Crystal Timing Budget and Accuracy for IDT Timing Clock Products

AN-803

APPLICATION NOTE

Introduction

This application note provides some basic guidelines in selecting the proper quartz crystal to meet a designs timing budget. It describes five parameters which influence the total system timing error of a quartz crystal and oscillator combination. There is also an example of how to calculate the maximum overall timing error for IDT timing devices.

Timing Budget Parameters

Frequency tolerance, also known as calibration accuracy, is the amount of frequency deviation from a specified center frequency at ambient temperature (referenced at 25°C). In addition, this deviation is associated with a set of operating conditions including load capacitance and drive level. Similar to the remaining four parameters, it is specified in units of ppm (parts per million). This is typically specified in the crystal manufactures datasheet.

Frequency Stability is the amount of frequency deviation from the ambient temperature frequency over the operating temperature range. This deviation is associated with a set of operating conditions including: Operating Temperature Range, Load Capacitance, and Drive Level. This parameter is specified with a maximum and minimum frequency deviation, expressed in percent (%) or parts per million (ppm). The frequency stability is determined by the following primary factors: Type of quartz cut and angle of the quartz cut. Some of the secondary factors include: mode of operation, drive level, load capacitance, and mechanical design. This is typically specified in the crystal manufacturer's datasheet.

Aging is the systematic change in frequency with time due to internal changes in the crystal which is related to the crystal contamination and drive level. Over time, particles drop off or fall onto the quartz surface, hence slightly changing the resonant frequency. Aging is often expressed as a maximum value in parts per million per year [ppm/year]. The rate of aging is typically greatest during the first 30 to 60 days after which time the aging rate decreases. The following factors effect crystal aging: adsorption and desorption of contamination on the surfaces of the quartz, stress relief of the mounting and bonding structures, material outgassing, and seal integrity. This specification can vary among manufactures. This is typically specified in the crystal manufacturer's datasheet.

Load capacitance (CL) is the fourth parameter to consider. A crystal can be characterized for either series or parallel load resonant mode of operation. Both modes are physically the same; they are just tuned to operate in a different area of the crystal reactance curve. For most applications, IDT recommends using parallel resonant crystals which require using external load capacitance (CL). Many times, this load is added without considering some of the board parasitic and internal capacitance of the oscillator. The correct method is to calculate all the board parasitics; then add the required capacitance to equal the specified load capacitances. The variation for load capacitance can be minimized by using smaller package capacitors with small tolerances.

Oscillator accuracy is the fifth parameter to consider. Many times, this parameter is ignored, but process shifts in the silicon, temperature and voltage can have an effect on the center frequency. This variation is dominated by the process shift parameters and can be minimized by the amount of internal load capacitance in the oscillator and the trim sensitivity of the quartz crystal. The crystals trim sensitivity is typically not specified in a datasheet but can be requested from the manufactures. It shows the effect on frequency due to load capacitance. Most of the time, if the oscillator is properly designed and manufactured on an established process, this variation is minimal.

Example: Calculating a Crystal Timing Budget

It's now time to choose the appropriate crystal. For the example below, we are targeting 50 ppm accuracy for the system. Figure 1 shows an example of a crystal electrical specification. Most manufactures have similar values and variables.

Figure 1. Example of a Crystal's Electrical Specifications

Electrical Specifications	
Nominal Frequency	25.000MHz
Frequency Tolerance	±15ppm Maximum
Frequency Stability	±15ppm Maximum
Aging at 25°C	±10ppm Maximum for 10 years
Load Capacitance	12pF Parallel Resonant
Mode of Operation	AT-Cut Fundamental

Frequency Tolerance = ±**15ppm**
Frequency Stability = ±**15ppm**
Aging = ±**10ppm** total for 10 years

The accuracy of the oscillator across temperature, voltage and process is ±3.5 ppm. This is assuming a trim sensitivity of 7ppm/pF, a 10% process shift and 5pF of internal load capacitance (C_L).

The load capacitance accuracy, which will include board and pin parasitics, is equal to ±0.5 ppm. This is assuming a trim sensitivity of 7ppm/pF, minimal PCB process shift, 1% tolerance load capacitors and external load capacitance of 7pF. The 5pF internal and 7pF external load capacitance will fulfill the required 12pF load capacitance to properly tune the crystal.

The sum of all the parameters is the total system timing error.

Maximum overall timing error = 15 + 15 + 10 + 3.5 + 5 = 44ppm

Recommended Vendors

Any concerns or questions regarding these crystal specifications, please contact the manufacturer. If your application requires a tighter accuracy system timing error, contact the manufacturer for a new custom part number. IDT does not have an exclusive preferred quartz crystal source. IDT devices function properly with many of the mainstream and established quartz crystal manufacturers.

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