Application Note

BRT_AN_009

RTC Calibration in FT93x

Version 1.0

Issue Date: 2017-03-09

This application note describes the calibration and trimming process of the Real Time Clock (RTC) in FT93X.

Bridgetek Pte Ltd. (BRT Chip)
178 Paya Lebar Road, #07-03 Singapore 409030
Tel : +65 6547 4827 Fax : +65 6841 6071
Web Site: http://www.brtchip.com

Table of Contents

1 Introduction

The FT930 or FT931 Real Time Clock (RTC) has a feature to compensate for the frequency variations caused by crystal tolerance and temperature. On-chip calibration and trimming support is provided to adjust the RTC's frequency. Two counters are used for counting the RTC reference clock from a signal generator and the RTC clock from a 32 KHz crystal in the calibration process.

The difference between the two counters is read and added to (or subtracted from)32767 as a trimming value, when the counter value for counting reference clock matches to the value of 32768 multiplied to the trimming time. The trimming time is determined by the RTC_CTRL[4] bit and RTC_CTRL[5] bit in the *RTC_CTRL* register, as mentioned in Table 1.The trimming value and trimming time are loaded to the *RTC_TRIM_VALUE* register automatically when the process is completed. The 1.2V input on VBAT has to be presented to maintain the value in the register. The detail is mentioned in Section 15 of the user manual.

1.1 Scope

This application note focuses on describing the following different calibration approaches. User may use either approach 1 or approach 2 for initial trimming. Approach 3 can be used for further trimming after some days from initial trimming.

1. Calibration with an accurate 32768Hz reference clock.
2. Calibration with the on-chip internal timer
3. Calibration by user observation

2 Approaches for Calibration Process

2.1 Calibration with a 32KHz reference clock

The FT930 or FT931 RTC provides an on-chip calibration and trimming facility. Users have to provide a 32768Hz from a signal generator to the RTC_REF pin and perform the calibration by following the procedure below. The RTC accuracy is the sum of the frequency accuracy in PPM of the reference clock and the accuracy per trimming code in PPM (see Table 2).

1) Ensure that the RTC is disabled. Clear RTC_CTRL.RTCEN bit to zero in the *RTC_CTRL* Register
2) Configure GPIO38 to be an input for the clock reference (RTC_REF).
3) Enable the RTC interrupt for the calibration process.
4) Configure the desired calibration time by setting RTC_CTRL[5] and RTC_CTRL[4] bits. Then set AUCAL bit, INTEN bit, and WRST/BS bits in the *RTC_CTRL register* to start the calibration. The RTC_CTRL[5] and RTC_CTRL[4] bits are set according to the selected calibration time, see Table 1.

RTC_CTRL[5]	RTC_CTRL[4]	Calibration Time
0	0	1 second
0	1	60 seconds
1	0	600 seconds
1	1	1000 seconds

Table 1 Calibration Time Options.

5) Wait for the interrupt for the completion of the calibration. In the ISR, the calibration is disabled by setting the CALINT bit in the *RTC_STAT* register and writing 0x200 to the *RTC_CTRL* register. The trimming value and trimming time will be uploaded to the Trimming Register (RTC_TRIM) for the trimming process.
6) Users may program a time and a date and then set the RTCEN bit and WRST/BS bit in the *RTC_CTRL* register. The RTC is now operating with the trimmed time and trimmed value.

The accuracy of the trimming value from the calibration process depends upon the selected calibration time. Table 2 shows the accuracy per trimming code versus the calibration time. The frequency range to be calibrated is also referenced in the table. A trimming value from the calibration process can be applied to the different frequency ranges based on the calibration time.

Calibration Time (in seconds)	Accuracy per Trimming Code (PPM)	Minimum Frequency (Hz) to be calibrated	Maximum Frequency (Hz) to be calibration
1	30.51757813	16385	49153
60	0.508626302	32494.95	33041.083
600	0.05086263	32740.695	32795.3083
1000	0.030517578	32751.617	32784.385

Table 2 Calibration Time/Accuracy vs Frequency Range

2.2 Calibration with The On-chip Internal Timer

The approach described in Section 2.1 is an accurate calibration process to get the trimming value. However, it has to be performed with a signal generator with a 32768Hz for the reference clock. It may also take a longer time to get a trimming value.

In this section, a software approach calibration is introduced based on FT93x system clock and software calculation. The RTC calibration accuracy depends on the system clock frequency accuracy.

To achieve the desired RTC calibration accuracy, the user needs to either supply a pre-calibrated 12 MHz system clock to FT93X or calibrate the 100 MHz system clock derived from the 12 MHz system clock crystal. There are several ways to measure the system clock frequency, for example, the user can enable the PWM to output a periodical waveform and measure the clock accuracy with a clock/frequency counter.

The calibration steps are shown below, assuming that the system clock is an accurate 12 MHz clock source.

1) In this method, the software monitors system timer count number over the 2 RTC time incremental period (1 second nominal). In the calibration process, the time measurement should not be affected by other tasks which could cause the measurement uncertainty. The timer is running at 100 MHz source, as a result, the error introduced by this method is one 100 MHz clock cycle or 10 ns if the measurement interval is 1 second.

2) First, ensure that the RTC is disabled. Clear RTC_CTRL.RTCEN bit to zero in the RTC Control Register.

3) The global and RTC Alarm1 interrupt are enabled .The RTC time is set to default and the RTC alarm time for the alarm interrupt is set to 1 second with "seconds match" option. The internal timer with 1us timer interval and count-down is also configured.

4) Start the RTC by setting the WRST/BS bit, A1IE bit, INTEN bit, and RTCEN bit in the *RTC_CTRL* register and then enable the internal timer.

5) During the calibration period, the internal timer register is being polled and compared with the previous polled value for checking the transition of 1us in a while loop of the main function. A variable (TmrIntCnt) is incremented for the transition.

6) Once the RTC Alarm1 triggers the Alarm1 ISR, the internal timer is stopped in the ISR. The RTC_STAT.A1INT is cleared and The RTC is reset by setting 0x200 to RTC_CTRL. This will disable the Alarm1 interrupt and the RTC. A flag is set for exiting the while loop in main function.

7) Upon exiting the while loop, the internal timer (current count) is read. The TmrIntCnt is incremented by 1 if current count > previous count. This is to compensate the case where the alarm interrupt comes at the moment of comparing the current count and previous count of the internal timer. The current count then subtracts from the initial value of the internal timer and is stored in a variable (RemainCnt). The code example for 1 to 7 is attached in Appendix C.

8) The *TmrIntCnt* and the *RemainCnt* are used for calculating the trimming value by Equation 1 and Equation 2:

$$trimming\ frequency(TrimFreq) = \frac{1 \times 10^8}{\text{TmrIntCnt} \times 100 + \text{RemainCnt}} \times 32768 \qquad \text{Equation 1}$$

$$trimming\ value(TrimVal) = (int(TrimFreq \times 1000) - 32768000) + 32767 \qquad \text{Equation 2}$$

9) With the trimming value and the default trimming time (which in this case is 1000 seconds), the value of the Trimming Register (RTC_TRIM) is determined by the following formula: *Trimming register value (RTC_TRIM) = (1000 << 16) + TrimVal*

10) After programming the Trimming Register, the user may program a time and date and then set the RTCEN bit and the WRST/BS bit in the Control Register to start the RTC.

2.3 Calibration by User's Observation

With the trimming procedure mentioned in section 2.1 or 2.2, users may observe the time difference between the RTC of the device and an external time reference after some days. The external time reference may be get from internet, wrist watch etc. Users can calculate the local RTC accuracy (RTC_PPM) from the difference to the external time reference. For example, user observes 60 seconds faster than the external time reference over 30 days. By using the Equation 3, the accuracy of the RTC (RTC_PPM) is about 23.1 ppm.

$$RTC\_PPM = \frac{delta\ in\ seconds\ between\ RTC\ and\ the\ external\ time\ reference}{\frac{86400sec/day \times 30days}{1000000}} \qquad \text{Equation 3}$$

Assuming that the user has set 1000 seconds as the trimming time in the previous trimming process, the Trimming Register (RTC_TRIM) can be updated using the following steps:

- Intial_trimval = RTC_TRIM & 0x0000ffff
- TrimVal = initial_trimval + (RTC_PPM /Accuracy per Trimming Code)[1].
  In this case, the Accuracy per Trimming Code is 0.03 with the Calibration Time in 1000 seconds as mentioned in Table 2.
- RTC_TRIM = (1000 << 16) + TrimVal

With the updated value in *RTC_TRIM*, users may program a time and a date observed from the external time reference to the Time Register (RTC_TIME) and the Date Register (RTC_DATE) accordingly, and then set the WRST/BS bit for updating the programmed registers. This can be done while the RTC is running.

[1] a positive or negative integer value.

3 Contact Information

Head Quarters – Singapore

Bridgetek Pte Ltd
178 Paya Lebar Road, #07-03
Singapore 409030
Tel: +65 6547 4827
Fax: +65 6841 6071

E-mail (Sales) sales.apac@brtchip.com
E-mail (Support) support.apac@brtchip.com

Branch Office – Taipei, Taiwan

Bridgetek Pte Ltd, Taiwan Branch
2 Floor, No. 516, Sec. 1, Nei Hu Road, Nei Hu District
Taipei 114
Taiwan , R.O.C.
Tel: +886 (2) 8797 5691
Fax: +886 (2) 8751 9737

E-mail (Sales) sales.apac@brtchip.com
E-mail (Support) support.apac@brtchip.com

Branch Office - Glasgow, United Kingdom

Bridgetek Pte. Ltd.
Unit 1, 2 Seaward Place, Centurion Business Park
Glasgow G41 1HH
United Kingdom
Tel: +44 (0) 141 429 2777
Fax: +44 (0) 141 429 2758

E-mail (Sales) sales.emea@brtichip.com
E-mail (Support) support.emea@brtchip.com

Branch Office – Vietnam

Bridgetek Vietnam Company Limited
Lutaco Tower Building, 5th Floor, 173A Nguyen Van Troi,
Ward 11, Phu Nhuan District,
Ho Chi Minh City, Vietnam
Tel : 08 38453222
Fax : 08 38455222

E-mail (Sales) sales.apac@brtchip.com
E-mail (Support) support.apac@brtchip.com

Web Site

http://brtchip.com/

Distributor and Sales Representatives

Please visit the Sales Network page of the Bridgetek Web site for the contact details of our distributor(s) and sales representative(s) in your country.

Appendix A - References

Document References

BRT_AN_010_FT93x_User_Manual

DS_FT930_1_2_3

Acronyms and Abbreviations

Terms	Description
HW	Hardware
PPM	Parts Per Million
RTC	Real Time Clock

Appendix B – List of Tables & Figures

List of Tables

List of Figures

Not Applicable.

Appendix C – Code Example

```
main()
{
	timer_initial_value=99
	interrupt_flag=1

	Disable the RTC // i.e. RTC_CTRL.RTCEN=0
	Initialize the internal timer
	Configure the internal timer with 1us interval,count-down mode
	Enable global interrupt
	Enable the RTC alarm interrupt

	Set the RTC time to default (RTC_TIME=0x00000000) and the RTC alarm time
	(RTC_AALARM1=0x80808001) for second match.

	Start the RTC by setting WRST/BS, A1IE, INTEN, and RTCEN in RTC_CTRL.
	Start the internal timer
	TmrIntCnt=0
	previous_count=timer_initial_value
	current_count=read internal timer counter


	while (interrupt_flag){//interrupt_flag=1 when waiting alarm_ISR
		{
			if (current_count>previous_count) TmrIntCnt++
			previous_count=current_count;
			current_count=read internal timer counter
		}
	//exit from alarm_ISR
	current_count=read internal timer counter

	//cover the case where alarm_interrupt comes at the moment of
	//comparison of current_count and previous count
	if (current_count>previous_count) TmrIntCnt++
	RemainCnt=timer_initial_value-current_count

}//end of main()

alarm_ISR
{
	Stop the internal timer
	Clear RTC_STAT.A1INT
	Disable the RTC by writing 0x200 to RTC_CTRL
	interrupt_flag=0

}//end of alarm_ISR
```

Appendix D – Revision History

Document Title: BRT_AN_009 RTC Calibration in FT93x
Document Reference No.: BRT_000108
Clearance No.: BRT#076
Product Page: http://brtchip.com/product/
Document Feedback: Send Feedback

Revision	Changes	Date
1.0	Initial release	2017-03-09