

Introduction

This application note provides some basic guidelines in selecting the proper quartz crystal to meet a design's 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 manufacturer's 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 manufacturers. 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 crystal's trim sensitivity is typically not specified in a datasheet but can be requested from the manufacturer. 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 = $15 + 15 + 10 + 3.5 + 5 = 44\text{ppm}$

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.

**Corporate Headquarters**

6024 Silver Creek Valley Road
San Jose, CA 95138 USA

Sales

1-800-345-7015 or
408-284-8200
Fax: 408-284-2775
www.IDT.com

Tech Support

email: clocks@idt.com
480-763-2056

DISCLAIMER Integrated Device Technology, Inc. (IDT) and its subsidiaries reserve the right to modify the products and/or specifications described herein at any time and at IDT's sole discretion. All information in this document, including descriptions of product features and performance, is subject to change without notice. Performance specifications and the operating parameters of the described products are determined in the independent state and are not guaranteed to perform the same way when installed in customer products. The information contained herein is provided without representation or warranty of any kind, whether express or implied, including, but not limited to, the suitability of IDT's products for any particular purpose, an implied warranty of merchantability, or non-infringement of the intellectual property rights of others. This document is presented only as a guide and does not convey any license under intellectual property rights of IDT or any third parties.

IDT's products are not intended for use in applications involving extreme environmental conditions or in life support systems or similar devices where the failure or malfunction of an IDT product can be reasonably expected to significantly affect the health or safety of users. Anyone using an IDT product in such a manner does so at their own risk, absent an express, written agreement by IDT.

Integrated Device Technology, IDT and the IDT logo are registered trademarks of IDT. Product specification subject to change without notice. Other trademarks and service marks used herein, including protected names, logos and designs, are the property of IDT or their respective third party owners.