A Novel Method for Low-Power, High-Precision Time-keeping based on MCXO

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***Abstract*—The watch crystal oscillator can achieve very-low-power time-keeping, even less than 1μW, which best overall accuracy with temperature-compensation has remained at about 1 ppm. For comparison, the timing system using Microprocessor Compensated (AT or SC-cut) Crystal Oscillator is capable of providing at least 10- to 100-times improvement in time-keeping accuracy, milliseconds-per-day, with the penalty of requiring considerably more power, about tens of milliwatts. In this paper a novel method for time-keeping based on MCXO is described, which is to simultaneously meet the needs of very-low-power and high-precision timing.**

I. Introduction

The quartz wristwatches that are common these days represent accurate very-low-power timekeeping. The temperature range over which watches would remain accurate however is very limited[1]. Though temperature compensation has been adopted in wristwatch quartz oscillators, the timekeeping accuracy is not better than 1ppm[2].

On the other hand, the AT-cut or SC-cut quartz oscillators, which has better temperature coefficient, using temperature compensation can easily get the thermal stability 0.1-0.3 ppm[3]. But their power consumption is about multi-miliwatts, which is a few orders of magnitude greater than the wristwatch quartz.

In this paper, we propose a novel method for time-keeping based on MCXO(AT-cut), by which the needs of very-low-power and high-precision timekeeping can be simultaneously meet.

II. OPERATION OF THE TEMPERATURE COMPENSATED TIMEKEEPING

Fig. 1 shows system of the conventional temperature compensated timekeeping. The system is composed of a temperature sensor, VCXO(Voltage Controlled Crystal Oscillator), DAC(D/A converter), microprocessor and counter/timer. In the operation of this system, the temperature sensor converts ambient temperature into a digital signal. The signal is transferred to the microprocessor. Next, the microprocessor calculates the digital compensation values of the VCXO. The DAC generates control voltage Vc to VCXO and Vc is compensating for the temperature. Finally, the compensated clock will drive the counter/timer for timekeeping.

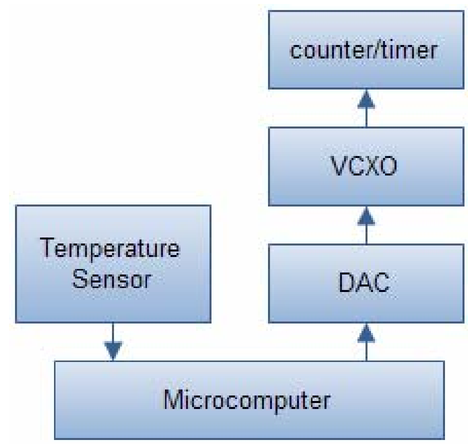

Figure 1. the conventional temperature compensated timekeeping

We consider the disadvantage of the conventional temperature compensated timekeeping, that is indirect temperature compensated timekeeping. The frequency stability is the first, achieved by analog circuits such as temperature sensor, DAC and VCXO. These analog circuits is the main sources of power consumption.

This disadvantage is overcome by direct temperature compensated timekeeping method. Fig. 2 shows the proposed system of direct temperature compensated timekeeping, which excludes DAC and VCXO, directly compensates the count number in the timer by the microprocessor. This method reduces analog circuit elements, so the power is decreased. The accuracy of proposed method is as same as conventional temperature compensated timekeeping, because they are all based on the MCXO technology. Further more, the fewer

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analog circuits, the more ability against variation of the manufacture process, voltage and temperature.

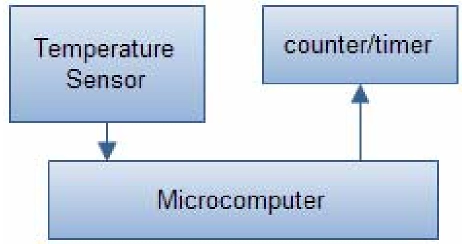

Figure 2. the direct temperature compensated timekeeping

III. OPERATION OF THE LOW-POWER TIMEKEEPING

In the conventional temperature compensation operation, for the continuous stability of frequency, the microprocessor needs to work uninterruptedly. The power of the microprocessor is comparable to the rest of MCXO.

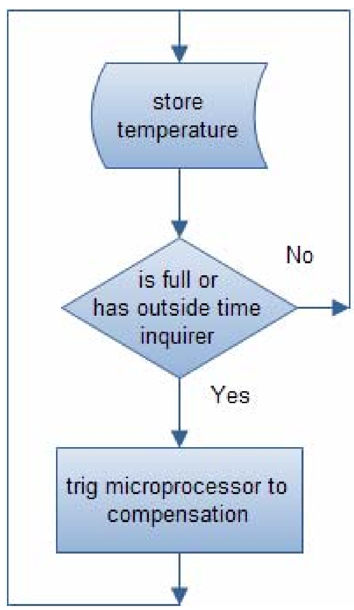

Figure 3. the novel compensation flow

To reduce power further, a novel compensation flow is designed, illustrated in Fig. 3. As that described in section II, the input information of the compensation procedure is the temperature and the count number, which can be stored in memory, not like the frequency. So the temperature information is stored in the memory until some event, such as a fill of memory or time inquirer from outside, trigs the microprocessor to compensate the count number with that temperature history. And between adjacent triger events, the microprocessor can even be power off. Since the time of the microprocessor to complete a cumulate compensation is negligible to the period of a fill of temperature information memory, so the average current of the intermittent operation is almost equal to the total power of a oscillator, a temperature sensor and a timer, which can be reduce to a few hundreds of microwatts using other low-power technology[4].

IV. EXPERIMENTAL RESULTS

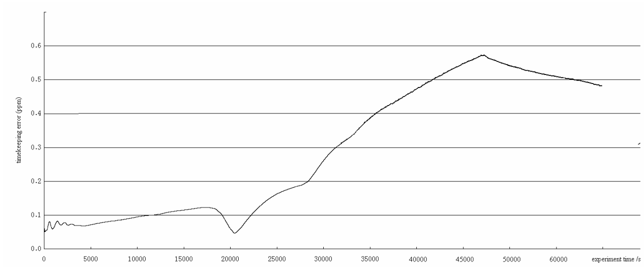

Figure 4. the timekeeping experiment

Fig. 4 shows the one day timekeeping accuracy log of our direct temperature compensated timekeeping prototype using a AT-cut quartz oscillator. The timekeeping error is less than 0.6ppm. The experimental temperature environment is 15 hours temperature change from 25 degrees to -20 degrees then to 65 degrees Centigrade until end of the experiment.

The average current of the low-power timekeeping is about 100uA in SPICE simulation with SMIC 0.18um process model.

V. CONCLUSION

Our novel method of timekeeping based on MCXO is the combination of direct temperature compensated timekeeping and intermittent temperature compensation. This method can achieve very low-power and high-precision timekeeping.

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