

# RX and RA families

## Design Guide for Main Clock Circuit and Sub-Clock Circuit

### Introduction

This application note introduces recommended resonators for the RX and RA families along with the relevant resonator matching evaluation results, oscillation evaluation methods, and some recommendations on board design as information for the design of the main clock oscillation circuit and the sub-clock oscillation circuit.

### Target Device

RX and RA families

### Contents

1. Using the Application Note .....	2
2. Connecting External Components .....	2
3. Introduction to the Resonator Manufacturers .....	3
4. Matching evaluation results .....	4
5. Oscillator matching evaluation method and oscillator circuit parameter calculation method ...	18
5.1 How to measure the negative resistance .....	18
5.2 Measurement method of oscillations' excitation power .....	18
5.3 Measurement method of the oscillation amplitude voltage .....	19
5.4 How to determine the load capacity .....	19
5.5 Calculation method of transconductance .....	20
6. Board design recommendations .....	21
6.1 How to stabilize the oscillation.....	21
6.1.1 EXTAL/XCIN and XTAL/XCOUT Routing.....	21
6.1.2 Use a ground shield .....	23
6.1.3 Usage of a bottom-ground.....	26
6.1.3.1 Multilayer boards thicker than 1.2 mm.....	26
6.1.3.2 Multilayer boards thinner than 1.2 mm .....	30
6.1.4 Other miscellaneous recommendations .....	31
6.2 Examples of patterns with a high risk of malfunction due to noise .....	31
Revision History .....	33

## 1. Using the Application Note

This application note is intended for those who are considering how to select or evaluate an external resonator connected to RX and RA families. For details, see each chapter.

- Chapter 2: This Chapter provides information on the external components connected to the RX and RA families clock systems.
- Chapter 3: This chapter introduces resonator manufacturers who have performed resonator matching evaluations with RX and RA and explains how to search for suitable resonators for RX and RA on their website (Tool). If you wish to select a resonator that has already been evaluated, refer to this chapter.
- Chapter 4: This chapter describes the resonator characteristics and provides information on the proposed components mounted on the board based on the evaluation. Refer to this chapter if you want to narrow down the resonator selection conditions.
- Chapter 5: This chapter describes how to select and evaluate external components if you want to perform the matching evaluation yourself.
- Chapter 6: This chapter describes the key points of the board design. Read this chapter before designing a board.

## 2. Connecting External Components

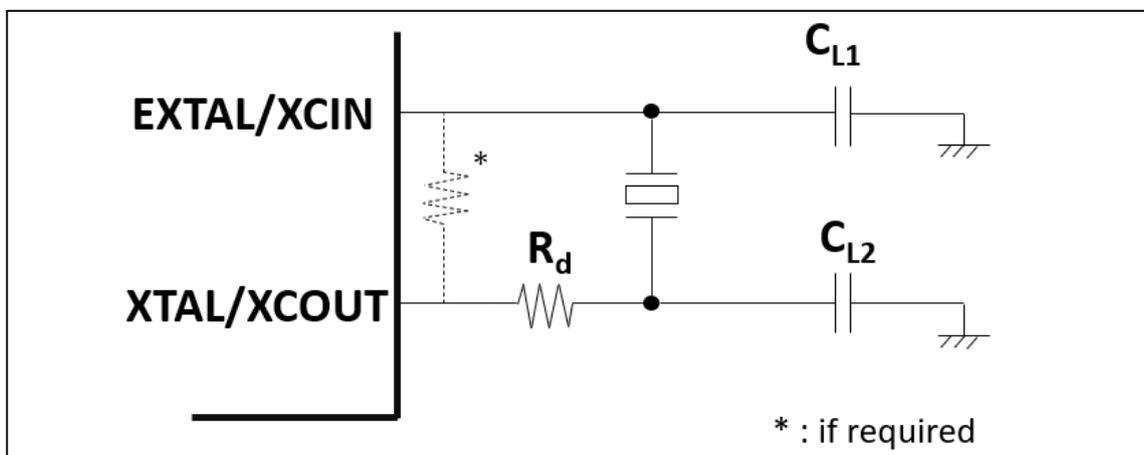
Most RX and RA MCUs support the use of a ceramic or crystal resonator as the main clock source, as shown in Figure 1. This should be connected between EXTAL and XTAL pins of the MCU. A crystal resonator can be used as the sub-clock source, which should be connected between XCIN and XCOU pins of the MCU.

The frequency of the external resonator for the main clock source should be within the range specified as the oscillator frequency of the main clock oscillator of the MCU. The frequency of the external resonator for the sub-clock source must be exactly 32.768 kHz. For details, refer to "Electrical Characteristics" and "Clock Generation Circuit" in the MCU User's Manual: Hardware.

The damping register ( $R_d$ ) and the load capacitors ( $C_{L1}$ ,  $C_{L2}$ ) according to the specifications of the resonator must be implemented as external components. When selecting external components, we recommend that you contact the resonator manufacturer for a matching evaluation. If you do not want to contact the resonator manufacturer and calculate suitable capacitances by yourself, refer to Chapter 5 "Oscillation Evaluation and Oscillation Circuit Constant Calculation Method".

Since RX and RA MCU have a built-in feedback resistor, it is not necessary to implement the feedback resistor (\*) shown in Figure 1. However, if the resonator manufacturer recommends implementing the feedback resistor, follow the resonator manufacturer's instructions.

Figure 1 Connection Example of External Resonator



### 3. Introduction to the Resonator Manufacturers

Several resonator manufacturers have performed evaluations of the RX and RA family's oscillator circuits, and publish a list of suitable resonators for each member of the RX or RA families. Table 1 shows some examples of resonators for which an evaluation has been performed. For the latest information, visit the resonator manufacturers' website.

**Table 1 Example Resonator List with Matching Evaluated**

Manufacturer	Resonator/Part Number	Oscillation frequency	Circuit-load capacitance (pF)	CL1 (pF)	CL2 (pF)	R <sub>d</sub> (ohm)	MCU group name
Kyocera Corporation	CX3225CA12000D0PRTC2	12 MHz	6.49	10	10	4700	RX72T, RX66T
Murata Manufacturing	XRCGB24M000F3M26R0	24 MHz	6	8	8	0	RX72M, RX72N, RX66N, RX671
Nippon Radio Industry Co., Ltd.	CHP-CRA-31	32.768 kHz	6	1	1	330	RX660
Seiko Instruments Inc.	SSP-T7-F	32.768 kHz	12.5	22	22	0	RA2L1

The following shows how to search for a resonator matching the RX and RA families on the resonator manufacturers' website.

#### ■ Kyocera Corporation:

Search Page: [Crystal Units vs. IC Matching Search](#)

- 1) Select "Renesas Electronics" from the dropdown of IC Manufacturers.
- 2) Select the group-name from the dropdown of IC family.  
Ex.) IC family: RX72N
- 3) Press the search button. The corresponding data is displayed.

#### ■ Murata Manufacturing Co., Ltd.

Search page: [IC-Timing Device Search Tool](#)

- 1) Select "Renesas Electronics" from the dropdown of IC manufacturers.
- 2) Select the group name from the dropdown of IC Part Numbers.  
Ex.) IC Part Number: RX72N
- 3) Press the search button. The corresponding data is displayed.

#### ■ NIHON DEMPA KOGYO CO., LTD.:

Search page: [IC Matching Information](#)

- 1) Select "Renesas Electronics" in Supplier Name checkboxes.
  - 2) Click the PDF icon in the row whose Families/Series is the group you want to know about.  
Ex) Select RX660.
- The corresponding data is displayed.

#### ■ Seiko Instruments Inc.:

Search page: [IC Matching Information](#)

1) Click the group name you want to know about. The corresponding data is displayed.

The matching parameters of the oscillator circuit published on the website of the resonator manufacturers are the experimental results of some samples under certain conditions, and Renesas do not guarantee them. Optimal parameters may be different for each user's actual system. Renesas recommend that users contact the resonator manufacturers for a matching evaluation of their specific system to determine the oscillator circuit parameters required.

The operating conditions of the MCU described on their website are used to stabilize the oscillation of their resonator in the evaluation and are not the recommended conditions by Renesas. For the recommended operating conditions for MCU, refer to "Electrical Characteristics" in MCU User's Manual: Hardware.

#### 4. Matching evaluation results

This chapter shows the evaluation results from several resonator manufacturers. Table 3 through Table 15 and Figure 2 through Figure 14 show the drive capability setting of MCU, the specification of the resonator (Frequency,  $C_L$ ), the parameters of external components mounted on the evaluation board ( $R_d$ ,  $C_{L1}$ ,  $C_{L2}$ ), and the evaluation results (Negative R, recommended ESR,  $V_{oh}$  <sup>Note 1</sup> and  $V_{ol}$  <sup>Note 1</sup>).

Note that these results are based on experimentation under certain conditions with some samples and are not guaranteed.

**Table 2 The matching evaluation Group**

Group	RX	RA
1	RX65N, RX651, RX671, RX66N, RX72N and RX72M	RA4M2, RA4M3, RA4E1, RA4E2 <sup>Note 2</sup> , RA4T1 <sup>Note 2</sup> , RA6M1, RA6M2, RA6M3, RA6M4, RA6M5, RA6T1, RA6T2 <sup>Note 3</sup> , RA6T3 <sup>Note 3</sup> , RA6E1 and RA6E2 <sup>Note 2</sup>
2	RX26T <sup>Note 3</sup> , RX660, RX66T <sup>Note 3</sup> and RX72T <sup>Note 3</sup>	N/A
3	RX64M and RX71M	N/A
4	RX130, RX13T <sup>Note 3</sup> , RX230, RX231, RX23E-A <sup>Note 3</sup> , RX23E-B, RX23T <sup>Note 3</sup> , RX23W, RX24T <sup>Note 3</sup> , and RX24U <sup>Note 3</sup>	RA2A1, RA4M1 and RA4W1
5	RX111, RX110 and RX113	N/A
6	RX140	N/A
7	N/A	RA2E1 and RA2L1

Note 1:  $V_{oh}$ ,  $V_{ol}$  of the sub-clock cannot be measured when a probe is touched to the clock terminals, so there is no evaluation result.

Note 2: 32-pin LQFP and QFN part numbers do not support their sub-clock oscillator function.

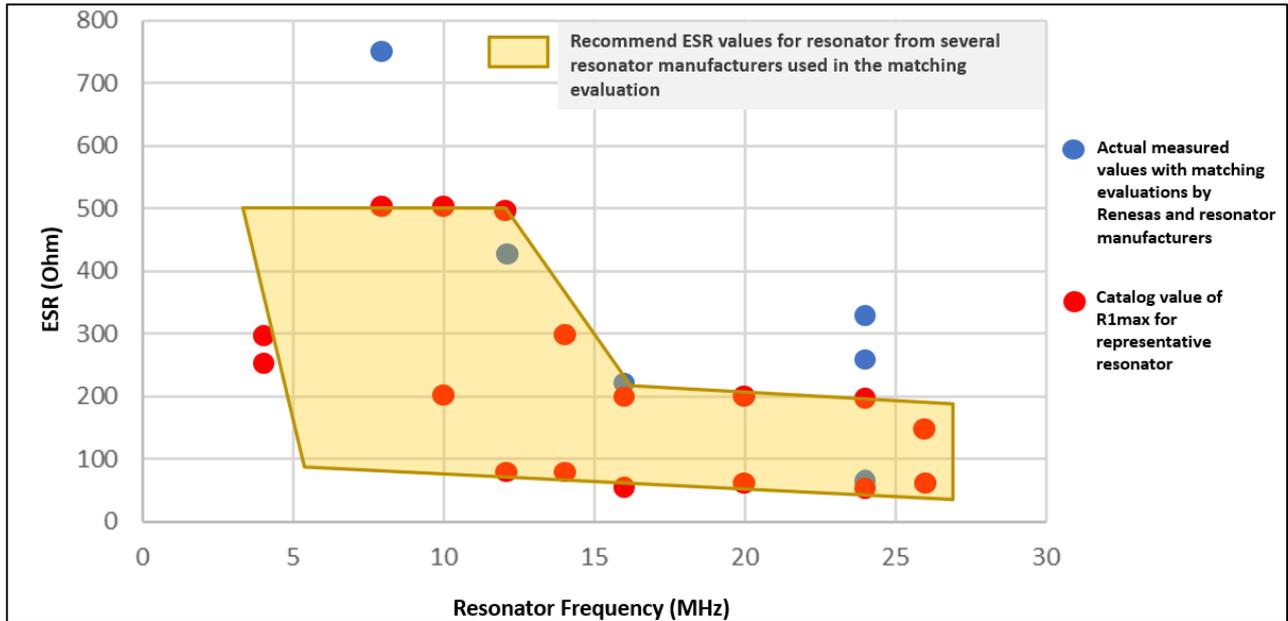
Note 3: These groups do not include a sub-clock oscillator.

**Table 3 Group 1, Main clock: Results of the matching evaluation**

Main Clock Oscillator Driving Setting <sup>Note 4</sup>	Resonator specification		Evaluation board implementation			Evaluation results			
	Frequency (MHz)	$C_L$ (pF)	$R_d$ (Ohm)	$C_{L1}$ (pF)	$C_{L2}$ (pF)	Negative R (Ohm)	Recommended ESR_max (Ohm)	$V_{oh}$	$V_{ol}$

Setting = 8 MHz	8.0	8.0	0	8.0	8.0	-3760	750	2.60	-0.04
8 MHz < Setting ≤ 16 MHz	12	8.0	0	6.0	6.0	-2150	430	2.48	0.00
8 MHz < Setting ≤ 16 MHz	16	8.0	0	5.0	5.0	-1120	220	2.44	0.00
16 MHz < Setting ≤ 20 MHz	20	8.0	0	6.0	6.0	-1020	200	2.52	0.00
20 MHz < Setting ≤ 24 MHz	24	8.0	0	6.0	6.0	-1320	260	2.42	-0.04

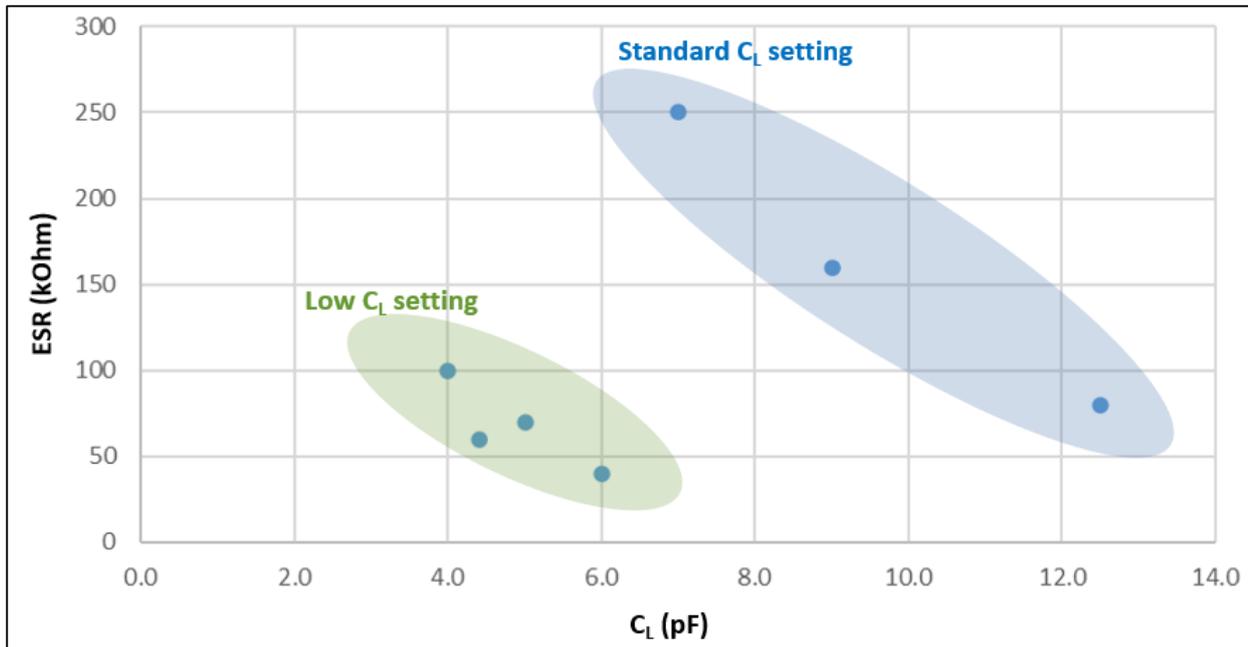
Figure 2 Group 1, Main clock: Resonator Frequency vs ESR max



**Table 4 Group 1, Sub-clock: Results of the matching evaluation**

Sub Clock Oscillator Driving Setting <sup>Note 5</sup>	Resonator specification		Evaluation board implementation			Evaluation results	
	Frequency (kHz)	C <sub>L</sub> (pF)	R <sub>d</sub> (Ohm)	C <sub>L1</sub> (pF)	C <sub>L2</sub> (pF)	Negative R (kOhm)	Recommended ESR <sub>max</sub> (kOhm)
Low C <sub>L</sub> <sup>Note 6</sup>	32	4.0	0	4.3	4.3	-510	100
	32	4.4	0	6.0	5.0	-340	60
	32	5.0	0	6.0	6.0	-370	70
	32	6.0	0	8.0	8.0	-240	40
Standard C <sub>L</sub> <sup>Note 6</sup>	32	7.0	0	12	12	-1250	250
	32	9.0	0	15	15	-840	160
	32	12.5	0	24	24	-430	80

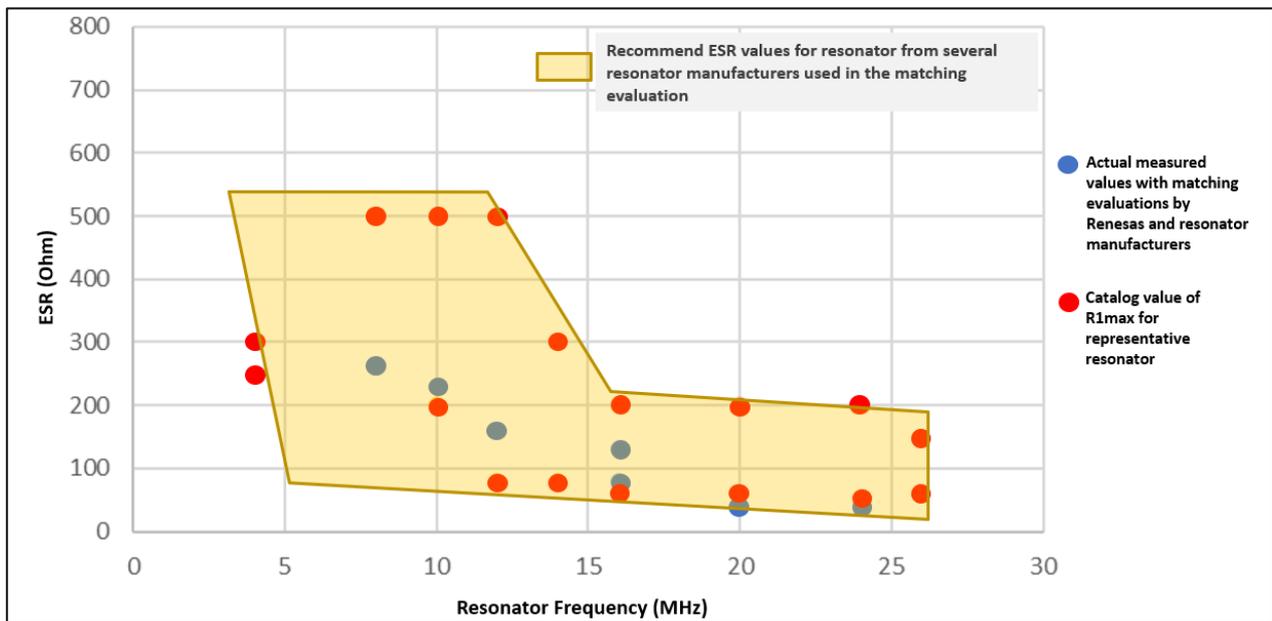
**Figure 3 Group 1, Sub-clock: C<sub>L</sub> vs ESR max**



**Table 5 Group 2, Main clock: Results of the matching evaluation**

Main Clock Oscillator Driving Setting <sup>Note 4</sup>	Resonator specification		Evaluation board implementation			Evaluation results			
	Frequency (MHz)	C <sub>L</sub> (pF)	R <sub>d</sub> (Ohm)	C <sub>L1</sub> (pF)	C <sub>L2</sub> (pF)	Negative R (Ohm)	Recommended ESR <sub>max</sub> (Ohm)	V <sub>oh</sub>	V <sub>ol</sub>
Setting = 8 MHz	8.0	8.0	4700	12	12	-1300	260	2.20	0.28
8 MHz < Setting ≤ 16 MHz	10	8.0	4700	12	12	-1150	230	2.24	0.24
	12	8.0	4700	10	10	-830	160	2.14	0.32
	16	8.0	3900	9.0	9.0	-440	80	2.00	0.48
16 MHz < Setting ≤ 20 MHz	20	8.0	3300	10	10	-240	40	1.92	0.52
20 MHz < Setting ≤ 24 MHz	24	8.0	2200	10	10	-200	40	1.88	0.52

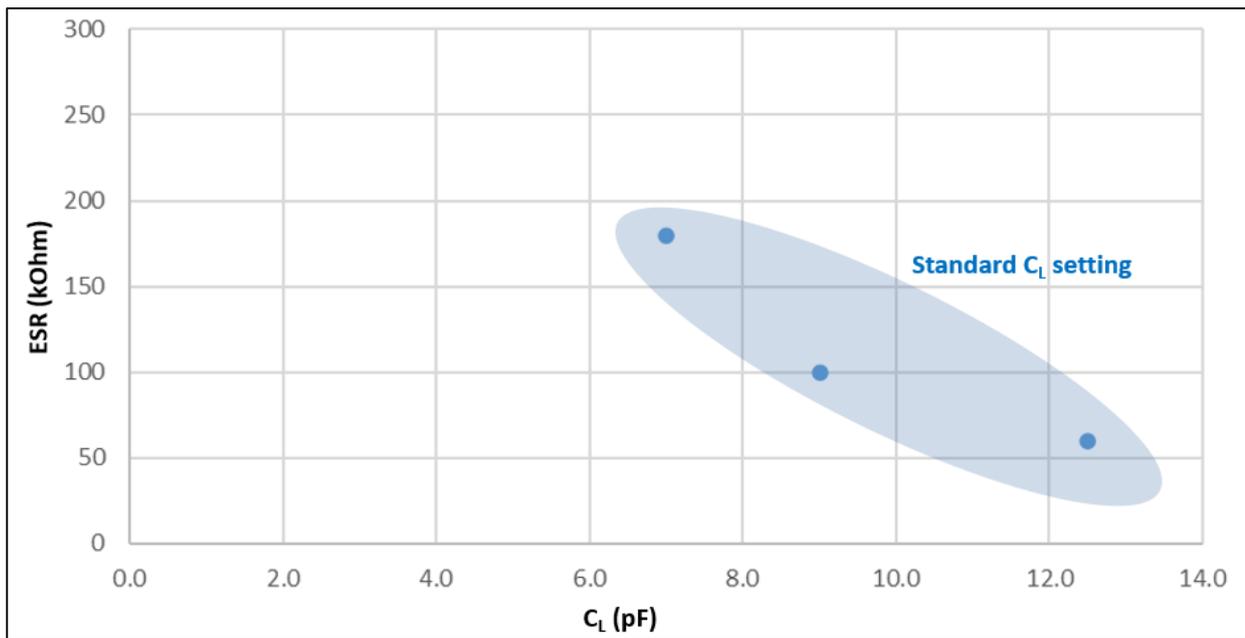
**Figure 4 Group 2, Main clock: Resonator Frequency vs ESR max**



**Table 6 Group 2, Sub-clock: Results of the matching evaluation**

Sub Clock Oscillator Driving Setting <sup>Note 5</sup>	Resonator specification		Evaluation board implementation			Evaluation results	
	Frequency (kHz)	C <sub>L</sub> (pF)	R <sub>d</sub> (Ohm)	C <sub>L1</sub> (pF)	C <sub>L2</sub> (pF)	Negative R (Ohm)	Recommended ESR <sub>max</sub> (kOhm)
Standard C <sub>L</sub> <sup>Note 6</sup>	32	7.0	0	10	10	-930	180
	32	9.0	0	15	15	-540	100
	32	12.5	0	28	12	-310	60

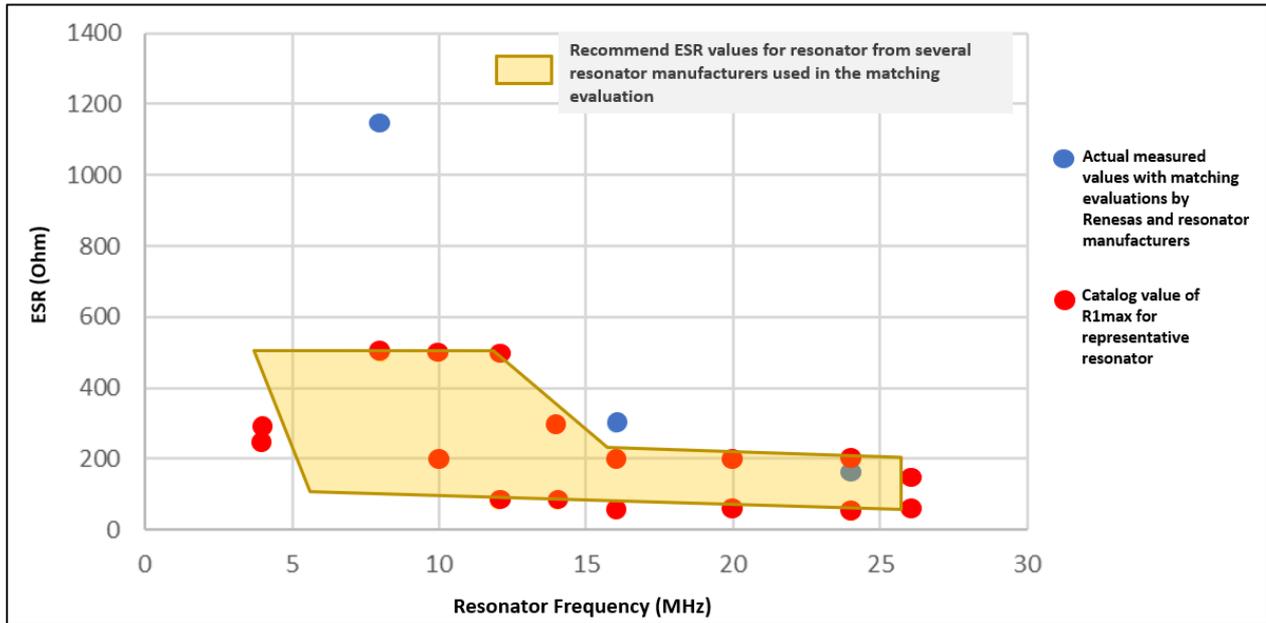
**Figure 5 Group 2, Sub-clock: C<sub>L</sub> vs ESR max**



**Table 7 Group 3 and Group 5, Main clock: Results of the matching evaluation**

Main Clock Oscillator Driving Setting <sup>Note 4</sup>	Resonator specification		Evaluation board implementation			Evaluation results			
	Frequency (MHz)	C <sub>L</sub> (pF)	R <sub>d</sub> (Ohm)	C <sub>L1</sub> (pF)	C <sub>L2</sub> (pF)	Negative R (Ohm)	Recommended ESR <sub>max</sub> (Ohm)	V <sub>oh</sub>	V <sub>ol</sub>
Setting = 8 MHz	8.0	8.0	0	8.0	8.0	-5760	1150	N/A	N/A
8 MHz < Setting ≤ 16 MHz	16	8.0	1000	7.0	7.0	-1520	300	N/A	N/A
16 MHz < Setting ≤ 20 MHz	20	8.0	1000	7.0	7.0	-1020	200	N/A	N/A
20 MHz < Setting ≤ 24 MHz	24	8.0	1000	7.0	7.0	-860	170	N/A	N/A

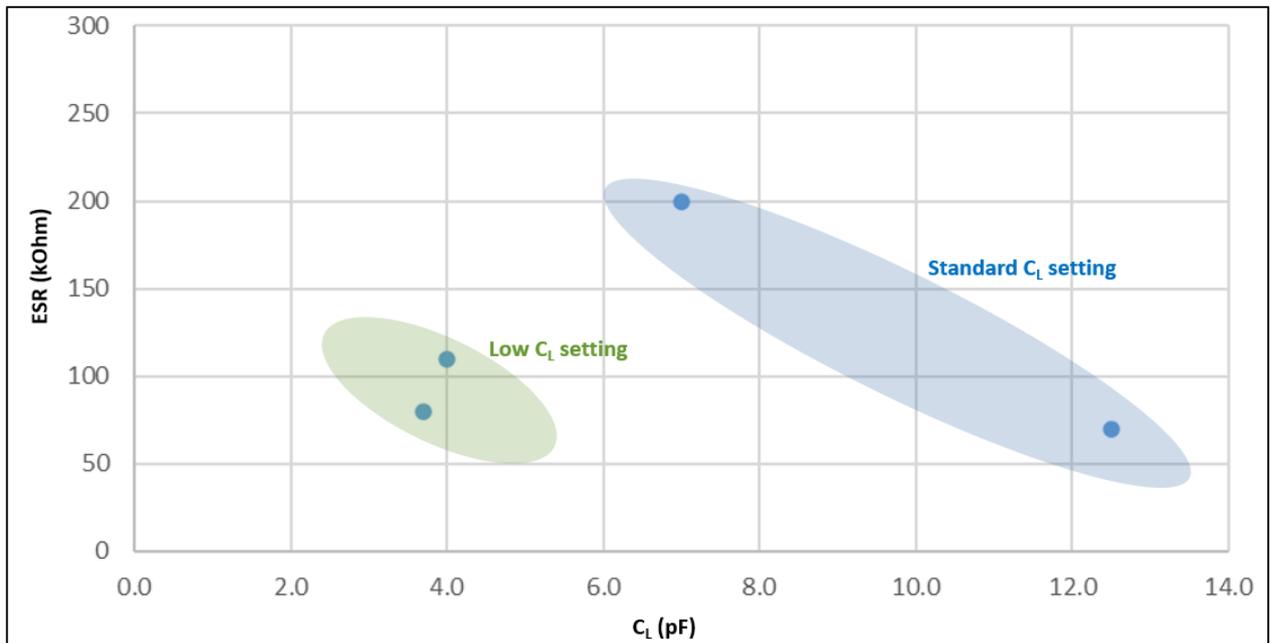
**Figure 6 Group 3 and Group 5, Main clock: Resonator Frequency vs ESR max**



**Table 8 Group 3, Sub-clock: Results of the matching evaluation**

Sub Clock Oscillator Driving Setting <sup>Note 5</sup>	Resonator specification		Evaluation board implementation			Evaluation results	
	Frequency (kHz)	C <sub>L</sub> (pF)	R <sub>d</sub> (Ohm)	C <sub>L1</sub> (pF)	C <sub>L2</sub> (pF)	Negative R (Ohm)	Recommended ESR <sub>max</sub> (kOhm)
C <sub>L</sub> <sup>Note 6</sup>	32	3.7	0	3.0	3.0	-430	80
	32	4.0	0	2.0	3.0	-570	110
Standard C <sub>L</sub> <sup>Note 6</sup>	32	7.0	0	9.0	9.0	-1000	200
	32	12.5	0	22	22	-350	70

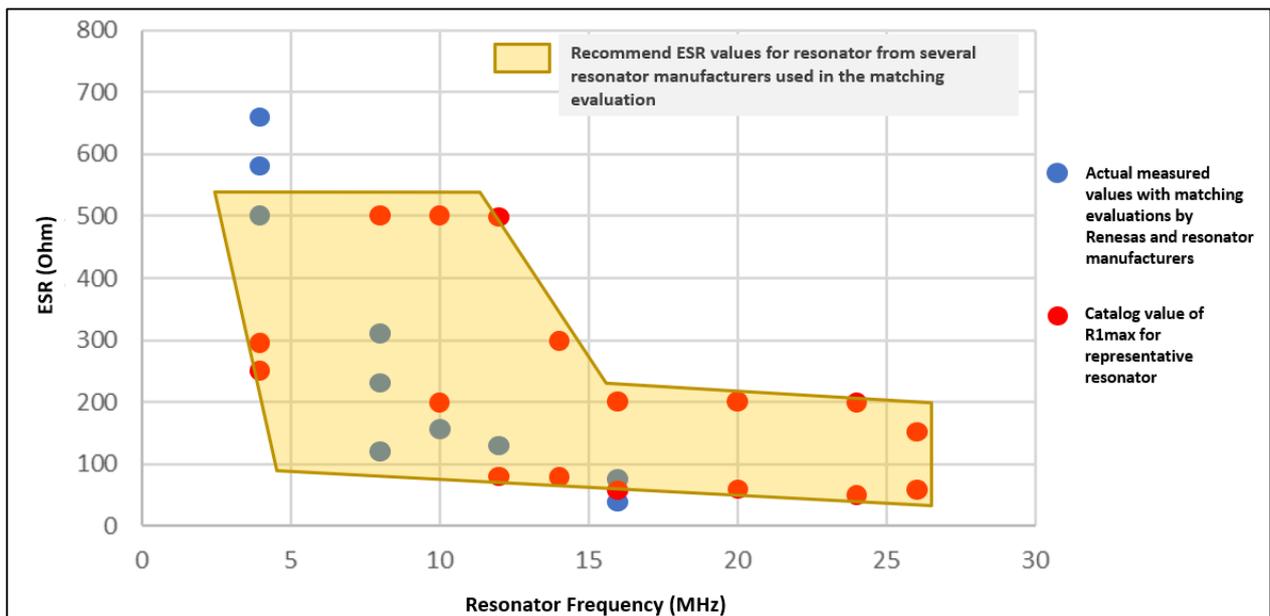
**Figure 7 Group 3, Sub-clock: C<sub>L</sub> vs ESR max**



**Table 9 Group 4, Main clock: Results of the matching evaluation**

Main Clock Oscillator Driving Setting <sup>Note 4</sup>	Resonator specification		Evaluation board implementation			Evaluation results			
	Frequency (MHz)	C <sub>L</sub> (pF)	R <sub>d</sub> (Ohm)	C <sub>L1</sub> (pF)	C <sub>L2</sub> (pF)	Negative R (Ohm)	Recommended ESR_max (Ohm)	V <sub>oh</sub>	V <sub>ol</sub>
1 MHz ≤ Setting ≤ 10 MHz	4.0	8.0	0	8.0	8.0	-2500	500	N/A	N/A
	4.0	8.0	0	8.0	8.0	-2900	580	N/A	N/A
	8.0	8.0	0	10	10	-634	120	N/A	N/A
	8.0	8.0	0	6.0	6.0	-1171	230	N/A	N/A
10 MHz ≤ Setting ≤ 20 MHz	10	8.0	0	7.0	7.0	-810	160	N/A	N/A
	10	8.0	0	6.0	6.0	-1010	200	N/A	N/A
	12	8.0	0	9.0	9.0	-670	130	N/A	N/A
	16	8.0	0	9.0	9.0	-360	70	N/A	N/A
	20	8.0	0	9.0	9.0	-230	40	N/A	N/A

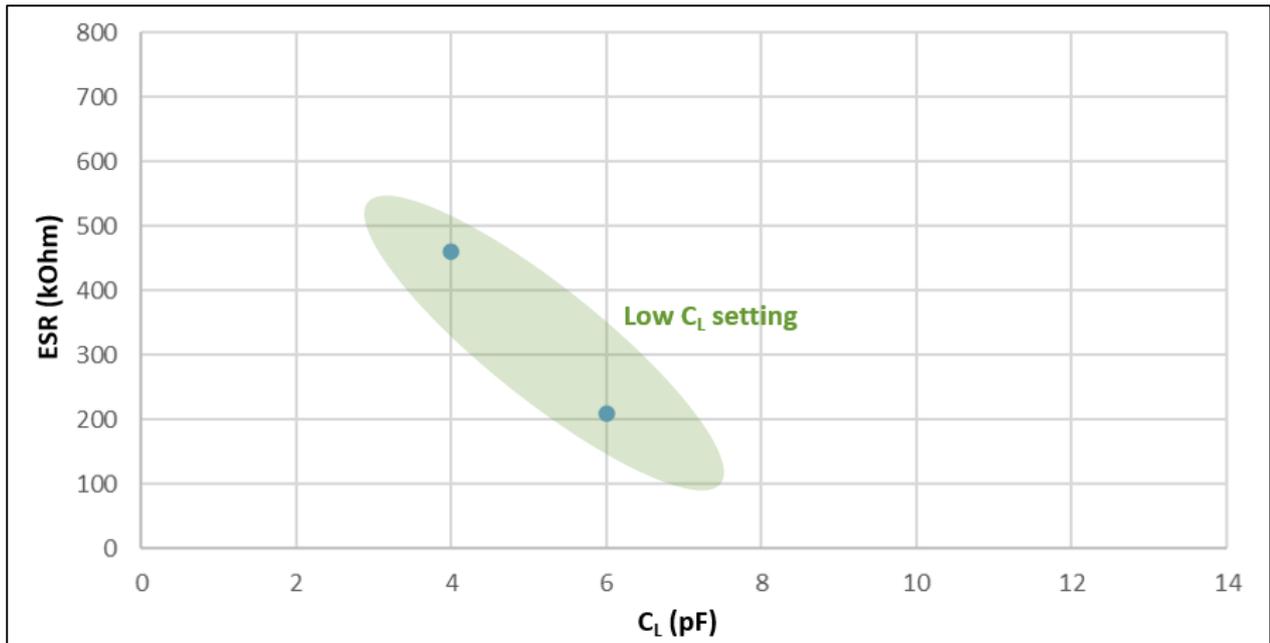
**Figure 8 Group 4, Main clock: Resonator Frequency vs ESR max**



**Table 10 Group 4, Sub-clock: Results of the matching evaluation**

Sub Clock Oscillator Driving Setting <sup>Note 5</sup>	Resonator specification		Evaluation board implementation			Evaluation results	
	Frequency (kHz)	C <sub>L</sub> (pF)	R <sub>d</sub> (Ohm)	C <sub>L1</sub> (pF)	C <sub>L2</sub> (pF)	Negative R (Ohm)	Recommended ESR <sub>max</sub> (kOhm)
Low C <sub>L</sub> <sup>Note 6</sup>	32	4.0	0	5.0	5.0	-2320	460
	32	6.0	0	9.0	9.0	-1060	210

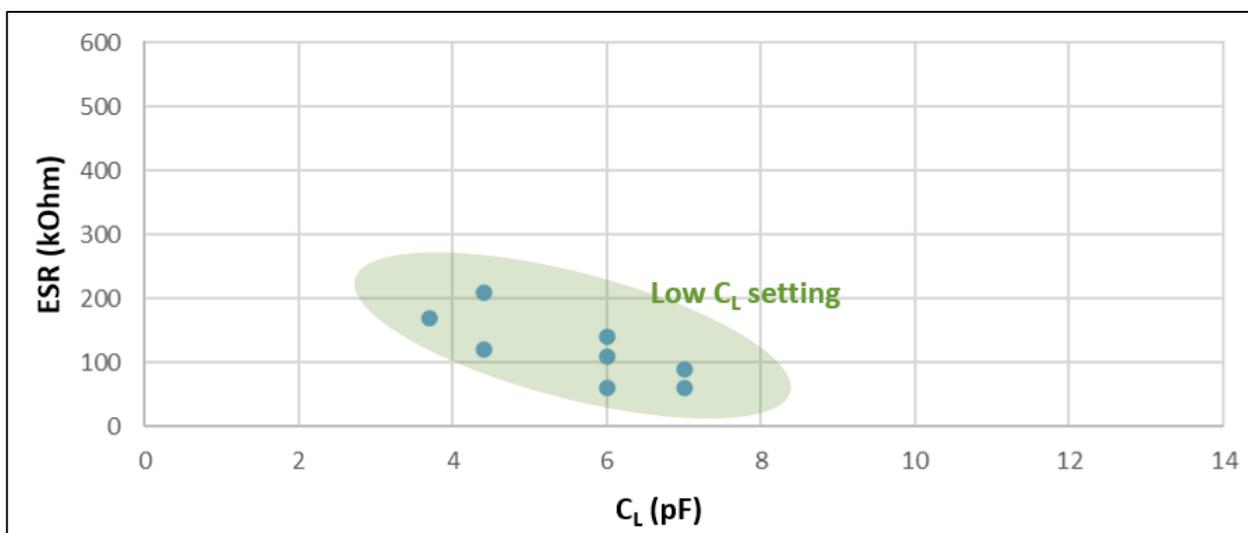
**Figure 9 Group 4, Sub-clock: C<sub>L</sub> vs ESR max**



**Table 11 Group 5, Sub-clock: Results of the matching evaluation**

Sub Clock Oscillator Driving Setting <sup>Note 5</sup>	Resonator specification		Evaluation board implementation			Evaluation results	
	Frequency (kHz)	C <sub>L</sub> (pF)	R <sub>d</sub> (Ohm)	C <sub>L1</sub> (pF)	C <sub>L2</sub> (pF)	Negative R (Ohm)	Recommended ESR_max (kOhm)
Low C <sub>L</sub> (Low drive) <sup>Note 6</sup>	32	3.7	0	4.0	4.0	-860	170
	32	4.4	0	5.0	6.0	-600	120
	32	6.0	0	9.0	9.0	-340	60
Low C <sub>L</sub> (Medium drive) <sup>Note 6</sup>	32	4.4	0	5.0	6.0	-1050	210
	32	6.0	0	9.0	9.0	-550	110
	32	7.0	0	10	12	-320	60
Low C <sub>L</sub> (High drive) <sup>Note 6</sup>	32	6.0	0	8.0	8.0	-740	140
	32	7.0	0	10	12	-450	90

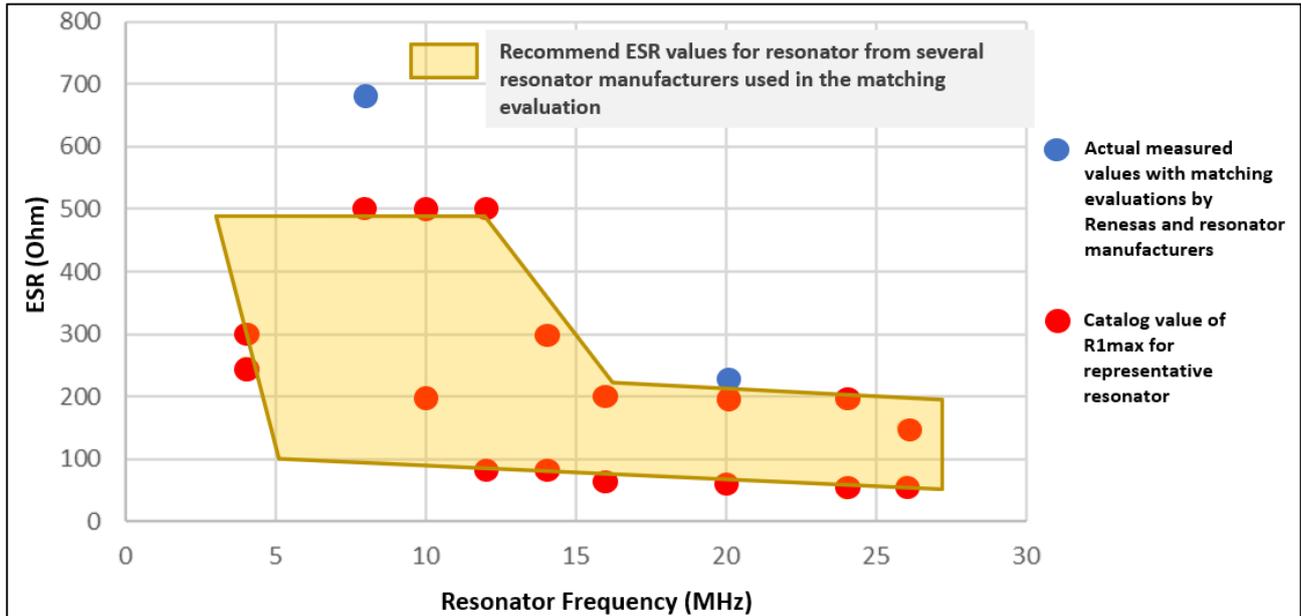
**Figure 10 Group 5, Sub-clock: C<sub>L</sub> vs ESR max**



**Table 12 Group 6, Main clock: Resonator Frequency vs ESR max**

Main Clock Oscillator Driving Setting <sup>Note 4</sup>	Resonator specification		Evaluation board implementation			Evaluation results			
	Frequency (MHz)	C <sub>L</sub> (pF)	R <sub>d</sub> (Ohm)	C <sub>L1</sub> (pF)	C <sub>L2</sub> (pF)	Negative R (Ohm)	Recommended ESR <sub>max</sub> (Ohm)	V <sub>oh</sub>	V <sub>ol</sub>
1 MHz ≤ Setting ≤ 10 MHz	8.0	6.0	330	5.0	5.0	-3440	680	1.58	0.02
10 MHz ≤ Setting ≤ 20 MHz	20	5.0	330	5.0	5.0	-1150	230	1.48	-0.04

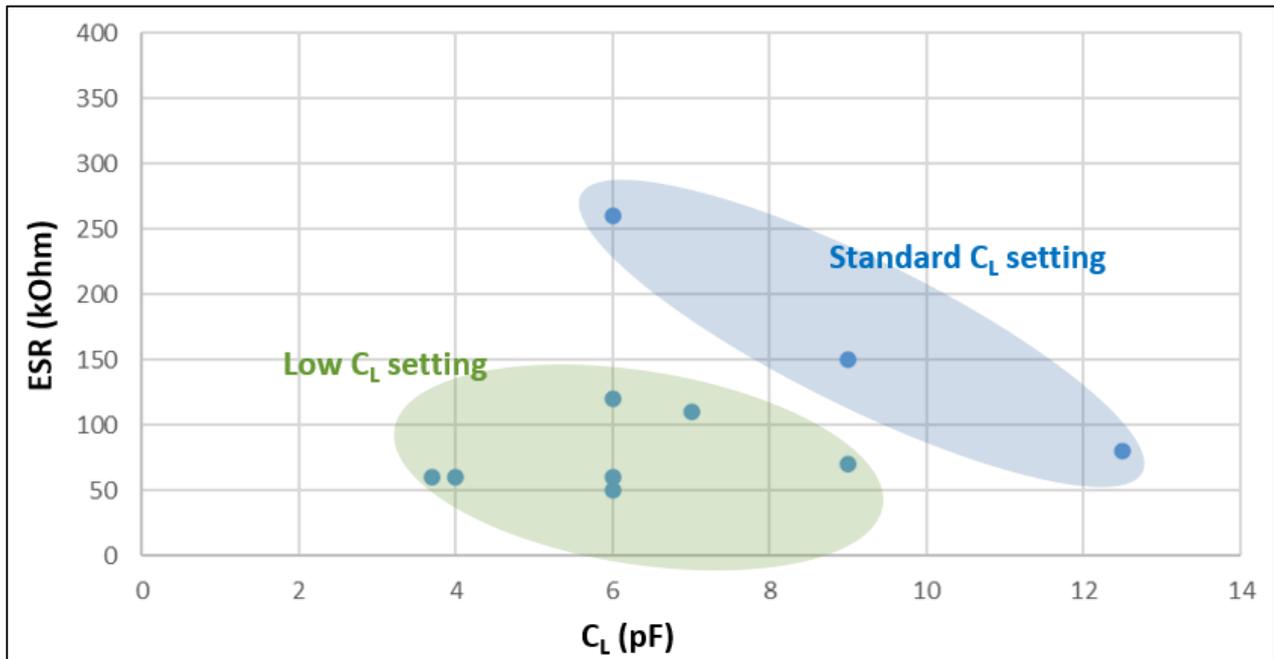
**Figure 11 Group 6, Main clock: Resonator Frequency vs ESR max**



**Table 13 Group 6, Sub-clock: Results of the matching evaluation**

Sub Clock Oscillator Driving Setting <sup>Note 5</sup>	Resonator specification		Evaluation board implementation			Evaluation results	
	Frequency (kHz)	C <sub>L</sub> (pF)	R <sub>d</sub> (Ohm)	C <sub>L1</sub> (pF)	C <sub>L2</sub> (pF)	Negative R (Ohm)	Recommended ESR <sub>max</sub> (kOhm)
Low C <sub>L</sub> (Low drive) <sup>Note 6</sup>	32	3.7	0	2.0	3.0	-340	60
	32	4.0	0	3.0	3.0	-300	60
	32	6.0	0	2.0	2.0	-290	50
Low C <sub>L</sub> (Medium drive) <sup>Note 6</sup>	32	6.0	0	7.0	7.0	-300	60
Low C <sub>L</sub> (High drive) <sup>Note 6</sup>	32	6.0	0	7.0	7.0	-610	120
	32	7.0	0	10	10	-590	110
	32	9.0	0	15	15	-350	70
Standard C <sub>L</sub> <sup>Note 6</sup>	32	6.0	0	7.0	7.0	-1340	260
	32	9.0	0	16	15	-760	150
	32	12.5	0	22	22	-420	80

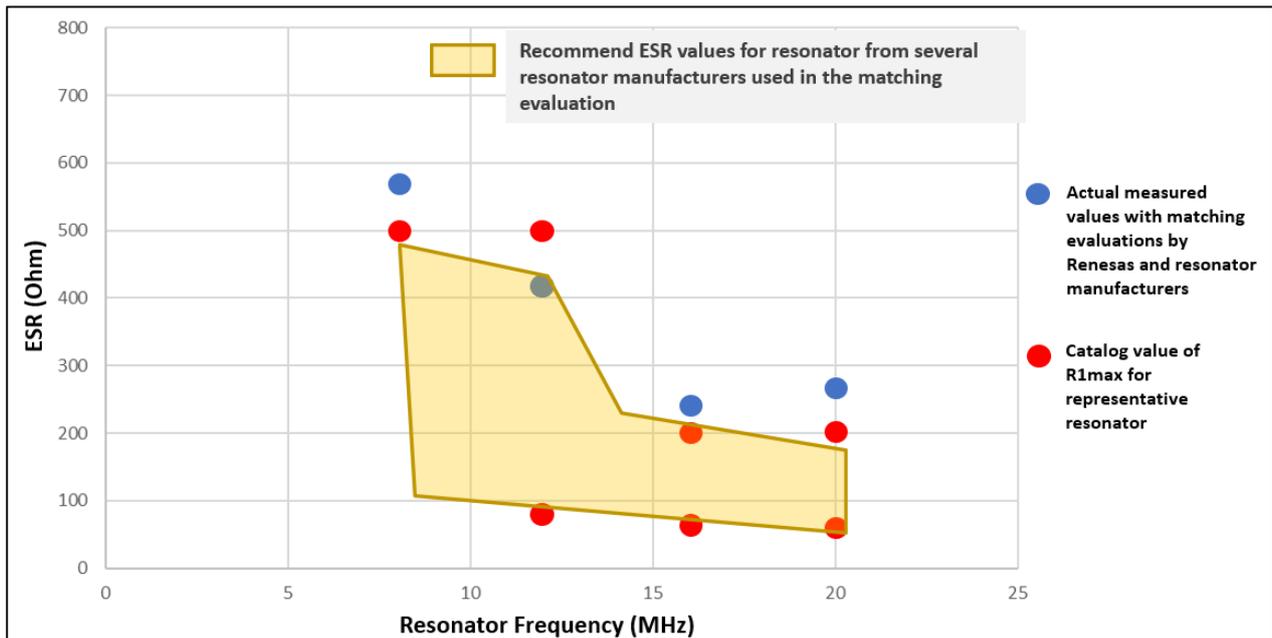
**Figure 12 Group 6, Sub-clock: C<sub>L</sub> vs ESR max**



**Table 14 Group 7, Main clock: Resonator Frequency vs ESR max**

Main Clock Oscillator Driving Setting <sup>Note 4</sup>	Resonator specification		Evaluation board implementation			Evaluation results			
	Frequency (MHz)	C <sub>L</sub> (pF)	R <sub>d</sub> (Ohm)	C <sub>L1</sub> (pF)	C <sub>L2</sub> (pF)	Negative R (Ohm)	Recommended ESR_max (Ohm)	V <sub>oh</sub>	V <sub>ol</sub>
1 MHz ≤ Setting ≤ 10 MHz	8.0	8.0	0	8.0	8.0	-2860	480	1.50	0.06
10 MHz ≤ Setting ≤ 20 MHz	12	8.0	0	8.0	8.0	-2060	410	1.54	-0.11
	16	8.0	0	8.0	8.0	-1246	240	1.56	-0.09
	20	5.0	470	4.0	4.0	-1360	270	1.53	-0.02

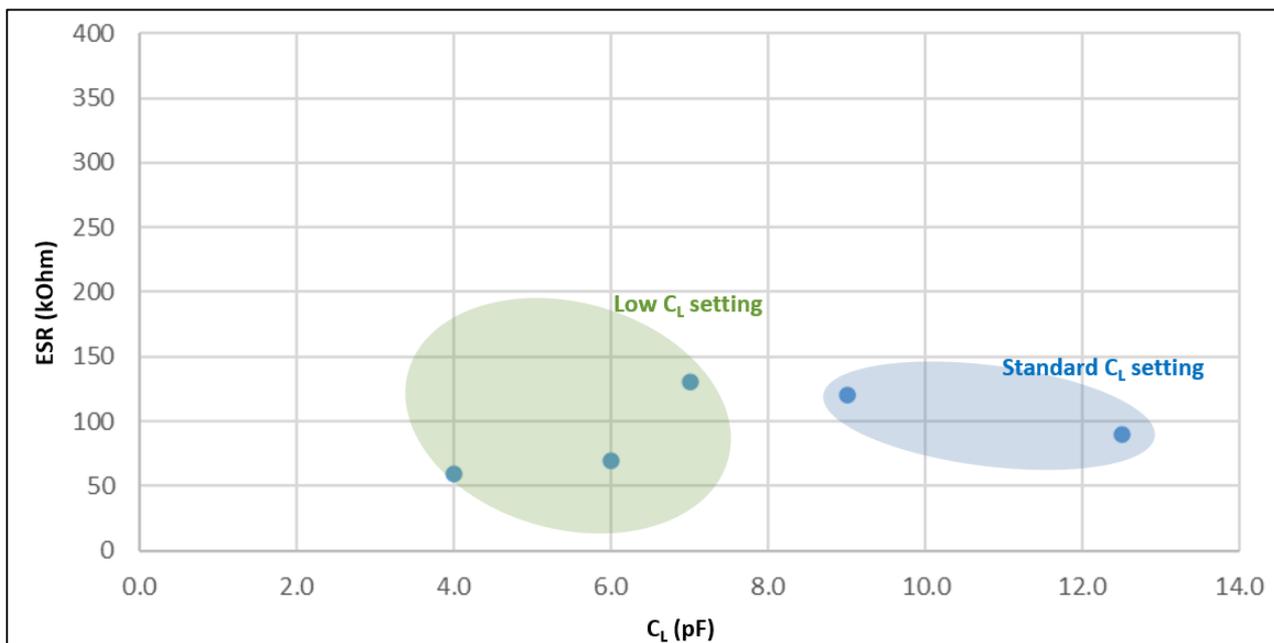
**Figure 13 Group 7, Main clock: Resonator Frequency vs ESR max**



**Table 15 Group 7, Sub-clock: Results of the matching evaluation**

Sub Clock Oscillator Driving Setting <sup>Note 5</sup>	Resonator specification		Evaluation board implementation			Evaluation results	
	Frequency (kHz)	C <sub>L</sub> (pF)	R <sub>d</sub> (Ohm)	C <sub>L1</sub> (pF)	C <sub>L2</sub> (pF)	Negative R (Ohm)	Recommended ESR <sub>max</sub> (kOhm)
Low C <sub>L</sub> (Low drive) <sup>Note 6</sup>	32	4.0	0	4.0	4.0	-305	60
Low C <sub>L</sub> (Medium drive) <sup>Note 6</sup>	32	6.0	0	9.0	9.0	-384	70
Low C <sub>L</sub> (High drive) <sup>Note 6</sup>	32	7.0	0	10	12	-669	130
Standard C <sub>L</sub> <sup>Note 6</sup>	32	9.0	0	15	18	-672	120
	32	12.5	0	22	22	-452	80

**Figure 14 Group 7, Sub-clock: C<sub>L</sub> vs ESR max**



Note 4: For the setting of the drive capability register of the main clock, refer to the "Clock Generation Circuit" chapter of the User's Manual: Hardware for both RX and RA.

Example:

RX66N: MODRV2[1:0] = b11 (Drive capability 8 MHz)

RA4E2: MODRV[1:0] = b11 (Drive capability 8 MHz)

Note 5: Refer to the following chapter for setting of the sub-clock drive capability register.

RX: Real-time Clock in the User's Manual: Hardware

RA: Chapter "Clock Generator" in the User's Manual: Hardware

Example:

RX66N: RTCDV[2:0] = b110 (Standard C<sub>L</sub>)

RA4E2: then SODRV[1] = b0 (Normal C<sub>L</sub>)

Note 6: The magnitude relationship between the drive capacity settings is as follows.

Notations used in this application note	Notations used in RX Family User's Manual	Notations used in RA Family User's Manual	Drive capability
Standard C <sub>L</sub>	Standard C <sub>L</sub>	Normal mode	4 (highest)

Low C <sub>L</sub> (High drive)	Low C <sub>L</sub> (High drive)	Low power mode 1	3
Low C <sub>L</sub> (Medium drive)	Low C <sub>L</sub> (Medium drive)	Low power mode 2	2
Low C <sub>L</sub> (Low drive)	Low C <sub>L</sub> (Low drive)	Low power mode 3	1 (minimum)

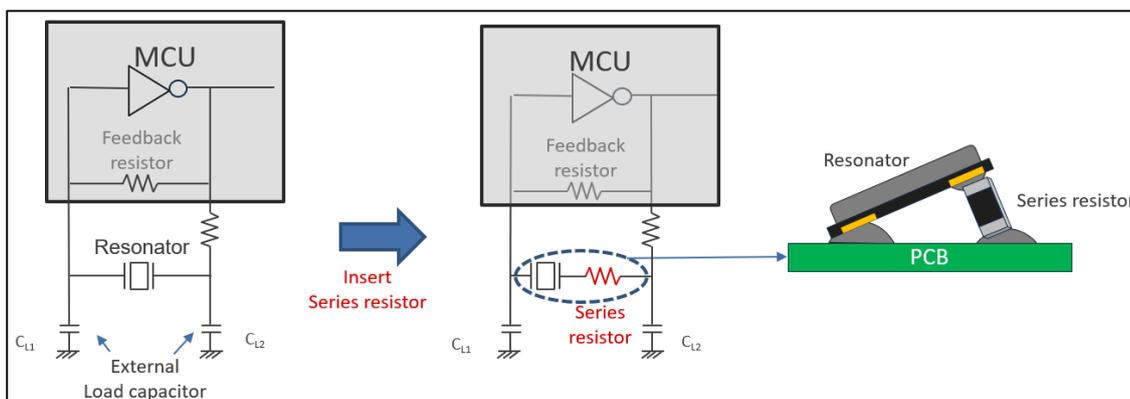
## 5. Oscillator matching evaluation method and oscillator circuit parameter calculation method

This chapter describes how to evaluate external components if you want to perform the matching evaluation yourself, and how to evaluate the stability of oscillation with the selected components.

### 5.1 How to measure the negative resistance

To measure the negative resistance of the oscillator circuit, insert a resistor in series with the resonator as shown in Figure 15, and check the maximum resistance of the resistor at which the oscillation of MCU clock output can be maintained. Use the FET probe (low capacitance, high impedance) when observing the MCU clock output waveform with an oscilloscope. It is recommended that the resistance of the series resistor be approximately five times ESR (equivalent series resistance) of the resonator.

Figure 15 Measurement method of the negative resistance



### 5.2 Measurement method of oscillations' excitation power

The oscillations' excitation power ( $\mu\text{W}$ ) is calculated from the oscillation current ( $I_{\text{RMS}}$ ) measured by a current probe clamped to the resonator and the wire inserted between the circuit board as shown in Figure 16, and the equivalent series resistance of the oscillator ( $R_{\text{load}}$ ).

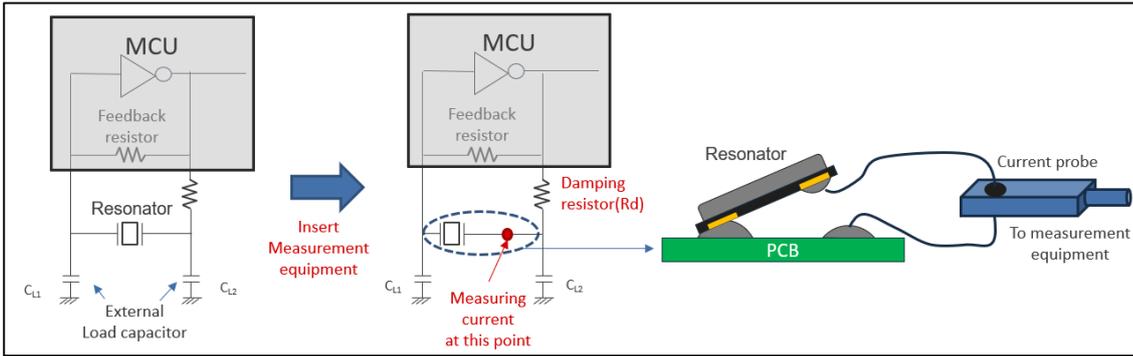
■ Oscillations excitation power =  $R_{\text{load}} * I_{\text{RMS}}^2$  ( $\mu\text{W}$ )

If the excitation power exceeds the specification of the resonator, consider the following measures.

- Add a damping resistor on the board.
- Decrease the oscillator drive capability of MCU.

See Note 6 in Chapter 4 for information of the MCU's oscillator drive capability.

**Figure 16 Measurement method of the oscillations excitation power**

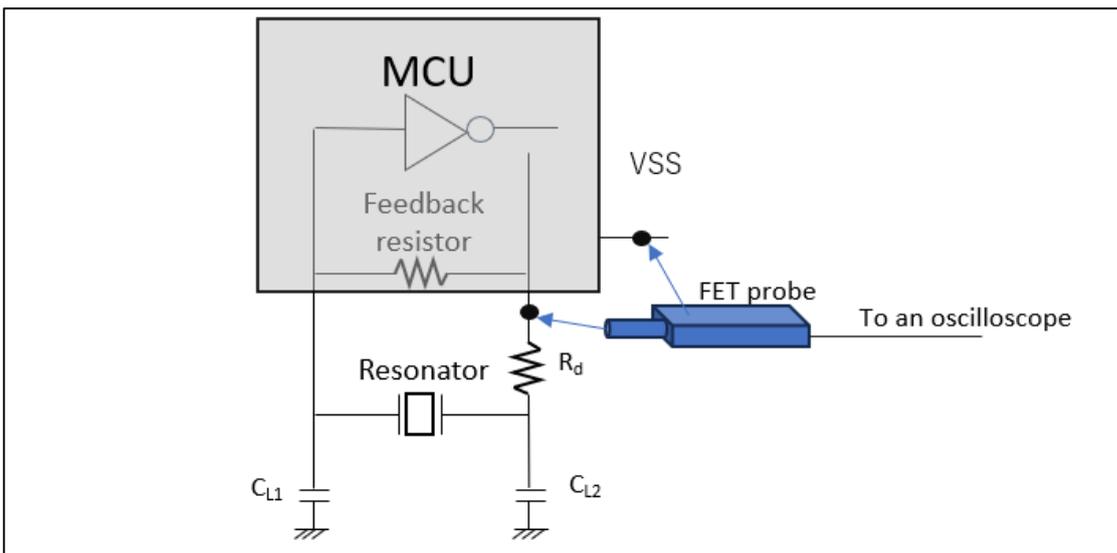


### 5.3 Measurement method of the oscillation amplitude voltage

Prepare a board with the selected external components according to Chapter 5.1 and Chapter 5.2. Connect a FET probe to XTAL/XCOUT and VSS of the MCU as shown in Figure 17 to measure the oscillation amplitude voltage. If the measured voltage exceeds the absolute maximum rating of the MCU, consider the following measures.

- Add a damping resistor on the board.
- Decrease the oscillator drive capability of the MCU.  
See Note 6 in Chapter 4 for information of the MCU’s oscillator drive capability.

**Figure 17 Oscillation Amplitude Voltage Measurement Method**



### 5.4 How to determine the load capacity

In general, to determine the external load capacitance, adjust the capacitance in the actual experiment so that the oscillation frequency becomes the target value. If you want to estimate the external load capacitance without experimenting, follow the procedure below to.

If you want to estimate the  $C_L$  of the load capacitor accurately, you must also consider the parasitic capacitance of the board, as shown in the Figure 18 (Exact Version). However, in this application note, to simplify the calculation, we use the formula in the Figure 18 (Simplified Version), where the parasitic capacitance value of the board is "zero". Other conditions are listed below.

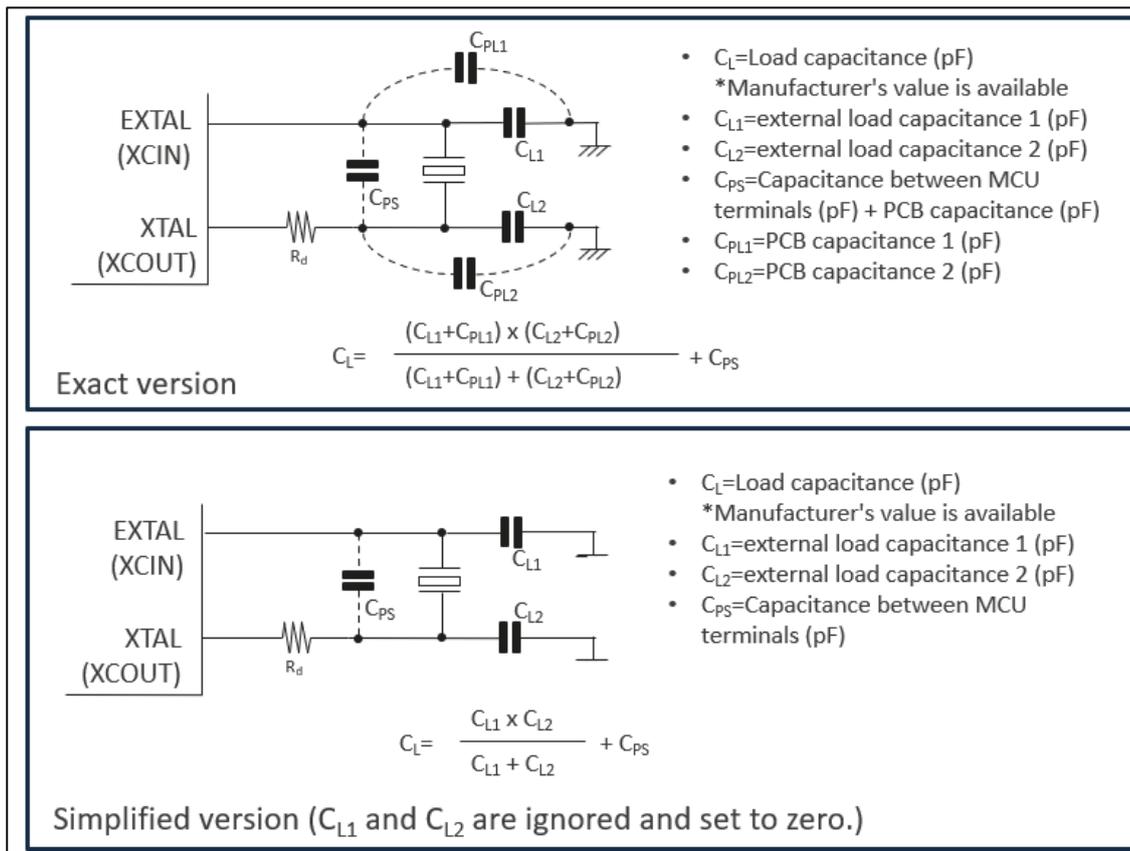
- $C_L$ : Use the resonator manufacturer’s recommended value for the external load capacity. For example, in this case we use  $C_L = 8 \text{ pF}$  as a typical value.

- $C_{L1}$  and  $C_{L2}$ : Assume them to the same value. ( $C_{L1} = C_{L2}$ )
- $C_{PS}$ : The typical MCU pin-to-pin capacitance is 1 pF. Use the actual measured value if you want to calculate it accurately.

Substituting these values into the equation shown in Figure 18 (Simplified version) gives capacitance of 14 pF for the external load capacitance,  $C_{L1}$  and  $C_{L2}$ .

$$\blacksquare C_{L1} = C_{L2} = (C_L - C_{PS}) * 2 = (8 - 1) * 2 = 14 \text{ pF}$$

**Figure 18 Formula for the External Load Capacity ( $C_{L1}$  and  $C_{L2}$ )**



## 5.5 Calculation method of transconductance

The transconductance ( $G_m$ ) of the MCU oscillator can be calculated using the following equation. As  $R$ ,  $C_{L1}$ ,  $C_{L2}$  in this equation, use the matching evaluation results described in Chapter 4. The calculation result is a reference value and is not guaranteed.

- $G_m = |R| * (\omega^2 \times C_{L1} \times C_{L2})$  \* When the resistance of the damping register ( $R_d$ ) is 0 Ohm
  - $R$ : Negative Resistance (Ohm)
  - $\omega$ : Angular frequency ( $2\pi \times$  frequency (Hz)) (rad/sec)
  - $C_{L1}$ ,  $C_{L2}$ : External load capacitance (pF)

## 6. Board design recommendations

### 6.1 How to stabilize the oscillation

#### 6.1.1 EXTAL/XCIN and XTAL/XCOU Routing

(1) through (6) below describe recommendations for the EXTAL/XCIN and XTAL/XCOU routing. Figure 19 through Figure 22 show examples of their traces.

- (1) Do not cross the EXTAL/XCIN and XTAL/XCOU wires with other signal wires.
- (2) Do not connect any testing terminals to the EXTAL/XCIN and XTAL/XCOU wires.
- (3) Make the EXTAL/XCIN and XTAL/XCOU wires width between 0.1 mm and 0.3 mm. The wires length from the MCU pins to the resonator pins should be within 10 mm as much as possible.
- (4) The trace connected to the EXTAL/XCIN pin, and the trace connected to the XTAL/XCOU pin should have as much space between them as possible (at least 0.3 mm).
- (5) Connect the two external load capacitors with the shortest routing distance and connect the routing to the ground pattern on the component surface (hereafter referred to as ground shield. See chapter 6.1.2 for details). If there is no space near the MCU of the PCB and the external load capacitors cannot be placed near the MCU as shown in Figure 19 to Figure 21, place them as shown in Figure 22.
- (6) To reduce the parasitic capacitance between the EXTAL/XCIN and XTAL/XCOU, add a ground trace between the resonator and the MCU.

Figure 19 Example of the EXTAL/XCIN and XTAL/XCOU Routing Pattern: LQFP Package

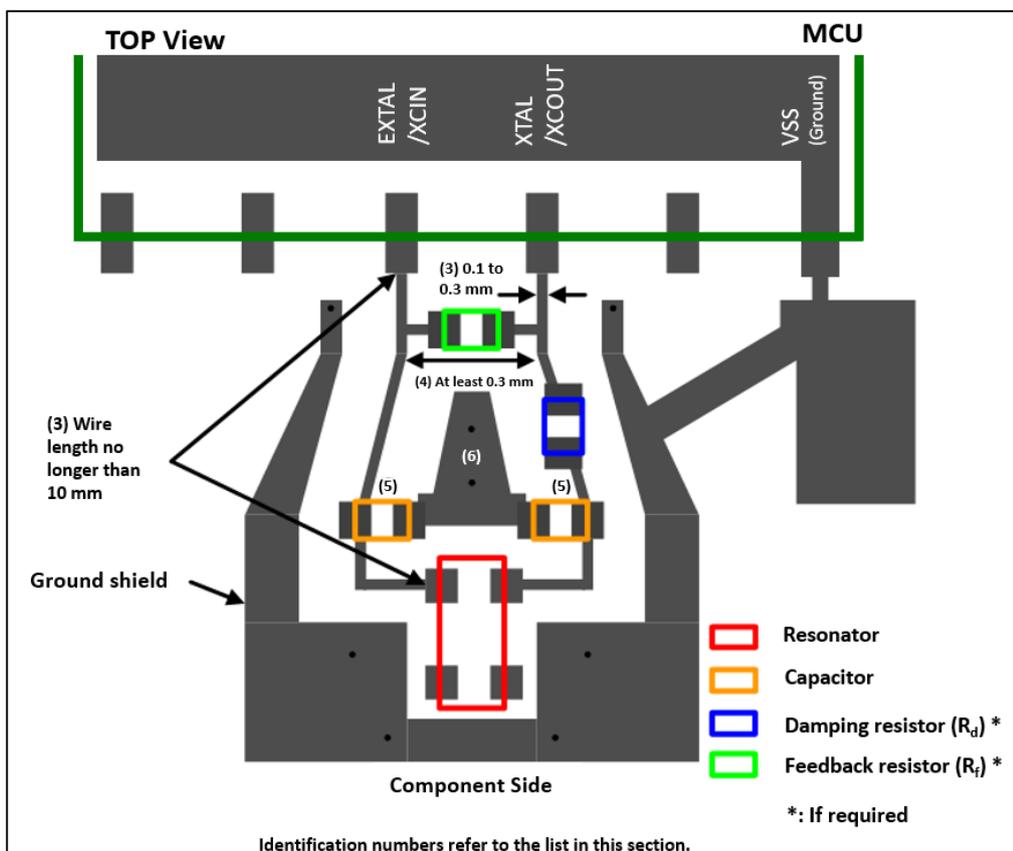


Figure 20 Example of the EXTAL/XCIN and XTAL/XCOU Routing Pattern: LGA Package

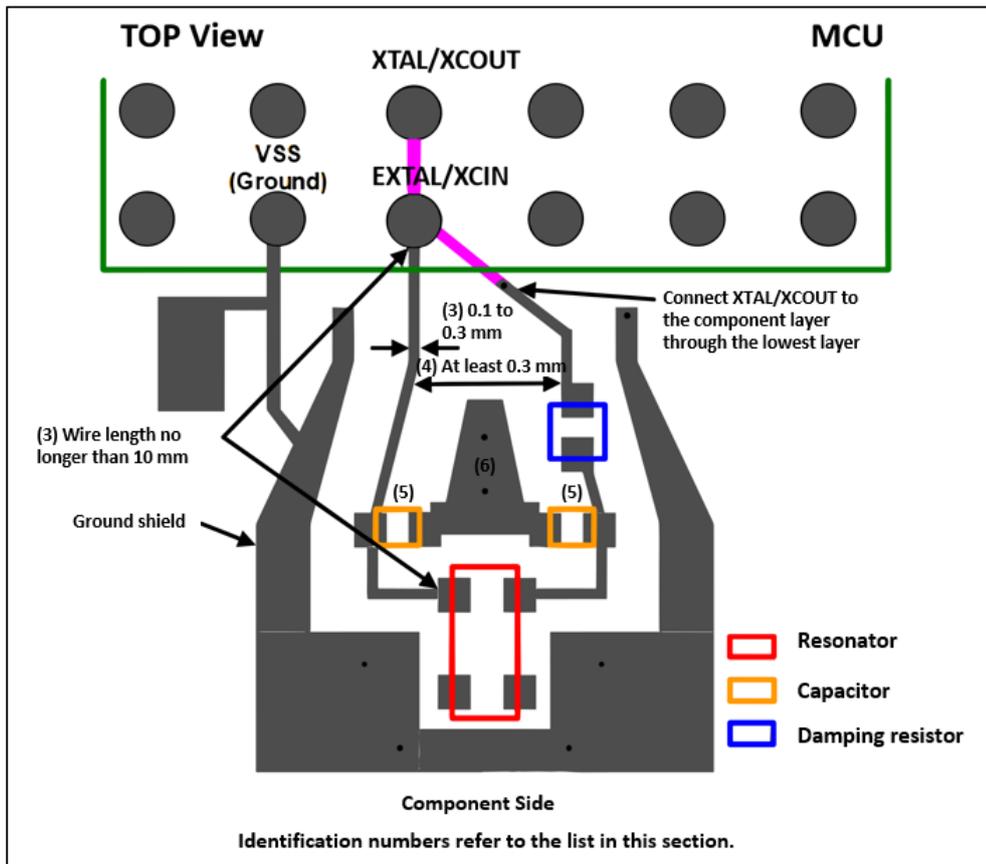
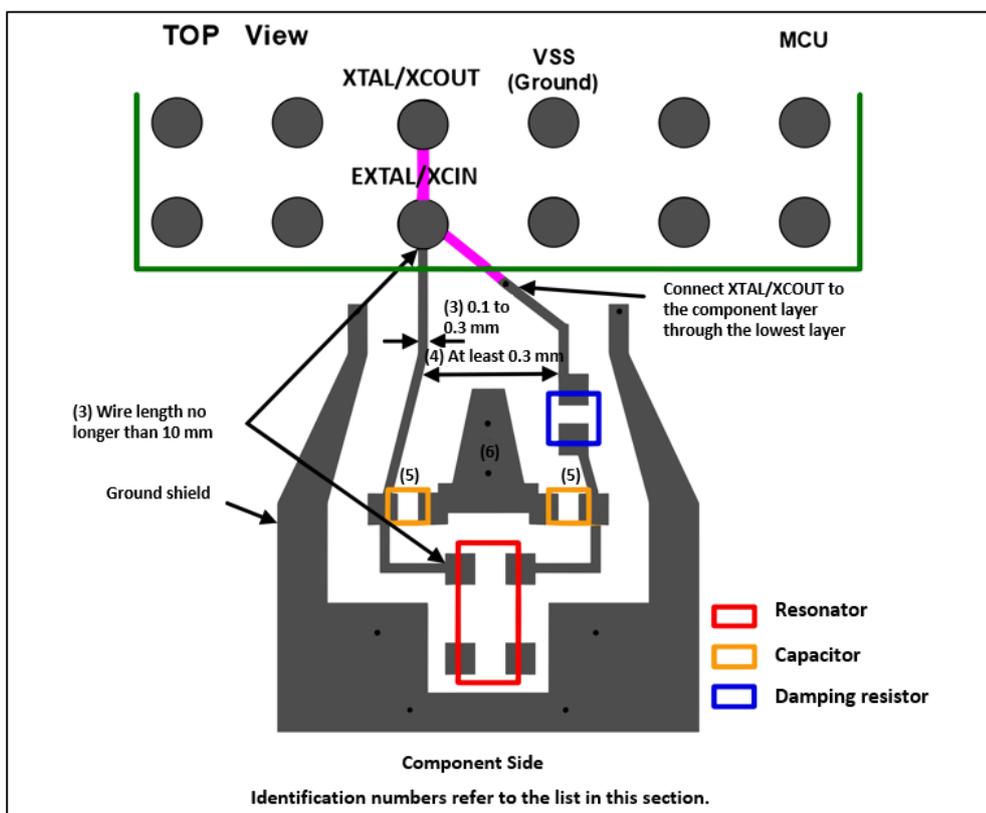
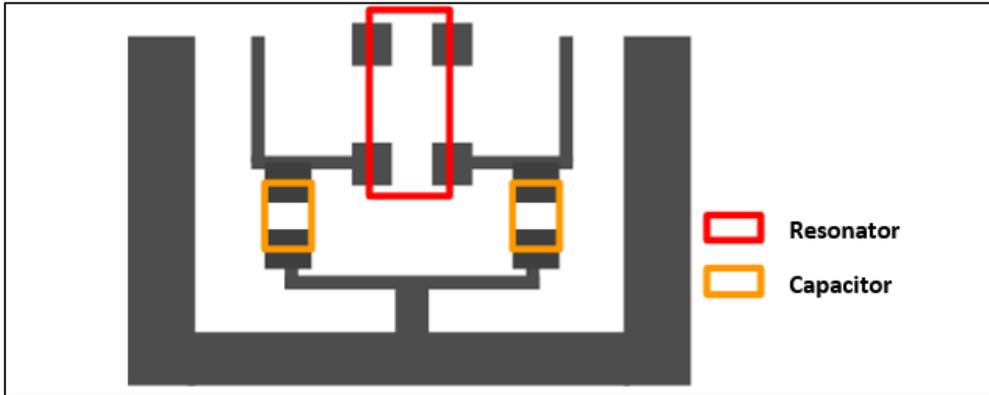


Figure 21 Example of the EXTAL/XCIN and XTAL/XCOU Routing Pattern: BGA Package



**Figure 22 Pattern example when two external capacities are difficult to place near MCU**

### 6.1.2 Use a ground shield

Shield the resonator with a ground trace. (1) through (4) below describe the recommendations for the ground shield. Figure 23 through Figure 25 show trace examples for each package.

In addition, the ground shield of the main clock oscillator circuit and the sub-clock oscillator circuit should not be a continuous pattern as shown in Figure 26. If the ground shield of the main clock oscillator and the ground shield of the sub-clock oscillator are directly connected, the output of the main clock oscillator may propagate as noise to the ground shield of the sub-clock and affect the oscillation of the sub-clock.

- (1) Place the ground shield on the same layer as the resonator trace routing.
- (2) Make the ground shield trace width at least 0.3 mm and leave a gap of 0.3 to 2.0 mm between the ground shield and other traces.
- (3) Route the ground shield as close as possible to the VSS pin on the MCU and make sure that the trace width is at least 0.3 mm.
- (4) To prevent current from flowing through the ground shield, branch the ground shield and the ground on the board near the VSS pin on the board.

Figure 23 Example of the ground shield tracing: LQFP Package

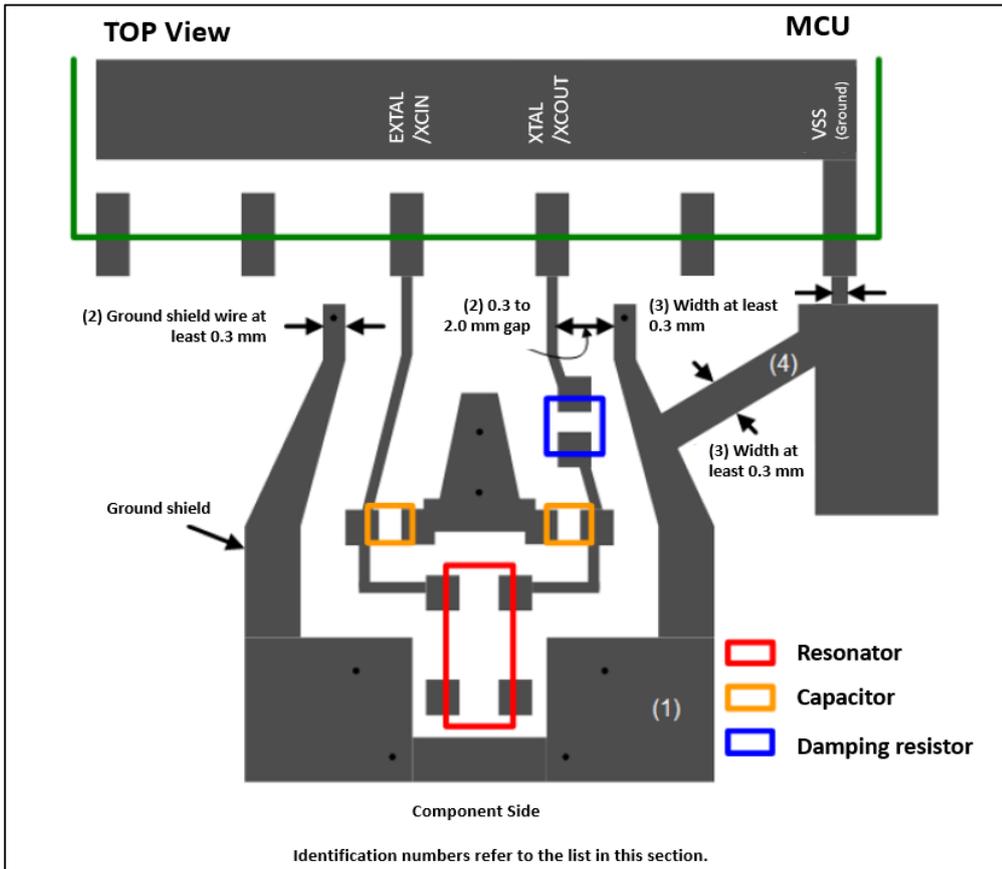


Figure 24 Example of the ground shield tracing: LGA Package

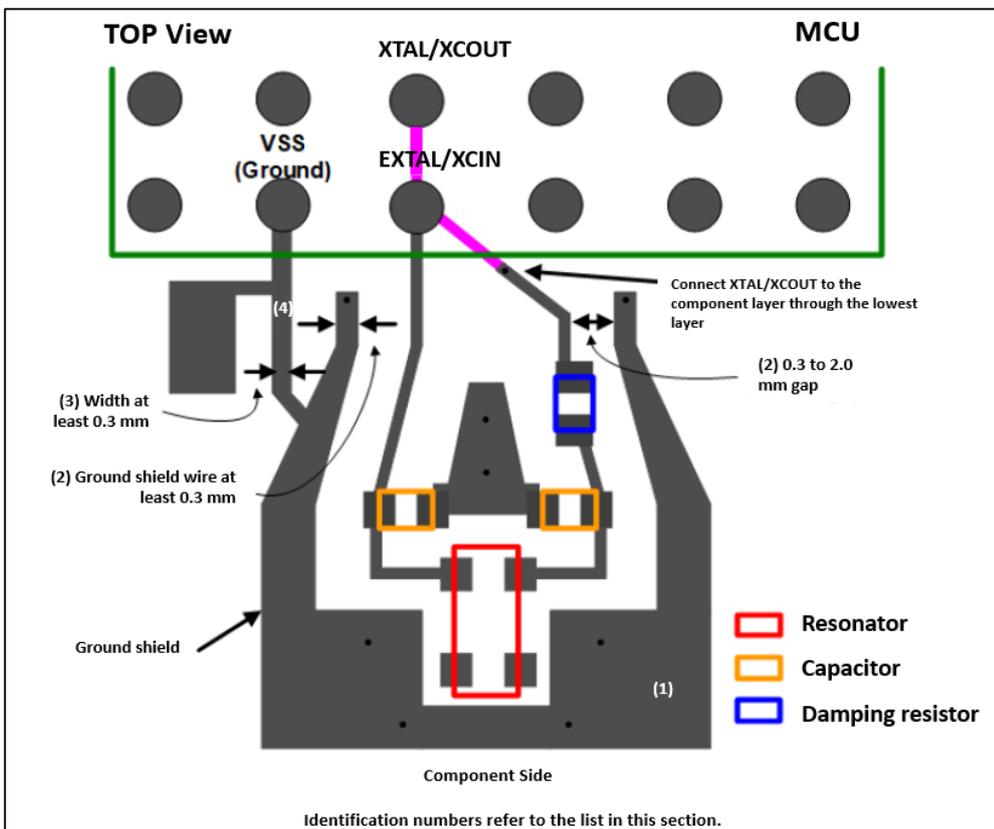


Figure 25 Example of the ground shield tracing: BGA Package

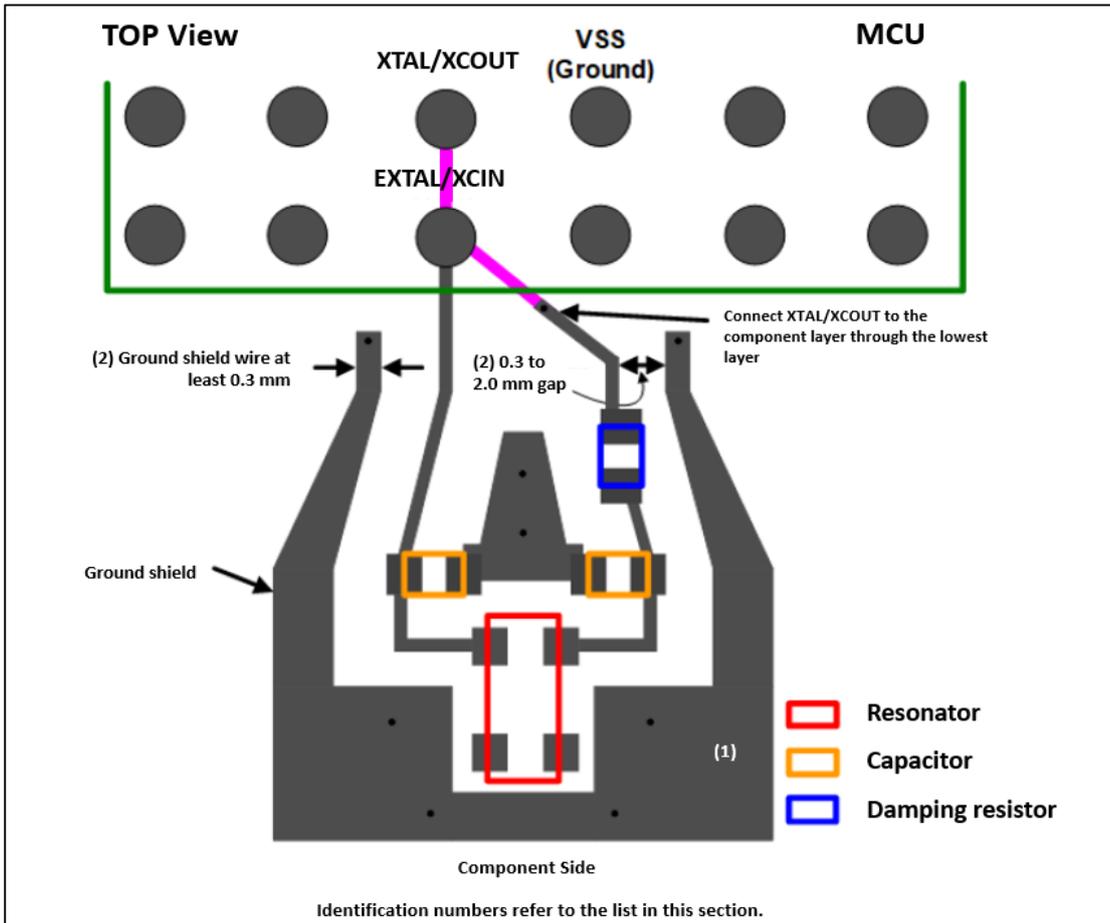
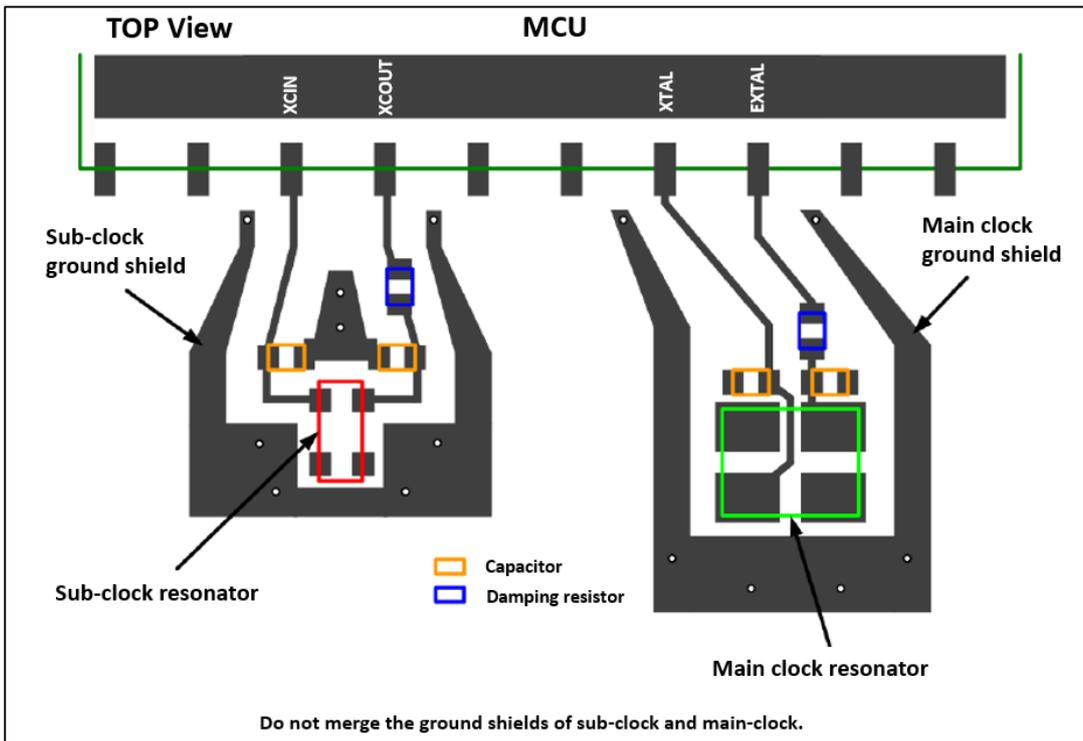


Figure 26 Example of the main clock and sub-lock ground shield configuration



### 6.1.3 Usage of a bottom-ground

#### 6.1.3.1 Multilayer boards thicker than 1.2 mm

For multilayer boards thicker than 1.2 mm, place a ground pattern (hereafter referred to as bottom ground) on the solder surface of the resonator area (see Figure 27 through Figure 29).

The recommendations of the bottom ground are shown below. Figure 27 through Figure 29 show examples of patterns for each package.

- (1) Do not place power supply, ground, or signal line patterns in the middle layer of the resonator area. The parasitic capacitance and crosstalk between layers may affect stable oscillation.
- (2) Connect the ground shield termination on the component side to the bottom ground. If the termination is not connected to bottom ground and is an open end, there is a risk that the ground shield will become a noise source by acting as an antenna.
- (3) Make the bottom ground at least 0.1 mm larger than the ground shield.
  - Case of LQFP and LGA/BGA (whose VSS is placed in the outer column):  
Connect the bottom ground only to the ground shield on the component side.  
Do not connect the bottom ground directly to the VSS terminal, but connect it through the ground shield.  
Do not connect any ground other than the VSS pin to the bottom ground and the ground shield.
  - Case of LQFP and LGA/BGA (whose VSS is placed in the inner column):  
Connect the bottom ground directly to the VSS pin.  
Do not connect any ground other than the VSS pin to the bottom ground and ground shield.

Figure 27 Routing example for a multilayer board thicker than 1.2 mm: LQFP Package

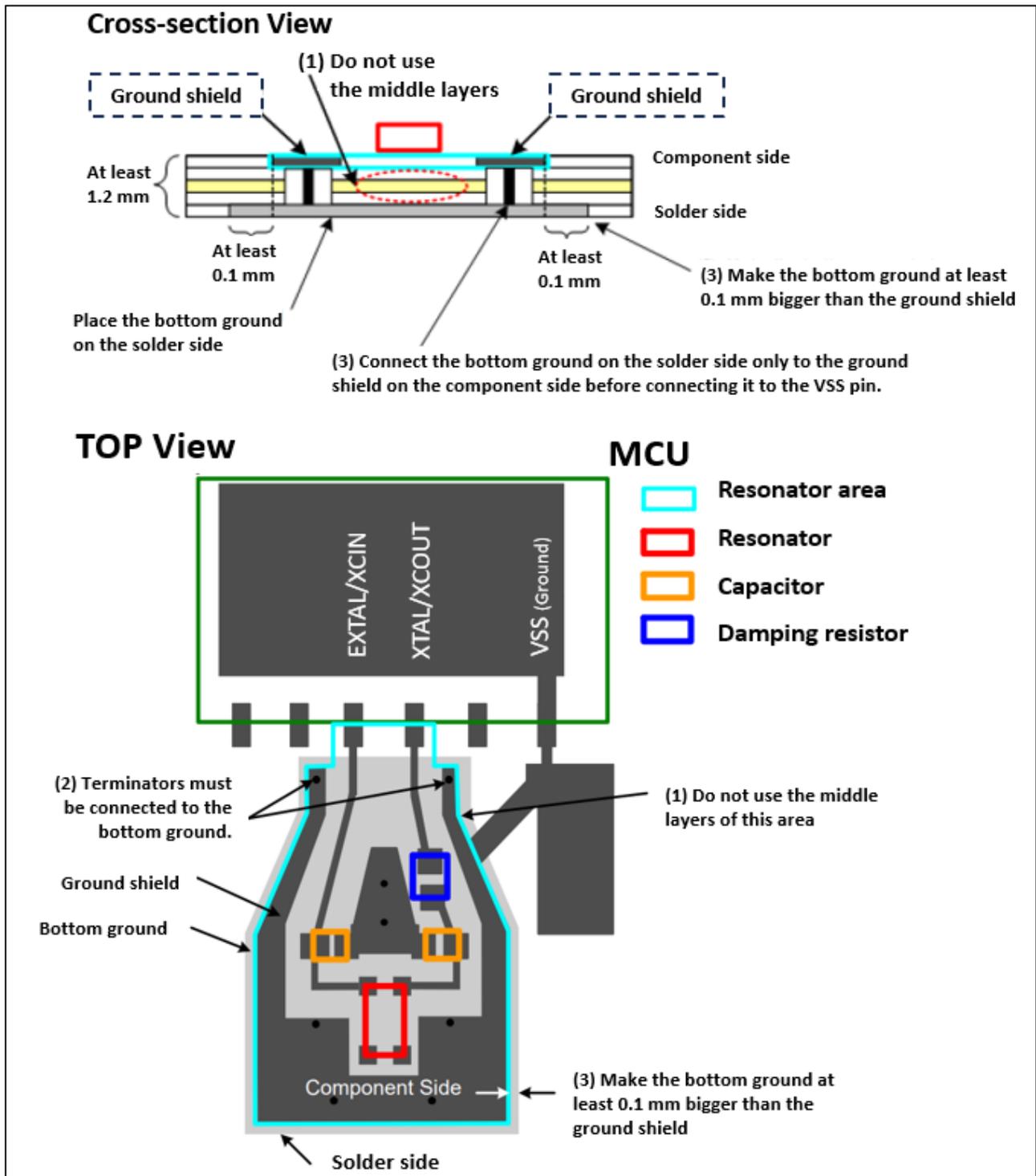


Figure 28 Routing example for a multilayered board thicker than 1.2 mm: LGA/BGA Package (VSS is placed in the outer column)

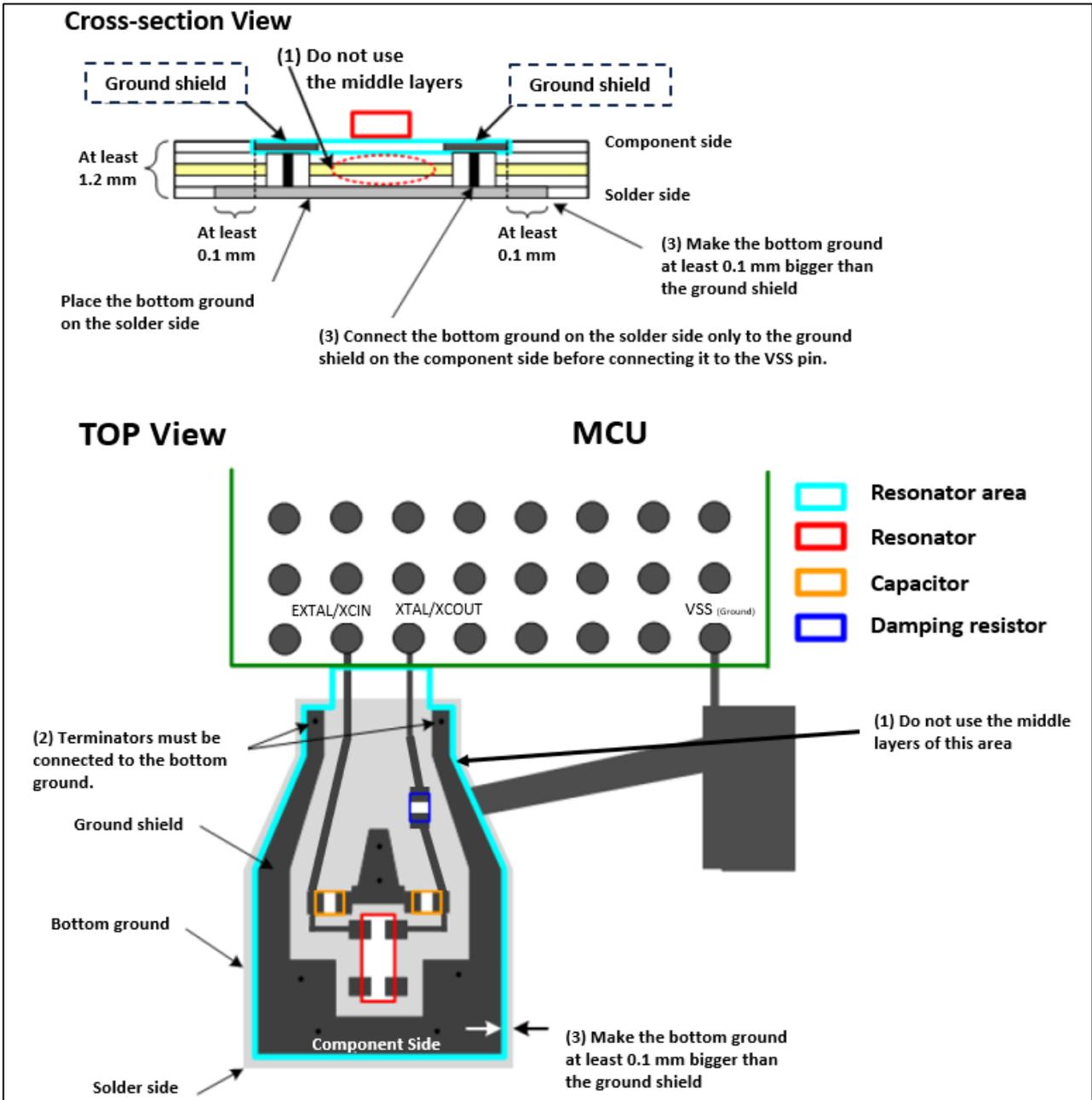
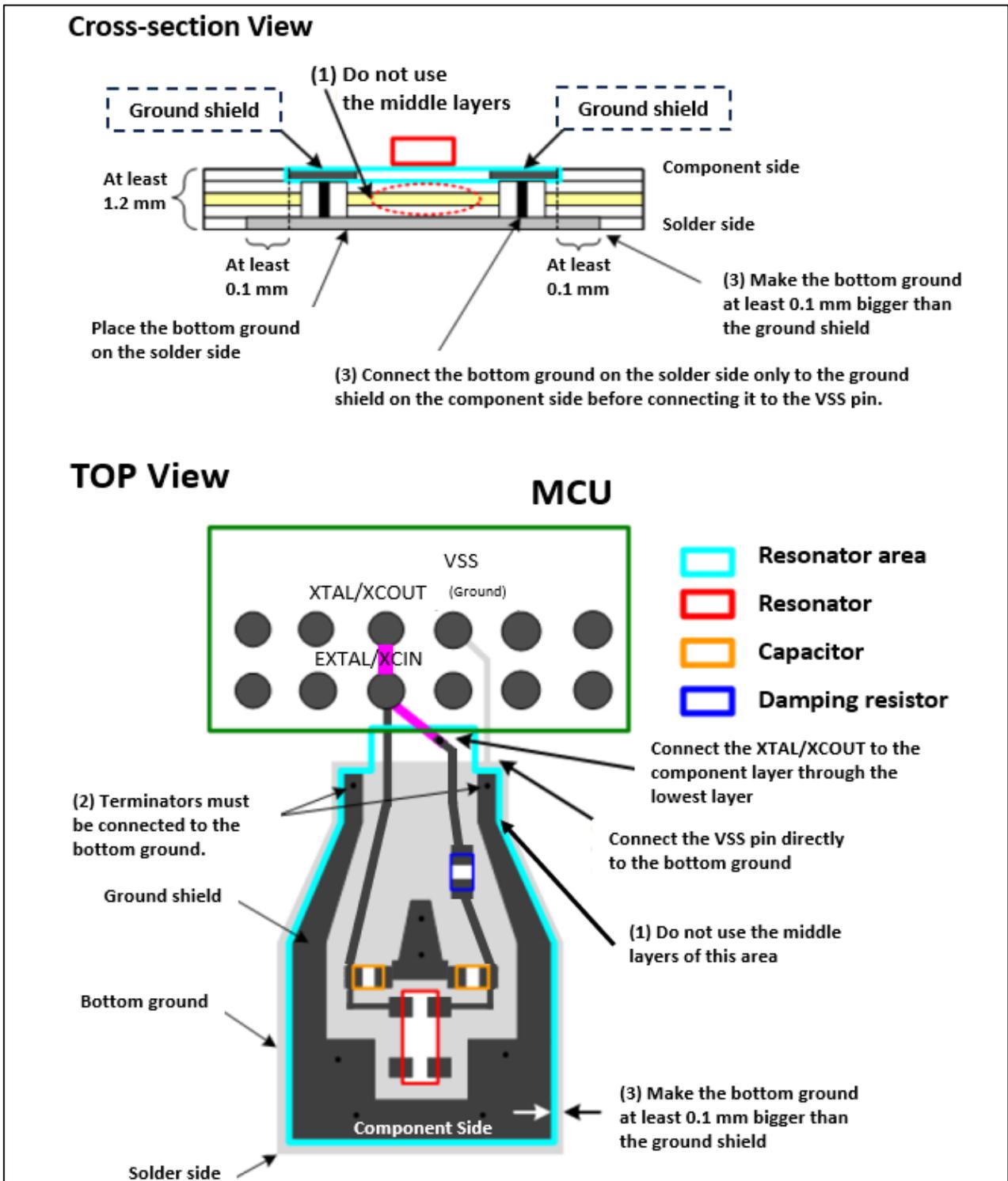


Figure 29 Routing example for a multilayered board thicker than 1.2 mm: LGA/BGA Package (VSS is placed in the inner column)

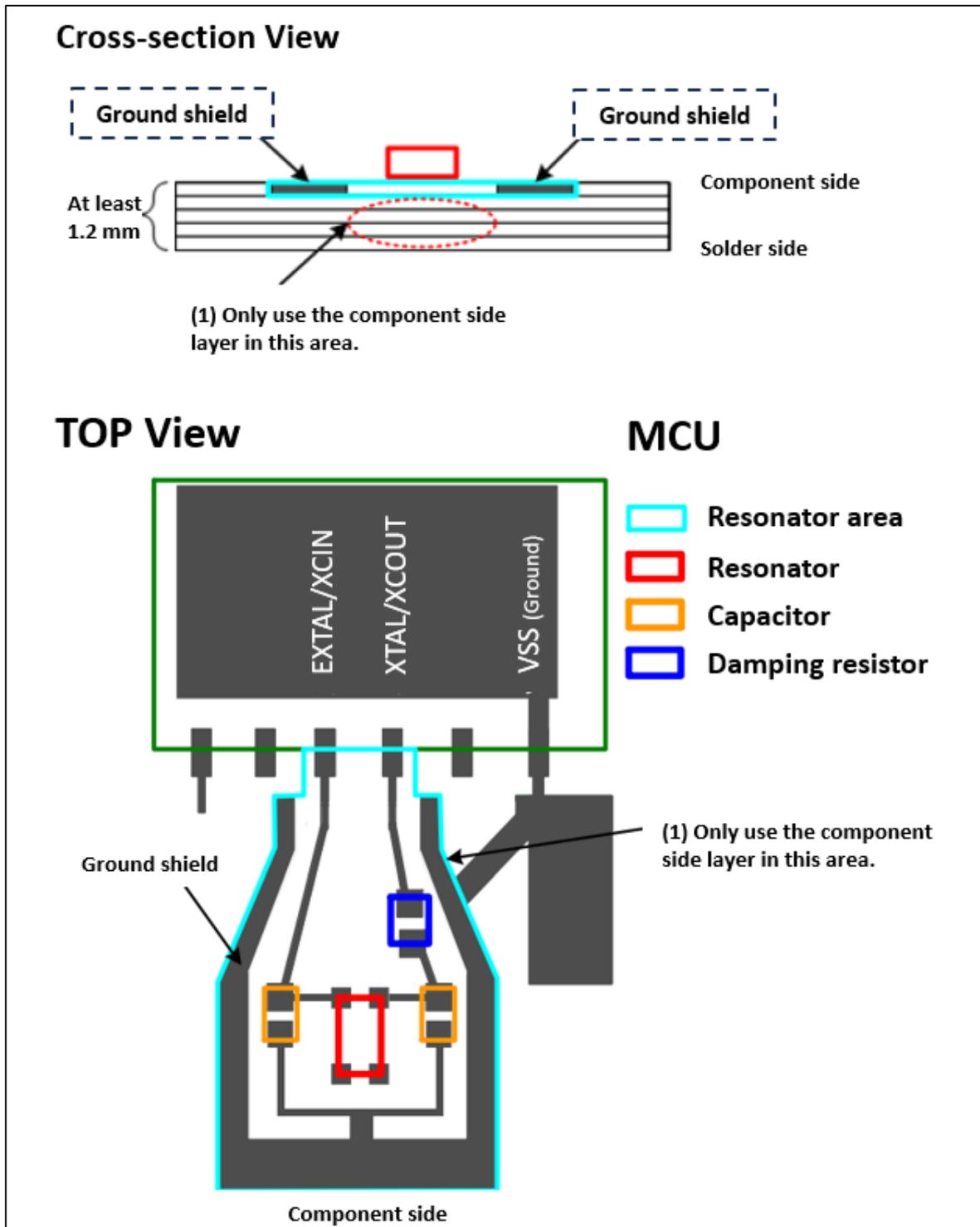


**6.1.3.2 Multilayer boards thinner than 1.2 mm**

The following are recommendations to consider when routing a multilayer board thinner than 1.2 mm. Figure 15 shows an example routing.

- (1) Do not place power supply, ground, and signal line patterns in the middle layer of the resonator area. Do not place power, ground, or signal line patterns on the solder surface as well. The parasitic capacitance and crosstalk between the layers may interfere with stable oscillation.

**Figure 30 Routing Example When a Multilayered Board is Less Than 1.2 mm: LQFP Package**

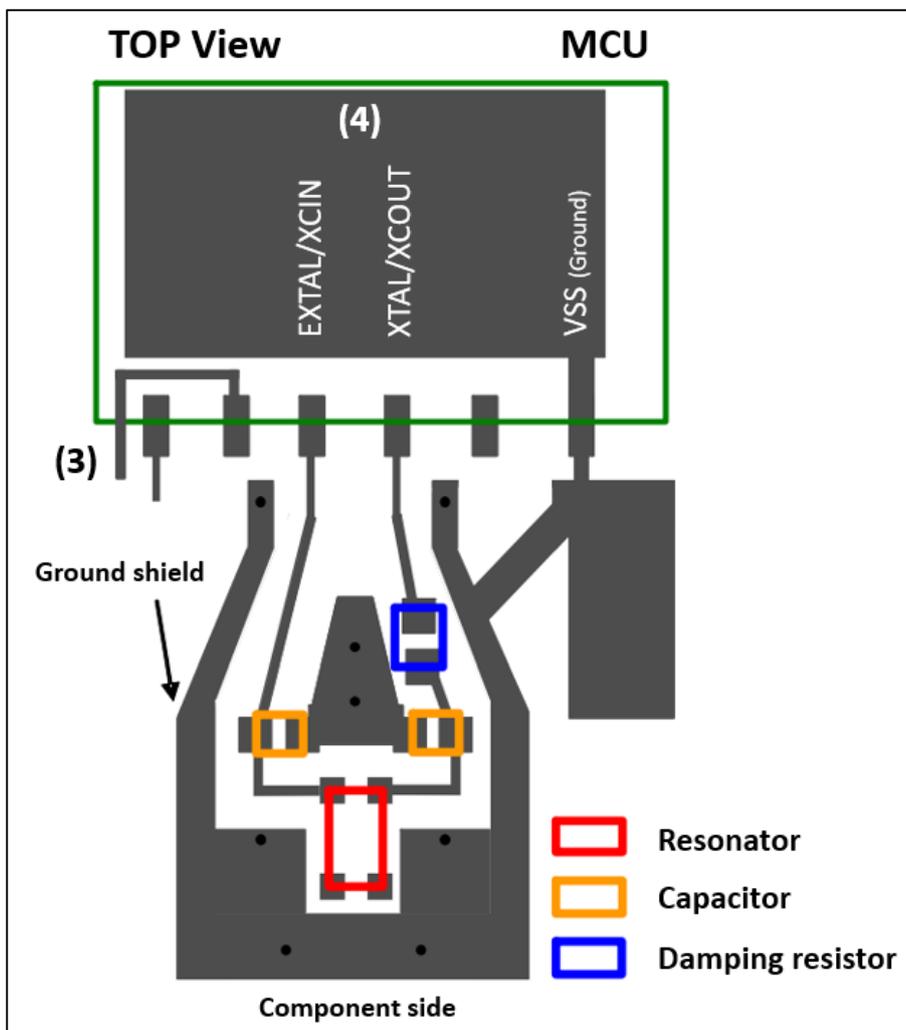


### 6.1.4 Other miscellaneous recommendations

The following are common recommendations for other packages including LQFP. Figure 31 also shows an LQFP pattern as an example.

- (1) Do not place the EXTAL/XCIN and XTAL/XCOOUT wires near traces with large current variations.
- (2) Do not place the EXTAL/XCIN and XTAL/XCOOUT wires in parallel with other signal wires, such as those for adjacent pins.
- (3) Do not place the wires of the terminals adjacent to EXTAL/XCIN and XTAL/XCOOUT in parallel with the EXTAL/XCIN and XTAL/XCOOUT traces. Do not connect them directly to the outside of the MCU, but first route them through the bottom of the MCU and then bring them out from a location away from the EXTAL/XCIN and XTAL/XCOOUT pins.
- (4) Place the ground trace on the bottom side of the MCU and make this as large as possible.

Figure 31 Example of Routing for Other Points: LQFP Package



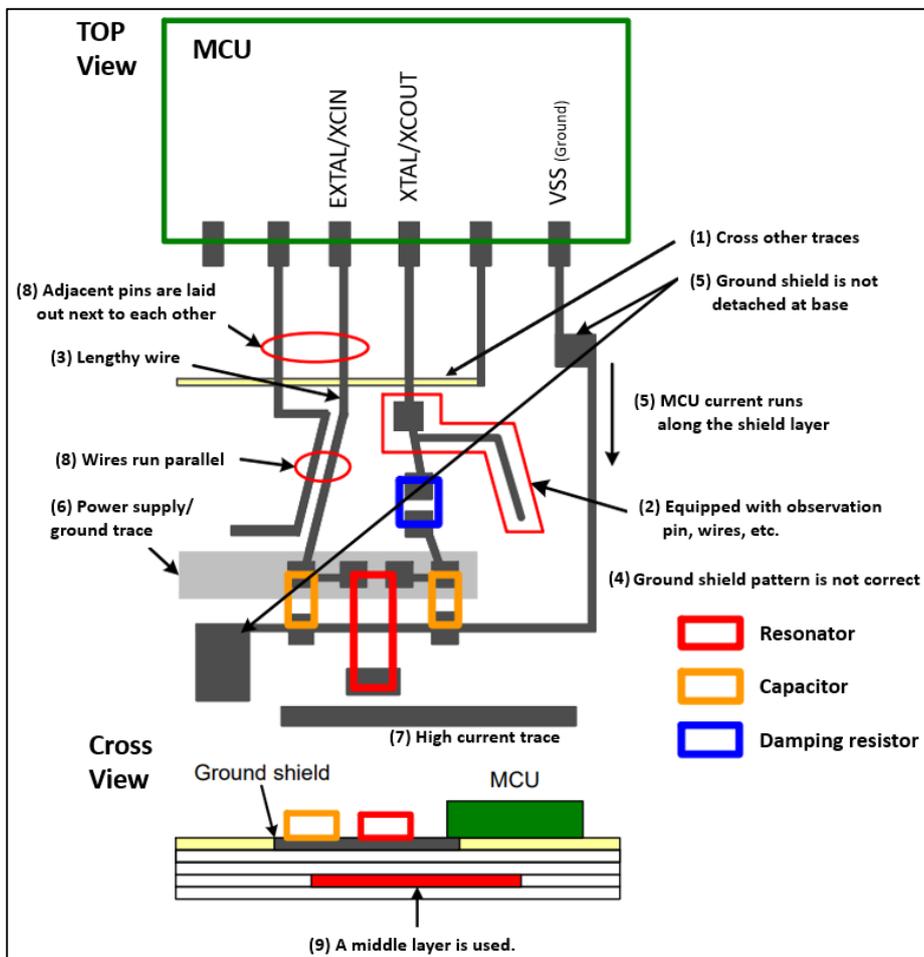
## 6.2 Examples of patterns with a high risk of malfunction due to noise

Avoid the issues listed below in your PCB design as they may cause the resonator to oscillate incorrectly or may increase EMI. Figure 32 shows some examples of patterns.

- (1) The EXTAL/XCIN and XTAL/XCOOUT wires cross other signal wires. The MCU may malfunction due to crosstalk.
- (2) Observation pins (test points) are attached to the EXTAL/XCIN and XTAL/XCOOUT wires. There is a risk of unstable oscillation due to impedance mismatch in the wiring and reflections in the oscillation waveform.

- (3) The EXTAL/XCIN and XTAL/XCOOUT wires are long.  
Parasitic capacitance or inductance can cause oscillation instability and loss of accuracy. It is also a source of EMI.
- (4) The ground shield does not cover the entire oscillation area, the wiring from the board ground is long or the wiring is thin.  
The oscillating circuit is easily affected by noise.  
There is a risk that the ground potential difference between the MCU and the external load capacitance may affect the accuracy of the oscillation frequency.
- (5) The ground shield is not isolated from the board ground immediately adjacent to the VSS terminal.  
The operating current of the MCU flows to the ground shield and may cause the resonator to malfunction.
- (6) The power and ground patterns are located under the EXTAL/XCIN and XTAL/XCOOUT wiring.  
Oscillation in the resonator circuit may stop due to a lack of clock caused by parasitic capacitance, impedance and noise.
- (7) Wires with high current flow are routed near the EXTAL/XCIN and XTAL/XCOOUT wiring.  
There is a risk that the resonator circuit will stop oscillating due to the effects of crosstalk.
- (8) The distance between the EXTAL/XCIN and XTAL/XCOOUT wiring, and the wiring of the adjacent terminals is close, and the parallel length is long.  
There is a risk that the resonator circuit will stop oscillating due to the effects of crosstalk.
- (9) Intermediate layers in the resonator area are used.  
If there are ground and/or power supply layers in the intermediate layer, there is a risk that parasitic capacitance will affect the oscillation characteristics.  
If signal lines are present, there is a risk of crosstalk causing the resonator circuit or signal lines to malfunction.
- (10) The oscillation area is extremely close to the board edge.  
Cause an increase in EMI radiated from the resonator circuit to the outside of the board.

Figure 32 Example of a pattern with a high risk of malfunction due to noise.



**Revision History**

Rev.	Date	Description	
		Page	Summary
1.00	Feb 2024		first edition

## General Precautions in the Handling of Microprocessing Unit and Microcontroller Unit Products

The following usage notes are applicable to all Microprocessing unit and Microcontroller unit products from Renesas. For detailed usage notes on the products covered by this document, refer to the relevant sections of the document as well as any technical updates that have been issued for the products.

### 1. Precaution against Electrostatic Discharge (ESD)

A strong electrical field, when exposed to a CMOS device, can cause destruction of the gate oxide and ultimately degrade the device operation. Steps must be taken to stop the generation of static electricity as much as possible, and quickly dissipate it when it occurs. Environmental control must be adequate. When it is dry, a humidifier should be used. This is recommended to avoid using insulators that can easily build up static electricity.

Semiconductor devices must be stored and transported in an anti-static container, static shielding bag or conductive material. All test and measurement tools including work benches and floors must be grounded. The operator must also be grounded using a wrist strap. Semiconductor devices must not be touched with bare hands. Similar precautions must be taken for printed circuit boards with mounted semiconductor devices.

### 2. Processing at power-on

The state of the product is undefined at the time when power is supplied. The states of internal circuits in the LSI are indeterminate and the states of register settings and pins are undefined at the time when power is supplied. In a finished product where the reset signal is applied to the external reset pin, the states of pins are not guaranteed from the time when power is supplied until the reset process is completed. In a similar way, the states of pins in a product that is reset by an on-chip power-on reset function are not guaranteed from the time when power is supplied until the power reaches the level at which resetting is specified.

### 3. Input of signal during power-off state

Do not input signals or an I/O pull-up power supply while the device is powered off. The current injection that results from input of such a signal or I/O pull-up power supply may cause malfunction and the abnormal current that passes in the device at this time may cause degradation of internal elements. Follow the guideline for input signal during power-off state as described in your product documentation.

### 4. Handling of unused pins

Handle unused pins in accordance with the directions given under handling of unused pins in the manual. The input pins of CMOS products are generally in the high-impedance state. In operation with an unused pin in the open-circuit state, extra electromagnetic noise is induced in the vicinity of the LSI, an associated shoot-through current flows internally, and malfunctions occur due to the false recognition of the pin state as an input signal become possible.

### 5. Clock signals

After applying a reset, only release the reset line after the operating clock signal becomes stable. When switching the clock signal during program execution, wait until the target clock signal is stabilized. When the clock signal is generated with an external resonator or from an external oscillator during a reset, ensure that the reset line is only released after full stabilization of the clock signal. Additionally, when switching to a clock signal produced with an external resonator or by an external oscillator while program execution is in progress, wait until the target clock signal is stable.

### 6. Voltage application waveform at input pin

Waveform distortion due to input noise or a reflected wave may cause malfunction. If the input of the CMOS device stays in the area between  $V_{IL}$  (Max.) and  $V_{IH}$  (Min.) due to noise, for example, the device may malfunction. Take care to prevent chattering noise from entering the device when the input level is fixed, and also in the transition period when the input level passes through the area between  $V_{IL}$  (Max.) and  $V_{IH}$  (Min.).

### 7. Prohibition of access to reserved addresses

Access to reserved addresses is prohibited. The reserved addresses are provided for possible future expansion of functions. Do not access these addresses as the correct operation of the LSI is not guaranteed.

### 8. Differences between products

Before changing from one product to another, for example to a product with a different part number, confirm that the change will not lead to problems. The characteristics of a microprocessing unit or microcontroller unit products in the same group but having a different part number might differ in terms of internal memory capacity, layout pattern, and other factors, which can affect the ranges of electrical characteristics, such as characteristic values, operating margins, immunity to noise, and amount of radiated noise. When changing to a product with a different part number, implement a system-evaluation test for the given product.

## 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 depend 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.

(Note 1) "Renesas Electronics" as used in this document means Renesas Electronics Corporation and also includes its directly or indirectly controlled subsidiaries.

(Note 2) "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](http://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/](http://www.renesas.com/contact/).