User's Guide

Keysight LTE/LTE-A Multi-Channel Reference Solution

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KEYSIGHT TECHNOLOGIES

Notices

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Manual Part Number

Y1299-90005

Published By

Keysight Technologies
Sector-8, IMT Manesar – 122051
Ground Floor and Second Floor, CP-11
Gurgaon, Haryana, India

Edition

Edition 1, October, 2015
Printed In USA

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CAUTION

A CAUTION notice denotes a hazard. It calls attention to an operating procedure, practice, or the like that, if not correctly performed or adhered to, could result in damage to the product or loss of important data. Do not proceed beyond a CAUTION notice until the indicated conditions are fully understood and met.

WARNING

A WARNING notice denotes a hazard. It calls attention to an operating procedure, practice, or the like that, if not correctly performed or adhered to, could result in personal injury or death. Do not proceed beyond a WARNING notice until the indicated conditions are fully understood and met.

The following safety precautions should be observed before using this product and any associated instrumentation.

This product is intended for use by qualified personnel who recognize shock hazards and are familiar with the safety precautions required to avoid

possible injury. Read and follow all installation, operation, and maintenance information carefully before using the product.

WARNING

If this product is not used as specified, the protection provided by the equipment could be impaired. This product must be used in a normal condition (in which all means for protection are intact) only.

The types of product users are:

- Responsible body is the individual or group responsible for the use and maintenance of equipment, for ensuring that the equipment is operated within its specifications and operating limits, and for ensuring operators are adequately trained.
- Operators use the product for its intended function. They must be trained in electrical safety procedures and proper use of the instrument. They must be protected from electric shock and contact with hazardous live circuits.
- Maintenance personnel perform routine procedures on the product to keep it operating properly (for example, setting the line voltage or replacing consumable materials). Maintenance procedures are described in the user documentation. The procedures explicitly state if the operator may perform them. Otherwise, they should be performed only by service personnel.
- Service personnel are trained to work on live circuits, perform safe installations, and repair products. Only properly trained service personnel may perform installation and service procedures.

WARNING

Operator is responsible to maintain safe operating conditions. To ensure safe operating conditions, modules should not be operated beyond the full temperature range specified in the Environmental and physical specification. Exceeding safe operating conditions can result in shorter lifespans, improper module performance and user safety issues. When the modules are in use and operation within the specified full temperature range is not maintained, module surface temperatures may exceed safe handling conditions which can cause discomfort or burns if touched. In the event of a module exceeding the full temperature range, always allow the module to cool before touching or removing modules from chassis.

Keysight products are designed for use with electrical signals that are rated Measurement Category I and Measurement Category II, as described in the International Electrotechnical Commission (IEC) Standard IEC 60664. Most measurement, control, and data I/O signals are Measurement Category I and must not be directly connected to mains voltage or to voltage sources with high transient over-voltages. Measurement Category II connections require protection for high transient over-voltages often associated with local AC mains connections. Assume all measurement, control, and data I/O connections are for connection to Category I sources unless otherwise marked or described in the user documentation.

Exercise extreme caution when a shock hazard is present. Lethal voltage may be present on cable connector jacks or test fixtures. The American National Standards Institute (ANSI) states that a shock hazard exists when voltage levels greater than 30V RMS, 42.4V peak, or 60VDC are present. A good safety practice is to expect that hazardous voltage is present in any unknown circuit before measuring.

Operators of this product must be protected from electric shock at all times. The responsible body must ensure that operators are prevented access and/or insulated from every connection point. In some cases, connections must be exposed to potential human contact. Product operators in these circumstances must be trained to protect themselves from the risk of electric shock. If the circuit is capable of operating at or above 1000V, no conductive part of the circuit may be exposed.

Do not connect switching cards directly to unlimited power circuits. They are intended to be used with impedance-limited sources. NEVER connect switching cards directly to AC mains. When connecting sources to switching cards, install protective devices to limit fault current and voltage to the card.

Before operating an instrument, ensure that the line cord is connected to a properly-grounded power receptacle. Inspect the connecting cables, test leads, and jumpers for possible wear, cracks, or breaks before each use.

When installing equipment where access to the main power cord is restricted, such as rack mounting, a separate main input power disconnect device must be provided in close proximity to the equipment and within easy reach of the operator.

For maximum safety, do not touch the product, test cables, or any other instruments while power is applied to the circuit under test. ALWAYS remove power from the entire test system and discharge any capacitors before: connecting or disconnecting cables or jumpers, installing or removing switching cards, or making internal changes, such as installing or removing jumpers.

Do not touch any object that could provide a current path to the common side of the circuit under test or power line (earth) ground. Always make measurements with dry hands while standing on a dry, insulated surface capable of withstanding the voltage being measured.

The instrument and accessories must be used in accordance with its specifications and operating instructions, or the safety of the equipment may be impaired.

Do not exceed the maximum signal levels of the instruments and accessories, as defined in the specifications and operating information, and as shown on the instrument or test fixture panels, or switching card.

When fuses are used in a product, replace with the same type and rating for continued protection against fire hazard.

Chassis connections must only be used as shield connections for measuring circuits, NOT as safety earth ground connections.

If you are using a test fixture, keep the lid closed while power is applied to the device under test. Safe operation requires the use of a lid interlock.

Instrumentation and accessories shall not be connected to humans.

Before performing any maintenance, disconnect the line cord and all test cables.

To maintain protection from electric shock and fire, replacement components in mains circuits – including the power transformer, test leads, and input jacks – must be purchased from Keysight. Standard fuses with applicable national safety approvals may be used if the rating and type are the same. Other components that are not safety-related may be purchased from other suppliers as long as they are equivalent to the original component (note that selected parts should be purchased only through Keysight to maintain accuracy and functionality of the product). If you are unsure about the applicability of a replacement component, call an Keysight office for information.

WARNING

No operator serviceable parts inside. Refer servicing to qualified personnel. To prevent electrical shock do not remove covers. For continued protection against fire hazard, replace fuse with same type and rating.

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This symbol indicates product compliance with the Canadian Interference-Causing Equipment Standard (ICES-001). It also identifies the product is an Industrial Scientific and Medical Group 1 Class A product (CISPR 11, Clause 4).

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This product complies with the WEEE Directive marketing requirement. The affixed product label (above) indicates that you must not discard this electrical/electronic product in domestic household waste. **Product Category**: With reference to the equipment types in the WEEE directive Annex 1, this product is classified as "Monitoring and Control instrumentation" product. Do not dispose in domestic household waste. To return unwanted products, contact your local Keysight office, or for more information see http://about.keysight.com/en/companyinfo/environment/takeback.shtml.

This symbol indicates the instrument is sensitive to electrostatic discharge (ESD). ESD can damage the highly sensitive components in your instrument. ESD damage is most likely to occur as the module is being installed or when cables are connected or disconnected. Protect the circuits from ESD damage by wearing a grounding strap that provides a high resistance path to ground. Alternatively, ground yourself to discharge any built-up static charge by touching the outer shell of any grounded instrument chassis before touching the port connectors.

This symbol on an instrument means caution, risk of danger. You should refer to the operating instructions located in the user documentation in all cases where the symbol is marked on the instrument.

This symbol indicates the time period during which no hazardous or toxic substance elements are expected to leak or deteriorate during normal use. Forty years is the expected useful life of the product.

Contents

MIMO Introduction

This multi-channel reference solution is used in particular to test:

- Multi-antenna techniques that are used in diversity
- Spatial multiplexing multiple-in, multiple-out (MIMO)
- Beamforming in cellular and wireless LAN applications

For further details refer to www.keysight.com/find/pxi-mimo.

Multi-channel transmitter and receiver testing may require synchronization of multiple signal generators and/or signal analyzers in time and frequency. For example, wireless LAN transmitters can be measured by multiple receivers operating at the same frequency and with acquisition timing aligned, and receivers can be tested using synchronized signal generators.

The M9381A VSG and M9391A VSA can be configured to operate in multi-channel configurations with a shared 100 MHz frequency reference, and an independent, or shared local oscillator (synthesizer) for each channel. This allows them to operate at the same frequency for multi-channel operation, and at different frequencies for modes in which multiple carriers are used, but baseband timing alignment is still required.

The arbitrary waveform playback of the M9381A VSG can be synchronized using backplane triggering of the PXIe chassis. The IQ acquisitions made by the M9391A PXIe VSA for demodulating multi-channel waveforms can be synchronized using a synchronization technique using the backplane of the PXIe chassis. Refer to the Keysight M9391A PXIe Vector Signal Analyzer and M9381A PXIe Vector Signal Generator Programming Guide for details. For additional information on multi-channel systems, refer to www.keysight.com/find/pxi-mimo.

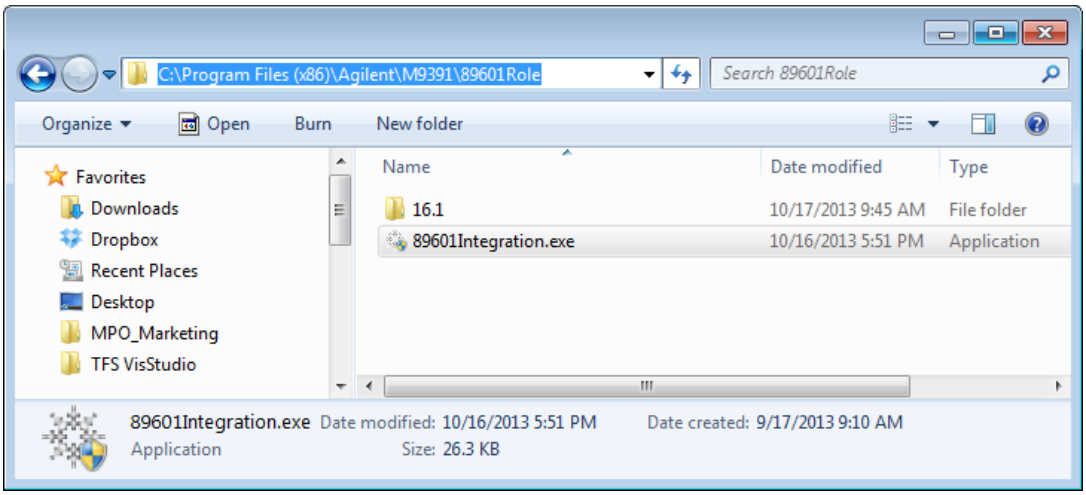
NOTE **The LTE/LTE-A Reference Solution can be assembled to make up to 8x8 channel phase coherent measurements**

For more information on LTE/LTE-A Multi-Channel Systems see:

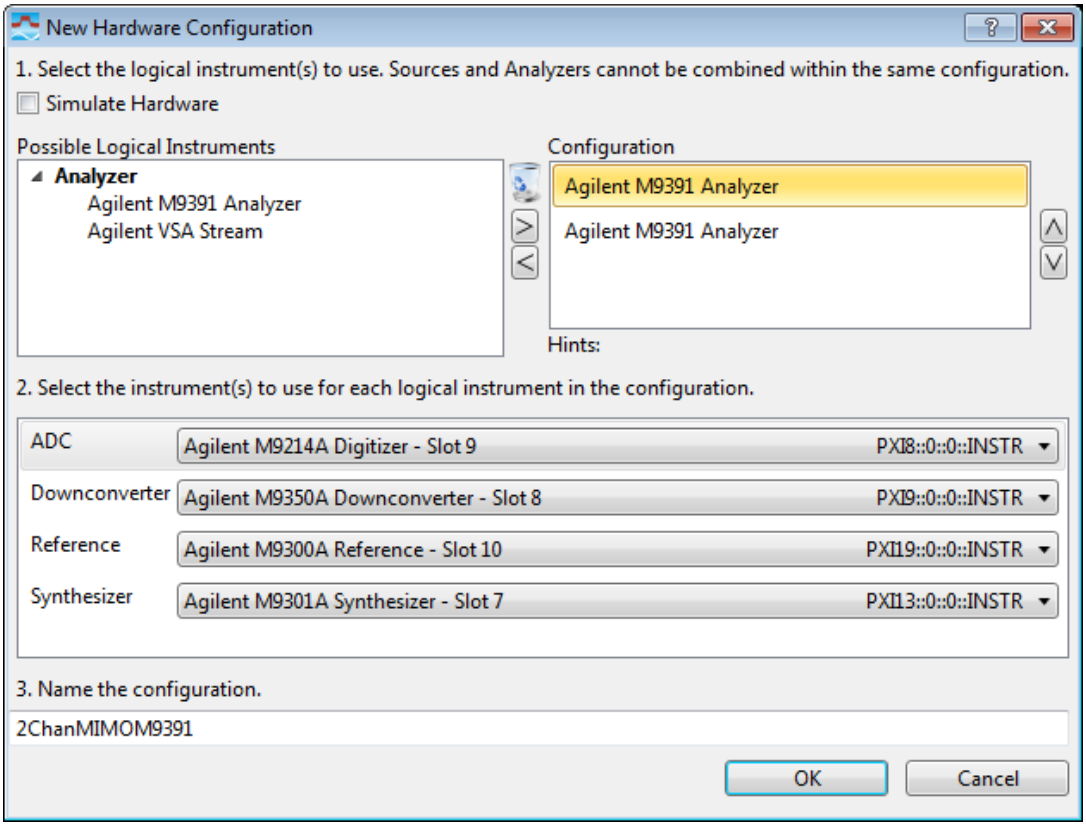
- Solution Brochure 5991-4684EN
- Configuration Guide 5991-4647EN

Application Software

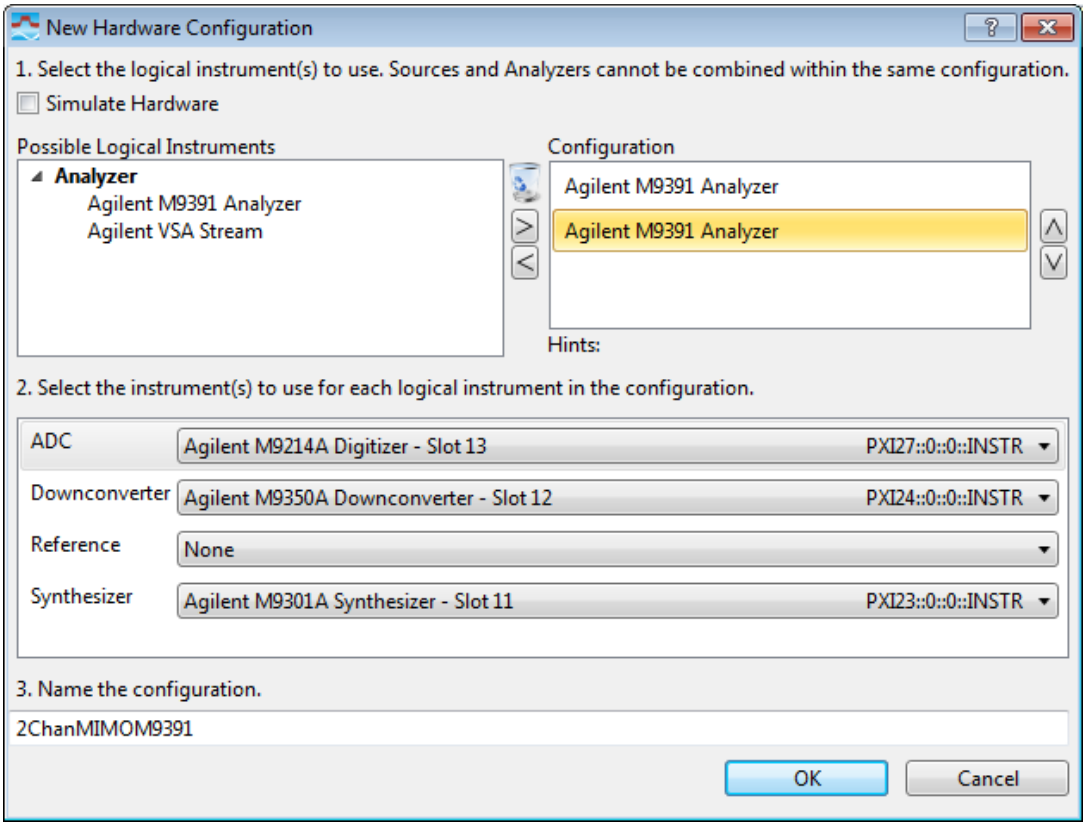
Signal Studio applications can be used to generate multi-channel waveforms up to 4 channels. The M9381A software allows the licensing for up to 4 PXI signal generators connected to a single controller to redeem a Signal Studio license simultaneously.



89600 VSA software will support up to 8 channels of M9391A VSA. When the M9391A VSA driver software is installed, it also installs the 89600 drivers (role) if 89600 VSA is already installed. If 89600 VSA software is installed after M9391A software, the 89600 drivers may be missing. In this case, you can run the 89600 integration script, which is available from the M9391A applications in the start menu.

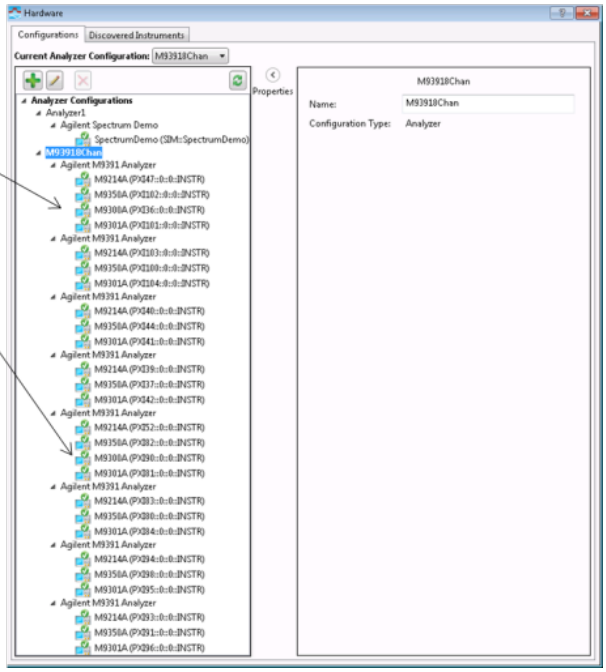


To set up the 89600 hardware configuration you will add up to 4 Keysight M9391 Analyzers to the configuration using the “New Hardware Configuration” dialog. Each of these must be populated with modules from the discovered hardware. 89600 automatically discovers any modules that could be used to make up an M9391A VSA. If you start 89600 too soon, prior to complete PXI enumeration by the operating system, you can always re-run the hardware discovery from the Hardware

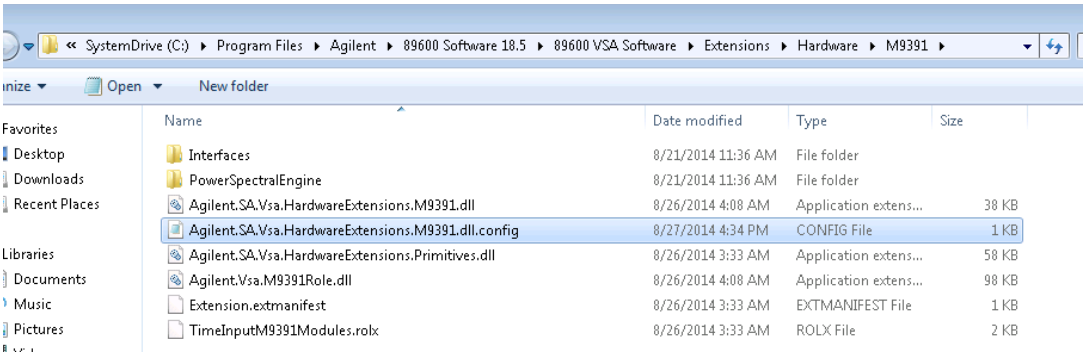


Configuration Dialog. M9391A must have a digitizer, downconverter, and synthesizer module selected.

- You should end up with one M9300A reference in each chassis



The master channel in each chassis must have a reference module selected in addition, and the other channels must not have one selected. By convention, the master channel is the first (topmost) in the list of configurations for the first chassis. The master channel for the second chassis (if present), can be at any position, but should be first among the modules for the second chassis.



Prior to 89600 release 19.0, if multi-chassis configurations are set up, a configuration file must be created which maps the analyzer channels to a set of chassis slots. This will enable the 89600 M9391 driver to correctly set up the multi-chassis synchronization. After the configuration file is placed in the hardware extension directory, for example: C:\Program Files\Keysight\89600 Software 18.7\89600 VSA

Software\Extensions\Hardware\M9391, the 89600 software must be restarted to read the configuration file.

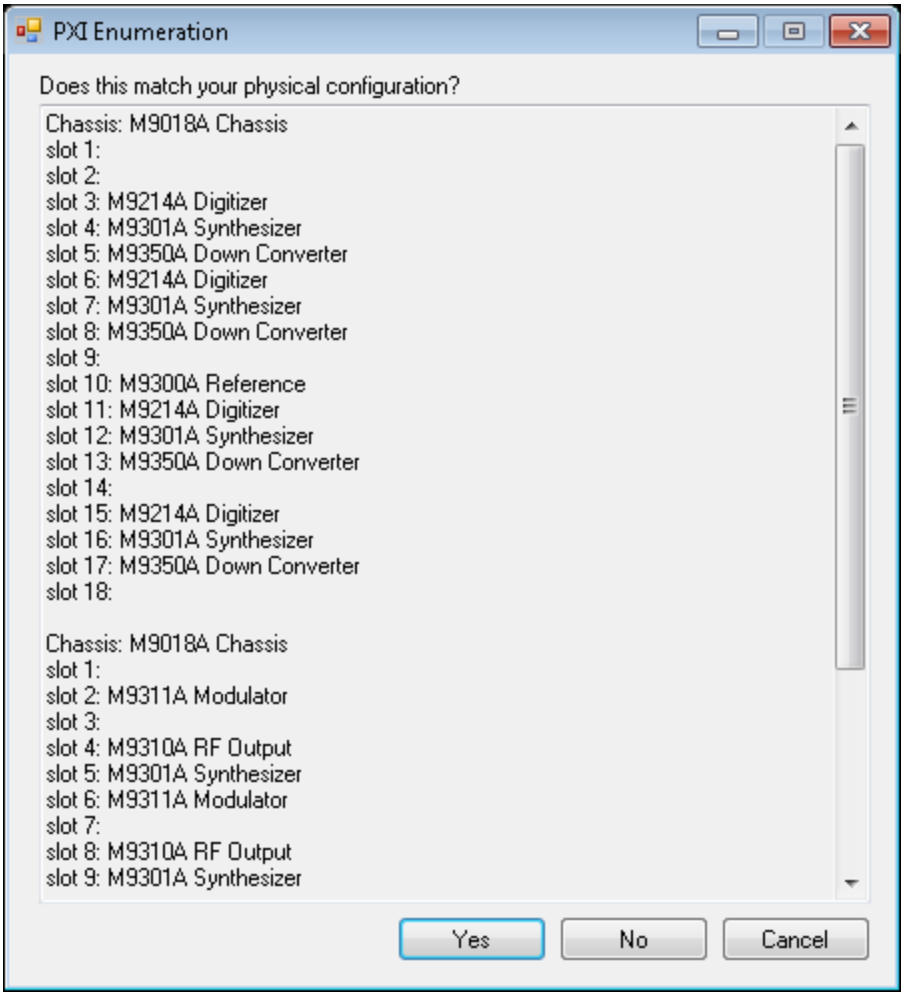
The Multi-Channel Config Utility, which will be covered later, can be used to automatically create a multi-channel M9391 configuration in 89600, including the special config file mentioned above.

Tools and Automation

This section take a look at the Tools used to configure a multichannel PXI VSG/VSA system, and the programming interfaces that can be used for automation.

PXI Module Detection

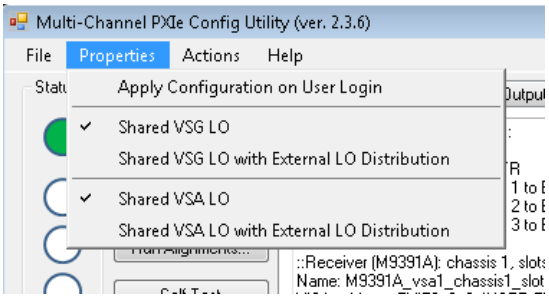
When the Config Utility is first launched, the application queries all available PXI modules in the system. If you have configured the system before, the data returned is compared against the configured system data. If the system has not been configured previously, the 'PXI Enumeration' window will be displayed to confirm that all modules have been found by the application.



Occasionally, some modules can be missing from this list. This usually means that the Keysight IO Libraries has not finished enumerating all devices. If this occurs, close the application and try again in a few minutes.

Multi-Channel Operation Properties

The multi-channel system can be configured to operate in several different ways by selecting the appropriate options in the 'Properties' menu.



By default (no option selected) the system will be configured to run with independent synthesizers (Independent LO). This means that each VSG or VSA will need to have its own synthesizer to provide a LO signal. This allows for the VSGs and VSAs to set independent center frequencies to perform tests for applications like carrier aggregation. Independent LO configured systems are not phase locked.

The Shared LO option allows the VSGs or VSAs to share a common synthesizer. Each VSG or VSA will need option 012 to enable this functionality. Shared LO systems are phase locked and can therefore be used for beamform testing. Up to 4 VSGs or VSAs can be connected directly to a M9301A synthesizer.

The Shared LO with External LO Distribution option allows for more than 4 VSGs or VSAs to share a synthesizer. This is done by connecting the M9301A synthesizer to a V2802A LO Distribution Network, which supports up to 8 VSGs or VSAs.

Generating a Configuration

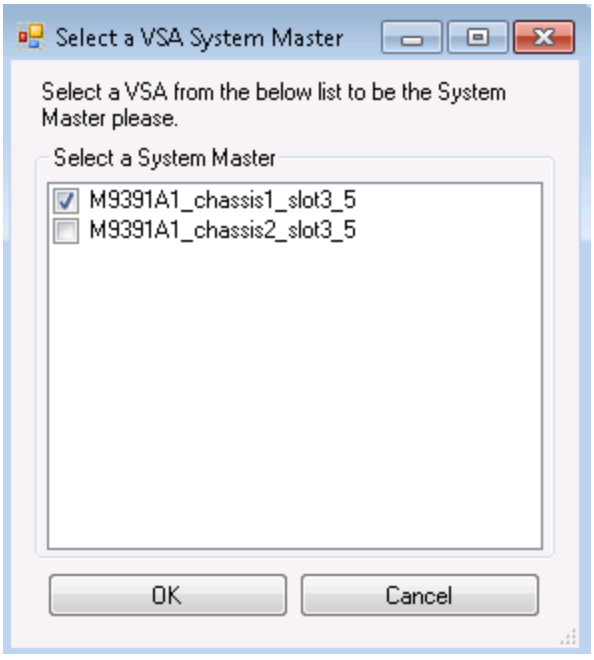
Clicking on the 'Generate Configuration...' button will begin a decision-making process for how the system will be configured. Some additional information will need to be provided by the user in order to make the correct configuration decisions.

Multi-Channel Device Selection

Though the application will find all the M9381A VSGs and M9391A VSAs in the system, there may be a need to only include a subset of the VSGs and VSAs in the multi-channel configuration. VSGs and VSAs that are not needed can be deselected in the 'Select Multi-Channel Devices' window.

System Master

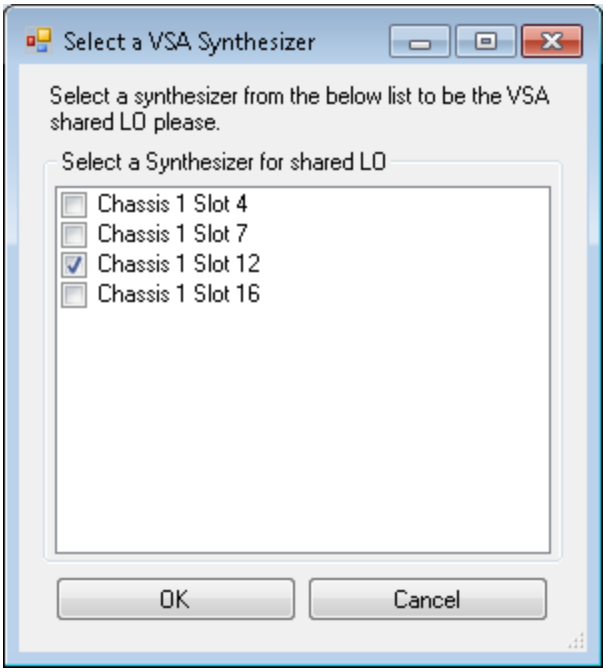
If the system contains VSGs in more than one chassis or VSAs in more than one chassis, one of the VSGs or VSAs will need to be selected to be a System Master. Any other items on the list will be considered Group Masters.



Shared Synthesizer

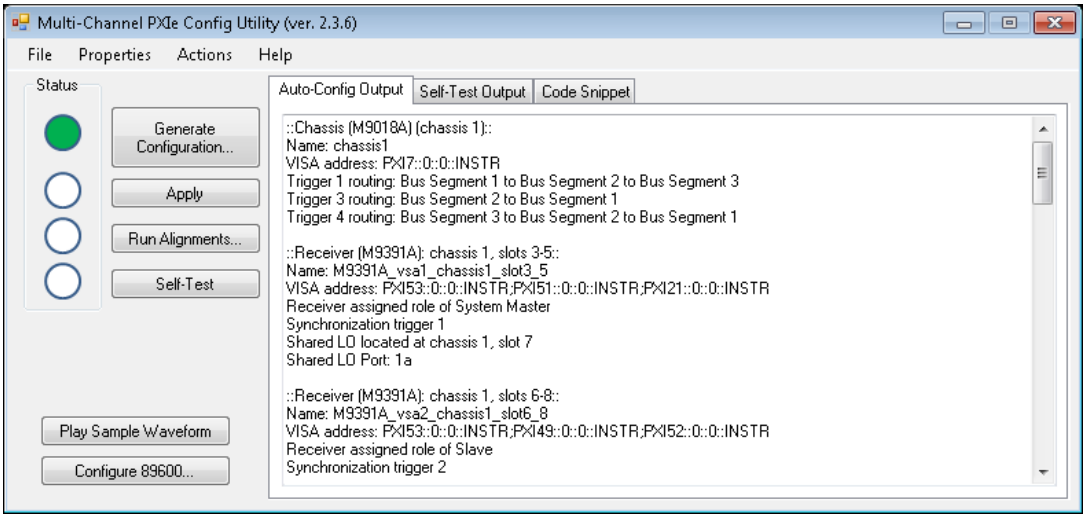
If a synthesizer is to be shared between VSGs or VSAs, but there are multiple potential synthesizers to choose from, one of the synthesizers will need to be

selected for sharing. The shared synthesizer will share its LO ports in a left-to-right ordering (the left-most channel gets LO Out 1A, the second gets 1B, and so on) when no external LO distribution network is in place.



Applying the Configuration

Generating a configuration does not apply the configuration to the system, but populates a text output of the configuration for user reference on how the system should be cabled and configured for proper operation of the system.



Clicking on the 'Apply' button will connect to the M9018A chassis and M9300A reference to make any changes necessary to operate multi-channel VSGs and VSAs. Changes are not made to the VSGs or VSAs at this stage (multi-channel VSG and VSA

settings are not persisted across sessions), but are required to be performed at run-time.

Running Alignments

The LO Level and IF Flatness alignments can be performed for the VSGs and VSAs in the system by selecting the 'Run Alignments...' button. A window will guide the user in making any additional connections for the M9391A VSAs that are required. The system should be powered on for an hour or more before running alignments.

System Self-Test

Self-test can be performed on all devices in the configuration (VSGs, VSAs, chassis, and references) by selecting the 'Self-Test' button. All settings, including those for the VSGs and VSAs, will be applied before self-test is run. Once self-test completes for each device, the self-test output will be populated into the 'Self-Test Output' tab.

Interfacing with the 89600 VSA Software

The Config Utility can create a hardware configuration in the 89600 for the VSAs in the configured system by clicking on the 'Configure 89600...' button. A name for the hardware configuration can be specified, as well as whether auto-calibrate should be enabled. If the 89600 VSA software is not currently running, it will be started before the hardware configuration is created.

Sample Waveform Playback

A simple way to verify the system is operating correctly is to connect to the VSAs in the 89600 VSA software, cable the system into a 'loopback' configuration, then click on the 'Play Sample Waveform' button. This action will connect to the VSGs, make any multi-channel configurations necessary, and then plays a simple square waveform at a 1 GHz center frequency. Rising and falling edges of the waveforms will line up if the waveform playback and acquisition were started simultaneously. You can release the VSGs and stop waveform playback by clicking the 'Stop Waveform' button.

Code Snippet

C# code is provided in the 'Code Snippet' tab to facilitate making the needed multi-channel configuration changes in custom applications. This is an important thing to include in custom applications because multi-channel VSG and VSA settings are not persisted across sessions.

Saving Aliases

Aliases are a useful way to connect to devices and recall connection settings. There are two ways to save aliases in the Config Utility, by configured name and by base name. Both are accessible in the 'Actions' menu, under 'Save Device Aliases by Configured Name' and 'Save Device Aliases by New Base Name...' respectively.

Saving Aliases by Configured Name

Each device in the configuration has a configured name, which can be seen in the 'Auto-Config Output' tab (for example a VSA might have the configured name M9391A_vsa1_chassis1_slot3_5). Saved aliases using this method will set the alias name to be the configured name. Reference module aliases are created separately from the VSG and VSA aliases.

Saving Aliases by Base Name

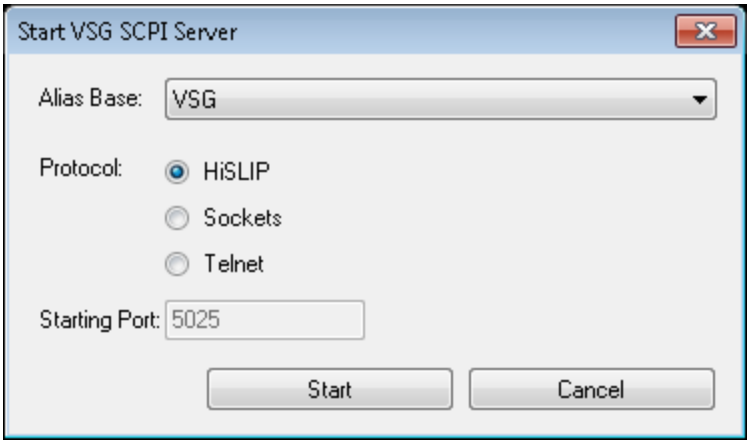
Aliases saved through this method will all have a related base name and will only be distinguishable by the channel number that is appended to the end. The format for each alias is '{base-name}-{channel number}'. For example, if there were two VSGs in the configurations, and the base name was specified as 'demo-vsg', the two aliases

saved would be ‘demo-vsg-1’ and ‘demo-vsg-2’. Reference modules are grouped together in the alias for the master device for a given chassis. Saving aliases by base name is the preferred way to save aliases in preparation to starting the VSG SCPI server.

VSG SCPI Server

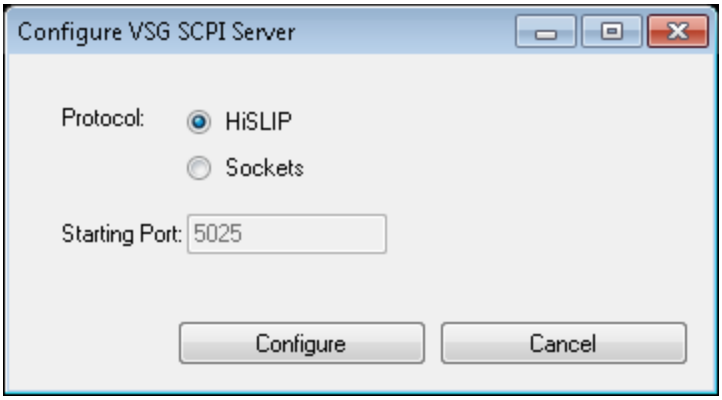
The VSG SCPI server can be started and configured based on the current configuration.

To start the SCPI service, select the ‘Start VSG SCPI Server...’ option under the ‘Actions’ menu. This will open the ‘Start VSG SCPI Server’ window.



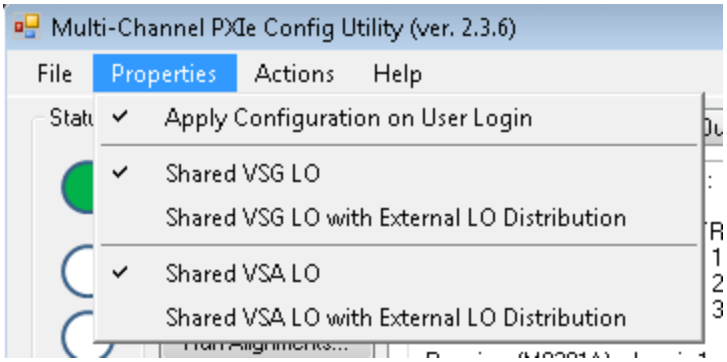
You can select an alias base name from the drop down. Only VSG base names with the required number of channels for the current configuration will be displayed. You can also select which protocol you would like to use: HiSLIP, Sockets, and Telnet. For the Sockets and Telnet options, you may also specify which starting port number you would like to use. Clicking the ‘Start’ button will launch the VSG SCPI server.

Once the SCPI server has finished launching, you can select the ‘Configure VSG SCPI Server...’ option under the ‘Actions’ menu. You can specify which protocol and starting port (Sockets only) to use in order to configure the SCPI server to match the current multi-channel configuration. Select the ‘Configure’ option to perform the operation.

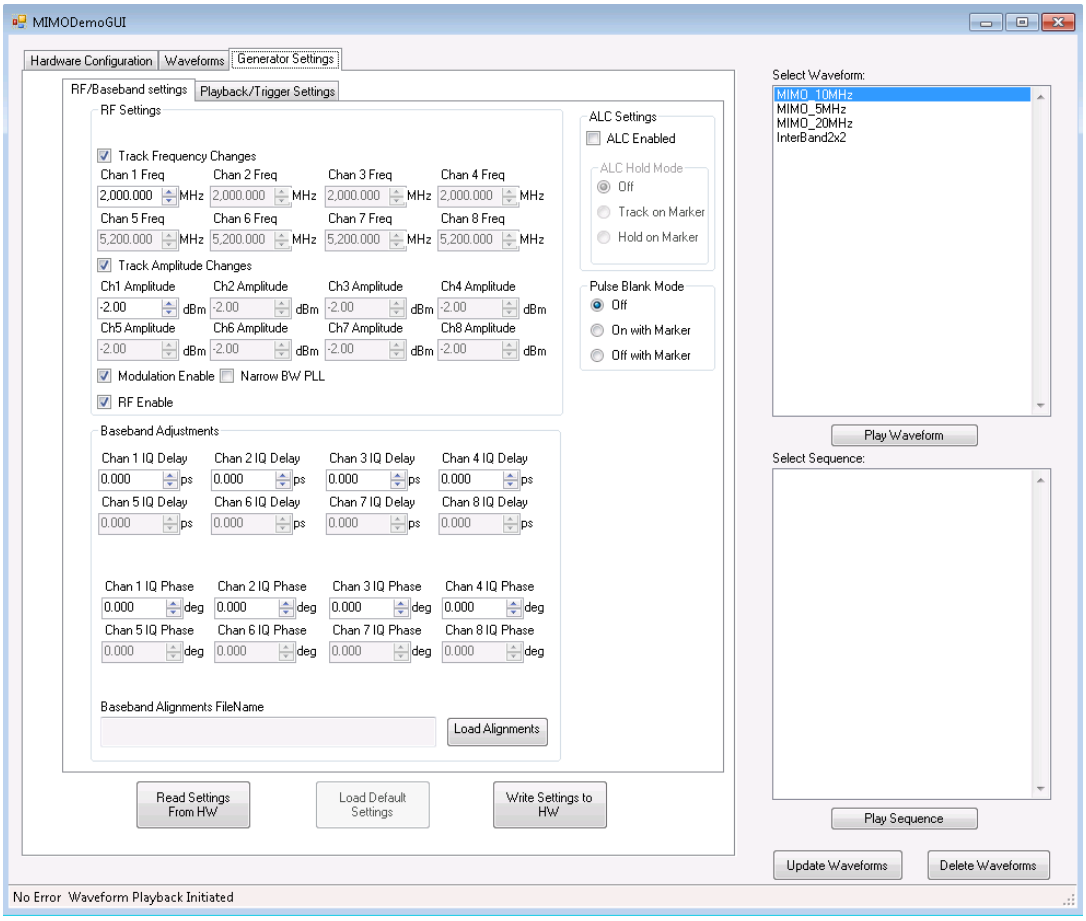


Persisting System Configuration

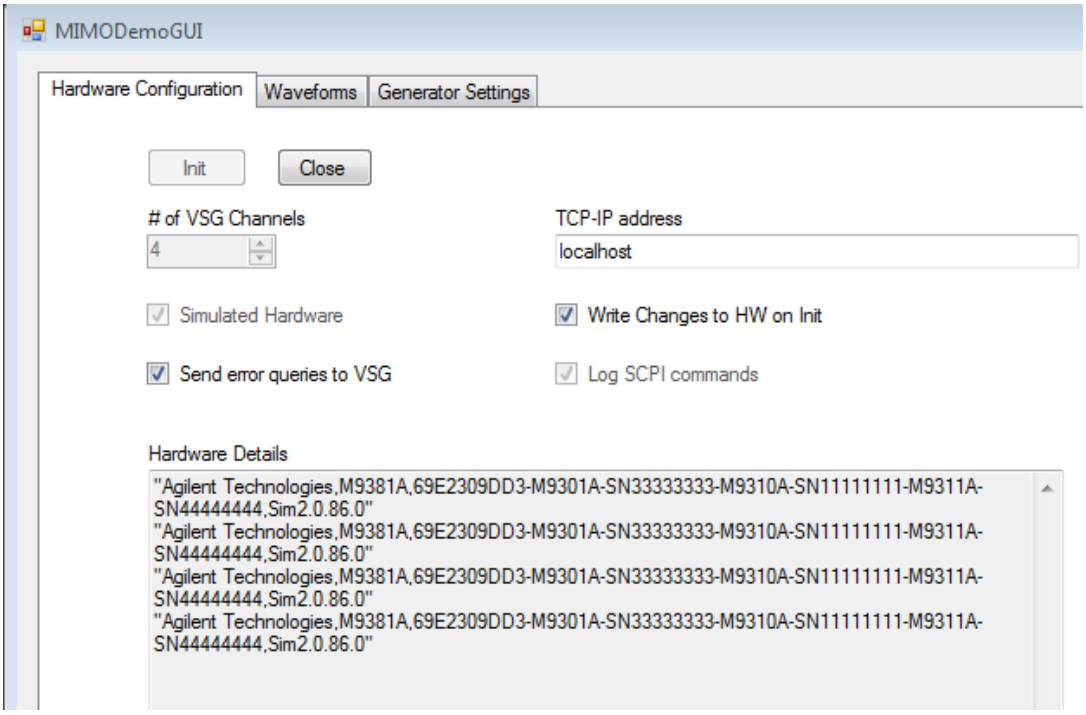
Even though chassis and reference settings persist across sessions, they do not persist across power cycles. If the system is restarted, any chassis and reference settings will be lost. To work around this issue, the Config Utility provides the capability to re-configure the system when the user logs into the system. To enable this functionality, select the 'Apply Configuration on User Login' option under the 'Properties' menu.



Multi-channel Demo Tool

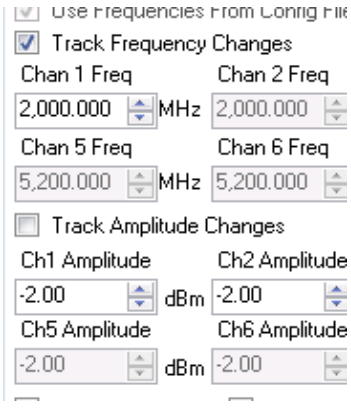


The Multi-channel Demo Tool Example Program controls up to 4 VSGs in either shared or independent LO configuration. It is a C# forms application, which uses the M9381A's SCPI interface to communicate with the multichannel VSG. Because it uses the SCPI interface, the same hardware can be used by other users or applications. For example, it is possible (for up to 2 channels currently) to load waveforms directly to the M9381A SCPI server from Signal Studio applications, and then use the Multi-channel Demo Tool to manipulate them. You can think of the tool as an example of a basic multi-channel soft front panel for the M9381A.



The Multi-channel Demo Tool resides in the same folder as the Multi-channel Config Utility. After you have run the configuration and committed the Multi-channel Config Utility, a file called Persisted.xml is created in this directory. This will be used by the Multi-channel Demo Tool to initialize the chassis backplane configuration. First, on the Hardware Configuration tab, select the correct number of channels for your system. Note that you can use the Multi-channel Config Utility to configure a smaller number of channels than your hardware supports, if needed. Next, fill in the TCPIP field with "localhost". Note that it is possible to use this tool to control VSG hardware on a remote host, but this is not currently supported, and not all functionality will operate correctly. The Multi-channel Demo Tool will connect to the hislip interfaces of the VSGs, and display their *IDN? results.

Before pressing the "Init" button, you must first ensure the M938x SCPI server is running, and that the correct number of channels is selected.



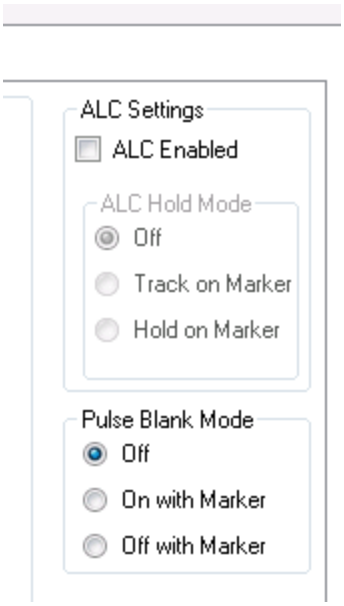
At this time, the synchronization setup will occur, but the other hardware settings will

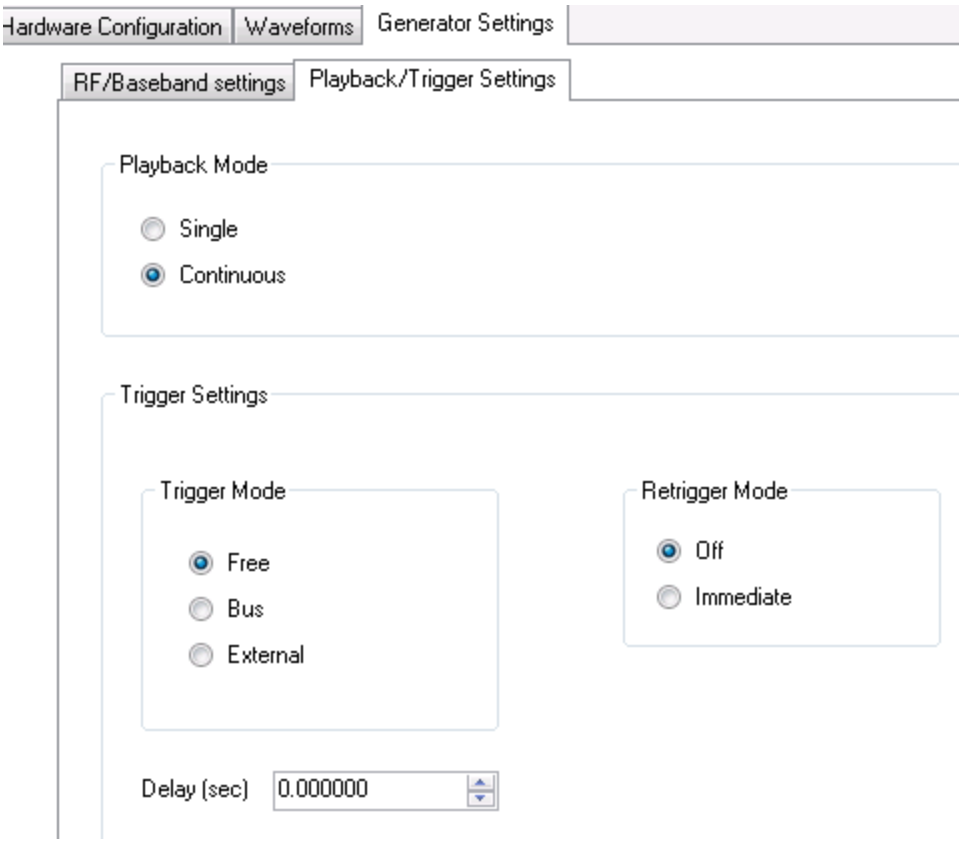
not be set on hardware yet. If you check the “Write Changes to HW on Init” checkbox, the hardware settings such as frequency and output power will be sent to hardware without pressing the “Write HW Settings” button.

You can close the connection later using the “Close” button, or simply close the window using the “X” on the window frame will also close the connection before exiting the program.

The Rx Test Settings tab contains controls for setting the RF center frequency, amplitude, and baseband timing alignment and phase alignment settings. The track frequency and amplitude buttons can be used to quickly set multiple channels to the same frequency and amplitude. Upon making any changes to these fields, the changes will immediately take place in hardware.

On the right side of the RF Settings tab are settings for the ALC mode and pulse blanking mode.

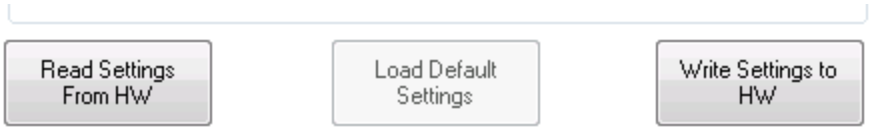


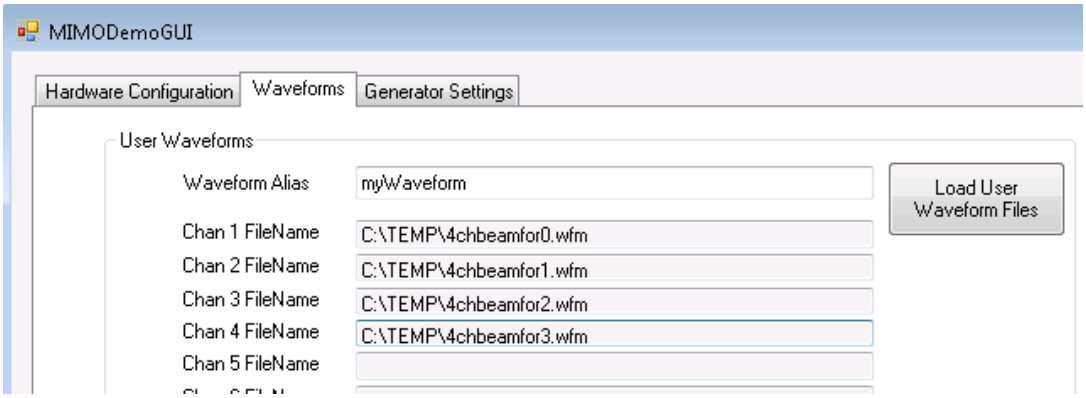


ALC settings will take effect immediately, but pulse blank mode settings will not take effect until the waveform is played again. Note that both ALC Hold and pulse blanking require a marker to be defined in the waveform header.
See the discussion on waveform header below for details.

The Playback/Trigger settings tab contains settings for playback and trigger settings. Retrigger mode will cause the waveform to immediately restart upon receipt of an additional external trigger on the front panel Trig 1 connector on the M9301A synthesizer module. Note this is only enabled for single channel currently. The main trigger mode must be set to Free when using retrigger mode.

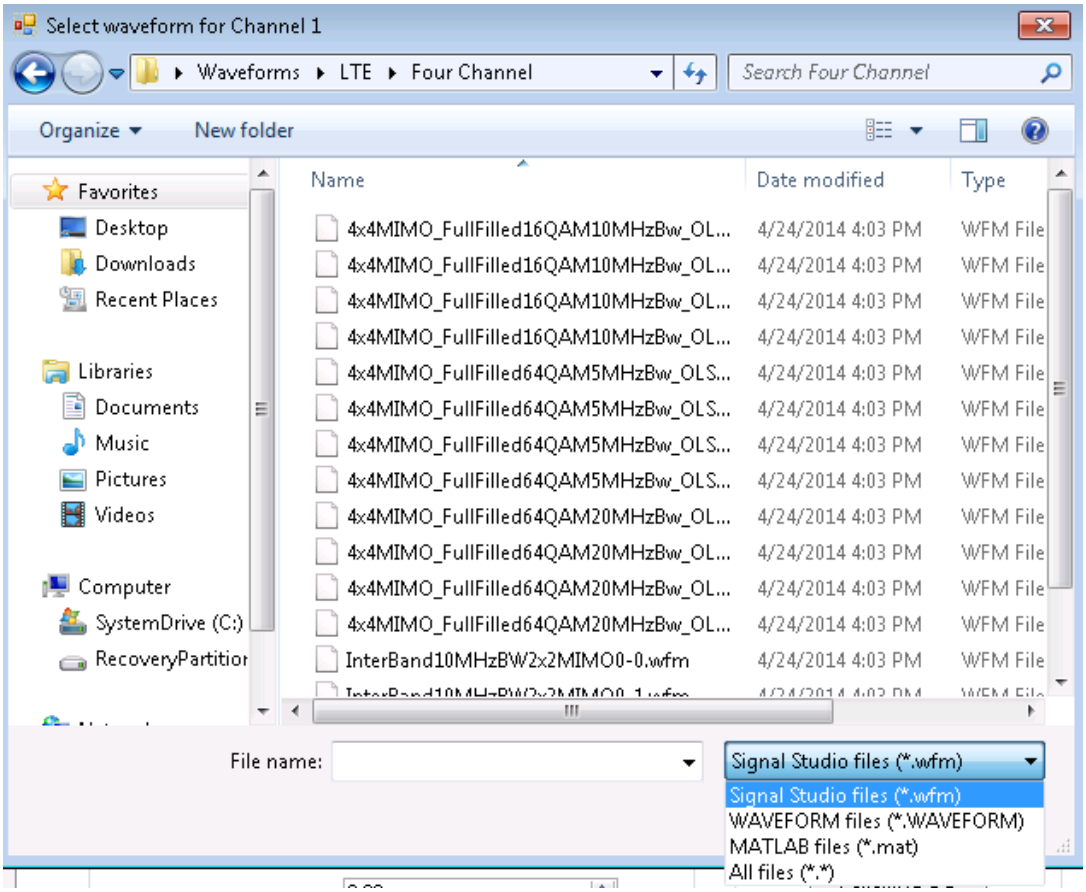
Upon startup, the settings are not automatically written to hardware. You can press the “Write Settings to HW” button to write all settings immediately to hardware, or press the “Read Settings from HW” to update the control values to the current hardware settings. This may be useful if multiple applications are controlling the hardware.





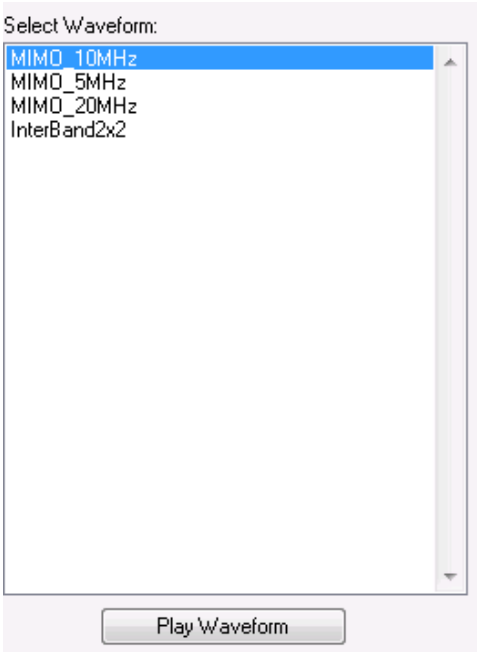
The Rx Waveforms tab lets you load individual waveforms, or load a set of waveforms from a CSV configuration file. It also allows you to override the waveform playback settings of sample rate, RMS value, and scale factor.

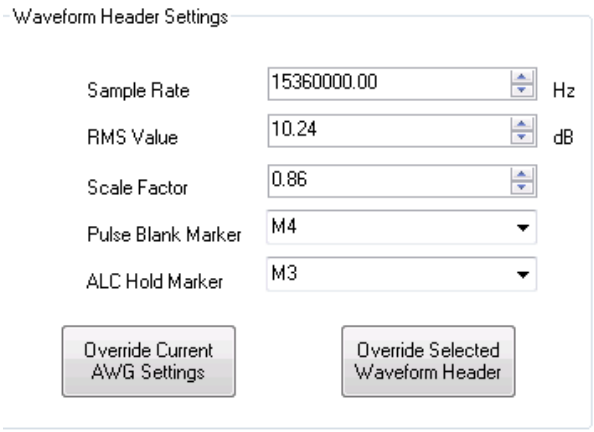
To load a single waveform into each VSG channel, first enter a name for the waveform into the Waveform Alias field, and then press the Load User Waveform Files button. A dialog will appear for each channel prompting to browse to the waveform file.



Waveform types supported include MATLAB .mat IQ data, Signal Studio .wfm, and MXG-compatible .WAVEFORM files. Consult the SCPI documentation for the M9381A's :MEM:COPY command for other supported file types. The SCPI documentation can be located on a typical installation via the Start menu, or in the filesystem here:

C:\Program Files (x86)\Keysight\M938x\Help\M938x_SCPI_Reference.chm



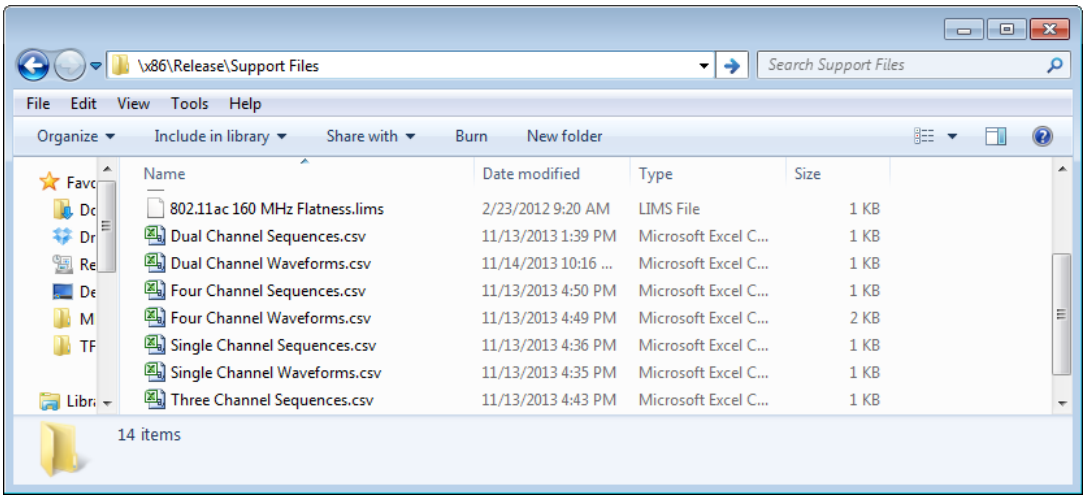


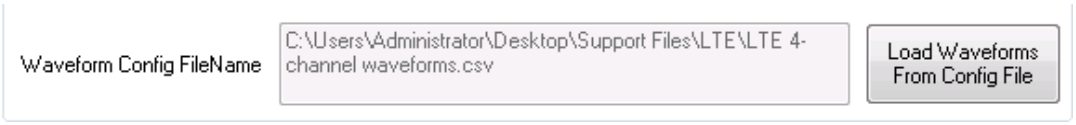
After the waveforms are selected, they will be loaded, and will appear in the waveform selection list. At this point they can be played, or modified using the Waveform Header Settings. The waveform settings of sample rate, RMS, scale factor, and markers will be updated whenever a waveform is played, and will reflect the current hardware settings. You can modify any of these parameters, and then press one of the two buttons at the bottom of this pane. Override Current AWG settings will immediately change the hardware settings on all channels to reflect the change you've made. This will not modify the waveform header information stored in the waveform catalog. Note that changing the sample rate for a multichannel VSG in this manner will result in the sample rate changing, but the waveforms will no longer be in sync. To accomplish a sample rate change and resynchronize the waveforms, use the Override Selected Waveform Header button to change the header in the

waveform catalog, and then press the Play Waveform button to reinitiate synchronized playback.

The Load Waveforms from Config File button will load a set of user-defined waveforms into ARB memory.

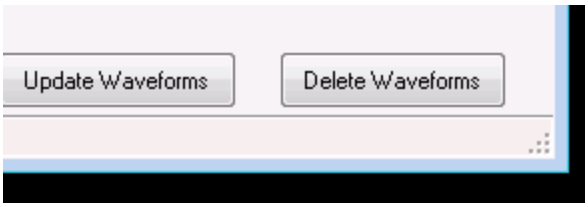
By default, the waveform and sequences will be loaded from the “XXX Channel Waveforms.csv” and files in the Support Files Directory, where XXX depends on the number of VSG channels in your hardware configuration:





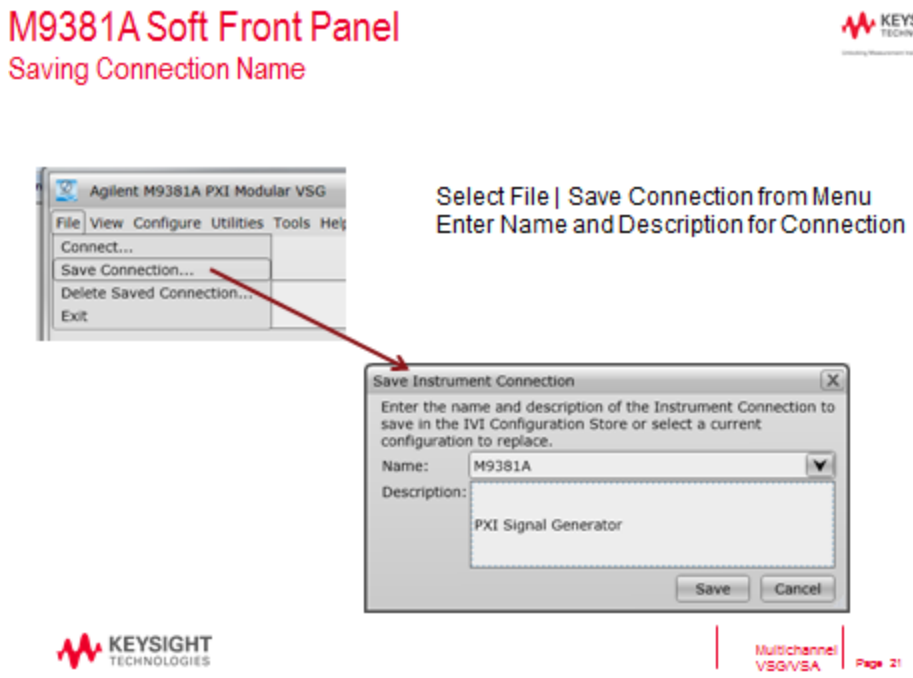
There are LTE and WLAN waveform configuration files supplied with the tool. You can also create your own custom waveform and sequence configuration files that can be loaded with the Load Waveforms from Config File button. These should be .csv files in the following format:

- Waveform file format: Each row contains the definition of one waveform. The columns are defined as follows: Name, file path (relative or absolute), waveform filename for VSG1, waveform filename for VSG2 (for 2+ channel configurations), waveform for VSG3 (optional), waveform for VSG4 (optional)



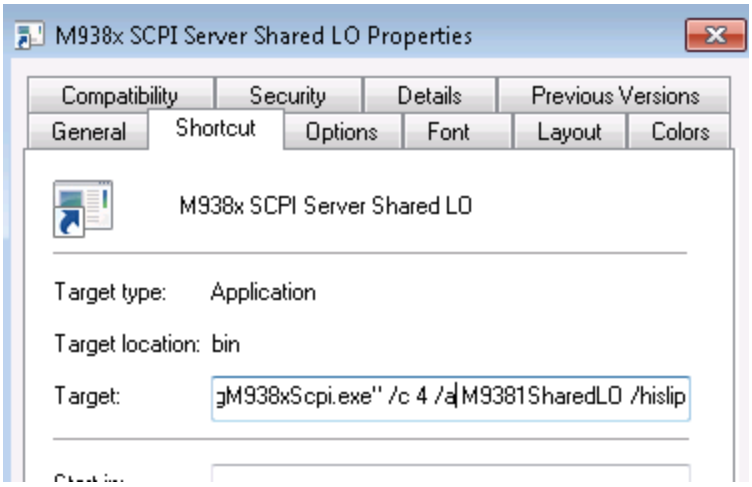
In the lower right corner of the screen, there is a button to delete all waveforms from the waveform catalog, and another to update the list of waveforms on the demo tool.

This is useful if another program is used to load waveforms via the SCPI interface, and you then wish to interact with them via the Demo Tool.



While the Multi-channel Config Utility makes many tasks easier for configuring and maintaining a multichannel M9381A VSG or M9391A VSA setup, the M9381A and M9391A SFP's are still needed for certain functions, such as setting calibration notification preferences, redeeming hardware option licenses, and performing certain calibrations. You can also use the SFP's to create IVI config store entries which represent an M9381A or M9391A instrument and its configuration settings. For example, the IF Flatness Alignment of the M9391A, which is required to be run when certain hardware configuration changes are made, such as moving the modules to different chassis slots, can be accessed via the M9391A SFP. Details of the SFP operations can be found in the M9381A and M9391A user's guides, which are installed with the drivers for those instruments.

SCPI Server



To set up the M9381A SCPI server, you first need to create IVI config store entries that share a common name, but end in -#, where # is the channel # of the VSG, beginning with 1. For example, a 2-channel VSG might have IVI config store entries of *M9381SharedLO-1* and *M9381SharedLO-2*. The first channel should be the master channel for purposes of synchronization. Note that the Multi-channel Config Utility can be used to automatically create these IVI config store entries.

After you have created the IVI config store entries, you should create a shortcut to the M938x SCPI server.exe. This can be done by navigating to the M938x SCPI server in the start menu programs folder, and selecting “send to desktop (create shortcut)” from the context menu. Right click on the shortcut, and edit the properties. Append a “c #” to the end of the target string, where # is the number of channels. You can also specify the base name of your instrument aliases you saved as IVI Config entries, specify a communications format, and more. Refer to the SCPI server documentation for more details.

When starting up the demo system, you should first launch the SCPI server using the shortcut you created. Next, you should launch the Multi-channel Demo Tool, and press “Init”. Lastly, you should start up the 89600 VSA software and select the correct hardware configuration.

Phase Coherent Alignment Tools

While the phase and baseband time stability of the M9381A VSG and M9391A VSA are very good and repeatable, there may be situations where you may wish to calibrate out any residual time and phase delta between the channels, or introduce a known delta.

For a discussion of phase coherent signal generation, see this app note:
http://literature.cdn.keysight.com/litweb/pdf/5990-5442EN.pdf

To correct time and phase for the M9381A VSG and M9391A VSA, there is a BasebandDelay and BasebandPhase property, which is performed digitally after making the change and applying the correction.

API

VSG IVI and SCPI examples:

```
IAgM938xEx2 M9381VSG;
M9381VSG.Modulation3.BasebandDelay = 10e-9; // 10 ns delay
M9381VSG.Modulation3.BasebandPhase = 1.0; // 1 degree phase rotation
M9381VSG.Apply();
```

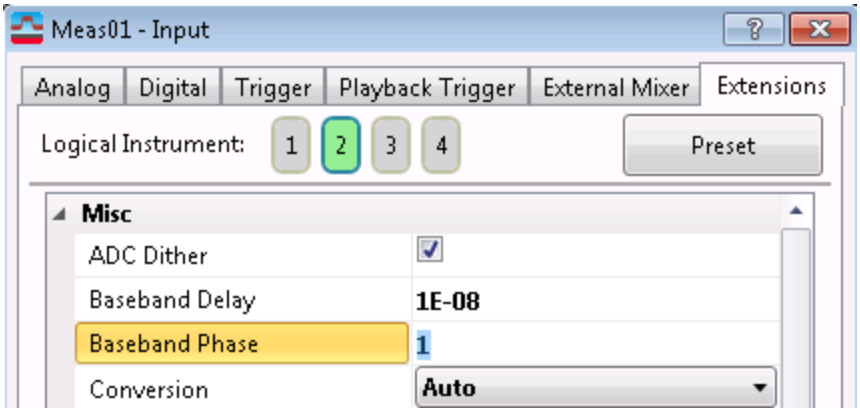
Or for SCPI interface:

```
:DM:IQAD ON // Must enable IQ Adjustment
:DM:IQAD:DEL 10.0 // delay in ns
:DM:IQAD:PHAS 20.0 // delay in degrees
```

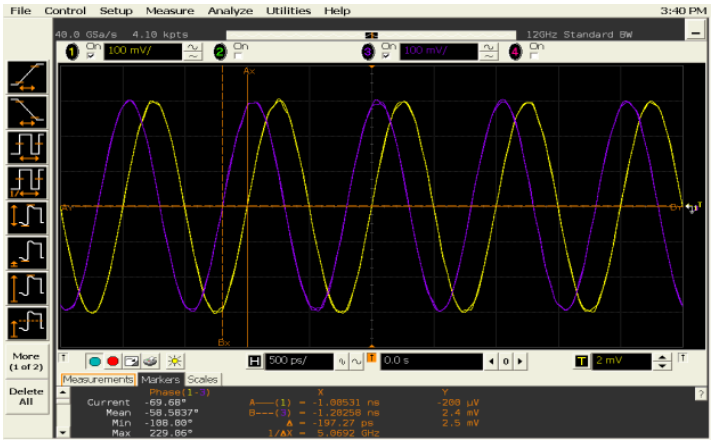
VSA IVI example:

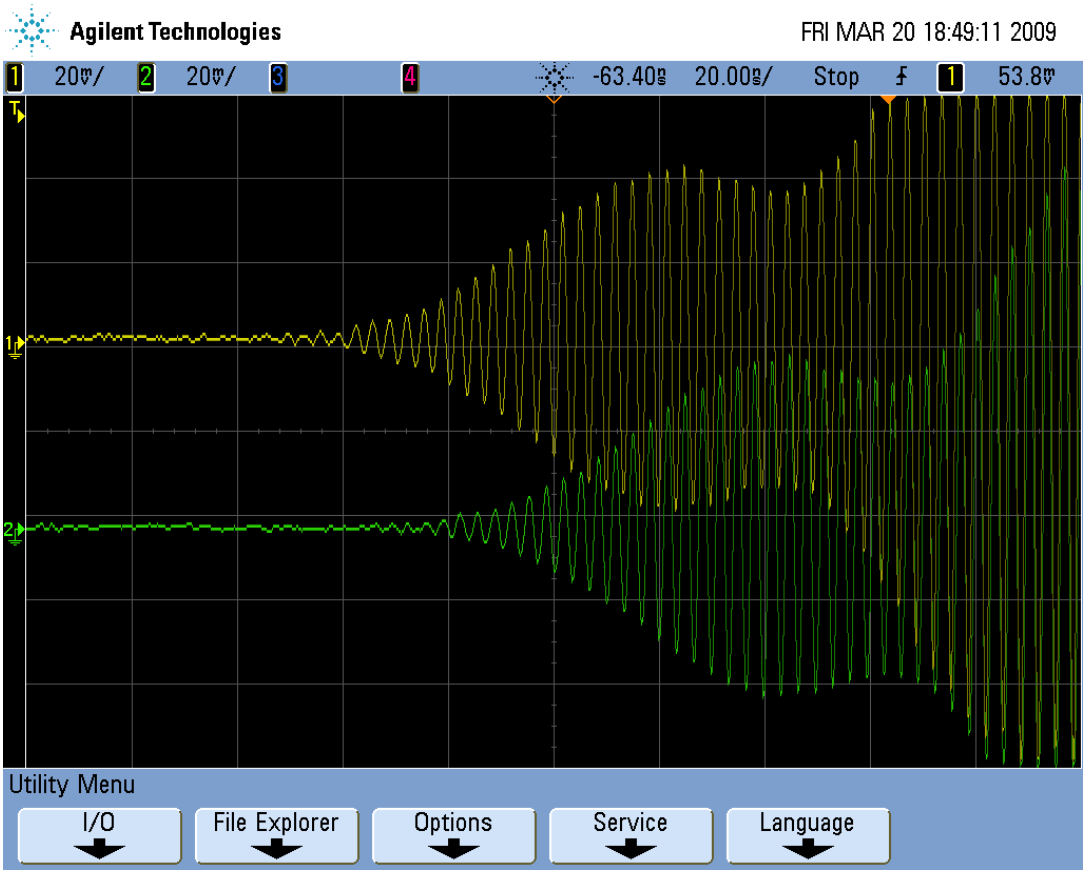
```
IAgM9391Ex2 M9391VSA;
M9391VSA.IQAcquisition2.OffsetDelay = 10e-9; // 10 ns delay
M9391VSA.IQAcquisition2.OffsetPhase = 1.0; // 1 degree phase rotation
M9391VSA.Apply();
```

The delay and phase adjustments are also exposed in the input extensions in the 89600 VSA software for the M9391A VSA. This can be set manually, or programmatically via the 89600 VSA .NET API.



Manually measuring VSG or VSA timing and phase alignment

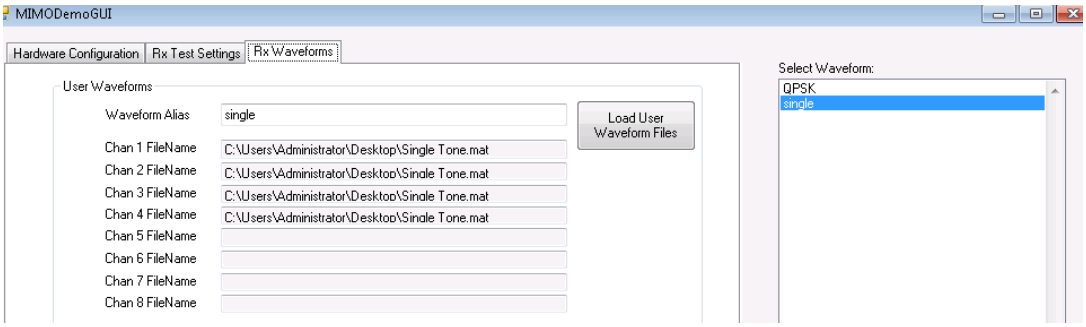


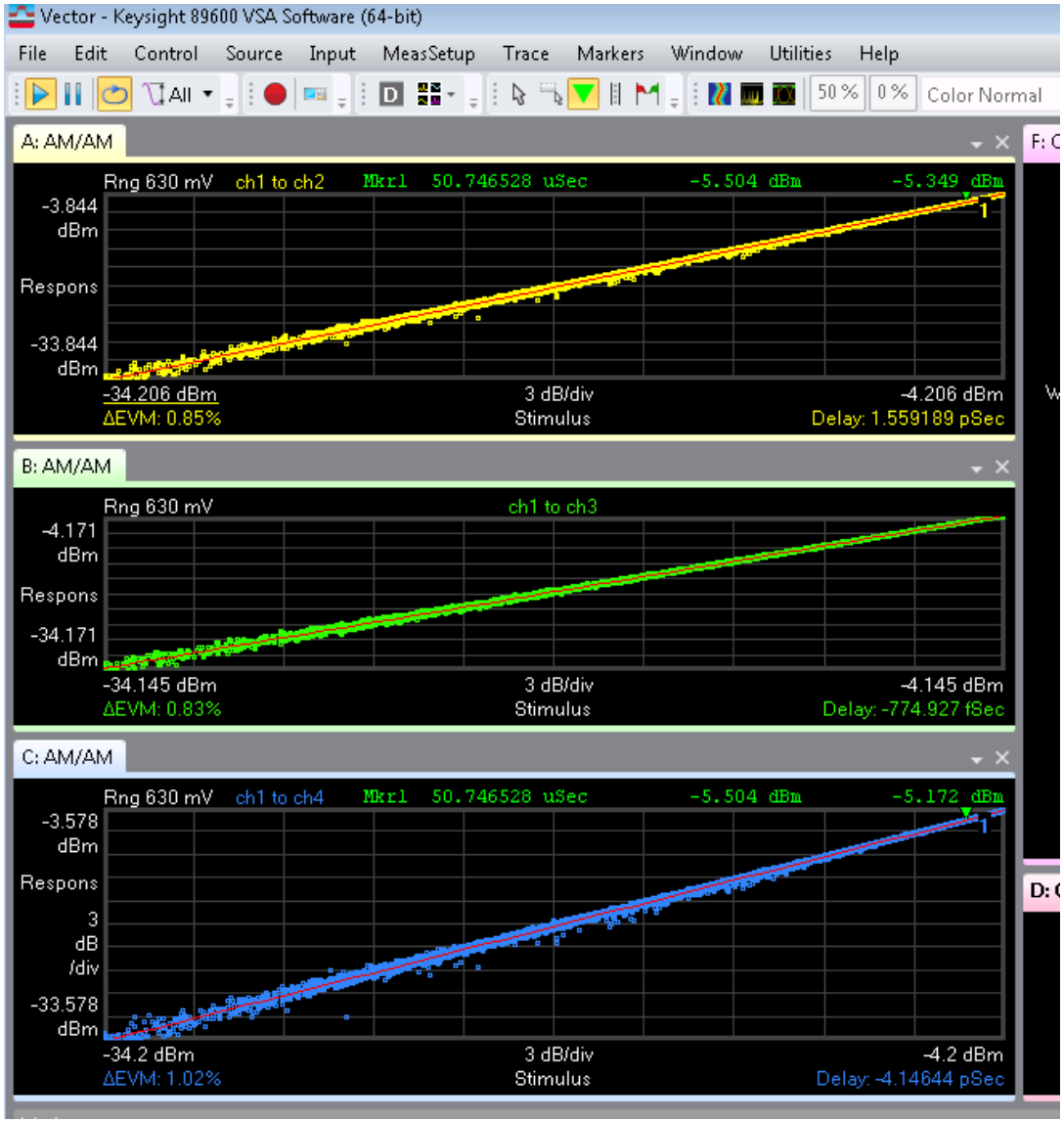


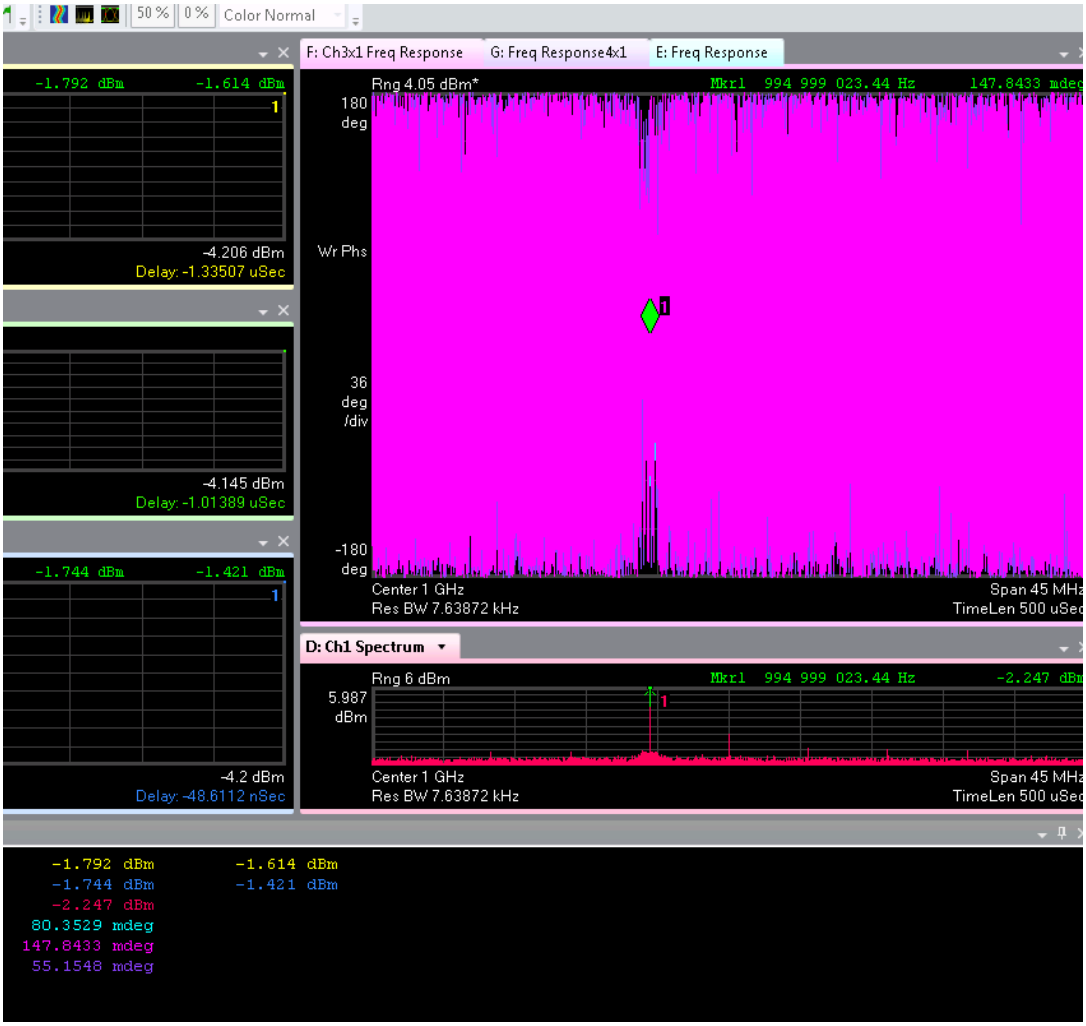
There are a number of techniques that can be used to measure the channel to channel alignment. To measure the alignment of multiple VSGs, a wide bandwidth oscilloscope can be used. The channel to channel alignment of a scope should be very good, so this technique may produce the best results. It is also possible to use a single VSG with a splitter to align a multi-channel VSA, and then use the aligned VSA channels to measure the alignment of the multi-channel VSG. With this technique, there may be more uncertainty on the VSG alignment, because you are adding the uncertainty of the VSA alignment to the measurements of the VSGs. The screen

shots at right show the use of an oscilloscope to measure the baseband timing alignment, and the phase alignment.

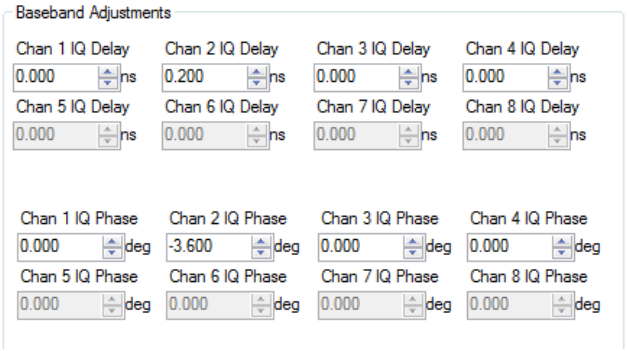
Another technique to measure the VSG alignment, also using an oscilloscope, is to use the oscilloscope with 89600 VSA software, and measure the delay and phase alignment in this way. The delay can be measured by playing the same wideband modulated waveform on all VSG channels, and using an AM/AM cross-channel measurement to calculate delay. After the timing skew has been removed, phase can be measured by playing a waveform that has CW frequency components, such as a multi-tone waveform, and using cross-channel frequency response's phase component to measure the relative phase at the tone.




Vector - Keysight 89600 VSA Software (64-bit)
File Edit Control Source Input MeasSetup Trace Markers Window Utilities Help
All
50 %
0 %
Color Normal
A: AM/AM
Rng 630 mV ch1 to ch2 Mkr1 50.746528 uSec -5.504 dBm -5.349 dBm
-3.844 dBm
Respons
-33.844 dBm
-34.206 dBm
3 dB/div
-4.206 dBm
ΔEVM: 0.85%
Stimulus
Delay: 1.559189 pSec
B: AM/AM
Rng 630 mV ch1 to ch3
-4.171 dBm
Respons
-34.171 dBm
-34.145 dBm
3 dB/div
-4.145 dBm
ΔEVM: 0.83%
Stimulus
Delay: -774.927 fSec
C: AM/AM
Rng 630 mV ch1 to ch4 Mkr1 50.746528 uSec -5.504 dBm -5.172 dBm
-3.578 dBm
Respons
3 dB /div
-33.578 dBm
-34.2 dBm
3 dB/div
-4.2 dBm
ΔEVM: 1.02%
Stimulus
Delay: -4.14644 pSec

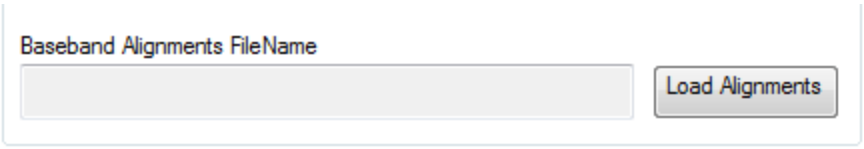


Measuring phase (left) and delay (right) using 89600 VSA Software



After measuring the delay and phase, the Multi-channel Demo Tool provides two

mechanisms for adjusting the channel to channel alignment. On the Rx Test Settings tab, there is a control for each channel, which will immediately adjust the delay or phase when modified.



If you have aligned several frequencies, you can create a CSV file which contains the adjustments, and import that into the Multi-channel Demo Tool. The adjustments will be entered into a dictionary of adjustments, keyed off frequency. Whenever you change the center frequency using the Multi-channel Demo Tool, it will automatically apply the appropriate correction from the dictionary.

	A	B	C	D	E	F	G	H	I
1	Center Frequency (Hz)	Sample Rate (Hz)	Amplitude (dBm)	Channel 1 Tim	Channel 1 Pha	Channel 1 Magnitud	Channel 2 Time Adjustment (ps)	Channel 2 Phase Adjustment (deg)	Channel 2 Magnitude Adjustment (dB)
2	1000000000	15360000	-5	0	0	0	82.0067110856	9.4475998417	0.3950385599
3	2100000000	15360000	-5	0	0	0	71.7522342445	7.9727749848	0.2537592242
4	3000000000	15360000	-5	0	0	0	19.4775295329	22.2541827873	0.2264852395

Alignments .csv file format

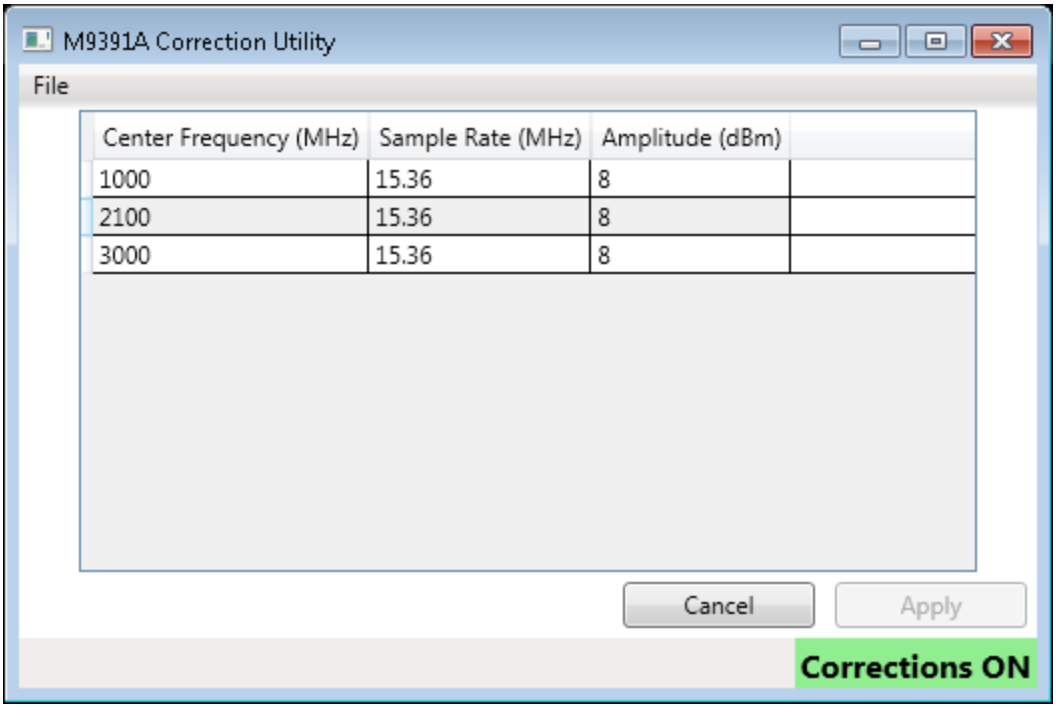
The inverse technique can be used to align the channels of the VSA, by playing a wideband modulated signal on one VSG, splitting it and connecting to the channels of a multi-channel M9391A VSA. Proceed by measuring delay and phase with 89600 VSA software connected to the M9391A VSA using the same technique as above.

M9391A Correction Utility

Select the M9391A Correction Utility in the path Start >All Programs > Keysight > Multi-Channel Tools

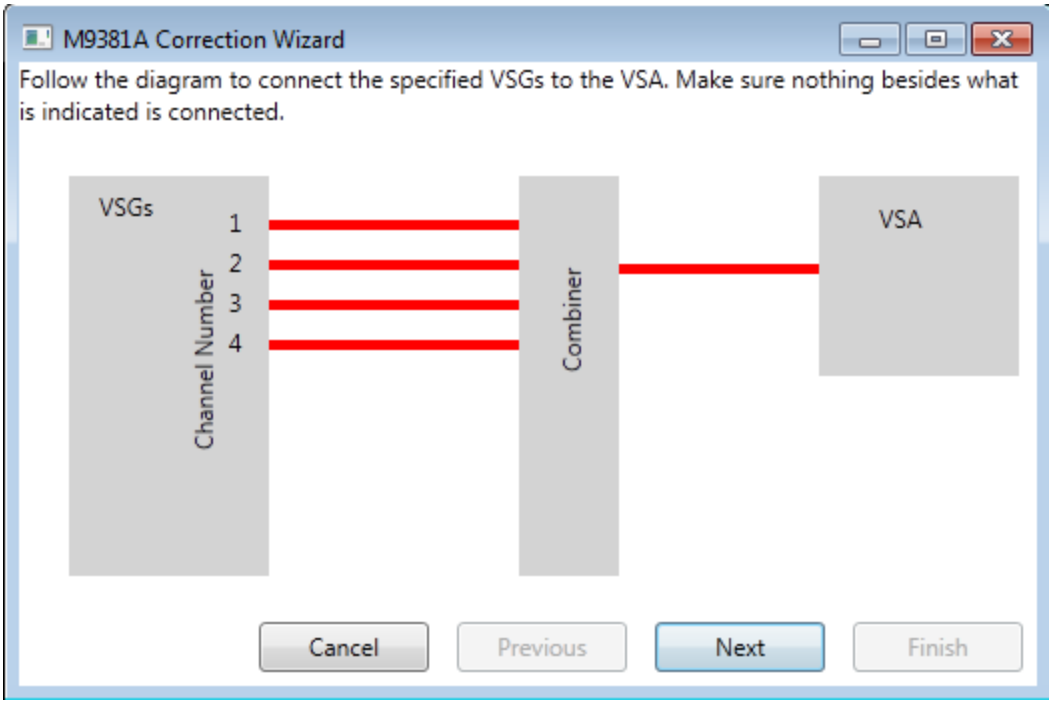
The M9391A Correction Utility measures the timing and phase delta between up to 8 channels of M9391A using a splitter with the input generated from a single channel VSG. Currently the M9381A and the N5182 are both supported via the SCPI interface (HiSLIP or Socket) for generating the test signal. The M9391As are supported through the IVI driver or the 89600 VSA software. After hardware connections are established, you may enter any number of bands, comprised of center frequency, sample rate, and amplitude (range). After these are entered, you will be prompted to

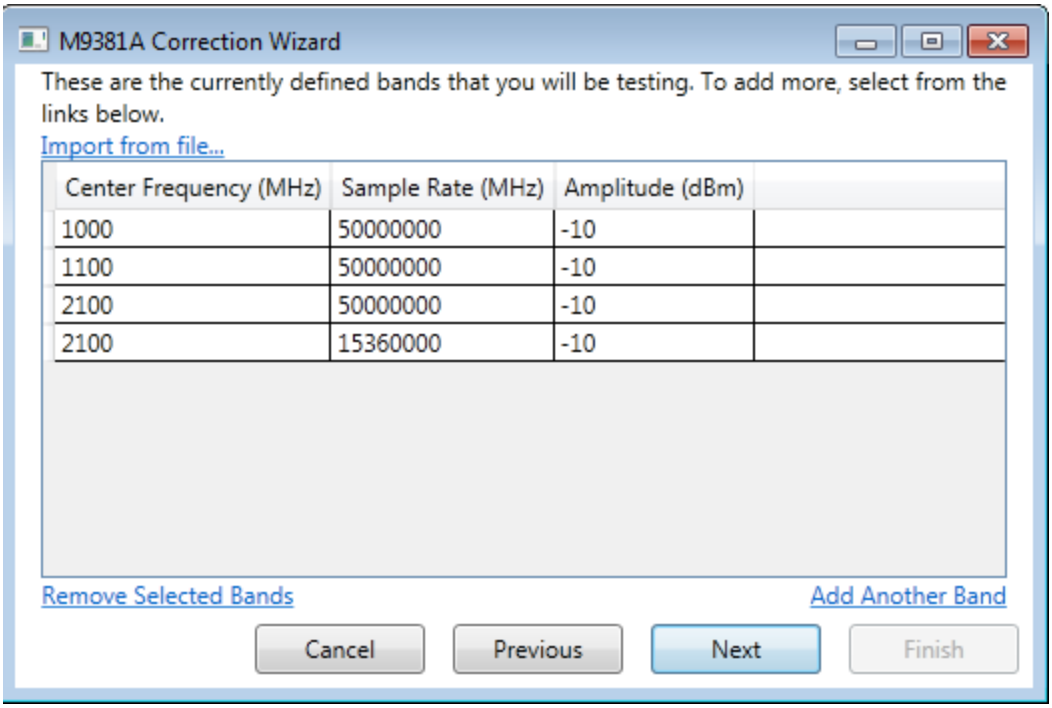
connect the VSA inputs to the power divider, and the divider to the VSG output. When the measurements are complete, you can save the corrections to a file. This file can be imported into the M9391A Correction Utility at a later time to apply corrections directly into the 89600 VSA software.



M9381A Correction Utility

Select the M9381A Correction Utility in the path Start >All Programs > Keysight > Multi-Channel Tools





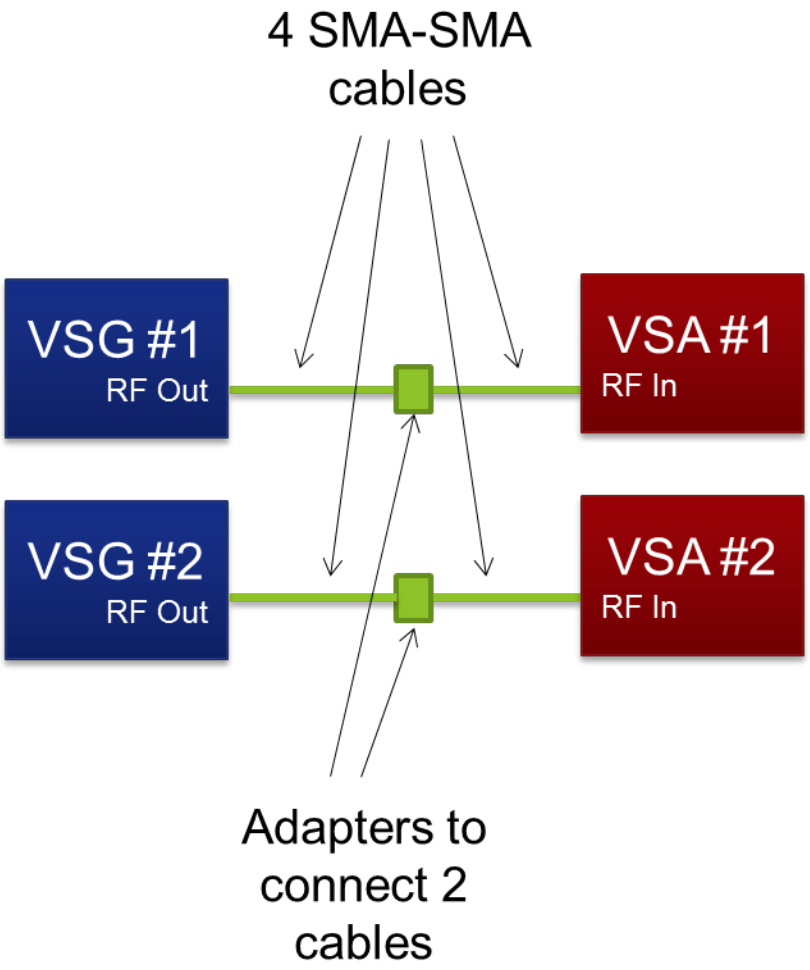
The M9381A Correction Utility measures the timing and phase delta between up to 8 channels of M9381A using a combiner with the output fed into a single channel VSA. Currently an M9391A analyzer is supported via the IVI driver, or an analyzer connected to the 89600 VSA software. The software connects to the M9381A VSGs via a running SCPI server, over hislip connections. After hardware connections are

established, you may enter any number of bands, comprised of center frequency, sample rate, and output power (amplitude). After these are entered, you will be prompted to connect the VSG outputs to the power combiner, and the combiner to the VSA RF input. When the measurements are complete, you can save the corrections to a file, which can be imported into the Multi-channel Demo Tool.

Correction Suggestions

When performing corrections, it is important to keep the following in mind.

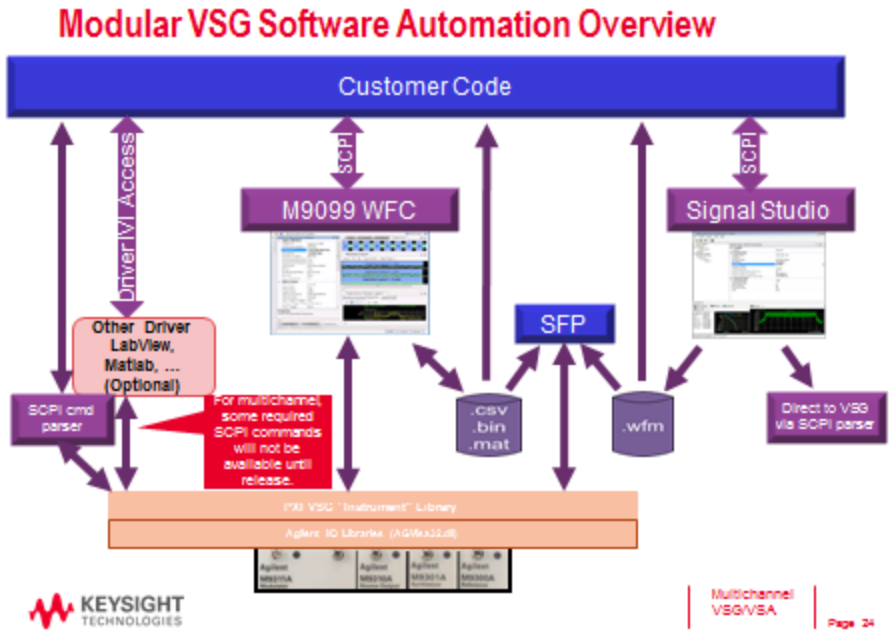
- Splitter/Combiner Quality – It is important to use a good splitter that matches the application you want to correct. You will want to use a splitter/combiner with ±2 degrees phase tracking, 0.25 dB amplitude tracking, and ranges from DC to 6 GHz. The Keysight 11636B Power Divider is suggested.
- Include 6 dB Attenuators – Adding 6 dB attenuators to each of the legs of the splitter/combiner will decrease VSWR interference. The Keysight 6 dB 8493A Attenuator is suggested.
- Cables – It is important to remember that the RF cables used when generating corrections are included in the correction values. If you do not wish cables to interfere with these measurements, matched cables will need to be used. Otherwise, your correction is only valid when using the VSG/VSA with the cable that was used to generate corrections. Furthermore, it is important to avoid double-counting your cables when generating corrections (once for the VSG, then again for the VSA). For correction verification, we suggest the following cabling scheme to avoid this issue.

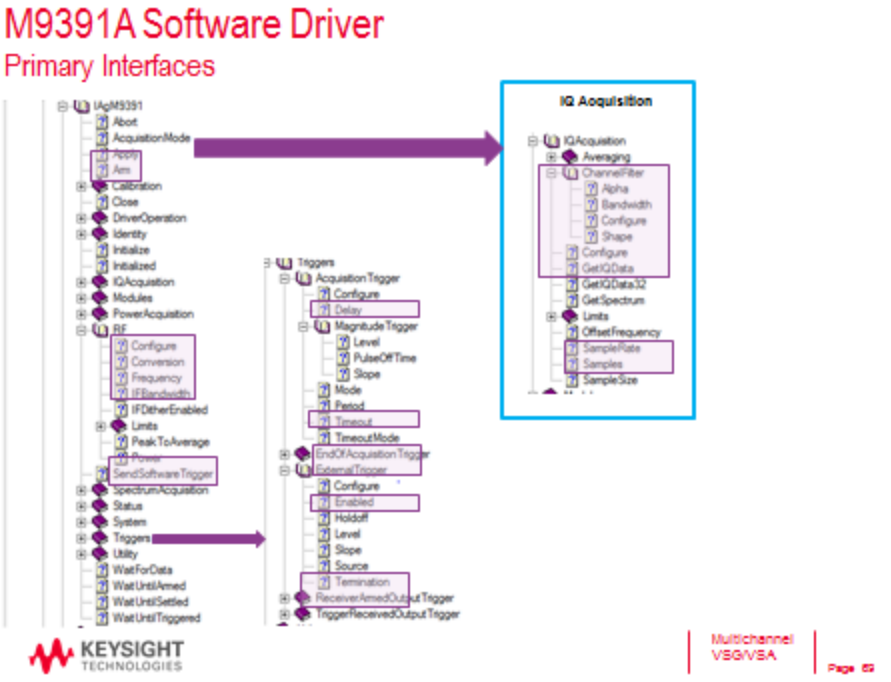


- Shared Reference – Because corrections depend on very precise timing, it is important that your devices being corrected and the device assisting correction (for example, a set of M9391As being corrected by an MXG) share a common reference signal. Both the MXG and the M9300A have Ref In and 10 MHz out ports that can be used for this purpose. Please note that the M9300A Reference must be manually configured to lock to an external reference from the SFP.

APIs

This will be only a brief overview of the APIs, and some of the key details needed for multichannel. For more details, please refer to the M938x SCPI interface documentation, M938x IVI documentation, and M9381A/M9391A programming guide.

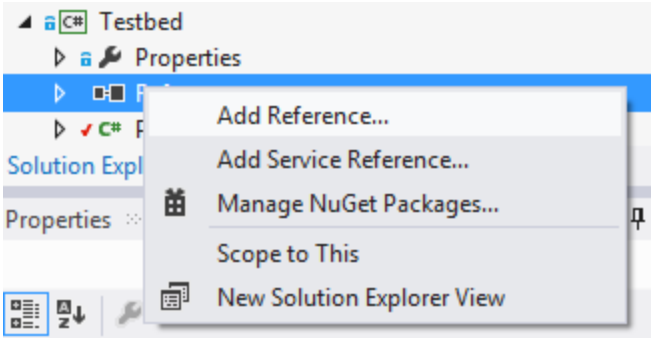




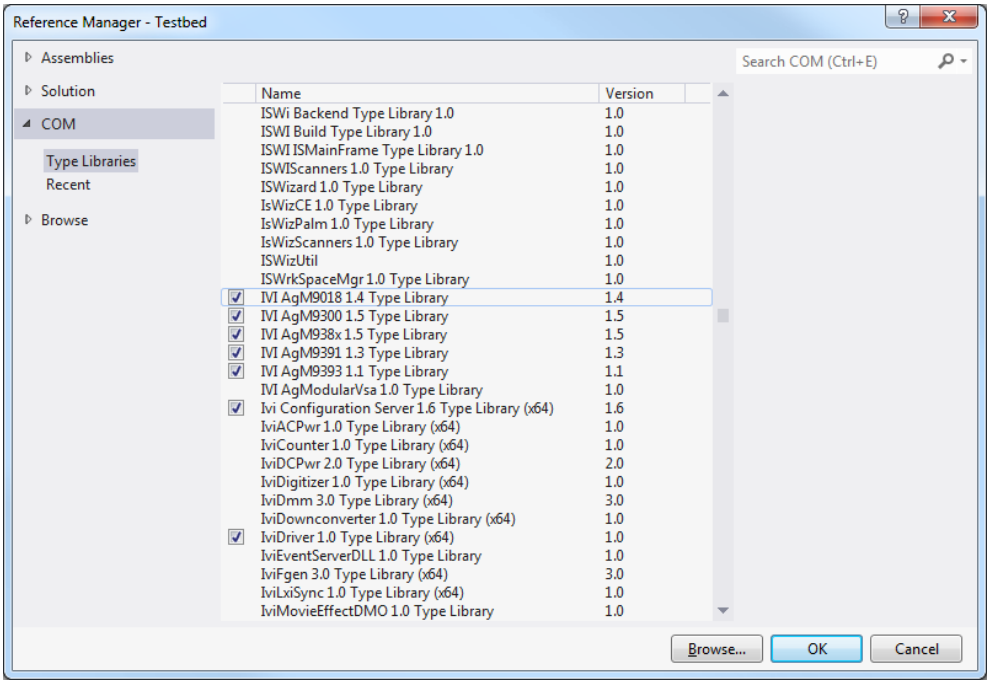
Programming Environment Setup

Perform the following steps in order to setup your environment to access the libraries necessary to do your development.

1. Create a new C# project in Visual Studio
2. Right-Click on the project's References Tree-Item and select Add Reference...



3. Select the COM – Type Libraries



4. Select the following libraries
    a. IVI AgM9018 Type Library
    b. IVI AgM9300 Type Library
    c. IVI AgM938x Type Library
    d. IVI AgM9391 Type Library
5. At the top of your .cs file, make sure you add the following lines

```
using Agilent.AgM9018.Interop;
using Agilent.AgM9300.Interop;
using Agilent.AgM938x.Interop;
using Agilent.AgM9391.Interop;
```

M9018A IVI API

You will need to reconfigure the M9018A's backplane trigger bus settings in order to allow the trigger signals from the different channels in the MIMO configuration to reach their destinations. This can also be handled by the Multi-Channel Config Utility.

```
M9018A.TriggerBus.Connect(1, AgM9018TrigBusEnum.AgM9018TrigBus1To2);
M9018A.TriggerBus.Connect(2, AgM9018TrigBusEnum.AgM9018TrigBus2To1);
```

M9381A IVI API

Initialization for Shared LO

Initialization in a Shared LO configuration requires some special driver setup parameters. ShareSynthesizerVisaSession should be set to true, SharedSynthesizerRole should be set to either "master" or "slave" (the default is master), and SynthesizerOutputPort should be set to 1a, 1b, 2a, or 2b (the default is 1a).

```
//Initialize with Shared LO
M9381A_SM.Initialize("M9381A_SM", false, false,
    "DriverSetup= ShareSynthesizerVisaSession=true"); // master and 1a are
defaults
M9381A_S1.Initialize("M9381A_S1", false, false,
    "DriverSetup=
ShareSynthesizerVisaSession=true,SharedSynthesizerRole=slave,SynthesizerOutpu
tPort=1b");
M9381A_S2.Initialize("M9381A_S2", false, false,
    "DriverSetup=
ShareSynthesizerVisaSession=true,SharedSynthesizerRole=slave,SynthesizerOutpu
tPort=2a");
M9381A_S3.Initialize("M9381A_S3", false, false,
    "DriverSetup=
ShareSynthesizerVisaSession=true,SharedSynthesizerRole=slave,SynthesizerOutpu
tPort=2b");
```

AddHint Method

IVI

The AddHint method informs the M9381A VSG to use trigger lines besides the defaults.

```
//Defaults to Trigger 6
M9381A.System.PXIResources.AddHint("M9301A", "M9311A", "EXTERNAL TRIGGER",
    AgM938xPXIResourceTypeEnum.AgM938xPXIResourceTypeTTL_TRIGGER,
    AgM938xPXIResourcesEnum.AgM938xPXIResourcesTTL_TRIGGER_4);

//Defaults to Trigger 7
M9381A.System.PXIResources.AddHint("M9311A", "M9310A", "ALC TRIGGER",
    AgM938xPXIResourceTypeEnum.AgM938xPXIResourceTypeTTL_TRIGGER,
    AgM938xPXIResourcesEnum.AgM938xPXIResourcesTTL_TRIGGER_5);

M9381A.Apply();
```

SCPI

These can also be set through SCPI commands.

```
:SOURce:RADio:ARB:TRIGger:SOURce:EXTernal:ROUTing PXI4
SOURce:POWer:ALC:TRIGger:SOURce PXI5
```

InitializeSynchronizationClocks Method

IVI

The InitializeSynchronizationClocks method tells the source to use SyncRef10. This should be called after the reference has been configured to drive the 10 MHz Backplane clock.

```
//Configure to use SyncRef10
M9381A.MultiChannelSync.InitializeSynchronizationClocks();
```

SCPI

```
:SOURce:RADio:ARB:MBSync:INITialize
```

Role Setup

There are 3 different roles that the M9381A can have in a MIMO configuration:

- System Master
  - There is only one system master VSG in the entire system. It takes the place of what would have been the Group Master in one of the VSG chassis.
- Group Master
  - Each chassis needs exactly one Group Master (except for the chassis with the System Master, as the System Master replaces the Group Master in its chassis). The Group Master defaults to the left-most VSG in a chassis.
- Slave
  - All other VSGs are slaves.

Slaves communicate with their Group Master, who in turn communicates with the System Master in order to coordinate the complete system.

IVI

```
//Only one channel should be assigned as System Master.
M9381A_SM.MultiChannelSync.SynchronizationRole =
    AgM938xMultiChannelSyncRoleEnum.AgM938xMultiChannelSyncRoleSystemMaster;

//Each chassis needs one master, either System Master or Group Master.
M9381A_GM.MultiChannelSync.SynchronizationRole =
    AgM938xMultiChannelSyncRoleEnum.AgM938xMultiChannelSyncRoleGroupMaster;

//All other channels should be marked Slave
M9381A_S1.MultiChannelSync.SynchronizationRole =
    AgM938xMultiChannelSyncRoleEnum.AgM938xMultiChannelSyncRoleSlave;
```

```
M9381A_S2.MultiChannelSync.SynchronizationRole =
    AgM938xMultiChannelSyncRoleEnum.AgM938xMultiChannelSyncRoleSlave;
M9381A_S3.MultiChannelSync.SynchronizationRole =
    AgM938xMultiChannelSyncRoleEnum.AgM938xMultiChannelSyncRoleSlave;
```

SCPI

```
:SOURce:RADio:ARB:MBSync SYSTemmaster
:SOURce:RADio:ARB:MBSync GROUpmaster
:SOURce:RADio:ARB:MBSync SLAVe
```

Note: These commands must be called after the Group Synchronization Signal and Slave Synchronization Signal have been set.

Slave Setup

Slave setup is done by specifying the two trigger lines that the Master to Slave and Slave to Master signaling will be done. The GroupSynchronizationSignal (Master to Slave) is the same for all VSGs in the chassis. The SlaveSynchronizationSignal (Slave to Master) needs to be unique to the Slave.

IVI

```
//Slave Configuration (Master -> Slave)
M9381A_S1.MultiChannelSync.GroupSynchronizationSignal =
    AgM938xPXIResourcesEnum.AgM938xPXIResourcesTTL_TRIGGER_0;
M9381A_S2.MultiChannelSync.GroupSynchronizationSignal =
    AgM938xPXIResourcesEnum.AgM938xPXIResourcesTTL_TRIGGER_0;
M9381A_S3.MultiChannelSync.GroupSynchronizationSignal =
    AgM938xPXIResourcesEnum.AgM938xPXIResourcesTTL_TRIGGER_0;

//Slave Configuration (Slave -> Master)
M9381A_S1.MultiChannelSync.SlaveSynchronizationSignal =
    AgM938xPXIResourcesEnum.AgM938xPXIResourcesTTL_TRIGGER_1;
M9381A_S2.MultiChannelSync.SlaveSynchronizationSignal =
    AgM938xPXIResourcesEnum.AgM938xPXIResourcesTTL_TRIGGER_2;
M9381A_S3.MultiChannelSync.SlaveSynchronizationSignal =
    AgM938xPXIResourcesEnum.AgM938xPXIResourcesTTL_TRIGGER_3;

M9381A_S1.Apply();
M9381A_S2.Apply();
M9381A_S3.Apply();
```

SCPI

```
:SOURce:RADio:ARB:MBSync:GSYNc PXI0
:SOURce:RADio:ARB:MBSync:SSYNc PXI1
```

System Master and Group Master Setup

Master setup is done by specifying the trigger line that the master will use to signal its slaves (GroupSynchronizationSignal) as well as specifying what trigger lines will be used by the slaves to signal back in the form of a mask (GroupSynchronizationMask). The mask is composed of the sum of all the 2^ SlaveSynchronizationSignals for its slaves.

IVI

```
//Master Configuration (Master -> Slave)
M9381A_SM.MultiChannelSync.GroupSynchronizationSignal =
    AgM938xPXIResourcesEnum.AgM938xPXIResourcesTTL_TRIGGER_0;

//Master Configuration (Slave -> Master)
//Assuming the slaves' SlaveSynchronizationSignal has already been set
int GroupSynchronizationMask = 0;
GroupSynchronizationMask +=
    (int)Math.Pow(2, (double)M9381A_
S1.MultiChannelSync.SlaveSynchronizationSignal);
GroupSynchronizationMask +=
    (int)Math.Pow(2, (double)M9381A_
S2.MultiChannelSync.SlaveSynchronizationSignal);
GroupSynchronizationMask +=
    (int)Math.Pow(2, (double)M9381A_
S3.MultiChannelSync.SlaveSynchronizationSignal);
M9381A_SM.MultiChannelSync.GroupSynchronizationMask =
GroupSynchronizationMask;

M9381A_SM.Apply();
```

SCPI

```
:SOURce:RADio:ARB:MBSync:GSYNc PXI0
:SOURce:RADio:ARB:MBSync:GMASk 56
```

Play Waveform

Playing a waveform in a MIMO configuration is very similar to playing a waveform in a single-channel configuration. The main difference is that the System Master channel needs to be started last.

IVI

```
//Prepare Waveform
M9381A_SM.ALC.Enabled = false;
M9381A_S1.ALC.Enabled = false;
M9381A_S2.ALC.Enabled = false;
M9381A_S3.ALC.Enabled = false;
M9381A_SM.Modulation.Stop();
M9381A_S1.Modulation.Stop();
M9381A_S2.Modulation.Stop();
M9381A_S3.Modulation.Stop();
M9381A_SM.Modulation.IQ.RemoveArb(ARB_REFERENCE_NAME);
M9381A_S1.Modulation.IQ.RemoveArb(ARB_REFERENCE_NAME);
M9381A_S2.Modulation.IQ.RemoveArb(ARB_REFERENCE_NAME);
M9381A_S3.Modulation.IQ.RemoveArb(ARB_REFERENCE_NAME);
M9381A_SM.Modulation.IQ.UploadArbAgilentFile(ARB_REFERENCE_NAME,
arbFilePath);
M9381A_S1.Modulation.IQ.UploadArbAgilentFile(ARB_REFERENCE_NAME,
arbFilePath);
M9381A_S2.Modulation.IQ.UploadArbAgilentFile(ARB_REFERENCE_NAME,
arbFilePath);
```

```
M9381A_S3.Modulation.IQ.UploadArbAgilentFile(ARB_REFERENCE_NAME,
arbFilePath);
M9381A_SM.Modulation.PlaybackMode =

AgM938xModulationPlaybackModeEnum.AgM938xModulationPlaybackModeContinuous;
M9381A_S1.Modulation.PlaybackMode =

AgM938xModulationPlaybackModeEnum.AgM938xModulationPlaybackModeContinuous;
M9381A_S2.Modulation.PlaybackMode =

AgM938xModulationPlaybackModeEnum.AgM938xModulationPlaybackModeContinuous;
M9381A_S3.Modulation.PlaybackMode =

AgM938xModulationPlaybackModeEnum.AgM938xModulationPlaybackModeContinuous;
M9381A_SM.RF.Configure(freq, powerLevel);
M9381A_S1.RF.Configure(freq, powerLevel);
M9381A_S2.RF.Configure(freq, powerLevel);
M9381A_S3.RF.Configure(freq, powerLevel);
M9381A_SM.RF.ConfigureOutput(true,
    AgM938xOutputPulseModeEnum.AgM938xOutputPulseModeNotPulsed);
M9381A_S1.RF.ConfigureOutput(true,
    AgM938xOutputPulseModeEnum.AgM938xOutputPulseModeNotPulsed);
M9381A_S2.RF.ConfigureOutput(true,
    AgM938xOutputPulseModeEnum.AgM938xOutputPulseModeNotPulsed);
M9381A_S3.RF.ConfigureOutput(true,
    AgM938xOutputPulseModeEnum.AgM938xOutputPulseModeNotPulsed);
M9381A_SM.Modulation.Enabled = true;
M9381A_S1.Modulation.Enabled = true;
M9381A_S2.Modulation.Enabled = true;
M9381A_S3.Modulation.Enabled = true;
M9381A_SM.Apply();
M9381A_S1.Apply();
M9381A_S2.Apply();
M9381A_S3.Apply();

//Start Waveform. Start System Master last
M9381A_S1.Modulation.PlayArb(ARB_REFERENCE_NAME,
    AgM938xStartEventEnum.AgM938xStartEventImmediate);
M9381A_S2.Modulation.PlayArb(ARB_REFERENCE_NAME,
    AgM938xStartEventEnum.AgM938xStartEventImmediate);
M9381A_S3.Modulation.PlayArb(ARB_REFERENCE_NAME,
    AgM938xStartEventEnum.AgM938xStartEventImmediate);
System.Threading.Thread.Sleep(100);
M9381A_SM.Modulation.PlayArb(ARB_REFERENCE_NAME,
    AgM938xStartEventEnum.AgM938xStartEventImmediate);
```

SCPI

```
:SOURce:POWer:ALC OFF
:SOURce:RADio:ARB:STATe OFF
:OUTPut:MODulation OFF
:MEMory:DELete “arb_name”
:MEMory:COPY “filename.csv”,”arb_name”
SOURce:RADio:ARB:TRIGger:TYPE CONTinuous
:SOURce:FREQuency:CENTer 1GHZ
```

```
:SOURce:POWer:LEVel:IMMediate:AMPLitude -10
:OUTPut:STATe ON
:OUTPut:MODulation ON
:SOURce:RADio:ARB:STATe ON
```

Note: The master channel is the last channel to call `:SOURce:RADio:ARB:STATe ON`

Retrigger settings

Setting the retrigger property to “true” or Immediate will cause an external trigger received to cause the waveform playback to start from the beginning immediately, even if the waveform is currently playing.

IVI

```
//enable restart on external trigger
M9381A_SM.Triggers3.ExternalTrigger3.ArbRestart = true;
```

SCPI

```
:SOURce:RADio:ARB:RETRigger IMMediate
```

M9391A IVI API

The M9391A API is essentially the same as the M9381A. You will perform essentially the same Initialization and InitializeSynchronizationClocks calls and Role setup, but using the objects provided by the M9391A driver.

Read Waveform

Reading a waveform in a MIMO configuration is similar to a single-channel configuration. The only changes are providing the System Master’s DelayAdjust to all the other channels and arming the System Master last.

```
M9391A_SM.RF.Frequency = freq;
M9391A_S1.RF.Frequency = freq;
M9391A_S2.RF.Frequency = freq;
M9391A_S3.RF.Frequency = freq;
M9391A_SM.RF.Power = power;
M9391A_S1.RF.Power = power;
M9391A_S2.RF.Power = power;
M9391A_S3.RF.Power = power;
M9391A_SM.RF.Conversion = AgM9391ConversionEnum.AgM9391ConversionAuto;
M9391A_S1.RF.Conversion = AgM9391ConversionEnum.AgM9391ConversionAuto;
M9391A_S2.RF.Conversion = AgM9391ConversionEnum.AgM9391ConversionAuto;
M9391A_S3.RF.Conversion = AgM9391ConversionEnum.AgM9391ConversionAuto;
M9391A_SM.RF.IFBandwidth = ifBandwidth;
M9391A_S1.RF.IFBandwidth = ifBandwidth;
M9391A_S2.RF.IFBandwidth = ifBandwidth;
M9391A_S3.RF.IFBandwidth = ifBandwidth;
```

```
M9391A_SM.AcquisitionMode =
    AgM9391AcquisitionModeEnum.AgM9391AcquisitionModeIQ;
M9391A_S1.AcquisitionMode =
    AgM9391AcquisitionModeEnum.AgM9391AcquisitionModeIQ;
M9391A_S2.AcquisitionMode =
    AgM9391AcquisitionModeEnum.AgM9391AcquisitionModeIQ;
M9391A_S3.AcquisitionMode =
    AgM9391AcquisitionModeEnum.AgM9391AcquisitionModeIQ;
M9391A_SM.IQAcquisition.SampleRate = sampleRate;
M9391A_S1.IQAcquisition.SampleRate = sampleRate;
M9391A_S2.IQAcquisition.SampleRate = sampleRate;
M9391A_S3.IQAcquisition.SampleRate = sampleRate;
M9391A_SM.IQAcquisition.SampleSize =
    AgM9391SampleSizeEnum.AgM9391SampleSize64Bits;
M9391A_S1.IQAcquisition.SampleSize =
    AgM9391SampleSizeEnum.AgM9391SampleSize64Bits;
M9391A_S2.IQAcquisition.SampleSize =
    AgM9391SampleSizeEnum.AgM9391SampleSize64Bits;
M9391A_S3.IQAcquisition.SampleSize =
    AgM9391SampleSizeEnum.AgM9391SampleSize64Bits;
M9391A_SM.IQAcquisition.Samples = (int)(duration * sampleRate);
M9391A_S1.IQAcquisition.Samples = (int)(duration * sampleRate);
M9391A_S2.IQAcquisition.Samples = (int)(duration * sampleRate);
M9391A_S3.IQAcquisition.Samples = (int)(duration * sampleRate);
M9391A_SM.Triggers.AcquisitionTrigger.Mode =
    AgM9391AcquisitionTriggerModeEnum.AgM9391AcquisitionTriggerModeMagnitude;
M9391A_S1.Triggers.AcquisitionTrigger.Mode =
    AgM9391AcquisitionTriggerModeEnum.AgM9391AcquisitionTriggerModeMagnitude;
M9391A_S2.Triggers.AcquisitionTrigger.Mode =
    AgM9391AcquisitionTriggerModeEnum.AgM9391AcquisitionTriggerModeMagnitude;
M9391A_S3.Triggers.AcquisitionTrigger.Mode =
    AgM9391AcquisitionTriggerModeEnum.AgM9391AcquisitionTriggerModeMagnitude;

var acqTriggerMaster = M9391A_SM.Triggers.AcquisitionTrigger;
acqTriggerMaster.MagnitudeTrigger.Slope =
AgM9391TriggerSlopeEnum.AgM9391TriggerSlopePositive;
acqTriggerMaster.MagnitudeTrigger.Level = magTrigLevel;
acqTriggerMaster.MagnitudeTrigger.PulseOffTime = 1e-6;
acqTriggerMaster.TimeoutMode =
AgM9391TriggerTimeoutModeEnum.AgM9391TriggerTimeoutModeAutoTriggerOnTimeout;
acqTriggerMaster.Timeout = 10000;

M9391A_SM.Apply();
M9391A_S1.MultiChannelSync.DelayAdjust = M9391A_
SM.MultiChannelSync.DelayAdjust;
M9391A_S2.MultiChannelSync.DelayAdjust = M9391A_
SM.MultiChannelSync.DelayAdjust;
M9391A_S3.MultiChannelSync.DelayAdjust = M9391A_
SM.MultiChannelSync.DelayAdjust;
M9391A_S1.Apply();
M9391A_S2.Apply();
M9391A_S3.Apply();

//Arm System Master last
```

```
M9391A_S1.Arm();
M9391A_S2.Arm();
M9391A_S3.Arm();
M9391A_SM.Arm();

if (!M9391A_SM.WaitForData((int)(acqTriggerMaster.Timeout)))
    throw new Exception();

M9391A_SM.IQAcquisition.ReadIQData(0,
    AgM9391IQUnitsEnum.AgM9391IQUnitsSquareRootMilliWatts,
    0,
    M9391A_SM.IQAcquisition.Samples,
    ref iqData,
    ref overloaded);
M9391A_S1.IQAcquisition.ReadIQData(0,
    AgM9391IQUnitsEnum.AgM9391IQUnitsSquareRootMilliWatts,
    0,
    M9391A_S1.IQAcquisition.Samples,
    ref iqData,
    ref overloaded);
M9391A_S2.IQAcquisition.ReadIQData(0,
    AgM9391IQUnitsEnum.AgM9391IQUnitsSquareRootMilliWatts,
    0,
    M9391A_S2.IQAcquisition.Samples,
    ref iqData,
    ref overloaded);
M9391A_S3.IQAcquisition.ReadIQData(0,
    AgM9391IQUnitsEnum.AgM9391IQUnitsSquareRootMilliWatts,
    0,
    M9391A_S3.IQAcquisition.Samples,
    ref iqData,
    ref overloaded);
```

M9300A IVI API

Note that the M938x IVI interface contains the same M9300A commands, under the Modules.Reference interface.

BackPlaneReferenceEnabled Property

IVI

In order for SyncRef10 to work, the reference needs to drive the 10 MHz Backplane clock. This is accomplished by setting the BackPlaneReferenceEnabled property to

true.

```
//Set Reference to drive the 10 MHz Backplane clock
M9300A.ReferenceBase3.BackPlaneReferenceEnabled = true;
```

Note: When the M9300A is included in an M9381A configuration, the M9300A API can be accessed via the Modules.Reference API of the M938x.

SCPI

When using the SCPI interface, you can make this same change by sending a command to the M9381A channel that includes the M9300A module (usually channel 1).

```
:MODule:REFerence:BACKplane ON
```

Aligning 10 MHz between chassis

For SyncRef10 to achieve precise alignment on modules in separate chassis, the 10 MHz backplane clock phase must be precisely aligned. To accomplish this, run the following command on each M9300A:

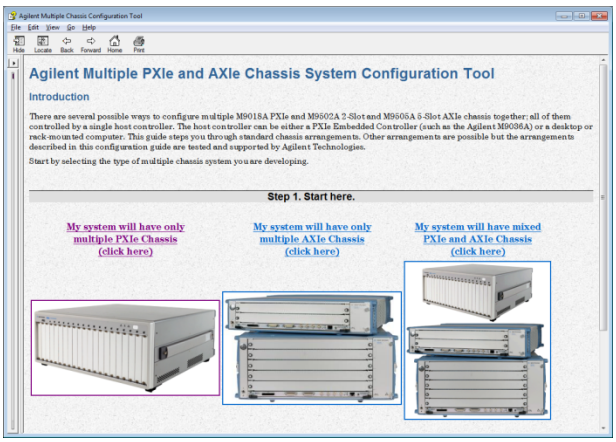
IVI

```
M9300A.ReferenceBase3.AlignExternalReferenceAnd10MHzOut();
```

SCPI

```
:MODule:REFerence:ALIGnclock
```

Hardware Configuration Considerations



When configuring systems with multiple chassis, there are many things to consider. Guidance on this topic can be found at the following website:
http://www.keysight.com/find/pxie-multichassis
There is a link to a multi chassis configuration help tool, which will guide you through the process of configuring and installing a multi-chassis system.

The following is a partial list of considerations when setting up a multichannel configuration:

- M9214A and M9311A modules should be in 8-lane PCIe slots when possible for optimal throughput. These are slots 2,6,11, and 15 in the M9018A chassis. Other slots are 4-lane slots. This may not be possible in all situations. They will still operate properly.
- If M9037A controller is used with multiple chassis, bios settings must be set to “large system” to allow for increased PCIe device count.
- M9021A PCIe extender cards MUST be in 8-lane PXI slot (2,6,11,15)
- If M9037A controller is used with more than 2 chassis, Keysight I/O libraries version 17.0 or greater must be used.
- M9018A chassis driver version 1.4.397.1 or a newer version must be used
- M9018A FPGA version must be updated to version 1.05. This must be performed in a service center, or by an authorized Keysight application engineer.
- After installing hardware, multiple reboots may be required before all PCIe devices are enumerated.
- Chassis numbers can be changed in Keysight Connection Expert if you prefer chassis numbering to be in a specific order.

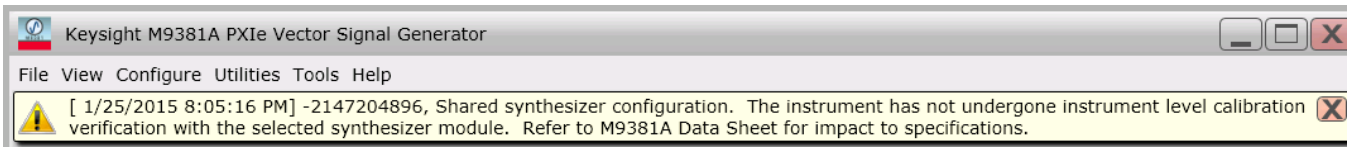
- On each bootup, it may take more than a minute for a large system with multiple chassis and many modules to fully enumerate and appear in Connection Expert (or be used by a test program)
- When more than 1 chassis is connected to a controller, the one with embedded controller should be powered on last, or powered down first to ensure proper controller operation. Turning off subordinate controllers may result in Windows system crashes (blue screen)
- Keep all module screws loose while installing in a chassis, until all modules are seated, and all RF cables are attached. Tighten the module screws last.

When configuring a chassis with RF VSG and VSA, it is very important that proper care is taken to ensure adequate cooling. Operating the RF PXI VSG and VSA at high temperature may degrade performance, or damage the modules.

- Each empty PXI slot should have a slot blocker to minimize airflow to empty slots, and ensure adequate airflow through the actual modules installed in other slots.
- Each empty PXI slot should have a slot cover.
- Do not adjust the chassis fan speed to reduce noise. Leave the chassis on Auto fan speed mode, or High speed if the ambient temperature is very warm. Guidelines can be found in the M9018A getting started guide.

When you purchase an M9381A or M9391A instrument, it comes as a bundle, including an M9301A synthesizer for each channel. When you configure these

instruments in shared LO configuration, you may install the M9301A for each channel, or you may optionally only install a single M9301A for the complete configuration. Since each M9381A or M9391A channel is calibrated as a bundle, the calibration certificate is only valid for that bundle in independent LO mode. While a VSG or VSA is configured with shared LO that is not part of the instrument's bundle, the hard specifications are not warranted.



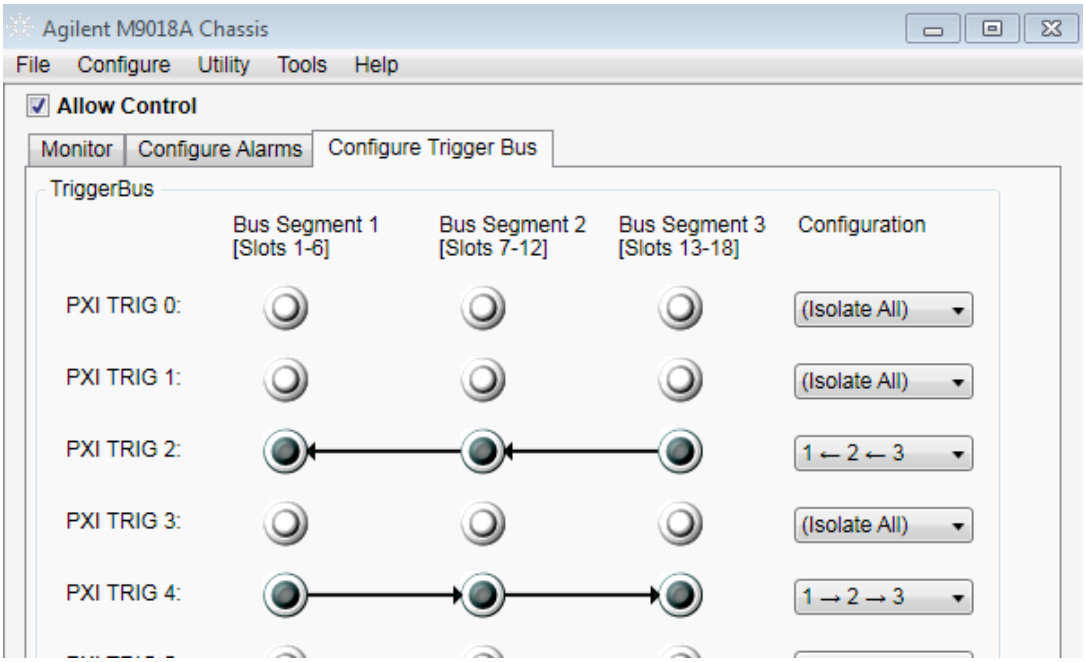
When you initialize the M9381A or M9391A IVI driver session, if you are in a shared LO configuration, or you have not initialized a calibrated set of modules, the driver will warn that there is no calibration for this collection of modules. In shared LO configuration, the error message will explain that this is expected for a shared LO configuration. You can disable this warning and checking from within the M9381A and M9391A SFP. From the Calibration Information and Preferences Dialog, uncheck the "Instrument Cal Warnings" checkbox to prevent further warnings. You can re-enable this at any time.

There are a number of calibrations and field alignments that need to be updated or performed for optimal performance of a multichannel M9381A VSG or M9391A VSA. The table below describes the calibrations and when they should be performed.

Calibration/Alignment	Service Center or Field	Notes
M9391A IF Flatness Alignment	Service center or field (will be enabled in SFP, or on Multi-channel Config Utility)	Must be performed if modules are moved to different slots, if 100 MHz or IF cable length changes, and when first configuring a multichannel system. Needed for accurate baseband timing alignment.
M9381A/M9391A LO Level alignment	Field alignment (persistent)	Appears on SFP when option is selected to use an external LO distribution box. Must be run once on initial setup, after shared LO cabling is attached. Must be run again each time software drivers are updated. Required for proper LO drive level – impact

Calibration/Alignment	Service Center or Field	Notes
		on modulation quality and amplitude accuracy if not performed.
M9381A/M9391A LO flatness calibration	Service center	Will be performed on new units in production. Old units will require service center update, but only needed if external LO distribution unit will be used. Required before LO level alignment can be performed.
Chassis 10 MHz external reference align to backplane	Field alignment (not persistent)	When synchronizing 2 chassis of M9381A or M9391A, required for accurate baseband timing alignment between the two chassis. Must be run once after each power cycle.

After putting together a multichannel VSG or VSA configuration, one of the things you will have to deal with is routing PXI chassis backplane triggers. This is because the PXI chassis's 4 backplane triggers are isolated into 3 trigger bus segments. To propagate a trigger between bus segments, the chassis SFP or API must be used to explicitly enable routing of these triggers. These settings are not persisted. Later we will see how to do this programmatically, or using the provided config utilities or demo program.



The synchronization scheme requires one PXI trigger per VSG or VSA channel. One group trigger must be allocated from a “master” M9311A or M9214A module in each chassis to all of the other M9311A or M9214A modules. Additionally, each “slave” M9311A or M9214A module must use a unique synchronization trigger routed to the “master”.

Triggers are also required for inter-module communciation within an M9381A VSG. A trigger must be routed from the M9311A to the M9310A to propagate the ALC Hold trigger. A second trigger must be routed from M9301A to the M9311A to route the front panel external trigger signal. Note that in a shared LO configuration, the M9301A synthesizer module might be far from the M9311A module in some cases, and this trigger must be routed to all of the M9311A modules in the chassis.

Synchronizing Multiple Chassis

When synchronizing multiple chassis, you must provide the same 10 MHz frequency reference to the M9300A located in slot 10 of each chassis. You can either use the 10 MHz *OCXO Out* from the Keysight M9300A PXIe Frequency Reference master or an external 10 MHz frequency reference.

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Edition 1, October, 2015
Printed In USA

Y1299-90005
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