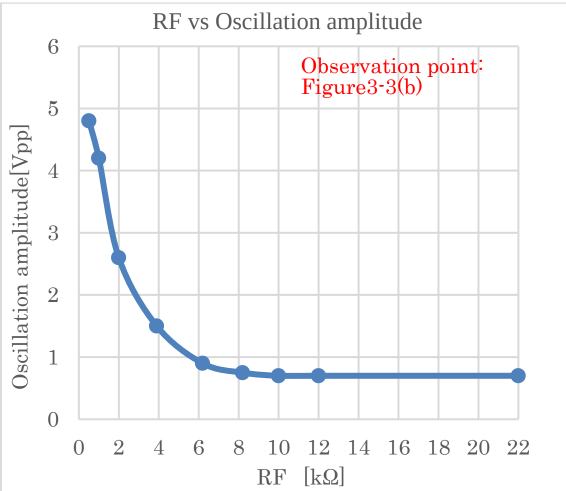


Figure 3-4 RF vs Oscillation Amplitude

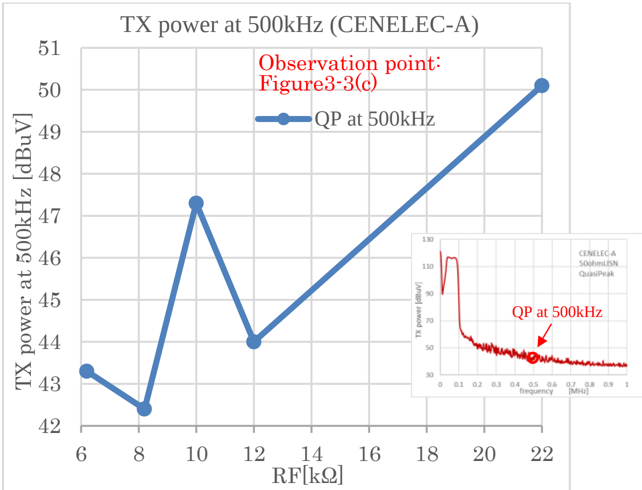


Figure 3-5 RF vs out-of-band noise (at 500kHz in CENELEC-A band)

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 C30 = 1uF and R16 = 120Ω shown in Figure 3 6 (a) for the purpose of balancing the load on the negative phase output side.

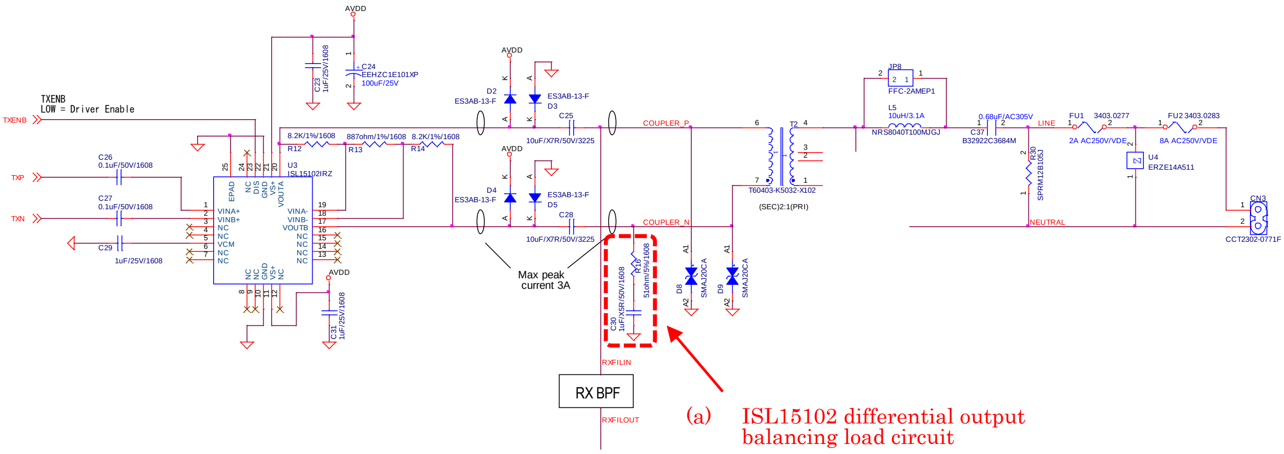


Figure 3-6 3.1.2 ISL15102 differential output balancing load circuit

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.

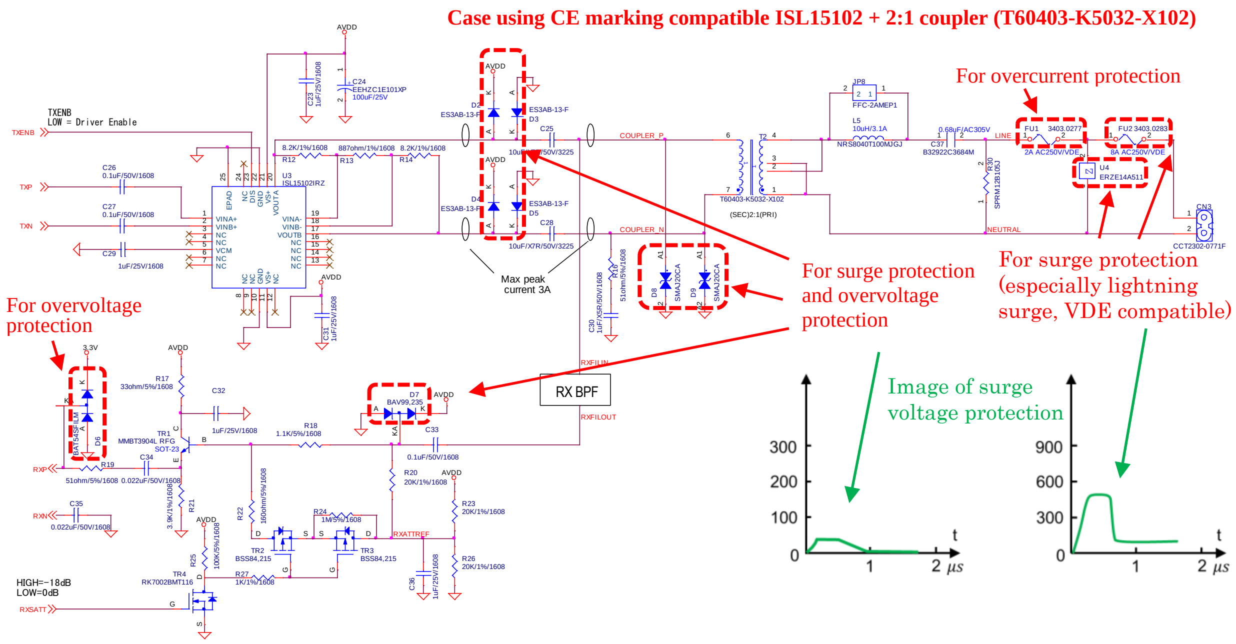


Figure 3-7 Example of connection of protection circuit used for PLC board (CE marking compatible)

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.

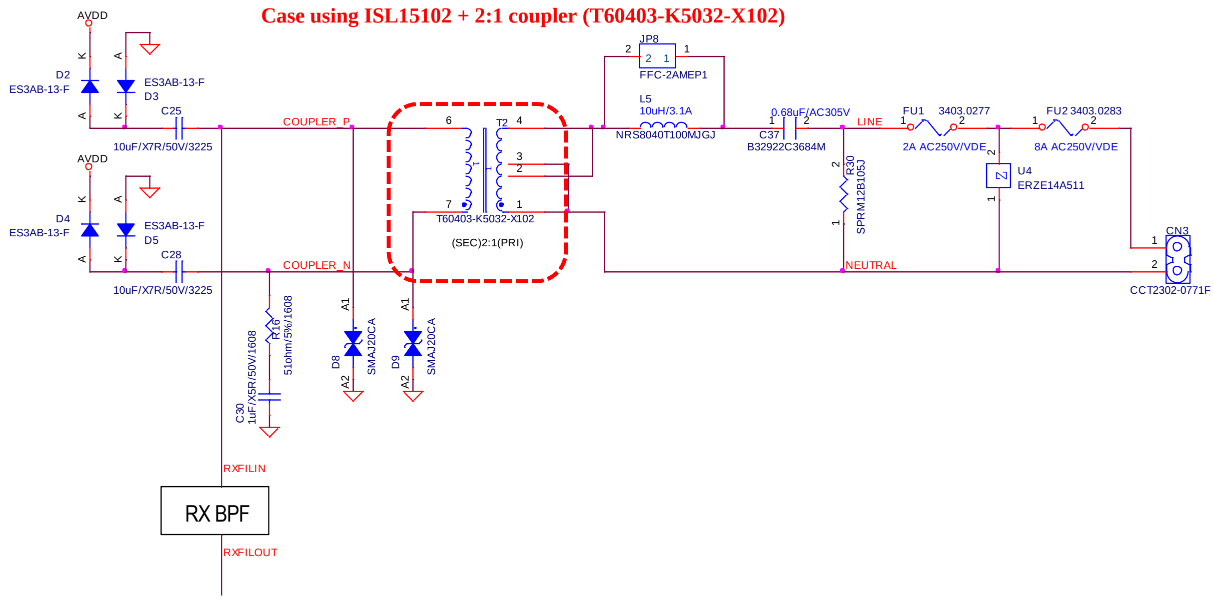


Figure 3-8 The recommended 2:1 PLC coupler (T60403-5032-X102) connection example

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 R9A06G061.
- 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.

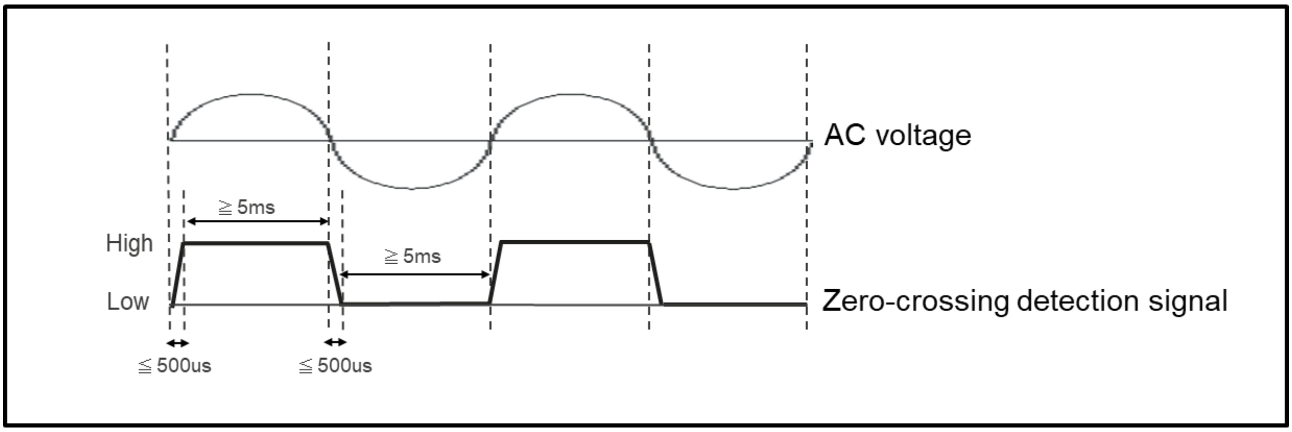


Figure 3-9 The zero-cross detection signal

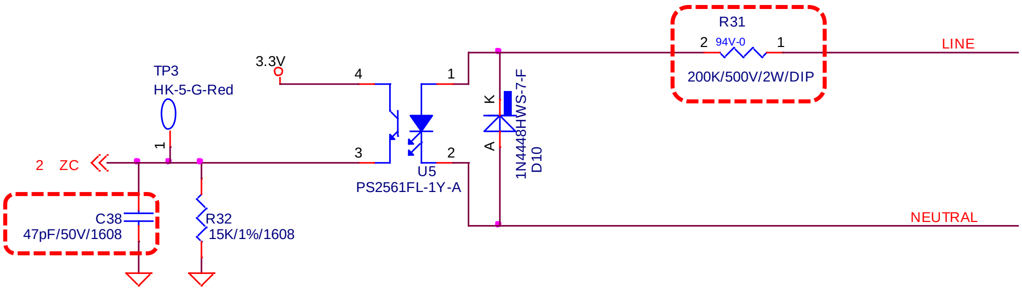
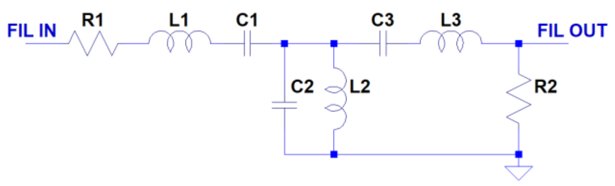


Figure 3-10 Example of a zero-cross detection circuit

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.



	CENELEC-A (35k-90kHz)	FCC/ARIB (150k-500kHz)	Global (35k-500kHz)
R1	330ohm	560ohm	470ohm
R2	1300ohm	2200ohm	2000ohm
L1	1000uH	220uH	150uH
L2	560uH	390uH	1000uH
L3	1000uH/-	220uH/-	150uH/-
C1	8.2nF	2.2nF	8.2nF
C2	15nF	1.2nF	1.5nF
C3	8.2nF/-	2.2nF/-	8.2nF/-

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

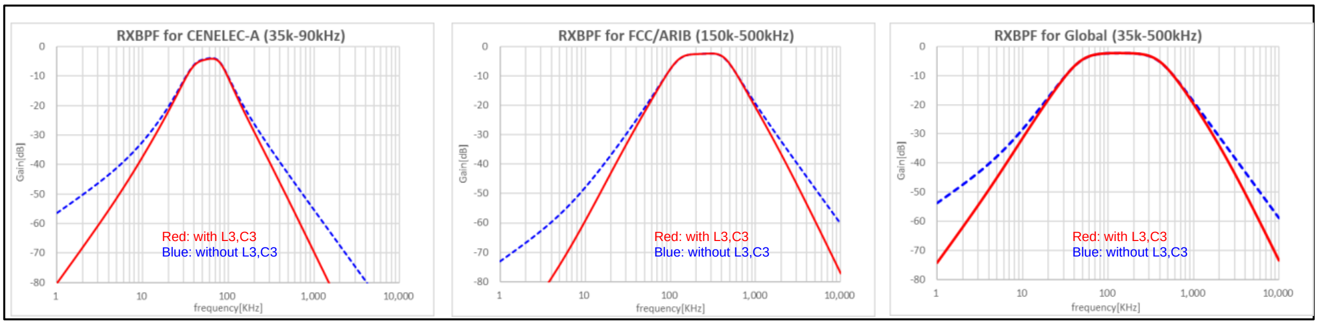


Figure 3-12 Frequency characteristics example of RX-BPF

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 R9A06G061 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 -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 R18 and R22.

$$G_{SATT} = 20\log\left(\frac{R22}{R18 + R22}\right) = 20\log\left(\frac{160}{1100 + 160}\right) = -17.93[\mathrm{dB}]$$

- 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 R9A06G061 will generate harmonics due to saturation, making it difficult to identify the received signal.

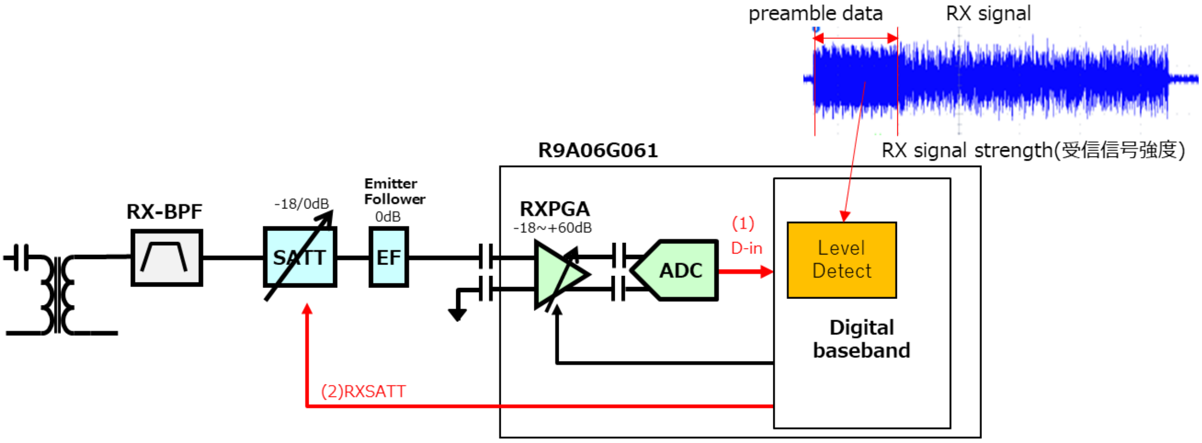


Figure 3 -3-13 Step Attenuator (SATT) control method

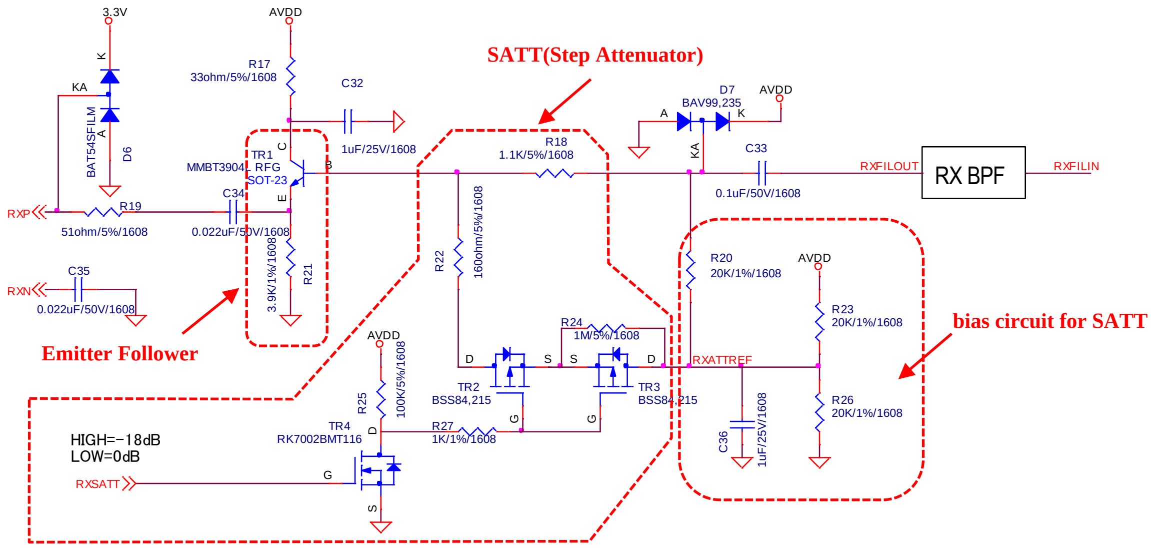


Figure 3-14 Example of Step Attenuator (SATT) circuit

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 C37 to be within the band of the CENELEC-A band, 35kHz-90kHz.

$$f_Q = \frac{1}{2\pi\sqrt{L5 \cdot C37}}$$

- In the case of ISL15102 + 2:1 PLC coupler configuration, by inserting L5=10uH for C37=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.

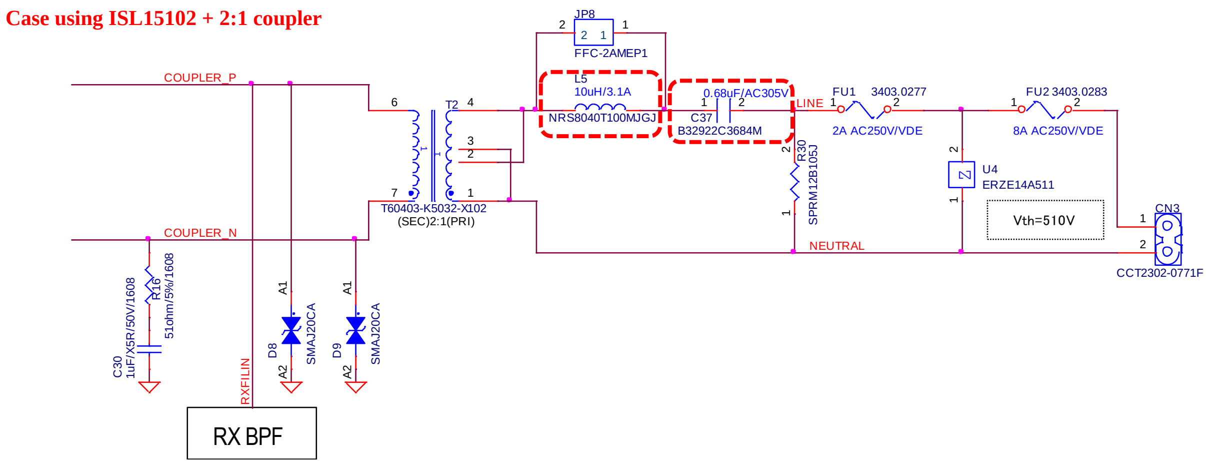


Figure 3-15 Example of connection for low impedance load measures in CENELEC-A band

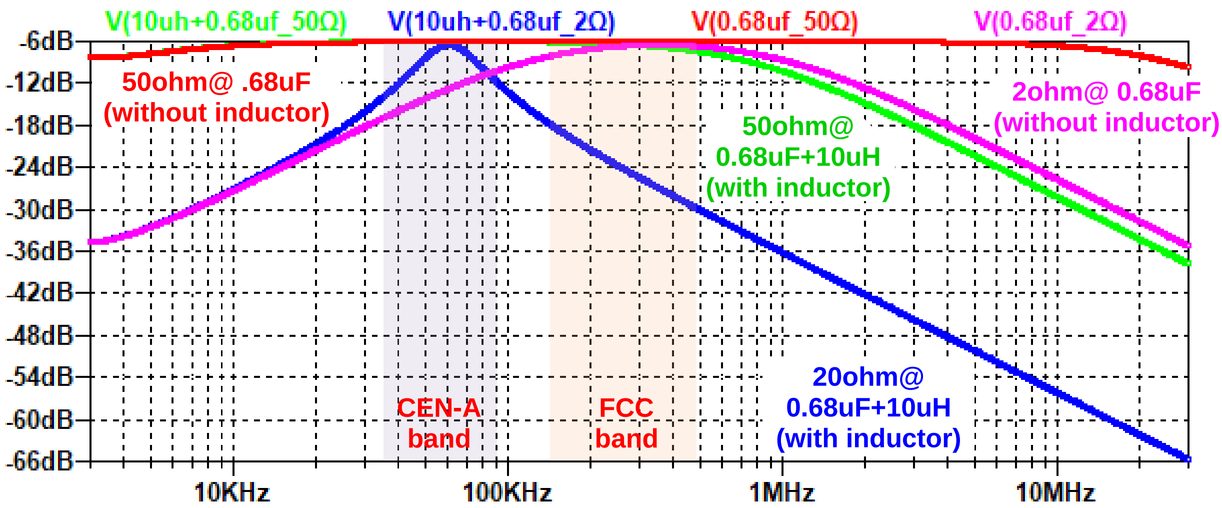


Figure 3-16 Example of frequency characteristics for low impedance load measures in CENELEC-A band

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 C37 and T2 (main inductance). To move the peak due to the resonance to the outside of 3kHz-9kHz, it is recommended to set C37 = 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 C37 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 C37 are within the band of CENELEC-A band. If C37=0.68uF, it is recommended to insert L5=6.8uH.
- If C37, 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)

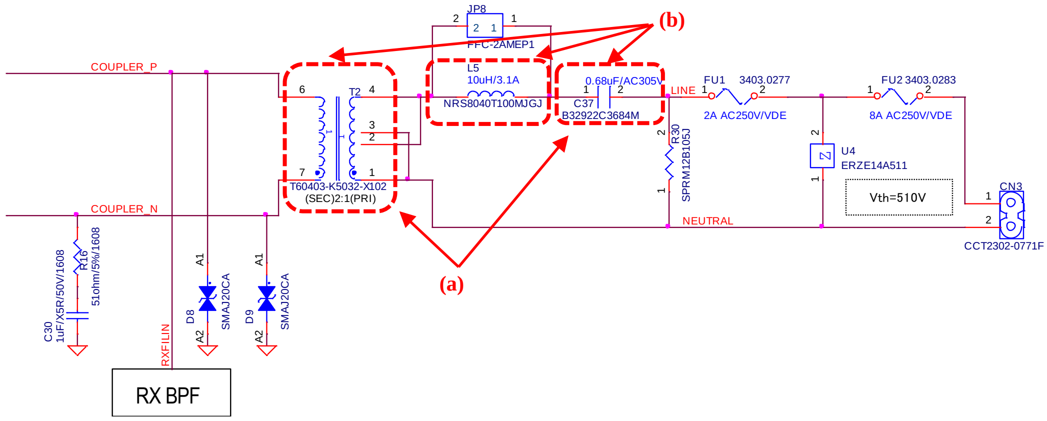


Figure 3-17 Example of impedance measures for EN50065-7 in CENELEC-A band

Table 3-2 EN50065-7:Minimum impedance value |Ze| of an equipment working in the frequency range 9 kHz to 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 R9A06G061 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.

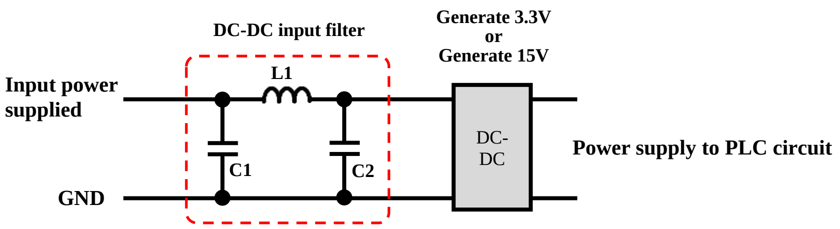


Figure 4-1 Example of input filter for DC-DC power supply circuit

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.

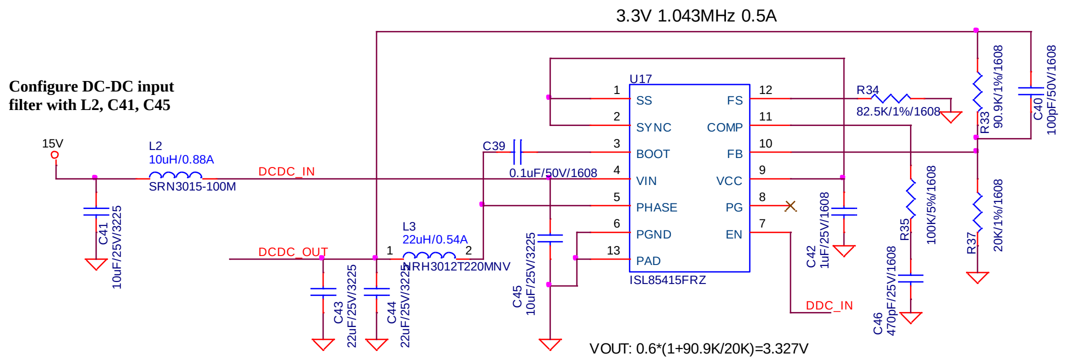


Figure 4-2 Example of DC-DC power supply circuit using ISL85415

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.

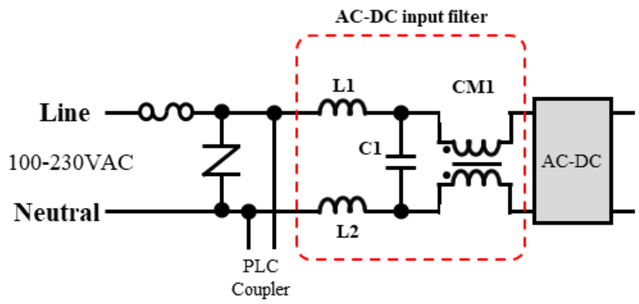


Figure 5-1 Example of input filter for AC-DC power supply circuit

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 shows the PLC board RTK0EE0009D02001BJ (for CENECLEC-A, FCC, Global) of Renesas Electronics as a circuit design example for 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

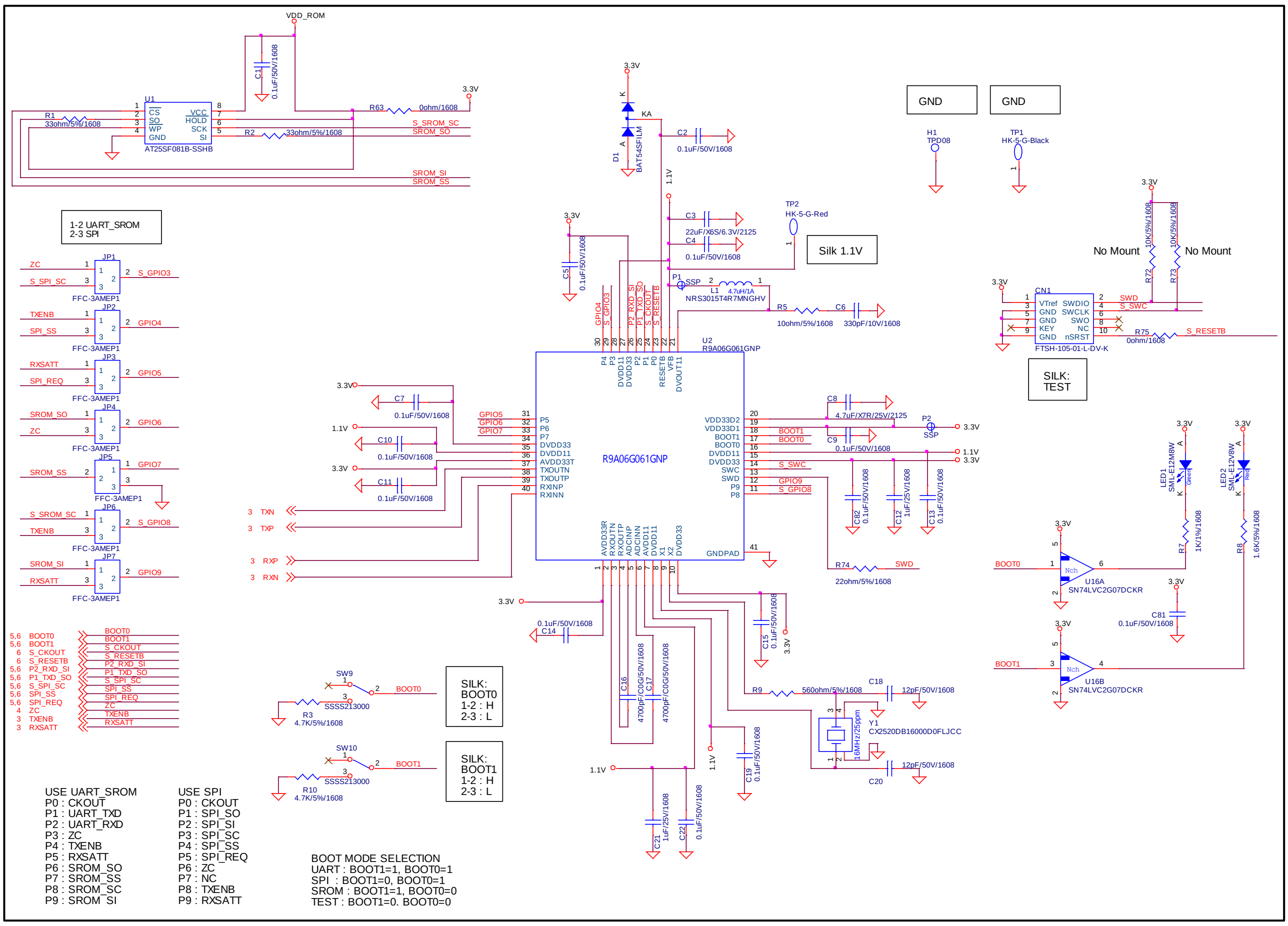


Figure 6-1 AC-PLC board (R9A06G061 peripheral circuit)

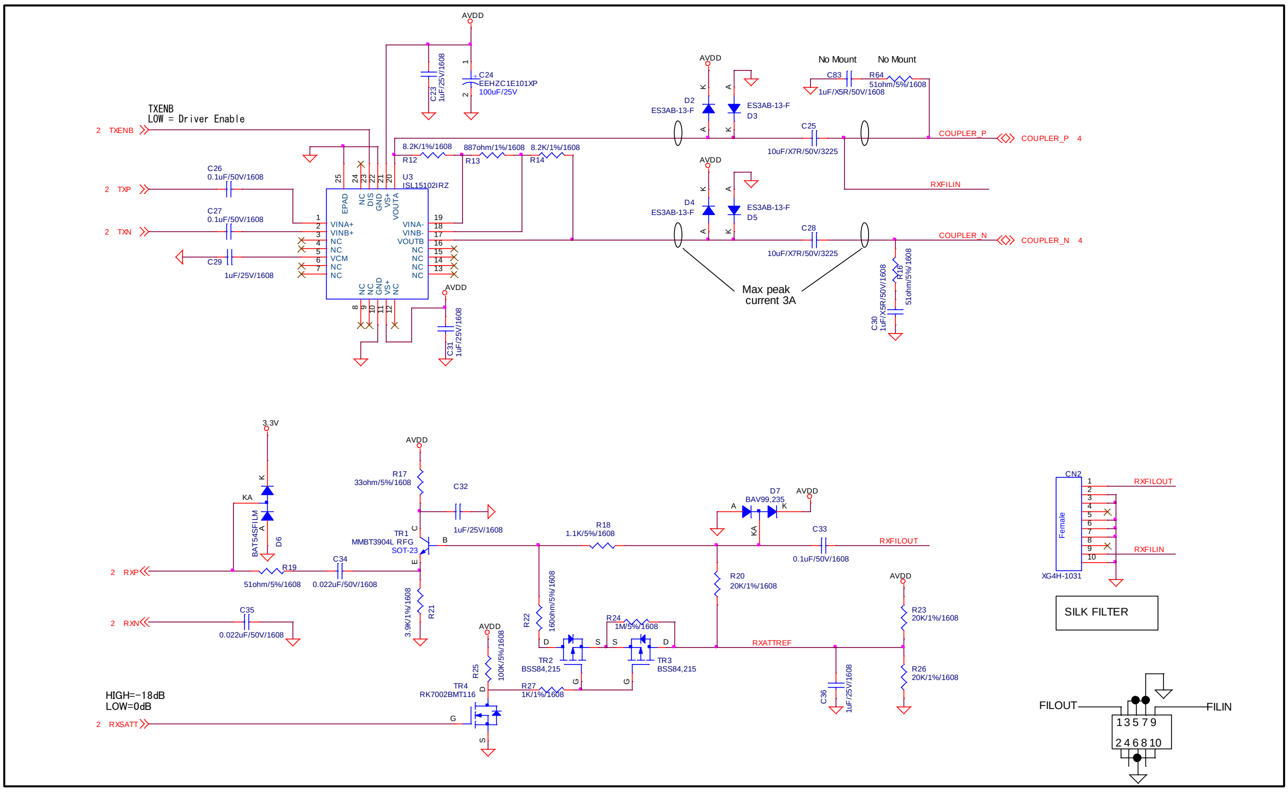


Figure 6-2 AC-PLC board (AFE peripheral circuit)

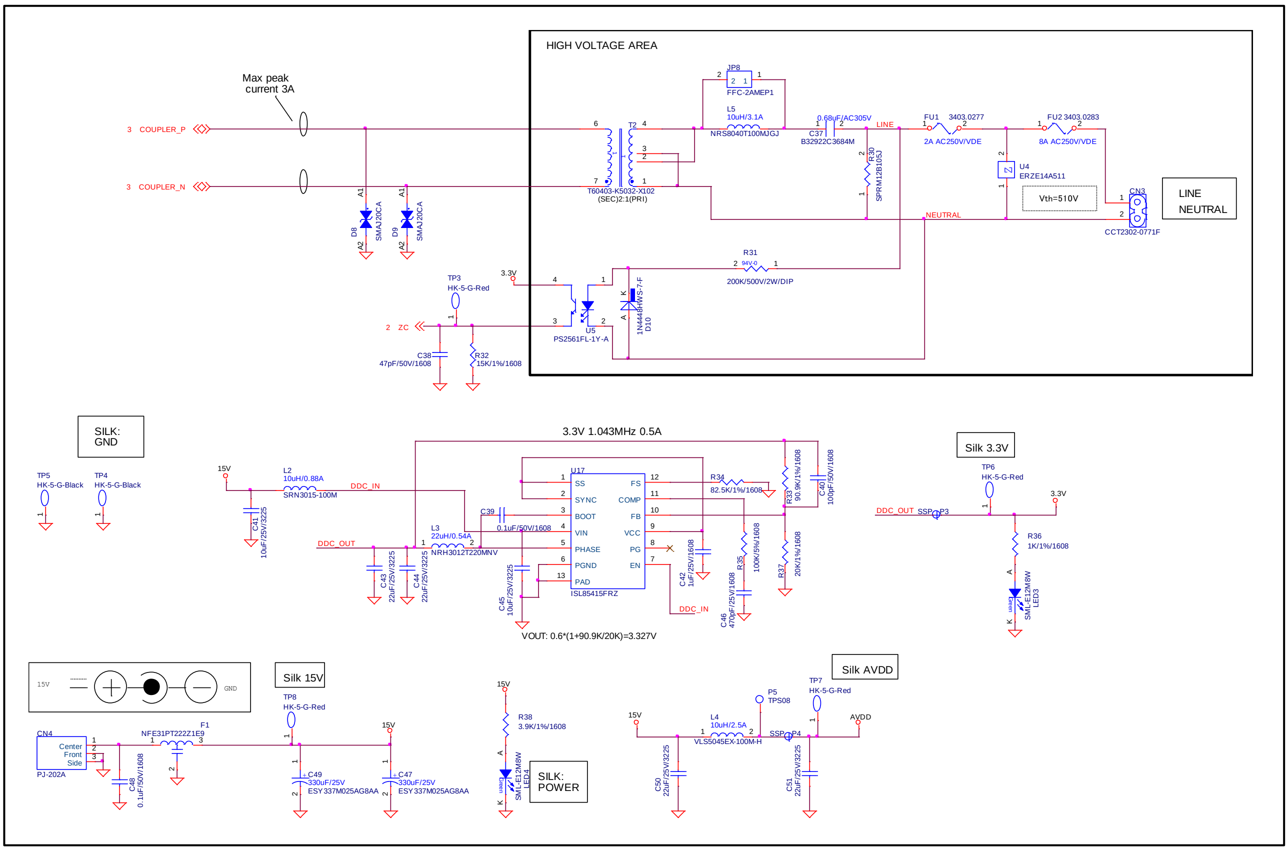


Figure 6-3 AC-PLC board (AC coupling circuit, DC-DC power supply circuit)

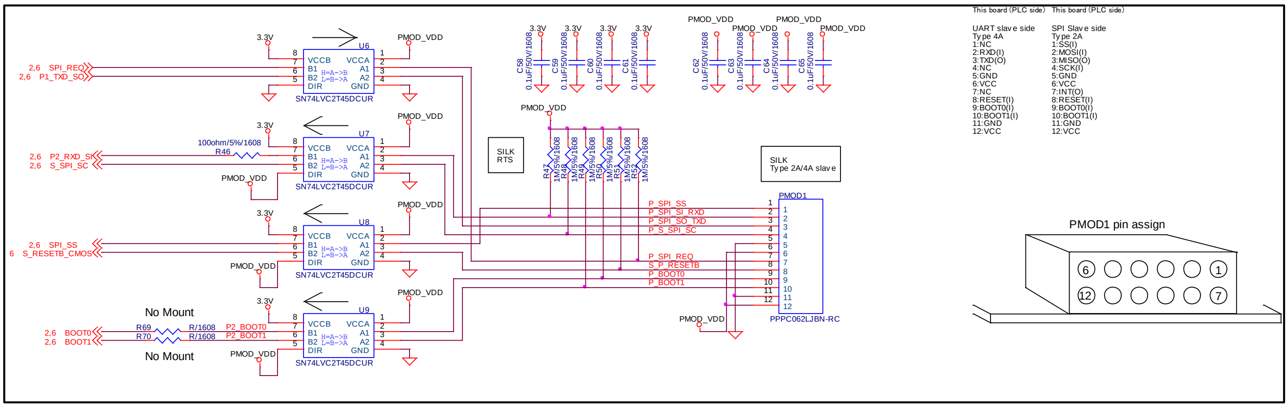


Figure 6-4 AC-PLC board (PMOD circuit)

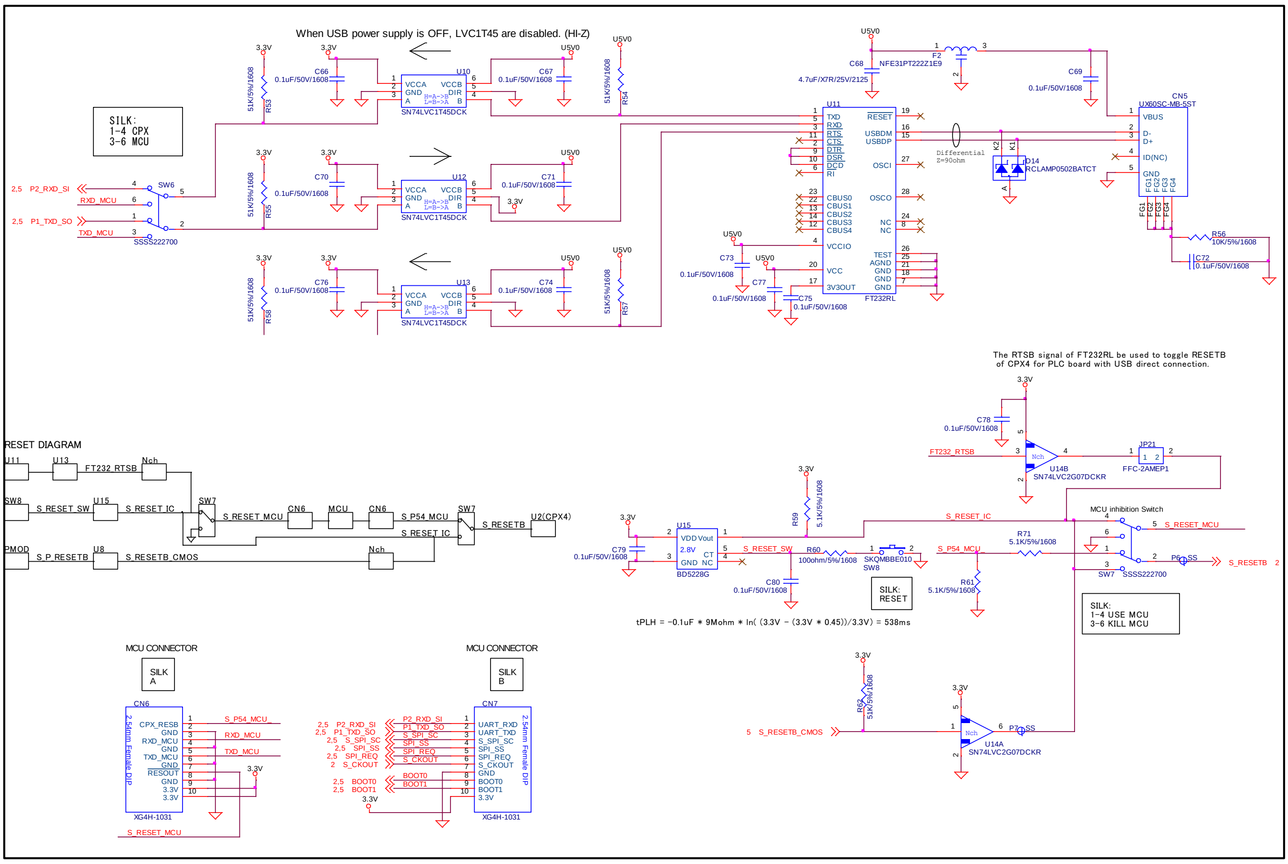


Figure 6-5 AC-PLC board (USB-serial circuit and RESET circuit)

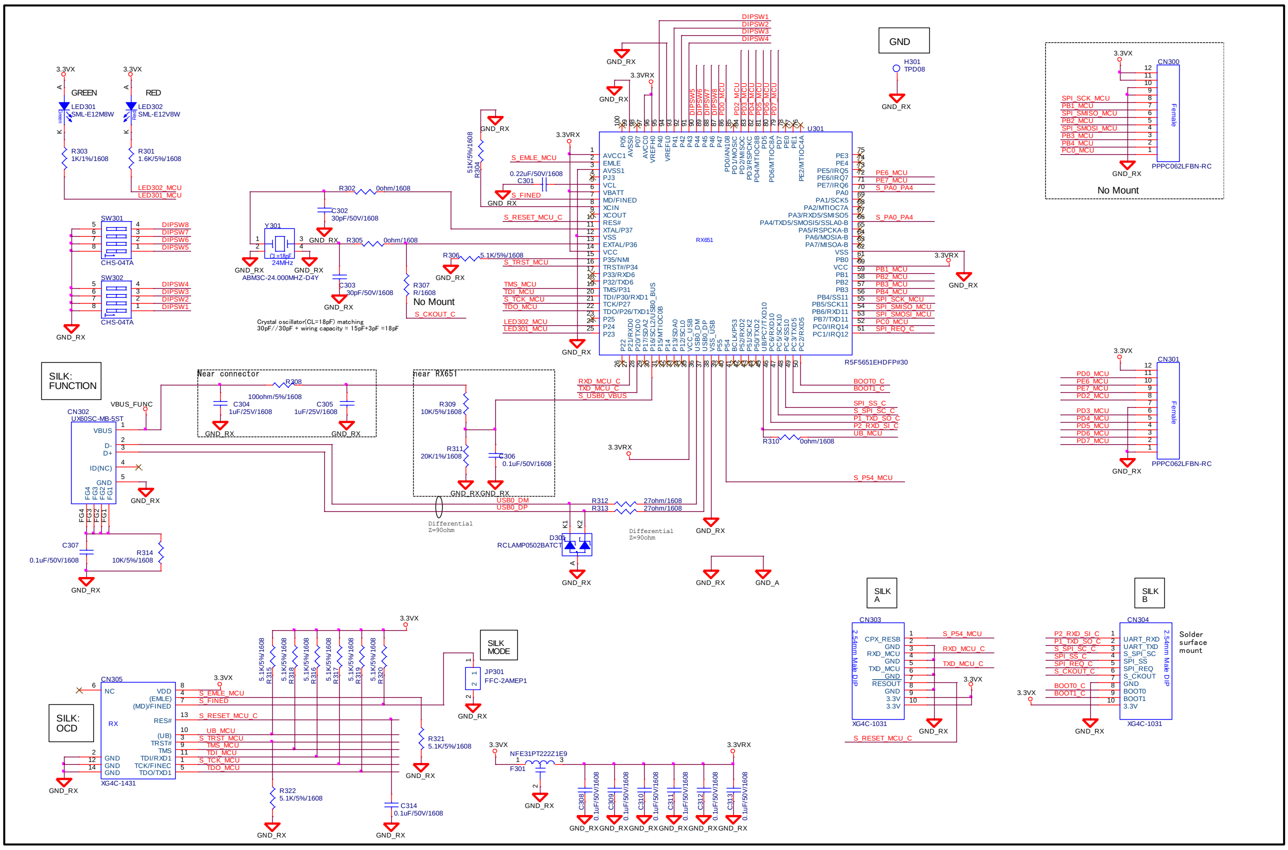


Figure 6-6 RX651 MCU board

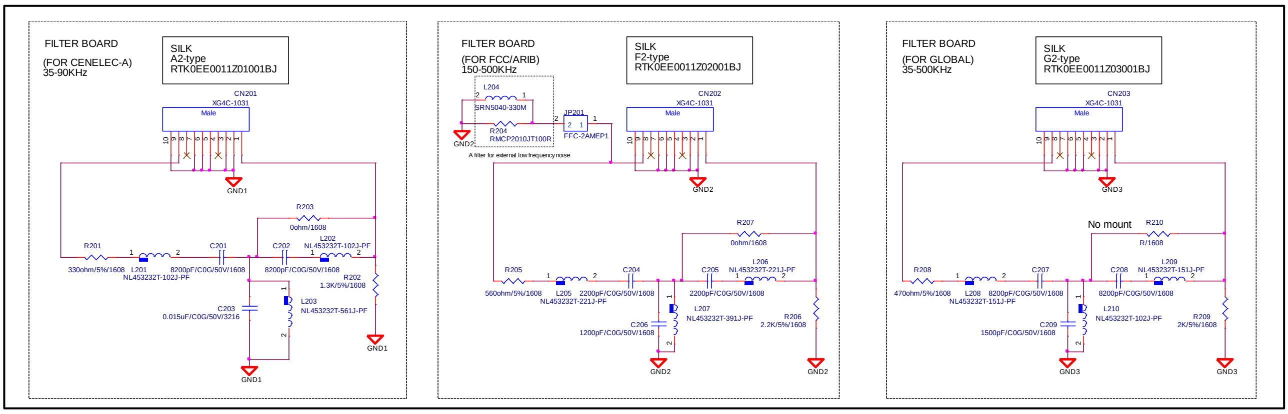


Figure 6-7 Filter board (RX-BPF)

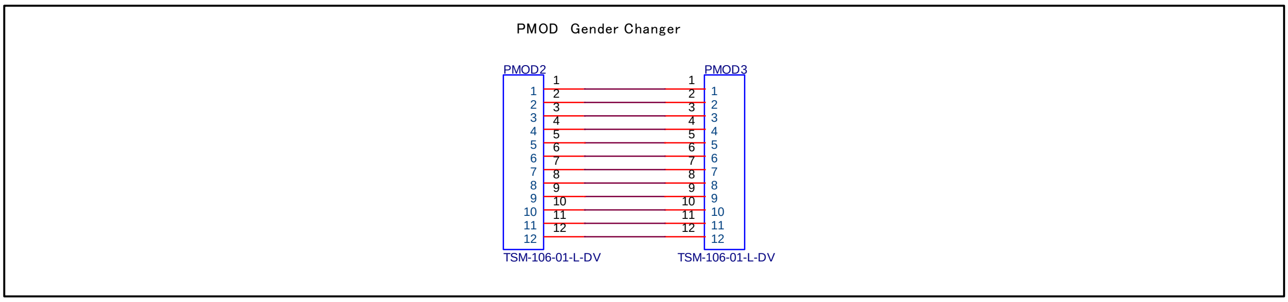


Figure 6-8 PMOD conversion board

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	FTSH-105-01-L-DV-K	SAMTEC	
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	HIROSE	
42	C1,C2,C4,C5,C7,C9,C10,C11,C13,C14,C15,C19,C22,C26,C27,C33,C39,C48,C58,C59,C60,C61,C62,C63,C64,C65,C66,C67,C69,C70,C71,C72,C73,C74,C75,C76,C77,C78,C79,C80,C81,C82	Ceramic Capacitor	CC0603KRX7R9BB104	Yageo	(1*) 0.1uF/X7R/50V/1608
8	C12,C21,C23,C29,C31,C32,C36,C42	Ceramic Capacitor	CGA3E1X7R1E105K080AC	TDK	(1*) 1uF/X7R/25V/1608
2	C16,C17	Ceramic Capacitor	CGA3E2C0G1H472J	TDK	(1*) 4700pF/C0G/50V/1608
2	C18,C20	Ceramic Capacitor	CGA3E2C0G1H120J080AA	TDK	(1*) 12pF/C0G/50V/1608
1	C24	ALUM CAP	EEHZC1E101XP	Panasonic	
2	C25,C28	Ceramic Capacitor	GRM32ER71H106KA12L	MURATA	
1	C3	Ceramic Capacitor	C2012X6S0J226M085AC	TDK	(1*) 22uF/X6S/6.3V/2125
1	C30	Ceramic Capacitor	CGA3E3X5R1H105K080AB	TDK	(1*) 1uF/X5R/50V/1608
2	C34,C35	Ceramic Capacitor	C1608X7R1H223K	TDK	(1*) 0.022uF/X7R/50V/1608
1	C37	Film Capacitor	B32922C3684M	EPCOS	
1	C38	Ceramic Capacitor	CGA3E2C0G1H470J080AA	TDK	(1*) 47pF/C0G/50V/1608
1	C40	Ceramic Capacitor	C1608C0G1H101J080AA	TDK	(1*) 100pF/C0G/50V/1608
2	C41,C45	Ceramic Capacitor	GRM32DR71E106KA12L	MURATA	(1*) 10uF/X7R/25V/3225
4	C43,C44,C50,C51	Ceramic Capacitor	TMK325B7226KMHT	Taiyo Yuden	(1*) 22uF/X7R/25V/3225
1	C46	Ceramic Capacitor	C0603C471J3GACAUTO	KEMET	(1*) 470pF/C0G/25V/1608
2	C47,C49	ELECTROLYTIC CAP	ESY337M025AG8AA	KEMET	
1	C6	Ceramic Capacitor	C0603C331J3GACTU	KEMET	(1*) 330pF/C0G/10V/1608
2	C8,C68	Ceramic Capacitor	TMK325B7226KMHP	Taiyo Yuden	(1*) 4.7uF/X7R/25V/2125
2	D1,D6	DIODE	BAT54SFILM	STMicroelectronics	
1	D10	DIODE	1N4448HWS-7-F	Diodes Inc	
1	D14	DIODE	RCLAMP0502BATCT	Semtech	
4	D2,D3,D4,D5	DIODE	ES3AB-13-F	Diodes Inc	
1	D7	DIODE	BAV99,235	NXP	
2	D8,D9	DIODE	SMAJ20CA	Bourns Inc.	
2	F1,F2	Filter	NFE31PT222Z1E9	Murata	
1	FU1	FUSE	3403.0277	Schurter Inc	
1	FU2	FUSE	3403.0283	Schurter Inc	
7	JP1,JP2,JP3,JP4,JP5,JP6,JP7	Connector	FFC-3AMEP1	HONDA	(1*)
2	JP8,JP21	Connector	FFC-2AMEP1	HONDA	(1*)
1	L1	Inductor	NRS3015T4R7MNGHV	Taiyo Yuden	(2*) VLS3015CX-4R7M(TDK)
1	L2	Inductor	SRN3015-100M	Bourns	(2*) VLS3015CX-100M (TDK)
1	L3	Inductor	NRH3012T220MNV	Taiyo Yuden	(2*) VLS3015ET-220M (TDK)
1	L4	Inductor	VLS5045EX-100M-H	TDK	(2*) SRN5040TA-100M (Bourns)
1	L5	Inductor	NRS8040T100MJGJ	Taiyo Yuden	(2*) SRN8040-100M (Bourns)
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,R17	Resistor	RK73B1JTTD330J	KOA	(1*) 33ohm/5%/0.125W/1608
2	R12,R14	Resistor	RK73H1JTTD8201F	KOA	(1*) 8.2K/1%/0.125W/1608
1	R13	Resistor	RK73H1JTTD8870F	KOA	(1*) 887ohm/1%/0.125W/1608
2	R16,R19	Resistor	RK73B1JTTD510J	KOA	(1*) 51ohm/5%/0.125W/1608
1	R18	Resistor	RK73B1JTTD112J	KOA	(1*) 1.1K/5%/0.125W/1608
4	R20,R23,R26,R37	Resistor	RK73H1JTTD2002F	KOA	(1*) 20K/1%/0.125W/1608
2	R21,R38	Resistor	RK73H1JTTD3901F	KOA	(1*) 3.9K/1%/0.125W/1608
1	R22	Resistor	RK73B1JTTD161J	KOA	(1*) 160ohm/5%/0.125W/1608
7	R24,R47,R48,R49,R50,R51,R52	Resistor	RK73B1JTTD105J	KOA	(1*) 1M/5%/0.125W/1608
2	R25,R35	Resistor	RK73B1JTTD104J	KOA	(1*) 100K/5%/0.125W/1608
2	R3,R10	Resistor	RK73B1JTTD472J	KOA	(1*) 4.7K/5%/0.125W/1608
1	R30	Resistor	SPRM12B105J	Akane Dengu	(2*) RCR50+CT52A105J, RCR50ENCT52A105J, RCR60CT52A105J(KOA), VR37000001004J R500(Vishay)
1	R31	Resistor	FMP200JR-52-200K	Yageo	(1*) 200K/500V/2W/DIP
1	R311	Resistor	RK73H1JTTD2002F	KOA	(1*) 20K/1%/0.125W/1608
2	R312,R313	Resistor	RK73B1JTTD270J	KOA	(1*) 27ohm/5%/0.125W/1608
1	R32	Resistor	RK73H1JTTD1502F	KOA	(1*) 15K/1%/0.125W/1608
1	R33	Resistor	RK73H1JTTD9092F	KOA	(1*) 90.9K/1%/0.125W/1608
1	R34	Resistor	RK73H1JTTD8252F	KOA	(1*) 82.5K/1%/0.125W/1608
2	R46,R60	Resistor	RK73B1JTTD101J	KOA	(1*) 100ohm/5%/0.125W/1608
1	R5	Resistor	RK73B1JTTD100J	KOA	(1*) 10ohm/5%/0.125W/1608
6	R53,R54,R55,R57,R58,R62,	Resistor	RK73B1JTTD513J	KOA	(1*) 51K/5%/0.125W/1608
1	R56	Resistor	RK73B1JTTD103J	KOA	(1*) 10K/5%/0.125W/1608
3	R59,R61,R71	Resistor	RK73B1JTTD512J	KOA	(1*) 5.1K/5%/0.125W/1608
2	R63,R75	Resistor	RK73Z1JTTD	KOA	(1*) 0ohm/1608
3	R7,R27,R36	Resistor	RK73H1JTTD1001F	KOA	(1*) 1K/1%/0.125W/1608
1	R303	Resistor	RK73H1JTTD1001F	KOA	(1*) 1K/1%/0.125W/1608
1	R74	Resistor	RK73B1JTTD220J	KOA	(1*) 22ohm/5%/0.125W/1608
1	R8	Resistor	RK73B1JTTD162J	KOA	(1*) 1.6K/5%/0.125W/1608
1	R9	Resistor	RK73B1JTTD561J	KOA	(1*) 560ohm/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
2	SW6,SW7	Switch	SSSS222700	ALPS	
1	SW8	Switch	SKQMBBE010	ALPS	
2	SW9,SW10	Switch	SSSS213000	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	AT25SF081B-SSHB	Adesto	(2*) W25Q80DVSNIG(Winbond)
3	U10,U12,U13	IC	SN74LVC1T45DCK	TI	
2	U14,U16	IC	SN74LVC2G07DCKR	TI	
1	U15	IC	BD5228G-TR	Rohm	(2*) BD5228G, BD5228G-2MTR(Rohm)
1	U17	IC	ISL85415FRZ	INTERSIL	
1	U2	IC	R9A06G061GNP	Renesas	
1	U3	IC	ISL15102IRZ	INTERSIL	
1	U4	Surge Absorber	ERZE14A511	Panasonic	(2*) ERZ-E14A471（Panasonic)
1	U5	Photocoupler	PS2561FL-1Y-A	RENESAS/CEL	(2*) PS2561FL-1Y-K-A
4	U6,U7,U8,U9	IC	SN74LVC2T45DCUR	TI	
1	Y1	Crystal	CX2520DB16000D0FLJCC	Kyocera	(2*):DSX221SH (spec:16MHz,CL:8pF, Frequecy tolerance:±10ppm, Frequecy cahacteristics over temperature:±15ppm)

(1*)Equivalent product can be changed
(2*)Alternative product

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	CC0603KRX7R9BB104	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	RK73H1JTTD1001F	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
2	R312,R313	RESISTOR	RK73B1JTTD270J	KOA	(1*) 27ohm/5%/1608
2	SW301,SW302	SWITCH	CHS-04TA	COPAL	
1	U301	IC	R5F5651EHDFP#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 (Bourns)
1	L203	Inductor	NL453232T-561J-PF	TDK	(2*) PM1812-561J-RC (Bourns)
1	L204	Inductor	SRN5040-330M	Bourns Inc.	(2*) NR5040T330M (Taiyo Yuden)
2	L205,L206	Inductor	NL453232T-221J-PF	TDK	(2*) PM1812-221J-RC (Bourns)
1	L207	Inductor	NL453232T-391J-PF	TDK	(2*) PM1812-391J-RC (Bourns)
2	L208,L209	Inductor	NL453232T-151J-PF	TDK	(2*) PM1812-151J-RC (Bourns)
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/jp/en

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

Revision History

Rev.	Date	Description	
		Page	Summary
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Corporate Headquarters

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