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Note

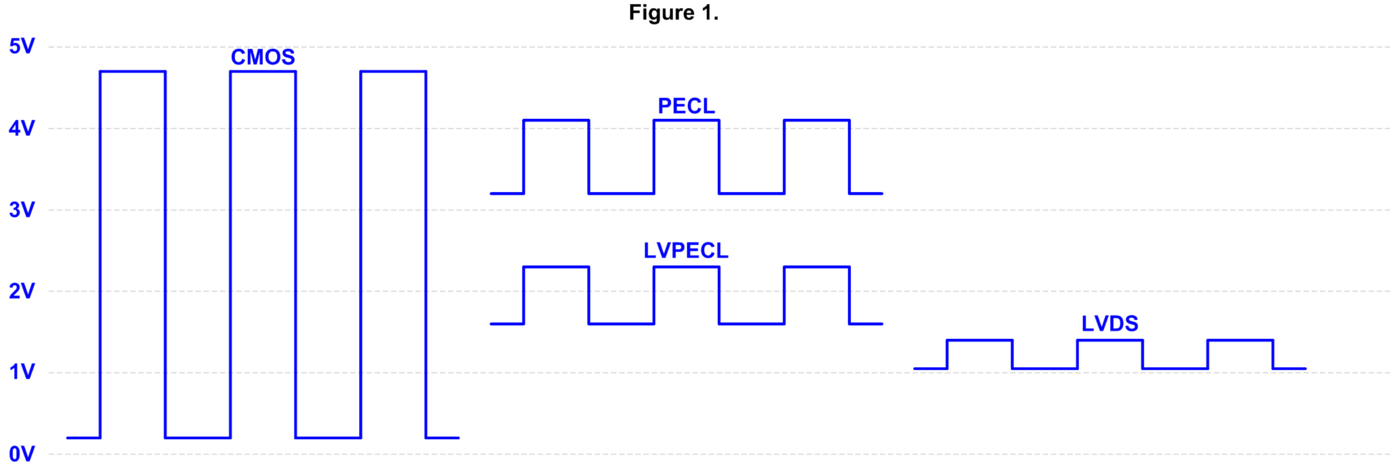
Clock Oscillators

Introduction

For the moderate stability crystal controlled oscillator where neither temperature compensation nor oven operation are required, there are three primary parameters: output wave shape, frequency and accuracy/stability.

A. Output. The vast majority of systems require a crystal oscillator output which is PECL compatible, CMOS compatible or follows some other standard interface. Any of these outputs can be simply generated by circuits which follow the crystal oscillator stage. Some common logic levels are illustrated in Figure 1.

Figure 1.



B.Accuracy/Stability. The most basic element in an oscillator specification is the output frequency. At any given time however, the oscillator's output frequency will differ from the desired specified frequency resulting in a frequency error. This error is comprised of three primary components:

1. Initial accuracy. This is generally defined as the difference between the oscillator output frequency and the specified frequency at 25°C at the time of shipment by the oscillator manufacturer. When specifying accuracy it is assumed that the user has no provisions to adjust the oscillator's output frequency. When a frequency tuning control is included, accuracy no longer needs to be specified; instead the range and settability of the tuning adjustment become more consequential.

2. Temperature Stability. Figure 2 shows a typical characteristic of crystal frequency vs. temperature. It is one of a family of curves illustrated in Figure 3.

Figure 2

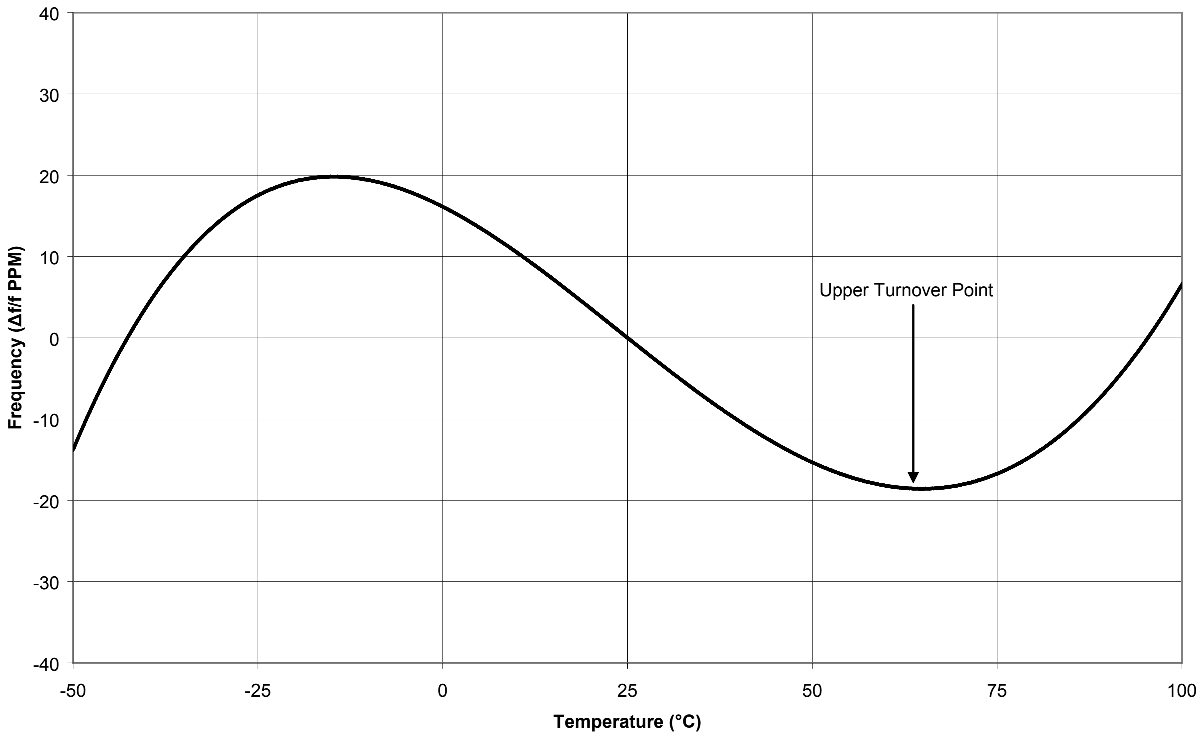
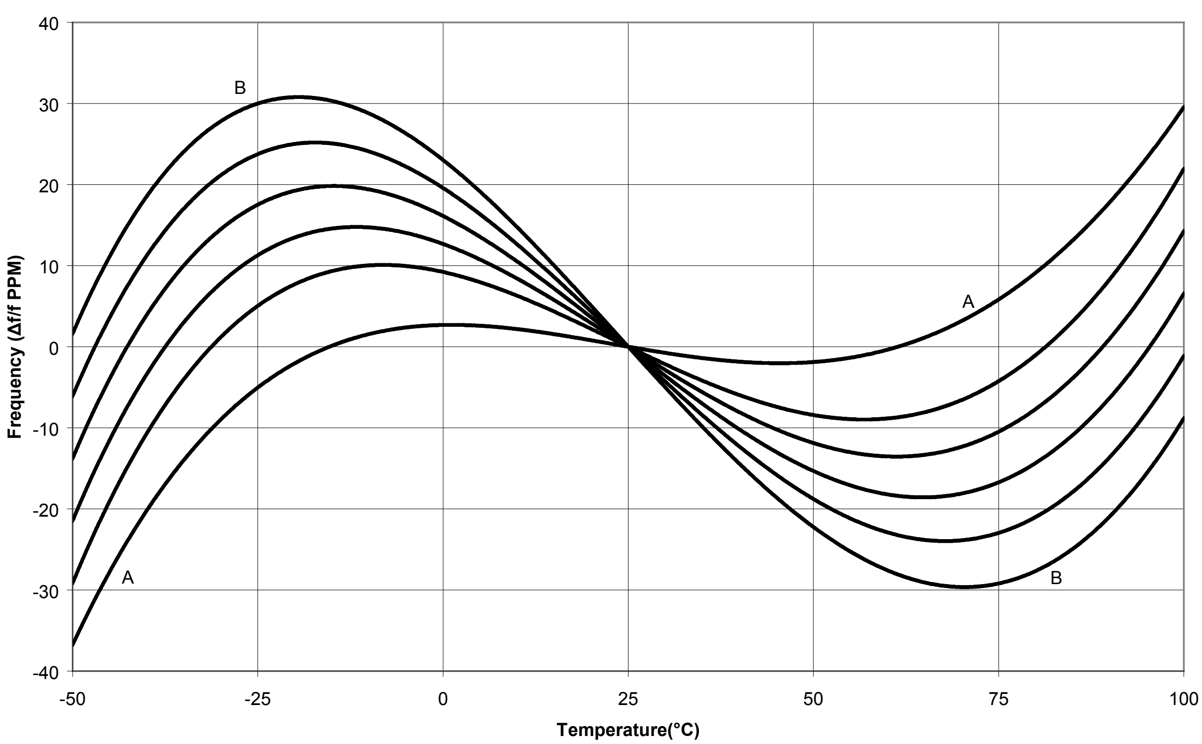


Figure 3 shows that one extreme, curve A, has a relatively flat slope (good temperature stability) near room temperature, but is very frequency sensitive at high and low temperatures. The other extreme, curve B, shows greater sensitivity near room ambient but also provides the overall best temperature stability over wide temperature ranges.

Figure 3



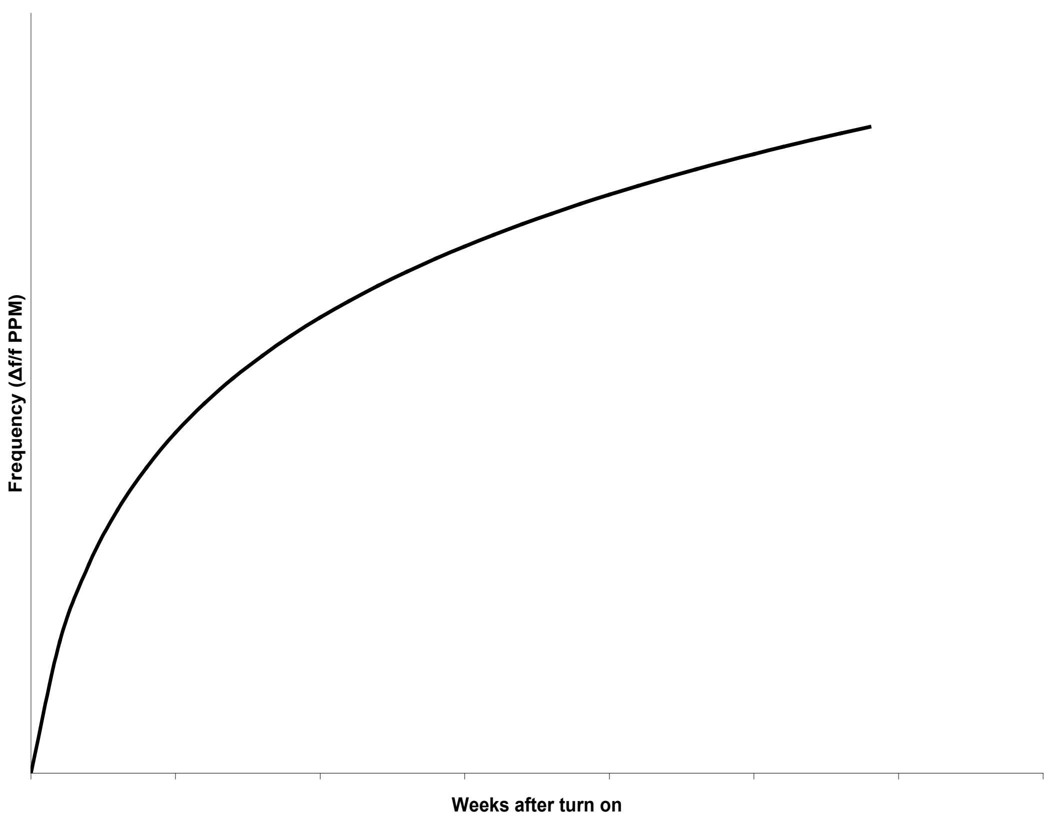
The angle at which the quartz crystal is cut determines the temperature characteristic of a specific crystal. The proper characteristic from this family of curves is selected for each individual crystal oscillator requirement. In a well designed oscillator the stability vs. temperature is determined primarily by the temperature characteristic of the crystal, and the oscillator manufacturer must select the crystal characteristics which conform to the oscillator circuit to insure that the intrinsic stability of the crystal is not degraded.

A temperature stability of, for example, ± 10 ppm over 0°C to +50°C means a peak-to-peak frequency change of 20 ppm over the specified temperature range, not referenced to the frequency at any specific temperature. This is the generally accepted definition of temperature stability which, in MIL-0-55310, is called "frequency-temperature stability".

If a reference temperature is desired with a maximum allowable frequency change from that reference, it should be specified, for example, as "±10 ppm over 0°C to +50°C referenced to the frequency at +25°C."

While Vectron segregates initial accuracy and temperature stability, the two may be combined in specifying an overall allowable error for oscillators with no frequency tuning adjustment. The appropriate term is "frequency-temperature accuracy" and it is the maximum allowable deviation from the specified nominal frequency over a given temperature range.

Figure 4



3. Aging (Long-term stability). Aging refers to the continuous change in crystal operating frequency with time, all other parameters (temperature, supply voltage, etc.) held constant. The better the processing of the crystal, the lower the aging rate (that is, the higher the long-term stability). Figure 4 shows a typical aging curve. It illustrates that when a crystal oscillator is initially turned on by the manufacturer, the crystal ages rapidly but its stability improves with time. While the aging rate will typically continue to improve with time, most crystals achieve close to their lowest aging rate within several months after turn-on.

As long as crystal current is moderate, solder sealed or resistance welded AT-cut crystals used in most clock oscillators provide typical aging of 5 ppm during the first year and 3 ppm per year thereafter (5 ppm = .0005% = 5×10^{-6}). If the error introduced by this degree of crystal aging exceeds that allowed in the user's system, this can be overcome by (1) specifying the inclusion of a frequency tuning adjustment in the oscillator to permit periodic recalibration and/or, (2) using a higher quality crystal. Improved aging to 1×10^{-6} per year can be achieved by employing a specially processed crystal housed in an evacuated glass or coldweld sealed holder. Because aging generally introduces a small part of the overall error in moderate stability clock oscillators, it is often ignored in specifying these devices.

There are numerous other factors contributing to crystal oscillator instability, such as affect of supply voltage variation, load variation and physical orientation; however, they are not significant with respect to the major errors already detailed and are therefore excluded from discussion in this clock oscillator section.

Summary

In summary, for most clock oscillator requirements, a specification will be sufficiently complete if it includes the following electrical elements: frequency, output level (wave shape), supply voltage, initial accuracy and temperature stability.

When the overall accuracy/stability specification becomes too stringent to be met with a simple clock oscillator, improvements can be accomplished in three areas:

The initial accuracy error may be essentially eliminated and aging periodically compensated for by incorporating into the oscillator a frequency adjustment as previously discussed.

Aging may be improved by using a higher grade crystal, as previously discussed, and with a higher grade circuit maintaining low constant crystal current.

The temperature stability may be improved by using temperature compensation techniques or housing the oscillator in an oven.

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