# Application Note

## RTC Calibration application notes

### Introduction

The Nsing Technology microcontroller has a built-in RTC module that provides functions such as calendar and alarm, while also offering digital calibration function to enhance the working accuracy of the RTC module in response to environmental temperature changes.

This document aims to assist users in correctly utilizing the digital calibration function of the RTC module, reducing the impact on the RTC working accuracy caused by external crystal frequency deviation due to environmental temperature changes.



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# 1. Overview

## 1.1 RTC Brief Introduction

RTC provides the ability to automatically wake up in low power mode.

The Real Time Clock (RTC) is an independent BCD timer/counter. RTC provides a clock/calendar with programmable alarm interrupts. The RTC also includes a periodically programmable wake-up flag with an interrupt function.

Two 32-bit registers contain decimal format (BCD) for sub second, second, minute, hour (12 or 24 hour format), day (day of the week), month, and year. The system can automatically perform monthly compensation for 28, 29 (leap years), 30, and 31 days. Daylight saving time compensation is also available.

The sub second value is provided in binary format as a separate 32-bit register. Other 32-bit registers contain programmable alarm clock sub seconds, seconds, minutes, hours, days, and days.

The digital calibration function can compensate for deviations in the accuracy of the crystal oscillator.

After the Backup domain is reset, all RTC registers are protected against possible accidental write access.

When enabling events on GPIO and saving the current calendar in a register, the timestamp function can be enabled.

As long as RTC is enabled and the voltage remains within the operating range, RTC will not stop regardless of the device status (RUN, SLEEP, STOP, or STANDBY Mode).



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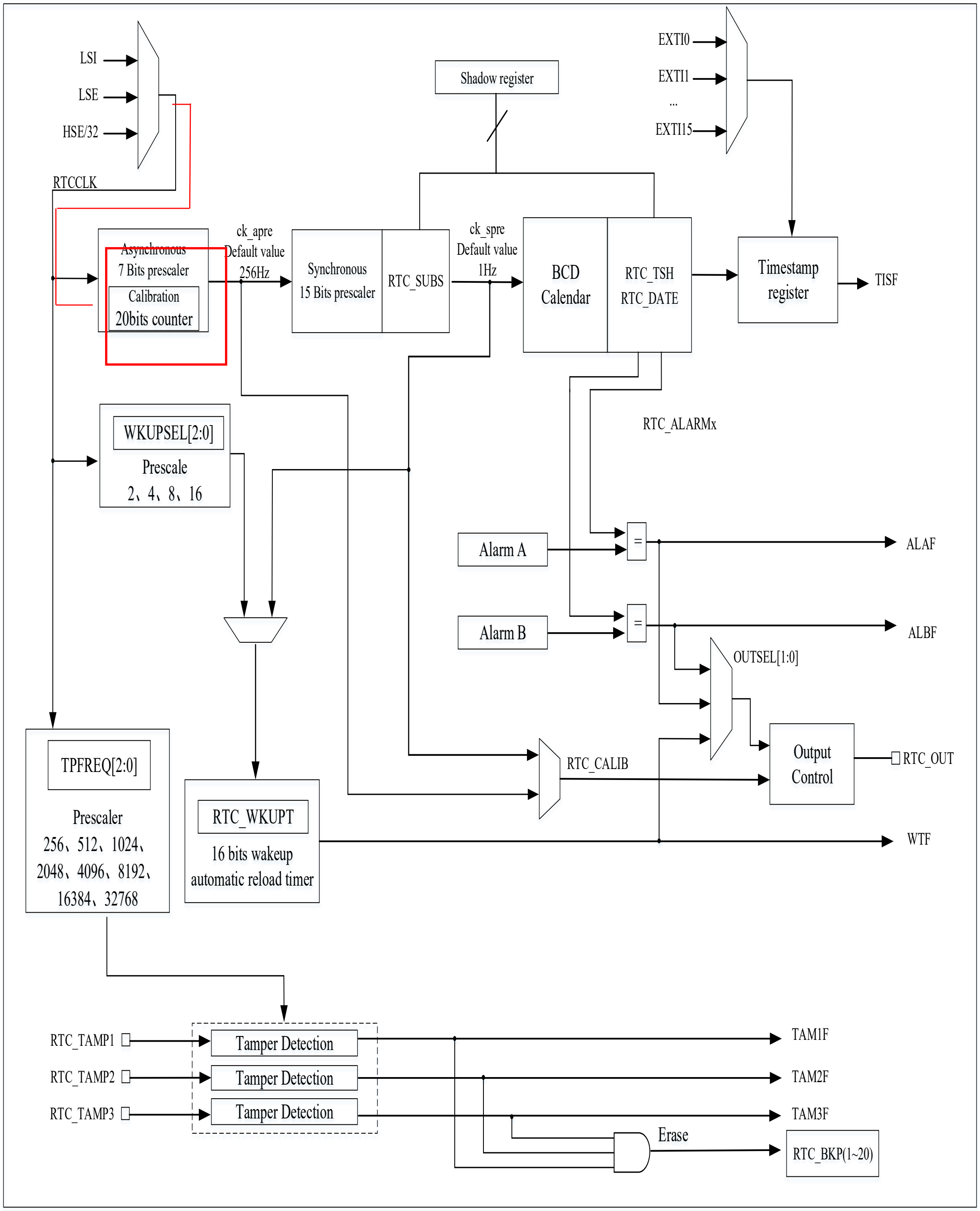
**Figure 1-1 Block Diagram of N32 RTC**




The red wireframe in the figure is the digital calibration module, which can adjust the clock input to the calendar module, thereby adjusting the timing accuracy of the RTC calendar.



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## 1.2 Principle Of RTC Digital Clock Precision Calibration

Digital precision calibration is achieved by adjusting the number of RTC clock pulses in the calibration period. Digital precision calibration resolution is 0.954 PPM with the range from -487.1 PPM to +488.5 PPM.

When the input frequency is 32768 Hz, calibration period can be configured as $2^{20}/2^{19}/2^{18}$ RTCCLK cycles or 32/16/8 seconds. The precision calibration register (RTC_CALIB) indicates that RTC_CALIB.CM[8:0] RTCCLK clock cycles will be reduced within the specified cycle.

The value of RTC_CALIB.CM[8:0] represents the number of RTCCLK pulses to be reduced during specified period. While RTC_CALIB.CP can be used to increase 488.5 PPM, every $2^{11}$ RTCCLK cycles will inserts a RTCCLK pulse.

When using RTC_CALIB.CM[8:0] and RTC_CALIB.CP in combination, it can increase cycles range from -511 to +512 RTCCLK cycles. The calibration range from -487.1 ppm to +488.5 ppm, and the resolution is about 0.954 ppm.

The effective calibrated frequency ($f_{CAL}$) can be calculated by the following formula:

$$f_{CAL} = f_{RTCCLK} * \left(1 + \frac{RTC\_CALIB.CP*512 - RTC\_CALIB.CM[8:0]}{2^n + RTC\_CALIB.CM[8:0] - RTC\_CALIB.CP * 512}\right)$$

*Note: n=20/19/18*

**Calibrated when RTC_PRE .DIVA[6:0]<3**

When the asynchronous prescaler value (RTC_PRE.DIVA[6:0]) is less than 3, the RTC_CALIB.CP cannot be programmed to 1, and RTC_CALIB.CP value will be ignored if the it has been set to 1.

When RTC_PRE .DIVA[6:0]<3, the value of RTC_PRE.DIVS[14:0] should be decrease. Assume RTCCLK frequency is 32768Hz:

- When RTC_PRE .DIVA[6:0] =2, RTC_PRE.DIVS[14:0]=8189.
- When RTC_PRE .DIVA[6:0] =1, RTC_PRE.DIVS[14:0]=16379.
- When RTC_PRE .DIVA[6:0] =0, RTC_PRE.DIVS[14:0]=32759.

The effective calibrated frequency ($f_{CAL}$) can be calculated by the following formula:

$$f_{CAL} = f_{RTCCLK} * \left(1 + \frac{256 - RTC\_CALIB.CM[8:0]}{2^n + RTC\_CALIB.CM[8:0] - 265}\right)$$

*Note: n=20/19/18*

**Verify RTC calibration**

RTC output 1Hz waveform for measuring and verifying RTC precision.



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Up to 2 RTCCLK cycles measurement error may occur when measure the RTC frequency in a limit measurement period. If the measurement period is the same as calibration period, the error can be eliminated.

- The calibration period is 32 seconds (default).

  Using an accurate 32-second period to measure the 1Hz calibration output can ensure that the measurement error is within 0.447ppm (0.5 RTCCLK cycles within 32 seconds).

- The calibration period is 16 seconds.

  Using an accurate 16-second period to measure the 1Hz calibration output can ensure that the measurement error is within 0.954ppm (0.5 RTCCLK cycles within 16 seconds).

- The calibration period is 8 seconds.

  Using an accurate 8-second period to measure the 1Hz calibration output can ensure that the measurement error is within 1.907ppm (0.5 RTCCLK cycles within 8 seconds).

**Dynamic recalibration**

When RTC_INITSTS.INITF=0, RTC_CALIB register can update by using following steps:

- Wait RTC_INITSTS.RECPF=0.
- A new value is written to the RTC_CALIB, then RTC_INITSTS.RECPF is automatically set to 1.
- The new calibration settings will take effect within 3 ck_apre cycles after a data write to the RTC_CALIB.

# 2. Operation Method

## 2.1 RTC Digital Clock Output I/O Pin Configuration

This function configures PC13 as the RTC_OUT function pin, outputting a 1Hz digital clock waveform without calibration.

The configuration program is as follows:

```
/* Calibrate output 1Hz signal */
RTC_ConfigCalibOutput(RTC_CALIB_OUTPUT_1HZ);
/* Calibrate output config,push pull */
RTC_ConfigOutputType(RTC_OUTPUT_PUSHPULL);
/* Calibrate output enable*/
RTC_EnableCalibOutput(ENABLE);
```

RTC_ OUT output is shown in the figure below:



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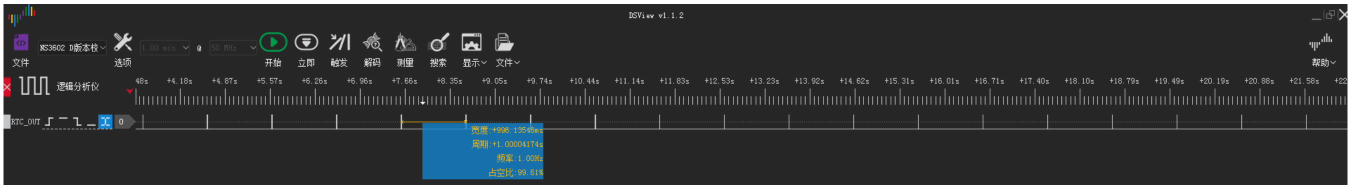
**Figure 2-1 Precise calibration output waveform of RTC digital clock**




When configuring RTC_OUT as a digital clock that has been precisely calibrated to output, measure the time interval of the RTC_OUT pin output after RTC calendar calibration to understand whether the digital clock precision calibration module is inserted and reduces RTC_CLK



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## 2.2 RTC Digital Clock Precision Calibration Configuration API

The API for precise calibration configuration of RTC digital clocks is provided in the SDK RTC driver file. The code is as follows:

```
/**
 * @brief  Configures the Smooth Calibration Settings.
 * @param RTC_SmoothCalibPeriod Select the Smooth Calibration Period.
 *   This parameter can be can be one of the following values:
 *     @arg SMOOTH_CALIB_32SEC The smooth calibration periode is 32s.
 *     @arg SMOOTH_CALIB_16SEC The smooth calibration periode is 16s.
 *     @arg SMOOTH_CALIB_8SEC The smooth calibartion periode is 8s.
 * @param RTC_SmoothCalibPlusPulses Select to Set or reset the CALP bit.
 *   This parameter can be one of the following values:
 *     @arg RTC_SMOOTH_CALIB_PLUS_PULSES_SET Add one RTCCLK puls every 2**11 pulses.
 *     @arg RTC_SMOOTH_CALIB_PLUS_PULSES__RESET No RTCCLK pulses are added.
 * @param RTC_SmouthCalibMinusPulsesValue Select the value of CALM[8:0] bits.
 *   This parameter can be one any value from 0 to 0x000001FF.
 * @return An ErrorStatus enumeration value:
 *         - SUCCESS: RTC Calib registers are configured
 *         - ERROR: RTC Calib registers are not configured
 */
ErrorStatus RTC_ConfigSmoothCalib(uint32_t RTC_SmoothCalibPeriod,
                                  uint32_t RTC_SmoothCalibPlusPulses,
                                  uint32_t RTC_SmouthCalibMinusPulsesValue)
{
    ErrorStatus status    = ERROR;
    uint32_t recalpfcount = 0;
    /* Check the parameters */
    assert_param(IS_RTC_SMOOTH_CALIB_PERIOD_SEL(RTC_SmoothCalibPeriod));
    assert_param(IS_RTC_SMOOTH_CALIB_PLUS(RTC_SmoothCalibPlusPulses));
```



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```
    assert_param(IS_RTC_SMOOTH_CALIB_MINUS(RTC_SmouthCalibMinusPulsesValue));
    /* Disable the write protection for RTC registers */
    RTC->WRP = 0xCA;
    RTC->WRP = 0x53;
    /* check if a calibration is pending*/
    if ((RTC->INITSTS & RTC_INITSTS_RECPF) != RESET)
    {
      /* wait until the Calibration is completed*/
      while (((RTC->INITSTS & RTC_INITSTS_RECPF) != RESET) && (recalpfcount != RECALPF_TIMEOUT))
      {
        recalpfcount++;
      }
    }
    /* check if the calibration pending is completed or if there is no calibration operation at all*/
    if ((RTC->INITSTS & RTC_INITSTS_RECPF) == RESET)
    {
      /* Configure the Smooth calibration settings */
      RTC->CALIB = (uint32_t)((uint32_t)RTC_SmoothCalibPeriod | (uint32_t)RTC_SmoothCalibPlusPulses
                   | (uint32_t)RTC_SmouthCalibMinusPulsesValue);
      status = SUCCESS;
    }
    else
    {
      status = ERROR;
    }
    /* Enable the write protection for RTC registers */
    RTC->WRP = 0xFF;
    return (ErrorStatus)(status);
}
```



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The users can use this function to control the RTC digital clock precise calibration module to increase or decrease RTC_CLK within a specified clock period, thereby controlling the increase or decrease of calendar time

## 2.3 RTC Calibration Formula Calculation

The users can confirm the error value after calibration by setting the period and the number of added or subtracted RTCCLKs in the "RTC calibration formula calculation excel sheet.xlsx", calculate the offset value (PPM) after calibration settings.

As shown in the following figure:

Figure 2-2 RTC Digital Clock Precise Calibration Error Calculation Excel Spreadsheet Chart

| RTC Asynchronous Prescaler (DIVA) ≥ 3 | | | | |
|---|---|---|---|---|
| Error After Calibration (PPM) | Frequency After Calibration ($f_{CAL}$) | Calibration Cycle (S) | Reduce The Number Of RTCCLKs (CM) | Increase The Number Of RTCCLKs (CP) |
| -487.0902032 | 32752.03903 | 32 | 511 | 0 |
| | | | | |
| | | | | |
| | | | | |
| RTC Asynchronous Prescaler (DIVA) ≤ 3 | | | | |
| Error After Calibration (PPM) | Frequency After Calibration ($f_{CAL}$) | Calibration Cycle (S) | Reduce The Number Of RTCCLKs (CM) | Increase The Number Of RTCCLKs (CP) |
| 973.6949624 | 32799.90604 | 8 | 1 | 512 |

# 3. RTC 32-Second Digital Clock Calibration Application Example

## 3.1 RTC Digital Clock Precision Calibration Configuration API

The RTC digital clock precise calibration algorithm is described in Section 1.2.

The following example illustrates the calibration algorithm of the RTC digital clock precise calibration module, with RTC_CLK=32.768KHz, calibration period of 32 seconds, CP=1, CM=511 used as an example to explain the process of RTC precise calibration.

The program configuration is as follows

```
RTC_ConfigSmoothCalib(SMOOTH_CALIB_32SEC,RTC_SMOOTH_CALIB_PLUS_PULSES_SET,511);
```

## 3.2 Detailed Explanation Of RTC Digital Clock Precise Calibration Algorithm

The calibration cycle for the above API configuration is 32S. When CP=1, 512 RTC_CLK clocks will be added within 32S. When CM=511, 511 RTC_CLK clocks will be reduced within 32S. According to the calibration formula $32768.031\text{Hz} = 32768\text{Hz} * (1 + \frac{1*512-511}{2^{20} + 511 - 1*512})$, it is known that the $f_{CAL}$ after calibration is 32768.031Hz, According to the calibration algorithm, we can obtain the insertion or reduction of RTC_CLK in the digital clock precision calibration module every second.

The following table details the number of RTC_CLK clocks per second for the digital clock tight calibration module.



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**Figure 2-2 RTC_CLK distribution diagram for calibration cycle 32S/CP=1/CM=511 per second**

| CALM[8:0] | 复位后减少计数的 $RTC_{CLK}$ | 减少计数 $RTC_{CLK}$ 起始点 | 减少计数的 $RTC_{CLK}$ 步进值 | 减少计数的 $RTC_{CLK}$ 位置 | RTCOUT 1HZ秒间隔 | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| CALM[0] | 1 | $2^{19}$ | | | 1s | 1s | 1s | 1s | 1s | 1s | 1s | 1s | 1s | 1s | 1s | 1s | 1s | 1s | 1s | 1s+30.5us |
| CALM[1] | 2 | $2^{18}$ | $2^{19}$ | $2^{18}+2^{19}*N$ (N∈[0,1]) | 1s | 1s | 1s | 1s | 1s | 1s | 1s | 1s+30.5us | 1s | 1s | 1s | 1s | 1s | 1s | 1s | 1s |
| CALM[2] | 4 | $2^{17}$ | $2^{18}$ | $2^{17}+2^{18}*N$ (N∈[0,3]) | 1s | 1s | 1s | 1s+30.5us | 1s | 1s | 1s | 1s | 1s | 1s | 1s | 1s+30.5us | 1s | 1s | 1s | 1s |
| CALM[3] | 8 | $2^{16}$ | $2^{17}$ | $2^{16}+2^{17}*N$ (N∈[0,7]) | 1s | 1s+30.5us | 1s | 1s | 1s | 1s+30.5us | 1s | 1s | 1s | 1s+30.5us | 1s | 1s | 1s | 1s+30.5us | 1s | 1s |
| CALM[4] | 16 | $2^{15}$ | $2^{16}$ | $2^{15}+2^{16}*N$ (N∈[0,15]) | 1s+30.5us | 1s | 1s+30.5us | 1s | 1s+30.5us | 1s | 1s+30.5us | 1s | 1s+30.5us | 1s | 1s+30.5us | 1s | 1s+30.5us | 1s | 1s+30.5us | 1s |
| CALM[5] | 32 | $2^{14}$ | $2^{15}$ | $2^{14}+2^{15}*N$ (N∈[0,31]) | 1s+30.5us | 1s+30.5us | 1s+30.5us | 1s+30.5us | 1s+30.5us | 1s+30.5us | 1s+30.5us | 1s+30.5us | 1s+30.5us | 1s+30.5us | 1s+30.5us | 1s+30.5us | 1s+30.5us | 1s+30.5us | 1s+30.5us | 1s+30.5us |
| CALM[6] | 64 | $2^{13}$ | $2^{14}$ | $2^{13}+2^{14}*N$ (N∈[0,63]) | 1s+30.5*2us | 1s+30.5*2us | 1s+30.5*2us | 1s+30.5*2us | 1s+30.5*2us | 1s+30.5*2us | 1s+30.5*2us | 1s+30.5*2us | 1s+30.5*2us | 1s+30.5*2us | 1s+30.5*2us | 1s+30.5*2us | 1s+30.5*2us | 1s+30.5*2us | 1s+30.5*2us | 1s+30.5*2us |
| CALM[7] | 128 | $2^{12}$ | $2^{13}$ | $2^{12}+2^{13}*N$ (N∈[0,127]) | 1s+30.5*4us | 1s+30.5*4us | 1s+30.5*4us | 1s+30.5*4us | 1s+30.5*4us | 1s+30.5*4us | 1s+30.5*4us | 1s+30.5*4us | 1s+30.5*4us | 1s+30.5*4us | 1s+30.5*4us | 1s+30.5*4us | 1s+30.5*4us | 1s+30.5*4us | 1s+30.5*4us | 1s+30.5*4us |
| CALM[8] | 256 | $2^{11}$ | $2^{12}$ | $2^{11}+2^{12}*N$ (N∈[0,255]) | 1s+30.5*8us | 1s+30.5*8us | 1s+30.5*8us | 1s+30.5*8us | 1s+30.5*8us | 1s+30.5*8us | 1s+30.5*8us | 1s+30.5*8us | 1s+30.5*8us | 1s+30.5*8us | 1s+30.5*8us | 1s+30.5*8us | 1s+30.5*8us | 1s+30.5*8us | 1s+30.5*8us | 1s+30.5*8us |
| CALM[8:0]= 0x1FF | 511 | | | | 1s+30.5*16us | 1s+30.5*16us | 1s+30.5*16us | 1s+30.5*16us | 1s+30.5*16us | 1s+30.5*16us | 1s+30.5*16us | 1s+30.5*16us | 1s+30.5*16us | 1s+30.5*16us | 1s+30.5*16us | 1s+30.5*16us | 1s+30.5*16us | 1s+30.5*16us | 1s+30.5*16us | 1s+30.5*16us |
| CALP | 复位后增加计数的 $RTC_{CLK}$ | 增加计数 $RTC_{CLK}$ 起始点 | 增加计数的 $RTC_{CLK}$ 步进值 | 增加计数的 $RTC_{CLK}$ 位置 | RTCOUT 1HZ秒间隔 | | | | | | | | | | | | | | | |
| | | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| CALP[0]=1 | 512 | $2^{11}$ | $2^{11}$ | $2^{11}+2^{11}*N$ (N∈[0,511]) | 1s-30.5us*16 | 1s-30.5us*16 | 1s-30.5us*16 | 1s-30.5us*16 | 1s-30.5us*16 | 1s-30.5us*16 | 1s-30.5us*16 | 1s-30.5us*16 | 1s-30.5us*16 | 1s-30.5us*16 | 1s-30.5us*16 | 1s-30.5us*16 | 1s-30.5us*16 | 1s-30.5us*16 | 1s-30.5us*16 | 1s-30.5us*16 |
| CALM[8:0]= 0x1FF CALP[0]=1 | | | | | 1s +30.5*16us -30.5us*16 | 1s +30.5*16us -30.5us*16 | 1s +30.5*16us -30.5us*16 | 1s +30.5*16us -30.5us*16 | 1s +30.5*16us -30.5us*16 | 1s +30.5*16us -30.5us*16 | 1s +30.5*16us -30.5us*16 | 1s +30.5*16us -30.5us*16 | 1s +30.5*16us -30.5us*16 | 1s +30.5*16us -30.5us*16 | 1s +30.5*16us -30.5us*16 | 1s +30.5*16us -30.5us*16 | 1s +30.5*16us -30.5us*16 | 1s +30.5*16us -30.5us*16 | 1s +30.5*16us -30.5us*16 | 1s +30.5*16us -30.5us*16 |

| CALM[8:0] | 复位后减少计数的 $RTC_{CLK}$ | 减少计数 $RTC_{CLK}$ 起始点 | 减少计数的 $RTC_{CLK}$ 步进值 | 减少计数的 $RTC_{CLK}$ 位置 | RTCOUT 1HZ秒间隔 | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 |
| CALM[0] | 1 | $2^{19}$ | | | 1s | 1s | 1s | 1s | 1s | 1s | 1s | 1s | 1s | 1s | 1s | 1s | 1s | 1s | 1s | 1s |
| CALM[1] | 2 | $2^{18}$ | $2^{19}$ | $2^{18}+2^{19}*N$ (N∈[0,1]) | 1s | 1s | 1s | 1s | 1s | 1s | 1s | 1s+30.5us | 1s | 1s | 1s | 1s | 1s | 1s | 1s | 1s |
| CALM[2] | 4 | $2^{17}$ | $2^{18}$ | $2^{17}+2^{18}*N$ (N∈[0,3]) | 1s | 1s | 1s | 1s+30.5us | 1s | 1s | 1s | 1s | 1s | 1s | 1s | 1s+30.5us | 1s | 1s | 1s | 1s |
| CALM[3] | 8 | $2^{16}$ | $2^{17}$ | $2^{16}+2^{17}*N$ (N∈[0,7]) | 1s | 1s+30.5us | 1s | 1s | 1s | 1s+30.5us | 1s | 1s | 1s | 1s+30.5us | 1s | 1s | 1s | 1s+30.5us | 1s | 1s |
| CALM[4] | 16 | $2^{15}$ | $2^{16}$ | $2^{15}+2^{16}*N$ (N∈[0,15]) | 1s+30.5us | 1s | 1s+30.5us | 1s | 1s+30.5us | 1s | 1s+30.5us | 1s | 1s+30.5us | 1s | 1s+30.5us | 1s | 1s+30.5us | 1s | 1s+30.5us | 1s |
| CALM[5] | 32 | $2^{14}$ | $2^{15}$ | $2^{14}+2^{15}*N$ (N∈[0,31]) | 1s+30.5us | 1s+30.5us | 1s+30.5us | 1s+30.5us | 1s+30.5us | 1s+30.5us | 1s+30.5us | 1s+30.5us | 1s+30.5us | 1s+30.5us | 1s+30.5us | 1s+30.5us | 1s+30.5us | 1s+30.5us | 1s+30.5us | 1s+30.5us |
| CALM[6] | 64 | $2^{13}$ | $2^{14}$ | $2^{13}+2^{14}*N$ (N∈[0,63]) | 1s+30.5*2us | 1s+30.5*2us | 1s+30.5*2us | 1s+30.5*2us | 1s+30.5*2us | 1s+30.5*2us | 1s+30.5*2us | 1s+30.5*2us | 1s+30.5*2us | 1s+30.5*2us | 1s+30.5*2us | 1s+30.5*2us | 1s+30.5*2us | 1s+30.5*2us | 1s+30.5*2us | 1s+30.5*2us |
| CALM[7] | 128 | $2^{12}$ | $2^{13}$ | $2^{12}+2^{13}*N$ (N∈[0,127]) | 1s+30.5*4us | 1s+30.5*4us | 1s+30.5*4us | 1s+30.5*4us | 1s+30.5*4us | 1s+30.5*4us | 1s+30.5*4us | 1s+30.5*4us | 1s+30.5*4us | 1s+30.5*4us | 1s+30.5*4us | 1s+30.5*4us | 1s+30.5*4us | 1s+30.5*4us | 1s+30.5*4us | 1s+30.5*4us |
| CALM[8] | 256 | $2^{11}$ | $2^{12}$ | $2^{11}+2^{12}*N$ (N∈[0,255]) | 1s+30.5*8us | 1s+30.5*8us | 1s+30.5*8us | 1s+30.5*8us | 1s+30.5*8us | 1s+30.5*8us | 1s+30.5*8us | 1s+30.5*8us | 1s+30.5*8us | 1s+30.5*8us | 1s+30.5*8us | 1s+30.5*8us | 1s+30.5*8us | 1s+30.5*8us | 1s+30.5*8us | 1s+30.5*8us |
| CALM[8:0]= 0x1FF | 511 | | | | 1s+30.5*16us | 1s+30.5*16us | 1s+30.5*16us | 1s+30.5*16us | 1s+30.5*16us | 1s+30.5*16us | 1s+30.5*16us | 1s+30.5*16us | 1s+30.5*16us | 1s+30.5*16us | 1s+30.5*16us | 1s+30.5*16us | 1s+30.5*16us | 1s+30.5*16us | 1s+30.5*16us | 1s+30.5*15us |
| CALP | 复位后增加计数的 $RTC_{CLK}$ | 增加计数 $RTC_{CLK}$ 起始点 | 增加计数的 $RTC_{CLK}$ 步进值 | 增加计数的 $RTC_{CLK}$ 位置 | | | | | | | | | | | | | | | | |
| | | | | | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 |
| CALP[0]=1 | 512 | $2^{11}$ | $2^{11}$ | $2^{11}+2^{11}*N$ (N∈[0,511]) | 1s-30.5us*16 | 1s-30.5us*16 | 1s-30.5us*16 | 1s-30.5us*16 | 1s-30.5us*16 | 1s-30.5us*16 | 1s-30.5us*16 | 1s-30.5us*16 | 1s-30.5us*16 | 1s-30.5us*16 | 1s-30.5us*16 | 1s-30.5us*16 | 1s-30.5us*16 | 1s-30.5us*16 | 1s-30.5us*16 | 1s-30.5us*16 |
| CALM[8:0]= 0x1FF CALP[0]=1 | | | | | 1s +30.5*16us -30.5us*16 | 1s +30.5*16us -30.5us*16 | 1s +30.5*16us -30.5us*16 | 1s +30.5*16us -30.5us*16 | 1s +30.5*16us -30.5us*16 | 1s +30.5*16us -30.5us*16 | 1s +30.5*16us -30.5us*16 | 1s +30.5*16us -30.5us*16 | 1s +30.5*16us -30.5us*16 | 1s +30.5*16us -30.5us*16 | 1s +30.5*16us -30.5us*16 | 1s +30.5*16us -30.5us*16 | 1s +30.5*16us -30.5us*16 | 1s +30.5*16us -30.5us*16 | 1s +30.5*16us -30.5us*16 | 1s +30.5*15us -30.5us*16 |

From the figure above, it can be seen that the 32nd S actually decreases by 30.5us (adding an RTC_CLK), which is 999.965ms.

## 3.3 Measurement of RTC Digital Clock Precision Calibration Algorithm

By measuring the RTC calibration signal output from the RTC_OUT pin, it was found that the actual time for 1-31 seconds was 1 second, and for the 32nd second, the RTC calendar actually measured 999.981ms. This aligns with the theoretical calibration algorithm calculation values in Section 3.2



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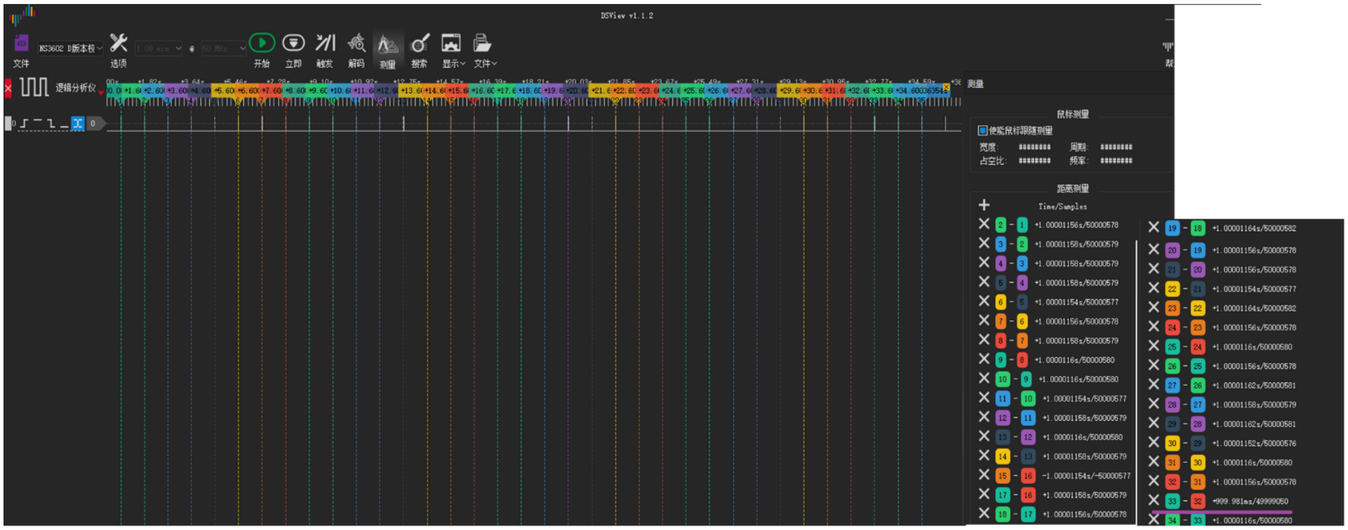

# 4. Temperature Compensation of LSE Using Precise Calibration Application Example

## 4.1 LSE Temperature Curve

If high-precision RTC calendar timing is required in practical applications, external quartz crystals are often used to provide clocks for RTC modules. However, the external quartz crystal is affected by the environment, The actual frequency also fluctuates. At this time, it is necessary to use the digital clock precision calibration module to calibrate the external quartz crystal. The following figure shows the temperature curve corresponding to the frequency deviation of a certain crystal model.



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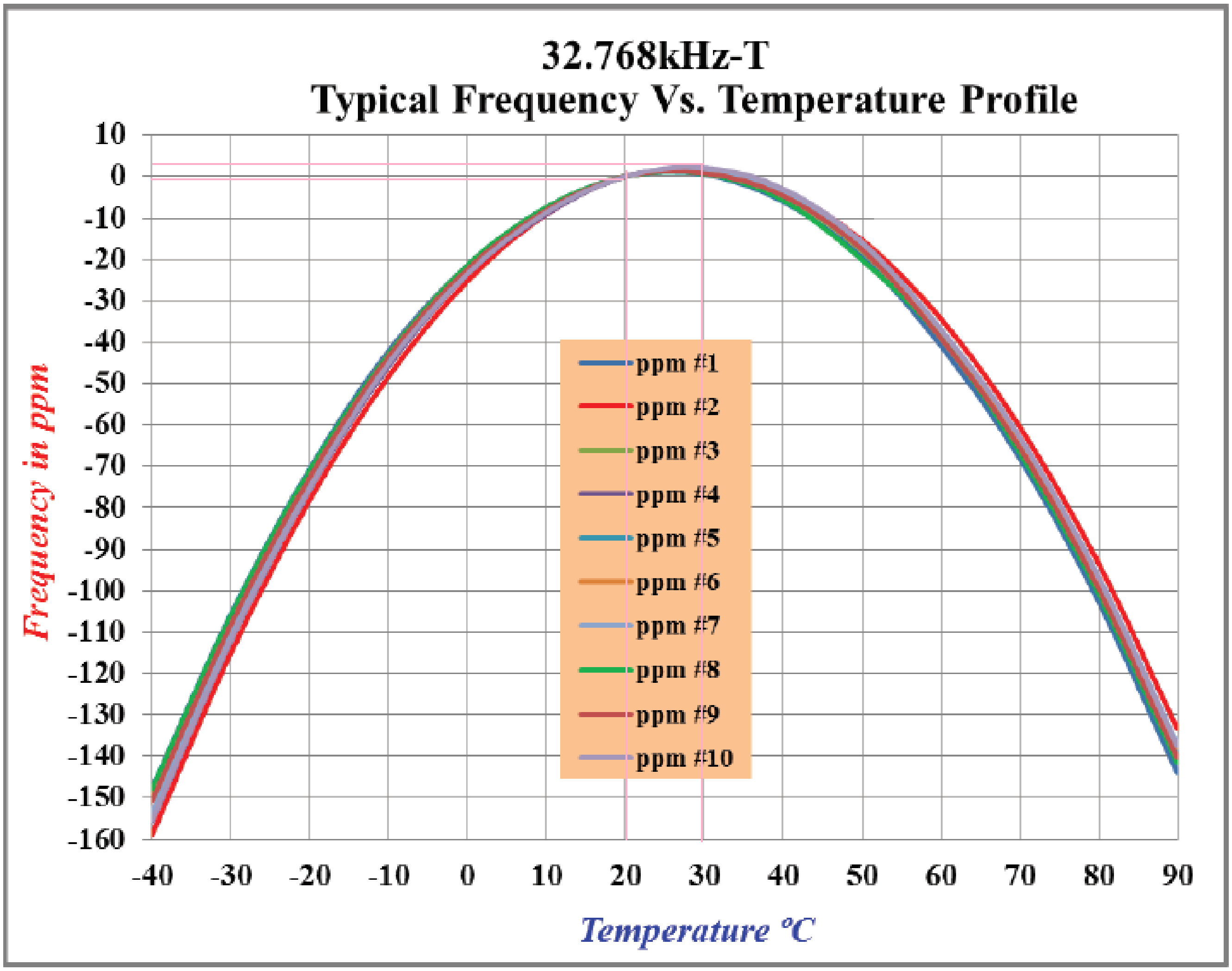
Figure 4-1 Temperature Curve of Quartz Crystal Frequency Deviation




## 4.2 Theoretical Calibration Value of RTC Precision Calibration Module

The resolution of the RTC precision calibration module is approximately 0.954 ppm (32S calibration cycle). According to the frequency deviation temperature curve of quartz crystal in Figure 4-1, the theoretical error of this crystal at room temperature (20 to 30°C) is about - 2 to 4 ppm. It can be concluded that in theory, the RTC precision calibration module 32S requires a reduction of 2 ~ -4.19 RTC_CLKs. To compensate for the temperature deviation caused by temperature changes when using this crystal frequency.

## 4.3 RTC Precision Calibration Configuration Code

Based on the above theoretical calculation, select to insert 2 RTC_CLKs to compensate for external crystal 2ppm. The calibration configuration code is as follows:



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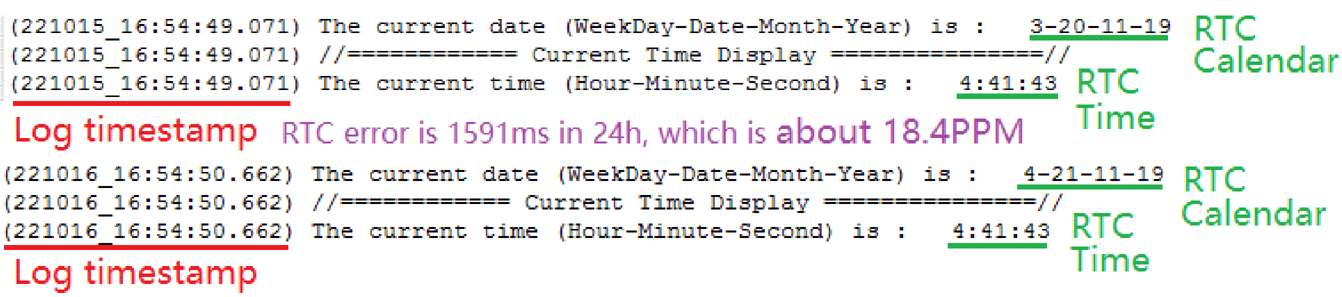
```
RTC_ConfigSmoothCalib(SMOOTH_CALIB_32SEC,RTC_SMOOTH_CALIB_PLUS_PULSES_SET,510);
```

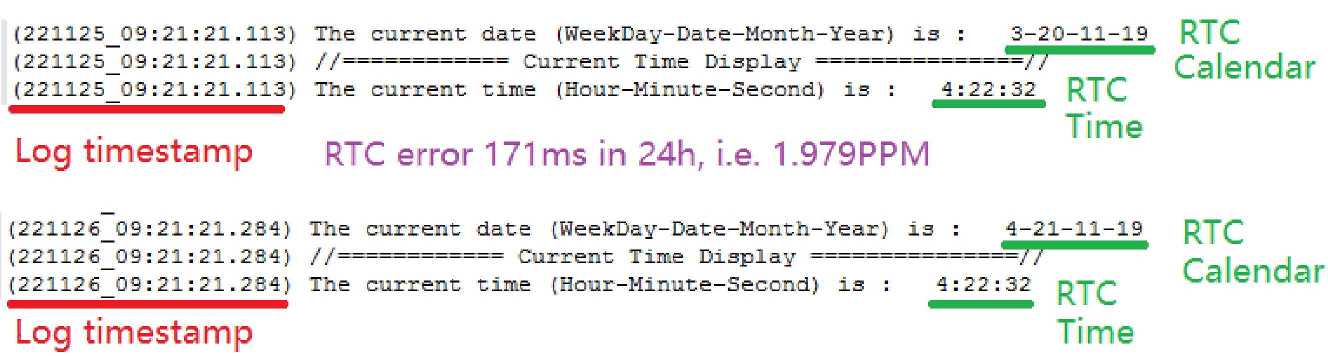
## 4.4 RTC Precision Calibration And Actual Measurement

After actual measurement at normal temperature (20~30 °C)) without using the RTC precision calibration module, the error is 18.4PPM. Considering that the actual situation is more complicated than the ideal temperature curve of LSE, the actual situation deviates from the theoretical value by more than ten PPM. Normal, the actual value needs to be measured to get it.




Through continuous calibration attempts at room temperature (20 to 30 °C) and insert 5 LSEs in a 32S cycle, RTC 24-hour error 171ms (1.97ppm) , which can significantly improve the RTC time accuracy.

```
RTC_ConfigSmoothCalib(SMOOTH_CALIB_32SEC,RTC_SMOOTH_CALIB_PLUS_PULSES_SET,506);
```



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# 5. Version History

| Version | Date | Changes |
| --- | --- | --- |
| V1.0 | 2022.11.16 | Initial version |
| | | |



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