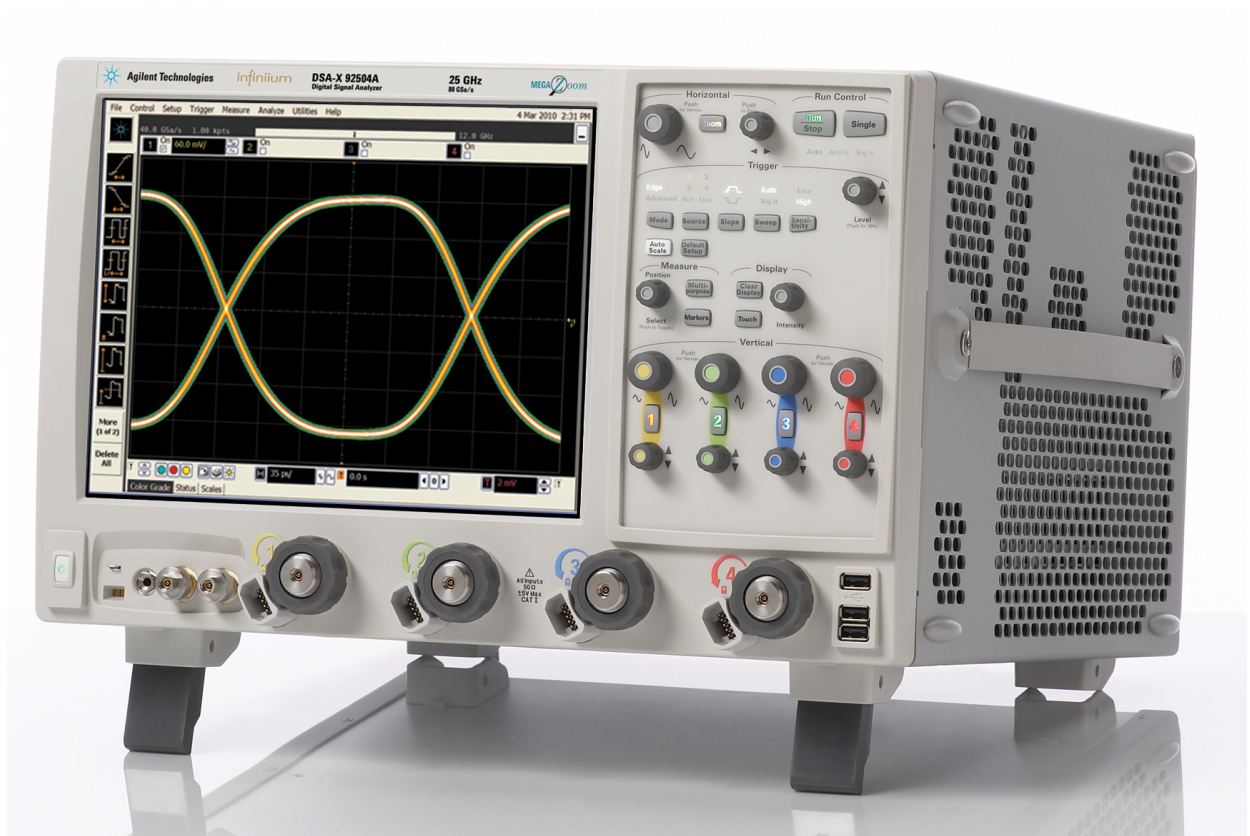




# Four Channel 90000 X-Series >20 GHz System

Agilent Infiniium 90000X Series Oscilloscopes

Application Note



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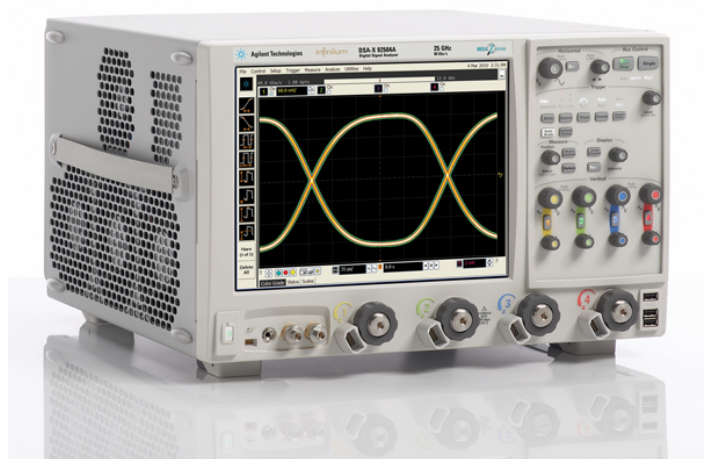
## Introduction

The next generation of greater than 100 Gb/s optical systems require four oscilloscope channels with greater than 16 GHz of bandwidth for testing and design. Current solutions suffer from significant signal integrity limitations. Therefore, there is a strong need for a true analog high-performance test solution for this market. The new Agilent Infiniium 90000 X-Series oscilloscopes is the highest performing oscilloscope in the industry and by using four simultaneous channels, the user has access to tremendous performance and the best solution available for these greater than 100 Gb/s optical systems.

Working as a joint team with Alcatel-Lucent Bell Labs, Agilent Technologies recently demonstrated this synchronized 4 channel system of 32 GHz at 80 GSa/s. The wideband and measurement accuracy of the oscilloscopes in this configuration made it possible to more than double the interface rates demonstrated just a year ago. In addition to the highest true analog bandwidth, the 90000 X-Series oscilloscopes have the highest effective number of bits (more than 5.5) and the lowest inter-scope skew (less than 0.5 ps, standard deviation).

In two papers<sup>1-2</sup> accepted at ECOC 2010, Agilent and Alcatel-Lucent Bell Labs illustrated breakthrough interface technologies and a description of how the team achieved the world's fastest interface rates across a variety of configurations. Additionally, this oscilloscope technology makes it possible for experimentation at more than 400 Gb/s which is necessary for future optical network development.

This Application Note will describe how to configure the equipment to synchronize two 90000 X-Series oscilloscopes and will also cover the main MATLAB function (Tango) used to perform the synchronization.



1. "Generation and 1,200-km Transmission of 448-Gb/s ETDM 56-Gbaud PDM 16-QAM Using a Single I/Q Modulator" P.J Winzer, A.H. Gnauck, S. Chandrasekhar, S. Draving, J. Evangelista, and B. Zhu. *ECOC 2010*.

2. "Single Coherent Detection of 606-Gb/s CO-FDM Signal with 32-QAM Subcarrier Modulation Using 4x80-GSamples/s ADCs" Xiang Liu, S. Chandrasekhar, P.J. Winzer, S. Draving, J. Evangelista, N. Hoffman, B. Zhu, and D.W. Peckham. *ECOC 2010*.

## What is Tango?

Tango is a MATLAB function that uses remote commands to digitize four full-bandwidth Agilent Infiniium 90000 X-Series oscilloscope channels simultaneously and return them within a single structured-array output argument. It accomplishes this by synchronizing two DSO90000 X-Series oscilloscopes. Upon invocation, the Tango function reads the current configuration of the Leader oscilloscope and then uses that information to configure both the Leader and Follower oscilloscope for a waveform acquisition. The use model is for the user to configure the system's settings by adjusting the settings only on the Leader. Once configured, the Follower is armed to trigger on the TrigOut signal from the Leader, and the Leader is armed and waits for a valid trigger event to occur. Note that the Leader can be manually configured to trigger on any of its normal trigger sources except channel 4.

After both oscilloscopes trigger and acquire their waveforms, Tango reads the waveforms from the oscilloscopes and corrects the trigger jitter of the Follower's waveform. Next, Tango digitizes the common calibration signal to correct for drift between the oscilloscopes and then returns the resulting synchronized waveforms. Finally, Tango returns both oscilloscopes to the states it put them in just prior to capturing their input signals.

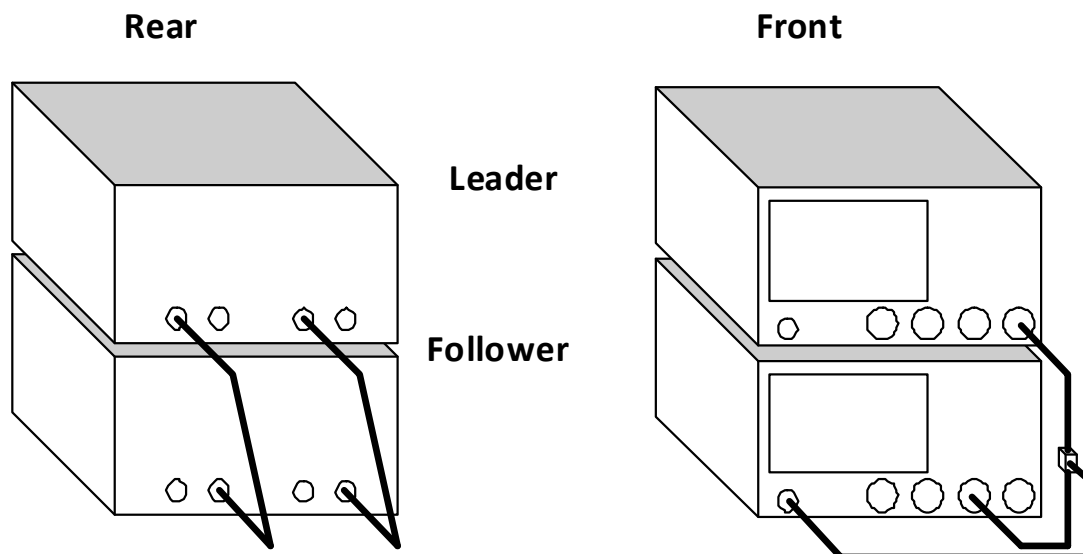
## What Equipment is Required?

The following equipment is required:

- 2x Infiniium DSO90000 X-Series oscilloscopes
- Instrument controller PC running Agilent IO Libraries and MATLAB. Note: This controller can actually be the Follower oscilloscope, but MATLAB will need to be installed on the Follower to do so.
- 2x N2812A high performance input cables
- Passive power splitter or divider
- 3x BNC cables
- 2x LAN, GPIB, or USB cables (depending on how you are connecting the controller to the oscilloscopes)

## Setting Up the Equipment

Figure 1 shows the correct configuration of the equipment. Specific connection instructions are on the following page.



**Figure 1** Correct equipment configuration

- 1 Connect TrigOut from the Leader to AuxOut on the Follower through a BNC cable.
- 2 Connect 10 MHz Out from the Leader to 10 MHz In on the Follower through a BNC cable.
- 3 Connect the Follower's CalOut signal to one of the spare channels on both oscilloscopes using high quality SMA cables and a passive power splitter or divider.
- 4 Connect the four target input signals to channels 1 and 3 on the Leader and channels 2 and 4 on the Follower (these connections are not shown in Figure 1).
- 5 Connect the controller to the two oscilloscopes either by LAN, GPIB, or USB.

Tango assumes that channels 1 and 3 of the Leader are used and channels 2 and 4 of the Follower are used. It always forces the skew settings on both oscilloscopes to zero, but does allow the user to pass in a manual skew parameter for each output waveform. Tango only captures a single waveform per each invocation.

Also, an additional function called PutOnDancingShoes initializes the necessary workspace variables for Tango. PutOnDancingShoes need only be called once the application is restarted, the MATLAB workspace variables are cleared, or the physical configuration changes.

A top-level MATLAB script called DancingWithTheStars can be used to test or demonstrate the Tango and PutOnDancingShoes functions. DancingWithTheStars sets some of the optional input parameters for the Tango function, iteratively calls the Tango function, and then plots and saves the resultant waveforms. It can also optionally calculate jitter between the four channels.

## Parameter Passing

Tango uses structured arrays for parameter passing and almost all parameters are optional. You can look in the various subfunctions to find out what all of the optional parameters are as well as their default values. Most of the default values are defined in PutOnDancingShoes.

Most of the parameters that users will want to set are defined explicitly (though some are temporarily commented out) in DancingWithTheStars. These are called Param.Xxx, Leader.Xxx, or Follower.Xxx. All other parameters apply to DancingWithTheStars only.

The following is a list of common PutOnDancingShoes/Tango Parameters:

- **Leader.Addr** - Visa address of Leader oscilloscope (string). This is a required parameter.
- **Follower.Addr** - Visa address of Follower oscilloscope (string). It is a required parameter. Note that you can use 'TCIP0::localhost::inst0::INSTR' when the Follower is also the controller.
- **Follower.Chan2.Scale** - Explicit channel 2 scale setting (double). Defaults to the Leader's channel 1 scale setting.
- **Follower.Chan2.Offset** - Explicit channel 2 offset setting (double). Defaults to the Leader's channel 1 offset setting.
- **Follower.Chan4.Scale** - Explicit channel 4 scale setting (double). Defaults to the Leader's channel 3 scale setting.
- **Follower.Chan4.Offset** - Explicit channel 4 offset setting (double). Defaults to the Leader's channel 3 offset setting.
- **Param.AlignSamples** - Aligns waveform samples of all waveform records (0=disabled, 1=enabled). Makes all waveforms have the same record lengths and x-origin values.

- **Param.LoadSetup.FileName** - Name of the setup file loaded into the Leader by PutOnDancingShoes (string). A setup is only loaded if this optional file name parameter is defined. Tango reads the Leader's initial settings and then temporarily changes them during execution. It normally returns the Leader back to its initial configuration, but if Tango crashes or is aborted during execution, presetting the Leader to the desired configuration can be helpful.
- **ZeroSkew** - Manual deskew values that align all four channels with respect to one another (4x1 double array). These appear to work backwards, just like they do in the oscilloscope application. Used for calculating jitter and PostJitterFree. This is added to AddSkew to form the actual skew values passed to Tango.
- **PlotWaveforms** - Plots waveforms (0=disabled, 1=enabled)
- **Units** - Units of x-axis on plots (string). Used for calculating jitter and PostJitterFree. You should change this value in conjunction with Mult.

The following is a list of common DancingWithTheStars parameters:

- **Debug** - Enables verbose reporting during execution (0=quiet, 1=verbose). This parameter is also inherited by Tenco by default.
- **PathName** - Defines the path name for all save/load operations (string)
- **FileName** - Defines the file name prefix for all save/load operations (string)
- **NumSongs** - Number of Tango iterations to run for graphs and calculations (integer)
- **DigitizeWaveforms** - Enables the actual calling of the Tango function (0=disabled, 1=enabled). This can be used in conjunction with LoadWaveforms to post process saved waveforms.
- **SaveWaveforms** - Saves waveforms to a file (0=disabled, 1=enabled)
- **LoadWaveforms** - Enables the loading of waveforms from a file (0=disabled, 1=enabled). This can be used in conjunction with DigitizeWaveforms to post process saved waveforms.
- **CalcJitter** - Calculates display jitter from multiple acquisitions (0=disabled, 1=enabled)
- **Freq** - Fundamental frequency of input signal (double). Used for calculating jitter and PostJitterFree.
- **YThresh** - Threshold value for edge finding (double). Used for calculating jitter and PostJitterFree.
- **YHyst** - Hysteresis value for edge finding (double). Used for calculating jitter and PostJitterFree.
- **XMin** - Left-most value of plot's x-axis (string 'auto' or value scaled Mult)
- **XMax** - Right-most value of plot's x-axis (string 'auto' or value scaled Mult)
- **AddSkew** - Additional skew values used to plot the waveforms (4x1 double array). These appear to work backwards, just like they do in the oscilloscope application. This is added to ZeroSkew to form the actual skew values passed to Tango.
- **Mult** - x units multiplier (double). This affects jitter calculations and plots. For plots, the user should change this value in conjunction with Units.
- **PostJitterFree** - Performs a JitterFree-type error correction on Tango waveforms (0=disabled, 1=enabled). This is useful when operating a mode where JitterFree is disabled on the Leader.





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