Start-up Measurements on Oscillators

- *Using the CNT-90/CNT-91 to Measure Oscillator Start-up*

White paper from Pendulum Instruments

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Problem

A common measurement task in oscillator manufacturing is to verify the oscillator start-up performance. In other words, how long time after switch-on is the oscillator operating with ”satisfactory” frequency accuracy. The accuracy limits are typically in the order of one or a few ppm.

Solution

The Pendulum Instrument CNT-90 or CNT-91 timer/counter/analyzers provide a very cost-effective solution to this measurement problem. Both units feature continuous timestamping frequency measurements.

The relevant difference between the two units in this specific application, is that the CNT-91 has 2x better resolution or 50 ps/(measuring time) for short measurement times, and also Frequency-back-to-back (FREQ BtB) as built-in measurement function. With this function, you avoid the dead time between measurements, which is found in the “normal” Frequency measurement function. You also can get up to twice as many frequency samples for low frequency oscillators within the same total measurement time, compared to normal Frequency (with dead-time)

CNT-90 has a resolution of 100 ps/(measuring time) for short measuring times, but no Frequency Back-to-Back, only the normal Frequency (with a short dead-time). However both CNT-90 and CNT-91 have a raw time stamping measurement mode, providing zero-dead-time measurement data of number of input cycles and elapsed time for post-processing in a PC. This makes it possible to calculate e.g. frequency or period back-to-back in remote operation also in CNT-90.

Set-up

1. Connect the supply voltage to the oscillators under test (DUT) via a capacitor plus diode to the input A of CNT-90 or CNT-91 (fig.1)
2. Connect the output of the DUT via a resistor to the input A (same input!) of CNT-90 (fig.1)
4. Connect the CNT-90 or CNT-91 via USB or GPIB to a PC running an application program, e.g. TimeView^{TM}.
5. Program function FREQ A (CNT-90) or FREQ BtB A (CNT-91) measurements,
    manual trigger level (not AUTO),
    1 MΩ input impedance and
    positive trigger slope.
6. Set a suitable measurement time that fits the required resolution. E.g. 50 microseconds for 1 ppm resolution/sample in CNT-91, or 10 microseconds for 10 ppm resolution in CNT-90 (see below).
7. Set an array size with a suitable number of samples (define the total time to capture frequency data. E.g. 1000 Samples and 50 microseconds Frequency back-to-back measurements gives a total time for the measurement of 50μs * 1000 = 50 ms
8. Set INIT:CONT OFF plus INIT
9. Switch on supply voltage to DUT and start to measure, and get the data (READ:ARR?)

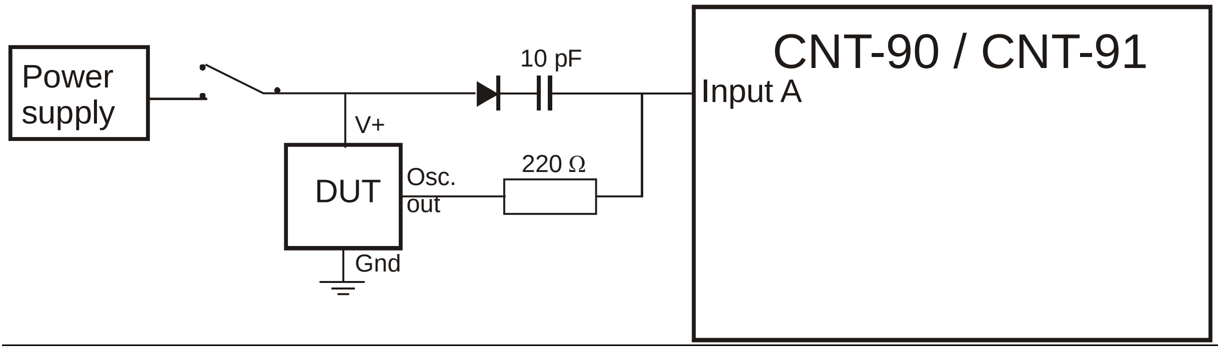


Figure 1. Set-up for Oscillator start-up measurements

The supply voltage change (a positive slope through the capacitor) is transferred to the counters measurement input as a trigger slope, and generates first timestamp (time 0 ns), the following timestamps are generated by the oscillations of the DUT.
For a low-frequency oscillator, e.g. a 32.768 kHz oscillator, every individual clock cycle can be time stamped using Frequency BtB, see figure 2. With normal Frequency measurements it is only possible to timestamp every second period.

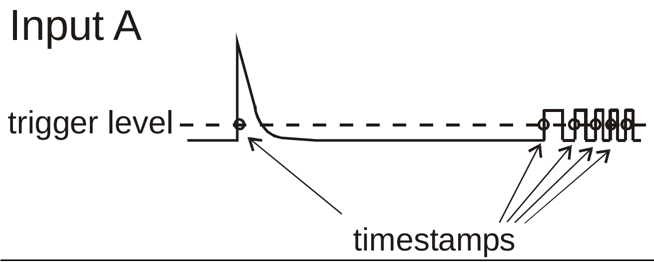


Figure 2. For LF-oscillators ALL cycles can be time-stamped

For a high-frequency input signal, e.g. 10 or 100 MHz, the timestamps are taken at intervals defined by the set measuring time. See figure 3

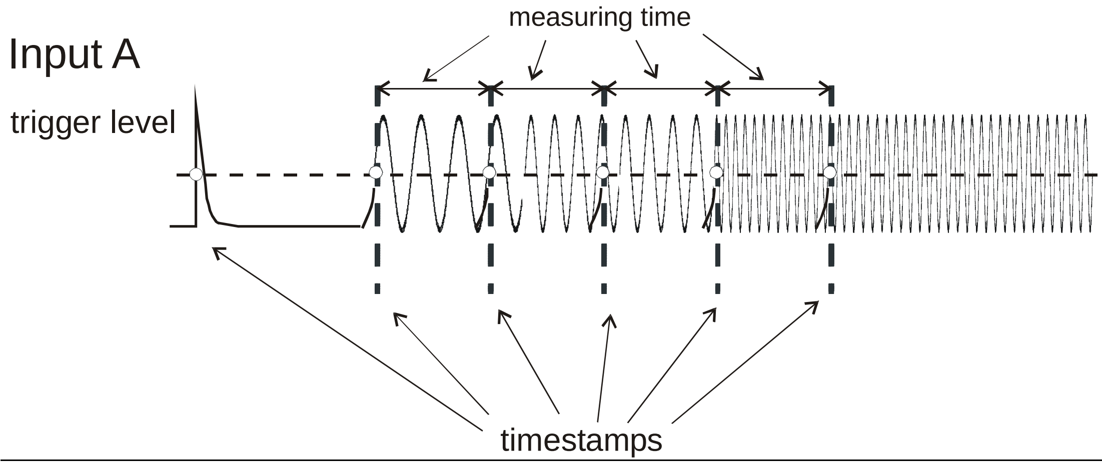


Figure 3. The set measuring time defines the time between samples

The stored timestamp value is the *start* of the measurement time, but the actual frequency value is the average during the entire measurement time, from start to stop. If the change in frequency can be approximated to be linear during the individual measurement time, then the frequency value should be referenced to "timestamp value + 50% of measuring time".

Measuring time determines resolution

The relative resolution of a frequency sample is determined by the measuring time:

$$\text{Rel. } resolution = \frac{50\,ps}{meas\ time}\ (CNT91)\ \ or\ = \frac{100\,ps}{meas\ time}\ (CNT90)$$

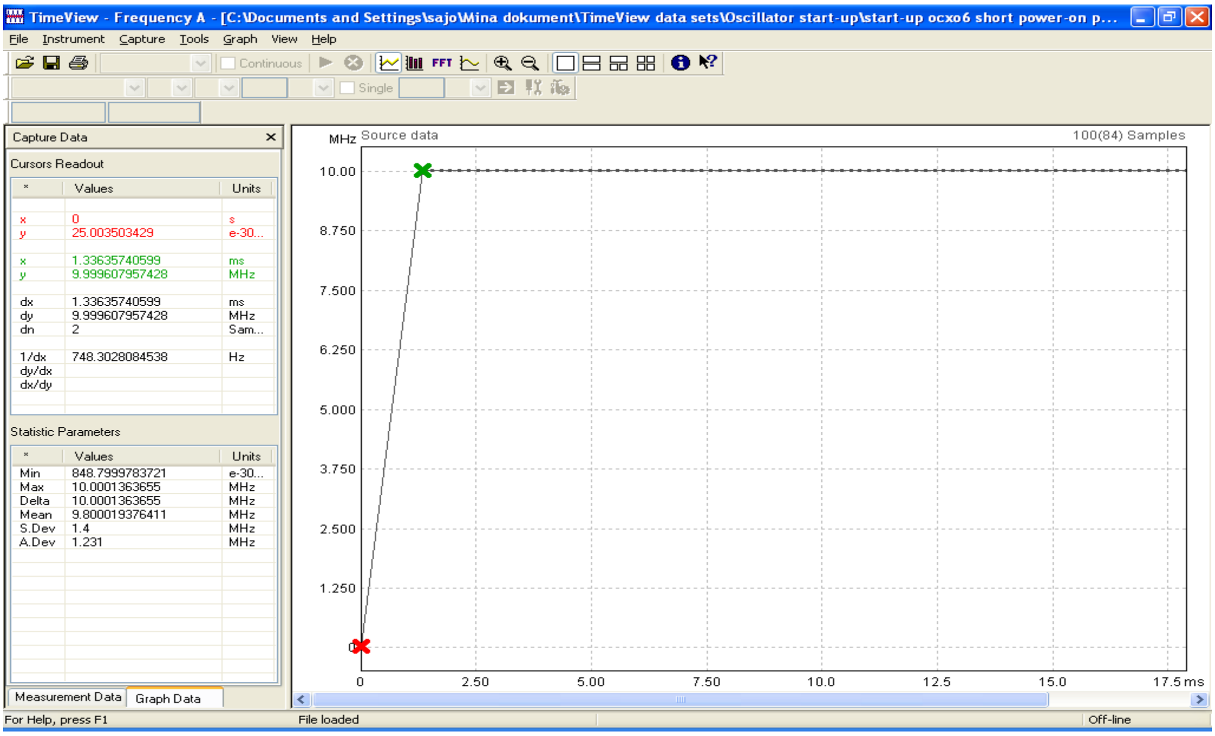
To measure with a resolution of e.g. 1ppm, a measurement time of 50 µs is recommended for CNT-91. That is timestamps will be recorded at 50 µs intervals in CNT-91 using FREQ BtB, or at 50 µs + *x* intervals in CNT-91 using FREQ in CNT-90, where x is the dead time between measurements. This dead time is typically 8 µs, but can be brought down to 3 µs, by turning off internal calibration during the measurement (CAL:INT OFF).

Number of samples determines total measuring time

The total measuring time equals (measuring time per sample)*(number of samples).
Assume you use CNT-91 with FREQ Back-to-Back, and 50 µs measuring time. By e.g. setting number of samples to 100, you will measure 100 frequency values with corresponding timestamps over a total time of 5ms + *y*, where y is the dead time for the DUT from power-on to first oscillation.

Using TimeView to measure oscillator warm-up

You can use Time in two different capture modes to measure the oscillator start-up time. The most straight-forward method is to set up TimeView for Frequency (or Frequency BtB) measurements and perform a single-shot capture (free-run). An example with a 10 MHz TCXO as DUT, using 200 µs measuring time is shown below:



Cursors Readout

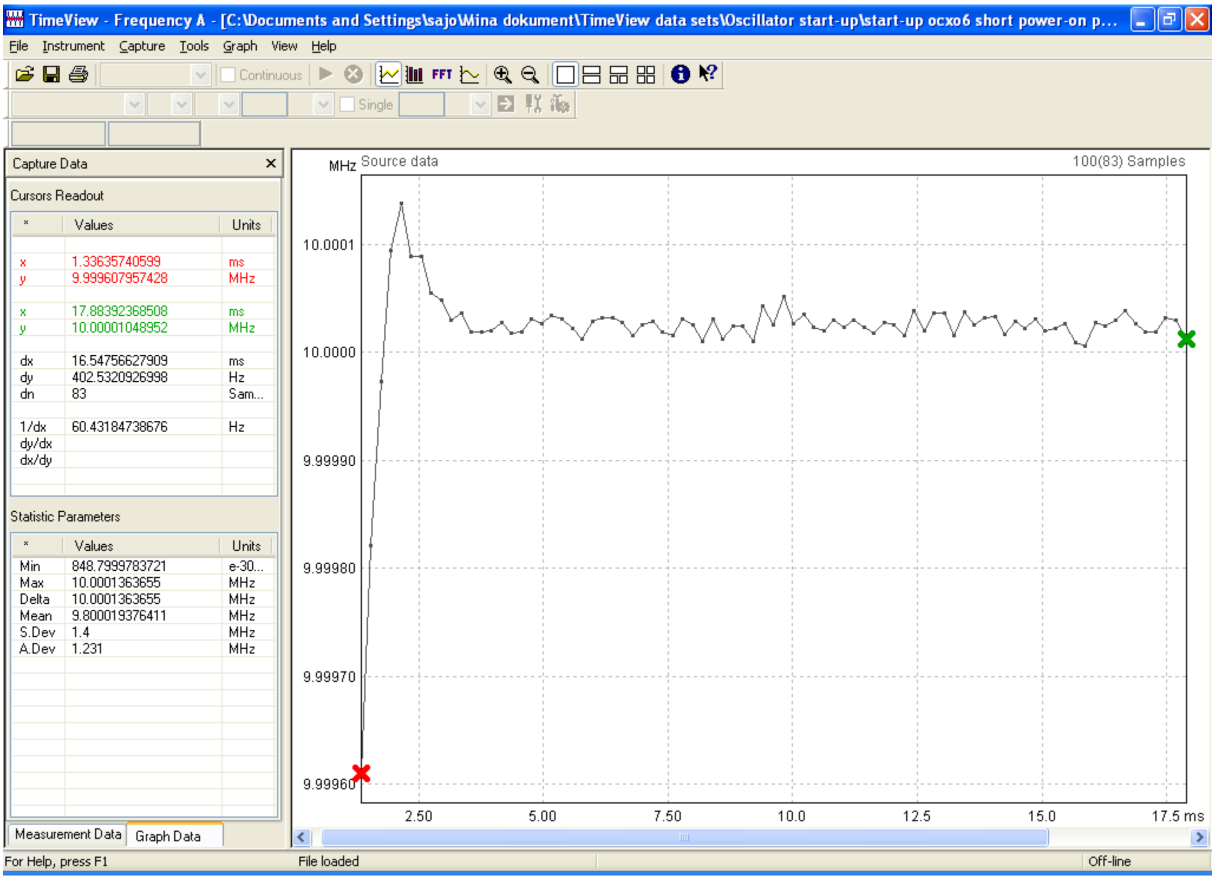
×	Values	Units
x	0	s
y	25.003503429	e-30...
x	1.33635740599	ms
y	9.999607957428	MHz
dx	1.33635740599	ms
dy	9.999607957428	MHz
dn	2	Sam...
1/dx	748.3028084538	Hz
dy/dx		
dx/dy		

Statistic Parameters

×	Values	Units
Min	848.7999783721	e-30...
Max	10.0001363655	MHz
Delta	10.0001363655	MHz
Mean	9.800019376411	MHz
S.Dev	1.4	MHz
A.Dev	1.231	MHz

The TimeView graph shows the frequency samples (Y) over a time axis (X). The first sample is the time-stamped power-on trigger (red cursor). The cursor read-out value (X = 0 seconds) is also the origin of the TimeView time scale.

The following samples are a sequence of 200 µs measurements starting after approx 1.3 ms (green cursor X-read-out), when the oscillator starts to generate its first oscillations.
A zoom-in the above graph reveals more details:



TimeView - Frequency A - [C:\Documents and Settings\sajo\Mina dokument\TimeView data sets\Oscillator start-up\start-up ocxo6 short power-on p...

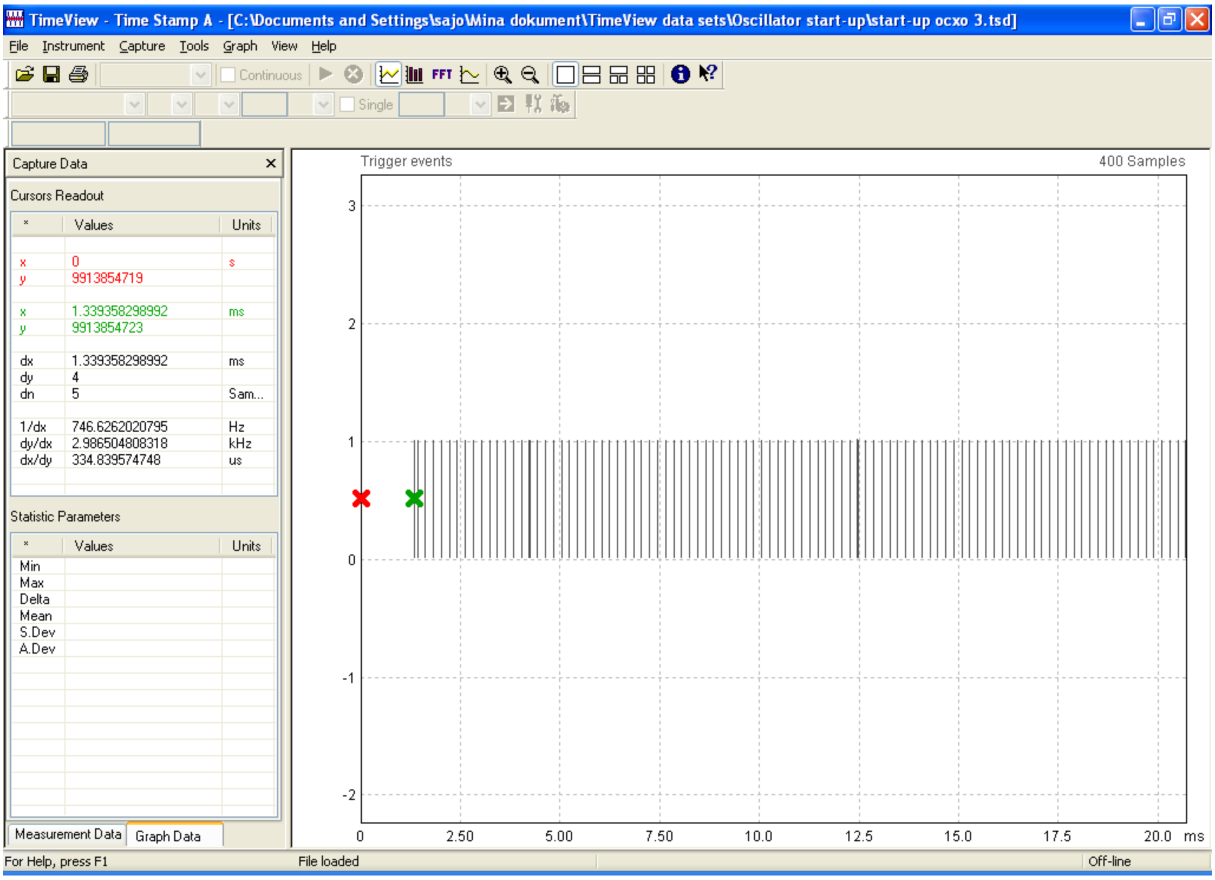
Cursors Readout

*	Values	Units
x	1.33635740599	ms
y	9.999607957428	MHz
x	17.88392368508	ms
y	10.00001048952	MHz
dx	16.54756627909	ms
dy	402.5320926998	Hz
dn	83	Sam...
1/dx	60.43184738676	Hz
dy/dx		
dx/dy		

Statistic Parameters

*	Values	Units
Min	848.7999783721	e-30...
Max	10.0001363655	MHz
Delta	10.0001363655	MHz
Mean	9.800019376411	MHz
S.Dev	1.4	MHz
A.Dev	1.231	MHz

Another possible method is to use Raw time-stamping data capture, with display of the trigger events after the set pacing time (200 µs in this example). See below:



TimeView - Time Stamp A - [C:\Documents and Settings\sajo\Mina dokument\TimeView data sets\Oscillator start-up\start-up ocxo 3.tsd]

Capture Data

Cursors Readout

*	Values	Units
x	0	s
y	9913854719	
x	1.339358298992	ms
y	9913854723	
dx	1.339358298992	ms
dy	4	
dn	5	Sam...
1/dx	746.6262020795	Hz
dy/dx	2.986504808318	kHz
dx/dy	334.839574748	us

Statistic Parameters

*	Values	Units
Min		
Max		
Delta		
Mean		
S.Dev		
A.Dev		

For Help, press F1

File loaded

Off-line

The graph shows the trigger events as vertical bars, after the time scale (X) starting with the first time-stamped trigger event (the power-on-pulse). Also here you can see that the time from power-on to first oscillations is approx 1.3 ms (green cursor read-out)

From this trigger-event view you cannot read the frequency sample values directly, so you need to save the data file and open in some other program, like Microsoft Excel. Each time-stamp value pair contains the accumulated number of input cycles and the accumulated elapsed time, so the frequency is simply calculated as:
(number of cycles between timestamps)/(time difference between timestamps

The data saved from the FREQ measurement in free-run mode contains already calculated frequency values between timestamps.

Conclusion

With the use of the continuously time-stamping counters CNT-90 or CNT-91, it is possible to do several measurements suitable for oscillator manufacturing:

- high-resolution, **high-speed frequency verification** during factory test trimming
- **long term stability** (ageing) measurements
- **short-term stability** ADEV vs time (zero-dead-time measurement)
- and – as described - **oscillator start-up** frequency measurements
- and - last but not least – the CNT-90/91 provide a very **cost-effective** solution