Time and Frequency Measurements for Oscillator Manufacturers

Using the FCA3000 and FCA3100 Series Timer/Counter/Analyzers

Application Note

Tektronix®

Introduction

Designing and manufacturing oscillators requires accurate measurements of time and frequency parameters which can be a challenge without the right test methodology. This application note explores techniques and tips for using the Tektronix FCA3000/3100 Series Timer/Counter/Analyzers for fast, accurate measurements of precision oscillators in both design and production environments.

Common Measurements

Common time and frequency measurements made during the design and manufacture of oscillators include:

Measurement Task	Environment
■ Adjustment and verification of frequency	■ Production
■ Frequency verification to specs	■ Quality Control
■ Long term stability (ageing) of oscillators	■ Production ■ Quality Control
■ Temperature stability measurements of oscillators	■ R & D ■ Quality Control
■ Short-term-stability test; ADEV vs τ	■ R & D ■ Production
■ Start-up performance	■ R & D ■ Quality Control
■ Wander parameter measurements (TIE, TDEV) in clock modules for telecom	■ R & D ■ Quality Control
■ Verification of frequency purity	■ R & D
■ PLL parameter testing	■ R & D

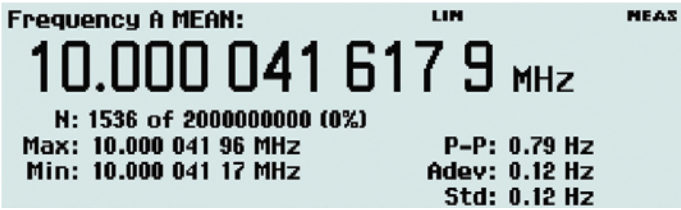

Figure 1. Using Allan Deviation (Adev) statistics reporting on the FCA3100 Series to identify short-term instability.

Complete and Accurate Oscillator Characterization During Design

In R & D, engineers must perform a wide range of tasks to characterize an oscillator design. This includes characterizing the start-up behavior of the oscillator, verifying short term stability (ADEV vs τ), analyzing the clock PLL's behavior, sample testing wander parameters (TIE, TDEV), and detecting frequency glitches.

The FCA3100 Series provides precision measurements with 12 digits/s frequency resolution and 50 ps time resolution to ensure accurate characterization of an oscillator. Automated measurements such as TIE (Time Interval Error), TDEV (Time Deviation), frequency and phase simplify making many of the necessary measurements during oscillator design.

For tracking how the oscillator output changes over time or environmental conditions, the measurement statistics mode enables seeing measurement trends. Designers often find the Allan Deviation to be a key measurement for characterizing short-term instability.

Short-term Instability Testing with Allan Deviation (ADEV)

When trying to isolate short-term instability caused by jitter, this is not possible with Standard Deviation techniques which consider the effects of all types of deviation, as all samples in the population are compared with the total mean value. Tektronix Timer/Counter Analyzers give you the ability to isolate and basically narrow in on short-term instability.

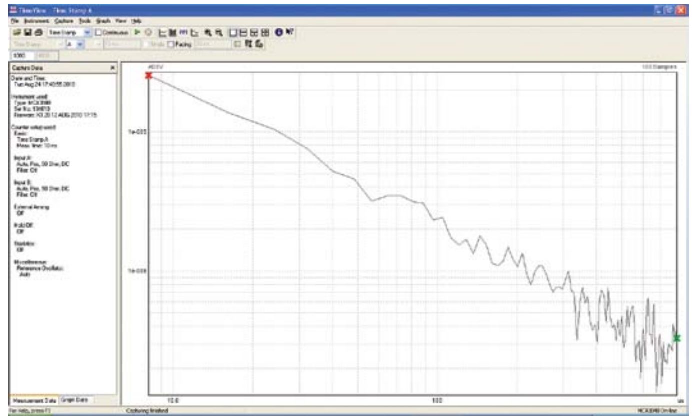

Figure 2. A TimeView™ plot of ADEV vs t for an OCXO.

Allan Deviation is a statistic used for characterizing short-term instability by means of samples (measurements) taken at short intervals. The fundamental idea is to eliminate the influence of long-term drift due to aging, temperature or wander. This is done by making consecutive comparisons of adjacent samples rather than throughout the entire population of data. ADEV is the RMS of the difference between any two back-to-back frequency samples f_k and $f_k + \tau$, each of length τ, over any 2τ period.

Correct ADEV calculation assumes zero dead-time or back-to-back measurements, which means that traditional counters cannot be used. Only counters with zero dead-time and time-stamping - such as the FCA3100 Series - can accomplish this task. With a single press of the Analyze button on the front panel, Allan Deviation can be viewed in the statistics readout, as seen in Figure 1. Alternatively, the FCA3000 Series using TimeView™ Modulation Domain Analysis software can be used as well.

Using TimeView™ Modulation Domain Analysis Software

What TimeView™ Does

For R & D engineers, trying to gain insight into an oscillator's short-term and start-up behavior can be a challenging task without the right measurement tools. Tektronix FCA3000/3100 Series timer/counters combined with the optional TimeView Modulation Domain Analysis software easily provides this capability which no other type of instrument can do. Furthermore TimeView can monitor ageing, measure Time Interval Error (for network clocks) and find any frequency anomaly (glitches, phase shifts) in oscillators.

How TimeView Works

TimeView takes the zero dead-time data (frequency, time or phase) from an FCA3100 Series product then displays and processes the data. The basic presentation mode is to show the variation of frequency, time or phase versus time. This unique modulation domain presentation mode reveals signal properties that complement the traditional time domain (oscilloscope view) or frequency domain (spectrum analyzer view).

The TimeView statistics presentation mode presents numerical statistics and histogram presentation to reveal jitter types and possible modulation. The FFT presentation mode detects both intentional and unwanted modulation of the oscillator-frequency. And the timestamp presentation mode can be used to calculate short-term stability ADEV over τ. See plot in Figure 2.

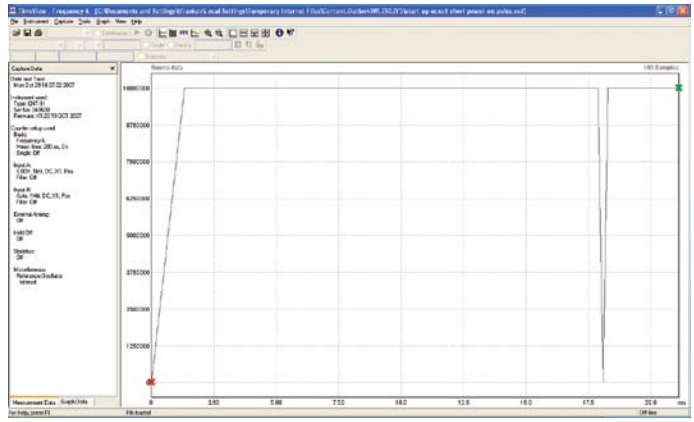

Figure 3. TCXO output frequency vs time after power up (left most red cursor).

Using TimeView to Measure Oscillator Warm-up

When trying to capture oscillator warm-up time, you can quickly capture this by setting up TimeView to make frequency Back-to-Back (BtB) measurements and free-run data capture. An example with a 10 MHz TCXO as the Device Under Test, (using 200 µs measuring time is shown in Figure 3. The TimeView chart shows the frequency samples (Y) over a time axis (X). The first sample is the time-stamped power-on trigger (red cursor) and also the origin of the TimeView time scale.

Wander Parameter Measurements (TIE, TDEV) in Clock Modules for Telecom

Oscillators and clock modules intended for use in synchronous telecom networks, occasionally have additional specifications for wander parameters (sometimes Maximum Time Interval Error (MTIE), but most often Time Deviation (TDEV) related to wander. These wander parameters are post-processed results of the basic Time Interval Error measurement (TIE). TIE is the time difference between the trigger event (normally the zero-crossing) of the actual clock or data signal, compared to the ideal or reference 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. The FCA3100 Series is the only frequency counter on the market with built-in TIE measurements, thanks to the continuous zero dead-time measurement principle.

Improving Productivity in the Production Environment

Manufacturers everywhere are looking for every possible technique for improving productivity. Whether implementing lean manufacturing or reducing test times, higher productivity means lower cost and higher profits. Tektronix FCA Series timer/counter/analyzers are just the tool for all companies manufacturing or measuring oscillators or clock modules with a desire to improve processing time. In production test stations for example, the products' high frequency and time resolution, combined with the industry's best timer/counter measurement speed and a 53131A/53132A GPIB compatibility mode, makes the FCA3000/3100 Series the best choice for oscillator manufacturing.

Saving Test Time During Production

High-volume production testing of oscillators is typically done in automated test systems using custom designed test jigs for several oscillators that are either measured in parallel or sequentially switched. Total throughput is limited by the Production Operator, the measurement time, the oscillator switching overhead, and the data transfer time. In these measurements, bus measurement speed and resolution are key parameters.

The FCA3100 Series product offers the ultimate resolution (1E-11 at just 100 ms measuring time), and GPIB bus speed (up to 4000 low-resolution measurements/s). To verify frequency to 8 significant digits requires only 5 ms of measurement.

Getting the Most Out of Your Timer/Counter in the Production Environment

Fast switching between FREQ A and FREQ B

A fast way of doing frequency measurements on oscillator DUTs (DUT = Device Under Test), is to let the Production Operator connect two oscillators at a time to one counter. Therefore the test sequence is:

- Connect DUT 1 and 2 to input A and B, measure A, measure B
- Switch to DUT 3 and 4, connect to input A and B, measure A, measure B, etc

Instead of:

- Connect DUT 1 to input A, measure A
- Switch to DUT 2 to input A, measure A
- Switch to DUT 3, etc

Using the FCA3100 Series, the switching time to make first a measurement on A then on B is <30 ms, which should be compared to the time it takes the Production Operator to switch DUTs.

Short start time-out to detect faulty DUTs

One of the problems with fast production test of oscillators is that a DUT can be faulty, meaning you let the handler connect the DUT to the counter, you start the measurement and nothing happens. The oscillator under test is broken and gives no output signal. Some counters may more or less wait forever until the controller aborts the started frequency measurement. Other counters have programmable time-out and can abort the measurement automatically.

One problem with time-out settings in traditional counters is that they define the time when the measurement should have stopped, not started, and the time-out time must be longer than the gate time (measuring time). For example, if the measuring time is 500 ms, the time-out should be set to 500 ms or longer, meaning you need to wait longer than 500 ms before you know that the DUT is broken.

The FCA3100 Series counter/timers can set time-out both for start and stop of the measurement, and can be set to a very short start time-out time of just 10 ms, to quickly detect faulty oscillators.

Low volume 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 FCA3100 Series products offer unique advantages, like:

- Graphical representation of test limits on the built-in display
- USB connector to the PC running test software; no need to invest in GPIB cards

Production quality control

In the Quality Control department, the FCA Series timer/counters can be used for all types of verification of frequency or time parameters. And with the addition of Tektronix TimeView Modulation Domain Analysis software, it is possible to measure the ageing of an oscillator over days, weeks or even months, monitoring frequency variation due to environmental changes such as temperature.

Calibration labs

In the calibration lab, the high 50 ps time interval resolution on the FCA3100 Series timer/counters and optional high stability oven oscillator enables accurate and fast phase comparisons between in-house frequency standards, e.g., rubidium or cesium standards. The measurement versatility makes the FCA3100 Series the ideal calibrator for frequency time-bases in signal generators, spectrum analyzers and oscilloscopes for time-interval or phase calibrations.

Summary

The combination of an FCA3000 or FCA3100 Series Timer/Counter/Analyzer with TimeView software is a powerful, feature-rich toolset for making oscillator measurements in R & D or manufacturing environments. The ease of use, combined with measurement throughput speed, will significantly improve productivity across several applications.

The FCA Series offers a range of models to meet your needs and your budget:

	FCA3000	**FCA3100**
Maximum Frequency	300 MHz, 3 GHz, 20 GHz models	300 MHz, 3 GHz, 20 GHz models
Resolution	■ 100 ps (time) ■ 12 digits/s (freq)	■ 50 ps (time) ■ 12 digits/s (freq)
Data Transfer Rate	■ 250 k Samples/sec (internal) ■ 5 k Samples/sec (block)	■ 250 k Samples/sec (internal) ■ 15 k Samples/sec (block)
Available Measurements	**13 Automated Measurements** Frequency, Period, Ratio, Time Interval, Time Interval Error, Pulse Width, Rise/Fall Time, Phase Angle, Duty Cycle, V_{max}, V_{min}, V_{p-p}	**14 Automated Measurements** Frequency, Period, Ratio, Time Interval, Time Interval Error, Pulse Width, Rise/Fall Time, Phase Angle, Duty Cycle, V_{max}, V_{min}, V_{p-p}, Totalize
Built-in Analysis Modes	Trend Plot, Measurement Statistics, Allan Deviation, Histogram	Trend Plot, Measurement Statistics, Allan Deviation, Histogram
Rear-Panel Connectivity	USB, GPIB	USB, GPIB

Contact Tektronix:

ASEAN / Australasia (65) 6356 3900
Austria* 00800 2255 4835
Balkans, Israel, South Africa and other ISE Countries +41 52 675 3777
Belgium* 00800 2255 4835
Brazil +55 (11) 3759 7600
Canada 1 (800) 833-9200
Central East Europe, Ukraine and the Baltics +41 52 675 3777
Central Europe & Greece +41 52 675 3777
Denmark +45 80 88 1401
Finland +41 52 675 3777
France* 00800 2255 4835
Germany* 00800 2255 4835
Hong Kong 400-820-5835
India 000-800-650-1835
Italy* 00800 2255 4835
Japan 81 (3) 6714-3010
Luxembourg +41 52 675 3777
Mexico, Central/South America & Caribbean 52 (55) 56 04 50 90
Middle East, Asia and North Africa +41 52 675 3777
The Netherlands* 00800 2255 4835
Norway 800 16098
People's Republic of China 400-820-5835
Poland +41 52 675 3777
Portugal 80 08 12370
Republic of Korea 001-800-8255-2835
Russia & CIS +7 (495) 7484900
South Africa +27 11 206 8360
Spain* 00800 2255 4835
Sweden* 00800 2255 4835
Switzerland* 00800 2255 4835
Taiwan 886 (2) 2722-9622
United Kingdom & Ireland* 00800 2255 4835
USA 1 (800) 833-9200

*** If the European phone number above is not accessible, please call +41 52 675 3777**

Contact List Updated 25 May 2010

For Further Information

Tektronix maintains a comprehensive, constantly expanding collection of application notes, technical briefs and other resources to help engineers working on the cutting edge of technology. Please visit **www.tektronix.com**

08/10 EA/WWW 3CW-25569-0

Tektronix®