RA2L1 Group
Capacitive Touch Low Power Guide

Introduction
This application note explains Capacitive Touch measurement that uses the Asynchronous General-Purpose Timer (AGT) function and Low power mode (Software Standby mode, Snooze mode) installed in RA2L1.

Target Device
RA2L1
Contents

1. Specification .................................................................................................................. 3
   1.1 Project description ................................................................................................. 3
   1.2 Used Peripherals ................................................................................................. 3
   1.3 CPU Operation Mode ......................................................................................... 3
   1.4 CTSU Operation Status .................................................................................... 3
   1.5 Register settings ................................................................................................. 4
   1.6 File Configuration ............................................................................................... 4

2. Operation Conditions ..................................................................................................... 5

3. Software Description ..................................................................................................... 6
   3.1 Operation image .................................................................................................. 6
   3.2 FSP driver and middleware .............................................................................. 6
   3.3 List of Variables ............................................................................................... 7
   3.4 List of Functions ............................................................................................... 7
      3.4.1 qe_touch_main () ....................................................................................... 7
      3.4.2 r_captouch_low_power_scan () ............................................................... 8
      3.4.3 r_captouch_low_power_disable_rtc () ..................................................... 8

4. Flowcharts ..................................................................................................................... 9
   4.1 qe_touch_main () .............................................................................................. 9
   4.2 r_captouch_low_power_scan () ........................................................................ 10
   4.3 r_captouch_low_power_disable_rtc () ............................................................ 11

5. Current consumption .................................................................................................... 12
   5.1 Operation Conditions ....................................................................................... 13
   5.2 Equipment and Software ................................................................................... 14
   5.3 RA2L1 Cap Touch CPU board jumper settings .................................................. 14
   5.4 RA2L1 Cap Touch CPU board ......................................................................... 15
      5.4.1 RA2L1 Cap Touch CPU board - front .................................................... 15
      5.4.2 RA2L1 Cap Touch CPU board - back .................................................... 15
   5.5 Environment to measure current consumption .................................................. 16
   5.6 Setting to measure current consumption ............................................................ 16
   5.7 Current Consumption Measurement Results ..................................................... 17
   5.8 Current Consumption Calculation Results ......................................................... 18

6. References ..................................................................................................................... 19

Revision History ............................................................................................................... 20
1. Specification

1.1 Project description
Sample code that this application note describes is confirmed to operate on the Capacitive Touch Evaluation System for RA2L1 MCU Group (RTK0EG0022S01001BJ). The setting of this project is adjusted to R7FA2L1AB2DFP implemented on Capacitive Touch Evaluation System for RA2L1 Group. Modify the device setting in the project when you use the other device.

1.2 Used Peripherals
Table 1-1 lists the used peripherals in the sample code.

<table>
<thead>
<tr>
<th>Used Peripherals</th>
<th>Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacitive Touch Sensing Unit (CTSU)</td>
<td>Measures electrostatic capacitance of the touch sensor.</td>
</tr>
<tr>
<td>Data Transfer Controller (DTC)</td>
<td>Transfers CTSUSO setting value in RAM to CTSU register.</td>
</tr>
<tr>
<td></td>
<td>Transfers CTSUSC counter in CTSU register to RAM.</td>
</tr>
<tr>
<td>Asynchronous General-Purpose Timer (AGT)</td>
<td>- Timer used to cancel Software Standby mode.</td>
</tr>
<tr>
<td>Event Link Controller (ELC)</td>
<td>- Starts CTSU measurement by Snooze entry.</td>
</tr>
</tbody>
</table>

1.3 CPU Operation Mode
Table 1-2 lists CPU mode used in this sample code.

<table>
<thead>
<tr>
<th>CPU operation mode</th>
<th>Transition condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Snooze mode</td>
<td>- Transition from AGT counter underflow in Software Standby mode</td>
</tr>
<tr>
<td>Normal mode (Touch measurement End process and Touch On/Off detection process and Touch measurement Start process)</td>
<td>- Transition from CTSU measurement end interrupt in Snooze mode</td>
</tr>
<tr>
<td>Software Standby mode</td>
<td>- Transition by API of r_lpm driver</td>
</tr>
</tbody>
</table>

1.4 CTSU Operation Status
Table 1-3 lists CTSU operation status used in this sample code.

<table>
<thead>
<tr>
<th>CTSU Operation Status</th>
<th>Transition condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating</td>
<td>- Touch measurement start</td>
</tr>
<tr>
<td>Suspended</td>
<td>- Touch measurement stop</td>
</tr>
</tbody>
</table>
1.5 Register settings

Register settings changed from the reset value are shown below.

Table 1-4 Register settings

<table>
<thead>
<tr>
<th>Function</th>
<th>Register</th>
<th>Value</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>I/O Ports</td>
<td>P108PFS</td>
<td>0x00000000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>P110PFS</td>
<td>0x00000000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>P112PFS</td>
<td>0x00000000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>P201PFS</td>
<td>0x00000000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>P204PFS</td>
<td>0x00000000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>P300PFS</td>
<td>0x00000000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>P304PFS</td>
<td>0x00000000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>P306PFS</td>
<td>0x00000000</td>
<td></td>
</tr>
<tr>
<td>Realtime Clock</td>
<td>RCR2</td>
<td>0x00</td>
<td>Set according to 22.6.7 &quot;Initialization Procedure When RTC Is Not to Be Used&quot; in RA2L1 Group User’s Manual: Hardware</td>
</tr>
<tr>
<td>(RTC)</td>
<td>RCR4</td>
<td>0x01</td>
<td>RCKSEL bit (Count Source Select in normal operation mode): 1 LOCO is selected</td>
</tr>
<tr>
<td>Low Power Modes</td>
<td>SBYCR</td>
<td>0x8000</td>
<td>SSBY bit (Software Standby Mode Select): 1 Software Standby mode</td>
</tr>
<tr>
<td></td>
<td>SNZCR</td>
<td>0x82</td>
<td>RXDREQEN bit (RXD0 Snooze Request Enable): 0 Ignore RXD0 falling edge in Software Standby mode</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>SNZDTCEN bit (DTC Enable in Snooze mode): 1 Enable DTC operation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>SNZE (Snooze mode Enable): 1 Enable Snooze mode</td>
</tr>
<tr>
<td>Clock Generation</td>
<td>SOSCCR</td>
<td>0x01</td>
<td>SOSTP bit (Sub Clock Oscillator Stop): 1 Stop the sub-clock oscillator</td>
</tr>
<tr>
<td>Circuit</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1.6 File Configuration

Table 1-5 lists the file added or changed in the sample code generated by RA configurator and QE for Capacitive Touch.

Table 1-5 Files added or changed in the sample code

<table>
<thead>
<tr>
<th>Name</th>
<th>Outline</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>qe_touch_sample.c</td>
<td>Main processing</td>
<td>Changed file</td>
</tr>
</tbody>
</table>
2. Operation Conditions

This application note confirms operation based on the items and conditions stated below.

Table 2-1 Operation Conditions

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCU</td>
<td>R7FA2L1AB2DFP (RA2L1 Group)</td>
</tr>
<tr>
<td>Operating frequency</td>
<td>32MHz High-speed on-chip oscillator (HOCO)</td>
</tr>
<tr>
<td></td>
<td>32KHz Low-speed on-chip oscillator (LOCO)</td>
</tr>
<tr>
<td>Operating voltage</td>
<td>5.0V</td>
</tr>
<tr>
<td>Target board</td>
<td>RA2L1 MCU Group Capacitive Touch Evaluation System (RTK0EG022S01001BJ)</td>
</tr>
<tr>
<td>Integrated development environment</td>
<td>e² studio (2021-10)</td>
</tr>
<tr>
<td>C compiler</td>
<td>GCC Arm Embedded (9.3.1.20200408)</td>
</tr>
<tr>
<td>Endian</td>
<td>Little endian</td>
</tr>
<tr>
<td>Operation mode</td>
<td>Single chip mode</td>
</tr>
<tr>
<td>Debugger</td>
<td>E2 Emulator Lite</td>
</tr>
<tr>
<td>FSP Version</td>
<td>Ver.3.4.0</td>
</tr>
<tr>
<td>Sample code Version</td>
<td>Ver.1.00</td>
</tr>
</tbody>
</table>
3. Software Description

The sample code operates as follows by using the FSP driver and middleware functions.

1. After reset release by power on, the sample code opens rm_touch middleware.
2. Transit to Software Standby mode.
3. Transit to Snooze mode by AGT counter underflow and start CTSU measurement by Snooze entry.
4. Transit to Normal mode from Snooze mode by CTSU measurement end interrupt.
5. When Touch-On is detected, user LED (LED3) is lit.
6. Repeat from step 2 to step 5.

3.1 Operation image

Figure 3-1 shows CPU operation mode and CTSU operation status according to the process in the sample code.

![Operation image](image)

3.2 FSP driver and middleware

Table 3-1 lists FSP driver and middleware used in the sample code.

<table>
<thead>
<tr>
<th>FSP driver, middleware</th>
<th>Version</th>
</tr>
</thead>
<tbody>
<tr>
<td>Board Support Package (BSP)</td>
<td>3.4.0</td>
</tr>
<tr>
<td>CTSU Driver (r_ctsu)</td>
<td>3.4.0</td>
</tr>
<tr>
<td>Capacitive Touch Middleware (rm_touch)</td>
<td>3.4.0</td>
</tr>
<tr>
<td>I/O Port Driver (r_ioprt)</td>
<td>3.4.0</td>
</tr>
<tr>
<td>Timer Driver (r_agt)</td>
<td>3.4.0</td>
</tr>
<tr>
<td>Low Power Mode Driver (r_lpm)</td>
<td>3.4.0</td>
</tr>
<tr>
<td>Event Link Controller (r_elc)</td>
<td>3.4.0</td>
</tr>
</tbody>
</table>
3.3 List of Variables
Variables added and changed in this sample code are shown below.

Table 3-2 Variables (qe_touch_sample.c)

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Variable name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>uint64_t</td>
<td>button_status</td>
<td>Result of Touch On/Off detection</td>
</tr>
</tbody>
</table>

3.4 List of Functions
The specification for functions added or changed in this sample code are shown below.

3.4.1 qe_touch_main()

**Outline**
Control Touch measurement and low power mode.

**Declaration**

```c
void qe_touch_main (void)
```

**Description**
Controls CTSU measurement and transition to Low power mode.

1. Open r_agt driver.
2. Open r_lpm driver.
3. Open r_elc driver.
4. Enable Event Link.
5. Disable Realtime Clock.
6. When Touch-On is detected, user LED (LED3) is lit.
7. Set external trigger to CTSU Measurement Operation Start Trigger and start CTSU measurement.
8. Start count of AGT.
9. Transit to Software Standby mode and transit to Snooze mode by AGT counter underflow and start CTSU measurement by Snooze entry.
10. Transit to Normal mode from Snooze mode by CTSU measurement end interrupt.
11. Stop count of AGT.
12. Repeat from step 6 to step 11.

**Argument**
-

**Return value**
-
### 3.4.2 r_captouch_low_power_scan

**r_captouch_low_power_scan ()**

**Outline**
Control touch measurement

**Declaration**
void r_captouch_low_power_scan (void)

**Description**
Controls touch measurement.
1. Start touch measurement.
2. Start count of AGT.
3. Transit to Software Standby mode.
4. Stop AGT count.

**Argument**
-

**Return value**
-

---

### 3.4.3 r_captouch_low_power_disable_rtc

**r_captouch_low_power_disable_rtc ()**

**Outline**
Disable RTC

**Declaration**
void r_captouch_low_power_disable_rtc (void)

**Description**
Initialize RTC registers.

**Argument**
-

**Return value**
-
4. Flowcharts

4.1 qe_touch_main()

Flowchart is shown below.

![Flowchart of qe_touch_main()](image)

Figure 4-1 qe_touch_main()
4.2 r_captouch_low_power_scan ()

Flowchart is shown below.

![Flowchart](image-url)

Figure 4-2 r_captouch_low_power_scan ()
4.3  r_captouch_low_power_disable_rtc ()

Flowchart is shown below.

Figure 4-3 r_captouch_low_power_disable_rtc ()
5. Current consumption

The system configuration in the following red box shows a model of the electrostatic capacitive touch low power consumption operation described in this application note.

Measure Capacitive Touch in low power mode
(100ms cycle)

Touch the power button

Transition to normal measurement from low power measurement by touch the power button and start to measure all button with 20ms cycle.

Figure 5-1 Model of the electrostatic capacitive touch low power consumption operation
5.1 Operation Conditions
Table 5-1 shows operation condition.

Table 5-1 Operation Conditions

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating frequency</td>
<td>32MHz High-speed on-chip oscillator (HOCO) 32KHz Low-speed on-chip oscillator (LOCO)</td>
</tr>
<tr>
<td>System clock (ICLK)</td>
<td>1MHz</td>
</tr>
<tr>
<td>Peripheral module clock B (PCLKB)</td>
<td>1MHz</td>
</tr>
<tr>
<td>Peripheral module clock D (PCLKD)</td>
<td>1MHz</td>
</tr>
<tr>
<td>Internal Clock Supply Architecture Type</td>
<td>Internal Clock Supply Architecture Type B</td>
</tr>
<tr>
<td>Capacitive Touch measurement cycle</td>
<td>100ms</td>
</tr>
<tr>
<td>Sensor drive pulse frequency</td>
<td>2MHz</td>
</tr>
<tr>
<td>Capacitance measurement pin</td>
<td>TS11-CFC</td>
</tr>
<tr>
<td>Active shield control pin</td>
<td>TS00</td>
</tr>
<tr>
<td>CTSU Measurement Mode</td>
<td>Self-capacitance method</td>
</tr>
<tr>
<td>CTSU Scan Mode</td>
<td>Multi-scan mode</td>
</tr>
<tr>
<td>CTSU Measurement Operation Start Trigger Select</td>
<td>External trigger</td>
</tr>
<tr>
<td>CTSU Wait State Power-Saving Enable</td>
<td>Enable power-saving function during wait state.Id</td>
</tr>
<tr>
<td>CTSU Power Supply Operating Mode</td>
<td>Normal voltage operating mode</td>
</tr>
<tr>
<td>CTSU Current Range Adjustment</td>
<td>40µA</td>
</tr>
<tr>
<td>CTSU Non-Measured Channel Output</td>
<td>Output a pulse in phase with the transmit channel</td>
</tr>
<tr>
<td>Wait Time Sensor Stabilization</td>
<td>64µs (Recommended value)</td>
</tr>
<tr>
<td>CTSU Measurement Count</td>
<td>7 times</td>
</tr>
</tbody>
</table>
5.2 Equipment and Software

Table 5-2 shows equipment and software used in current consumption measurement.

<table>
<thead>
<tr>
<th>Type</th>
<th>Name</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digital multi meter</td>
<td>Keithley DM7510</td>
<td>Measure current consumption</td>
</tr>
<tr>
<td>Power supply</td>
<td>KENWOOD PA18-1.2A</td>
<td>Supply power to RA2L1 Cap Touch CPU board</td>
</tr>
<tr>
<td>Software</td>
<td>Keithley KickStart Software</td>
<td>Get result of current consumption measurement from Keithley DM7510 and output the result to log-file.</td>
</tr>
</tbody>
</table>

5.3 RA2L1 Cap Touch CPU board jumper settings

Table 5-3 shows jumper settings of RA2L1 Cap Touch CPU board to measure current consumption.

<table>
<thead>
<tr>
<th>Position</th>
<th>Circuit group</th>
<th>Jumper</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>JP2</td>
<td>Power</td>
<td>Close 1-2 pin</td>
<td>Power supply from DC jack</td>
</tr>
<tr>
<td>JP3</td>
<td>Power</td>
<td>Open</td>
<td>Measure current consumption</td>
</tr>
</tbody>
</table>
5.4 RA2L1 Cap Touch CPU board
The front and back of RA2L1 Cap Touch CPU board are as follows.

5.4.1 RA2L1 Cap Touch CPU board - front

Figure 5-2 RA2L1 Cap Touch CPU board - front

5.4.2 RA2L1 Cap Touch CPU board - back

Figure 5-3 RA2L1 Cap Touch CPU board - back
5.5 Environment to measure current consumption

Figure 5-4 shows environment to measure current consumption.

![Figure 5-4 Environment to measure current consumption](image)

5.6 Setting to measure current consumption

Figure 5-5 shows settings of Keithley KickStart to measure current consumption.

![Figure 5-5 Settings of Keithley KickStart to measure current consumption](image)
5.7 Current Consumption Measurement Results

Figure 5-6 to Figure 5-7 show the current consumption waveforms for a series of operations in which the CPU operation mode transitions to Software Standby mode, Snooze mode (touch measurement processing), and Normal mode (Touch measurement end processing and Touch On/Off judgment processing). Figure 5-6 and Figure 5-7 show the touch measurement at TS pin 1 channel.

![Figure 5-6 Current consumption waveform: TS pin 1ch measurement (1/2)](image)

![Figure 5-7 Current consumption waveform: TS pin 1ch measurement (2/2)](image)
5.8 Current Consumption Calculation Results

The average current consumption of TS pin 1 channel measured with a touch measurement cycle of 100ms is shown below (Figure 5-8).

![Figure 5-8 Operation timing of CTSU](image)

Current consumption (touch measurement cycle of 100ms) = **15.4489 uA**
6. References

User’s Manual: Hardware
RA2L1 User’s Manual Hardware R01UH0853
(The latest version can be downloaded from the Renesas Electronics website.)

Technical Update/Technical News
(The latest version can be downloaded from the Renesas Electronics website.)

User’s Manual: Development Tools
(The latest version can be downloaded from the Renesas Electronics website.)

User’s Manual: RA2L1 MCU Group Capacitive Touch Evaluation System
(The latest version can be downloaded from the Renesas Electronics website.)
## Revision History

<table>
<thead>
<tr>
<th>Rev.</th>
<th>Date</th>
<th>Page</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.00</td>
<td>Dec.17.21</td>
<td>-</td>
<td>First edition issued</td>
</tr>
<tr>
<td>1.10</td>
<td>May.17.22</td>
<td>16,17,18,19</td>
<td>Changed the current measurement method</td>
</tr>
</tbody>
</table>
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.

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 the products, software, or information.

2. Renesas Electronics hereby expressly disclaims any warranties against infringement or liability for any 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 activities.

6. Renesas Electronics products are classified according to the following two quality grades: "Standard" and "High Quality". The intended applications for each Renesas Electronics product depends on the product’s quality grade, as indicated below.

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

   "High Quality": Transportation equipment (automobiles, trains, ships, etc.); traffic control (traffic lights); aircraft; nuclear power control systems; aircraft control systems; key plants; military 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 implants; etc.), or may cause serious property damage (space systems; underwater repeaters; nuclear power control systems; aircraft control systems; key plants; military equipment; etc.). Renesas Electronics disclaims any and all liability for any damages or losses incurred by you or your 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 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 applicable laws and regulations. Renesas Electronics disclaims any and all liability for damages or losses occurring as a result of your noncompliance with applicable laws and regulations.

11. Renesas Electronics products and technologies shall not be used for or incorporated into any products or systems whose manufacture, use, or sale is prohibited under any applicable domestic or foreign laws or regulations. You shall comply with any applicable export control laws and regulations promulgated and administered by the governments of any countries asserting jurisdiction over the parties or transactions.

12. It is the responsibility of the buyer or distributor of Renesas Electronics products, or any other party who distributes, disposes of, or otherwise sells or transfers the product to a third party, to notify such third party in advance of the contents and conditions set forth in this document.

13. This document shall not be reprinted, reproduced or duplicated in any form, in whole or in part, without prior written consent of Renesas Electronics.

14. Please contact a Renesas Electronics sales office if you have any questions regarding the information contained in this document or Renesas Electronics products.

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

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

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

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

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

© 2022 Renesas Electronics Corporation. All rights reserved.