Accelerators (IIRFA/TFU) performance in motor application
RA Family

Abstract
The purpose of this application note is to explain how to use IIRFA and TFU and how to reduce processing time when used.

Operation checking device
Operations of the target software of this application note are checked by using the following device.

IIRFA/TFU
- RA6T2 (R7FA6T2BD3CFP)
- TFU only
- RA4T1 (R7FA4T1BB3CFM)
- RA6T3 (R7FA6T3BB3CFM)

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1. Overview

This application note shows the effect of IIRFA and TFU to reduce processing time. Sample code with IIRFA and TFU and sample code written in C language without them are used to check the processing time.

2. Development environment

Table 2-1 and Table 2-2 show development environment of the software explained in this application note.

Table 2-1 Hardware Development Environment

<table>
<thead>
<tr>
<th>Microcontroller</th>
<th>Evaluation board</th>
</tr>
</thead>
<tbody>
<tr>
<td>RA6T2 (R7FA6T2BD3CFP)</td>
<td>RA6T2 (R7FA6T2BD3CFP) / RTK0EMA270C00000BJ</td>
</tr>
<tr>
<td>RA4T1 (R7FA4T1BB3CFM)</td>
<td>RA4T1 (R7FA4T1BB3CFM) / RTK0EMA430C00000BJ</td>
</tr>
<tr>
<td>RA6T3 (R7FA6T3BB3CFM)</td>
<td>RA6T3 (R7FA6T3BB3CFM) / RTK0EMA330C00000BJ</td>
</tr>
</tbody>
</table>

Table 2-2 Software Development Environment

<table>
<thead>
<tr>
<th>e²studio version</th>
<th>FSP version</th>
<th>Toolchain version</th>
</tr>
</thead>
<tbody>
<tr>
<td>V2023-04</td>
<td>V4.4.0</td>
<td>GCC ARM Embedded: V10.3.1.20210824</td>
</tr>
</tbody>
</table>

For purchase and technical support, please contact Sales representatives and dealers of Renesas Electronics Corporation.
3. Software

Sample software is described below.

IIRFA is not implemented in RA4T1 and RA6T3. Therefore, the explanation about IIRFA is valid only to RA6T2.

3.1 Specifications

IIRFA processing time is measured with filter processing (5-stage notch filter, 1-stage notch filter, and 2nd-order low-pass filter). In the case where IIRFA is not used, the process is implemented with four arithmetic operations in c code.

TFU processing time is measured with the dq conversion process used in vector control.

The following table summarizes the functions of this sample program.

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start measurement</td>
<td>Starts measurement triggered by writing &quot;1&quot; to the measurement start variable from RMW</td>
</tr>
<tr>
<td>Measurement Function</td>
<td>Measurement using GPT</td>
</tr>
</tbody>
</table>
| Filter processing for IIRFA measurement | 5-stage notch filter  
1-stage notch filter  
Second-order low-pass filter |
| Processing for TFU measurement | dq transform in vector control                                              |
| Setting to the IIRFA input register | Set using FSP API (R_IIRFA_Filter)  
Directly set to register |
| Enabling/disabling of IIRFA/TFU | [IIRFA] Measurements when IIRFA is not used are performed by quadrature with c-code.  
[TFU] Enable/disable with compile option |
| Switching of measurement target | Filters (3 types) for IIRFA measurement and TFU are switched by RMW operation |
3.2 Sample Program Structure

Each CPU board is a target of this sample program. This program measures the processing time of IIRFA and TFU with GPT.

An overall diagram is shown below.

![Figure 3-1 Program Structure](image)

3.3 Project Structure

The structure in the project folder of the sample program is shown below.

<table>
<thead>
<tr>
<th>Folder</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ra_cfg</td>
<td>(Auto-generated) configuration file</td>
</tr>
<tr>
<td>ra_gen</td>
<td>(Auto-generated) Register set values, initial values of instance members</td>
</tr>
<tr>
<td>ra</td>
<td>(Auto-generated) FSP source code</td>
</tr>
<tr>
<td>src</td>
<td>Measurement target/measurement process</td>
</tr>
</tbody>
</table>

The file structure in the src folder is shown below.

<table>
<thead>
<tr>
<th>File</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>iir_tfu_main.c</td>
<td>Sample program source code file</td>
</tr>
<tr>
<td>iir_tfu_main.h</td>
<td>Sample program header file</td>
</tr>
</tbody>
</table>
3.4 Processing of Measured Targets

3.4.1 Filter processing for IIRFA measurement (notch filter, LPF)

The processing time of IIRFA is measured as a notch filter or second-order low-pass filter.

The notch filter consists of the following transfer functions.

\[
\frac{s^2 + \frac{\omega_n^2}{Q_2} + \omega_n^2}{s^2 + \frac{\omega_n^2}{Q_1} + \omega_n^2}
\]

The second-order low-pass filter consists of the following transfer functions.

\[
\frac{\omega_n^2}{s^2 + 2\omega_n\zeta_n s + \omega_n^2}
\]

These operations during filter processing are performed by four arithmetic operations using IIRFA and C code.

3.4.2 Processing for TFU measurement (dq conversion)

The processing time of TFU is measured as the dq conversion process in vector control.

The dq transformation is calculated by the following transformation formula.

\[
C = \sqrt{\frac{2}{3}} \begin{bmatrix}
\cos\theta & \cos(\theta - 2\pi/3) & \cos(\theta + 2\pi/3) \\
-sin\theta & -\sin(\theta - 2\pi/3) & -\sin(\theta + 2\pi/3)
\end{bmatrix}
\]

\[
\begin{bmatrix}
v_d \\
v_q
\end{bmatrix} = C \begin{bmatrix}
v_u \\
v_v \\
v_w
\end{bmatrix}
\]

The sin and cos operations during this conversion are performed in each cases of TFU enable or disable.
3.5 Selection of measurement Target

Variables to select the measurement target are listed below.

Table 3-4 Variables for selecting measurement targets

<table>
<thead>
<tr>
<th>Item</th>
<th>Type</th>
<th>Variable name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>uint8_t</td>
<td>g_u1_measure_select</td>
<td>0: IIRFA 5-stage notch filter</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1: IIRFA 1-stage notch filter</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2: IIRFA 2nd order low-pass filter</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3: TFU dq conversion</td>
</tr>
</tbody>
</table>

The executable process is selected according to the value of `g_u1_measure_select`.

3.6 Starting measurements

Variables for starting measurements are listed below.

Table 3-5 Variables for starting measurement

<table>
<thead>
<tr>
<th>Item</th>
<th>Type</th>
<th>Variable name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>uint8_t</td>
<td>g_u1_measure_start</td>
<td>0 : Standby/Stopped measurement</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1: Measurement started</td>
</tr>
</tbody>
</table>

'g_u1_measure_start' is monitored in the main loop to move from the wait state to the measurement process.
3.7 Measurement Processing

The count of free-run timer is read at the beginning and ending of the process. From the difference of these counts and timer clock frequency, the processing time is calculated.

Variables for measurement are shown below.

**Table 3-6 Variables for measurement**

<table>
<thead>
<tr>
<th>Item</th>
<th>Type</th>
<th>Variable name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>At the start of measurement</td>
<td>uint32_t</td>
<td>g_u4_gpt_count_s</td>
<td>Stores timer count value at the start of measurement</td>
</tr>
<tr>
<td>At the end of measurement</td>
<td>uint32_t</td>
<td>g_u4_gpt_count_e</td>
<td>Stores timer count value at the end of measurement</td>
</tr>
<tr>
<td>Measured value</td>
<td>float</td>
<td>g_f4_measure_iir_api</td>
<td>Stores the processing time calculation value when using IIRFA (API)</td>
</tr>
<tr>
<td></td>
<td>float</td>
<td>g_f4_measure_iir_direct</td>
<td>Stores the processing time calculation value when IIRFA (register direct) is used.</td>
</tr>
<tr>
<td></td>
<td>float</td>
<td>g_f4_measure_iir_non</td>
<td>Stores the processing time calculation value when IIRFA is not used</td>
</tr>
<tr>
<td></td>
<td>float</td>
<td>g_f4_measure_dq</td>
<td>Stores the processing time calculation value of dq conversion</td>
</tr>
</tbody>
</table>

The processing time is calculated as follows

\[
\text{Processing time [\mu s]} = \frac{\text{(count at end of measurement - count at start of measurement)}}{\text{GPT clock [MHz]}}.
\]
3.8 Peripheral Functions

The following table shows used peripheral functions.

<table>
<thead>
<tr>
<th>Peripheral</th>
<th>Resource</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>IIRFA</td>
<td>Channel 0, 1, 2</td>
<td>Used for notch filter and second-order low-pass filter operations.</td>
</tr>
<tr>
<td>TFU</td>
<td>-</td>
<td>Used to calculate the sine (sin) and cosine (cos) in a dq conversion</td>
</tr>
<tr>
<td>GPT</td>
<td>Channel 0</td>
<td>Used as a free-run timer to measure processing time</td>
</tr>
<tr>
<td>AGT</td>
<td>AGT0</td>
<td>250[µs] interval timer</td>
</tr>
</tbody>
</table>

The following is a diagram of the entire FSP stack.

3.8.1 IIRFA

3.8.1.1 Configuration

Filter processing is performed as a 5-stage notch filter (stages 0-4), a 1-stage notch filter (stage 5), and a 2nd-order low-pass filter (stage 6).
### 3.8.1.2 IIRFA Filter parameter settings

IIRFA filter configuration is done by setting values in the iir_filter_cfg_t structure and using R_IIRFA_Configure().

R_IIRFA_Configure() takes iir_filter_cfg_t as its argument, and the following settings are used.

- **Notch filter**

  **Table 3-8 Notch filter settings**

<table>
<thead>
<tr>
<th>Structure</th>
<th>Member</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>iir_filter_cfg_t</td>
<td>iir_filter_coeffs_t</td>
<td></td>
</tr>
<tr>
<td></td>
<td>b0</td>
<td>0.9349</td>
</tr>
<tr>
<td></td>
<td>b1</td>
<td>-1.78</td>
</tr>
<tr>
<td></td>
<td>b2</td>
<td>0.9281</td>
</tr>
<tr>
<td></td>
<td>a1</td>
<td>1.78</td>
</tr>
<tr>
<td></td>
<td>a2</td>
<td>-0.863</td>
</tr>
<tr>
<td>stage_base</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>stage_num</td>
<td>5-stages: 5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1-stage: 1</td>
<td></td>
</tr>
</tbody>
</table>

- **Second-order low-pass filter**

  **Table 3-9 Second-order low-pass filter settings**

<table>
<thead>
<tr>
<th>Structure</th>
<th>Member</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>iir_filter_cfg_t</td>
<td>iir_filter_coeffs_t</td>
<td></td>
</tr>
<tr>
<td></td>
<td>b0</td>
<td>0.37334</td>
</tr>
<tr>
<td></td>
<td>b1</td>
<td>2*0.37334</td>
</tr>
<tr>
<td></td>
<td>b2</td>
<td>0.37334</td>
</tr>
<tr>
<td></td>
<td>a1</td>
<td>-0.37334*1.1894</td>
</tr>
<tr>
<td></td>
<td>a2</td>
<td>-0.37334*0.13205</td>
</tr>
<tr>
<td>stage_base</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>stage_num</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>
3.8.1.3 C language Filter parameter settings

The filter coefficients for implementation by C source should be set as follows.

- Notch filter

Table 3-10 Notch filter settings

<table>
<thead>
<tr>
<th>Coefficient name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ka</td>
<td>0.9349</td>
</tr>
<tr>
<td>kb</td>
<td>-1.78</td>
</tr>
<tr>
<td>kc</td>
<td>0.9281</td>
</tr>
<tr>
<td>kd</td>
<td>-0.863</td>
</tr>
</tbody>
</table>

- Second-order low-pass filter

Table 3-11 Second-order low-pass filter settings

<table>
<thead>
<tr>
<th>Coefficient name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ka</td>
<td>0.37334</td>
</tr>
<tr>
<td>kb</td>
<td>1.1894</td>
</tr>
<tr>
<td>kc</td>
<td>0.13205</td>
</tr>
</tbody>
</table>

3.8.1.4 Method of setting input data

For setting input data to IIRFA, two kinds of method can be used to input data into IIRFA (API used or not used).

Table 3-12 Setting Input Data

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>API Used</td>
<td>Data set using R_IIRFA_Filter() (R_IIRFA_Filter() sets a pointer to the input data variable as an argument)</td>
</tr>
<tr>
<td>API not used</td>
<td>Direct data set in R_IIRFA-&gt;IIRCH[g_iirfa0_ctrl.channel].INP (Write input data value to the above register)</td>
</tr>
</tbody>
</table>
3.8.2 TFU
TFU is used for trigonometric operations (sine, cosine) in dq conversion.

![TFU enable/disable setting](figure3-4)

3.8.3 GPT
GPT is used for a free-run timer to measure processing time.

![FSP configuration for GPT](figure3-5)
### 3.8.4 AGT

AGT is used as interval timer for processing RMW communication.

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter Checking</td>
<td>Default (BSP)</td>
</tr>
<tr>
<td>Pin Output Support</td>
<td>Disabled</td>
</tr>
<tr>
<td>Pin Input Support</td>
<td>Disabled</td>
</tr>
<tr>
<td>Module g_timer1 Timer, Low-Power (r_agt)</td>
<td></td>
</tr>
<tr>
<td>Name</td>
<td>g_timer1</td>
</tr>
<tr>
<td>Channel</td>
<td>0</td>
</tr>
<tr>
<td>Mode</td>
<td>Periodic</td>
</tr>
<tr>
<td>Period</td>
<td>250</td>
</tr>
<tr>
<td>Period Unit</td>
<td>Microseconds</td>
</tr>
<tr>
<td>Count Source</td>
<td>PCLKB</td>
</tr>
<tr>
<td>Output</td>
<td></td>
</tr>
<tr>
<td>Input</td>
<td></td>
</tr>
<tr>
<td>Interrupts</td>
<td></td>
</tr>
<tr>
<td>Pins</td>
<td></td>
</tr>
<tr>
<td>AGTEE0</td>
<td>&lt;unavailable&gt;</td>
</tr>
<tr>
<td>AGTIO0</td>
<td>&lt;unavailable&gt;</td>
</tr>
<tr>
<td>AGTO0</td>
<td>&lt;unavailable&gt;</td>
</tr>
<tr>
<td>AGTOA0</td>
<td>&lt;unavailable&gt;</td>
</tr>
<tr>
<td>AGTOB0</td>
<td>&lt;unavailable&gt;</td>
</tr>
</tbody>
</table>

**Figure 3-6 FSP configuration for AGT**
4. Measurement procedure

This section describes the procedure for measuring processing time.

4.1 Importing the Demo Project

The sample application provided with this document may be imported into e²studio using the steps in this section.

1) Select File → Import.

![Figure 4-1 File Menu]

Figure 4-1 File Menu
2) Select “Existing Projects into Workspace”.

![Figure 4-2 Import Wizard Selection](image)

3) input the path.

Click “Browse...” button and select the demo project. Click ‘Finish’ button, then the sample project is imported.

![Figure 4-3 Import Projects](image)
4.2 TFU
Enable/Disable TFU.
Select the [BSP] - ["CPU Name" Family] - [TFU Mathlib] setting.
Enable: Enable
Disable: Disable

![TFU Settings Table]

**Figure 4-4 Enable/Disable TFU**

4.3 Build and Download
Build and download the program.
Refer to the “e²studio Getting Started Guide (R20UT4204)”. 
4.4 RMW connections

Renesas Motor Workbench, a motor control development support tool, is used as a user interface (for Start of measurement and check of measurement results). Renesas Motor Workbench (RMW) can be downloaded from our website.

![Figure 4-5  Windows of Renesas Motor Workbench](image)

**How to use Renesas Motor Workbench (motor control development support tool)**

- Click the icon to start the tool.
- On the menu bar of the Main Window, select [File] > [Open RMT File].
  - The RMT file in the "rmw" folder in the project folder is loaded.
- In the [Connection] area, from the [COM] drop-down list, select the COM of the connected kit.
- In the [Select Tool] area, click the [Analyzer] button to open the Analyzer Window.

**What is the RMT file?**

- The RMT file is a file that stores the environmental information that was manipulated or configured by using RMW.
- If the environmental information has been saved in the RMT file, the environment can be restored with the saved information by calling the RMT file.
- If the address information of a program is changed, load the map file that was generated during program building, and then save the RMT file again.
4.5 Performing Measurements

4.5.1 Selection of measurement target

Write defined values for each measurement target into the variable which is provided for measurement target selection from RMW according to the following table.

Variable to select measured target: g_u1_measure_select

<table>
<thead>
<tr>
<th>No</th>
<th>Target of measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>IIRFA 5-stage notch filter</td>
</tr>
<tr>
<td>1</td>
<td>IIRFA 1-stage notch filter</td>
</tr>
<tr>
<td>2</td>
<td>IIRFA 2nd order low pass filter</td>
</tr>
<tr>
<td>3</td>
<td>TFU dq conversion</td>
</tr>
</tbody>
</table>

(1) Enter the value to be measured in g_u1_measure_select
(2) Click "Write"

![Figure 4-6 Selection of measurement target](image-url)
4.5.2 Start of measurement

Write "1" to the variable for starting measurement from RMW to start measurement.
Variable for starting measurement: g_u1_measure_start

(1) Enter 1 in g_u1_measure_start
(2) Click Write

![Figure 4-7 Start of measurement](image)

4.5.3 Confirmation of measurement results

Confirm the measurement result (measured period) by reading defined variables as shown below on RMW.

Table 4-2 Variables for measurement

<table>
<thead>
<tr>
<th>Variables</th>
<th>Discription</th>
</tr>
</thead>
<tbody>
<tr>
<td>g_f4_measure_iir_api</td>
<td>Stores the processing time calculation value [us] when using IIRFA (API)</td>
</tr>
<tr>
<td>g_f4_measure_iir_direct</td>
<td>Stores the processing time calculation value [us] when using IIRFA (register direct)</td>
</tr>
<tr>
<td>g_f4_measure_iir_non</td>
<td>Stores the processing time calculation value [us] when IIRFA is not used</td>
</tr>
<tr>
<td>g_f4_measure_dq</td>
<td>Stores the processing time calculation value [us] of dq conversion</td>
</tr>
</tbody>
</table>

(1) Click Read
(2) Confirm the measured value
(1) Click “Read” button

(2) Check each measurement

Figure 4-8 Confirmation of measured values
4.6 Measurement results

Measured results with using the sample program are shown below.

- IIRFA

Table 4-3 Measurement results (IIRFA) [us]

<table>
<thead>
<tr>
<th>Filter</th>
<th>processing method</th>
<th>C source</th>
<th>API Used</th>
<th>API not used</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-stage notch filter</td>
<td></td>
<td>5.13</td>
<td>1.06</td>
<td>0.24</td>
</tr>
<tr>
<td>1-stage notch filter</td>
<td></td>
<td>1.23</td>
<td>0.95</td>
<td>0.22</td>
</tr>
<tr>
<td>2nd order low-pass filter</td>
<td></td>
<td>0.71</td>
<td>0.95</td>
<td>0.22</td>
</tr>
</tbody>
</table>

![Figure 4-9 Measurement results (IIRFA)](image-url)
Table 4-4 Measurement results (TFU) [μs]

<table>
<thead>
<tr>
<th>Measured target</th>
<th>Target MCU</th>
<th>TFU disabled</th>
<th>TFU enabled</th>
</tr>
</thead>
<tbody>
<tr>
<td>dq transformation</td>
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<td>0.71</td>
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<td></td>
<td>RA4T1</td>
<td>5.74</td>
<td>1.63</td>
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<td>RA6T3</td>
<td>3.17</td>
<td>0.92</td>
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Figure 4-10 Measurement results (TFU)
5. Reference Documents

RA6T2 Group User’s Manual: Hardware (R01UH0951)
RA4T1 Group User’s Manual: Hardware (R01UH0999)
RA6T3 Group User’s Manual: Hardware (R01UH0998)
RA Flexible Software Package Documentation
Renesas Motor Workbench User’s Manual (R21UZ0004)
Renesas Motor Workbench Quick start guide (R21QS0011)
MCK-RA6T2 User’s Manual (R12UZ0091)
MCK-RA4T1 User’s Manual (R12UZ0117)
MCK-RA6T3 User’s Manual (R12UZ0116)
## Revision History

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<th>Description</th>
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<td>May 23, 2023</td>
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<td>First edition issued</td>
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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.
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TOYOSU FORESSIA, 3-2-24 Toyosu,
Koto-ku, Tokyo 135-0061, Japan
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