71M651x
Energy Meter IC

AN_651X_032 **APPLICATION NOTE**

MAY 2006

Crystal Frequency Variations

The frequency generated by the 71M6511 or 71M6513 in conjunction with the external 32786Hz crystal may vary slightly, depending on the way the IC is supplied with power.

This Application Note explains the reason for the frequency deviation and methods that can be used to minimize this effect.

Frequency Deviation between 3.3V Supply and Battery Supply

Factors Determining the Oscillation Frequency

The ICs of the 71M651X Energy Meter Family use an external crystal to generate all internal clocks. This crystal is connected to the IC as shown in Figure 1, using two external capacitors

The oscillator frequency is determined by several factors, such as crystal parameters, capacitor values, the oscillator circuit, and trace and pin capacitance.

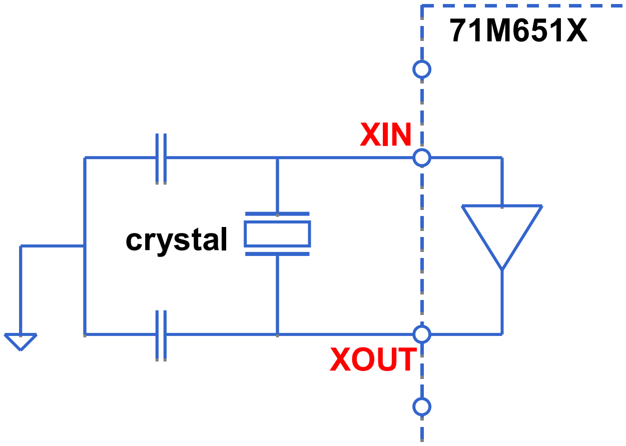

Figure 1: Crystal with Capacitors Connected to IC

The oscillator circuit used for the crystal is supplied by the internal V2P5 voltage of the IC. When the IC is operated with the regular 3.3V supply, the internal impedance of the V2P5 supply is slightly different as when the IC operates on battery. This reflects in a slight change of frequency, which depends on the crystal type, the crystal capacitors and the parasitic capacitance of pins, traces and the IC itself. The frequency difference will change with different capacitor values as well as with all other mentioned parameters.

Measuring Oscillator Frequency Deviation

The oscillator frequency should be observed indirectly, i.e. via the frequency measured at the TMUXOUT pin. To direct the RTC clock frequency to this pin, the four least significant bits of the I/O RAM register 0x2000 (*TMUX*) must be set to 0x0D. With this setting, the 32kHz clock driving the RTC will appear at the TMUXOUT pin.

If the TMUXOUT pin is not available, e.g. in a production unit, the crystal frequency can be measured with a probe that is connected to the XOUT pin via a 200kΩ resistor, as shown in

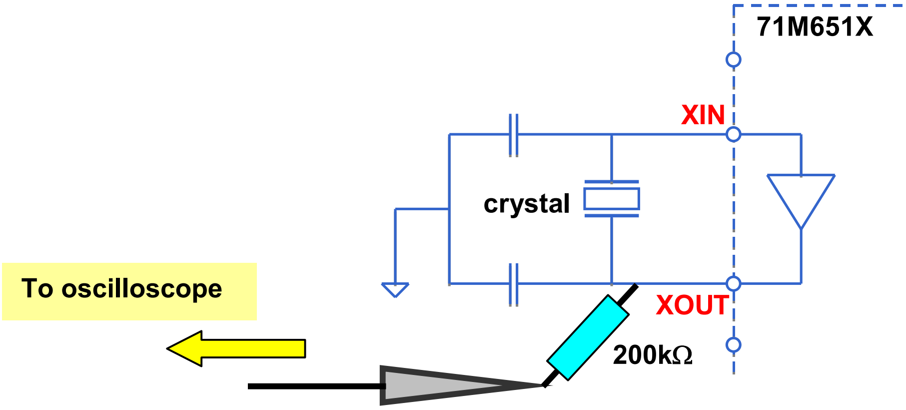

Figure 2: Probing the Crystal Frequency

Observed Magnitudes of Oscillator Frequency Deviation

Table 1 shows oscillator frequencies observed at three different battery voltages and at main supply voltage with various capacitor values, as obtained from a typical PCB with a commercially available crystal (ECS 327-12.5-17-TR). The measured values are displayed in Figure 3. Table 2 shows the measured values translated to deviation from the nominal frequency, expressed in PPM.

	Battery Voltage			V3P3
C [pF]	**3.6**	**3**	**2.5**	**3.3**
22	32768.15	32768.13	32768.04	32768.17
12	32769.99	32769.89	32769.73	32770
10	32770.78	32770.64	32768.04	32770.4

Table 1: Frequencies Observed at Various Voltages

	Battery Voltage			V3P3
C [pF]	**3.6**	**3**	**2.5**	**3.3**
22	4.6	4.0	1.2	5.2
12	60.7	57.7	52.8	61.0
10	84.8	80.6	1.2	73.2

Table 2: Frequency Deviation in PPM

As can be seen from the tables and from Figure 3, the variance in frequency is most pronounced when small capacitor values are used.

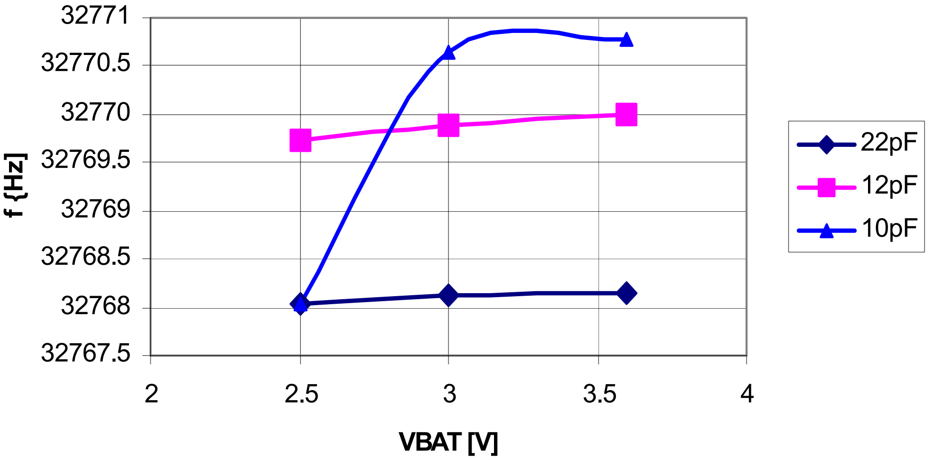

Figure 3: Frequency Deviation

Techniques to Minimize Oscillator Frequency Deviation

Obviously, the choice of the crystal and the capacitor values will have an immediate effect on the observed frequency deviation. Care should be taken when using larger values for the capacitors: If the values are too large, the circuitry may become more susceptible to EFT (electrical fast transients). Also, start-up behavior and frequency over temperature should also be analyzed before settling on a capacitor value. Good layout practices should be observed, also: The traces between the IC and the crystal should be short, located above a ground plane, and should be kept away from digital signal traces.

Apart from using proper capacitor values, firmware techniques can be used to counter frequency deviations. If the frequency deviation can be characterized for battery operation versus operation from the main power supply, the RTC can be corrected when the part returns from battery operation to normal operation. This correction must take into account the duration of the battery operation (T_B) and the expected deviation (d_f). The correction can then be calculated to (in seconds):

$$x = \frac{T_B \cdot d_f}{10^6} s$$

Where: T_B = time in battery operation (seconds)

d_f = frequency deviation from nominal (in PPM)

Example:

Let us assume that the crystal used with the 71M6511 or 71M6513 oscillates at 61 PPM above nominal when the IC is operated with the main power supply, but oscillates only at 57.7 PPM above nominal when the IC is operated with a 3.0V battery.

The Demo Code supplied with the 71M6511 and 71M6513 Demo Kits has a convenient way to compensate for linear and temperature-dependent frequency deviations in the form of the compensation coefficients Y_CAL, Y_CALC, and Y_CALC2. For this example, we need only the linear compensation: The 61 PPM deviation is compensated by writing the decimal value 610 into the memory location for the Y_CAL correction coefficient (Y_CAL is internally scaled by 1/10). After applying Y_CAL, the IC will subtract one second off the RTC count whenever the accumulated time multiplied by 61 PPM reaches a full second, which will be approximately every 4.5 hours.

For the battery operation, the automatic adjustment is disabled since it is implemented in firmware, and the MPU is inactive when the IC is in battery mode. Let us assume that the IC loses main power at point t_1 in time, goes to battery mode, and regains main power at t_2. It is important that the meter detects the loss of main power early and stores important metering data before the IC transitions to battery power. The sag detection mechanism provided by the CE is a useful tool to predict impeding loss of main power. At this point, the date and time data from the RTC must be stored to non-volatile memory in addition to the metering data. It is also useful to store a pattern that indicates that the IC was expecting the transition to battery operation. Since the MPU RAM is battery-buffered, this type of memory can be used for non-volatile storage.

When the IC returns to main power operation it needs to check whether it is coming out of a hardware reset, watchdog timer or battery operation condition. If the previously stored pattern is found, the firmware will conclude that it is dealing with a return from battery power, and will proceed by retrieving the stored time t_1. The firmware will then determine the time duration spent in battery mode (T_B) by subtracting t_1 from the current time. Let us assume that the meter was 4 days in battery mode. The correction to be applied would then have to be:

$$x = \frac{T_B \cdot d_f}{10^6} s = \frac{4 \cdot 24 \cdot 3600 \cdot 57.7}{10^6} s = 19.94 s$$

Since the RTC runs 57.7 PPM faster in battery mode, the correction is negative, i.e. 20 seconds will have to be subtracted from the current time.

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