Introduction
This document describes guidelines to be observed when designing an RF board.

Target Device
- RL78/G1D

Note: The contents of this document are provided as a reference and do not guarantee the signal quality in the system. When designing the actual system, thoroughly evaluate the product in the overall system and apply these contents on your own responsibility.

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The specifications in this document are tentative and subject to change without notice. The parameters for the product may change before production or Renesas Electronics Corporation, on its own responsibility, may withdraw the product prior to its production.
1. Overview

This document uses the pin names of the RF unit incorporated in the RL78/G1D. Table 1 briefly describes the RF unit pins used in the RL78/G1D.

### Table 1 Description of RF unit pins in RL78/G1D

<table>
<thead>
<tr>
<th>Pin Number</th>
<th>Pin Name</th>
<th>I/O</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>39</td>
<td>CLKOUT_RF</td>
<td>Output</td>
<td>16, 8, 4 MHz clock output</td>
</tr>
<tr>
<td>40</td>
<td>EXSLK_RF</td>
<td>Input</td>
<td>RF slow clock (32.768 kHz) external input When using RF, the RF slow clock can be supplied externally. In this case, connect it to PCLBUZ0 (sub-system clock). When using RF, the RF slow clock can be supplied externally. In this case, connect it to PCLBUZ0 (sub-system clock).</td>
</tr>
<tr>
<td>27</td>
<td>RFCTLEN</td>
<td>Input</td>
<td>Inputs the RF enable control signal (high: enable, low: disable). When using the RF transceiver, connect RFCTLEN to P130 in the MCU.</td>
</tr>
<tr>
<td>26</td>
<td>TXSELH_RF</td>
<td>Output</td>
<td>External PA/LNA control output</td>
</tr>
<tr>
<td>25</td>
<td>TXSELL_RF</td>
<td>Output</td>
<td>External PA/LNA control output</td>
</tr>
<tr>
<td>33</td>
<td>XTAL1_RF</td>
<td>-</td>
<td>Resonator (32 MHz) connection for RF high-speed reference clock</td>
</tr>
<tr>
<td>32</td>
<td>XTAL2_RF</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>ANT</td>
<td>-</td>
<td>Antenna connection</td>
</tr>
<tr>
<td>29</td>
<td>IC0</td>
<td>-</td>
<td>Internal circuit connection (connect to VSS_RF or AVSS_RF)</td>
</tr>
<tr>
<td>28</td>
<td>IC1</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>DCLOUT</td>
<td>-</td>
<td>Connects an external inductor for the DC-DC converter</td>
</tr>
<tr>
<td>38</td>
<td>DCLIN</td>
<td>-</td>
<td>Connects an external inductor and capacitor for the DC-DC converter</td>
</tr>
<tr>
<td>35</td>
<td>VDD_RF</td>
<td>-</td>
<td>Positive power supply for the RF unit</td>
</tr>
<tr>
<td>34</td>
<td>AVDD_RF</td>
<td>-</td>
<td>Positive power supply for the RF unit (analog)</td>
</tr>
<tr>
<td>37</td>
<td>VSS_RF</td>
<td>-</td>
<td>Ground potential for the RF unit</td>
</tr>
<tr>
<td>31</td>
<td>AVSS_RF</td>
<td>-</td>
<td>Ground potential for the RF unit (analog)</td>
</tr>
<tr>
<td></td>
<td>GND1</td>
<td>-</td>
<td>Ground potential pad on the back of the package Make this pin the same potential as AVSS_RF</td>
</tr>
</tbody>
</table>

1.1 Related documents

The following document is related to this application note. Also refer to this document when using this application note.

- RL78/G1D User’s Manual: Hardware (R01UH0515EJ)
2. Oscillator

Note the following when designing an oscillator.

- Place the crystal resonator close to the XTAL1_RF and XTAL2_RF pins that are used to connect a resonator to generate the RF reference clock. Grounding the oscillator by using a guard ring is recommended.
- Maintain sufficient clearance between patterns to the crystal resonator.
- Place the load capacitor close to the crystal resonator electrode.
- Not placing the wiring and pattern in the lower layer of wiring to the crystal oscillator and crystal oscillator is recommended.
- Before using a crystal resonator, contact the resonator manufacturer to determine the circuit constants.

Figure 1 shows an example of how to connect a crystal resonator, Figure 2 shows an example of pattern.

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![Diagram of Crystal Resonator Connection](image1)

**Figure 1 Example of crystal resonator connection**

Note: Active clock accuracy less than equal ±50ppm. Sleep clock accuracy less than equal ±500ppm, has been defined in the Bluetooth specification. Accuracy of 32MHz and 32.768kHz oscillator, as high as possible it is desirable.

![Pattern Example around the Crystal Resonator](image2)

**Figure 2 Pattern example of around the crystal resonator**
Table 2 shows confirmed operation crystal oscillator list (Reference).

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Parts number</th>
<th>Frequency (MHz)</th>
<th>Load Capacitance CL (pF)</th>
<th>Recommended Circuit Constants (reference)</th>
<th>Oscillation Voltage Range (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nihon Dempa Kogyo Co., Ltd.</td>
<td>NX1612SA-32.00MHz-CHP-CIS-3</td>
<td>32.00</td>
<td>6.0</td>
<td>8.5</td>
<td>8.0, MIN. 1.6, MAX. 3.2</td>
</tr>
<tr>
<td>KYOCERA Crystal Device Corporation</td>
<td>CX1612DB32000A0WPNC1</td>
<td>32.00</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0, MIN. 1.6, MAX. 3.2</td>
</tr>
<tr>
<td>RIVER ELETEC CORPORATION</td>
<td>FCX-07L</td>
<td>32.00</td>
<td>5.5</td>
<td>7.0</td>
<td>7.0, MIN. 1.6, MAX. 3.6</td>
</tr>
<tr>
<td></td>
<td>FCX-06</td>
<td>32.00</td>
<td>6.0</td>
<td>8.0</td>
<td>8.0, MIN. 1.6, MAX. 3.6</td>
</tr>
<tr>
<td>Seiko Epson Corporation</td>
<td>FA-118T</td>
<td>32.00</td>
<td>6.0</td>
<td>10.0</td>
<td>9.0, MIN. 1.6, MAX. 3.6</td>
</tr>
<tr>
<td>Murata Manufacturing Co., Ltd.</td>
<td>XRCGB32M000F2P26R0</td>
<td>32.00</td>
<td>5.0</td>
<td>8.0</td>
<td>8.0, MIN. 1.6, MAX. 3.6</td>
</tr>
<tr>
<td></td>
<td>XRCMD32M000FZQ52R0</td>
<td>32.00</td>
<td>6.0</td>
<td>10.0</td>
<td>10.0, MIN. 1.6, MAX. 3.6</td>
</tr>
<tr>
<td>Daishinku Corp.</td>
<td>DSX1612SL</td>
<td>32.00</td>
<td>8.0</td>
<td>6.0</td>
<td>6.0, MIN. 1.6, MAX. 3.6</td>
</tr>
</tbody>
</table>
3. **Antenna connection pin**

Note the following when designing a circuit that uses an antenna connection pin:

- Calculate and adjust the interval between the antenna connection pin ANT, ground pin, and microstrip line based on the thickness of the PCB material (permittivity) so that an impedance of 50 Ω is generated.
- When using an SMA connector, design the board so that an impedance of 50 Ω is generated, including the impedance at the SMA connector.
- Design an area of at least three times the line width for the ground of the coplanar waveguide.
- The ground surface of the back of the coplanar waveguide is solid ground, and not placing the signal lines.
- For how to design the circuit and pattern around antennas such as chip antennas, contact the antenna manufacturer.

Note: Depending on the antenna, parts such as an inductor is required.
4. **External circuit for DC-DC converter**

Note the following when designing an external circuit for the DC-DC converter.

4.1 **Feedback loop of DC-DC converter**

Note the following when designing the feedback loop of the DC-DC converter.

- Keep the wiring length between the DCLOUT pin, the inductor, the capacitor, and the VSS_RF pin of the smoothing circuit as short and thick as possible.
- Placing the inductor and capacitor as close as possible to the DCLOUT pin is recommended.
- Not placing the wiring and pattern in the lower layer of the inductor is recommended.

Figure 3 shows an example of feedback loop circuit of DC-DC converter, Figure 4 shows an example of pattern.

![Figure 3 Feedback loop of DC-DC converter](image)

![Figure 4 Pattern of feedback loop of DC-DC converter](image)
5. **Power supply and ground patterns**

Note the following when designing the power supply and ground patterns.

### 5.1 Power supply

Note the following when designing the power supply.

- Supply the power to the power supply pin directly from a power supply which has little noise, such as a battery or low drop-out (LDO) regulator. 
  - When the power is supplied from a switching power supply, such as an external DC/DC converter, input the power externally or use the 32.768 kHz crystal oscillator. Do not use the on-chip oscillator for the RF slow clock. 
  - Design the circuit such that the highest noise levels do not exceed 100 mV. 
  - When a switching power supply such as an external DC/DC converter is in use with the RF slow clock (on-chip oscillator), apply one of the measures below.
    1. Keep the switching frequency of the switching power supply to no more than 10 Hz or at 200 kHz or above. 
    2. Insert an LDO regulator between the switching power supply and the power supply pin of the RF chip, making sure that this is in compliance with the recommended conditions of usage for the regulator. 

- Separate the VDD_RF, AVDD_RF, and VDD from the power supply pattern.

- AVDD_RF pin wiring
  Make the wiring impedance low.

- Connect the bypass capacitors for the VDD_RF, AVDD_RF, and VDD pins close to the power supply pins.

Figure 5 shows an example of how to place the bypass capacitors.

![Figure 5 Example of bypass capacitor connection](image)

Note) Noise varies depending on the board mounting. Add bypass capacitors as required.
5.2 Ground pattern

Note the following when designing the ground pattern.

- Design the pattern so that the power supply and ground layers are on as wide a plane as possible.
- Place the ground plane for shielding as far from the oscillator as possible.
- Place as many vias as possible and short the pins with the ground pins on other layers so as to keep the impedance low.
- Earth the three MCU ground pins, AVSS_RF, and VSS_RF, separately.
- Connect the exposed die pad of QFN packages to the AVSS_RF pin. Make the impedance on this ground low.
6. Circuit diagram for reference

Figure 6 shows a reference circuit diagram.
### 7. Parts list for reference

Table 3 lists the parts.

#### Table 3 Parts list (for reference)

<table>
<thead>
<tr>
<th>No.</th>
<th>Mount Quantity</th>
<th>Mount Parts Reference</th>
<th>Size code (mm)</th>
<th>Type</th>
<th>Parts number</th>
<th>Manufacturer</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>IC1</td>
<td>RL78/G1D chip</td>
<td>Chip ceramic cap</td>
<td>R5F11AGJ</td>
<td>Renesas</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>C1</td>
<td>1005</td>
<td>Chip ceramic cap</td>
<td>GRM155R61A225KE95 2.2µF/10V</td>
<td>Murata</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>C2</td>
<td>1005</td>
<td>Chip ceramic cap</td>
<td>GRM155C1H8R5CA01 8.5pF/50V</td>
<td>Murata</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>C3</td>
<td>1005</td>
<td>Chip ceramic cap</td>
<td>GRM155C1H8R0CA01 8.0pF/50V</td>
<td>Murata</td>
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<tr>
<td>5</td>
<td>2</td>
<td>C4, C7</td>
<td>1005</td>
<td>Chip ceramic cap</td>
<td>GRM155R61E104KA87 0.1µF/25V</td>
<td>Murata</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>C5</td>
<td>1005</td>
<td>Chip ceramic cap</td>
<td>C1005X5R0J106MT 10µF/6.3V</td>
<td>TDK</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>C6</td>
<td>1005</td>
<td>Chip ceramic cap</td>
<td>GRM155B31A474KE14 0.47µF/10V</td>
<td>Murata</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>C8</td>
<td>1005</td>
<td>Chip ceramic cap</td>
<td>GRM155C1H150GA01 15pF/50V</td>
<td>Murata</td>
</tr>
<tr>
<td>9</td>
<td>1</td>
<td>C9</td>
<td>1005</td>
<td>Chip ceramic cap</td>
<td>GRM155C1H180GA01 18pF/50V</td>
<td>Murata</td>
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<td>10</td>
<td>1</td>
<td>L1</td>
<td>1608</td>
<td>Inductor</td>
<td>MLZ1608N100LT 10µH</td>
<td>TDK</td>
</tr>
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<td>11</td>
<td>1</td>
<td>X1</td>
<td>1612</td>
<td>Crystal</td>
<td>NX1612SA-32.000MHz-CHP-CIS-3 (-40 to +85 °C)</td>
<td>NDK</td>
</tr>
<tr>
<td>12</td>
<td>1</td>
<td>X2</td>
<td>2012</td>
<td>Crystal</td>
<td>TFX-03 32.768kHz 9pF/±20ppm (-40 to +85 °C)</td>
<td>River Eletec</td>
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<td>13</td>
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<td>R1</td>
<td>1005</td>
<td>Chip resistor</td>
<td>RK73B1ETTP102J 1kΩ</td>
<td>KOA</td>
</tr>
<tr>
<td>14</td>
<td>1</td>
<td>R2</td>
<td>1005</td>
<td>Chip resistor</td>
<td>RK73B1ETTP103J 10kΩ</td>
<td>KOA</td>
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<tr>
<td>15</td>
<td>1</td>
<td>R3</td>
<td>1005</td>
<td>Chip resistor</td>
<td>RK73H1ETTP6804F 6.8MΩ</td>
<td>KOA</td>
</tr>
</tbody>
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Website and Support

Renesas Electronics Website
http://www.renesas.com/

Inquiries
http://www.renesas.com/contact/

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## Revision History

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<tr>
<td></td>
<td></td>
<td>3</td>
<td>Notes add, [Figure 2 Pattern example of around the crystal resonator] added</td>
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<td></td>
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<td>4</td>
<td>[Table 2 Tested crystal oscillator List (Reference)] added</td>
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<tr>
<td></td>
<td></td>
<td>6</td>
<td>Notes wording change, [Figure 4 Pattern of feedback loop of DC-DC converter] added</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10</td>
<td>modification of manufacturer's name of X1, R3's Model and manufacturer name changes</td>
</tr>
<tr>
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<td>Re-numbering to entire Caption</td>
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<tr>
<td>1.30</td>
<td>Dec 16, 2016</td>
<td>4</td>
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<td></td>
<td></td>
<td>7</td>
<td>Add description about noise of power supply pin to [5.1 Power supply]</td>
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</table>
General Precautions in the Handling of MPU/MCU Products

The following usage notes are applicable to all MPU/MCU 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. 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 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. Unused pins should be handled as described under Handling of Unused Pins in the manual.

2. Processing at Power-on
   The state of the product is undefined at the moment 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 moment 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 moment 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 moment when power is supplied until the power reaches the level at which resetting has been specified.

3. Prohibition of Access to Reserved Addresses
   Access to reserved addresses is prohibited.
   - The reserved addresses are provided for the possible future expansion of functions. Do not access these addresses; the correct operation of LSI is not guaranteed if they are accessed.

4. Clock Signals
   After applying a reset, only release the reset line after the operating clock signal has become stable.
   When switching the clock signal during program execution, wait until the target clock signal has 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.
     Moreover, 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.

5. Differences between Products
   Before changing from one product to another, i.e. to a product with a different part number, confirm that the change will not lead to problems.
   - The characteristics of an MPU or MCU in the same group but having a different part number may differ in terms of the 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.
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SALES OFFICES

Renesas Electronics Corporation http://www.renesas.com

Renesas Electronics Americas Inc.,
2501 Scott Boulevard Santa Clara, CA 95050-2549, U.S.A.
Tel: +1-408-588-6000, Fax: +1-408-588-6130

Renesas Electronics Canada Limited
9251 Yonge Street, Suite 8309 Richmond Hill, Ontario Canada L4C 9T3
Tel: +1-905-237-2004

Renesas Electronics Europe Limited
Dukes Meadow, Millboard Road, Bourne End, Buckinghamshire, SL8 5FH, U.K
Tel: +44-1428-585-100, Fax: +44-1428-585-900

Renesas Electronics Europe GmbH
Arndtstrasse 10, 40472 Düsseldorf, Germany
Tel: +49-211-6503-0, Fax: +49-211-6503-1327

Renesas Electronics (China) Co., Ltd.
Room 1709, Quantum Plaza, No.27 Zhonglu, Haidian District, Beijing 100191, P.R.China
Tel: +86-10-8235-1155, Fax: +86-10-8235-7679

Renesas Electronics (Shanghai) Co., Ltd.
Unit 201, Tower A, Central Towers, 505 Laneag Road, Putuo District, Shanghai, P. R. China 200333
Tel: +86-21-2226-0888, Fax: +86-21-2226-0999

Renesas Electronics Hong Kong Limited
Unit 1601-1611, 16/F., Tower 2, Grand Century Place, 193 Prince Edward Road West, Mong Kok, Kowloon, Hong Kong
Tel: +852-2266-6668, Fax: +852-2886-9022

Renesas Electronics Taiwan Co., Ltd.
13F., No. 263, Fu Shing North Road, Taipei 10543, Taiwan
Tel: +886-2-8175-9600, Fax: +886-2-8175-9670

Renesas Electronics Singapore Pte. Ltd.
80 Bendemeer Road, Unit 06-02 Hyflux Innovation Centre, Singapore 339949
Tel: +65-6213-0200, Fax: +65-6213-0300

Renesas Electronics Malaysia Sdn.Bhd.
Unit 1207, Block B, Menara Amcorp, Amcorp Trade Centre, No. 18, Jln Periaran Barat, 46050 Petaling Jaya, Selangor Darul Ehsan, Malaysia
Tel: +60-3-6213-0300, Fax: +60-3-7955-9510

Renesas Electronics India Pvt. Ltd.
No.777C, 100 Feet Road, HAL Stage, Indiranagar, Bangalore, India
Tel: +91-40-67208700, Fax: +91-40-67208777

Renesas Electronics Korea Co., Ltd.
12F., 234 Teheran-ro, Gangnam-Gu, Seoul, 135-080, Korea
Tel: +82-2-585-3737, Fax: +82-2-585-5141

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