Crystal Oscillator Topics

Parallel vs. Serial Resonant Oscillator Circuits

All frequency synthesis components from IC DESIGNS require a reference frequency, usually provided by a quartz crystal. The on-board crystal oscillators are parallel-resonant designs. Although most oscillator circuits are designed to use parallel-resonant crystals, most inexpensive off-the-shelf crystals are series-resonant devices. Accordingly, many oscillator applications (such as CPU clock/timer designs) often run about 0.05% too fast.

When a crystal is manufactured, the manufacturing specifications must specify the type of oscillator circuit in which it is intended to be used. The two types will result in a difference in the output frequency of approximately 500 ppm (0.05%). To guarantee accurate output, the specification must therefore take this difference into account when the crystal is manufactured.

For maximum accuracy, a parallel-resonant crystal of the proper specification will be required. Whether or not the extra cost is justified depends on the application. In many cases, an error of 0.05% is acceptable; in applications such as time-keeping, however, it is often not.

Specifying a Custom Parallel-Resonant Crystal

To order a specially made crystal, the correct specification to give the vendor is parallel-resonant, plus a value for the load capacitance presented by the oscillator. As an example, the correct specification crystal oscillator would read as follows:

Type = Parallel-resonant
Freq = 14.31818 MHz
C_{load} = 17 pF

As an alternative to a custom crystal, parallel-resonant crystals with a specified C_{load} = 20 pF may be available from dealer stock. Such a crystal may be a viable alternative to a custom crystal, offering only slightly less accuracy at lower unit cost.

Accuracy Considerations for Time-Keeping in PC Design

Time-keeping is a stringent application, where a 50 ppm error in reference frequency produces a real-time clocking error of 2 minutes per month. In many personal computer applications, both 32.768 KHz and 14.31818 MHz are used for time-keeping. Highly accurate values of both these frequencies are therefore required.

Most IC DESIGNS frequency synthesis components produce a 14.31818-MHz signal on one or more output pins. However, as previously pointed out, the accuracy of these outputs will depend upon proper specifications of the 14.31818-MHz reference crystal by the designer. Correctly specifying the reference crystal is therefore important in time-keeping applications.

Some IC Designs components also offer an additional output from an on-board 32.768-KHz oscillator. This oscillator is designed to work with an industry-standard 32.768-KHz crystal specified as parallel-resonant, C_{load} = 12 pF and is readily available from dealer stock, so the resulting output should always be accurate enough for time-keeping applications.

Selecting a High-Accuracy Reference Crystal

Background

Our monolithic oscillator products deliver a wide range of output frequencies, replacing many individual quartz oscillators. And yet, one quartz crystal is needed to set the reference frequency, usually 14.31818 MHz. In this section, the emphasis is on maximizing the accuracy of the reference. Specific part numbers will be named, and a worst-case analysis performed.

Changing Requirements

IC DESIGNS' earliest design-ins did not specifically recommend a parallel-resonant crystal instead of the more common (but less suitable) series-resonant type. Such designs tended to have error rates of 500−600 ppm.

This was acceptable at the time because VGA monitors can tolerate a pixel frequency deviation of 1% from nominal (10,000 ppm), so reference accuracy was not a major factor.

Today, however, IC DESIGNS' expanding product line targets many time-critical applications where the reference frequency must be held within ±100 ppm over the operating temperature range.

Crystal Specifics

Earlier in this note, we recommended specifying a parallel-resonant crystal, with load capacitance (C_{load}) of 17−20 pF. Here are some specific part numbers for surface-mount devices:

- **Fox Crystal #FPX143−20** − With C_{load} = 20 pF, it is close enough to our 17 pF specification to be only 35 ppm high. If a tighter initial accuracy is desired, one can add two external load capacitors to ground, or specify a different load capacitance. Telephone: (813) 693−0099.
- **Epson America #MA-506 14.313M-B** − This sells off-the-shelf with C_{load} = 16 pF. In our lab, we find them to be nominally on target; they are the best off-the-shelf match available. Telephone: (310) 782−0770.

Drive Level Precautions

Any quartz crystal is subject to mechanical failure if oscillated at an excessive voltage level. For a CMOS amplifier, the drive level is around 700 µW. However, the parts are tested at 100 µW; fortunately, a maximum rating exists of 1000−2000 µW.

Do not use any crystal that does not have a 1000 µW rating. It may drift excessively, or even become a delayed failure mechanism.

Error Budget Analysis

We can guarantee ±100 ppm worst case with the Epson #MA-506 14.318M-B. This is important for products like the ICD2028. To verify this, one simply adds up the relevant sources of error in an error budget (this is true for any crystal).

Source of Error	Amount
Crystal frequency tolerance	±50 ppm
Crystal temperature tolerance	±30 ppm
ICD2028 frequency tolerance	±05 ppm
ICD2028 temperature tolerance	±06 ppm
ICD2028 supply tolerance	±03 ppm
Total	±94 ppm

One can also look at the well respected "Monte Carlo Analysis," which says that, if a number of uncorrelated variables are changing randomly, it is not reasonable to add up the individual worst-case figures to come up with an aggregate worst-case value.

Instead, if one has n variables, X1, X2,...Xn, all varying randomly and independently, then the overall variation is:

$$X_{total} = \sqrt{X_2^1 + X_2^2 + \ldots X_n^2}$$

According to this calculation, the design will remain within 59 ppm, which is much lower than the simple addition of the uncorrelated variables.

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