RTC Correction Scheme

# Application Guide

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# About This Document

## Purpose

This document describes the RTC correction scheme, ensuring that the RTC counts correctly.

## Related Versions

The following table lists the product version related to this document.

| Product Name | Version |
|---|---|
| Hi3518 | V100 |

## Intended Audience

This document is intended for:

Technical support personnel

## Change History

Changes between document issues are cumulative. Therefore, the latest document issue contains all changes made in previous issues.

### Issue 00B01 (2012-12-26)

This issue is the first official release.

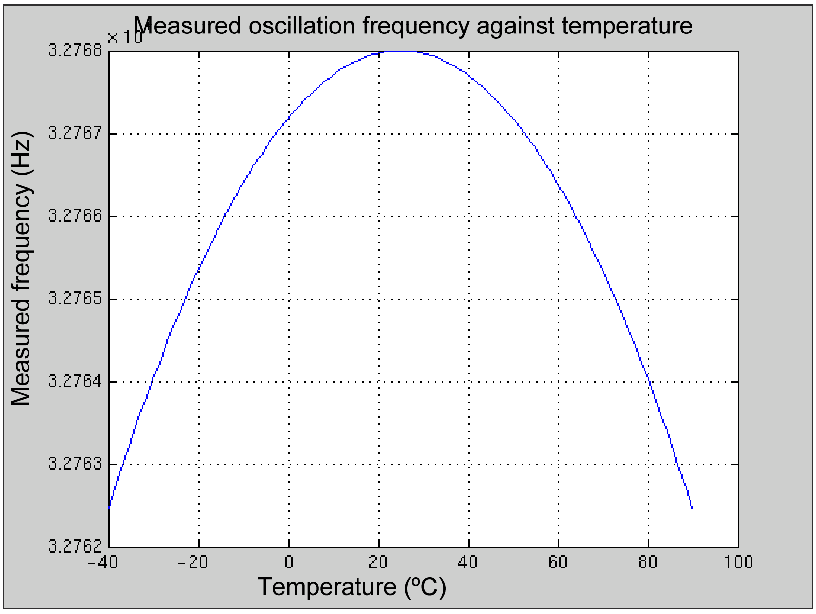
# Contents

# 1 Overview

The Hi3518 RTC counting frequency must be fixed at 100 Hz, ensuring that the RTC counting is correct. The RTC counting frequency is calculated as follows: RTC counting frequency = Frequency of the clock generated by the internal oscillation circuits/Frequency divider (327.xx).

The frequency of the clock generated by the internal oscillation circuit is affected and varies according to the temperature. In this case, the frequency divider can be adjusted to ensure the constant RTC counting frequency. Figure 1-1 shows the relationship between the oscillation frequency output by the 32 kHz crystal and the temperature.

**Figure 1-1** Relationship between the oscillation frequency output by the 32 kHz crystal and the temperature




The curve in Figure 1-1 is expressed by the following formula: $F = [K_s \times (T - T_0)^2 + 1 + C] \times 32768$

where

- F indicates the crystal oscillation frequency at the temperature T, and its unit is Hz.

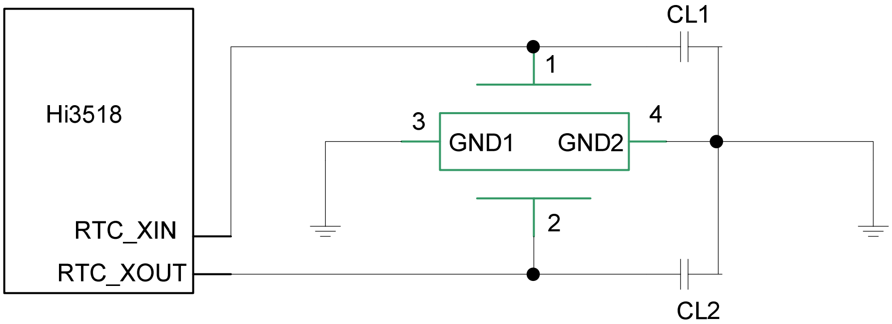
- $K_s$ indicates the quadratic coefficient of the curve and it is related to the selected crystal. $K_s$ in Figure 1-1 is calculated as follows: $-4 \times 10^{-8}$ºC$^{-2}$.
- $T_0$ indicates the transition temperature and the value range is 25±5ºC. Figure 1-1 The $T_0$ value in Figure 1-1 is 24.94ºC (76.89ºF). A temperature code in the RTC indicates 0.705882ºC (33.27ºF). For details about the relationship between the temperature code and the temperature, see the *RTC Crystal Correction Parameter Creation Table*.
- C indicates the frequency offset at the transition temperature and its value is **0** in the preceding figure. C is affected by the following two factors:
  - Load capacitance
  - Crystal difference

# 2 Hardware Reference Circuit of the Crystal

## 2.1 Hardware Reference Circuit

Crystals and capacitors need to be selected for the hardware reference circuit, as shown in Figure 2-1.

**Figure 2-1** Hardware reference circuit of the crystal




## 2.2 Selecting Crystals

The following specifications must be taken into account during crystal selection:

- Load capacitance (or CL): Crystals impose strict requirements on the load capacitance. The crystal frequency can reach the nominal frequency only when the actual load capacitance is the same as the load capacitance in crystal specifications.

  The Hi3518 crystal oscillation circuit is designed based on the crystal whose load capacitance is 12.5 pF. You are advised to use the crystal with 12.5 pF load capacitance because this crystal is the mainstream in 32.768 kHz crystal markets.

- Series resistance: crystal resonance equivalent series resistance (ESR). Greater ESR indicates that the crystal is more difficult to drive. The typical and maximum values of $R_s$ are specified in crystal specifications.

  The crystal whose maximum series resistance is less than 50 kilohms is recommended for the Hi3518 crystal oscillation circuit.

- Maximum drive level: maximum crystal oscillation amplitude. If the oscillation amplitude exceeds a specified amplitude, the crystal is easy to be damaged.

  The oscillation amplitude of the pins RTC_XIN and RTC_XOUT are specified on the Hi3518 crystal oscillation circuit. The actual drive level (less than the maximum drive level in crystal specifications) when the circuit works is calculated as follows:

  $DL\_actual = 0.5 \times Rs\_max \times (\pi \times f \times V_{ppXIN} \times CL \times 2)^2$

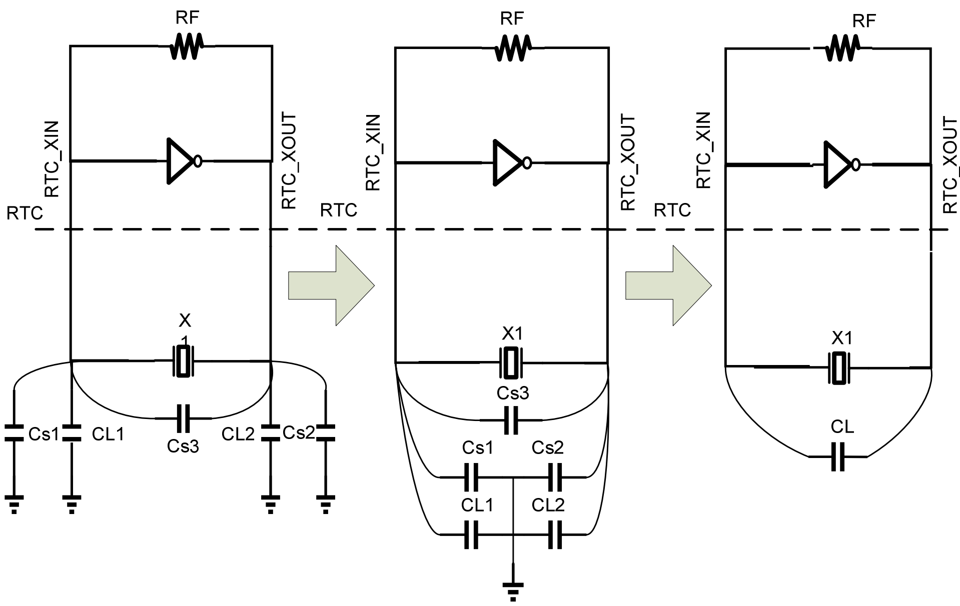
  where

  – $R_s$_max indicates the maximum series resistance in crystal specifications.
  – f indicates the crystal resonance frequency.
  – $V_{ppXIN}$ indicates the peak-to-peak voltage of the oscillation waveform for the RTC_XIN pin measured by using the oscilloscope.
  – CL is the load capacitance in crystal specifications.

# 2.3 Selecting Capacitors

The actual CL diagram is shown in Figure 2-2.

**Figure 2-2** Actual CL diagram




Typically, the values of CL1 and CL2 are the same on the Pierce oscillator. The values are calculated as follows:

CL1 = CL2 = CL_SPEC x 2 – Stray capacitance

CL_SPEC is the load capacitance in crystal specifications. The stray capacitance might be caused by the PCB and its value range is 3–5 pF. For example, if the load capacitance of a crystal is 12.5 pF, the values of CL1 and CL2 are calculated as follows: 12.5 pF x 2 – 3 pF = 22 pF. The stray capacitance varies according to the PCB. Therefore, you can obtain the output frequency that is approximate to 32.768 kHz by selecting an appropriate CL1 after the PCB is determined.

# 3 Implementing RTC Correction

The RTC correction frequency ranges from 32760 Hz to 32776 Hz (at chip operating temperatures). To implement RTC correction, perform the following steps:

**Step 1** Measure and configure the curves of the oscillation frequency offset and temperature.

**Step 2** Dynamically update temperatures on the RTC correction circuit.

**----End**

## 3.1 Measuring and Configuring Curves of the Oscillation Frequency Offset and Temperature

**Measuring Curves of the Oscillation Frequency Offset and Temperature**

You can obtain curves of the oscillation frequency offset and temperature by inputting the measured temperature and the oscillation frequency output by the crystal to the *RTC Crystal Correction Creation Table*. You can select the following methods to measure curves of the oscillation frequency offset and temperature by taking the measurement accuracy and cost into account:

- Multimetering

  You can obtain relationships between various temperatures and oscillation frequencies at chip operating temperatures. This scheme applies to the scenario in which crystal parameters need to be reevaluated.

- Three Test Points

  Frequencies measured only at –20°C (–4ºF), +25°C (77ºF), and +80°C (176ºF) are used. This scheme applies to the scenario in which crystal parameters need to be fast determined.

- Two test points

  Frequencies measured only at –20°C (–4ºF) and +80°C (176ºF) are used. This method applies to the scenario in which the crystal model is known because the quadratic coefficient $K^s$ of the oscillation frequency offset and temperature function is known and its change is unobvious (the function coefficients of various crystals are almost the same).

- One test point

  The frequency measured at the room temperature is used. This method applies to the scenario in which crystals of the same model and batch are used because the quadratic coefficient $K^s$ of the oscillation frequency offset and temperature function and the transition temperature $T^0$ are known and their changes are unobvious (the function coefficients of various crystals are almost the same).

**Configuring Curves of the Oscillation Frequency Offset and Temperature**

Coefficients of the oscillation frequency offset and temperature function correspond to registers in the RTC. $LUT_n$ is related to $K_s$ x $(T_n – 24.94)^2$ ([n $\in$ [1, 47], Tn = –40 + n x (180/255)], TEMP_OFFSET is related to $T_0$, and TOT_OFFSET is related to C.

After selecting an appropriate measurement method, enter measured frequencies and temperatures into the desired sheet and click `Create rtc_temp_lut_tbl.h` to create the configuration file. Replace the file in the RTC driver with the generated **rtc_temp_lut_tbl.h** file and recompile the RTC driver. In this way, the coefficients are configured to the RTC each time the chip is booted.

The generated curves of the oscillation frequency offset and the temperature vary according to the crystal. You can use the following three methods to configure the RTC driver file based on the measurement accuracy and cost:

- Measure the function coefficients of various crystals and configure the coefficients to the RTC. The maximum RTC counting error is 5 ppm. The function coefficients of each crystal must be configured by using the configuration file **rtc_temp_lut_tbl.h**.
- Measure a specified number of crystals of the same batch, recalculate the calculated coefficients, and configure the crystals based on the recalculated coefficients. The maximum RTC counting error is calculated as follows: 5 ppm + error caused by crystal differences. The counting error is affected by crystal production consistency.
- Measure no crystal, and use the initial chip coefficients or the coefficient configuration file generated by using the data provided by the crystal manufacturer. This RTC counting error is determined by the crystal consistency and the match degree of the inherent coefficients of the oscillation frequency and temperature function and the configured coefficients of the oscillation frequency and temperature function in the RTC.

## 3.2 Dynamically Updating Temperatures on the RTC Correction Circuit

The correction temperature may be one of the following:

- Fixed temperature

  This method applies to the scenario in which temperatures vary unobviously when the chip runs.
- Temperature obtained by the temperature sensor in the RTC

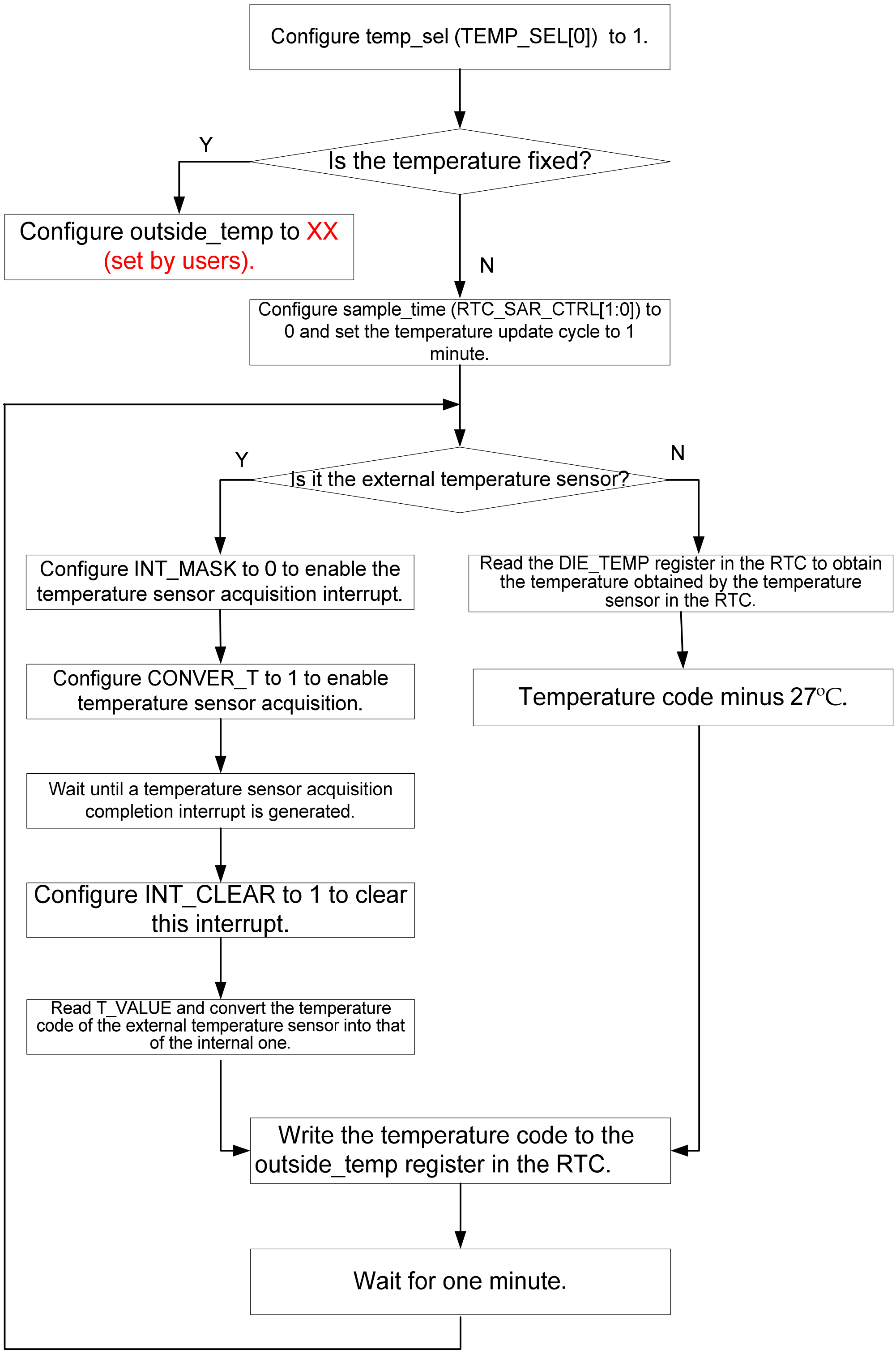
  The correction temperature is the temperature obtained by the temperature sensor in the RTC minus the experience deviation (offset of the chip internal temperature and the ambient temperature when the chip runs). This method reduces cost of the external temperature sensor, but the measurement accuracy is low. The relationship between the temperature obtained by the internal temperature sensor and the crystal temperature on the PCB is not determined. The correction temperature is the temperature obtained by the sensor minus an experience deviation (such as 27°C). Therefore, a big error is caused for the correction accuracy (a 5 ppm error is caused if the temperature offset is 0.7°C at a time at a high or low temperature).

- Temperature obtained by the external temperature sensor

  The maximum RTC counting error is 5 ppm because the external temperature sensor is placed close to the crystal surface and reflects crystal temperatures accurately.

You can implement RTC correction by updating temperatures of RTC temperature registers regularly after registers for the crystal oscillation function are configured, as shown in Figure 3-1

**Figure 3-1** Configuration process of updating temperatures



# 4 RTC Driver Usage

## 4.1 Preparation

Obtain the function coefficients of the oscillation frequency offset and temperature in the RTC Crystal Correction Creation Table based on descriptions in section 3.2, click `Create rtc_temp_lut_tbl.h` to generate the **rtc_temp_lut_tbl.h** header file, and replace the file of the same name in the RTC directory with the generated file.

## 4.2 Compilation

Run the following commands in the RTC directory to generate the hirtc.ko driver and sample program test:

```
cd rtc
make
make test
```

## 4.3 Usage

Copy hirtc.ko on the board and run the following command to insert the driver module:

```
insmod hirtc.ko t_second=T
```

The t_second parameter indicates the temperature collection interval in second. The default interval is 5s. Do not input this parameter if the default value remains.

RTC driver functions are described in the test sample program running on the board, as shown in Figure 4-1.

**Figure 4-1** Test sample program usage

```
# ./test

Usage: ./test [options] [parameter1] ...
Options:
        -s(set)         Set time/alarm,     e.g '-s time 2012/7/15/13/37/59'
        -g(get)         Get time/alarm,     e.g '-g alarm'
        -w(write)       Write RTC register, e.g '-w <reg> <val>'
        -r(ead)         Read RTC register,  e.g '-r <reg>'
        -a(alarm)       Alarm ON/OFF'
        -reset          RTC reset
        -m(mode)        Mode of temperature gather, e.g '-m <mode> <temp>, mode[0-2]'
```

### Configuring and Obtaining the RTC Time

Run the following command to configure the RTC time:

```
./test –s time <year/month/day/hour/minute/second>
```

Run the following command to obtain the RTC time:

```
./test –g time
```

### Configuring and Obtaining the RTC Alarm Time

Run the following command to configure the RTC alarm time:

```
./test –s alarm <year/month/day/hour/minute/second>
```

Run the following command to obtain the RTC alarm time:

```
./test –g alarm
```

Run the following command to set whether an interrupt is generated when the alarm time reaches. The driver interrupt routine is added by users.

```
./test –a ON/OFF
```

### Reading and Configuring Registers in the RTC

Run the following command to read a register in the RTC. This function is used for auxiliary tests, such as reading temperatures collected by the internal t_sensor and reading configured updated RTC temperatures.

```
./test –r <reg>
```

Run the following command to configure the register in the RTC. This function is used for auxiliary tests.

```
./test –w <reg> <value>
```

For details about the reg value, see section 3.9 in the *Hi3518 HD IP Camera SoC Data Sheet.pdf*.**Resetting the RTC**

Run the following command to reset the RTC:

```
./test –reset
```

### Configuring the Temperature Acquisition Mode

Run the following command to configure the temperature acquisition mode:

```
./test –m <mode> <value>
```

Temperature acquisition modes and their values are described in Table 4-1.

**Table 4-1** Temperatures acquisition modes and their values

| Temperature Acquisition Mode | Mode No. | Value |
|---|---|---|
| Fixed temperature, manual update | 0 | Crystal ambient temperature |
| Temperature obtained by the external temperature sensor, automatic update | 1 | NA |
| Temperature obtained by the internal temperature sensor, automatic update | 2 | NA |

### User Interface

See the **hi_rtc.h** file.

# 5 Q&A

## 5.1 No Oscillation on the Oscillator

**[Symptom]**

The 32.768 kHz clock has no output, and the value of the second register on the RTC counting circuit is constant.

**[Analysis]**

Use the oscilloscope probe to check oscillation waveforms on the RTC_XIN pin, and various oscillation waveforms are caused in the following situations:

- If there is no oscillation waveform on the pin, the crystal may be damaged.
- If about 32 kHz sine waves are detected and the peak-to-peak amplitude is less than 600 mV, capacitance of CL1 and CL2 may be large, causing the oscillation circuit drive capability to be insufficient and the peak-to-peak amplitude is smaller than that at 32.768 kHz frequency. Therefore, oscillation waveforms cannot pass the subsequent Schmitt trigger.
- If about 200 kHz sine waves are detected and the peak-to-peak amplitude is less than 600 mV, capacitance of CL1 and CL2 may be small, causing the oscillation circuit to oscillate to 200 kHz frequency at which the amplitude is smaller than that at 32.768 kHz frequency. Therefore, oscillation waveforms cannot pass the subsequent Schmitt trigger.

**[Solution]**

- Replace the crystal if it is damaged.
- If about 32 kHz sine waves are detected and the peak-to-peak amplitude is small, check whether capacitance of CL1 and CL2 is large and replace the capacitors with appropriate capacitors.
- If about 200 kHz sine waves are detected and the peak-to-peak amplitude is small, check whether capacitance of CL1 and CL2 is small and replace the capacitors with appropriate capacitors.

## 5.2 200 kHz Frequency Output by the Oscillator

**[Symptom]**

The frequency output by the 32.768 kHz clock is approximate to 200 kHz, and the value of the second register on the RTC counting circuit increases by 6 per second.

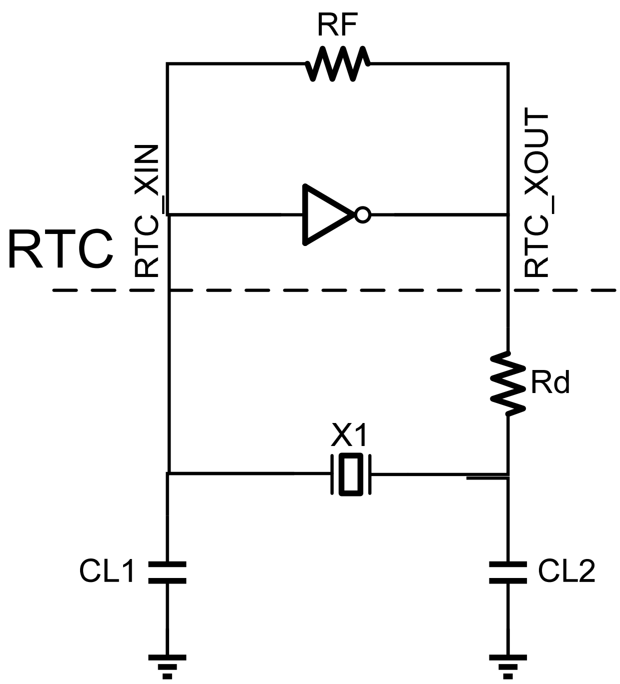
**[Analysis]**

If exceptions occur on the 32.768 kHz crystal, the crystal may oscillate near to six times of the fundamental frequency because the resonance point of 6.1 times of the fundamental frequency is available on this crystal.

**[Solution]**

Check whether capacitance of CL1 and CL2 is small. If capacitance of the two capacitors are appropriate and the oscillation frequency is 200 kHz, add an Rd whose value is 1/(2 π x 32768 x CL2) to the circuit, as shown in Figure 5-1. The Rd and CL2 form an RC filter, reducing the loop gain at 6.1 times of the fundamental frequency.

**Figure 5-1** Circuit for resolving the 200 kHz output frequency issue




NOTE

You are not advised to add an Rd to the circuit. Ensure that the signal amplitude on the RTC_XOUT pin is not small before adding an Rd to the circuit.

## 5.3 Incorrect Oscillation Frequency

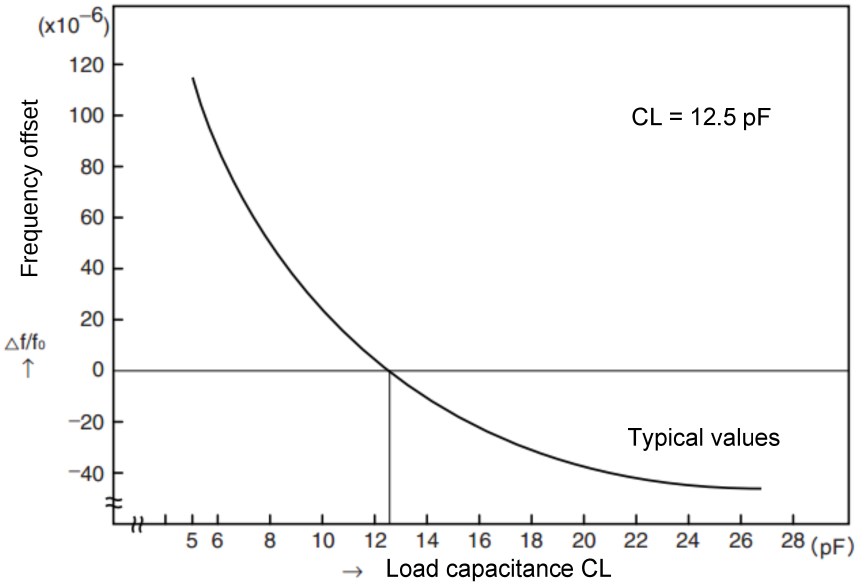
**[Symptom]**

The frequency output by the 32.768 kHz clock is not 32.768 kHz.

**[Analysis]**

The crystal and load capacitance work together to determine the oscillation frequency on the oscillation circuit. The crystal determines the frequency range (frequencies corresponding to the frequency offset 0 in Figure 5-2, and the actual load capacitance determines the frequency offset (the value of the frequency offset 0 in Figure 5-2).

**Figure 5-2** Relationship between the frequency offset and the actual load capacitance CL




**[Solution]**

Firstly, ensure that crystal pin bending does not apply stress to the internal crystal and the soldering temperature complies with specifications in the data sheet. Secondly, check whether capacitance of CL1 and CL2 are appropriate and replace the two capacitors with appropriate ones.