RX671 Group

Using FLL to Boost HOCO Frequency Accuracy

Introduction
This application note explains the use of the frequency locked loop (FLL) function to boost the frequency accuracy of the high-speed on-chip oscillator (HOCO) and describes the provided sample code that uses the clock frequency accuracy measurement circuit (CAC) to measure the HOCO frequency with the FLL enabled and confirm that the frequency error is within the acceptable range.

Target Device
RX671 Group

When using this application note with other Renesas MCUs, careful evaluation is recommended after making modifications to comply with the alternate MCU.
1. Specifications

Enabling the FLL boosts the HOCO frequency accuracy by using the subclock to apply correction to the HOCO. The sample program accompanying this application note confirms that the HOCO frequency error is within the acceptable range before using the HOCO with FLL enabled for the main processing. In addition, this application note shows how to use the CAC to measure the HOCO frequency.

2. Operation Confirmation Environment

2.1 Operation Confirmation Conditions

The operation of the sample code accompanying this application note has been confirmed under the conditions listed in Table 2.1.

Table 2.1 Operation Confirmation Conditions

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCU used</td>
<td>R5F5671EHDFB (RX671 Group)</td>
</tr>
<tr>
<td>Operating frequencies</td>
<td>• HOCO: 20 MHz</td>
</tr>
<tr>
<td></td>
<td>• Subclock: 32.768 kHz</td>
</tr>
<tr>
<td></td>
<td>• Oscillator drive capacity (standard CL)</td>
</tr>
<tr>
<td></td>
<td>• System clock (ICLK): 20 MHz (HOCO × 1)</td>
</tr>
<tr>
<td>Operating voltage</td>
<td>3.3 V</td>
</tr>
<tr>
<td>Integrated development environment</td>
<td>Renesas Electronics</td>
</tr>
<tr>
<td></td>
<td>e² studio Version: 2021-07</td>
</tr>
<tr>
<td>C compiler</td>
<td>Renesas Electronics</td>
</tr>
<tr>
<td></td>
<td>C/C++ Compiler Package for RX Family V3.03.00</td>
</tr>
<tr>
<td></td>
<td>Compile option</td>
</tr>
<tr>
<td></td>
<td>Default settings of integrated development environment</td>
</tr>
<tr>
<td>BSP module version</td>
<td>Version 6.11</td>
</tr>
<tr>
<td>CAC module version</td>
<td>Version 1.9.0</td>
</tr>
<tr>
<td>iodename.h version</td>
<td>Version 1.00</td>
</tr>
<tr>
<td>Endian order</td>
<td>Little endian</td>
</tr>
<tr>
<td>Operating mode</td>
<td>Single-chip mode</td>
</tr>
<tr>
<td>Processor mode</td>
<td>Supervisor mode</td>
</tr>
<tr>
<td>Sample code version</td>
<td>Version 1.00</td>
</tr>
<tr>
<td>Board used</td>
<td>Renesas Starter Kit+ for RX671 (product No.: RTK55671EDC10000BJ)</td>
</tr>
</tbody>
</table>

3. Related Application Note

An application note related to this application note is listed below. Refer to it in conjunction with this document.

RX Family Board Support Package Module Using Firmware Integration Technology (R01AN1685EJ)
4. Software

4.1 Operation Overview

The sample program accompanying this application note uses code output by Smart Configurator.

The BSP clock_source_select function is used to make FLL settings. After this, the CAC is used to measure the HOCO frequency and the frequency accuracy is checked. Table 4.1 lists the clocks used by the CAC.

Frequency measurement starts after a reset and is performed four times consecutively. CAC_BUSY is stored in the variable g_cac_status while measurement is taking place.

The mean of the four measurements is used as the measurement result for confirming whether the frequency error is within the acceptable range. The program described in this application note uses “within ±0.25% of the clock frequency” as the acceptable range for the HOCO frequency. The method used to check whether the frequency error is within the acceptable range is to compare the measurement result to the values set in the CAC upper-limit value setting register (CAULVR) and CAC lower-limit value setting register (CALLVR).

The clock frequency error is within the acceptable range when CALLVR register value ≤ measurement result ≤ CAULVR register value, so such a result is judged to be normal. In this case, CAC_OK is stored in the variable g_cac_status.

The clock frequency error is outside the acceptable range when measurement result < CALLVR register value or measurement result > CAULVR register value, so such a result is judged to be abnormal. In this case, CAC_ERROR is stored in the variable g_cac_status.

Table 4.1 Clocks Used by CAC

<table>
<thead>
<tr>
<th>Clock</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurement reference clock</td>
<td>0.000032 MHz (subclock (32.768 kHz) × 1/1,024)</td>
</tr>
<tr>
<td>Measurement target clock</td>
<td>0.625 MHz (HOCO (20 MHz) × 1/32)</td>
</tr>
</tbody>
</table>
### 4.2 BSP Settings

Table 4.2 and Figure 4.1 show the BSP settings specified in Smart Configurator. Note that the default values are used for settings not listed in Table 4.2.

#### Table 4.2 Modified Clock Settings

<table>
<thead>
<tr>
<th>Clock</th>
<th>Frequency</th>
<th>Setting Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subclock</td>
<td>Frequency</td>
<td>32.768 kHz</td>
</tr>
<tr>
<td></td>
<td>Oscillator drive capacity</td>
<td>Standard CL</td>
</tr>
<tr>
<td>HOCO</td>
<td>Frequency</td>
<td>20 MHz</td>
</tr>
<tr>
<td></td>
<td>Enable FLL function</td>
<td>Enabled</td>
</tr>
<tr>
<td>System clock</td>
<td>Frequency</td>
<td>20 MHz</td>
</tr>
<tr>
<td></td>
<td>Clock source</td>
<td>HOCO × 1</td>
</tr>
</tbody>
</table>

![Figure 4.1 Clock Settings in Smart Configurator](image-url)
4.3 CAC Settings

Table 4.3 and Figure 4.2 show the CAC settings specified in Smart Configurator.

### Table 4.3 Modified CAC Settings

<table>
<thead>
<tr>
<th>Main Item</th>
<th>Subitem</th>
<th>Setting Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurement reference setting</td>
<td>Clock select</td>
<td>Sub-clock</td>
</tr>
<tr>
<td></td>
<td>Frequency</td>
<td>1/1,024 (0.000032 MHz)</td>
</tr>
<tr>
<td></td>
<td>Digital filter selection</td>
<td>Disabled</td>
</tr>
<tr>
<td></td>
<td>Valid edge</td>
<td>Rising</td>
</tr>
<tr>
<td>Measurement target setting</td>
<td>Clock select</td>
<td>HOCO clock</td>
</tr>
<tr>
<td></td>
<td>Frequency</td>
<td>1/32 (0.625 MHz)</td>
</tr>
<tr>
<td>Counter value comparison setting</td>
<td>Maximum positive deviation</td>
<td>0.25%</td>
</tr>
<tr>
<td></td>
<td>Maximum negative deviation</td>
<td>0.25%</td>
</tr>
<tr>
<td>Interrupt setting</td>
<td>Enable frequency error interrupt (FERRI)</td>
<td>Unchecked</td>
</tr>
<tr>
<td></td>
<td>Enable measurement end interrupt (MENDI)</td>
<td>Level 15 (highest)</td>
</tr>
<tr>
<td></td>
<td>Enable overflow interrupt (OVFI)</td>
<td>Unchecked</td>
</tr>
</tbody>
</table>

![Figure 4.2 CAC Settings in Smart Configurator](image-url)
4.4 File Structure
Table 4.4 lists the file containing the sample code. Note that files generated by the integrated development environment are omitted.

Table 4.4 Sample Code File

<table>
<thead>
<tr>
<th>File Name</th>
<th>Description</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>main.c</td>
<td>Main processing</td>
<td></td>
</tr>
</tbody>
</table>

4.5 Option Setting Memory
Table 4.5 lists the status of the option setting memory used by the sample code. Settings should be optimized for the user system as necessary.

Table 4.5 Option Setting Memory Used by Sample Code

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Address</th>
<th>Setting Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MDE</td>
<td>FE7F 5D03h to FE7F 5D00h</td>
<td>FFFF FFFFh</td>
<td>Little-endian</td>
</tr>
<tr>
<td>OFS0</td>
<td>FE7F 5D07h to FE7F 5D04h</td>
<td>FFFF FFFFh</td>
<td>Voltage monitor 0 reset disabled after a reset HOCO oscillation disabled after a reset</td>
</tr>
<tr>
<td>OFS1</td>
<td>FE7F 5D08h to FE7F 5D08h</td>
<td>FFFF FFFFh</td>
<td>IWDT stopped after a reset</td>
</tr>
</tbody>
</table>
4.6 Constants
Table 4.6 and Table 4.7 list the constants used in the sample code.

Table 4.6 Constants Used in Sample Code (Modifiable by User)

<table>
<thead>
<tr>
<th>Constant Name</th>
<th>Setting Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHECK_CNT</td>
<td>4</td>
<td>Frequency measurement count*1</td>
</tr>
</tbody>
</table>

Note: 1. Only set a value between 1 and 255.

Table 4.7 Constants Used in Sample Code (Not Modifiable by User)

<table>
<thead>
<tr>
<th>Constant Name</th>
<th>Setting Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAC_ERROR</td>
<td>0x00</td>
<td>Frequency measurement result is abnormal.</td>
</tr>
<tr>
<td>CAC_OK</td>
<td>0x01</td>
<td>Frequency measurement result is normal.</td>
</tr>
<tr>
<td>CAC_BUSY</td>
<td>0x02</td>
<td>Frequency measurement is in progress.</td>
</tr>
</tbody>
</table>

4.7 Variables
Table 4.8 and Table 4.9 list the global variables used in the sample code.

Table 4.8 Global Variables Used in Sample Code

<table>
<thead>
<tr>
<th>Type</th>
<th>Variable Name</th>
<th>Description</th>
<th>Used by Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>volatile uint8_t</td>
<td>g_cac_status</td>
<td>Frequency measurement status 0x00: Frequency measurement result is abnormal. 0x01: Frequency measurement result is normal. 0x02: Frequency measurement is in progress.</td>
<td>R_CAC_Start r_Config_CAC_mendi_interrupt</td>
</tr>
</tbody>
</table>

Table 4.9 Static Variables Used in Sample Code

<table>
<thead>
<tr>
<th>Type</th>
<th>Variable Name</th>
<th>Description</th>
<th>Used by Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>static uint8_t</td>
<td>s_measure_counter</td>
<td>Frequency measurement counter</td>
<td>R_CAC_Start r_Config_CAC_mendi_interrupt</td>
</tr>
<tr>
<td>static uint32_t</td>
<td>s_result_buffer</td>
<td>Frequency measurement result storage buffer</td>
<td>R_CAC_Start r_Config_CAC_mendi_interrupt</td>
</tr>
<tr>
<td>static uint32_t</td>
<td>s_result_average</td>
<td>Mean frequency measurement result storage buffer</td>
<td>R_CAC_Start r_Config_CAC_mendi_interrupt</td>
</tr>
</tbody>
</table>
4.8 Functions

Table 4.10 lists the functions used in the sample code.

<table>
<thead>
<tr>
<th>Function Name</th>
<th>Description</th>
<th>Contained in File</th>
</tr>
</thead>
<tbody>
<tr>
<td>main</td>
<td>Main processing</td>
<td>main.c</td>
</tr>
<tr>
<td>R_CAC_Start</td>
<td>Clock frequency measurement start</td>
<td>Config_CAC_user.c</td>
</tr>
</tbody>
</table>

4.9 Function Specifications

The sample code function specifications are listed below.

**main**

Outline: Main processing
Header: None
Declaration: void main (void)
Description: This function starts clock frequency measurement.
Arguments: None
Return value: None

**R_CAC_Start**

Outline: Clock frequency measurement start processing
Header: Config_CAC.h
Declaration: void R_CAC_Start (void)
Description: Performs processing to start clock frequency measurement.
Arguments: None
Return value: None

**r_Config_CAC_mendi_interrupt**

Outline: CAC measurement end interrupt handler
Header: Config_CAC.h
Declaration: void r_Config_CAC_mendi_interrupt (void)
Description: Judges whether the HOCO’s frequency error is within the acceptable range based on the measurement result.
Arguments: None
Return value: None
4.10 Flowcharts

4.10.1 Main Processing
Figure 4.3 is a flowchart of the main processing.

![Flowchart of the main processing](image)

Figure 4.3 Main Processing

4.10.2 CAC Measurement Start Processing
Figure 4.4 is a flowchart of the CAC measurement start processing.

![Flowchart of the CAC measurement start processing](image)

Figure 4.4 CAC Measurement Start Processing
4.10.3 CAC Measurement End Interrupt
Figure 4.5 is a flowchart of the CAC measurement end interrupt handler.

```
// r_Config_CAC_mendi_interrupt
Clear the measurement end flag in the CAC status register
CAICR register ← CAICR register | 20h

Number of measurements < 4?

Yes
Store measurement result
s_result_buffer ← s_result_buffer + Measurement result(CAC.CACNTBR)
Update measurement count
s_measure_counter ← s_measure_counter + 1

No

Number of measurements = 4?

Yes
Stop clock frequency measurement
R_Config_CAC_Stop()
Calculate average of measurement results
s_result_average ← s_result_buffer / CHECK_CNT

Is the error in the measurement result within the allowable range?

No

Yes
Set the frequency measurement status to successful termination
g_cac_status ← CAC_OK
Set the frequency measurement status to error termination
g_cac_status ← CAC_ERROR

return
```

Figure 4.5 CAC Measurement End Interrupt
4.11 Procedure for Using Sample Code in CS+

This application notes support the following development tools.

- e2 studio Version: 2021-07 and RX Compiler CC-RX V3.03.00
- CS+ V8.06.00 and RX Compiler CC-RX V3.03.00

Using this application note with CS+

This application note contains a project only for e2 studio. When you use this project with CS+, import the project to CS+ by following procedures.

Launch CS+ and click "Start".
Select [Open Existing MCU Simulator Online/e2 studio/CubeSuite/High-performance Embedded Workshop/PM+ project] in Start menu.

Select the file with the extension [.rcpc] and click [Open] button.

Select the device used in the project.
Select Project type, and specify the project name and its location. Click OK button if they are OK.

Select Project type, and specify the project name and its location. Click OK button if they are OK.

The project name depends on the AN.
5. Reference Documents

User’s Manual: Hardware
   RX671 Group User’s Manual: Hardware (R01UH0899EJ)
   (The latest version can be downloaded from the Renesas Electronics website.)

User’s Manual: Software
   Smart Configurator User’s Manual: RX API Reference (R20UT4360EJ)
   (The latest version can be downloaded from the Renesas Electronics website.)

User’s Manual: Development Tools
   RX Family: CC-RX Compiler User’s Manual (R20UT3248EJ)
   (The latest version can be downloaded from the Renesas Electronics website.)

Technical Updates/Technical News
   (The latest information can be downloaded from the Renesas Electronics website.)
### Revision History

<table>
<thead>
<tr>
<th>Rev.</th>
<th>Date</th>
<th>Description</th>
<th>Page</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.00</td>
<td>Aug. 25, 2021</td>
<td>—</td>
<td></td>
<td>First edition issued</td>
</tr>
</tbody>
</table>
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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

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