53220A and 53230A Universal Counter Comprehensive Demo Guide

<u>Summary:</u> This comprehensive guide features the 53220A and 53230A universal counters. Each section of the demo guide is made to stand by itself, meaning you do not have to do all the steps and you can do them in any order. The demo sections are as follows:

1. Initial Setup
2. Making frequency and period measurements
3. Using histograms and trend charts
4. Using math
5. Using statistics
6. Time interval measurements
7. Gapless sampling and Modulation Domain Capability (53230A, channels 1 and 2 only)

Appendix A: Allan variance tutorial

Appendix B: Frequency measurement modes: auto, reciprocal, continuous

Appendix C: Demoing customer signals on channels 1 and 2

Appendix D: Demoing channel 3

Appendix E: Option 150 (53230A only) and pulsed RF applications

<u>Equipment:</u> 53230A or 53220A Universal Counter, 33522A FG/AWG, and 2 BNC cables.

<u>Conventions:</u> hard keys are **bold** and soft keys are <u>underlined</u>

<u>Comprehensive Demo Guide</u>

1. Initial setup

a. Turn-on the 532xxA and 33522A. Connect the BNC cable to chan 1 of the 532xxA and chan 1 of the 33522A.

b. On the 33522A:

   i. Press **Chan1** → <u>Output Load</u> → <u>Set to High Z</u> to match the counter input impedance. Press <u>Output On</u>.

   ii. Press **Parameters** → <u>Frequency</u> use the key pad to enter **10** and press <u>MHz</u>.

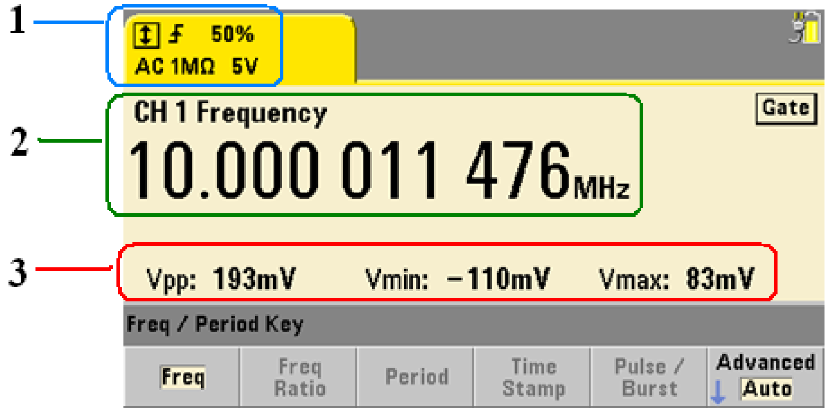
The 3352xA is now outputting a 10 MHz sine wave.

2. Making frequency and period measurements

a. Ensure you have completed step 1 the “Initial setup”.

The 532xxA will automatically start making frequency measurements. Making frequency measurements is the most common use of counters by our customers so that is why its turn-on default state is making frequency measurements. You should see a display like the screen shot in figure 1.

Figure 1. Default frequency measurement



From figure 1:

- 1 → Input conditioning settings: positive edge trigger, trigger at 50% amplitude point of edge, AC coupled, input Z 1M (other choice 50), input voltage range 5V (other choice 50V)
- 2 → Channel 1 frequency measurement (11 digits of resolution)
- 3 → Amplitude measurements

b. On the 532xxA:

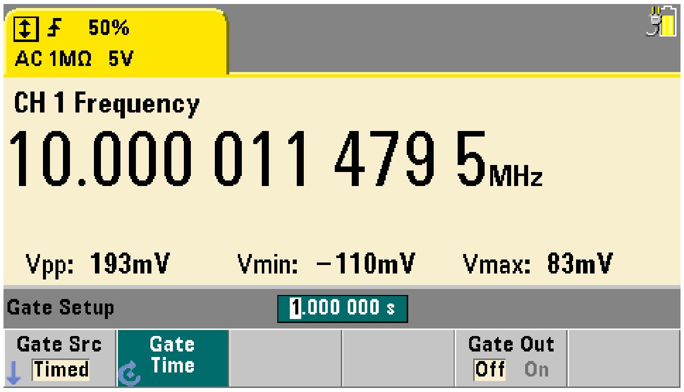
i. Press **Gate**. Above the Gate softkey menu you can see the current gate time is 100 ms (default value)

The gate time is the measurement window of the counter. Each frequency measurement you see on the display is the averaged value (actually we employ a more sophisticated confidential algorithm) of all the measurements made in that 100 ms gate time. The higher gate time means more resolution but lower measurement speed. A lower gate time means more measurement speed but less resolution.

ii. Press <u>Gate</u> → **Shift** → **1** (from key pad) → <u>Seconds</u>

The gate time is now set for 1 second. Notice we are now getting 12 digits of resolution per second, the max resolution for the 53220A and 53230A. Screen shot shown below in figure 2. If you set the gate time to 10 seconds you will get 13 digits of resolution (still 12 digits per second).

Figure 2. 12 digit resolution



iii. Change the gate time to 1 us

This is the min gate time. Notice we only get 5 digits of resolution. It is at this gate setting that the 53230A can store 75,000 readings/s to memory.

iv. Press **Freq Period** → Period to get the period measurement

Note: 10 digit/s in 1 sec on 53210 and 12 digit/s in 1 sec on 53220 and 53230

Note: See Appendix B for information on frequency modes: auto, reciprocal, continuous

3. Histograms and trend charts

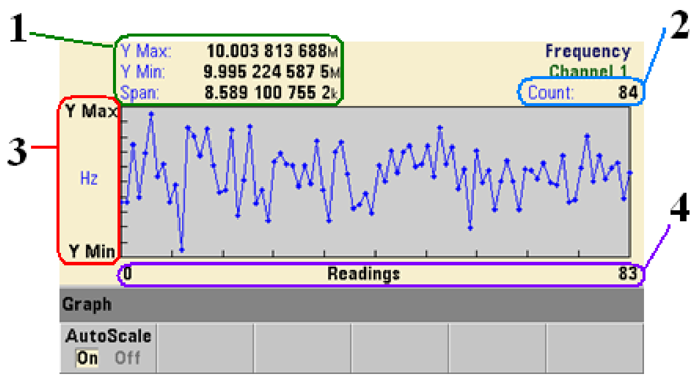
These are two real fun features that can really catch the eye of perspective customers. Our older family of counters could not do this because they did not have the display for it or the memory. Histograms and Trend charts are a great way to create a quick interesting demo at a show.

a. If the 33522A is not in its "Initial setup" condition (step 1), press **System** → Store/Recall → Set to Defaults. Go back to step 1 and complete the "Initial setup"
b. On the 3352xA:
   i. Press **Modulate** → Type → FM → Shape → More → Noise. Press Freq Dev use key pad to enter **300** and press kHz. Press Bandwidth use key pad to enter **10** and press kHz. Press Modulate On to turn on the modulation.

The 3352xA is now outputting a 10 MHz carrier with 10 KHz of Gaussian noise on it.

c. On the 532xxA, Press **Utility** → Store/Recall → Set to Defaults. The 532xxA is now in its default state
d. Press **Graph** → Trend Chart. The display should look like the one in Figure 3.

Figure 3. Trend chart

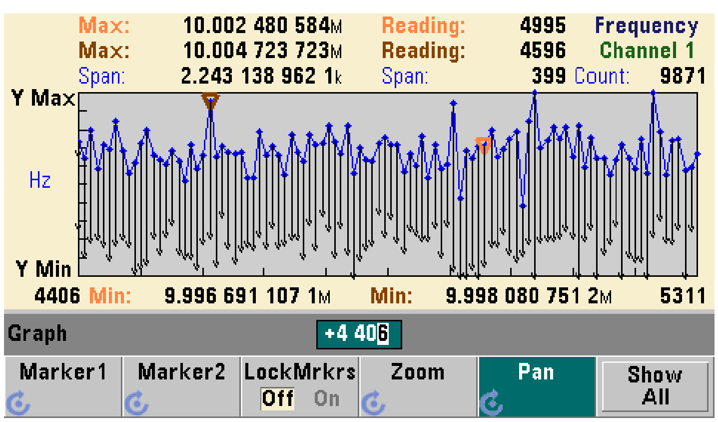


From the figure:

- 1 → ‘Y Max’ is the highest valued measurement (in this case frequency), ‘Y Min’ is the lowest valued measurement, and ‘Span’ is the difference between Y Max and Y Min
- 2 → ‘Count’ number of stored measurements. ‘Frequency’ is the measurement we are making
- 3 → ‘Y Max’ and ‘Y Min’ is the max and min bounds of the chart. If ‘AutoScale’ is on (default) the bounds are set automatically. You can turn it off to set the bounds manually
- 4 → ‘Readings’ the range of readings the trend chart displays (default up to 100)

e. Press Zoom & Markers. The Marker1, Marker2, Zoom, and Pan controls allow you to analyze and move through the readings. Use the knob to zoom in and out, pan through the readings, and move around the markers

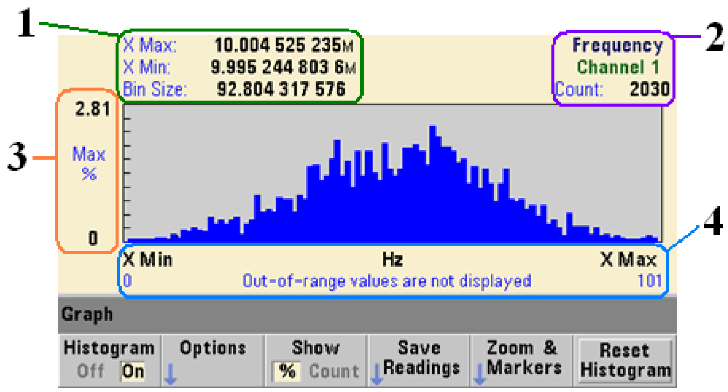
Below in figure 4 is an example data log of almost 10 K readings. Using the “Pan” and “Zoom” functions we choose to view about 900 readings. Using the Markers we were able to get the Max and Min readings within a chunk of readings. We also get the frequency span and readings span between the two markers. If you can, let the trend chart run for a while and then try out some of the data analysis features just mentioned.



Now we will check out the Histogram view

f. Press **Graph** → Histogram. This will bring up the histogram graphing functionality. Below in figure 4 is a screen shot of the 532xxA histogram feature.

Figure 4. Histogram



From the figure:

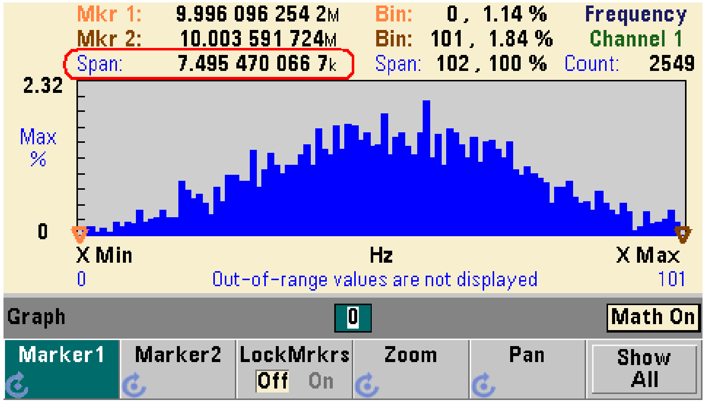
- 1 → 'X Max' is the highest valued measurement (in this case frequency), 'X Min' is the lowest valued measurement, and 'Bin Size' is the measurement range (width) of each 'stack' in the histogram. For instance the Bin Size in the figure is 92.8 since we are making frequency measurements that means each bin or stack is 92.8 Hz in span.
- 2 → 'Count' number of measurements in Histogram. 'Frequency' is the measurement we are making
- 3 → Displays percentage of measurements at a given frequency. This can be changed to 'Count' instead of '%'
- 4 → The measurement range of the x-axis (in this case frequency). Notice out of range readings are not displayed.

Notice in the figure that after >2000 readings the Gaussian shape of the input signal from the 33522A is taking shape (remember we configured it for FM with noise at 10 KHz BW). This is a great way to demo the 532xxA at a show because customers who test time bases or oscillators know Gaussian distribution and will appreciated this feature.

a. Press Zoom & Markers. The Marker1, Marker2, Zoom, and Pan controls allow you to analyze and move through the readings. Use the knob to zoom in and out, pan through the readings, and move around the markers
b. In figure 5 below the markers were placed on the farthest measurement on the left and right side of the curve.

Notice the span value (frequency range between markers) at the top circled in red at 7.5 KHz. This is what we would expect since the FM noise bandwidth of the input signal is 10 KHz (the span would be closer to 10 KHz if we would have set a shorter gate time)

Figure 5. Histogram using markers



4. Using math

Customers doing time base checks or oscillator testing often base the tolerance of the test on parts per million (PPM) not Hz. Often the PPM conversion is done in the customer's software, but using the Math function in the 53200 series we can do it on the instrument.

a. If the 33522A is not in its "Initial setup" condition (step 1), press **System** → Store/Recall → Set to Defaults. Go back to step 1 and complete the "Initial setup"

The 3352xA is now outputting a 10 MHz sine wave.

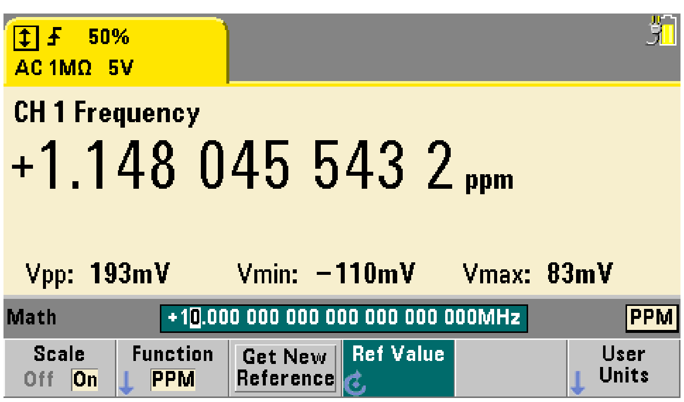
b. On the 532xxA:
   i. Press **Utility** → Store/Recall → Set to Defaults. The 532xxA is now in its default state
   ii. Press **Math** → Null/Scale.

The scale function lets you compare the measured value to a reference value you set

   iii. Press Ref Value → **Shift** → **10** (on number keypad) → Mega. Our reference value is 10 MHz
   iv. Press Function → PPM → Scale On

The 532xxA is now displaying how many PPM the measured value is from 10 MHz, see the screen shot in figure 5.

Figure 5. Scaling in PPM



v. Press Function. Check out some of the other scaling features: Null (difference in Hz), percentage (PCT), PPM, parts per billion (PPB), Mx-B

5. Using Statistics

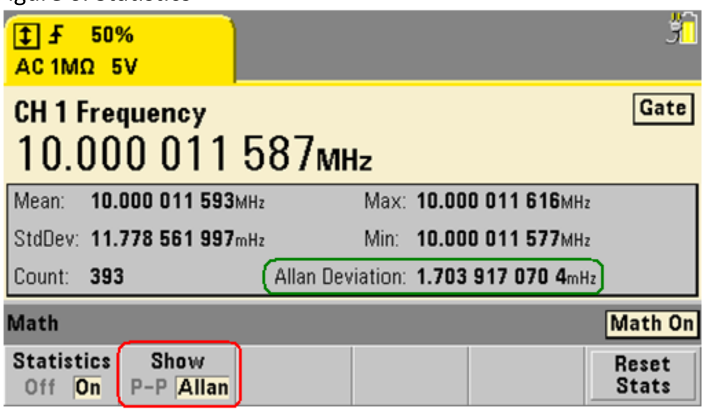
a. If the 33522A is not in its "Initial setup" condition (step 1), press → **System** → Store/Recall → Set to Defaults. Go back to step 1 and complete the "Initial setup"

The 3352xA is now outputting a 10 MHz sine wave.

b. On the 532xxA, Press **Utility** → Store/Recall → Set to Defaults. The 532xxA is now in its default state

c. Press **Math** → Statistics → Statistics On. You should see a display like the one shown in figure 6

Figure 6. Statistics



The 532xxA is now making the following freq measurements: current, mean, min, max, standard dev, and Allan Deviation.

Allan Deviation (circled in green): The 53230A and 53220A universal counters can perform Allan Deviation measurements. This type of measurement is used to determine frequency stability in clocks, oscillators, and amplifiers. It was developed to analyze noise that traditional statistical methods could not pick up. Only the 53230A can perform true Allen Deviation measurements since it has gapless sampling. Both the 53230A and the 53220A can perform pseudo Allan Deviation measurements (that is what we are doing right now). For more on Allan Deviation refer to appendix A.

d. Press Show P-P (circled in red) to display Peak to Peak calculations. Peak to Peak is nothing more than the span or difference of max and min.

6. Time Interval Measurements

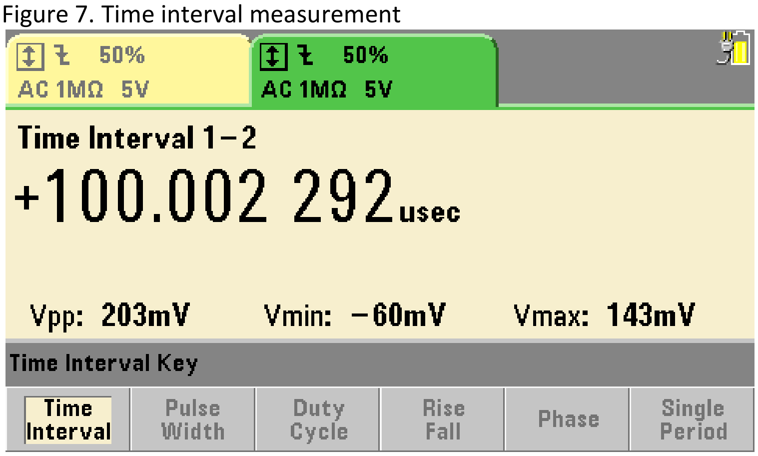
The 53220A provides a single shot time resolution of 100 ps and the 53230A provides a single shot time resolution of 20 ps, this is an industry leading specification! Single shot resolution refers to the minimum difference in time the counter can distinguish two edge events. If the events are continuous, like two repeating clock signals, the counter's precision can get down to the picosecond level (noise floor) when averaging is used because it cancels out random noise.

a. Connect the second BNC cable to channel 2 of the 532xxA and to channel 2 of the 33522A.
b. On the 33522A, press → **System** → Store/Recall → Set to Defaults
c. Press **chan1** → Output Load → Set to High Z → Output On
d. Press **Waveforms** → Pulse
e. Press **chan2** → Output Load → Set to High Z → Output On
f. Press **Waveforms** → Pulse → Pulse Width and key in **200** and press us
g. Press Phase → Sync Internal

Chan 1 and chan 2 of the 33522A are both outputting an in phase pulse at 1 KHz. The only difference is chan 1's pulse width is 100 us and chan 2's pulse width is 200 us.

h. On the 532xxA, press **Utility** → Store/Recall → Set to Defaults
i. Press **Time Interval** → Time Interval → Time Int. Ensure 1-2 is selected. 1-2 means we are measuring the time interval between the start event on chan 1 and stop event on chan 2
j. Press Start Ch Level → Slope Neg. The start event (chan 1) is set to be a negative edge
k. Press **Back** → Stop Ch Level → Slope Neg. The stop event (chan 2) is set to be a negative edge
l. Since the pulse width going into chan 1 is 100 us and the one going to chan 2 is 200 us we should see a time interval measurement of about 100 us as shown in figure 7.

Figure 7. Time interval measurement

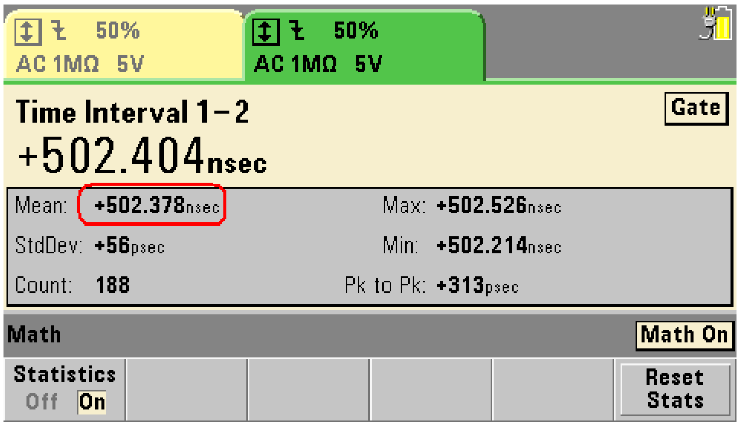


m. On the 33522A, Press **Chan 2** → **Parameters** → Pulse Width. Key in **100.5** and press us. Press Phase → Sync Internal.
n. The 532xxA should display about 500 ns since the chan 1 falling edge occurs 500 ns before the chan 2 falling edge (100.5 us ch2 – 100 us ch1 = 500 ns).

Notice that the pico second area of the 532xxA's reading is fairly jumpy. This is due to jitter and other random noise on the input signal. If a customer wanted to find the average of the time interval down into sub nano second resolution they would use statistics.

o. Press **Math** → Statistics → Statistics On. Your display should look like the screen shot in figure 8.

Figure 8. Time interval with statistics



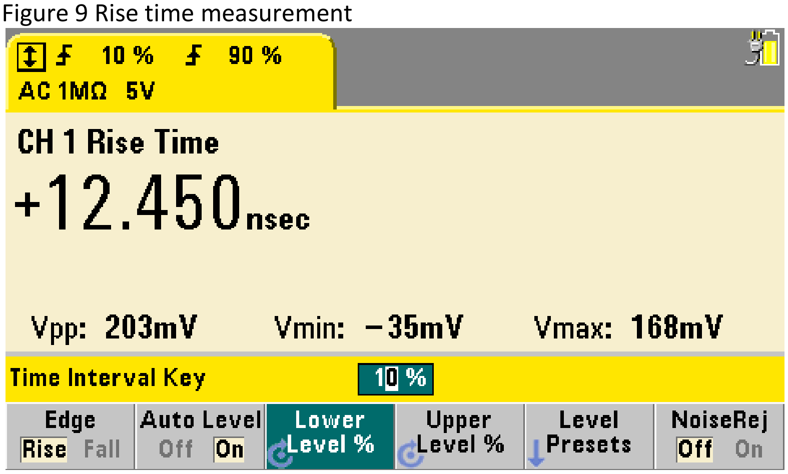
Circled in red is the mean of 188 measurements. Let's say a customer is testing some high speed digital signals and is expecting a 500 ns time interval between the edges. They would look at the average and say if I ignore the random error caused by noise, the timing of my two signals is off by 2.38 ns (or 2.38 ns of systematic error).

p. Press **Chan 1** and **Time Interval**

Notice in the menu at the bottom of the display, besides just time interval you can perform the following measurements: Pulse Width, Duty Cycle, Rise/Fall Time, Phase, Single Period.

q. Press Rise/Fall. Chan 1 is now making a rise time on the positive edge of the input pulse as show below in figure 9

Figure 9 Rise time measurement



Rise time is nothing but a time interval measurement with the start event edge set for a 10% trigger level and the stop event edge set for a 90% trigger level

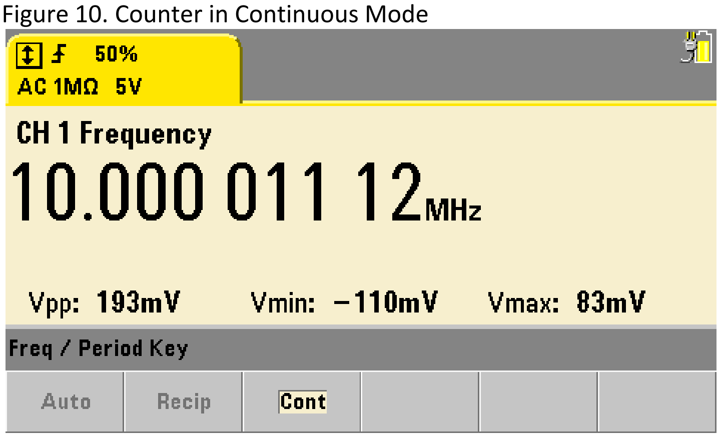
Note: 53210A does not do time interval measurements

7. Gapless sampling and Modulation Domain Capability (53230A, channels 1 and 2 only)

One valuable feature that some of the older HP counters had that the 53230A has is gapless sampling. Gapless sampling mean there is no dead time between measurement gates. Since there is no dead time between gates we know we are getting the total data of a signal within a given time period. The 53230A can perform up to 1 million gapless measurements, because 1 million is the size of the 53230A's memory. As far as speed is concerned, it can measure up to 1 million time stamped measurements per second, industry leading specification! This capability gives the 53230A the ability to make true Allan Deviation measurements. Also the user can easily access the gapless time stamped measurements giving them the ability to perform modulation domain analysis (MDA). This means the 53230A can fill some of the applications of our past MDA lines such as the 5373A.

a. Press **Freq Period** → Advanced → Cont. You should get a display like the screen shot shown in figure 10.

Figure 10. Counter in Continuous Mode



Now this display is not too exciting since it looks the same as the standard 'Auto Mode' frequency measurement screen. The continuous or gap-free mode on the 53230A provides little control over this capability from the front panel. To have full access to the gap-less sample capability you must use SCPI.

Note on competitor Pendulum and gap-free sampling:

Pendulum performs gapless sampling but at only 250 K readings/s (53230A can do 1 M readings/s). Pendulum does sell software to perform MDA, which we do not offer. For 53230A it is up to the customer to create software to perform the MDA function, we just provide the low level measurement capability and the gap-free measurement capability.

Note: See Appendix B for information on frequency modes: auto, reciprocal, continuous

Appendix A: Allan variance tutorial

The **Allan variance** (**AVAR**), also known as **two-sample variance** is a measure of frequency stability in clocks, oscillators and amplifiers. It is named after David W. Allan. It is expressed mathematically as

$$\sigma_y^2(\tau).$$

The **Allan deviation** (**ADEV**), is the square root of Allan variance (This is what the 532xxA calculates in statistics). It is also known as *sigma-tau*, and is expressed mathematically as

$$\sigma_y(\tau).$$

The *M-sample variance*, is a measure of frequency stability using M samples, time T between measures and observation time τ. *M*-sample is expressed as

$$\sigma_y^2(M, T, \tau).$$

The *Allan variance* is intended to estimate stability due to noise processes and not that of systematic errors or imperfections such as frequency drift or temperature effects. The Allan variance and Allan deviation describe frequency stability, i.e. the stability in frequency. There are also different adaptations or alterations of *Allan variance*. Notably the modified Allan variance, the total variance, and the Hadamard variance. There also exist time stability variants such as time deviation or time variance. Allan variance and its variants have proved useful outside of the scope of timekeeping and are a set of improved statistical tools to use whenever the noise processes are not unconditionally stable, but a derivative will be.

The *M*-sample variance is of historic importance as well as important background but has essentially been replaced by its special case of 2-sample variance with $T = \tau$ now being called **Allan variance**. It remains important since it allows dead time in measurements and bias functions allows conversion into Allan variance values.

Appendix B: Frequency measurement modes: auto, reciprocal, continuous

There are three measurement modes (auto, reciprocal, continuous) available for making **frequency**, **frequency ratio**, and **average period** measurements.

Auto - configures the counter to make resolution-enhanced measurements when possible, or reciprocal measurements otherwise depending on input signal conditions. All measurements using channel 3 are made using this mode.

Reciprocal - configures the counter for reciprocal-only measurements. In Reciprocal mode, the period of the input signal is measured and all frequency readings are derived from (are the reciprocal of) the period measurement.

Continuous - configures the counter for continuous (gap-free) measurements applicable for **Allan Deviation** computations (Chapter 6). In this mode, all samples (readings) per trigger are taken within a **single** gate open/gate close sequence and computed back-to-back. There is no lag between readings that otherwise occurs with the per sample gate open/gate close sequence. Continuous mode is **only** available with the **53230A,** and **only** for **frequency** and **average-period** measurements.

<u>Appendix C: Demoing customer signals on channels 1 and 2</u>

You may run into situations on customer visits where a customer may want to input their own signal into the 532xxA below is brief setup instructions when inputting signals from a customer provided signal source:

<u>Inputting customer signals into chan 1 and 2 (must be 350 MHz or less):</u> If you are using a source, such as a customer's DUT or a signal generator, you need to be aware of that device's output characteristics. The following 532xxA settings discussed can be accessed by pressing **Chan 1** for chan 1 input settings or **Chan 2** for chan 2 input settings:

- What is the source's output Z? 50 ohm or 1 Mohm or somewhere in between? 532xxA chan 1 or 2 input impedance can be set to 50 or 1 M. Choose the one closet to the output Z of the source.
- What is the amplitude of the sources output? The 532xxA provides to input volt ranges, 5 V and 50 V.
- Often digital signals can have a DC bias. Typically you want to remove the bias when measuring the signal with a counter. To do this ensure the 532xxA is set for AC coupling versus DC coupling (AC coupling is the default setting)

After going through the above list and inputting a signal into the 532xxA, if you are not getting a reading or the reading is jumping around check the following:

- Check the Vpp, Vmin, Vmax readings on the display are they too small or are they too large for the input voltage range? If so adjust the input voltage range. If the signal is real small you may want to manually set the trigger level.
- If the reading or Vpp, Vmin, and Vmax are jumping around you may have a noisy input signal, what to try: try adjust the trigger level to a steady point on the signal, turn on NoiseRej, if the signal is less than 100 KHz turn on 100 K BW Limit
- If the input signal is a low frequency, such as < 10 Hz. Try setting the input to DC coupled versus AC coupled

<u>Appendix D: Demoing channel 3</u>

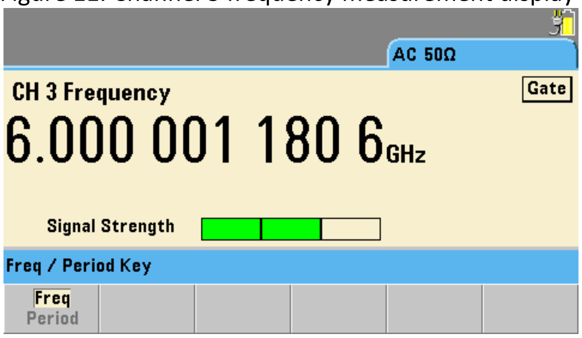
Chan 3 with option 106 the input frequency range is 100 MHz to 6 GHz, with option 115 the input frequency range is 300 MHz to 15 GHz. A good Agilent signal generator to use to show channel 3 is our MXG signal generator product line, N518xA. Of course any RF/Microwave source will work. The following is general run through on setting up a channel 3 measurement:

- Using an RF/Microwave cable with an SMA or N-Type connector (depending on the 532xxA connector type) connect the output of the signal source to the counter channel

3 input. It is not recommended that you use a BNC cable for frequencies above 500 MHz.

- Set the signal source to a desired frequency level that falls within the 532xxA's channel 3 frequency range. Set the output power to 0 dBm and turn the output on.
- On the 532xxA, press **Chan 3** button and the 532xxA will start making a frequency measurement on channel 3. The display should look like figure 11.

Figure 11. Channel 3 frequency measurement display



Notice that we have 11 digits of resolution using the default gate time (100 ms). This is the same as chan 1 and 2 on the 53220A and 53230A. If we were to change the gate time to 1 s we would see 12 digits of resolution just like chan 1 and 2 on the 53220A and 53230A. The resolution for chan 3 is the same as the resolution for chan 1 and 2. Unlike chan 1 and 2, chan 3 cannot measure the input amplitude. Under the frequency measurement in figure 11, you can see a gauge that gives you a general idea of the input signal strength. This is helpful to ensure chan 3 is not damaged by too high input power. Also it allows you to spot input signal that are too low. If the signal power is real low it will affect the accuracy of the measurement.

Appendix E: Option 150 (53230A Only) and pulsed RF applications

Channel 3 option 150 gives the 53230A the ability to make pulsed RF/uwave measurements. This type of measurement capability is needed by customers developing radar and electronic warfare equipment. Refer to figure 12 for a pulsed RF/uwave signal in the time domain and the corresponding commonly measured parameters. Option 150 gives you the ability to make the following measurements on a pulsed RF/uwave signal:

- Pulse Frequency (PF) or the Carrier frequency of the signal
- Pulse Repetition Interval (PRI)
- Pulse Repetition Frequency (PRF)
- Pulse Width (PW)

In this application space the 53230A provides two major advantages: low cost and low time configuration. The 53230A cannot measure the pulse power or give details on the pulse shape. To fill this gap a customer could add a N1911A power meter and power sensor. This leads to a complete solution for about $20K, which in this application space is low cost.

If you wanted to show the option 150 pulsed RF/uwave measurement capabilities you could use a signal generator with pulse modulation capability. A good choice that has a lot of units in demstock is the N5183/2/1A. Set the signal generator for the following settings:

- Carrier frequency of 4 GHz
- Turn pulse modulation on
- Set pulse width to 1 us
- Set pulse frequency to 1 KHz (PRI 1 ms)
- Turn output on

Figure 12. Pulsed RF/uwave signal