RTC Crystals – 6pF vs. 12.5pF

For All Processor Companions w/ RTC

Overview

The FM31xx, FM4005, FM30C256, and FM3808 are Integrated Processor Companion devices that feature a real-time clock or RTC. The RTC provides the date/time information for the system and operates on either V_{DD} or V_{BAK} (battery) power. The RTC oscillator was designed to use a 6pF crystal, however the more common 12.5pF type may be used if the designer considers the implications. This application note focuses on the use of 6pF vs. 12.5pF crystals for the RTC oscillator.

Oscillators and Crystal Loading

The RTC on all Ramtron processor companions is driven by a crystal oscillator. A common watch crystal is used as the resonating element. A relatively low oscillating frequency of 32,768 Hz provides an accurate, low power timebase for the divide-by counters that generate seconds, minutes, hours, etc. Watch crystals are produced by many suppliers that build crystals that resonate at 32.768 kHz when properly loaded.

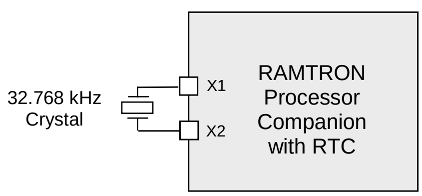

Figure 1. Crystal Hookup to RTC

All 32.768kHz crystals have a capacitive rating. There are two common crystals on the market, a "6pF" type and a "12.5pF" type. This rating is the recommended capacitive load that the crystal must see when operating. That is, the X1/X2 pins must present a 6pF load to a "6pF" crystal. The rating is <u>not</u> the capacitance of the crystal (shunt capacitance), which tends to be about 1 pF.

All Ramtron companion devices have been designed to use the 6pF type, not the 12.5pF type. However, the system designer may choose to use a 12.5pF type if the loading mismatch considerations are made.

Oscillator Frequency Shift

Typically, RTC calibration is required primarily to compensate for the crystal tolerance, whether ±10ppm, ±20ppm, or ±50ppm. The use of a 12.5pF crystal introduces a loading mismatch factor when calibrating the RTC. A 12.5pF crystal expects to see 12.5pF capacitive load to ensure accurate frequency. But since Ramtron processor companions were designed for 6pF crystals, the load presented to the crystal is roughly half the proper value. This lighter load therefore shifts the oscillation frequency. The shift has been measured and is about +90 ppm, or 2.9 Hz. The frequency will be 32,770.9 Hz. In calibration mode, this frequency shift is seen directly on the CAL pin as 512.046 Hz. Figure 2 shows the parallel resonance area as the bold line where the RTC oscillator operates. A 12.5pF crystal (with 6pF load) operates up higher on the curve.

A +90 ppm error translates to nearly 4 minutes per month (runs fast), so calibrating the RTC is highly desirable. Note that the effect of the calibration setting to minimize the frequency error will <u>not</u> be seen on the 512 Hz CAL pin. The RTC applies a digital correction to the counter logic downstream of the 512 Hz output.

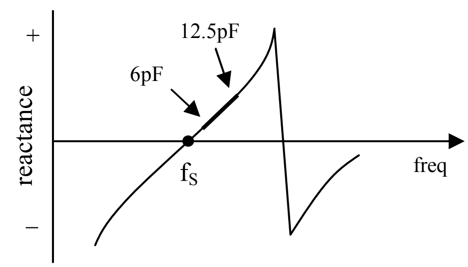

Figure 2. Higher Osc. Freq for 12.5pF Crystal

If you use a 12.5 pF crystal, it is recommended that the specified tolerance be ±20 ppm (or better) in order to ensure that the total error (tolerance + mismatch) remains within the ±135 ppm calibration range. If you use a 6 pF crystal, the tolerance may be as high as ±100 ppm since this is well within the calibration range.

Precautionary note: The oscillator's 32.768 kHz frequency cannot be monitored directly. Do not attach a scope probe or meter to the X1 or X2 pins. In calibration mode, the 512 Hz CAL pin is used to check the frequency. Also the calibration code may be entered only in calibration mode.

Calibration Procedure

The following sequence shows how to measure the oscillator frequency and apply a calibration code. The first 3 steps ensure I_{BAK} will be less than 1µA. On 2-wire devices, remember to use the Slave ID 1101b to access the RTC Registers.

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1. Apply V_{DD}
2. Apply V_{BAK}
3. Cycle V_{DD} off then on again
4. Turn on oscillator by setting /OSCEN bit low, Write 00h to RTC Register 01h
5. Set CAL bit high, Write 04h to RTC Register 00h
6. Measure 512 Hz output on CAL pin with a frequency counter
7. Determine calibration code setting from Calibration Adjustments table (see pg. 8-9 of FM31xx datasheet)
8. Apply calibration code. Example: Using a 12.5pF crystal, the oscillator runs fast and CAL output is 512.0490 Hz, Write 16h to RTC Register 01h
9. Reset CAL bit, Write 00h to RTC Register 00h

Temperature Effects

A key factor that contributes to timekeeping error is the crystal's temperature – even after the RTC has been calibrated. A calibration code can compensate for timekeeping errors due to capacitive load mismatch and crystal tolerance, but not for temperature. Figure 3 shows a typical temperature curve for 32.768 kHz crystals. As temperature rises or drops from +25°C, the oscillation frequency shifts lower and therefore the clock slows down.

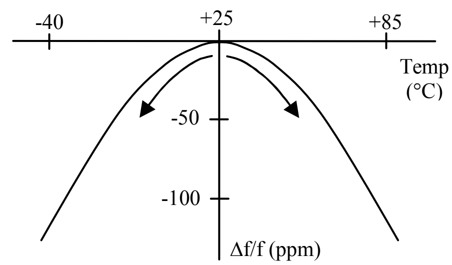

Figure 3. Crystal Freq Change vs. Temperature

If your system spends most of its time at room temperature and has few excursions above and below 25°C, then you should calibrate to "zero out" any frequency error by complying with the Calibration Adjustments table in the datasheet. On the other hand, if your system frequently spends time above and/or below room temperature, you will achieve improved clock accuracy by intentionally creating a slightly positive frequency error.

For example, suppose your system spends half the time at 25°C and half at 50°C, and the frequency error at 50°C is -30 ppm. Then applying a calibration code that is shifted +15 ppm will compensate for temperature changes. Please consult the crystal manufacturer for a temperature dependence curve.