Clock Measurements Using the GT210 Universal Counter and Stable32

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• Introduction

This paper describes methods for making clock frequency and phase measurements using a GuideTech Model GT210PCI-8 Universal Counter [1] along with the Stable32 stability analysis software package [2]. The GT210 (shown in Figure 1 is a board that plugs into a PCI slot in a PC [3]. It has four inputs for the A and B channel signals, a reference signal and an arming signal. The GT210 has 8 ps single-shot time interval resolution, 12 digits per second frequency resolution, and operates from DC to 2.7 GHz (480 MHz direct without prescaler). It can be used as either a single channel frequency counter or a two channel time interval counter.

Figure 1. Photograph of GT210 Counter Board

These tests are conducted with GT210PCI-8 S/N 25EB1009 along with its virtual front panel software. They resemble those conducted previously on a similar device [4].

• Measurement Methods

The following two measurement methods are utilized:

1. Direct frequency measurement using the GT210 as a high-resolution counter.
2. 1 pps time interval measurements using a pair of dividers to produce 1 pps reference and measurement signals and measuring their time difference with the GT210.

• Reference and Test Sources

The reference source for these measurements is an Efratom LPRO-101 rubidium oscillator and an associated distribution amplifier which is manually calibrated using a Trimble Thunderbolt GPS disciplined oscillator. The test source is a Milliren Technologies MTI 574-0126A 10 MHz OCVCXO set for a frequency offset of about +32 Hz.

• GT210 Virtual Front Panel

Operation of the GT210 universal counter is supported by a virtual front panel Windows® software application as shown in Figure 2. This program simulates the functionality of a conventional bench-top instrument to control the counter, view measurement plots and statistics, save the resulting data to disk, and launch Stable32 for detailed stability analysis of time interval data.

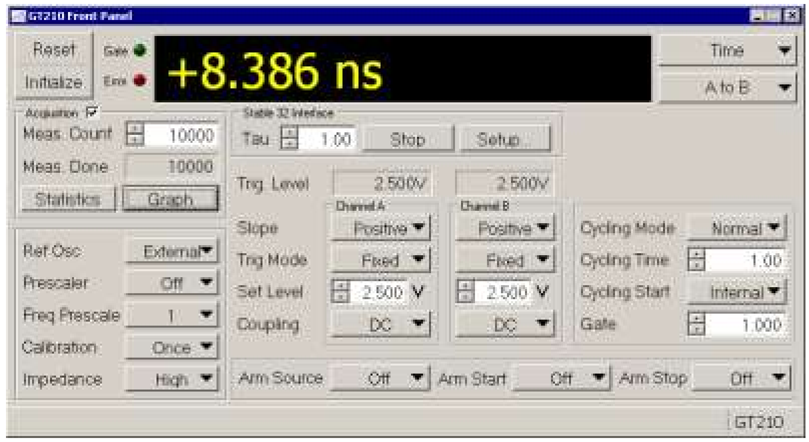


Figure 2. GT210 Virtual From Panel Screen

• GT210 Setup

The GT210 has several setup options that must be entered into their corresponding virtual panel controls to configure the instrument for the desired measurement. These are shown in Figures 2 for setup as a time interval counter. In all cases discussed, an external 10 MHz reference is used without external arming and instrument calibration is performed once prior to starting the measurements. The A and B inputs are used for time interval measurements, and they are set for high (1 kΩ) input impedance with +2.5 volt offset for 5 volt logic signals. Alternatively, the A channel input is used for direct frequency measurements and is set to low (50 Ω) input impedance with zero threshold voltage with a nominal +7 dBm drive level. The A channel input can also used for heterodyne frequency measurements, with high (1 kΩ) input impedance and a +2.5 volt offset voltage setting appropriate for the mixer/low pass filter and beat note amplifier.

Data acquisition is enabled by checking its box, and the measurement count is set to the desired number of points. The measurement statistics or a graphical plot can be selected with their buttons, and the data are captured to a text file with the Statistics/View All/Save commands. The Stable32 interface can be setup for the Stable32 program path and command line options, and then used to analyze time interval data at any time during a measurement run.

• Frequency Counter

Frequency measurements can be made with a frequency counter by simply applying the signal under test to the counter input. The instrument also requires a frequency reference, either internal or external, and accurate measurements require that an external reference be used. Modern interpolating reciprocal frequency counters make period measurements using analog interpolation to increase their resolution. The GT210PCI-8 has 8 ps single-shot resolution.

The GT210 was setup to make 1000 τ=1 second measurements on the small ovenized 10 MHz crystal oscillator versus the rubidium oscillator reference. The data are captured to a text file which is reasonably compatible with Stable32. The data are written as two columns of measurement point numbers and values with a 2-line header as shown in the example below. The header lines begin with non-numeric characters and are therefore ignored by Stable32. The point numbers are of little interest, and the frequency values must be converted to fractional frequency within Stable32 before their analysis. The measurement units can generally be ignored, but can pose a problem if they change within a data set. In that case, the Units.exe utility program included with Stable32 can help. In this case, the GT210-

generated text file can be read directly into Stable32. The data have a resolution of 100 μHz or 1x10^{-11}, consistent with the instrument's 8 ps per second resolution.

```
Results - Statistics - Frequency A
Number   Result
0:       +10.0000322014 MHz
1:       +10.0000321945 MHz
2:       +10.0000322009 MHz
3:       +10.0000321947 MHz
4:       +10.0000321888 MHz
5:       +10.0000322023 MHz
6:       +10.0000321936 MHz
7:       +10.0000322011 MHz
8:       +10.0000321948 MHz
9:       +10.0000322021 MHz
10:      +10.0000321973 MHz
```

The results of the 1000-point, τ=1 second frequency counter run are shown in Figure 3.

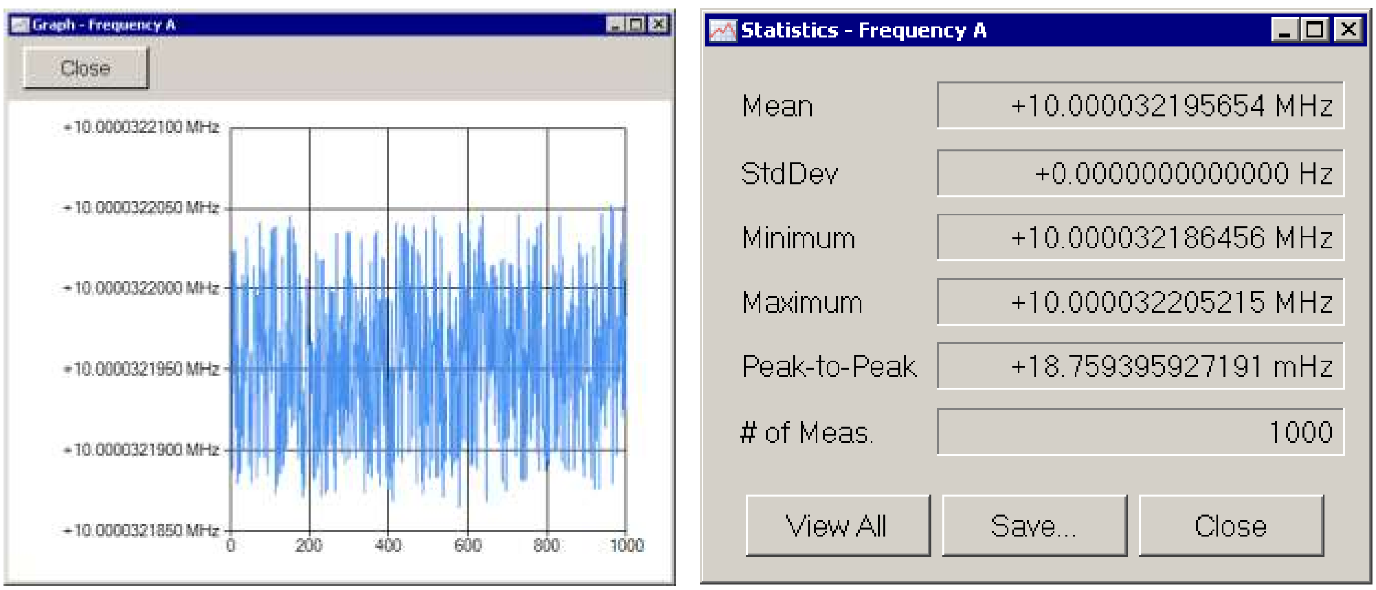


Figure 3. Results of Frequency Counter Measurement Run

The left plot shows the frequency data and the right table shows their statistics. The average frequency is about +32 Hz as expected. The zero standard deviation was the result of limited numeric precision, and that problem has been corrected in the latest version of the GT210 virtual front panel software. The p-p spread is about 15 mHz which implies a 1-second standard deviation of about 5x10^{-10}. Both the plot and statistics update dynamically as the data is collected and remain accessible after the run is complete. The plot is quite slow to draw for even moderately large data sets.

Note that the GT210 screen shows the standard deviation of the frequency or time interval measurements while the standard deviation shown by the Stable32 Statistics function is that of the fractional frequency deviations and thus comparable to the Allan deviation (Sigma).

The Stable32 analysis starts by reading the GT210 data file as 2-column frequency data, using the Scale function to add -10 and then multiply by 0.1 to convert it to fractional frequency, and then examining the data with the Statistics function as shown in Figure 4. Notice that the average frequency offset is about +32 and the standard deviation is about 4.3x10-10 as expected. The noise is the white FM of the frequency measuring instrument. The data are then normalized by removing their average value of about 3.22 ppm.

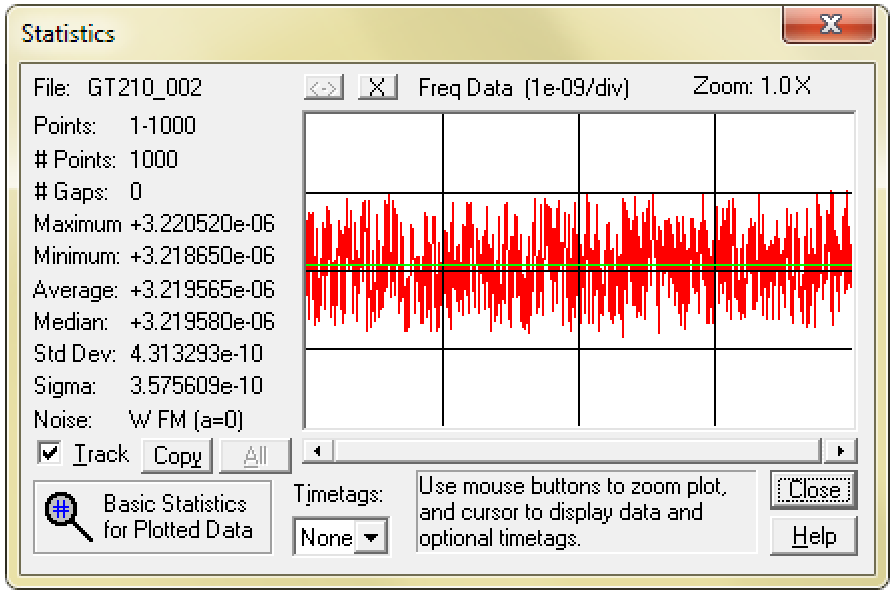


Figure 4. Raw Frequency Counter Data Statistics

The average frequency value agrees with that of a conventional Racal/Dana 1992 high-resolution universal counter. The resulting frequency and frequency stability plots are shown in Figures 5 and 6 respectively. The approximate -1 slope of the ADEV curve identifies the short-term noise as white FM (α=0) at a level of about $5x10^{-10}$ at 1 second. That is not the noise type expected for a crystal oscillator in that region (flicker FM) and is at least an order-of-magnitude larger than expected. The noise is therefore almost certainly that of the measuring system (GT210 counter) rather than the crystal oscillator under test (or the rubidium reference). We conclude that the GT210PCI-8 (or any such instrument), even with its high resolution, is inadequate to directly measure the performance of a moderately high stability ovenized crystal oscillator, and that this test characterizes the noise floor of the instrument. Its useful resolution is therefore about 9 ½ rather than 11 digits at 1 second.

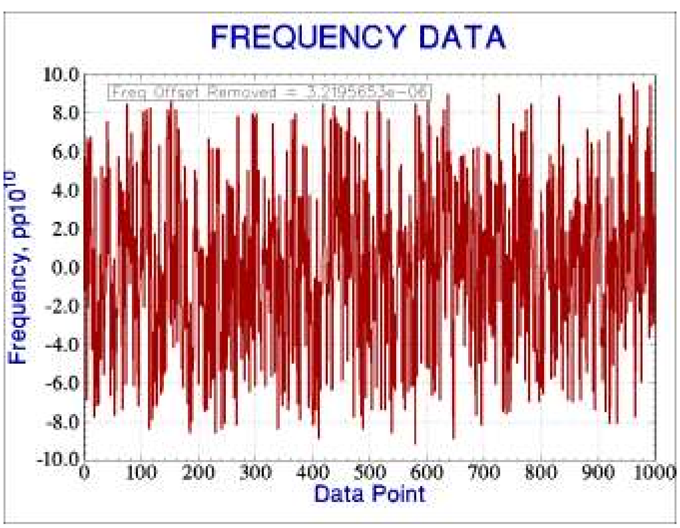


Figure 5. Fractional Frequency Data Plot

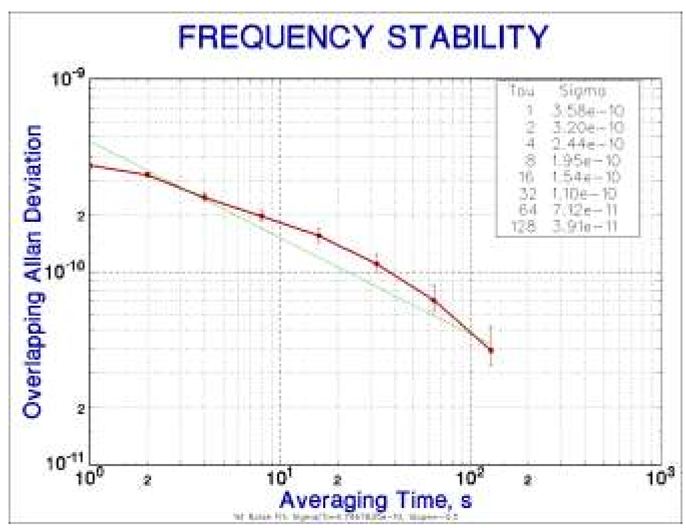


Figure 6. Frequency Stability Plot

- **Heterodyne Frequency Measuring System**

A heterodyne method mixes (subtracts) the two sources being compared, and measures the frequency or period of the resulting audio-frequency beat note as shown in the block diagram of Figure 7. The measurement resolution is increased by the heterodyne factor (the ratio of the carrier to the beat frequency).

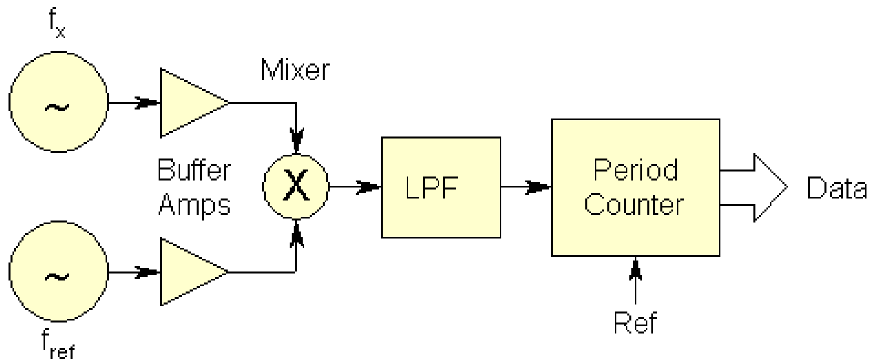


Figure 7. Block Diagram of Heterodyne Frequency Measuring System

The additional hardware consists of a heterodyne module comprising a passive double-balanced diode mixer, a low pass filter and a DC-coupled beat note amplifier. This heterodyne frequency measuring system can take advantage of the ≈ 32 Hz offset of the crystal oscillator under test (obtained by detuning it with its control voltage). In general, an offset reference source may be required (such as a DDS synthesizer). The expectation is that the GT210 noise and resolution will be improved by the heterodyne factor (≈ 3×10^5), or certainly enough so that the stability of the crystal oscillator can be measured. In fact, it is expected that the OCVCXO and LPRO Rb reference will both have 1-second stabilities on the order of 1×10^{-11}. An example of a heterodyne measurement of this source using a similar frequency counter is available in Reference [4] and equivalent results would be expected for the GT210 giving it the ability to measure the stability of a moderately high stability source when augmented with a heterodyne module.

- **1 PPS Clock Measuring System**

The 1 pps clock measuring system divides the two sources being compared down to 1 pps (or another low rate) and measures their time difference with the GT210 configured as a high resolution time interval counter (TIC) as shown in the block diagram of Figure 8.

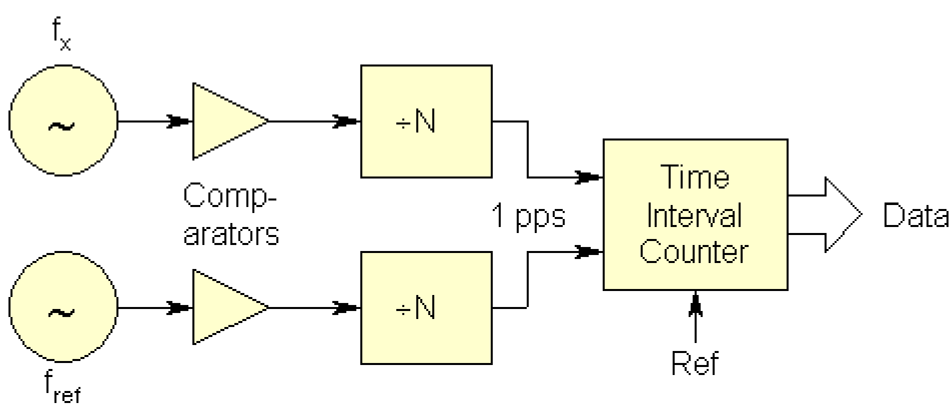


Figure 8. Block Diagram of 1 PPS TIC Clock Measuring System

This measurement method is made practical by the GT210s high-resolution interpolating time interval mode that offers 12-digits/second resolution (but a larger noise level). That resolution is not affected by the division ratio, which sets the minimum measurement time, and, along with the frequency offset, determines how long data can be taken before experiencing a phase spillover. For example, a source having a frequency offset of 1×10^{-6} can be measured for about 5.8 days before experiencing a 1 pps phase spillover after being initially centered at a phase difference of 0.5 second. Stable32 has specific means for removing phase spillovers if necessary. This measurement method is appropriate for frequency sources having medium stability (such as a non-ovenized crystal oscillator) and particularly for comparing a local clock against a GPS timing reference. The 10 MHz to 1 pps divider hardware can be as simple as a single 8-pin PIC microcontroller chip [5]. No divider is needed if a 1 pps signal is available from the source (e.g., a GPS timing receiver). An example of a suitable 10 MHz to 1 pps divider is described in References [8] and [9]. The most critical aspect is the noise of the input sinewave-to-digital converter [10].

The setup of the GT210 for making a time interval measurement is shown in Figure 9. The two 1 pps signals are applied to the A and B channel inputs, which are set for high impedance and +2.5 volt thresholds. When measuring A to B, A is the measurement channel and B is the reference channel.

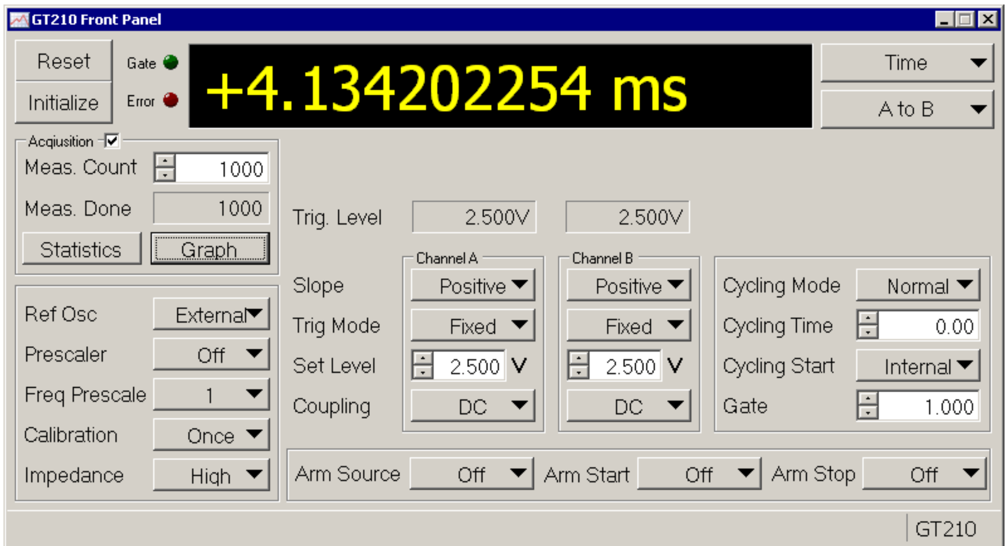


Figure 9. GT210 Virtual Front Panel Time Interval Counter Setup

The GT210 instrument unhelpfully writes its text data with variable units thus making its reading as numeric values more difficult as shown in the left figure below. In that case, even though Stable32 has a Units.exe utility to deal with that situation, it is better to choose the GT210 *.csv data file storage option which results in data in exponential format that can be directly read into Stable32 as shown in the right figure below. No scaling is needed when the data have units of seconds.

```
Results - Statistics - Time A to B
Number      Result
0:    +51.450046 us
1:    +54.669305 us
2:    +57.889575 us
3:    +61.109216 us
4:    +64.329057 us
5:    +67.549591 us
.
.
.
995:  +3.255184936 ms
996:  +3.258404844 ms
997:  +3.261625155 ms
998:  +3.264844400 ms
999:  +3.268064619 ms
```

Figure 10. Text (*.txt) Format

```
Results - Statistics - Time A to B
Number,Result,Units
0,+51.450046E-6,s
1,+54.669305E-6,s
2,+57.889575E-6,s
3,+61.109216E-6,s
4,+64.329057E-6,s
5,+67.549591E-6,s
.
.
.
995,+3.255184936E-3,s
996,+3.258404844E-3,s
997,+3.261625155E-3,s
998,+3.264844400E-3,s
999,+3.268064619E-3,s
```

Figure 11. Comma-Separated Variable (*.csv) Format

The results of the 1pps time interval counter measurement are shown in Figure 12.

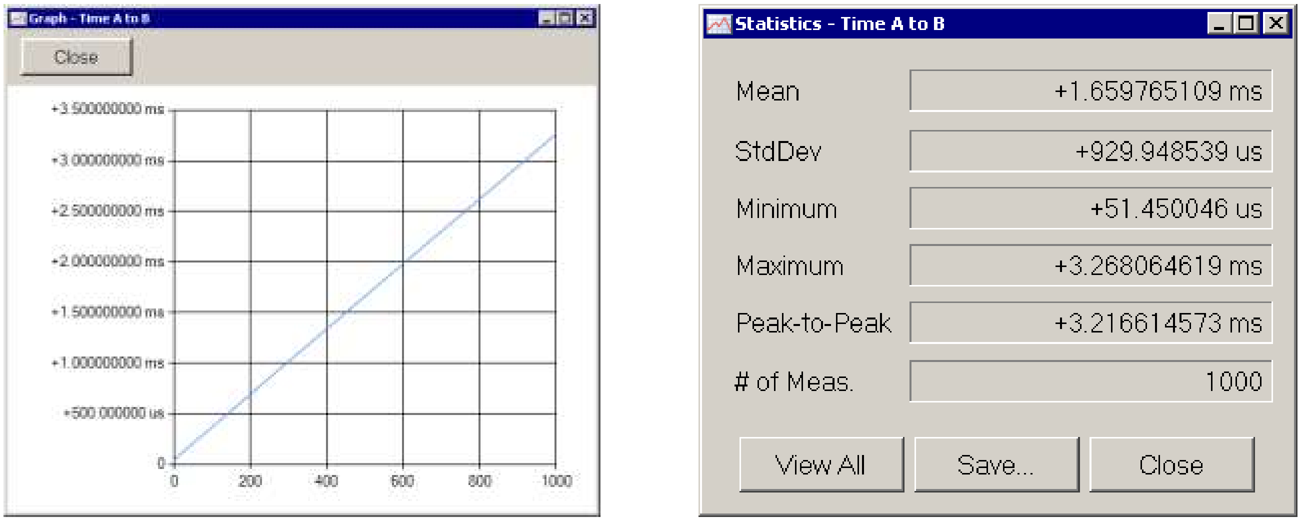


Figure 12. Results of 1 PPS Time Interval Counter Run

The phase record is nearly a straight line (see Figure 13) whose slope represents the frequency offset of the crystal oscillator. The noise of the measuring system, crystal oscillator and reference cause small variations around this line. Stable32 can "peel away" the information contained in the raw phase record, but there is no reason to believe that the basic GT210 will be low enough to characterize the crystal oscillator, especially since the wideband instrument input is not optimized for detecting the zero-crossings of the 1 pps signals.

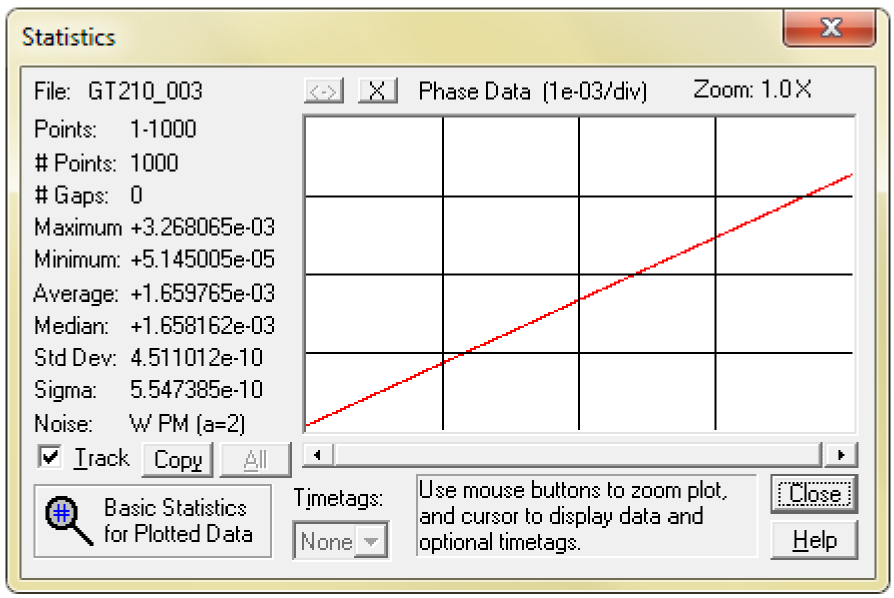


Figure 13. Time Interval Counter Statistics

The various steps in performing a Stable32 analysis on the 1 pps time interval data are shown in Figures 14 through 19. Figure 14 shows the raw phase record whose slope of about -3.20x10-6 represents the frequency offset of the crystal oscillator with respect to the Rb reference (negative in this case because of the reversed input connections). Figure 15 shows the phase residuals after removing this slope and the resulting phase offset. The reason for the slow phase variation isn't known but is probably room temperature thermal change affecting the crystal oscillator. The corresponding relative frequency plot is shown in Figure 16 and its Allan deviation stability in Figure 17, whose slope indicates that it is white PM noise from the measuring system (GT210) at a level of about $5.6\text{x}10^{-10}$ at 1 second, close to that found by direct frequency counter measurements and an order-and-a–half in magnitude higher than the OCVCXO unit under test. Figures 18 and 19 continue the analysis for TDEV and MTIE. But it is clear that the measuring system noise dominates the results and that they therefore say little about the crystal oscillator under test.

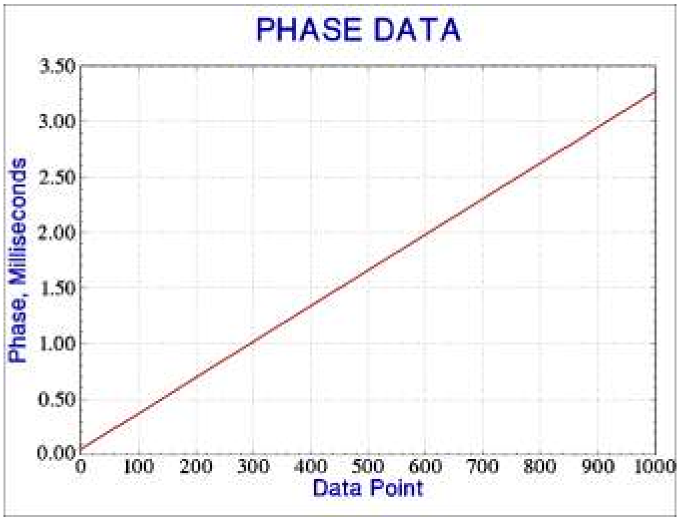


Figure 14. Phase Data Plot

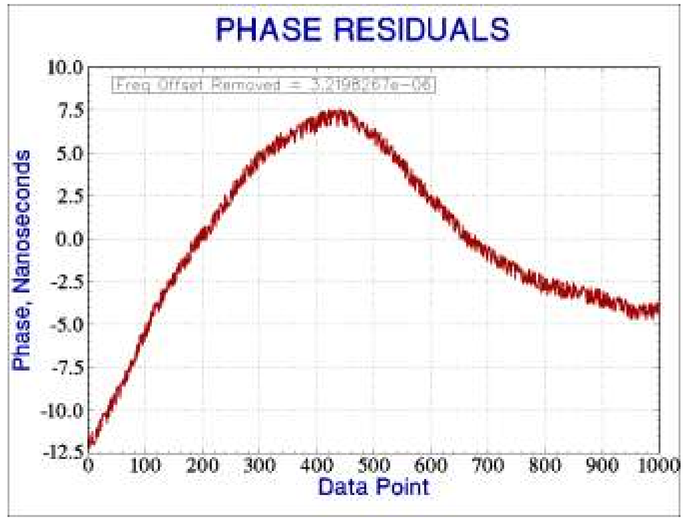


Figure 15. Phase Residuals w/o Frequency Offset

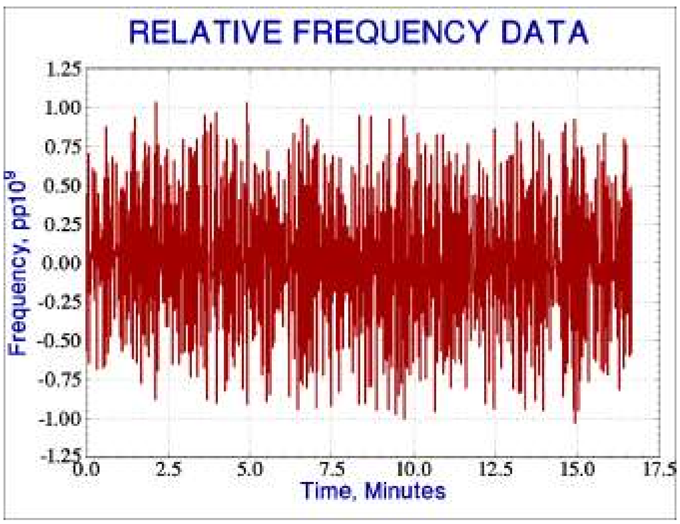


Figure 16. Relative Frequency Data Plot

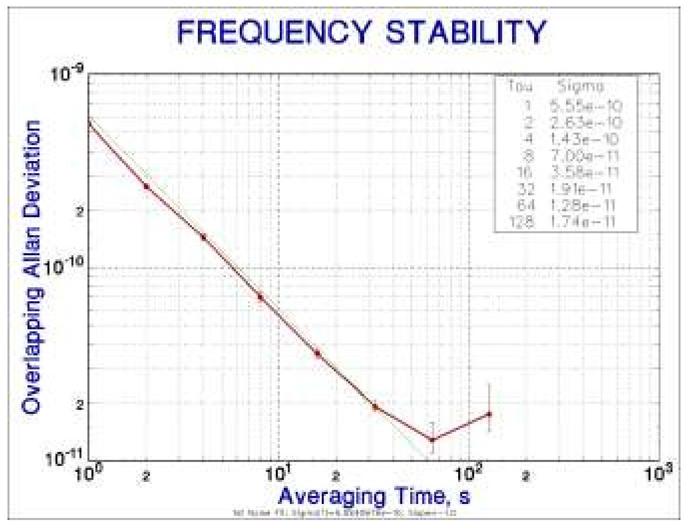


Figure 17. Frequency Stability Plot

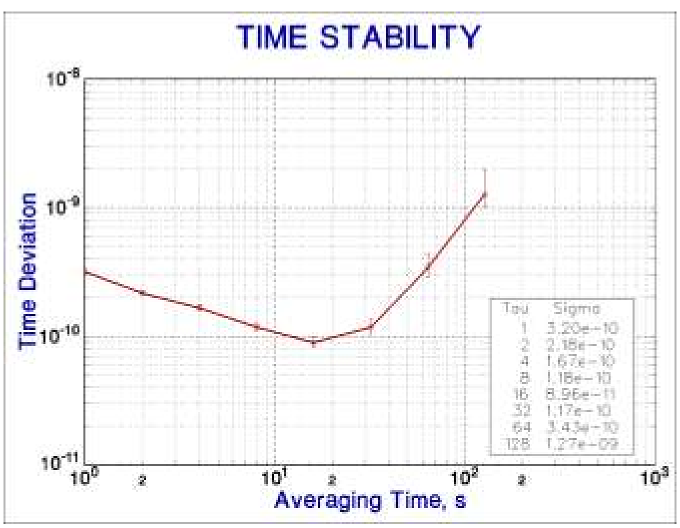


Figure 18. Time Deviation Plot

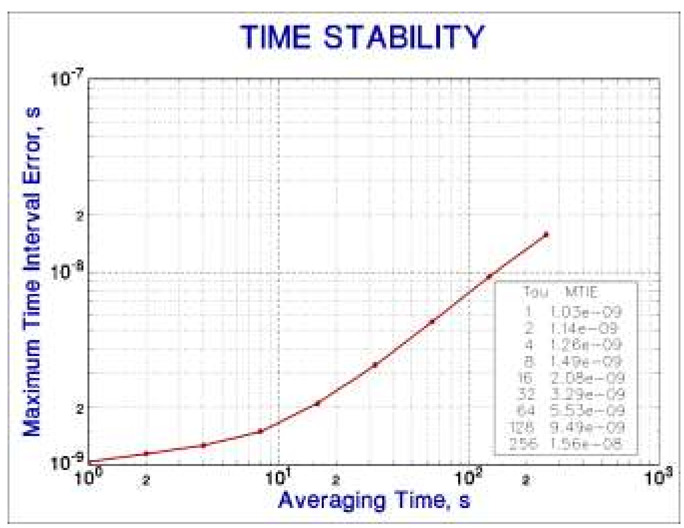


Figure 19. MTIE Plot

• Dual Mixer Time Difference (DMTD) Clock Measuring System

A Dual Mixer Time Difference clock measuring system combines the best features of the heterodyne and time interval systems by using a time interval counter to measure the relative phase of the beat signals from a pair of mixers driven from a common offset reference, as shown in the block diagram of Figure 20.

An example of a DMTD measurement system using a similar frequency counter is available in Reference [4] and equivalent results would be expected for the GT210 giving it the ability to measure the stability of a very high stability source.

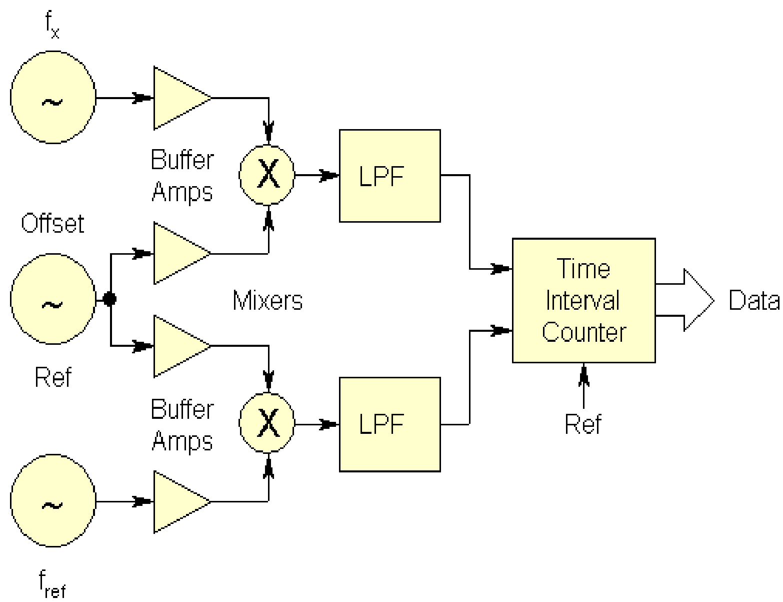


Figure 20. Block Diagram of DMTD Clock Measuring System

• Noise Floor

The noise floor of GT210 depends of the properties of the input signal (waveform, amplitude, noise, rise time and frequency) and generally exceeds the instrument's resolution because it has a very wide input bandwidth and is therefore susceptible to wideband noise. It is particularly important that low frequency signals (e.g., 1 pps) be conditioned with fast rise time.

• Coherent Noise Floor Measurement Setup

The setup for the coherent noise floor measurement is shown in Figure 21. The divider inputs are both +4 dBm 10 MHz signals from an LPRO-101 Rubidium Oscillator via a passive power splitter. The GT210 A and B inputs are 1 PPS +5 volt pulses from T2-Mini dividers into high impedance inputs with +2.5 volt thresholds, and the external 10 MHz clock input also comes from the same Rb reference. The data are 1,000 1-second time interval samples at various nominal phase conditions determined by the divider synchronization and cable lengths.

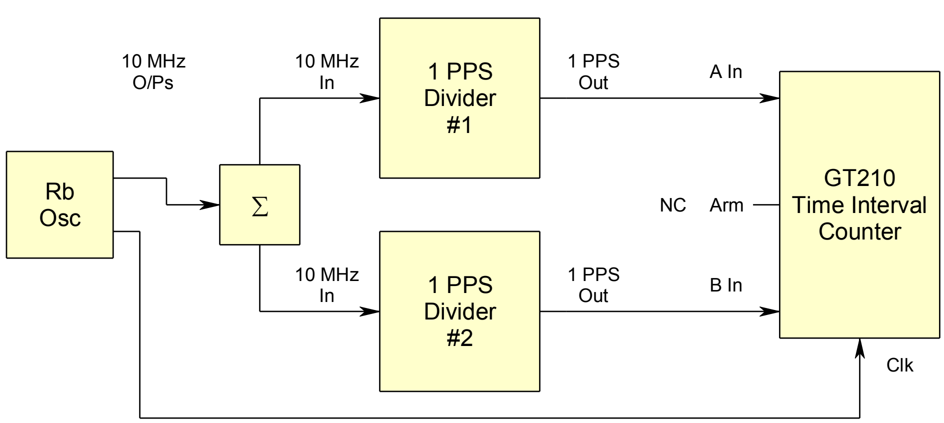


Figure 21. Coherent Noise Floor Test Setup

- **Coherent Noise Floor Measurement Results**

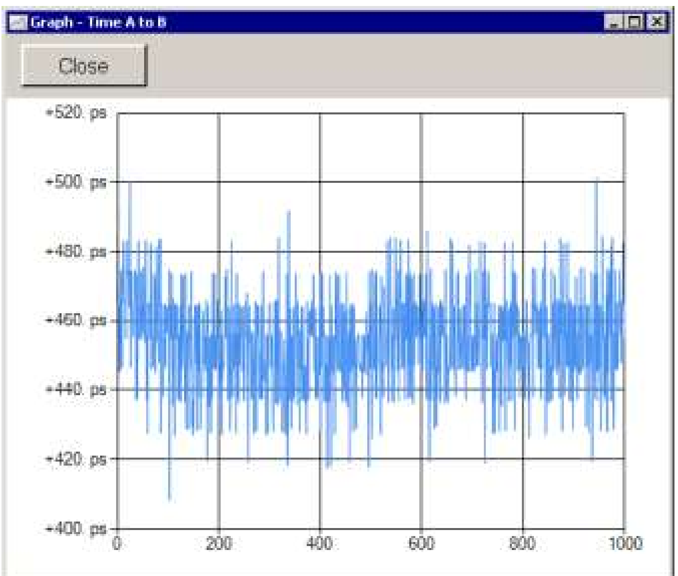
The results of the coherent noise floor measurement are shown in the Figure 22 plots and Figure 23 statistics for several values of nominal phase difference. Because the phase is nominally flat and its noise is nominally white, the rms scatter can be estimated on the basis of the calculated standard deviation. The 8 ps GT210 resolution is visible in the noise quantization.

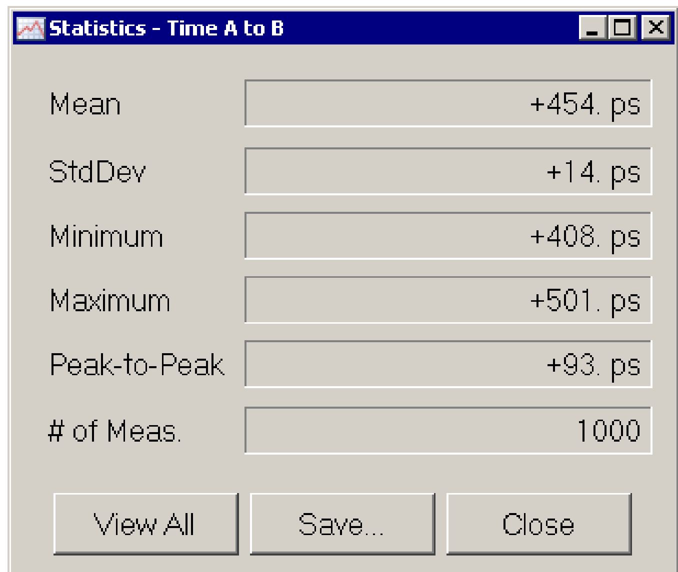
A larger nominal phase condition can increase the noise because of source or instrumental noise de-coherence, as shown in Figures 22 (left column plots) and 23 (right column statistics). However the former does not seem large enough, and the latter is not normally coherent. Note that the GT210 virtual front panel standard deviation values shown here are undependable for large mean values, a problem that GuideTech has now corrected.

Figure 22. Phase Data Plots

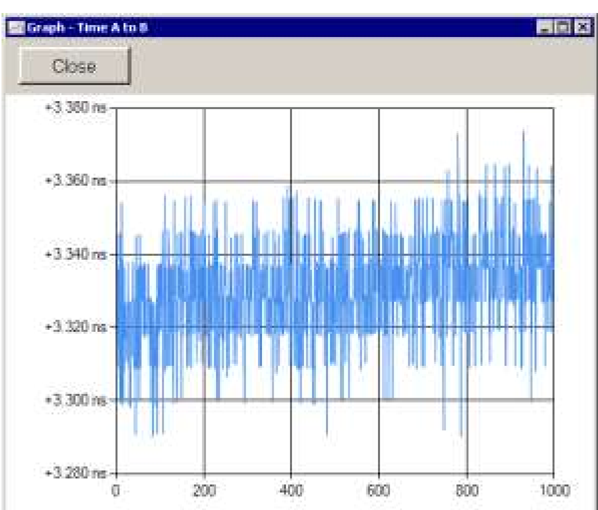
Figure 23. Statistics Displays

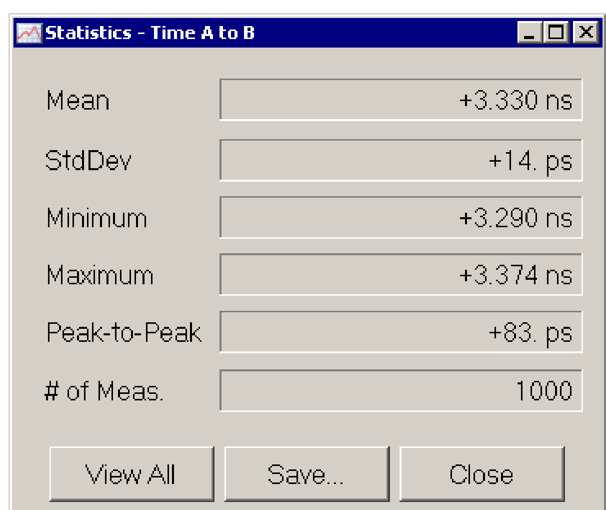
Nominal $\Delta\phi$ = 0.45 ns, Noise = 19 ps rms (per Stable32)



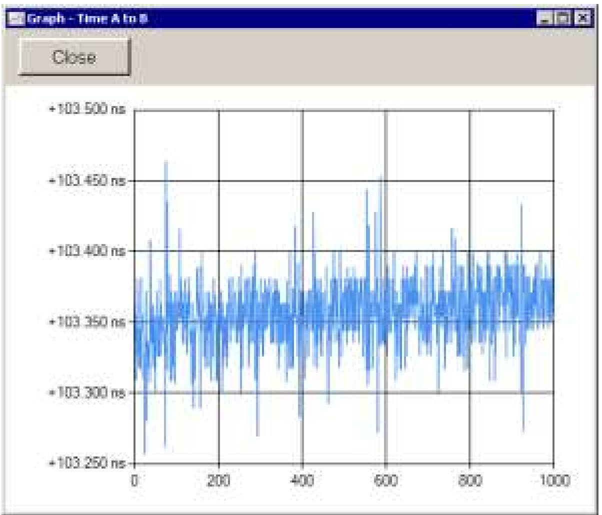


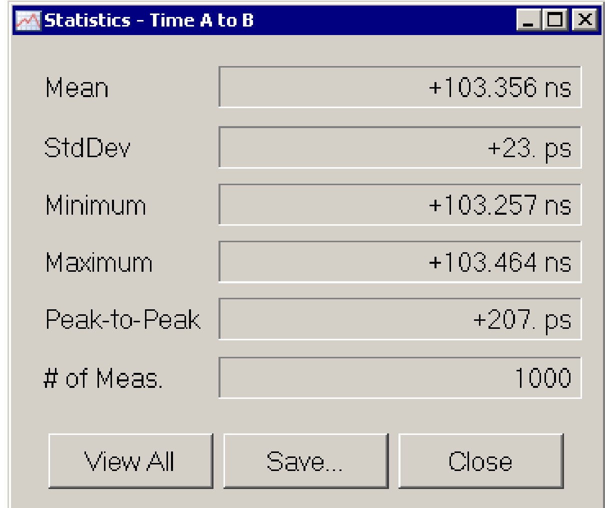
Nominal $\Delta\phi$ = 3.31 ns, Noise = 19 ps rms (per Stable32)



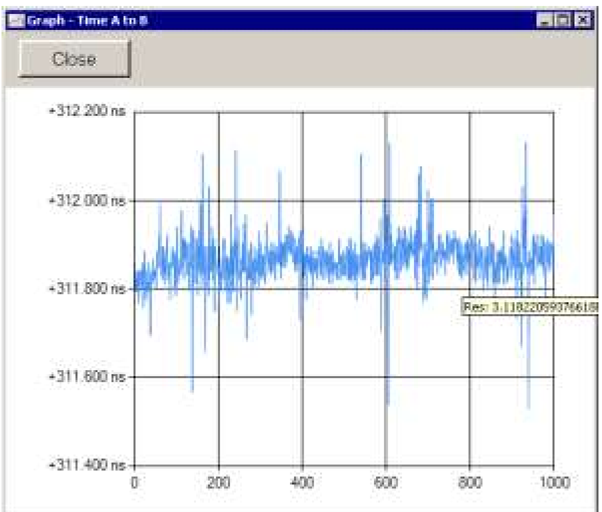


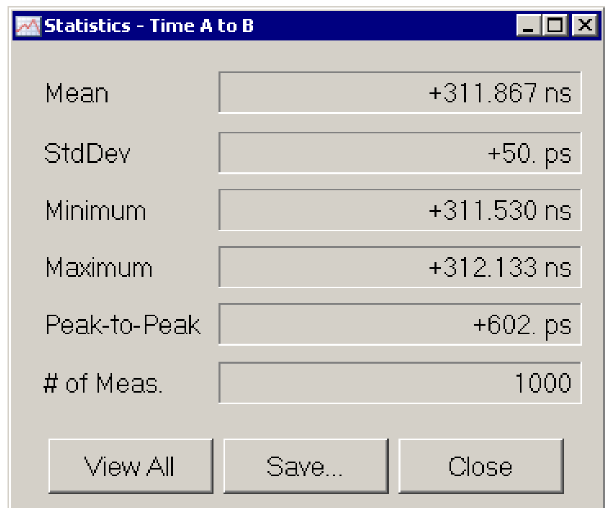
Nominal $\Delta\phi$ = 103.4 ns, Noise = 32 ps rms (per Stable32)



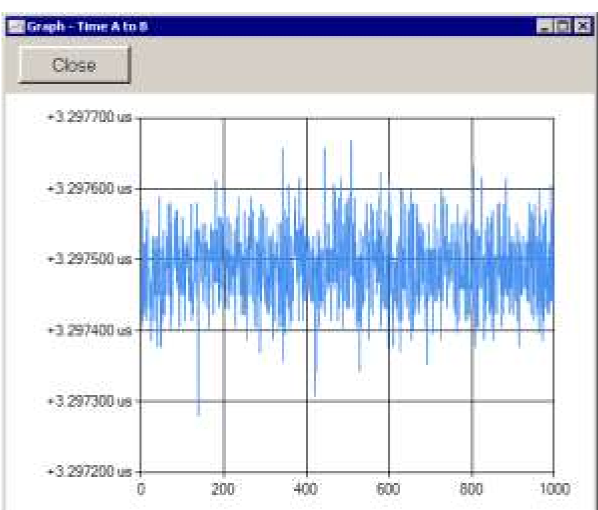


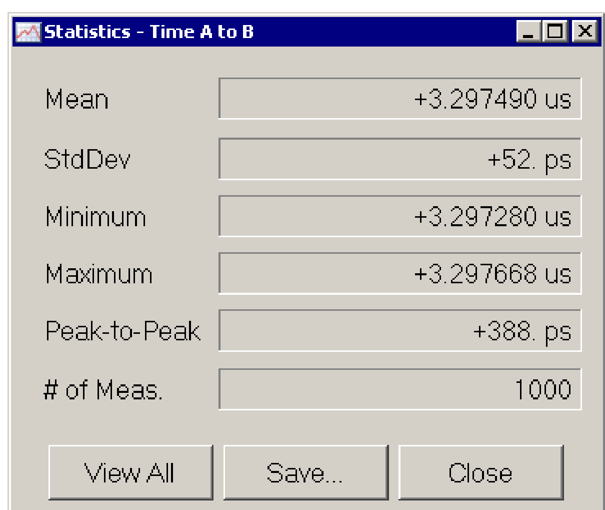
Nominal $\Delta\phi$ = 311.9 ns, Noise = 67 ps rms (per Stable32)



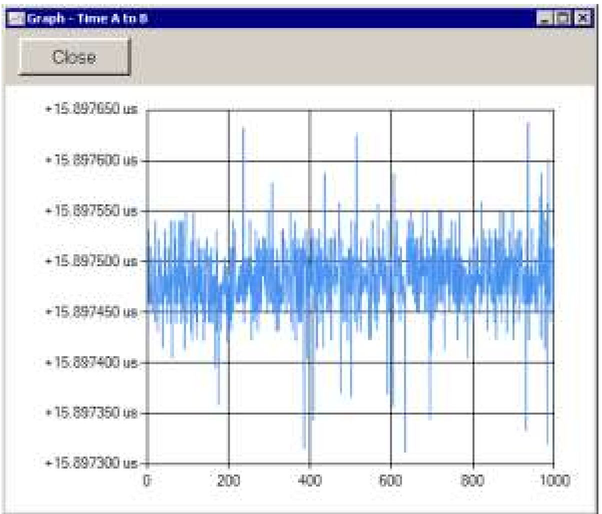


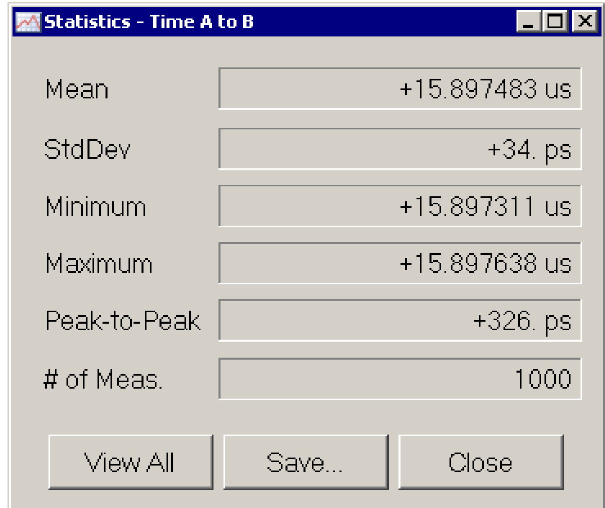
Nominal $\Delta\phi$ = 3.30 µs, Noise = 75 ps rms (per Stable32)



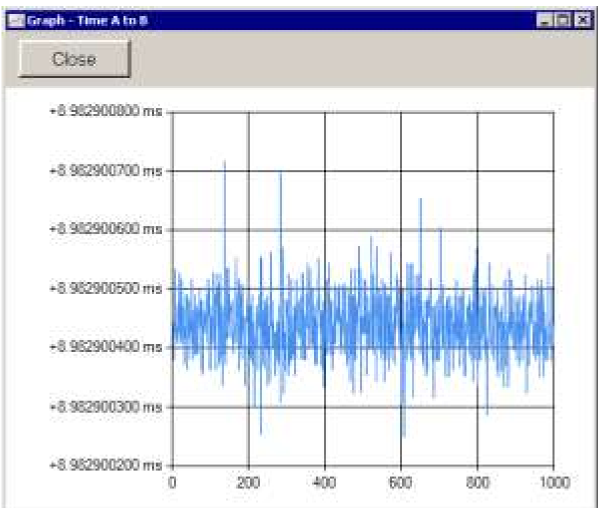


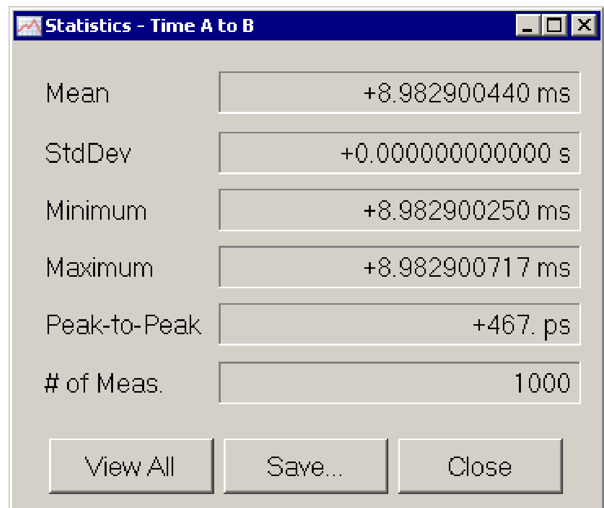
Nominal $\Delta\phi$ = 15.9 µs, Noise = 48 ps rms (per Stable32)



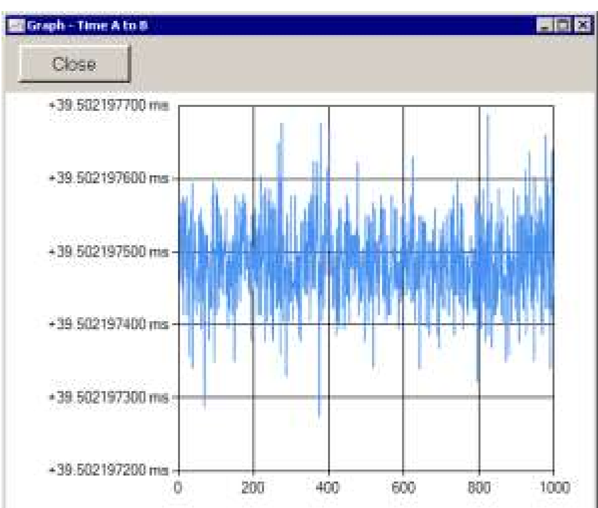


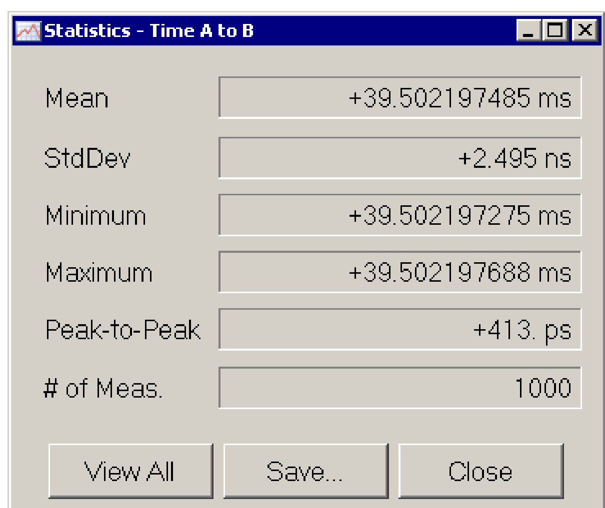
Nominal $\Delta\phi$ = 8.98 ms, Noise = 68 ps rms (per Stable32)



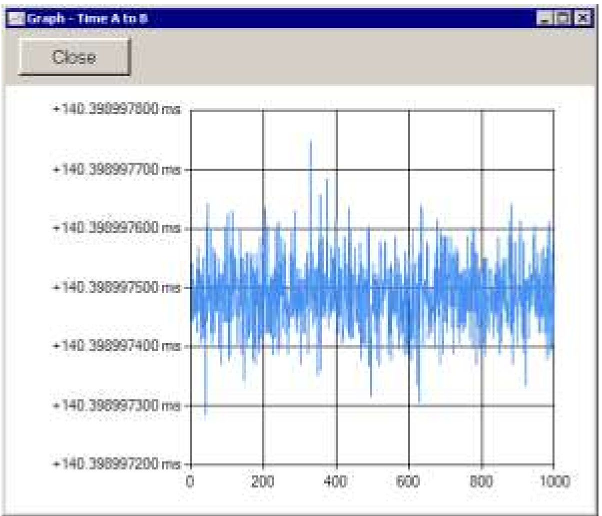


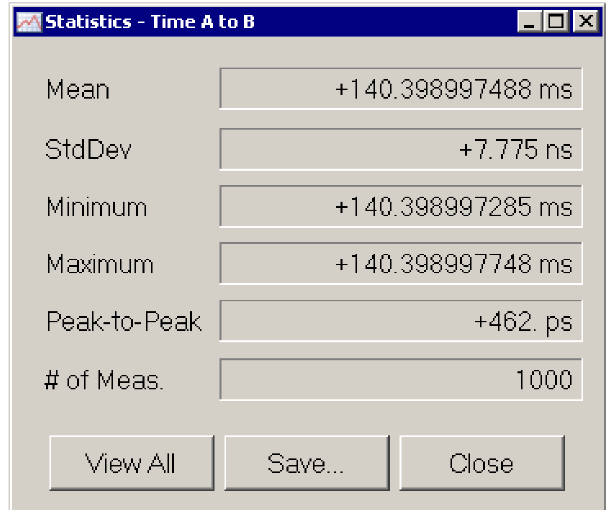
Nominal $\Delta\phi$ = 39.5 ms, Noise = 75 ps rms (per Stable32)



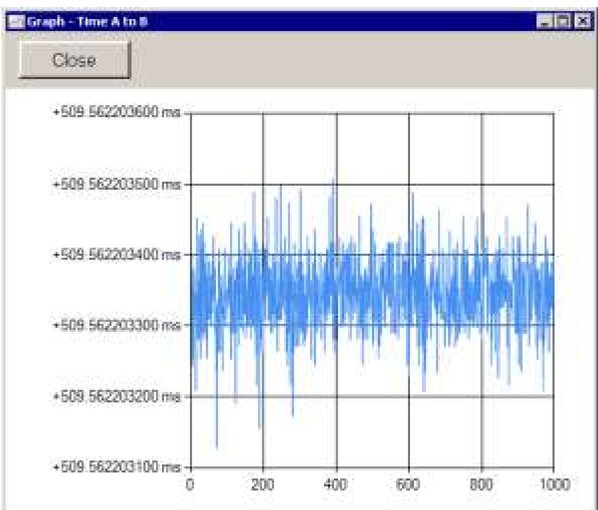


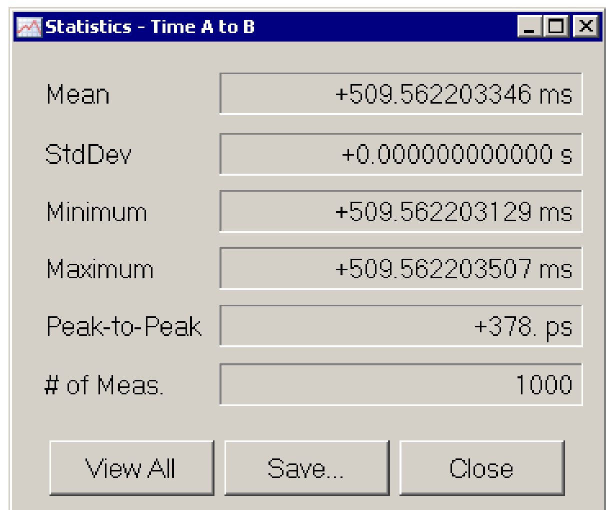
Nominal Δϕ = 140.4 ms, Noise = 78 ps rms (per Stable32)



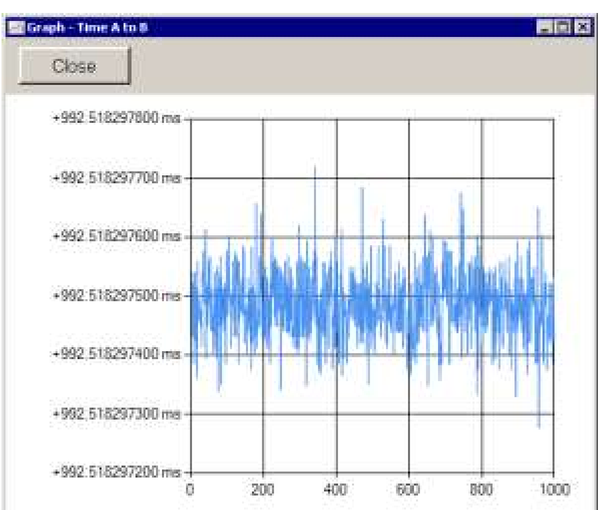


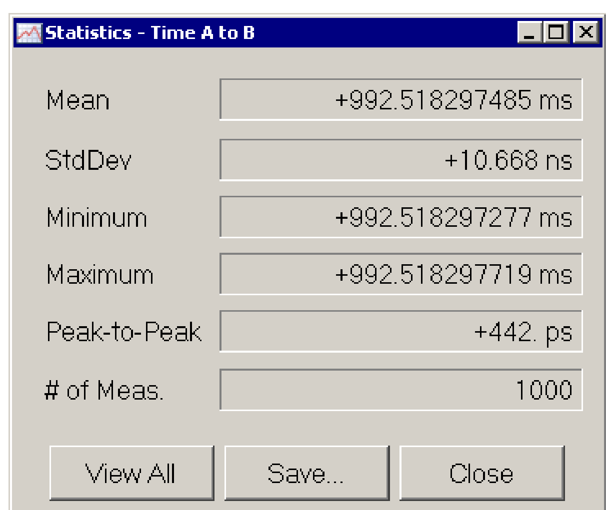
Nominal Δϕ = 509.6 ms, Noise = 72 ps rms (per Stable32)





Nominal Δϕ = 992.5 ms, Noise = 69 ps rms (per Stable32)





The noise does seem to increase significantly along with the nominal phase condition (see Figure 24), a phenomenon seen with other similar instruments, and can also be associated with more frequent and larger spikes in the phase record, perhaps due to the GT210 board's noisy PC environment. Interpolator calibration is another possible factor. One can only conclude that a small nominal phase difference is desirable to minimize measuring system noise, or, even better, to use a DMTD measuring system that does not require as much time interval counter performance.

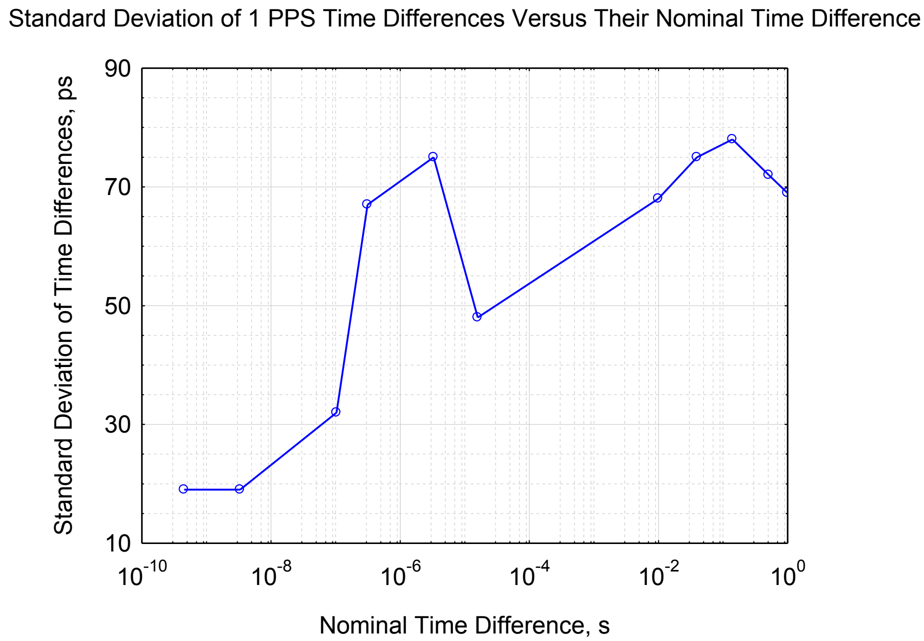


Figure 24. Noise Versus Nominal Phase Difference

- **Linearity**

Interpolator linearity is a critical attribute of time interval measuring like the GT210 since it is the basis of its high resolution. One way to assess this linearity is to apply a pair of coherent input signals having a precise small frequency difference and observe slope of the resulting phase ramp. A setup for doing that is shown in Figure 25. It comprises a Datum LPRO rubidium oscillator, an RF power splitter, a custom 48-bit DDS frequency synthesizer, a dual 10 MHz to 1 PPS 10^7 divider module and the GT210 time interval counter. The 10 MHz Rb output is applied coherently to the divider inputs and thus does not contribute significant noise to the results. The DDS makes a small stable frequency offset that produces a linear phase slew. For example, a frequency offset of 200 μHz corresponds to a fractional frequency offset of 2×10^{-11} which produces a phase slew of 20 ns during a 1000 second run, and 100 ns during a 5000 second run, the range of the GT210 interpolator. A fractional frequency offset of 2×10^{-12} produces a phase slew of 100 ns during a 50,000 second run which supports some data averaging to better show any interpolator nonlinearity, and can also provide insight into whether the noise level changes with the interpolator state.

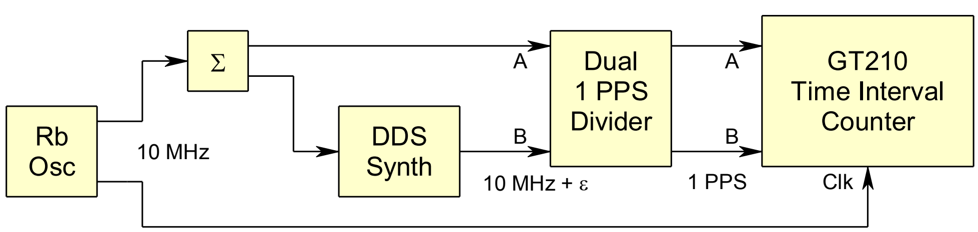


Figure 25. Linearity Test Setup

The results of this test are shown in Figures 26 through 33. There is no obvious nonlinearity.

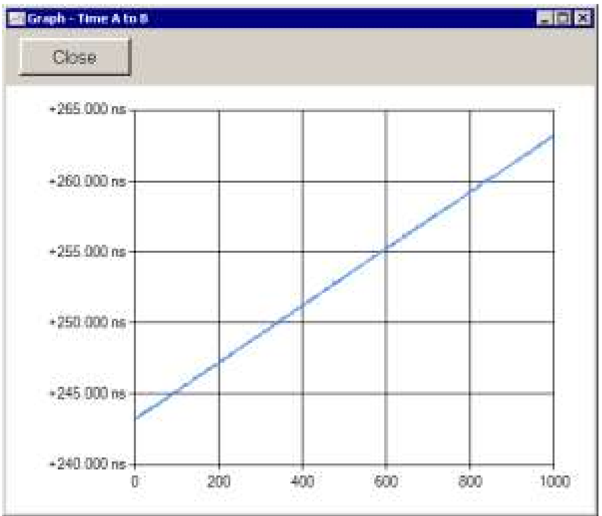


Figure 26. Phase Record for 20 ns Phase Slew

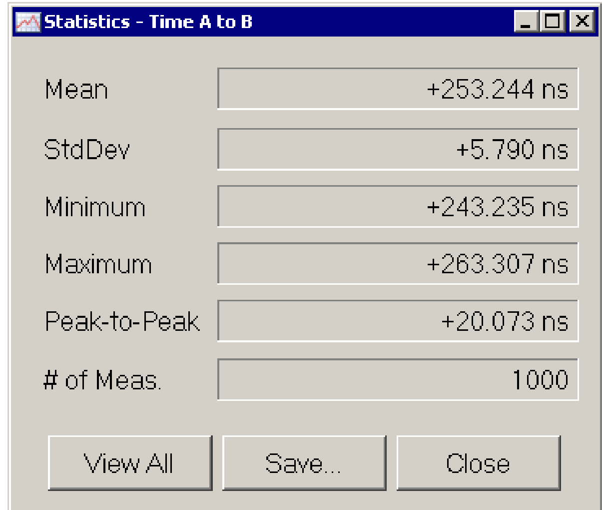


Figure 27. Statistics for 20 ns Phase Slew

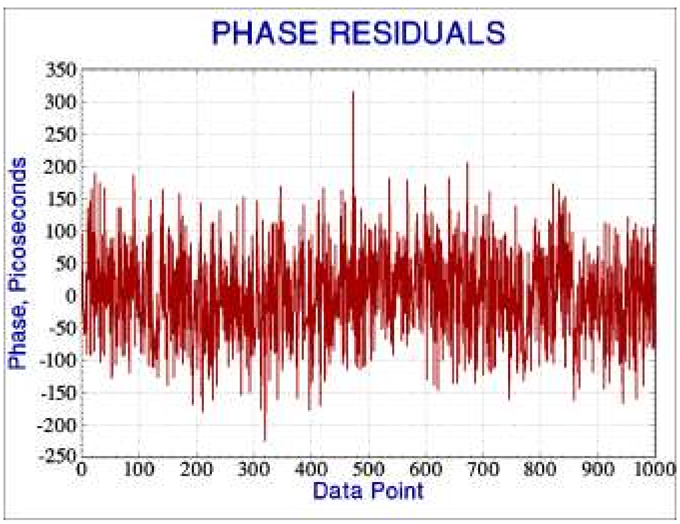


Figure 28. 20 ns Phase Residuals Plot

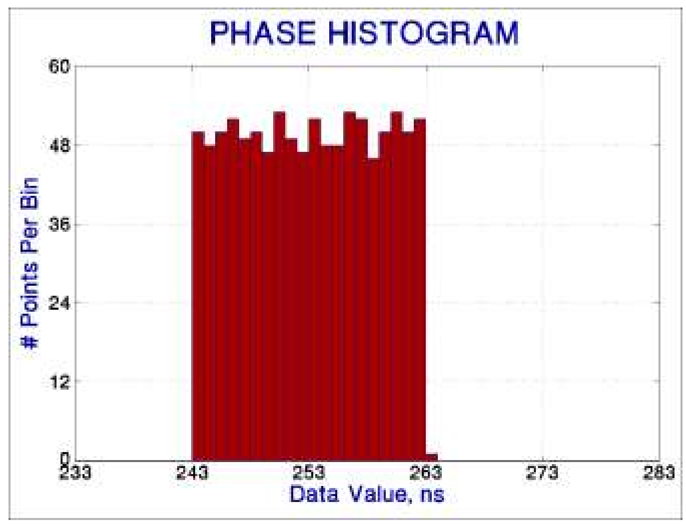


Figure 29. Histogram of 1000 Phase Values

Figure 28 shows the 20 ns phase residuals after removing a frequency offset of 2.0047×10^{-11} and an average phase offset of 243.21 ns. Except for one spike, there are white phase noise residuals and only the slightest hint of periodic nonlinearity, say 50 ps peak-to-peak. This is excellent performance. Averaging the data does not reveal any obvious nonlinearity. The 1-second noise is about 1×10^{-10} rms. The 1000-point phase histogram is essentially flat, another indication of good linearity.

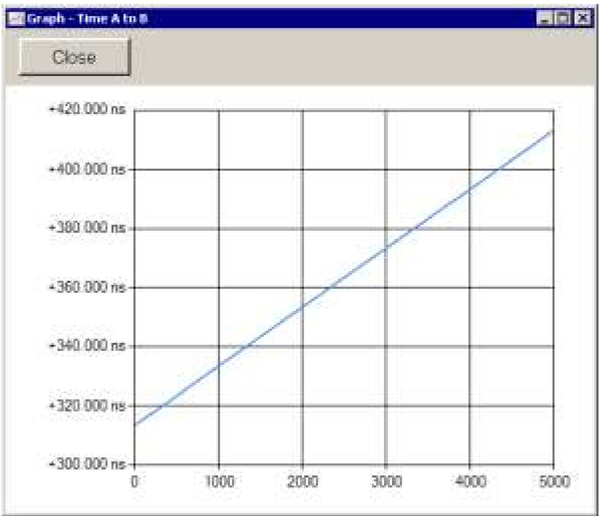


Figure 30. Phase Record for 100 ns Phase Slew

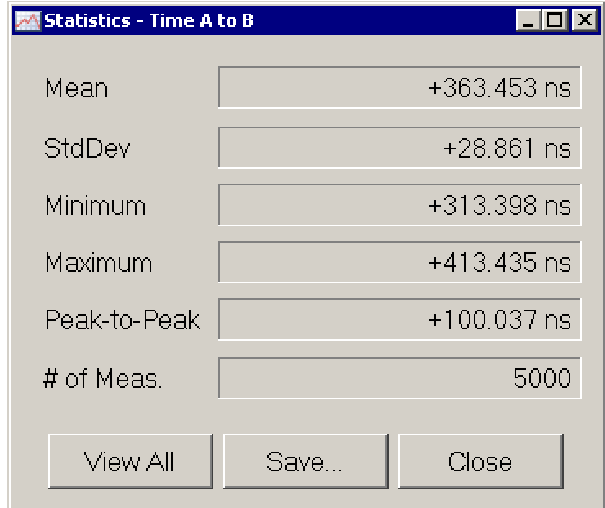


Figure 31. Statistics for 100 ns Phase Slew

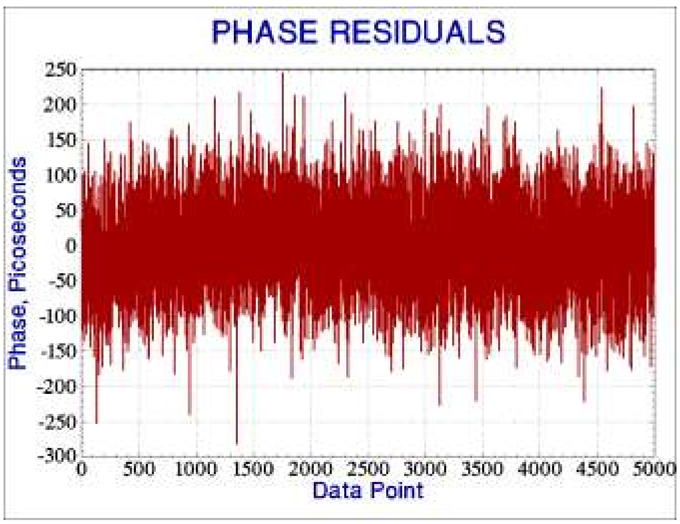


Figure 32. 100 ns Phase Residuals Plot

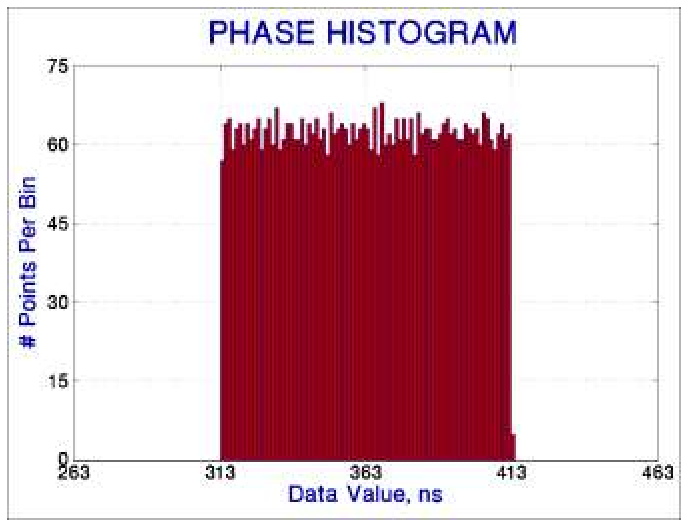


Figure 33. Histogram of 5000 Phase Values

Figure 32 shows the 100 ns phase residuals after removing a frequency offset of 1.999338×10^{-11} and an average phase offset of 313.46 ns. There are white phase noise residuals and no hint of periodic nonlinearity. This is very excellent performance. Averaging the data does not reveal any obvious nonlinearity. The 1-second noise is about 1.0×10^{-10} rms. The 5000-point phase histogram is essentially flat, another indication of good linearity. There is no sign that the noise level changes as a function of the interpolator state. The current GT210 interpolator has a 14-bit DAC with a range of about 11,000 counts providing a resolution of about 9 ps.

The results of a longer 50,000 second (≈ 14 hour) 100 ns phase slew with a nominal frequency offset of 2×10^{-12} are shown in Figures 30A through 33A.

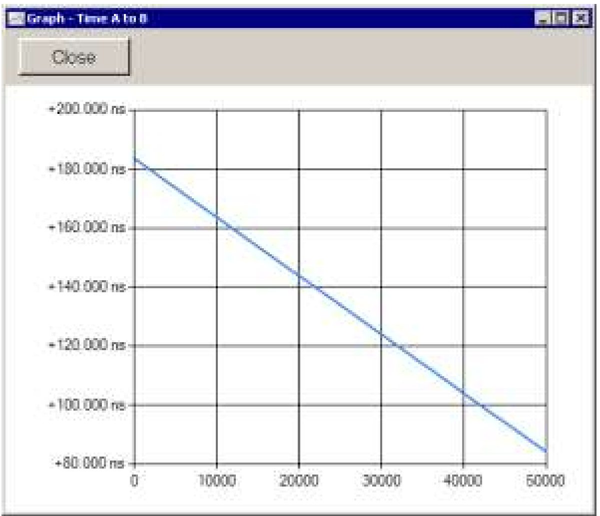


Figure 30A. Phase Record for Longer 100 ns Slew

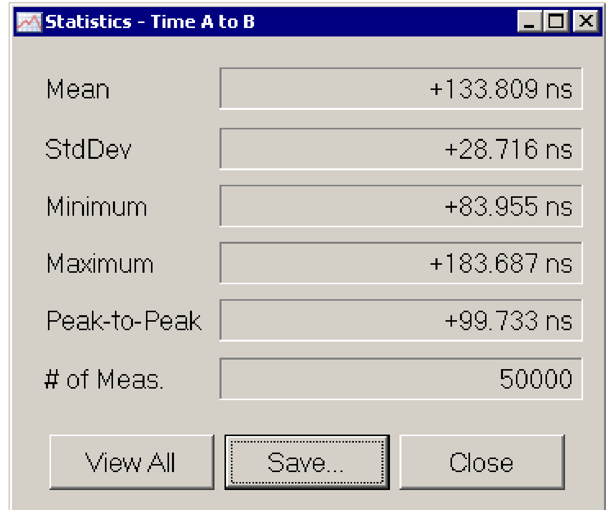


Figure 31A. Statistics for Longer 100 ns Slew

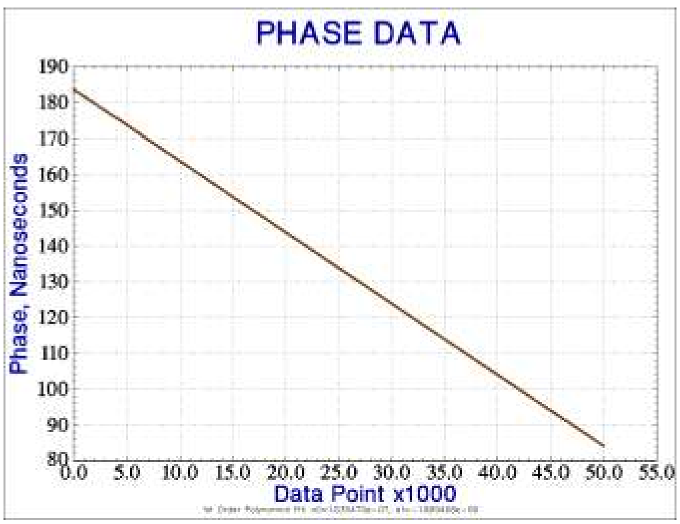


Figure 30B. Longer 100 ns Phase Plot

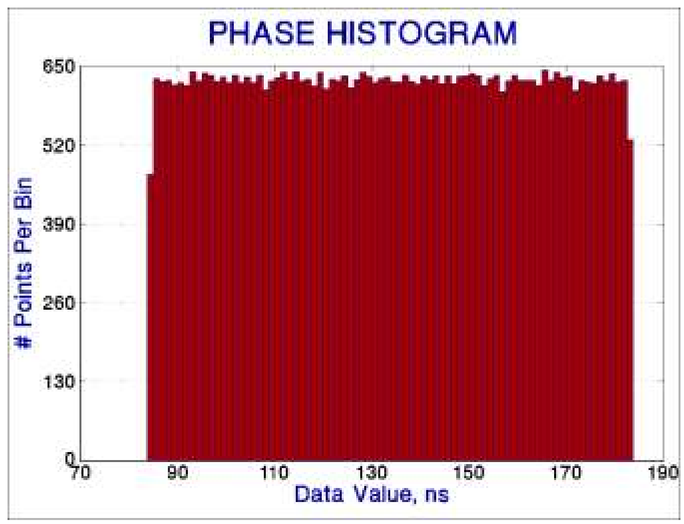


Figure 33A. Histogram of 50,000 Phase Values

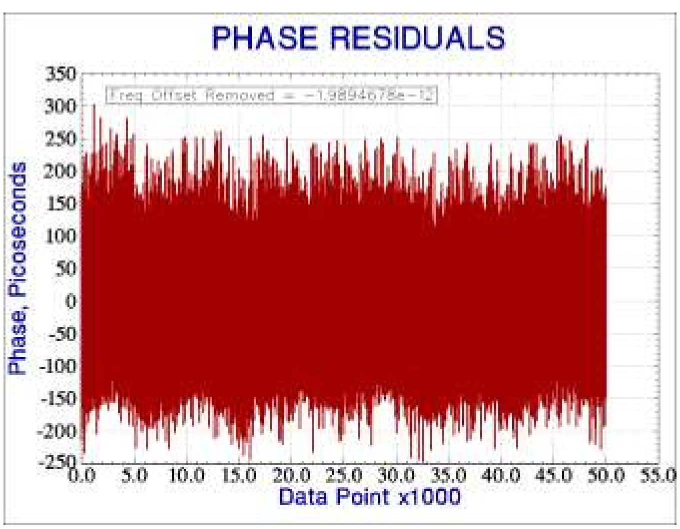


Figure 32B. 100 ns Phase Residuals Plot

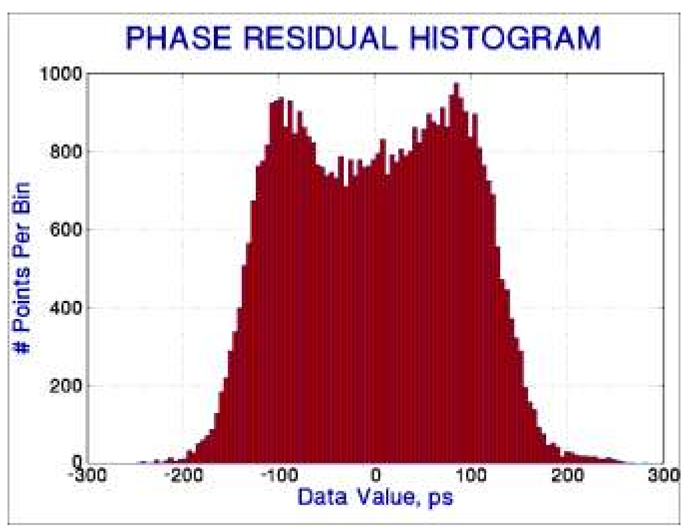


Figure 33B. Histogram of 50k Phase Residuals

The phase record is almost perfectly linear, visibly disturbed only by noise. The slope is -1.98947×10^{-12}, extremely close to the DDS frequency offset of -1.98952×10^{-12}. The phase histogram shows almost perfect uniformity, and its variations are mainly attributable to the noise rather than nonlinearity. Averaging the data does not seem to improve insight into the nonlinearity. The data range from 83.955 to 183.687 ns and span 80 of the 200 total bins of size 1.25 ns from 83.75 ns to 182.50 ns. Each bin would therefore be expected to have 50,000/80=625 counts for perfect linearity. Except for the first and last bins, the actual counts range from 608 to 644, implying a maximum differential linearity [11] of 19/625=3.0%, and an integral nonlinearity of only 0.50%. The phase residuals show the noise and some apparent cyclic variation probably caused by air conditioner room temperature cycling. There is some evidence of interpolator nonlinearity in the phase residual histogram, but its interpretation is unclear. What is clear is that the GT210 has excellent phase interpolator linearity.

- **Response Around Phase Spillover**

A test of the GT210 response around a phase spillover was conducted with coherent 1 pps signals having a small frequency offset. The GT210 data switched gracefully as the relative phase slewed downward to zero and spilled over to full scale, as shown in Figure 37. But when the step of 1 was removed, as shown in Figure 38, it is seen that (a) the spillover did not occur exactly at zero, and (b) the phase slope is different on the two sides of the spillover. The latter is caused by the instrument's "dead time" which causes the sampling interval to change from 1 to 2 seconds near the zero phase difference condition.

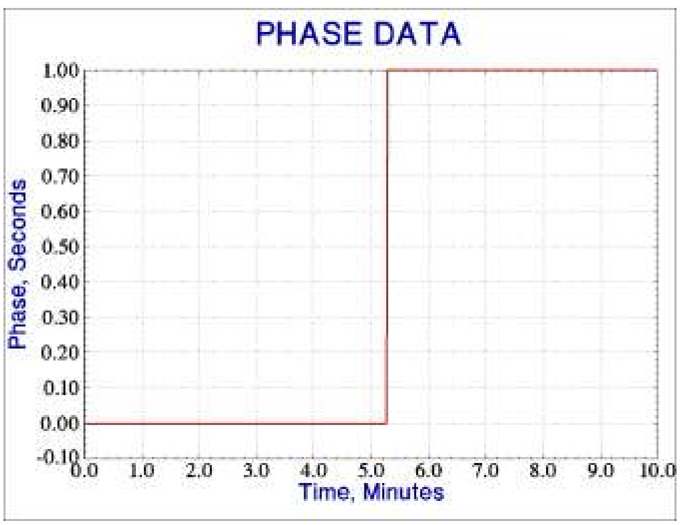


Figure 37. Phase Data at Spillover

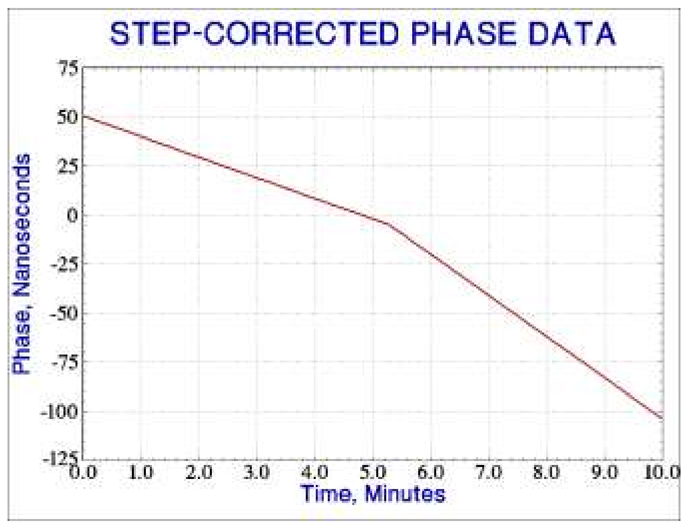


Figure 38. Step-Corrected Phase Data at Spillover

- **Measurement of Rubidium Oscillator versus GPS Disciplined Oscillator**

As a practical example of using the GT210, 10 MHz signals from an LPRO-101 rubidium oscillator and a temperature-stabilized Trimble Thunderbolt GPS disciplined oscillator were compared with the 1 pps clock measuring system of Figure 8. The dividers were initially synchronized to a small time offset, and the results of this measurement are shown in Figures 34 and 36.

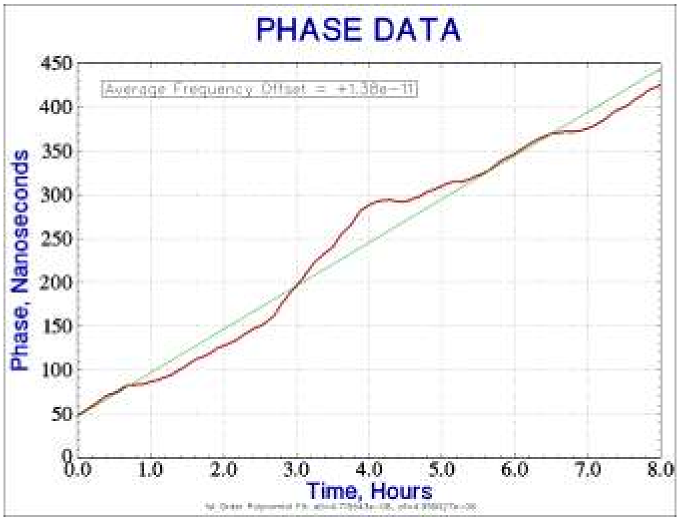


Figure 36. Stable34 Phase Data Plot

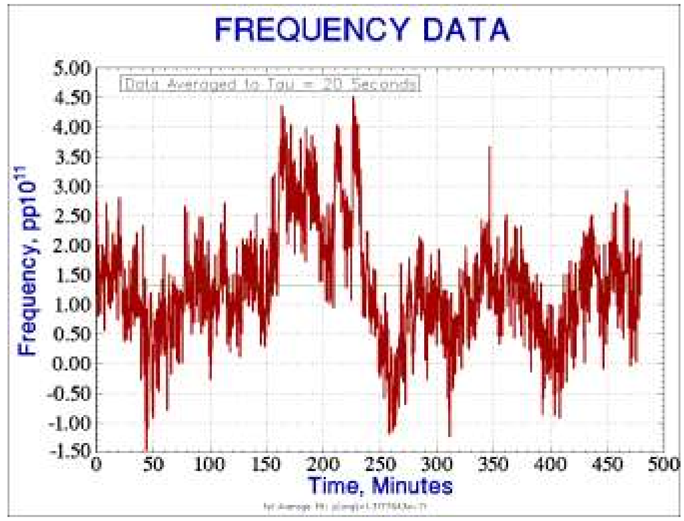


Figure 35. Stable32 Frequency Data Plot

The measuring system resolution and noise is adequate to determine the frequency offset of the rubidium oscillator (≈ $+1.38\mathrm{x}10^{-11}$) in a few hundred seconds. The white PM short-term noise (≈ $7.5\mathrm{x}10^{-11}$ at 1 second) is mainly that of the GPS reference. This setup is quite suitable for calibrating the Rb reference against GPS to the $\mathrm{pp}10^{11}$ level. The slow quasi-cyclic frequency variations are presumably due to room temperature fluctuations affecting both the GPS disciplined oscillator and the rubidium oscillator. Prior to this run, it took several hours for the frequency to settle, and I suspect that that was caused by the change in the GPSDO and the relatively slow time constant of the GPS lock loop.

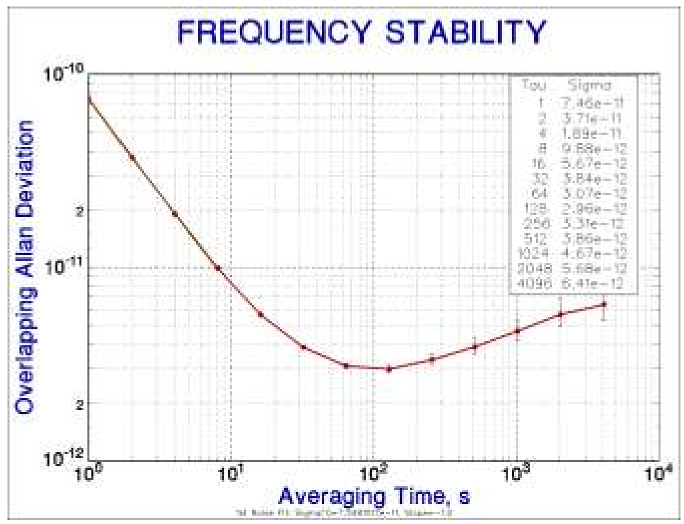


Figure 36. Stable32 Frequency Stability Plot

- **Measurements Between Two Rubidium Oscillators**

As another example of an actual measurement, the GT210 1 pps clock measuring system was used to compare two LPRO rubidium oscillators, as shown in Figures 37 through 42.

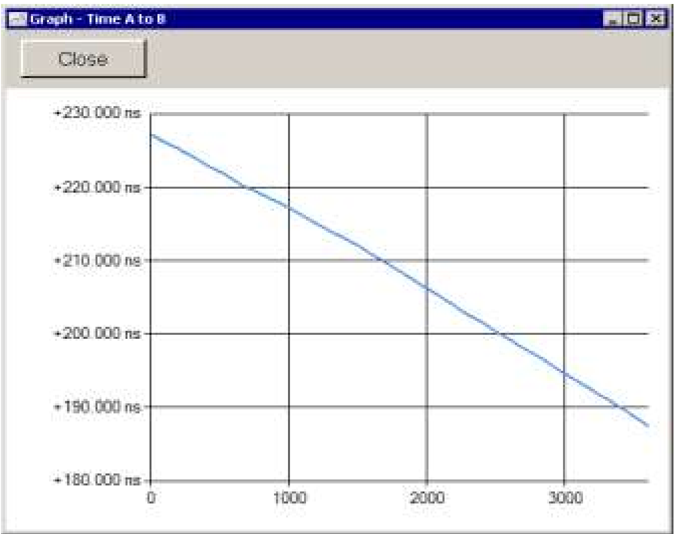


Figure 37 GT210 Phase Record

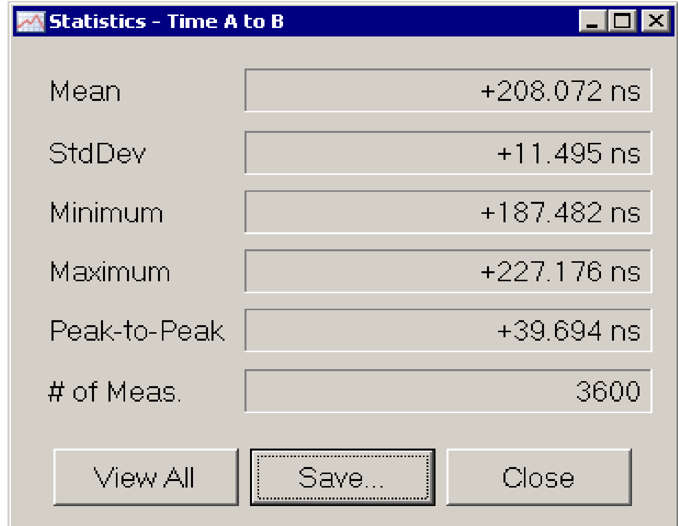


Figure 38 GT210 Statistics

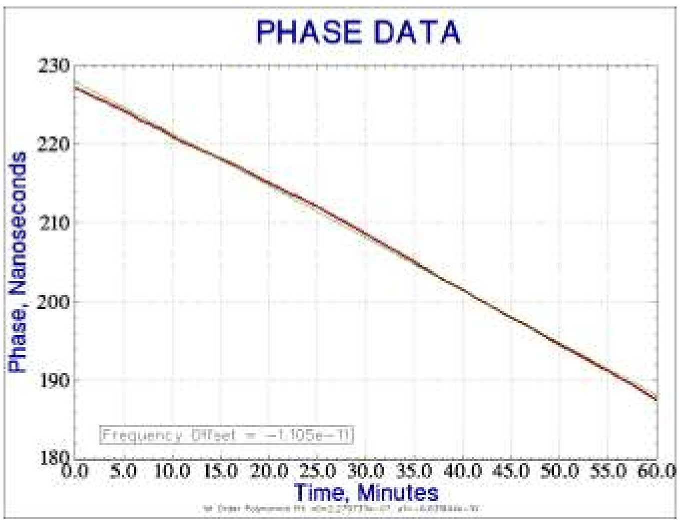


Figure 39 Stable32 Phase Plot

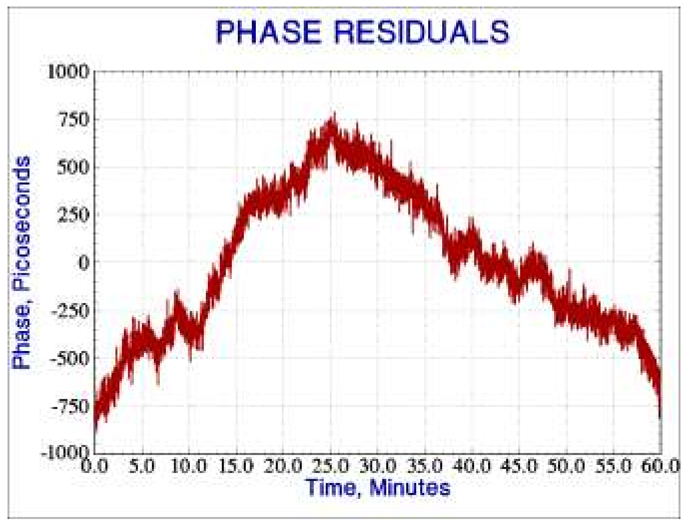


Figure 40 Stable32 Phase Residuals Plot

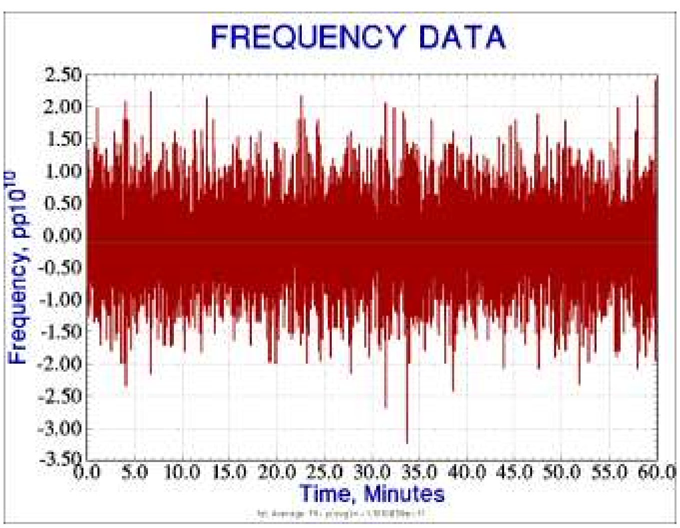


Figure 41 Stable32 Frequency Plot

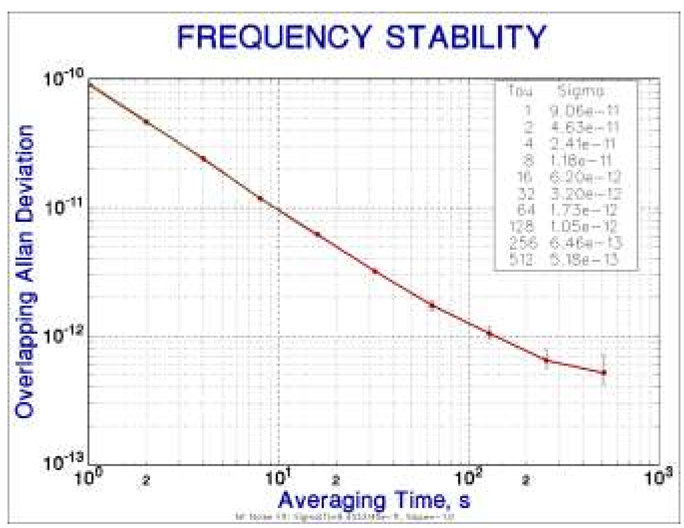


Figure 42 Stable32 Frequency Stability Plot

The measured stability is an order-of-magnitude worse than that of the rubidium oscillators, and is limited by the noise of the measuring system. Nevertheless, the measurement is quite satisfactory for determining the average frequency offset between the two sources.

The frequency offset can also be determined with the GT210 using a direct frequency measurement as shown in Figures 43 through 46.

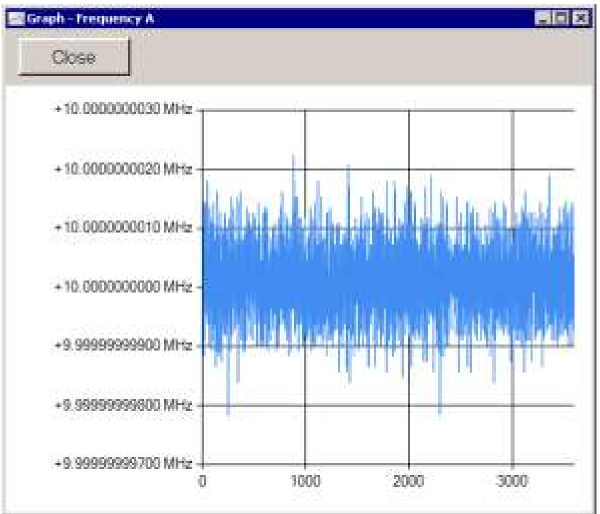


Figure 43 GT210 Frequency Record

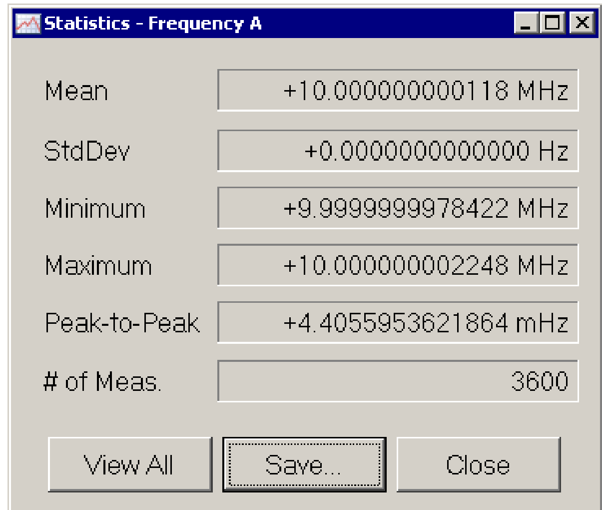


Figure 44 GT210 Statistics

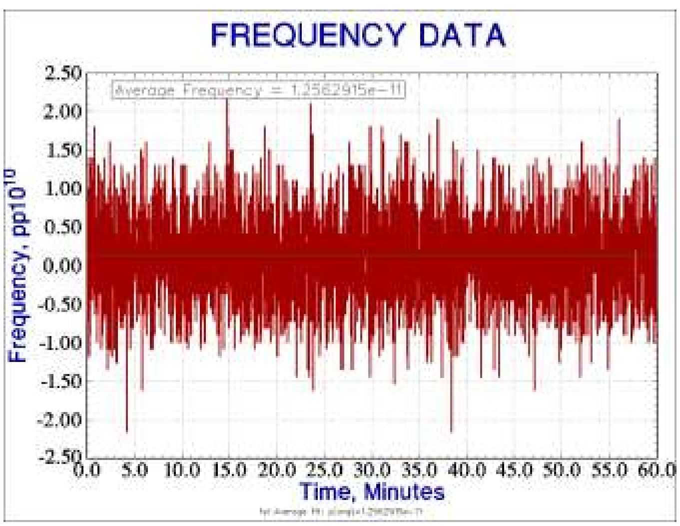


Figure 45 Stable32 Frequency Plot

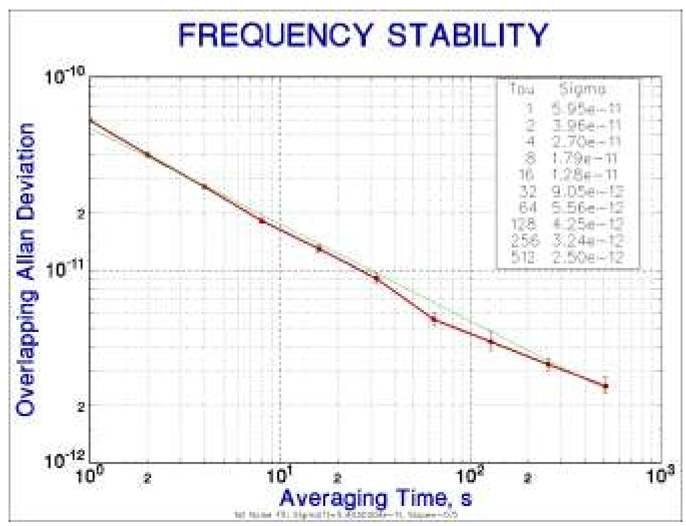


Figure 46 Stable32 Frequency Stability Plot

The GT210 statistics indicate a mean frequency of +113 μHz or $+1.13\times10^{-11}$ and zero standard deviation while Stable32 shows an average frequency of $+1.26\times10^{-11}$ and a standard deviation (not shown) of 5.72×10^{-11}. The frequency offset values are in reasonable agreement and, because of the GT210 virtual front panel's numerical problem with the standard deviation, one tends to use the Stable32 value. Both values are also in good agreement with the 2-day previous -1.10×10^{-11} from the 1 pps measurement except for the sign change due to the channel reversal.

The noise is white FM throughout the range of averaging times at a level of 6.0×10^{-11} at 1 second. That is significantly lower than the 9.1×10^{-11} 1-second Allan deviation measured with the 1 pps system (although both are much higher than the combined source noise of about 1x10-11 at 1 second).

• Conclusions

The GT210 is an excellent high-resolution counter, and its associated virtual front panel provides a very good user interface. The linearity of its phase interpolator appears exceptionally good. Overall, the instrument is well-suited for making direct measurements of medium-performance frequency sources, and, if augmented with heterodyne or dual-mixer hardware, the GT210 can measure high-performance clocks and oscillators.

• Acknowledgments

The GT210 counter used for these measurements was provided to Hamilton Technical Services by Mr. Ron Sigura of GuideTech, along with technical support from Mr. Freddy Ben-Zeev.

• References

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File: Clock Measurements Using the GT210 Counter.doc
W.J. Riley
Hamilton Technical Services
July 6, 2012
Revision A July 30, 2012