Timing Budget and Accuracy

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 a timing budget of a quartz crystal and oscillator. There is also an example of how to calculate the maximum overall timing error for an ICS FemtoClock™. Lastly, a list of recommended crystal vendors and parts numbers are provided for 100ppm accuracy applications.

Timing Budget Parameters

Frequency Tolerance:
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). Similar to the remaining four parameters, it is specified in units of ppm (Parts per Million).

Frequency Stability:
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.

Aging:
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.

Load Capacitance:
Load capacitance 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. Though we recommend using parallel load, most devices within the ICS NetCom Division can accept either a series or parallel load resonant crystal without additional components. For parallel load resonant circuits, there is a load capacitance spec (C_L). Many times, this load is added without considering some of the board parasitics. The correct method is to calculate all the board parasitics; then add the required capacitance to equal the specified load capacitances.

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Oscillator Accuracy:
The oscillator accuracy is the fifth parameter to consider. Many times, this parameter is ignored, but temperature, voltage and process shifts in the silicon can have effects on the resonant frequency.

Example: Calculating a Crystal Timing Budget

It's now time to choose the appropriate crystal. For the example below, we are targeting 100 ppm accuracy for the system. Figure 1 shows an example of a crystal electrical specification. Most manufactures have similar values and variables.

	STANDARD SPECIFICATIONS
Nominal Frequency	25MHz
Frequency Tolerance	±20ppm at 25°C
Frequency Stability	±30ppm over 0°C to +70°C
Aging at 25°C	±3ppm/First Year, ±15ppm/10 Years Maximum
Operating Temperature Range	0°C to +70°C
Load Capacitance	18pF
Shunt Capacitance (C0)	7pF Maximum
Equivalent Series Resistance	40 Ohms Maximum
Mode of Operation	Fundamental
Drive Level	1mWatts Maximum, 100µWatts Correlation
Crystal Cut	AT-Cut
Storage Temperature Range	-40°C to +85°C
Insulation Resistance	500 Megaohms Minimum at 100Vdc

Figure 1: Example of a crystal electrical specifications

Frequency Tolerance = ± 20 ppm

Frequency Stability = ± 30 ppm

Aging = ± 15 ppm total for 10 years.

The accuracy of the NetCom oscillator across temperature, voltage and process is
±10 ppm

The Load capacitance accuracy, which will include board and pin parasitics, is equal to
±3 ppm

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

Maximum overall timing error = 20 + 30 + 15 + 10 + 3 = 78 ppm

Recommended Vendors

The crystal Vendors below have all been used successfully by the NetCom Division within ICS. The part numbers were generated for applications with 100ppm maximum overall timing error requirements. 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.

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Frequency (MHz)	Part Number/ Operating Temperature: (0^0C to 70^0C)	Part Number/ Operating Temperature: (-40^0C to 85^0C)
14.835165	ECX-6170-14.835165M	ECX-6195-14.835165M
15.625000	ECX-6171-15.625M	ECX-6196-15.625M
18.750000	ECX6172-18.750M	ECX-6197-18.750M
19.012500	ECX-6173-19.0125M	ECX-6198-19.0125M
19.440000	ECX-6174-19.440M	ECX-6199-19.440M
19.531250	ECX-6175-19.53125M	ECX-6200-19.53125M
20.141601	ECX-6176-20.141601M	ECX-6201-20.141601M
20.000000	ECX6177-20.000M	ECX-6202-20.000M
22.222200	ECX-6178-22.2222M	ECX-6203-22.2222M
22.400000	ECX-6179-22.400M	ECX-6204-22.400M
22.500000	ECX-6180-22.500M	ECX-6205-22.500M
23.437500	ECX-6181-23.4375M	ECX-6206-23.4375M
24.000000	ECX-6182-24.000M	ECX-6207-24.000M
24.437500	ECX-6183-24.4375M	ECX-6208-24.4375M
24.500000	ECX-6184-24.500M	ECX-6209-24.500M
24.576000	ECX-6185-24.576M	ECX-6210-24.576M
24.750000	ECX-6186-24.750M	ECX-6211-24.750M
25.000000	ECX-6187-25.000M	ECX-6212-25.000M
25.500000	ECX-6188-25.500M	ECX-6213-25.500M
25.920000	ECX-6189-25.920M	ECX-6214-25.920M
26.041666	ECX-6147-20.041666M	ECX-6149-20.041666M
26.562500	ECX-6190-26.5625M	ECX-6215-26.5625M
26.666000	ECX-6191-26.666M	ECX-6216-26.666M
27.000000	ECX-6192-27.000M	ECX-6217-27.000M
29.166670	ECX-6193-29.16667M	ECX-6218-29.16667M
30.000000	ECX-6194-30.000M	ECX-6219-30.000M
31.250000	ECX-6146-31.250M	ECX-6148-31.250M
33.330000	ECX-6158-33.333M	ECX-6159-33.333M

Contact Information:
(800) 433-1280
http://www.ecliptek.com

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Frequency (MHz)	Part Number/ Operating Temperature: (0°C to 70°C)	Part Number/ Operating Temperature: (-40°C to 85°C)
14.835165	CXZ49GFB14835P0HBQ01	CXZ49GFB14835P0HPQ01
15.625000	CXZ49GFB15625P0HBQ01	CXZ49GFB15625P0HPQ01
18.750000	CXZ49GFB18750P0HBQ01	CXZ49GFB18750P0HPQ01
19.012500	CXZ49GFB19012P0HBQ01	CXZ49GFB19012P0HPQ01
19.440000	CXZ49GFB19440P0HBQ01	CXZ49GFB19440P0HPQ01
19.531250	CXZ49GFB19531P0HBQ01	CXZ49GFB19531P0HPQ01
20.000000	CXZ49GFB20000P0HBQ01	CXZ49GFB20000P0HPQ01
20.141600	CXZ49GFB20141P0HBQ01	CXZ49GFB20141P0HPQ01
22.222200	CXZ49GFB22222P0HBQ01	CXZ49GFB22222P0HPQ01
22.400000	CXZ49GFB22400P0HBQ01	CXZ49GFB22400P0HPQ01
22.500000	CXZ49GFB22500P0HBQ01	CXZ49GFB22500P0HPQ01
23.437500	CXZ49GFB23437P0HBQ01	CXZ49GFB23437P0HPQ01
24.000000	CXZ49GFB24000P0HBQ01	CXZ49GFB24000P0HPQ01
24.437500	CXZ49GFB24437P0HBQ01	CXZ49GFB24437P0HPQ01
24.500000	CXZ49GFB24500P0HBQ01	CXZ49GFB24500P0HPQ01
24.576000	CXZ49GFB24576P0HBQ01	CXZ49GFB24576P0HPQ01
24.750000	CXZ49GFB24750P0HBQ01	CXZ49GFB24750P0HPQ01
25.000000	CXZ49GFB25000P0HBQ01	CXZ49GFB25000P0HPQ01
25.500000	CXZ49GFB25500P0HBQ01	CXZ49GFB25500P0HPQ01
25.920000	CXZ49GFB25920P0HBQ01	CXZ49GFB25920P0HPQ01
26.041666	CXZ49GFB26041P0HBQ01	CXZ49GFB26041P0HPQ01
26.562500	CXZ49GFB26562P0HBQ01	CXZ49GFB26562P0HPQ01
26.666000	CXZ49GFB26666P0HBQ01	CXZ49GFB26666P0HPQ01
27.000000	CXZ49GFB27000P0HBQ01	CXZ49GFB27000P0HPQ01
29.166670	CXZ49GFB29166P0HBQ01	CXZ49GFB29166P0HPQ01
30.000000	CXZ49GFB30000P0HBQ01	CXZ49GFB30000P0HPQ01
31.250000	CXZ49GFB31250P0HBQ01	CXZ49GFB31250P0HPQ01
33.330000	CXZ49GFB33330P0HBQ01	CXZ49GFB33330P0HPQ01

Contact Information:
http://global.kyocera.com/prdct/electro/i_crystal.html

http://www.txc.com.tw/english/contact_us.html

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