Calibration of the DP8570A Family

National Semiconductor
Application Note 588
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This application note applies to the DP8570A, DP8571A, DP8572A, and DP8573A. With respect to the DP8573A, only the discussion of the 32.768 kHz oscillator applies.

The intrinsic properties of quartz make it a uniquely simple device for highly accurate and stable frequency generation. Crystals are not a primary frequency standard but used with care can provide stability far in excess of most requirements. Various configurations of oscillator circuits exist to enable the designer to implement such a source. Its performance, however, is largely dependant on the environment and its associated electrical components. Firstly, consider the basic element—the crystal itself.

A quartz crystal is a mechanically moving system and is very dependant on the environment in which it is operating. The encapsulation will therefore critically affect the long term stability and is a major cause of crystal aging. The choice of crystal holder is important; there are four main types:

TABLE I. Crystal Types

Crystal Type	Aging
Solder Sealed	100 ppm/year
Resistance Welded	4 ppm/year
Cold Welded	2 ppm/year
Glass Enclosed	1 ppm/year

The solder seal units have relatively poor aging characteristics and have now been superceded by resistance welded units. The other three types offer good aging characteristics.

The exact frequency of oscillation is also dependent on the ambient temperature, therefore another important feature to bear in mind when choosing a crystal is the Frequency/Temperature characteristic. If a typical manufacturer's specification is consulted it can easily be seen that there is quite a variation in stability for different temperatures; stabilities of ± 20 ppm over a range of $-20°C$ to $+70°C$ are not uncommon.

The capacitors are the components that are most likely to affect the accuracy of the oscillator and care must also be exercised in selection. Since the oscillator plays such an important part in the accuracy of the DP8570A (both timers and real-time selection) it is vital to use good quality examples. There are various types of capacitors available which offer close tolerances and good temperature coefficients. Any of these would be suitable in this application.

TABLE II. Capacitor Types

Capacitor	Typical Tolerance	Typical Temp Coef.
Polycarbonate	5%	50 ppm/°C
Ceramic	10%	30 ppm/°C
Silver Mica	1%	35 ppm/°C

Trimmer capacitors with polypropolene dielectrics give a poorer temp coefficient when compared with those above (typically 300 ppm/°C approx). However, they offer the benefit of allowing the oscillator to be tuned for optimum results.

The oscillator components must be built as close as possible to the pins of the device so as to minimize stray capacitance. The oscillator circuit pins are high impedance nodes and are susceptible to noise coupling from adjacent lines, hence the oscillator should also be surrounded by a guard ground. The maximum length of PCB tracks on either pin is 2.5 cm, longer tracks will reduce oscillator stability.

The accuracy and stability of the oscillator is dependent on various factors; principally external components used, ambient temperature and aging. The information given above is included as a guide to the problems encountered in designing a stable oscillator circuit. Manufacturers specifications should be consulted for more comprehensive data before embarking on designs.

Figures 4a and *4b* show typical curves of frequency temperature characteristics of tuning fork and A-T cut crystals.

DP8570 OSCILLATORS

For the DP8570A, the configuration of the crystal oscillator is the standard Pierce parallel resonant oscillator arrangement which has been designed for low power consumption and high stability, this is shown in *Figure 1*. The external components required are a crystal and two capacitors to provide the correct output loading. The configuration recommended is that of a fixed capacitor and a variable trimmer capacitor, adjusting the trimmer allows the crystal loading (and hence the oscillator frequency) to be fine tuned for optimum results. All other components are on-chip.

The DP8570A has three selectable oscillator frequencies which can be used as a clock source, these are split into two groups, there is the high frequency oscillator and the low frequency oscillator. When programmed for low frequency operation, a small low power inverter is selected along with the relevant bias and feedback resistors, similarly for high frequency operation a larger inverter with a different pair of resistors is selected, *Figure 1* illustrates the basic concept.

A fourth option is available, but this is for driving the OSC IN pin with an external 32.768 kHz signal. In this mode the OSC OUT pin is not connected.

The three different crystals frequencies are; 32.768 kHz, 4.194304 MHz or 4.9152 MHz, see data sheet for full explanation of crystal selection. The recommended capacitance values for these crystals are shown in Table 3.

TABLE III. Oscillator Capacitors

	Variable (Osc In)	Fixed (Osc Out)
32.768 KHz	2 pF–22 pF	47 pF
4.194304 MHz	0 pF–80 pF	68 pF
4.9152 MHz	29 pF–49 pF	68 pF

For optimum performance it is recommended that the variable capacitance is placed on OSC IN. The typical value quoted for the trimmer capacitor is the value that the manufacturer quotes for these commercially available types and which will allow accurate tuning of the oscillator. It is not meant to show the range or tolerance of an equivalent fixed value.

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This range is also based on a typical circuit board layout and may have to be changed depending on the parasitic capacitance of the printed circuit board or fixture being used. In all cases the load capacitance specified by the manufacturer is what determines proper oscillation. This load capacitance is the series combination of capacitance on each side of the crystal with respect to ground.

It is perfectly feasible to use two fixed values, however this will not allow optimum setting of the oscillator frequency. For example a 12 pF fixed capacitor with a tolerance of ±10% is a good substitute for the trimmer capacitor in a 32.768 kHz application.

The HF oscillator has been designed primarily for 4 MHz operation therefore greater care should be exercized when choosing external components for 5 MHz operation. The best configuration for the 5 MHz operation is to use a fixed capacitor in parallel with a trimmer capacitor on the OSC IN pin. Note the small variation of the OSC IN capacitance required to ensure correct start-up and oscillation.

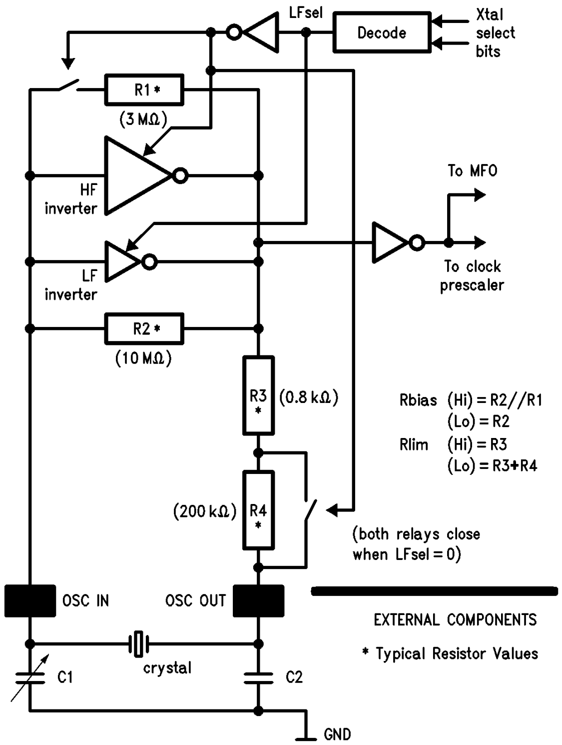

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FIGURE 1. DP8570A Oscillator

CALIBRATION ROUTINE

A calibration routine is necessary to maintain the oscillator output at the desired accuracy and thus optimize time keeping accuracy. The problem with calibrating these types of circutis is accessing the oscillator frequency. No test equipment should be connected directly to either oscillator pin, as the added loading will alter the characteristics of the oscillator making accurate tuning impossible.

For the DP8570A, the calibration can be accomplished using the Multi-Function Output (MFO) pin of the device. The MFO pin can be programmed for several different functions.

1. Buffered Crystal Output
2. Second Interrupt Pin
3. Timer 0 Output

The crystal frequency can be made available at this pin. Since it is buffered a measuring device can be connected directly to it and the oscillator will remain unaffected. Further, this task can be accomplished under software control and without entering test mode.

Adjustment of the oscillator can be carried out using the setup shown in *Figure 2*, by tuning the capacitance C1 the user can see what effect this variation has on the frequency value.

The following sequence of operations is the calibration routine that is required when setting up the oscillator.

1. Main Status Register. Write 01xx xxxx. Select RS = 1, PS = 0.
2. Output Mode Register. Write 1011 xxxx. Select MFO as buffered oscillator with push/pull and active high configuration.
3. Real Time Mode Register. Write 0000 0000. Select desired crystal frequency (32.768 kHz).
4. Main Status Register. Write 00xx xxxx. Select RS = 0, PS = 0.
5. Periodic Flag Register. Write 00xx xxxx. Select Battery backed mode and ensure not in test mode (bit D6 = 1 for single supply mode).
6. Monitor the MFO pin with an oscilloscope and observe that the oscillator is functioning at approximately its correct frequency.
7. Connect a frequency measuring instrument to the MFO pin.

   Care should be exercised when choosing an instrument with which to measure the frequency. To achieve accuracies of 10 ppm or greater high resolution high accuracy instruments only should be used. Instruments recommended are HP 5334A or PHILLIPS PM 6654.
8. Adjust the trimmer capacitor until the desired accuracy is obtained (2 ppm should be achievable). *Figure 5* shows the relationship between frequency error or in ppm vs time gained/lost in minutes/year.

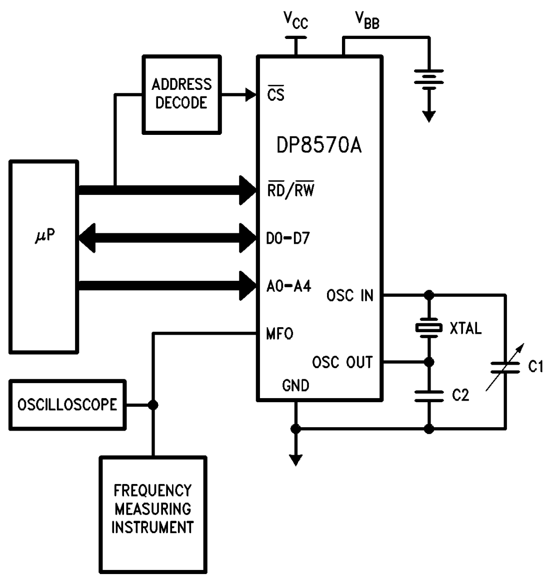

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FIGURE 2. Calibration Setup

TEST CONSIDERATIONS

Under test conditions a crystal cannot be used as there is no control over its output, a pulse generator must be used to clock the device in a controlled manner. This presents correlation problems when measuring I_{DD}/I_{BB} because the clock signal used in testing is a square wave and the values for current consumption will be different. The graphs in *Figure 3* show the values of operating current (I_{DD}) and standby current (I_{BB}) for different temperatures, voltage and crystal.

The graph that is the most important is I_{BB} at 32.768 kHz, the data sheet states that no more than 10 μA of standby current will be consumed across temperature for V_{BB} = 3V. Typical values at T = 25°C (V_{BB} = 3V) as measured on the tester are approximately 4 μA, this compares with 6 μA as measured with a crystal. If a user wishes to use the 10 μA specification, he must limit the battery supply to approximately 3.5V, (see Graph 3a). Graph 3b shows that the standby current does not vary a great deal with temperature.

For the I_{CC} measurement a typical value at V_{CC} = 5.5V, T = 25°C is 160 μA as measured with a tester as opposed to a value of 162 μA with a crystal. There is little difference between the two values. The same cannot be said for the high frequency crystals, the tester figure of 210 μA for V_{CC} = 3V, T = 25°C compared to only 97 μA for a crystal. The reason for this is as follows, when forcing with a clock source the current is largely dependent on the capacitance at the OSC OUT pin, the larger the value the larger the current drawn.

During testing the OSC OUT pin cannot be bent out of the test socket therefore there will aways be some value of stray capacitance connected to OSC OUT. Hence, increased current will always be expected.

For the lower frequency crystal the stray capacitance on OSC OUT does not play a major part so the current is greater because of the greater rate of change of the square wave compared to the sine wave output of a crystal.

CONCLUSION

The calibration of crystal oscillators is fairly straight forward but is of prime importance and as can be seen this task can be accomplished very easily. Regular monitoring of the oscillator frequency can thus be performed with no major disruption to the device's operation.

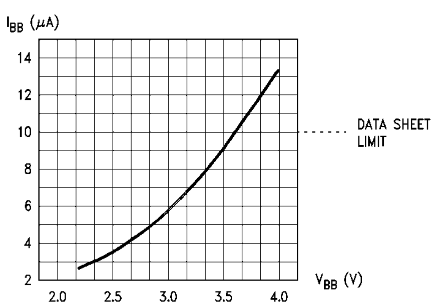

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FIGURE 3a. Standby Current against Battery Voltage T = 25°C (32.768 kHz)

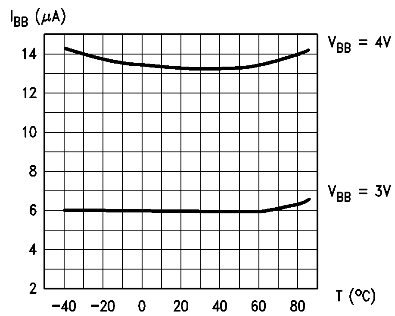

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FIGURE 3b. Standby Current against Temperature (32.768 kHz)

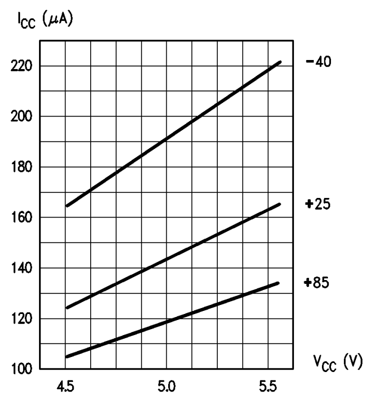

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FIGURE 3c. Operating Current against Supply Voltage (32.768 kHz)

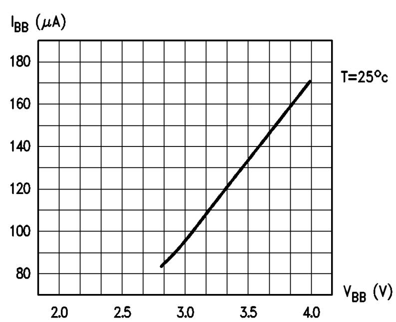

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FIGURE 3d. Standby Current against Battery Voltage (4.194304 MHz)

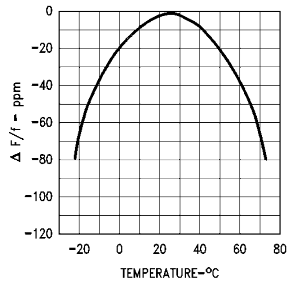

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FIGURE 4a. Frequency Temperature Characteristic for a Typical 32.768 kHz Tuning Fork Crystal

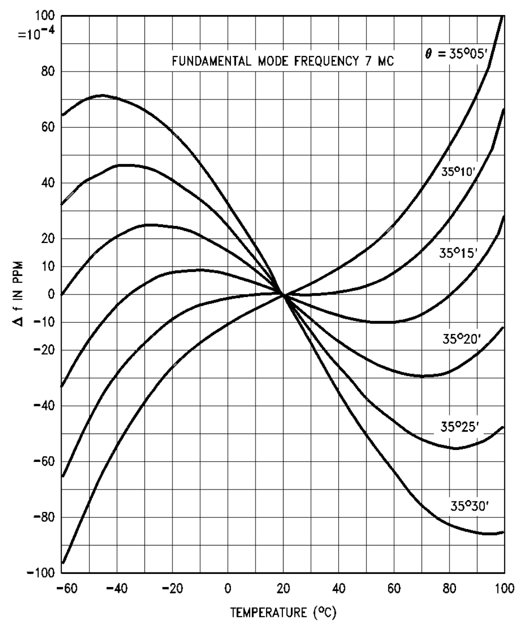

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FIGURE 4b. Frequency-Temperature-Angle Characteristics of Plated AT-Type Natural Quartz Crystal Resonators (from "Crystal Oscillator Design and Temperature Compensation")

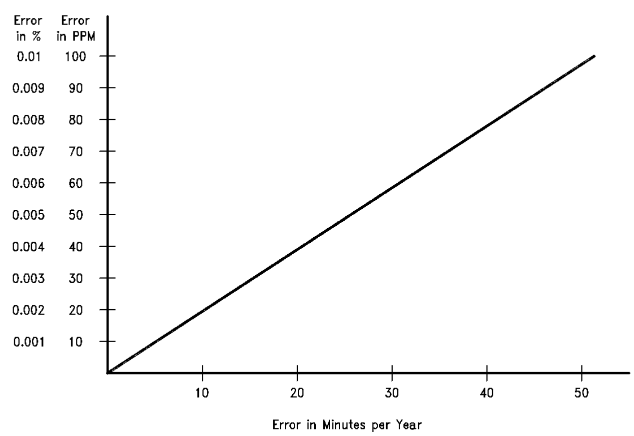

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FIGURE 5. Oscillator Error in % or PPM vs Error in Time

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