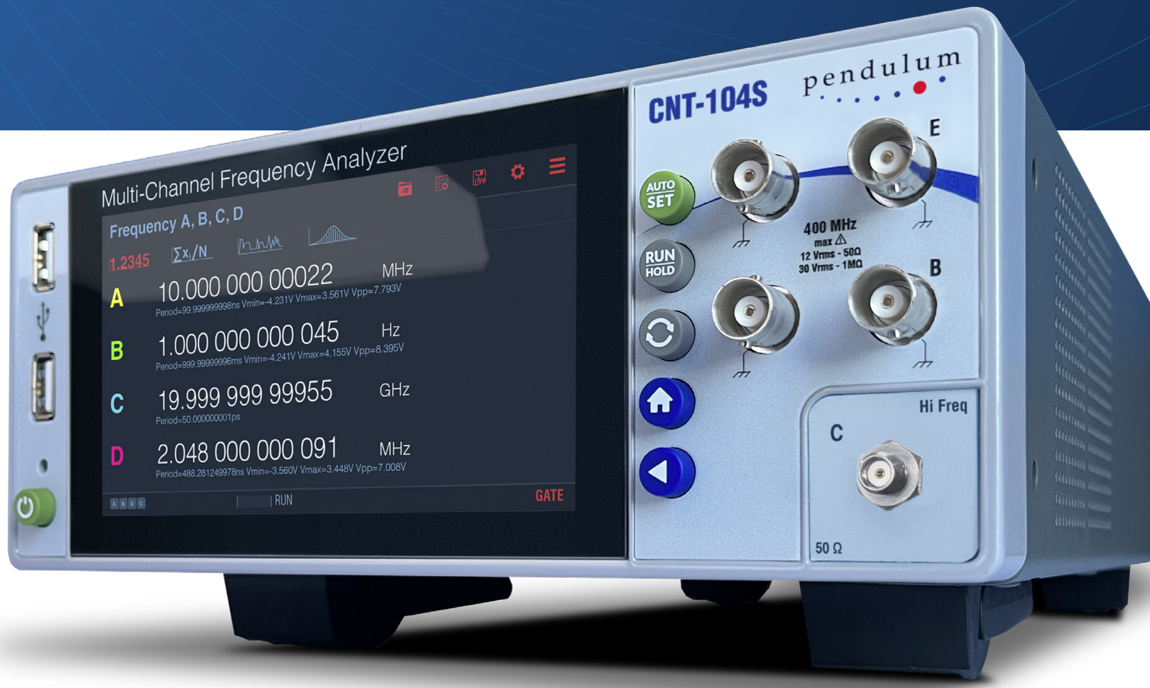
CNT-104S

Multi-channel Frequency Analyzer CNT-104S for Oscillator manufacturers

WHITE PAPER

Author: Staffan Johansson



Background

Instruments for measurement & analysis of time or frequency are used for many different purposes at oscillator manufacturers, at different departments:

- Adjustment and verification of frequency (production)
- Frequency verification to specs (QC – Quality Control)
- Long term stability (ageing) of oscillators (production / QC)
- Temperature stability measurements of oscillators (R&D / QC)
- Short-term-stability test; ADEV (R&D or production)
- Start-up performance (R&D / QC)
- Wander parameter measurements (TIE) in clock modules for telecom (R&D / QC)
- Verification of frequency purity (finding frequency micro-glitches) in R&D
- PLL parameter testing (R&D)
- Settling times for Voltage Controlled Oscillators (VCO)
- Phase comparisons of frequency standard clocks (Cal lab)
- Frequency calibration of other instruments (Cal lab)

With the CNT-104S from Pendulum Instruments, you can perform all these measurements in one single instrument.

And furthermore, you can test 4 oscillators/clock-modules in parallel in one single box.

The following pages will show some examples where the CNT-104S will give the highest possible performance for typical measurements in oscillator R&D and manufacturing processes.

CNT-104S

- FOUR PARALLEL ZERO-DEAD-TIME MEASUREMENTS IN ONE BOX
- 7 ps time-stamp resolution for very accurate phase comparisons of reference clocks
- 12-13 digits/s resolution for ultra-fast frequency measurements
- up to 20M results/s to internal memory for transient analysis
- built-in TIE measurements to measure TIE for network clocks
- Thousands of streaming block measurements/s continuously to external controller
- Modulation domain analysis built-in
- View and control measurements remotely via built-in web server interface

CNT-104S is the ideal tool for all companies manufacturing oscillators and clock modules. In production test stations, the 4 parallel channels, the high resolution and measurement speed, makes CNT-104S the best, and most cost-effective, choice for frequency adjustment and verification.

In the Quality Control Dept, the CNT-104S can be used for all types of verification of frequency or time parameters, e.g. ageing over days, weeks or months, frequency variation due to environmental changes of e.g. temperature, verification of Wander parameters (TIE) on sample tests, verification of short-term stability (ADEV), etc.

In the calibration lab, the high 7 ps time stamp resolution enables accurate and fast phase comparisons between in-house frequency standards. The measurement versatility makes CNT-104S the ideal calibrator for frequency time-bases in e.g. generators, spectrum analyzers etc. or for time-interval or phase calibrations.

In R&D, the modulation domain display enables fast and high-resolution measurements of frequency vs time, to e.g. characterize start-up behavior of oscillators, standard display of short term stability (ADEV), analysis of clock PLL design in the design phase, measurement of VCO settling times, sample testing of wander parameters (TIE), detection of frequency glitches, etc.

Ultra-fast frequency adjustment and testing in production

One CNT-104S can replace 4 traditional frequency counters!

Instead of testing oscillators in series one-by-one, you can test 4 oscillators in parallel.

Using two CNT-104S and the rack mount kit Option 22/05, you will have 8 parallel frequency measurement input channels occupying 19” width and 2U height. A huge saving of cost and rack space.

replaces

or

High resolution means high testing speed

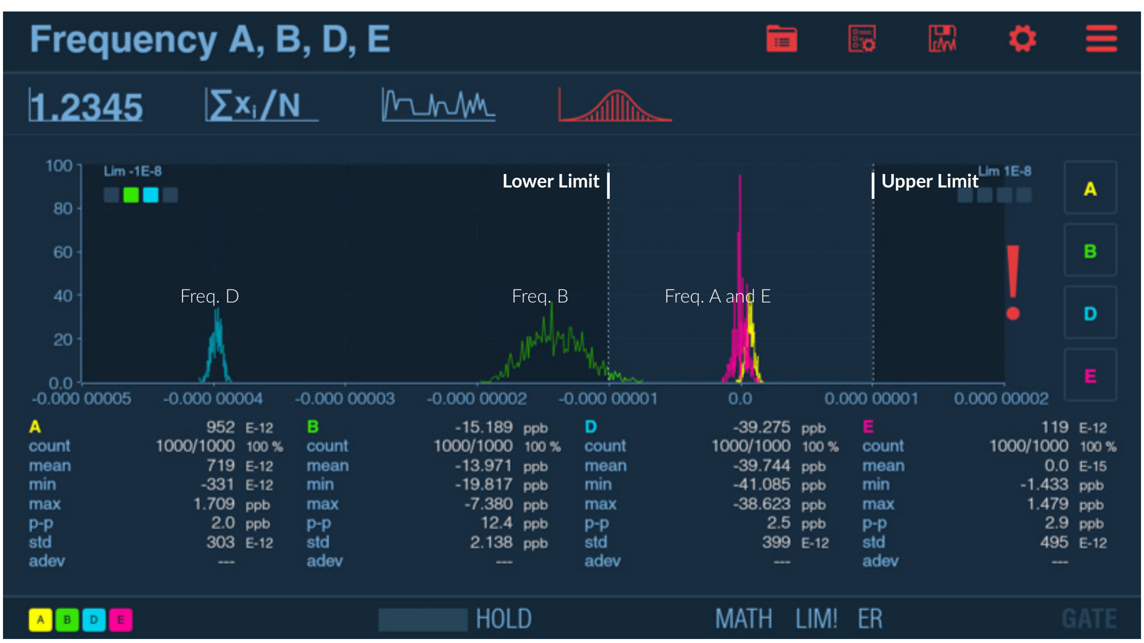
For high accuracy oscillators, like OCXO, you need to verify frequency to approx. 8-9 digits in the test system. The ultra-high resolution of CNT-104S gives you a 9-digit result in just one millisecond gate time.

Semi-automatic production testing

For low volume production testing, you may see semi-automatic test stations, with manual handling of the DUTs, and sometimes even manual read-out. In these applications, the CNT-104S offers some unique advantages, like graphical representation of test limits on the built-in display, with clear pass/fail indication on 4 parallel inputs (A, B, D, E).

Example: 4x 10 MHz oscillators connected. Tolerance range set to +/- 1E8, or +/- 10ppb.

2 oscillators are always inside range (A & E), 1 is constantly below (D), 1 is sometimes in range but mostly below (B).



Distribution view

- Spread of all samples
- Freq A and E are accurate and stable
- Freq D is stable but inaccurate
- Freq B is unstable and mostly inaccurate

Oscillator start-up measurements

A common task in oscillator manufacturing is to verify the oscillators 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 ppm to ppb.

The CNT-104S provides a very cost-effective solution to this measurement problem.

The CNT-104S has a very-high resolution also for short measurement times, and the gap-free measurement functions. With this function, you avoid the dead time between measurements, which is found in traditional Frequency counters.

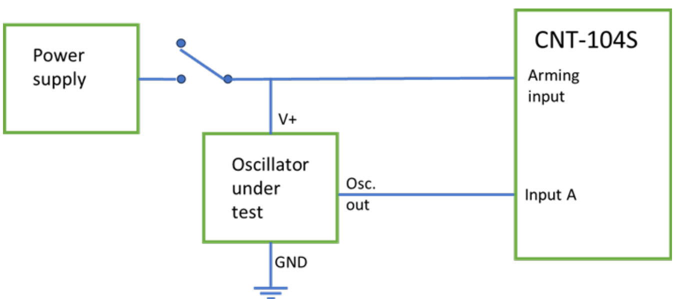
Set-up

1. Connect the oscillator under test (DUT) to the CNT-104S and supply voltage as shown below.

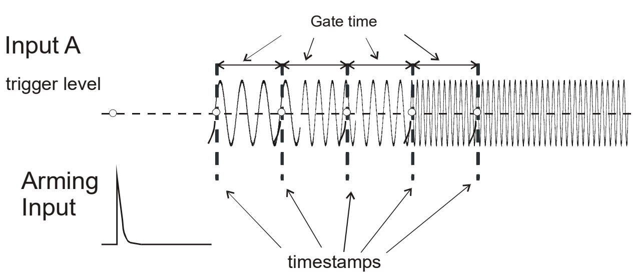
2.Set a suitable gate time (sample interval) that fits the required resolution. E.g. 1 microsecond for 0.1 ppm resolution/sample in CNT-104S.

3. Set a sample size with a suitable number of samples (define the total time to capture frequency data). E.g. 10000 Samples and 1 microsecond measurements gives a total time for the measurement of 1µs * 10000 = 10 ms (plus the delay from Arming = power-on to first cycle).

4. Switch on supply voltage to DUT, start to measure, and get the data.



The timestamps are taken at the intervals defined by the set Sample Interval = gate time. See figure below



Up to 4 oscillators can be tested in parallel.

An example of a start-up test is shown below. The test object is a 10 MHz TCXO, which starts to oscillate approx. 0.75 ms after power-on and reaches its nominal 10 MHz frequency after approx. 1.1 ms. The graph is a zoom-in of the first 1.4 ms of the measurement.

Further analysis that you can easily do are for example:

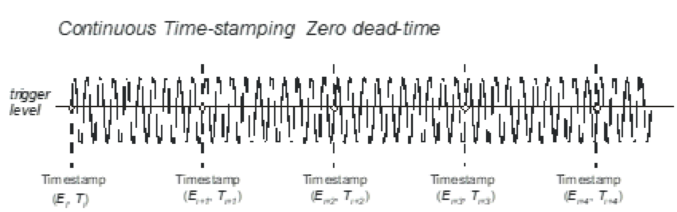
- From the Zoom and Pan, you can switch to cursor read-out view. By positioning cursors in the graph, the exact time, and the exact frequency values, can be read with ultimate accuracy.
- You can also use Zoom and Pan function to only view frequency values as from 1.1 ms and up, to only see the nominal 10 MHz variations in greater details.
- If you insert tolerance limits (Limit function in CNT-104S) in the graph, you can easily view when the frequency comes inside acceptance limits. It may be another ms or so, depending on requirements.

Wander parameter measurements (TIE) in clock modules for telecom

Oscillators and clock modules intended for use in synchronous telecom networks, sometimes have an additional specification for wander parameters (sometimes MTIE, but most often TDEV). These wander parameters are post-processed results of the basic TIE-measurement (TIE = Time Interval Error). TIE is the time difference between the trigger event (normally the zero-crossing) of the actual clock or data signal, compared to the ideal clock signal. TIE = 0 for the first value taken at time t=0, and TIE is thereafter the accumulated phase difference relative to the first sample taken.

CNT-104S has built-in TIE-measurements, thanks to the gap-free measurement principle, which is a must for TIE measurements. TIE is calculated in CNT-104S as:

$$TIE(i) = T_i - T_0 - \frac{E_i - E_0}{Freq_{nom}}$$



For e.g. a Stratum 1 type of 1.544 MHz clock, each zero crossing should ideally occur with a time difference of exactly 647.668 393 782 383 ns between trigger events. The ideal time stamp, for e.g. 1 million trigger events from start of measurement, should be 0.647 668 393 782 s.

Now assume that the timestamp of the actual signal for the 1 millionth time stamp is 0.647 668 310 000. That means that the TIE for time t = 0.648 s equals 83.782 ns (the difference between actual and ideal clock.

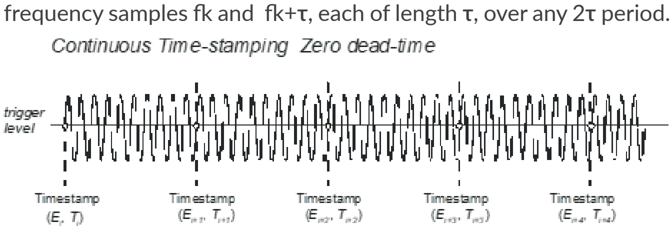
The TIE file of up to 4 parallel test objects can be exported into a spreadsheet program, e.g. Excel, MatLab, or Stable32 for further postprocessing and calculation of MTIE and TDEV. The file export format is CSV.

Example below shows parallel measurements of 4 different GPS-disciplined clocks (10 MHz). The 4 CSV files can be directly read by MS Excel for MTIE and TDEV calculation.

Short-term stability testing (ADEV vs τ)

Short-term stability of oscillators is measured as Allan Deviation (ADEV) for various measurement times. Correct ADEV calculation assumes zero-dead-time measurements, which means that traditional counters cannot be used.

ADEV is the RMS of the difference between any two back-to-back frequency samples fk and fk+τ, each of length τ, over any 2τ period.



Frequency back-to-back samples f_i over τ seconds each, are calculated as:

$$f_i = \frac{E_i - E_{i-1}}{T_i - T_{i-1}}$$

The CNT-104S makes automatic calculation of short-term stability (σy or ADEV) for any set sample interval, and of any frequency source up to 20 GHz, using the built-in formula:

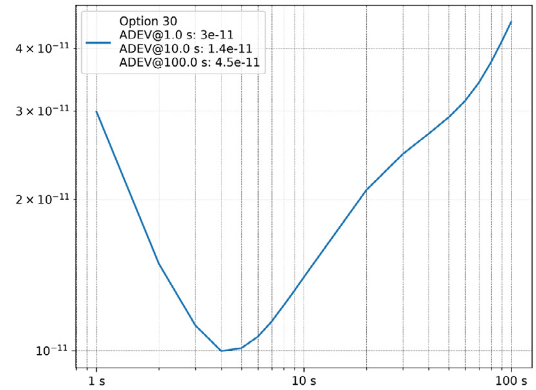
$$\sigma_y^2(\tau) \approx \frac{1}{2(n-1)} \sum_{k=0}^{k=n-1} (y(t_k+\tau) - y(t_k))^2$$

y(k) is the fractional frequency deviation [$y(k) = (f_k - f_{ref}) / f_{ref}$]

ADEV is calculated and displayed for any selected sample interval. You can either make a number of frequency measurements and note the values for e.g. sample interval 1, 2, 5, 10, 20, 50, 100s (7 measurements in total), and manually create a plot of ADEV vs. τ.

Or you can export a single Frequency or TIE file, for one measurement session only, containing up to 4 parallel test objects to MS Excel, MatLab, or Stable32 for easy calculation of the ADEV vs. τ graph.

Below is an example where the raw data file contains 1200 gap-free frequency measurement samples of a 10 MHz OCXO, with 1s Gate Time each. The data has been processed in MS Excel according to the standard formula.



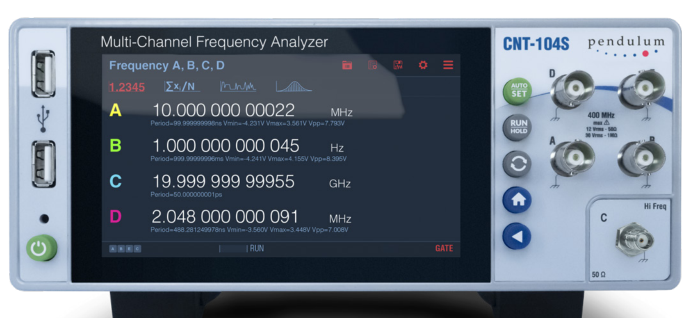
Conclusion

The CNT-104S Multi-Channel Frequency Analyzer, with or without post-processing of the data files in e.g. MS Excel, Matlab, or Stable32, can be used for several measurements common in oscillator manufacturing:

- Adjustment and verification of frequency (production)
- Frequency verification to specs (QC – Quality Control)
- Long term stability (ageing) of oscillators (production / QC)
- Temperature stability measurements of oscillators (R&D / QC)
- Short-term-stability test; ADEV (R&D or production)
- Start-up performance (R&D / QC)
- Wander parameter measurements (TIE) in clock modules for telecom (R&D / QC)
- Verification of frequency purity (finding frequency micro-glitches) in R&D
- PLL parameter testing (R&D)
- Settling times for Voltage Controlled Oscillators (VCO)
- Phase comparisons of 4 frequency standard clocks (Cal lab)
- Frequency calibration of other instruments (Cal lab)

CNT-104S Timer/Counter/Analyzer features

- Multi-Channel Frequency Analyzer for parallel testing of 4 DUTs
- Ultra-high resolution and speed
- Built-in in TIE and ADEV measurements
- And - last but not least – the CNT-104S provides a very cost-effective solution for parallel test, replacing up to 4 traditional timer/counters



13.12.2023 Multi-channel Frequency Analyzer CNT-104S for Oscillator manufacturers
Specifications subject to change or improvements without notice.
4031 601 10011

pendulum