Frequency Reference Comparison

All time interval analyzers, time interval counters and frequency counters actually measure time and frequency relative to a fixed reference. For example, if the reference frequency is 10 MHz and you are measuring a 50 MHz signal, what the instrument is really measuring is the ratio of the two frequencies (5.0) and then multiplies it by the reference frequency. The same thing happens with time measurements which are measured in increments of the period of the reference (100 ns for a 10 MHz reference frequency).

Therefore, an error in the reference scales the result by the same percentage. In the specifications for Carmel Instruments TIAs, this error is called TimebaseErr. For example, if the reference is 10.000001 MHz (1 Hz too high) it would be too high by 1 part in 10^{-7}, or 0.1 ppm, and any frequency measurement result would be too low by 0.1 ppm or 100 ppb.

1% = 1×10^{-2}

1 ppm = 1×10^{-6}

1 ppb = 1×10^{-9}

The error caused by the reference is an “absolute” error. It scales all results by the same amount so it does not affect the resolution of the instrument. For example, suppose you are measuring a time interval of 1 ms using the BI201 which has a resolution of 3 ps. If the frequency reference (the timebase) has an error of 1 ppm, then the error in the measurement result is 1 ns, or 1000 ps, even though the resolution is still 3 ps. That is, the result of multiple measurements of a stable 1 ms time interval would all repeat with standard deviation of 3 ps, but would all be off by the 1000 ps. In other words, the resolution is 3 ps, but the absolute accuracy for this measurement is 1000 ps.

All of Carmel Instruments time interval analyzers have an internal frequency reference (timebase) which is either a temperature compensated quartz oscillator (TCXO) or an oven quartz oscillator. The instruments also have an input for your own 10 MHz reference. This external reference clock input is useful not only for the purpose of providing a more accurate absolute timebase, but also to provide a reference which is common to other instruments. In most applications you are only concerned with relative measurements. An example would be if you are testing a phase locked loop (PLL) which multiplies its input frequency by a fixed fraction. If the input frequency to the PLL comes from a signal generator, you can connect the signal generator to the same frequency reference as the TIA and you would be measuring exact values.

Types of Frequency References

The table below has a comparison of the different types of frequency references. The temperature compensated quartz oscillator is the lowest cost frequency reference that Carmel Instruments uses. It is a high quality crystal oscillator which is also very low power. The higher performance timebases use an ovenized quartz oscillator which contains a heater that maintains the temperature of the crystal above ambient temperature (such as 85ºC). This, of course, is more costly and required much more power.

The GPS disciplined oscillators use the signal from the GPS satellites to continuously calibrate the frequency of the oscillator to maintain perfect long term accuracy. In the short term, the quality of the local oscillator is still critical. Note that the GPS-based references require an external antenna.

Specifications of Frequency References

Temperature – the error due to ambient temperature variations. This error is not necessarily linear, so you cannot conclude that if your temperature range is 10% of the operating range of the oscillator that you would only see 10% of the error. However, if your variation is only a few degrees then the likely error is much smaller than the specification.

Aging Per Day – the maximum amount of drift for one day.

Aging Per Year – the maximum amount of drift for one year. Note that the long term aging for Cesium is not specified since it is a primary standard.

	TCXO	Quartz Oven	Quartz Oven with GPS	Rubidium	Cesium
Example	NK732 std osc	NK732 opt oven osc	Symmetricom TimeProvider 100	Symmetricom 8040C	Symmetricom 5071A
Temperature	1 ppm (2×10^{-6})	0.005 ppm (5×10^{-9})		1×10^{-11}	1×10^{-13}
Aging per Day			$< 1 \times 10^{-11}$		$< 1 \times 10^{-13}$
Aging per Year	2 ppm (2×10^{-6})	0.05 ppm (5×10^{-8})	No aging	5×10^{-10}	

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