Startup Guide

Keysight
Quantum Engineering Toolkit (QET)

KEYSIGHT TECHNOLOGIES

Notices

Copyright Notice

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Regulatory Compliance

This product has been designed and tested in accordance with accepted industry standards, and has been supplied in a safe condition. To review the Declaration of Conformity, go to http://www.keysight.com/go/conformity.

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Safety Notices

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.

PRODUCT MARKINGS:

The CE mark is a registered trademark of the European Community.

Australian Communication and Media Authority mark to indicate regulatory compliance as a registered supplier.

ICES/NMB-001
ISM GRP.1 CLASS A

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).

South Korean Class A EMC Declaration. This equipment is Class A suitable for professional use and is for use in electromagnetic environments outside of the home. A 급 기기 (업무용 방송통신 기자재) 이 기기는 업무용 (A 급) 전자파적 합기기로서 판 매자 또는 사용자는 이 점을 주 의하시기 바라 며 , 가정외의 지역에서 사 용하는 것을 목적으 로 합니다.

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

1 Overview of the Quantum Engineering Toolkit (QET)

Keysight Technologies has developed the Quantum Engineering Toolkit (QET), a powerful system for use in single and multi-qubit research lab experiments. The goal of QET is to provide an integrated solution, born from the strong electronics expertise of Keysight Technologies, and make it easily available to quantum laboratories all around the world.

NOTE **In all equipment setups throughout this document, all cables are the same and shown in different colors for clarity only.**
See Cables, SMA (m) to SMA (m) on page 15.

In this document...

This document describes the hardware and software installation process needed to start up the Keysight Quantum Engineering Toolkit (QET) and get it ready for use.

Perform the following sequence:

1. Review Safety Requirements on page 3
2. Review Hardware Components on page 9
3. Install Hardware on page 17
4. Install Software on page 27
5. Verify Operation on page 33
6. Run the QET Initialization Utility on page 57

2 Review Safety Requirements

Review all safety information in this section before operating any equipment.

2. 1 Safety Notices

The following safety notices are used throughout this document. Familiarize yourself with each of the notices and their meaning before operating this system.

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.

2. 2 Before Applying LINE Power

CAUTION Install the instrument so that the ON/OFF switch is readily identifiable and is easily reached by the operator. The ON/OFF switch or the detachable power cord is the instrument disconnecting device. It disconnects the mains circuits from the mains supply before other parts of the instrument. Alternately, an externally installed switch or circuit breaker (which is readily identifiable and is easily reached by the operator) may be used as a disconnecting device.

CAUTION Before switching on this instrument, make sure that the correct fuse is installed and the supply voltage is in the specified range.

2. 3 General Safety

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.

CAUTION This product is designed for use in Installation Category II and Pollution Degree 2 per IEC 1010 and 664 respectively.

CAUTION VENTILATION REQUIREMENTS: When installing the product in a cabinet, the convection into and out of the product must not be restricted. The ambient temperature (outside the cabinet) must be less than the maximum operating temperature of the product by 4°C for every 100 Watts dissipated in the cabinet. If the total power dissipated in the cabinet is greater that 800 Watts, then forced convection must be used

2. 4 Contacting Keysight

Assistance with test and measurements needs and information on finding a local Keysight office are available on the Web at:
http://www.keysight.com/find/assist

2. 5 Servicing

WARNING No operator serviceable parts inside.
Refer servicing to qualified personnel.

WARNING To prevent electrical shock, do not remove covers.

WARNING Servicing instructions in this document are for use by qualified personnel only. To avoid electrical shock, do not perform any servicing unless you are qualified to do so.

WARNING The opening of covers or removal of parts is likely to expose dangerous voltages. Disconnect the instrument from all voltage sources while it is being opened

WARNING The power cord is connected to internal capacitors that may remain live for 5 seconds after disconnecting the plug from its power supply.

WARNING For continued protection against fire hazard replace line fuse only with same type and rating (115 V and 230 V operation:
T2.5 A 250 V). The use of other fuses or material is prohibited.

2. 6 Regulatory Information

Keysight Technologies PXI modular instrument chassis and instrument cards comply with the regulatory requirements listed in this section.

2. 6. 1 Compliance with Canadian EMC Requirements

This ISM device complies with Canadian ICES-001.

Cet appareil ISM est conforme a la norme NMB du Canada.

2. 6. 2 South Korean Class A EMC Declaration

South Korean Class A EMC Declaration.
This equipment is Class A suitable for professional use and is for use in electromagnetic environments outside of the home. A 급 기기 (업무용 방송통신 기자재) 이 기기는 업무용 (A 급) 전자파적 합기기로서 판 매자 또는 사용자는 이 점을 주 의하시기 바라 며 , 가정외의 지역에서 사 용하는 것을 목적으 로 합니다.

2. 6. 3 Compliance with German Noise Requirements

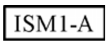
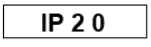
This is to declare that this instrument is in conformance with the German Regulation on Noise Declaration for Machines (Laermangabe nach der Maschinenlaermrerordung –3. GSGV Deutschland).

Acoustic Noise Emission/Geraeuschemission	
LpA <70 dB	LpA <70 dB
Operator position	am Arbeitsplatz
Normal position	normaler Betrieb
per ISO 7779	nach DIN 45635 t. 19

2. 6. 4 Declaration of Conformity

A Declaration of Conformity is on file for the PXI Series models and a copy is available upon request.

2. 7 Instrument Markings

	The instruction documentation symbol. The product is marked with this symbol when it is necessary for the user to refer to the instructions in the documentation.
	The AC symbol indicates the required nature of the line module input power.
	This symbol indicates separate collection for electrical and electronic equipment, mandated under EU law as of August 13, 2005. All electric and electronic equipment are required to be separated from normal waste for disposal (Reference WEEE Directive, 2002/96/EC).
	This symbol indicates that the power line switch is ON.
	This symbol indicates that the power line switch is in the STANDBY position.
	This symbol indicates that the power line switch is in the OFF position.
	This symbol is used to identify a terminal which is internally connected to the product frame or chassis.
	The CE mark is a registered trademark of the European Community. (If accompanied by a year, it is when the design was proven.)
	The CSA mark is a registered trademark of the CSA International.
	This mark designates the product is an Industrial Scientific and Medical Group 1 Class A product (reference CISPR 11, Clause 5).
	This is a marking to indicate product compliance with the Canadian Interference-Causing Equipment Standard (ICES-001).
	This mark designates Direct Current.
	The instrument has been designed to meet the requirements of IP 2 0 for egress and operational environment.
	The RCM mark is a registered trademark of the Australian Communications and Media Authority.

	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.
	This symbol on all primary or secondary packaging indicates compliance to China standard GB 18455-2001.
	South Korean Certification (KC) mark; includes the marking's identifier code which follows the format: MSIP-REM-YYY-ZZZZZZZZZZZZZZ or KCC-REM-YYY-ZZZZZZZZZZZZ.

3 Review Hardware Components

Before installing hardware or software, review the following hardware components.

NOTE **The following list of hardware components are the recommended models used with the Keysight Quantum Engineering Toolkit. Many of these hardware components have optional or alternate models available.**

Review the following hardware components:

- Hardware Components on page 10
  - HP Z8 G4 Workstation
    - M9049A PCIe Interface Module
    - M9023A Slot-1 PXIe Interface Module
    - Y1202A or Y1203A PCIe Cable
  - M9019A PXIe Chassis
    - M3202A PXIe Arbitrary Waveform Generator
    - M3102A PXIe Digitizer
    - M9347AH01 PXIe Dual DDS (LO)
    - (Optional) M9037A Slot-1 PXIe Embedded Controller
    - (Optional) M9300A PXIe Frequency Reference
    - Y1212A Slot Blockers and Y1213A EMC Filler Panels
  - U3022AH37 I/Q Modulator/Demodulator
    - Frequency-Band: 3 to 7 GHz, 5 to 9 GHz, or 6 to 18 GHz
    - High-Pass Filter
    - 8493A-30 Coaxial Fixed Attenuator
  - E8267D PSG Vector Signal Generator (Frequency Reference)
    - (Optional) Splitter/Power Divider
  - (Optional) E3662B Rack Cabinet
- Cables, SMA (m) to SMA (m) on page 15
- (Optional) Test Equipment on page 15
  - N9040B UXA Signal Analyzer (or equivalent)
  - DSA90254A Oscilloscope (or equivalent)

3. 1 Hardware Components

Select either an HP Z8 G4 Workstation or M9037A Slot-1 PXIe Embedded Controller.

NOTE **A Keysight M9037A Slot-1 PXIe embedded controller is only needed if an HP Z8 G4 Workstation or equivalent is not used.**

HP Z8 G4 Workstation

NOTE **The HP Z8 G4 Workstation contains a customized BIOS that allows additional PCIe addresses to be located when multiple PXIe chassis are connected to the PCIe bus.**

If one to three chassis are needed in an equipment configuration, use the HP Z8 G4 Workstation in place of a Slot-1 PXIe embedded controller.

If four to six chassis are needed in an equipment configuration, use this HP Z8 G4 Workstation, with an added dual-processor, in place of a Slot-1 PXIe embedded controller.

Alternate:

- See Tested PC and PXI/AXIe Chassis Configurations (5990-7632EN).

PCIe Interface Module

Keysight M9049A PCIe High Performance Host Adapter: Dual Port (x16), Gen 3

- One M9049A PCIe Host Adapter is installed in one of the PCIe expansion slots in the back of the HP Z8 G4 Workstation.
- One PCIe output port is connected, using Keysight Y1202A or Y1203A PCIe cable, to one of the input connectors on the front of the M9023A PXIe System Module - located in Slot-1 of the M9019A PXIe Chassis.

Alternate:

- Keysight M9048B PCIe Host Adapter: Single Port, x8, Gen 3

Slot-1 PXIe Interface Module

Keysight M9023A PXIe High Performance System Module: Dual Port (x16), Gen 3

- One PCIe output port is connected, using Keysight Y1202A or Y1203A PCIe Cable, to one of the input connectors on the front of the M9023A PXIe System Module - located in Slot-1 of the M9019A PXIe Chassis.
- One M9049A PCIe Host Adapter is installed in one of the PCIe expansion slots in the back of the HP Z8 G4 Workstation.

Alternate:

- Keysight M9022A PXIe System Module: Single Port, x8, Gen 3

PCIe Cable

Keysight Y1202A or Y1203A PCIe Cable

Keysight Y1202A PCIe Cable: x8, 2.0 m

Keysight Y1203A PCIe Cable: x8, 0.5 m

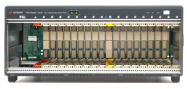
(Optional) Slot-1 PXIe Embedded Controller

Keysight M9037A PXIe High Performance Embedded Controller: 4-slot, 3U, Gen 3

NOTE **This Slot-1 PXIe embedded controller is only needed if an HP Z8 G4 Workstation or equivalent is not used.**

Alternate:

- Keysight M9036A PXIe Embedded Controller: 3-slot, 3U, Gen 2
- See HP Z8 G4 Workstation on page 10.
- See Tested PC and PXI/AXIe Chassis Configurations (5990-7632EN).



PXIe Chassis

Keysight M9019A PXIe Chassis: 18-slot, 3U, 24 GB/s, Gen 3

Alternate:

- Keysight M9018B PXIe Chassis: 18-slot, 3U, 8 GB/s, Gen 2
- Keysight M9010A PXIe Chassis: 10-slot, 3U, 24 GB/s, Gen 3

AWG

Keysight M3202A PXIe Arbitrary Waveform Generator: 1 GSa/s, 14 bit, 400 MHz

Optional:

- M3202A-HV1 Enabled HVI programming, if used with Keysight M3601A Hard Virtual Instrument (HVI) Design Environment Software
- M3202A-FP1 Enabled FPGA programming
  - if used with Keysight M3602A FPGA Design Environment Software
    - requires Option K32 or K41 and Memory Option M20

Alternate:

- Keysight M3201A PXIe Arbitrary Waveform Generator: 500 MSa/s, 16 bit, 200 MHz
- Keysight M3300A PXIe AWG and Digitizer Combination: 500 MSa/s, 16 bit and 100 MSa/s, 14 bit
- Keysight M3302A PXIe AWG and Digitizer Combination: 500 MSa/s, 16 bit, and 500 MSa/s, 14 bit

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Digitizer

Keysight M3102A PXIe Digitizer: 500 MSa/s, 14 bit, 200 MHz

Optional:

- M3102A-HV1 Enabled HVI programming, if used with Keysight M3601A Hard Virtual Instrument (HVI) Design Environment Software
- M3102A-FP1 Enabled FPGA programming
  - if used with Keysight M3602A FPGA Design Environment Software
    - requires Option K32 or K41 and Memory Option M20

Alternate:

- Keysight M3100A PXIe Digitizer: 100 MSa/s, 14 bit, 100 MHz
- Keysight M3300A PXIe AWG and Digitizer Combination: 500 MSa/s, 16 bit and 100 MSa/s, 14 bit
- Keysight M3302A PXIe AWG and Digitizer Combination: 500 MSa/s, 16 bit, and 500 MSa/s, 14 bit

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Dual DDS (LO)

Keysight M9347AH01 PXIe Dual Direct Digital Synthesizer Module: 9 kHz to 12 GHz

NOTE **To help with cooling, it is recommended that the M9347AH01 have empty slots on both sides of the module; the empty slots should contain both slot blockers and EMC filler panels.**

There are two clock input ports on the M9347AH01, "Clock In" and "Ref In":

- **Clock In** is designed for inputs of 4.8 GHz and 19.2 GHz at 0 to +20 dBm. The optimal input frequency and power used to drive the Clock In port is 19.2 GHz @ 0 dBm. See Keysight E8267D PSG Vector Signal Generator on page 14.

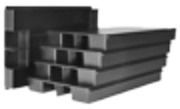
- **Ref In** is designed for inputs of 100 MHz at 0 to +14 dBm. See Keysight M9300A PXIe Frequency Reference.
- Both Clock In and Ref In cannot be used at the same time.
- The Clock Source selection, on the Keysight M9347 PXIe Module SFP, from the DDS Control tab, must match the selected port being used.

(Optional) PXIe Frequency Reference

Keysight M9300A PXIe Frequency Reference: 100 MHz

NOTE **When using the Keysight M9018B or M9019A PXIe Chassis, the M9300A must be installed in Slot-10 for proper time synchronization between instruments. When using the Keysight M9010A PXIe Chassis, the M9300A must be installed in Slot-6 for proper time synchronization between instruments**

The M9300A can be used to drive the M9347AH01 Ref In with 100 MHz at 0 to +14 dBm. The output of the M9300A can be fed into a splitter; the outputs can feed up to eight M9347AH01.



Slot Blockers

Keysight Y1212A Qty 1 Slot blocker kit: 5 slots

The Y1212A is used to block unused slots in the PXIe chassis. These slot blockers can be placed in empty slots to help improve airflow through PXIe modules.

EMC Filler Panels

Keysight Y1213A Qty 1 PXI EMC filler panel kit: 5 slots

The Y1213A is used to block EMC from unused slots in the PXIe chassis.

I/Q Modulator/Demodulator

Keysight U3022AH37 I/Q Modulator/Demodulator Test Set

- Can be configured as all I/Q Modulators, all I/Q Demodulators, or a combination of I/Q Modulators and/or I/Q Demodulators.
- I/Q Modulators and I/Q Demodulators are available in three frequency-band options: 3 to 7 GHz, 5 to 9 GHz, or 6 to 18 GHz.
- All I and Q port bandwidths are 10 MHz to 500 MHz.
- Provides up-conversion (through the I/Q Modulator path) and down-conversion (through the I/Q Demodulator path).
- I/Q Modulator sections have a SPST solid-state switch (Pin Sw connector) for providing isolation.

NOTE **I/Q Modulator Pin Sw connector is an SMB (m). If using an SMA (m) to SMA (m) cable to connect to I/Q Modulator Pin Sw, use an SMA (f) to SMB (m) to SMB (f) to SMB (f) or an SMA (f) to SMB (f).**

SMA (f) to SMB (m) Adapter (p/n 1250-0674)
SMB (f) to SMB (f) Adapter (p/n 1250-4000)

The I/Q Modulator Pin Sw connector is an SMB (m). Use an SMA (f) to SMB (m) adapter connected to an SMB (f) to SMB (f) adapter or use an SMA (f) to SMB (f).

High-Pass Filter
Mini-Circuits 15542 High-Pass Filter: 2,010 MHz to 10,100 MHz

Alternate:

- The selection of a high-pass filter is dependent on the frequency range of the I/Q Modulator/ Demodulator being used; I/Q Modulator/Demodulator test sets are available for frequency ranges:
  - 3 to 7 GHz
  - 5 to 9 GHz
  - 6 to 18 GHz

Coaxial Fixed Attenuator
Keysight 8493A-30 Coaxial Fixed Attenuator: DC to 12.4 GHz, 30 dB

Alternate:

- Keysight 8493B-30 Coaxial Fixed Attenuator: DC to 18 GHz, 30 dB

Frequency Reference
Keysight E8267D PSG Vector Signal Generator

- E8267D-520 Frequency Range, 250 kHz to 20 GHz (Used as a 19.2 GHz clock.)
- E8267D-UNY Ultra-Low Phase Noise Performance

E8267D-520 instruments ship with a 3.5 mm (m) RF output connector on the front panel.
E8267D-532 and -544 instruments ship with a 2.4 mm (m) RF output connector on the front panel.

The RF Output of the E8267D can be fed into an optional splitter; the outputs of the splitter can be fed into the inputs of up to eight M9347AH01.

The **Clock In** port on the Keysight M9347AH01 PXIe Dual Direct Digital Synthesizer is designed for inputs of 4.8 GHz and 19.2 GHz at 0 to +20 dBm.
The optimal input frequency and power used to drive the Clock In port is 19.2 GHz @ 0 dBm.

Optional:

- Keysight E8257D PSG Analog Signal Generator with Options 520 and UNY
- See Keysight M9300A PXIe Frequency Reference: 100 MHz on page 13

(Optional) Splitter/Power Divider

8-Way Power Divider, PULSAR MICROWAVE CORPORATION, PS8-53-454/4S, (https://www.pulsarmicrowave.com/spec_sheets/PS8-53-454-4S.pdf) or equivalent.

This power divider was selected for minimum loss.

(Optional) Rack Cabinet

Keysight E3662B Rack Cabinet, 2.0 m

Alternate:

- Keysight E3661B Rack Cabinet, 1.6 m

3. 2 Cables, SMA (m) to SMA (m)

Cables, SMA (m) to SMA (m)

In all equipment setups throughout this document, cables are shown in different colors for clarity only. All cables are RF Cable Assemblies, SMA (m) to SMA (m).
Keysight recommends Huber+Suhner, SUCOFLEX 126 (http://www.hubersuhner.com) or equivalent.

3. 3 (Optional) Test Equipment

The following test equipment may be used when verifying operation.

Signal Analyzer

Keysight N9040B UXA Signal Analyzer

- N9040B-508 Frequency Range, 2 Hz to 8.4 GHz
- or N9040B-513 Frequency Range, 2 Hz to 13.6 GHz
- or N9040B-526 Frequency Range, 2 Hz to 26.5 GHz
- The frequency range option that is selected depends on the frequency range of the Keysight U3022AH37 I/Q Modulator/Demodulator Test Set on page 13 being used.

Use this equipment or equivalent to measure signals when verifying operation.
See Verify Operation on page 33.

Alternate:

- Keysight N9030B PXA Signal Analyzer

Oscilloscope

Keysight DSA90254A Infiniium High Performance Oscilloscope: 2.5 GHz

Use this equipment or equivalent to measure signals when verifying operation.
See Verify Operation on page 33.

4 Install Hardware

WARNING Before installing hardware, Review Safety Requirements on page 3.

NOTE The following list of hardware components are the recommended models used with the Keysight Quantum Engineering Toolkit. The hardware configurations are shown using the Keysight M9019A PXIe Chassis; this chassis and many other hardware components may have optional or alternate models available. Refer to Review Hardware Components on page 9.

NOTE In all equipment setups throughout this document, all cables are the same and shown in different colors for clarity only.
See Cables, SMA (m) to SMA (m) on page 15.

Perform the following sequence when installing hardware:

1. Install an HP Z8 G4 Workstation on page 18
2. Install Hardware on a Workbench on page 19
    a. Install a PXIe Chassis on page 20
    b. Install PXIe Modules on page 20
    c. Install Slot Blockers and EMC Filler Panels on page 21
    d. Install an I/Q Modulator/Demodulator Test Set on page 21
    e. Install a Frequency Reference on page 21
    f. Connect Cables, High-Pass Filter, and Attenuator on page 23
3. (Optional) Install Hardware in a Rack Cabinet on page 24

4. 1 Install an HP Z8 G4 Workstation

NOTE

This HP Z8 G4 Workstation contains a customized BIOS that allows additional PCIe addresses to be located when multiple PXIe chassis are connected to the PCIe bus.

If **one** to **three** chassis are needed in the equipment configuration, use this HP Z8 G4 Workstation in place of a Slot-1 PXIe embedded controller.

If **four** to **six** chassis are needed in the equipment configuration, use this HP Z8 G4 Workstation, with the added dual-processor, in place of a Slot-1 PXIe embedded controller.

Interface Module

Keysight M9049A PCIe High Performance Host Adapter: Dual Port (x16), Gen 3

- One M9049A PCIe Host Adapter is installed in one of the PCIe expansion slots in the back of the HP Z8 G4 Workstation.
- One PCIe output port is connected, using Keysight Y1202A or Y1203A PCIe Cable, to one of the input connectors on the front of the M9023A PXIe System Module - located in Slot-1 of the M9019A PXIe Chassis.

Slot-1 PXIe Interface Module

Keysight M9023A PXIe High Performance System Module: Dual Port (x16), Gen 3

- One PCIe output port is connected, using Keysight Y1202A or Y1203A PCIe Cable, to one of the input connectors on the front of the M9023A PXIe System Module - located in Slot-1 of the M9019A PXIe Chassis.
- One M9049A PCIe Host Adapter is installed in one of the PCIe expansion slots in the back of the HP Z8 G4 Workstation.

For detailed instructions, refer to the Keysight PXIe System Modules and Cable Interface, Installation Guide (M9022-90001).

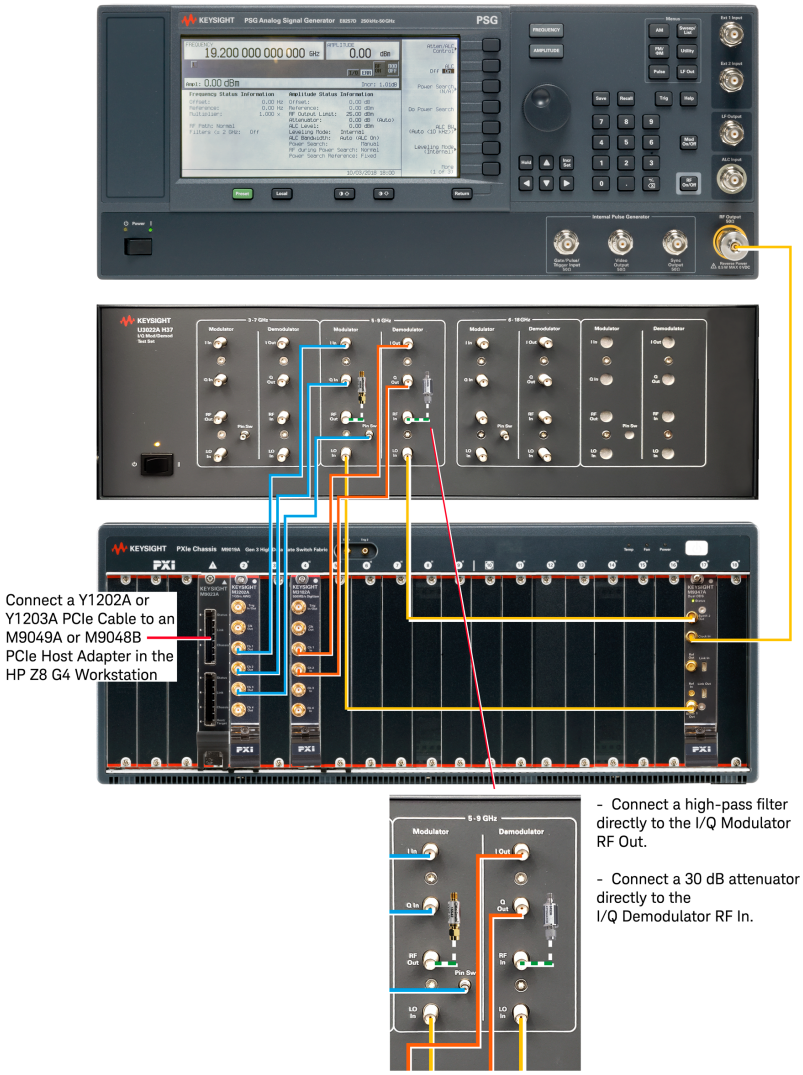
PCIe Cable

Keysight Y1202A or Y1203A PCIe Cable

Keysight Y1202A PCIe Cable: x8, 2.0 m

Keysight Y1203A PCIe Cable: x8, 0.5 m

4. 2 Install Hardware on a Workbench

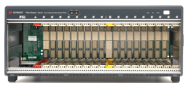


NOTE **In all equipment setups throughout this document, all cables are the same and shown in different colors for clarity only.**
See Cables, SMA (m) to SMA (m) on page 15.

Perform the following sequence when installing hardware on a workbench:

1. Install a PXIe Chassis on page 20
2. Install PXIe Modules on page 20
3. Install Slot Blockers and EMC Filler Panels on page 21
4. Install an I/Q Modulator/Demodulator Test Set on page 21
5. Install a Frequency Reference on page 21
6. Connect Cables, High-Pass Filter, and Attenuator on page 23

4. 2. 1 Install a PXIe Chassis



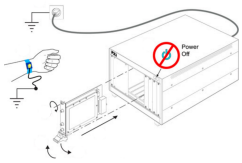
Keysight M9019A PXIe Chassis: 18-slot, 3U, 24 GB/s, Gen 3

1. Verify the chassis power switch is Off.
2. Verify the line cord is plugged into a grounded outlet to establish earth ground.
3. If the chassis has multiple fan speed settings, verify the fan switch is set to HIGH and the inhibit switch is set to DEF.

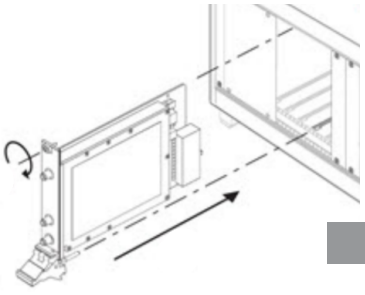
   For detailed instructions, refer to the Keysight PXIe Chassis Family, Startup Guide for the M9019A, M9018B, and M9010A (M9019-90001).

4. 2. 2 Install PXIe Modules

1. Holding each module by the injector/ejector handle, slide it into an available slot.
2. Install each module into a slot in the chassis by placing the module card edges into the front module guides (top and bottom). Note that a generic module installation is shown and may not reflect your module's actual size or placement.
3. Slide each module to the rear of the chassis and ensure that the injector/ejector handle is pushed down in the unlatched (downward) position.
4. Slide each module completely into the chassis. When you begin to feel resistance, pull up on the injector/ejector handle to fully inject the module into the chassis.
5. Secure all modules to the chassis using the module mounting screws.
   - Use a #1 Pozidriv or slotted screwdriver and torque all module mounting screws to 5 in-lb (0.57 N m).
   - Performance may suffer if the screws are not tightened properly.



WARNING Do not remove or insert any PXIe cards into the chassis with the power on. This could cause irreparable damage to both the PXIe cards and the chassis.



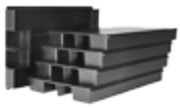
NOTE To help with cooling, it is recommended that each Keysight M9347AH01 PXIe Dual DDS module be located in a slot of the PXIe chassis that has empty slots on both sides of the module; these empty slots should contain both slot blockers and EMC filler panels. (See M9347-90001.)

4. 2. 3 Install Slot Blockers and EMC Filler Panels

NOTE **Missing slot blockers or EMC filler panels may disrupt air circulation in the chassis and are required to meet data sheet specifications. The left-most slot in the PXIe chassis does not accept a slot blocker.**

If there are any empty slots in the PXIe chassis after installing all PXIe modules:

1. Install slot blockers.
2. Install EMC filler panels.



Keysight Y1212A Qty 1 Slot blocker kit: 5 slots

Keysight Y1213A Qty 1 PXI EMC filler panel kit: 5 slots

4. 2. 4 Install an I/Q Modulator/Demodulator Test Set

Keysight U3022AH37 I/Q Modulator/Demodulator Test Set

For detailed instructions, refer to the Keysight U3022AH37 I/Q Modulator/Demodulator Test Set, User's and Service Guide (U3022-90011).

4. 2. 5 Install a Frequency Reference

Keysight E8267D PSG Vector Signal Generator

- E8267D-UNY Ultra-Low Phase Noise Performance
- E8267D-520 Frequency Range, 250 kHz to 20 GHz (Used as 19.2 GHz clock.)
  - RF output connector on the front panel:
    - Option-520 ships with a 3.5 mm (m)
    - Option-532 and -544 ships with a 2.4 mm (m)

The RF output of the E8267D can be fed into an optional splitter; the outputs of the splitter can be fed into the inputs of up to eight M9347AH01.

The **Clock In** port on the Keysight M9347AH01 PXIe Dual Direct Digital Synthesizer is designed for inputs of 4.8 GHz and 19.2 GHz at 0 to +20 dBm. The optimal input frequency and power used to drive the Clock In port is 19.2 GHz @ 0 dBm.
For detailed instructions, refer to the Keysight E8257D/67D PSG Signal Generators, Installation Guide (E8251-90352).

(Optional) Power Divider

8-Way Power Divider, PULSAR MICROWAVE CORPORATION, PS8-53-454/4S, (https://www.pulsarmicrowave.com/spec_sheets/PS8-53-454-4S.pdf) or equivalent.

4. 2. 6 Connect Cables, High-Pass Filter, and Attenuator

NOTE **In all equipment setups throughout this document, all cables are the same and shown in different colors for clarity only.**
See Cables, SMA (m) to SMA (m) on page 15.

1. Connect a Y1202A or Y1203A PCIe cable to an M9049A or M9049B PCIe Host Adapter in the HP Z8 G4 Workstation.

2. Connect SMA (m) to SMA (m) cables from an AWG to an I/Q Modulator:
   a. Connect AWG Ch 1 Out to I/Q Modulator I In.
   b. Connect AWG Ch 2 Out to I/Q Modulator Q In.
   c. Connect AWG Ch 3 Out to I/Q Modulator Pin Sw.

   NOTE **I/Q Modulator Pin Sw connector is an SMB (m). If using an SMA (m) to SMA (m) cable to connect to I/Q Modulator Pin Sw, use an SMA (f) to SMB (m) to SMB (f) to SMB (f) or a single SMA (f) to SMB (f).**

3. Connect SMA (m) to SMA (m) cables from an I/Q Demodulator to a Digitizer:
   a. Connect the I/Q Demodulator I Out to Digitizer Ch 1 In.
   b. Connect the I/Q Demodulator Q Out to Digitizer Ch 2 In.

4. Connect the E8267D PSG RF Output to the M9347AH01 Clock In:
   a. Connect a 3.5 mm (f) to 3.5 mm (f) adapter on the E8267D PSG RF Output with Option 520 or connect a 2.4 mm (f) to 3.5 mm (f) adapter on the E8267D PSG RF Output with Option 532 or 544.
   b. Connect one end of SMA (m) to SMA (m) cable to the 3.5 mm (f) adapter.
   c. Connect the other end of the SMA cable to the M9347AH01 Clock In.

5. Connect SMA (m) to SMA (m) cables from M9347AH01 to both the I/Q Modulator and I/Q Demodulator:
   a. Connect the M9347AH01 Synth Out 1 to I/Q Modulator LO In.
   b. Connect the M9347AH01 Synth Out 2 to I/Q Demodulator LO In.

6. Connect a high-pass filter directly to the I/Q Modulator RF Out. (This high-pass filter helps protect other devices from high power out.)

7. Connect a 30 dB attenuator directly to the I/Q Demodulator RF In. (The maximum U3022AH37 I/Q Demodulator RF In Power is 0 dBm. This 30 dB attenuator may be removed when running actual Qubit measurements; it is used here to protect the I/Q Demodulator RF In.)

4. 3 (Optional) Install Hardware in a Rack Cabinet

Hardware Placement in a Rack Cabinet

E3662B
2.0 m, 41U Rack

Frequency
Reference

PXIe Chassis #2
PXIe Modules:
- M3202A AWGs
- M3102A Digitizers
- M9347AH01 Dual DDS

U3022AH37
I/Q Modulator/
Demodulator
Test Set

PXIe Chassis #1
PXIe Modules:
- M3202A AWGs
- M3102A Digitizers
- M9347AH01 Dual DDS

HP Z8 G4
Workstation

WARNING **Order of Hardware Installation**
Always begin installing the PXIe chassis and heavy instruments at the bottom of the rack and work up. This maintains a lower center of gravity and reduces the possibility of the rack tipping.

Maximum Load
Racks can be loaded with a total of 1800 pounds (~816 Kilograms).

Anti-tip Stabilizer
Standard on each Keysight rack is a retractable anti-tip stabilizer mechanism. Located at the bottom center of the rack, it provides temporary additional stability when installing or removing equipment components. The anti-tip stabilizer should also be used when slide-mounted components are in their extended position.

Rack mounting kits:

- Keysight M9019A and M9018B PXIe Chassis,
  use Keysight Y1215C Flush Mount Adapter and Y1217A Rack Rail Kit.

- Keysight M9010A PXIe Chassis,
  use Keysight Y1271A Rackmount Kit and Y1217A Rack Rail Kit.

- Keysight U3022AH37 I/Q Modulator/Demodulator Test Set,
  use Keysight 1CP108A, Rack Mount Flange and Handle Kit,
  132.6 mm H (3U) - Two Brackets and Front Handles.

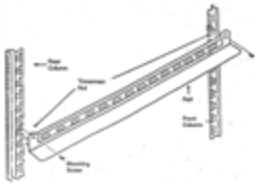
- Keysight E8267D PSG Vector Signal Generator,
  use 1CP106A Rack Mount Flange and Handle Kit,
  177.0 mm H (4U) - Brackets, Handles, Hole Plugs.

4. 3. 1 Install a Rack Cabinet

Rack Cabinet
Keysight E3662B Rack Cabinet, 2.0 m, 41U

For detailed instructions on racking equipment, refer to the Keysight Instrument Rack, User Manual for the E7590A, E3661B, and E3662B (5967-9318).

4. 3. 1. 1 Install rack cabinet support rails



1. Decide where in the rack the equipment is to be installed.

   WARNING **Always begin installing the PXIe chassis and heavy instruments at the bottom of the rack and work up. This maintains a lower center of gravity and reduces the possibility of the rack tipping.**

2. Locate the rectangular mounting holes for the support rail.

   NOTE **Every fifth mounting hole is notched.**

3. Position the four Tinnerman (10-32) nuts over the round holes adjacent to the rectangular mounting slots.
4. Slip the rail flanges into the rectangular mounting holes.

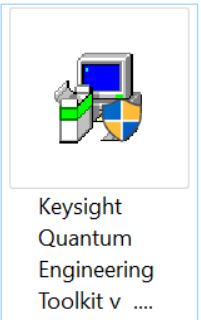
   The rail should stay in place.

   WARNING **Although rails will sit on columns, always secure rails with TORX screws prior to installing equipment.**

5. Verify that the Tinnerman nuts are aligned with the mounting holes in the rail.
6. Insert and tighten the mounting screws (10-32) on both the front and rear vertical columns. Repeat for the other rail.
7. Install the piece of equipment.
8. Slide it all the way into the rack, bezel flush with the front of the columns.
9. Secure to the rack columns if necessary.

5 Install Software

The Keysight Quantum Engineering Toolkit Setup Wizard installs all software needed to operate the Quantum Engineering Toolkit (QET).



Software is installed in the following order:

- Microsoft .NET Framework
- Keysight IO Libraries Suite
- Keysight M902x PXIe System Module
- Keysight PXIe Chassis Family
- Keysight M9347 PXI LO Drivers
- Keysight SD1 Drivers, Libraries, and SFP
- Keysight M3601A HVI Programming Environment
- Keysight M3602A FPGA Programming Environment
- Keysight QET Initialization Utility

Refer to the `Quantum_Engineering_Toolkit_Readme.txt` file for details on the specific versions of software that are being installed. Unless it is changed during the installation process, this file can be found in the following default location:
`C:\Users\<CurrentUser>\Documents\Keysight Quantum Engineering Toolkit`

NOTE

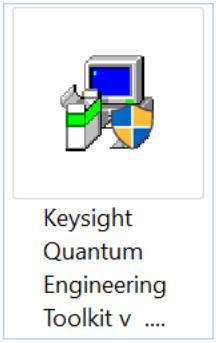
If any software is already installed, a prompt will ask if you would like to "Modify", "Repair", or "Remove" the software; "Repair" and "Modify" are acceptable choices.

If prompted, do NOT reboot after an individual software is done installing – this will not allow the rest of the software to be installed and the process will have to be restarted.

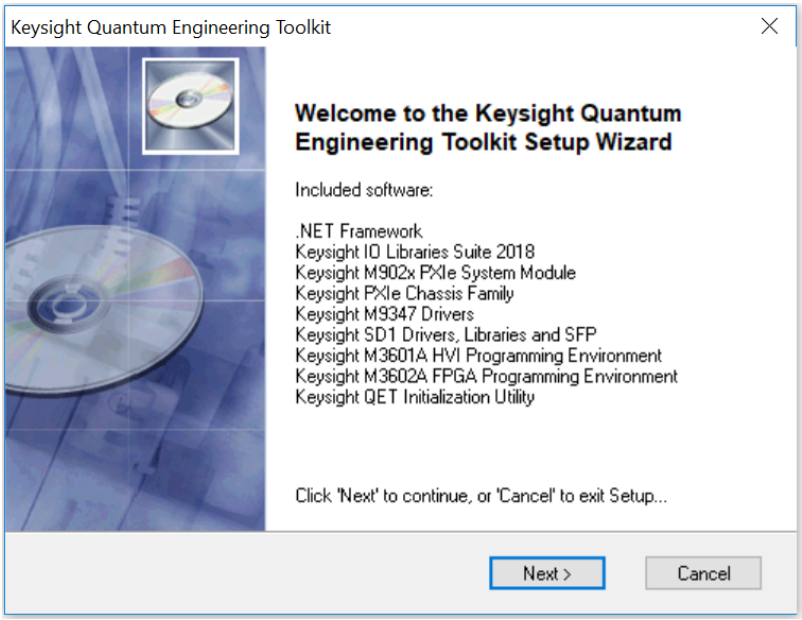
Reboot the system only after all software is installed.

5. 1 Run the QET Setup Wizard

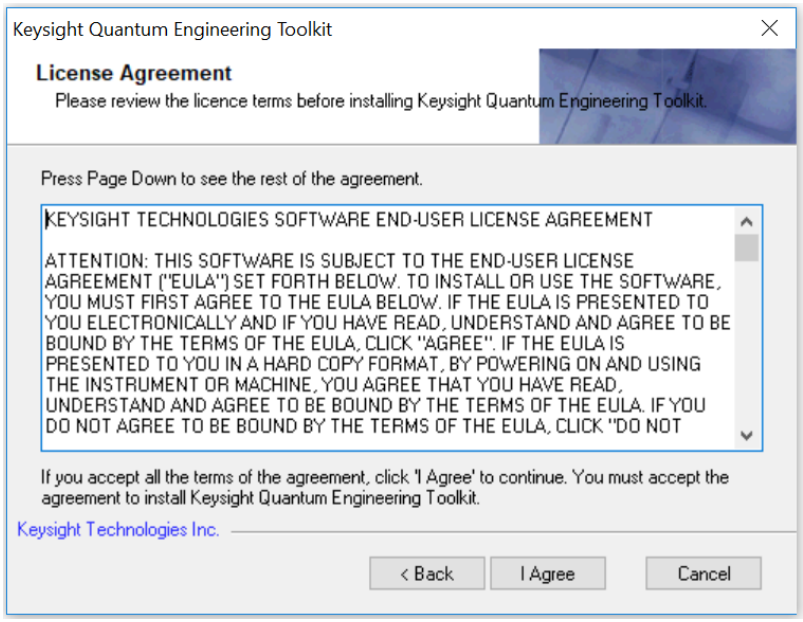
1. Download the QET Setup Wizard.
2. Double-click the QET Setup Wizard icon.



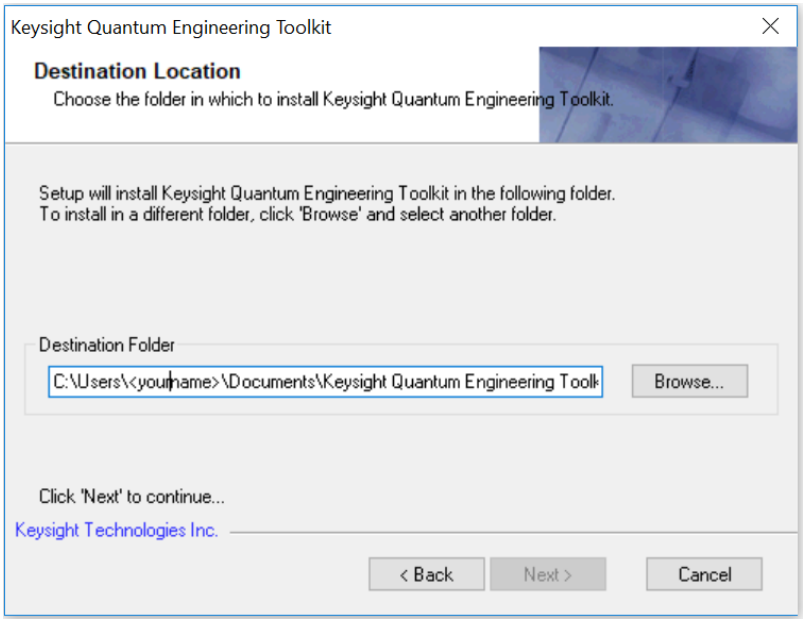
3. Click **Next** to continue.



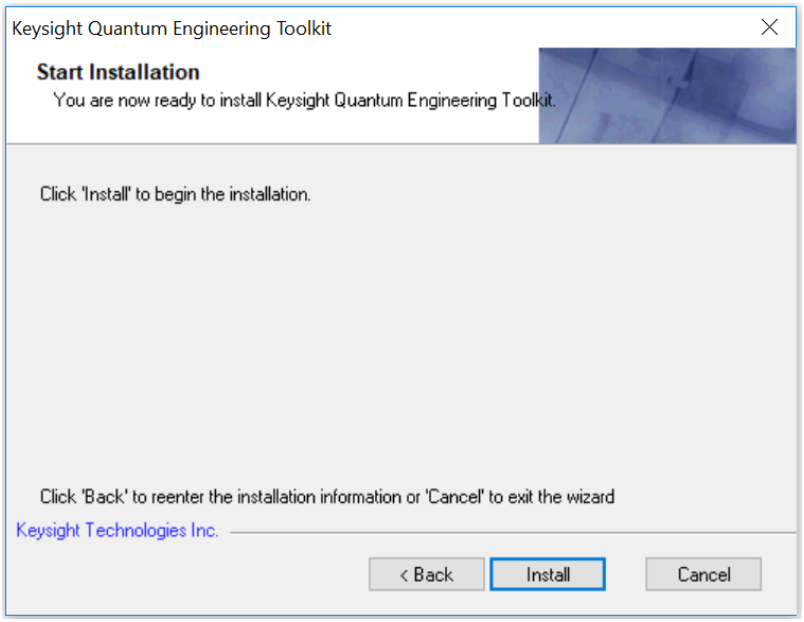
4. Click **I Agree** to continue after reviewing all terms of the End User License Agreement (EULA).



5. Click **Next** to continue or change the Destination Folder for file installation. Default Location:
   `C:\Users\<CurrentUser>\Documents\Keysight Quantum Engineering Toolkit`



6. Click **Next** to continue.



7. Read and follow the remaining on-screen prompts to unzip all components. A batch script executes and each component's installer will start.

NOTE

If any software is already installed, a prompt will ask if you would like to "Modify", "Repair", or "Remove" the software; "Repair" and "Modify" are acceptable choices.

If prompted, do NOT reboot after an individual software is done installing – this will not allow the rest of the software to be installed and the process will have to be restarted.

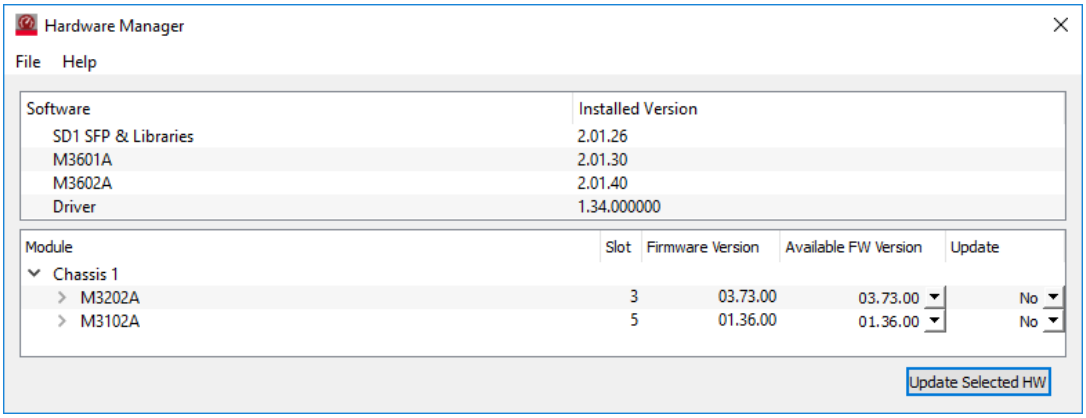
Reboot the system only after all software is installed.

8. Reboot the system after the batch script is completed.

   A readme file is placed in:
   `C:\Users\<CurrentUser>\Documents\Keysight Quantum Engineering Toolkit`

   Firmware updates for M3xxxA modules must be performed manually through Keysight SD1. Check for recommended firmware versions in the readme file and follow the instructions on the next page to update the firmware for all modules that require it.

5. 2 Update Firmware



1. Select **Start** > **Keysight** > **Keysight SD1 SFP**.
2. Select **Help** > **Hardware Manager**.
3. View the list under Module
   a. In the **Available FW Version** column, for each module listed, select the drop-down menu arrow and select a FW Version.
   b. In the **Update** column, for each module listed, select the drop-down menu arrow and select **Yes**.
4. Select **Update Selected HW**.
5. Follow the on-screen instructions to download and install all new firmware.
6. When prompted, shutdown the system – not doing so at the time of the prompt will result in firmware versions not being updated.

6 Verify Operation

NOTE The following list of hardware components are the recommended models used with the Keysight Quantum Engineering Toolkit. The hardware configurations are shown using the Keysight M9019A PXIe Chassis; this chassis and many other hardware components may have optional or alternate models available. Refer to Review Hardware Components on page 9.

NOTE Each of the following procedures has been written so that each one can be performed independent of the others; if you are performing all of these procedures in the order shown, you may notice that some of the steps are repeated.

Perform the following sequence when verifying operation:

1. Verify Operation of each AWG, Digitizer, and Chassis on page 34
   a. Connect Cables
   b. Configure each AWG and Digitizer
   c. Verify Operation of AWGs and Digitizers, Frequency Spectrum
   d. Verify Operation of AWGs and Digitizers, Time Domain
2. Verify Operation of each M9347AH01 PXIe Dual DDS (LO) on page 39
   a. Connect Cables
   b. Configure a Frequency Reference
   c. Configure an M9347AHO1 PXIe Dual DDS Module
   d. Verify Operation of each Dual DDS Module with a Spectrum Analyzer
3. Verify Operation of each U3022AH37 I/Q Modulator on page 43
   a. Connect Cables
   b. Configure a Frequency Reference
   c. Configure each AWG
   d. Configure an M9347AHO1 PXIe Dual DDS Module
   e. Verify Operation of the I/Q Modulator with a Spectrum Analyzer
4. Verify Operation of each U3022AH37 I/Q Demodulator on page 48
   a. Connect Cables, High-Pass Filter, and Attenuator
   b. Configure a Frequency Reference
   c. Configure each AWG and Digitizer
   d. Configure an M9347AHO1 PXIe Dual DDS module
   e. Verify Operation of the I/Q Demodulator, Frequency Spectrum
   f. Verify Operation of the I/Q Demodulator, Time Domain

6. 0. 1 Verify Operation of each AWG, Digitizer, and Chassis

6. 0. 1. 1 Connect Cables

NOTE **In all equipment setups throughout this document, all cables are the same and shown in different colors for clarity only.**
See Cables, SMA (m) to SMA (m) on page 15.

1. Connect a Y1202A or Y1203A PCIe cable to an M9049A or M9049B PCIe Host Adapter in the HP Z8 G4 Workstation.
2. Use SMA (m) to SMA (m) cables for the following connections:
   a. Connect AWG Ch 1 Out to Digitizer Ch 1 In.
   b. Connect AWG Ch 2 Out to Digitizer Ch 2 In.
   c. Connect AWG Ch 3 Out to Digitizer Ch 3 In.
   d. Connect AWG Ch 4 Out to Digitizer Ch 4 In.

6. 0. 1. 2 Configure each AWG and Digitizer

1. Start the Soft Front Panel and configure each AWG and Digitizer by selecting **Start** > **Keysight** > **Keysight SD1 SFP**.
2. Verify Operation Using the Frequency Spectrum
3. Verify Operation Using the Time Domain

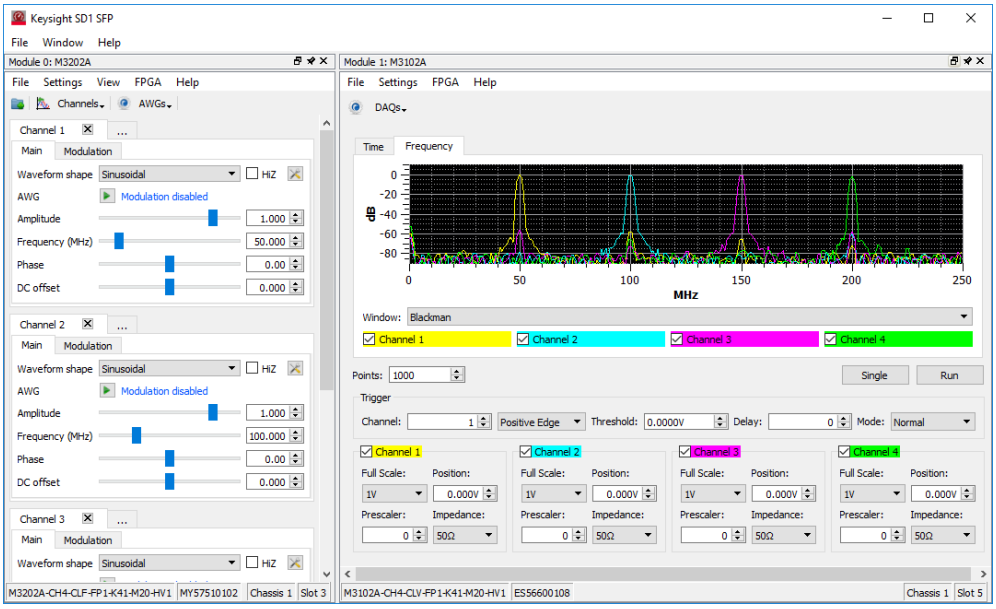
6. 0. 1. 3 Verify Operation of AWGs and Digitizers, Frequency Spectrum

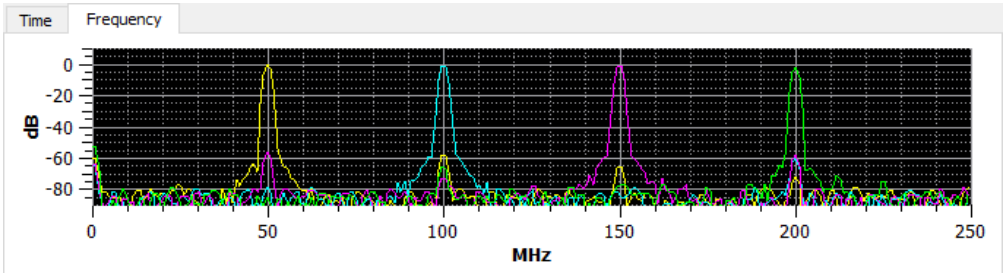
1. Configure channels 1, 2, 3, and 4 of the AWG.
    a. Select **View** > **New Panel**.
    b. Select **Channel** drop-down menu, **1**, and **OK** to add Channel 1.
    c. Repeat these steps to add Channels 2, 3, and 4.
    d. On Channel 1 SFP, select:
        - Waveform shape: **Sinusoidal**
        - Amplitude: **1.0 V**
        - Frequency (MHz): **50 MHz**
        - Phase: **0.00**
        - DC offset: **0.000**
    e. On Channel 2 SFP, select:
        - Waveform shape: **Sinusoidal**
        - Amplitude: **1.0 V**
        - Frequency (MHz): **100 MHz**
        - Phase: **0.00**
        - DC offset: **0.000**
    f. On Channel 3 SFP, select:
        - Waveform shape: **Sinusoidal**
        - Amplitude: **1.0 V**
        - Frequency (MHz): **150 MHz**
        - Phase: **0.00**
        - DC offset: **0.000**
    g. On Channel 4 SFP, select:
        - Waveform shape: **Sinusoidal**
        - Amplitude: **1.0 V**
        - Frequency (MHz): **200 MHz**
        - Phase: **0.00**
        - DC offset: **0.000**
    h. On Channel 1, 2, 3, and 4, clear the **HiZ** check box to enable the output of each channel.
    i. Select **Settings** > **Reset Accumulated Phase** > **Reset Phase**.

2. Configure channels 1, 2, 3, and 4 of the Digitizer.
    a. Select the **Frequency** tab.
    b. Select the check box for Channel 1, 2, 3, and 4.
    c. Set Points to **1000**.
    d. Set Channel 1, 2, 3, and 4 to the following settings:
        - Impedance: **50 Ω**
        - Full Scale: **1 V**
        - Position: **0.000 V**
        - Prescaler: **0**

3. Verify Operation Using the Frequency Spectrum

    Verify each channel is working correctly by looking at the **Frequency** tab of the Digitizer; there should be a signal at 50, 100, 150, and 200 MHz.

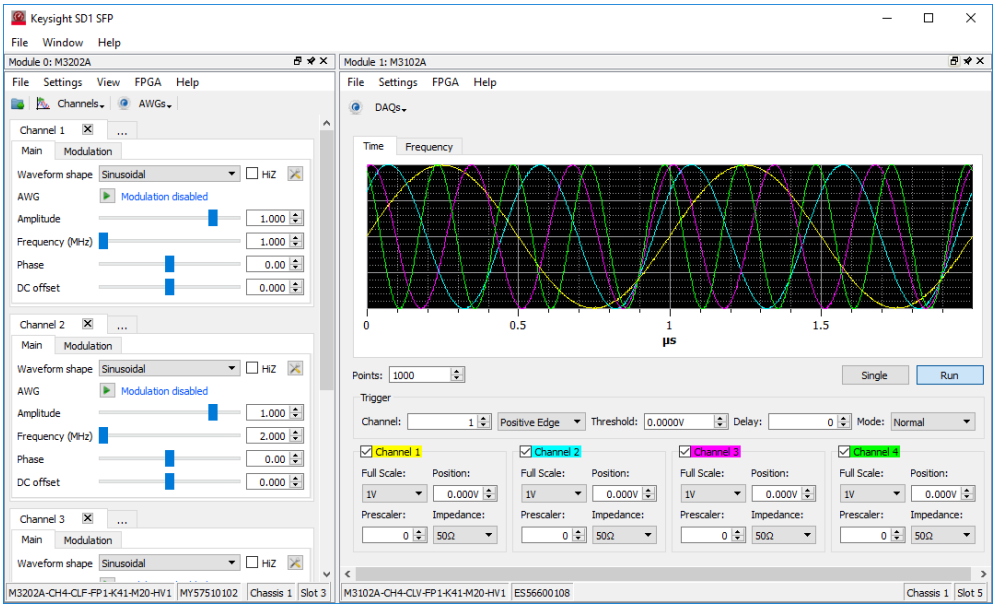




6. 0. 1. 4 Verify Operation of AWGs and Digitizers, Time Domain

1. Configure channels 1, 2, 3, and 4 of the AWG:
    a. On Channel 1 SFP, select:
        - Waveform shape: **Sinusoidal**
        - Amplitude: **1.0 V**
        - Frequency (MHz): **1 MHz**
        - Phase: **0.00**
        - DC offset: **0.000**
    b. On Channel 2 SFP, select:
        - Waveform shape: **Sinusoidal**
        - Amplitude: **1.0 V**
        - Frequency (MHz): **2 MHz**
        - Phase: **0.00**
        - DC offset: **0.000**
    c. On Channel 3 SFP, select:
        - Waveform shape: **Sinusoidal**
        - Amplitude: **1.0 V**
        - Frequency (MHz): **3 MHz**
        - Phase: **0.00**
        - DC offset: **0.000**
    d. On Channel 4 SFP, select:
        - Waveform shape: **Sinusoidal**
        - Amplitude: **1.0 V**
        - Frequency (MHz): **4 MHz**
        - Phase: **0.00**
        - DC offset: **0.000**
    e. On Channel 1, 2, 3, and 4, clear the **HiZ** check box to enable the output of each channel.
    f. Select **Settings** > **Reset Accumulated Phase** > **Reset Phase**.
2. Configure channels 1, 2, 3, and 4 of the Digitizer to view the Time domain.
    a. Select the **Time** tab.
    b. Select the check box for Channel 1, 2, 3, and 4.
    c. Set Points to 1000.
    d. Set Channel 1, 2, 3, and 4 to the following settings:
        - Full Scale: **1 V**
        - Position: **0.000 V**
        - Prescaler: **0**
        - Impedance: **50 Ω**

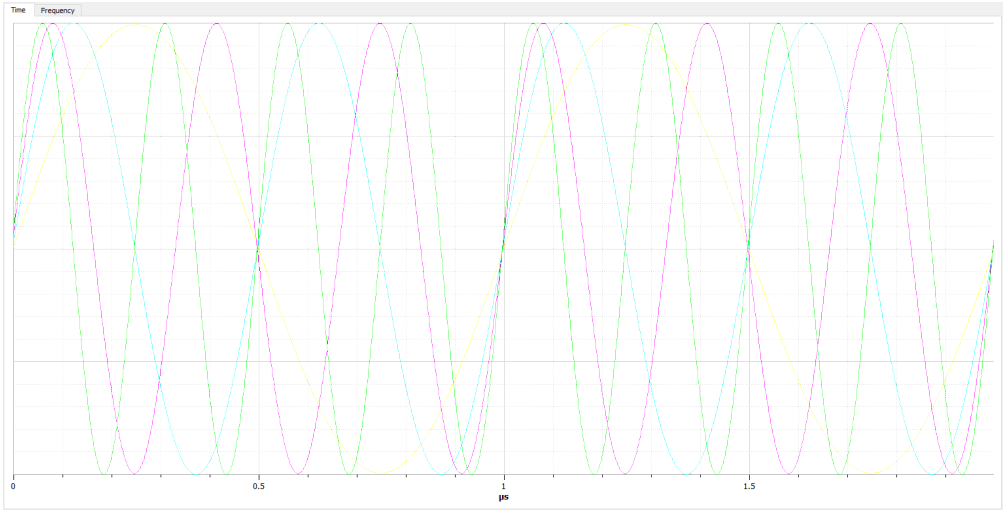
3. Verify each channel is working correctly by looking at the **Time** domain tab of the Digitizer.



There should be four sine waves displayed, each with a different period that corresponds to 1, 2, 3, and 4 MHz where:

$f_{(Frequency)} = 1/t_{(Period)}$

Frequency	Approximate Period
1 MHz	1.00 µs
2 MHz	0.50 µs
3 MHz	0.33 µs
4 MHz	0.25 µs



6. 0. 2 Verify Operation of each M9347AH01 PXIe Dual DDS (LO)

NOTE In all equipment setups throughout this document, all cables are the same and shown in different colors for clarity only.
See Cables, SMA (m) to SMA (m) on page 15.

6. 0. 2. 1 Connect Cables

NOTE **In all equipment setups throughout this document, all cables are the same and shown in different colors for clarity only.**
See Cables, SMA (m) to SMA (m) on page 15.

1. Connect a Y1202A or Y1203A PCIe cable to an M9049A or M9049B PCIe Host Adapter in the HP Z8 G4 Workstation.
2. Connect the E8267D PSG RF Output to the M9347AH01 Clock In.
   a. Connect a 3.5 mm (f) to 3.5 mm (f) adapter on the E8267D PSG RF Output with Option 520 or connect a 2.4 mm (f) to 3.5 mm (f) adapter on the E8267D PSG RF Output with Option 532 or 544.
   b. Connect one end of SMA (m) to SMA (m) cable to the 3.5 mm (f) adapter.
   c. Connect the other end of the SMA cable to the M9347AH01 Clock In.
3. Connect the M9347AH01 Synth Out 1 to a spectrum analyzer input.
   a. Connect a Type-N (m) to SMA (f) adapter on the spectrum analyzer input.
   b. Connect one end of SMA (m) to SMA (m) cable to the SMA (f) adapter.
   c. Connect the other end of the SMA cable to M9347AH01 Synth Out 1.

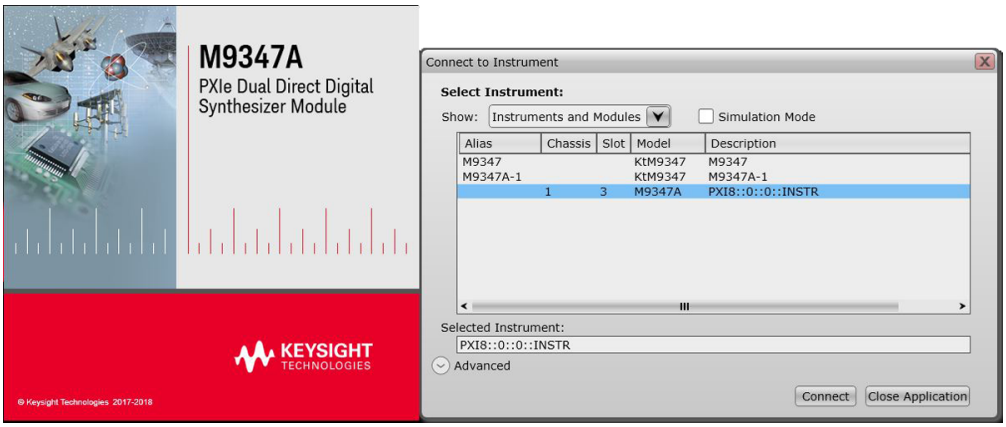
6. 0. 2. 2 Configure a Frequency Reference

- If using the Keysight E8257D or E8267D PSG Signal Generator as the frequency reference, perform the following:
  a. Select [FREQUENCY] and enter 19.2 GHz.
  b. Select [AMPLITUDE] and enter 0.00 dBm.
  c. Select [RF On/Off] so that RF Output is On.

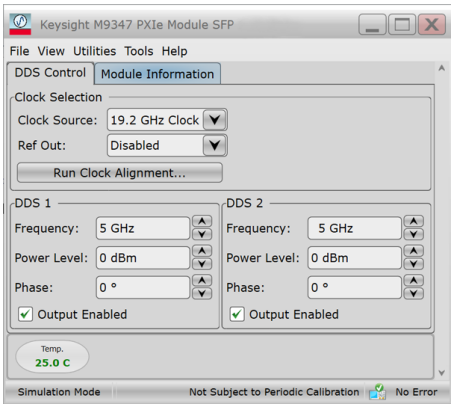
- If a different frequency reference is being used, refer to the user documentation for that product to learn how to set the frequency and power to the settings listed above.

6. 0. 2. 3 Configure an M9347AH01 PXIe Dual DDS Module

1. Start the Soft Front Panel for each M9347AH01 PXIe Dual DDS module by selecting **Start** > **Keysight M9347 PCIe Module** > **M9347 SFP.**
2. From the **Connect to Instrument** dialog, select a M9347AH01 module. (If there is more than one M9347AH01 module in the system, use the physical **Chassis** and **Slot** number, displayed in the dialog box, to determine which M9347AH01 that is to be connected.)

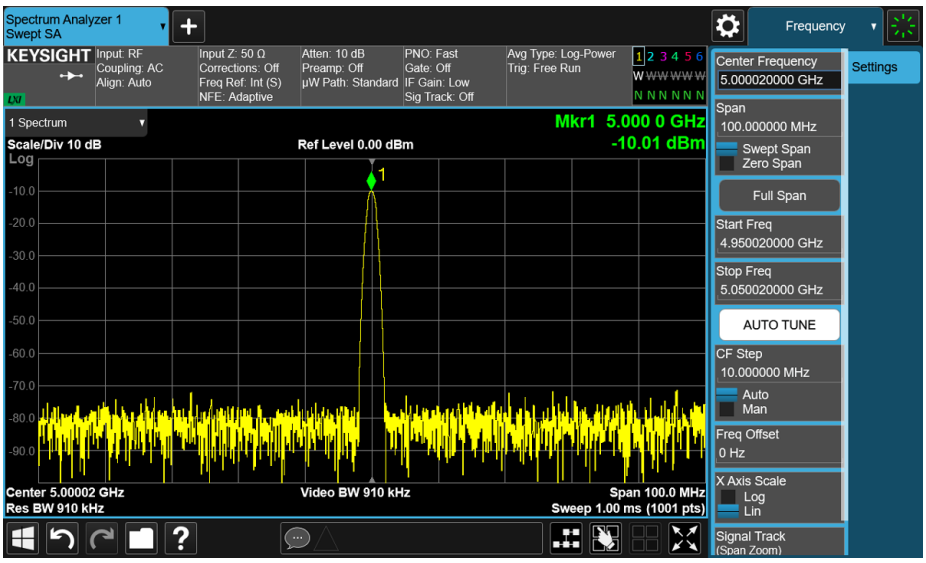


3. Using the Keysight M9347A PXIe Module SFP, select the **DDS Control** tab, and set the output settings for DDS 1 (Synth Out 1 connector):
   a. Set **Clock Source** to 19.2 GHz Clock. (This value should match the frequency being applied to **Clock In**.)
   b. Set **Ref Out** to Disabled.
   c. Select **Run Clock Alignment**. (This performs an internal alignment to lock the DDS chips to the system Clock Source. This alignment must be performed each time system Clock Source is changed.)
   d. Set **Frequency** to 5 GHz.
   e. Set **Power Level** to 0 dBm.
   f. Set **Phase** to 0 degrees.
   g. Select the check box, **Output Enabled**, to enable the Synth Out 1 connector.



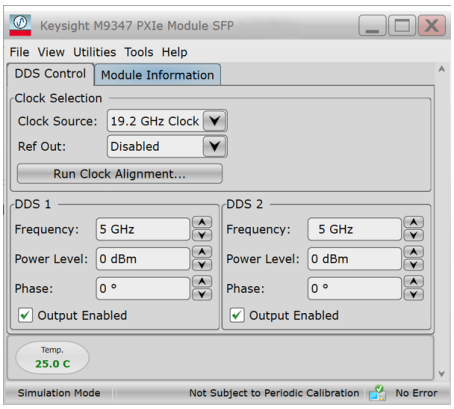
6. 0. 2. 4 Verify Operation of each Dual DDS with a Spectrum Analyzer

1. Using a spectrum analyzer, verify the output of the Synth Out 1 connector:
   a. Verify the Frequency is 5 GHz.
   b. Verify the Power Level is approximately 0 dBm.
   c. Verify there are no spikes near the signal.
   d. (Optional) Adjust the power level and frequency on the SFP and verify the power level and frequency change to the corresponding frequency and power levels on the spectrum analyzer.

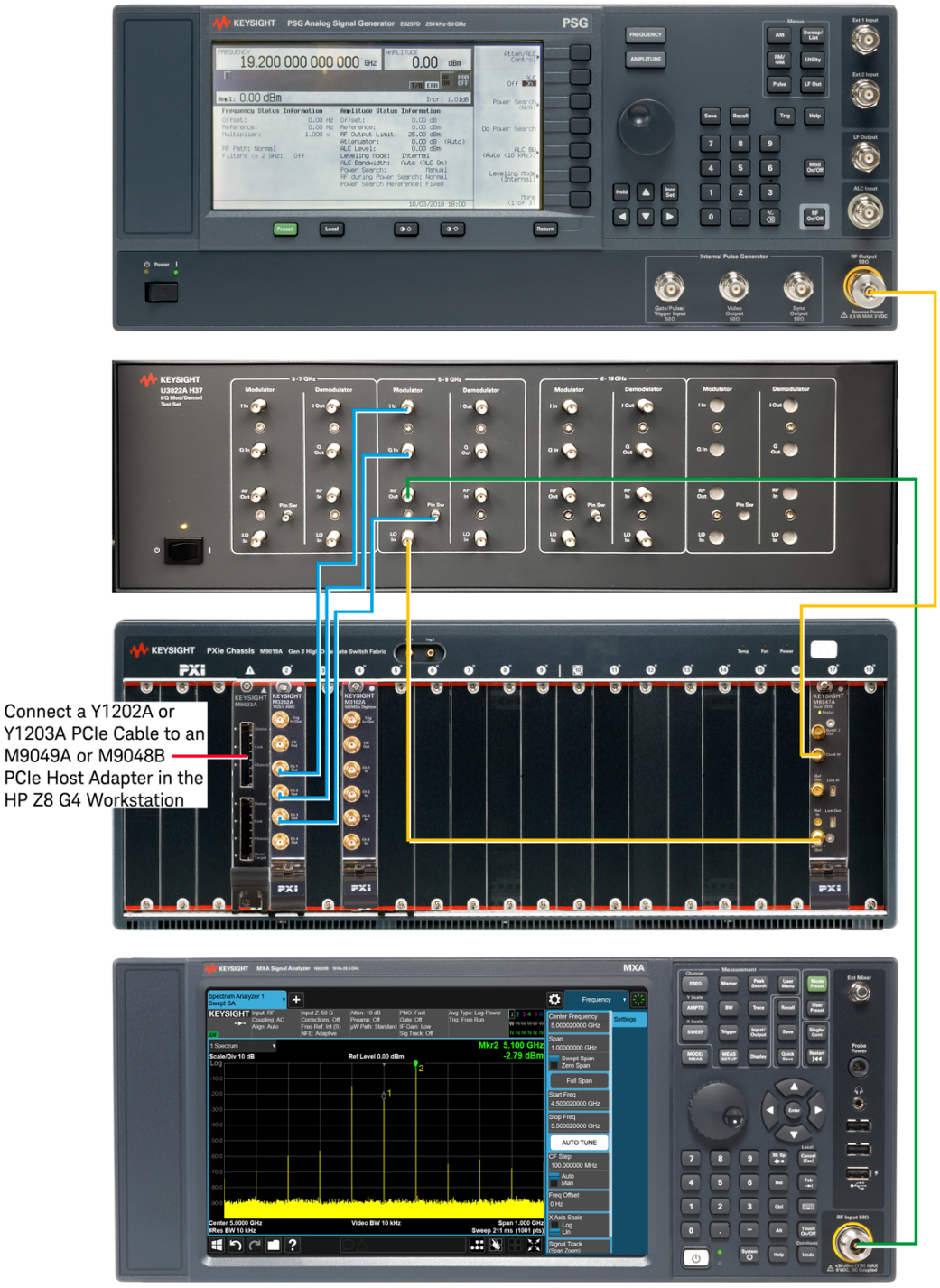


2. Move the connection from Synth Out 1 to Synth Out 2 and use the spectrum analyzer to repeat the verification steps for the Synth Out 2 connector.

   Settings for the Synth Out 2 connector are controlled with DDS 2 values.



6. 0. 3 Verify Operation of each U3022AH37 I/Q Modulator



NOTE In all equipment setups throughout this document, all cables are the same and shown in different colors for clarity only.
See Cables, SMA (m) to SMA (m) on page 15.

6. 0. 3. 1 Connect Cables

NOTE **In all equipment setups throughout this document, all cables are the same and shown in different colors for clarity only.**
See Cables, SMA (m) to SMA (m) on page 15.

1. Connect a Y1202A or Y1203A PCIe cable to an M9049A or M9049B PCIe Host Adapter in the HP Z8 G4 Workstation.
2. Connect SMA (m) to SMA (m) cables from AWG to I/Q Modulator being verified:
   a. Connect AWG Ch 1 Out to I/Q Modulator I In.
   b. Connect AWG Ch 2 Out to I/Q Modulator Q In.
   c. Connect AWG Ch 3 Out to I/Q Modulator Pin Sw.

   NOTE **I/Q Modulator Pin Sw connector is an SMB (m). If using an SMA (m) to SMA (m) cable to connect to I/Q Modulator Pin Sw, use an SMA (f) to SMB (m) to SMB (f) to SMB (f) or a single SMA (f) to SMB (f).**

3. Connect the E8267D PSG RF Output to the M9347AH01 Clock In.
   a. Connect a 3.5 mm (f) to 3.5 mm (f) adapter on the E8267D PSG RF Output with Option 520 or connect a 2.4 mm (f) to 3.5 mm (f) adapter on the E8267D PSG RF Output with Option 532 or 544.
   b. Connect one end of SMA (m) to SMA (m) cable to the 3.5 mm (f) adapter.
   c. Connect the other end of the SMA cable to the M9347AH01 Clock In.
4. Connect the M9347AH01 Synth Out 1 to I/Q Modulator LO In.
5. Connect the I/Q Modulator RF Out to the input of a spectrum analyzer.
   a. Connect a Type-N (m) to SMA (f) adapter on the spectrum analyzer input.
   b. Connect one end of an SMA (m) to SMA (m) cable to the SMA (f) adapter.
   c. Connect the other end of the SMA cable to an I/Q Modulator RF Out.

6. 0. 3. 2 Configure a Frequency Reference

- If using the Keysight E8257D or E8267D PSG Signal Generator as the frequency reference, perform the following:
  a. Select **[FREQUENCY]** and enter 19.2 GHz.
  b. Select **[AMPLITUDE]** and enter 0.00 dBm.
  c. Select **[RF On/Off]** so that RF Output is On.

- If a different frequency reference is being used, refer to the user documentation for that product to learn how to set the frequency and power to the settings listed above.

6. 0. 3. 3 Configure each AWG

1. Start the Soft Front Panel and Configure each AWG by selecting **Start** > **Keysight** > **Keysight SD1 SFP**.
2. Configure channels 1, 2, and 3 of the AWG:
   a. Select **View** > **New Panel**.
   b. Select **Channel** drop-down menu, **1**, and **OK** to add Channel 1.
   c. Repeat these steps to add Channels 2 and 3.
   d. On Channel 1 SFP, select:
      - Waveform shape: **Sinusoidal**
      - Amplitude: **0.1 V**
      - Frequency (MHz): **100 MHz**
      - Phase: **0.00 degrees**
        (This is the in-phase component of the I/Q signal being applied to the I/Q Modulator.)
      - DC offset: **0.000 V**
   e. On Channel 2 SFP, select:
      - Waveform shape: **Sinusoidal**
      - Amplitude: **0.1 V**
      - Frequency (MHz): **100 MHz**
      - Phase: **90.00 degrees**
        (This is the quadrature-phase component of the I/Q signal being applied to the I/Q Modulator.)
      - DC offset: **0.000 V**
   f. On Channel 3 SFP, select:
      - Waveform shape: **DC**
      - Amplitude: **0 V**
      - Frequency (MHz): **0**
      - Phase: **0.00 degrees**
      - DC offset: **0.5 V**

      CAUTION When operating the I/Q Modulator Pin Switch, the control signal may leak into the RF Out and damage an amplifier if it is connected directly to the output of the RF Out connector. To help protect devices, it is recommended that a high-pass filter be connected on the RF Out connector with a cutoff frequency of at least 2 GHz. (For example, a Mini-Circuits 15542 High-Pass Filter with a frequency range of 2010 to 10100 MHz.)

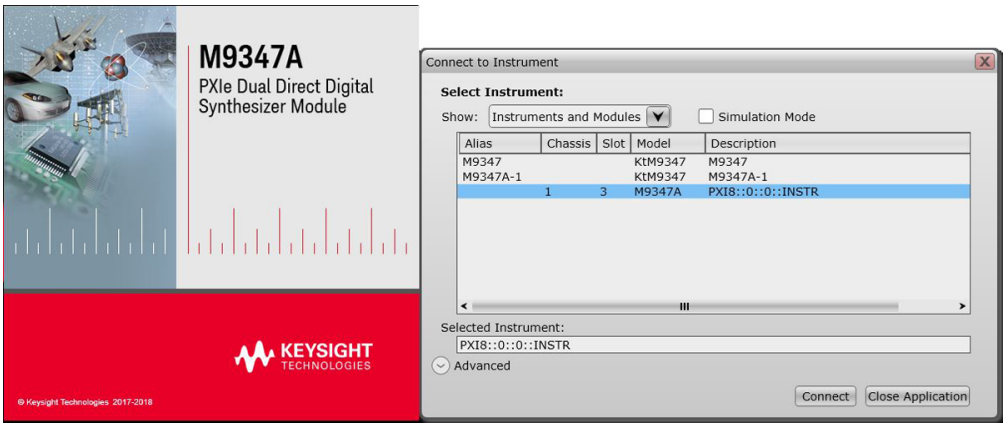
      

      The actual high-pass filter model depends on the frequency range of the I/Q Modulator being used.

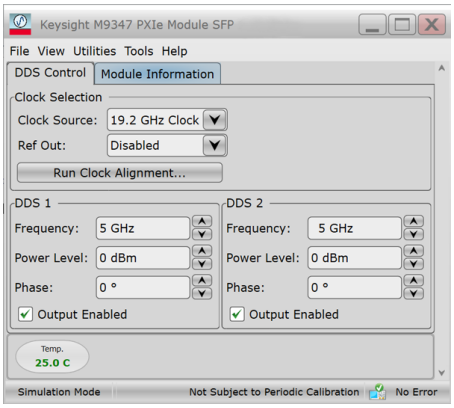
   g. On Channel 1, 2, and 3, clear the **HiZ** check box to enable outputs.

6. 0. 3. 4 Configure an M9347AH01 PXIe Dual DDS Module

1. Start the Soft Front Panel for each M9347AH01 PXIe Dual DDS module by selecting **Start** > **Keysight M9347A PCIe Module** > **M9347 SFP.**
2. From the **Connect to Instrument** dialog, select a M9347AH01 module. (If there is more than one M9347AH01 module in the system, use the physical Chassis and Slot number, displayed in the dialog box, to determine which M9347AH01 that is to be connected.)



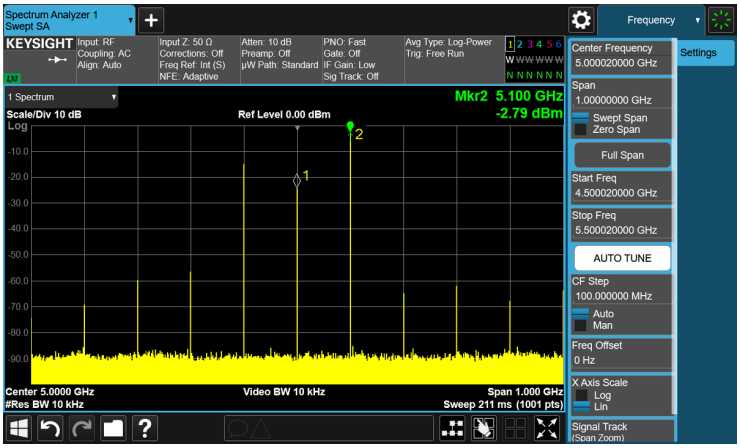
3. Using the Keysight M9347 PXIe Module SFP, select the **DDS Control** tab, and set the output settings for DDS 1 (Synth Out 1 connector):
   a. Set **Clock Source** to 19.2 GHz Clock. (This should match the frequency being applied to **Clock In**.)
   b. Set **Ref Out** to Disabled.
   c. Select **Run Clock Alignment**. (This performs an internal alignment to lock the DDS chips to the system Clock Source. This alignment must be performed whenever the system Clock Source is changed.)
   d. Set **Frequency** to 5 GHz.
   e. Set **Power Level** to 0 dBm.
   f. Set **Phase** to 0 degrees.
   g. Select the check box, **Output Enabled**, to enable the Synth Out 1 connector.



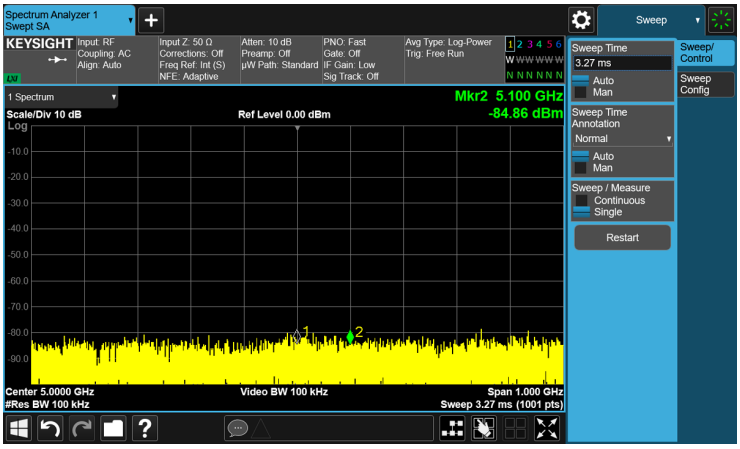
6. 0. 3. 5 Verify Operation of an I/Q Modulator with a Spectrum Analyzer

1. Verify there is an LO feed-through signal at 5 GHz as shown at Marker 1.

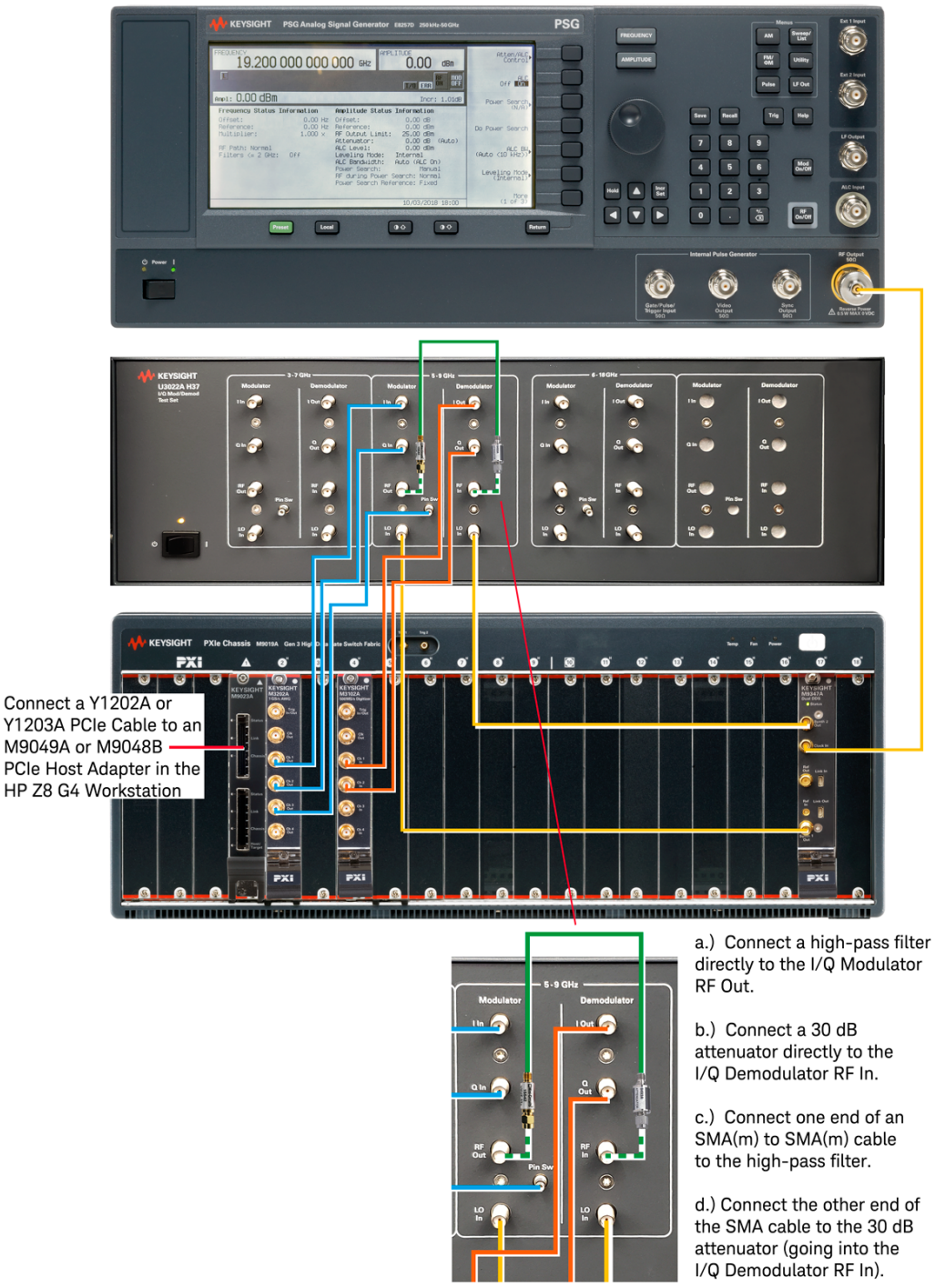
2. Verify there are mixing products that correspond to the frequencies set on the AWG Soft Front Panel; in the above example, Frequency was set to 100 MHz for Ch 1 and Ch 2, so there should be mixing product signals at 4.9 GHz and 5.1 GHz. (Marker 2 is used to label the 5.1 GHz signal. A signal is also shown at 4.9 GHz, but is not labeled with a Marker.)



3. Verify that when the signal level from AWG Ch 3, which should be connected to the I/Q Modulator Pin Sw, goes below 0.2 V, the pin switch in the I/Q Modulator is turned off; the result looks like the I/Q Modulator is turned off, as shown below.



6. 0. 4 Verify Operation of each U3022AH37 I/Q Demodulator



NOTE In all equipment setups throughout this document, all cables are the same and shown in different colors for clarity only.
See Cables, SMA (m) to SMA (m) on page 15.

6. 0. 4. 1 Connect Cables, High-Pass Filter, and Attenuator

NOTE **In all equipment setups throughout this document, all cables are the same and shown in different colors for clarity only.**
See Cables, SMA (m) to SMA (m) on page 15.

1. Connect a Y1202A or Y1203A PCIe cable to an M9049A or M9049B PCIe Host Adapter in the HP Z8 G4 Workstation.
2. Connect SMA (m) to SMA (m) cables from an AWG to an I/Q Modulator:
   a. Connect AWG Ch 1 Out to I/Q Modulator I In.
   b. Connect AWG Ch 2 Out to I/Q Modulator Q In.
   c. Connect AWG Ch 3 Out to I/Q Modulator Pin Sw.

   NOTE **I/Q Modulator Pin Sw connector is an SMB (m). If using an SMA (m) to SMA (m) cable to connect to I/Q Modulator Pin Sw, use an SMA (f) to SMB (m) to SMB (f) to SMB (f) or a single SMA (f) to SMB (f).**
3. Connect SMA (m) to SMA (m) cables from an I/Q Demodulator to a Digitizer:
   a. Connect the I/Q Demodulator I Out to Digitizer Ch 1 In.
   b. Connect the I/Q Demodulator Q Out to Digitizer Ch 2 In.
4. Connect the E8267D PSG RF Output to the M9347AH01 Clock In:
   a. Connect a 3.5 mm (f) to 3.5 mm (f) adapter on the E8267D PSG RF Output with Option 520 or connect a 2.4 mm (f) to 3.5 mm (f) adapter on the E8267D PSG RF Output with Option 532 or 544.
   b. Connect one end of SMA (m) to SMA (m) cable to the 3.5 mm (f) adapter.
   c. Connect the other end of the SMA cable to the M9347AH01 Clock In.
5. Connect SMA (m) to SMA (m) cables from M9347AH01 to both the I/Q Modulator and I/Q Demodulator:
   a. Connect the M9347AH01 Synth Out 1 to I/Q Modulator LO In.
   b. Connect the M9347AH01 Synth Out 2 to I/Q Demodulator LO In.
6. Connect the I/Q Modulator RF Out to the I/Q Demodulator RF In through a high-pass filter and a 30 dB attenuator:
   a. Connect a high-pass filter directly to the I/Q Modulator RF Out.
   b. Connect a 30 dB attenuator directly into the I/Q Demodulator RF In.
   c. Connect one end of an SMA (m) to SMA (m) cable to the high-pass filter; this is the side with RF Out.
   d. Connect the other end of the SMA cable to the 30 dB attenuator that is going into the I/Q Demodulator RF In.
   This 30 dB attenuator may be removed when running actual Qubit measurements; it is used here to protect the I/Q Demodulator RF In.

6. 0. 4. 2 Configure a Frequency Reference

- If using the Keysight E8257D or E8267D PSG Signal Generator as the frequency reference, perform the following:
  a. Select **[FREQUENCY]** and enter 19.2 GHz.
  b. Select **[AMPLITUDE]** and enter 0.00 dBm.
  c. Select **[RF On/Off]** so that RF Output is On.

- If a different frequency reference is being used, refer to the user documentation for that product to learn how to set the frequency and power to the settings listed above.

6. 0. 4. 3 Configure each AWG and Digitizer

1. Start the Soft Front Panel and configure each AWG and Digitizer by selecting **Start** > **Keysight** > **Keysight SD1 SFP**.
2. Configure channels 1, 2, and 3 of the AWG:
   a. Select **View** > **New Panel**.
   b. Select **Channel** drop-down menu, **1**, and **OK** to add Channel 1.
   c. Repeat these steps to add Channel 2.
   d. On Channel 1 SFP, select:
      - Waveform shape: **Sinusoidal**
      - Amplitude: **0.1 V**
      - Frequency (MHz): **100 MHz**
      - Phase: **0.00 degrees**
        (This is the in-phase component of the I/Q signal being applied to the I/Q Modulator.)
      - DC offset: **0.000 V**
   e. On Channel 2 SFP, select:
      - Waveform shape: **Sinusoidal**
      - Amplitude: **0.1 V**
      - Frequency (MHz): **100 MH**z
      - Phase: **90.00 degrees**
        (This is the quadrature-phase component of the I/Q signal being applied to the I/Q Modulator.)
      - DC offset: **0.000 V**
   f. On Channel 3 SFP, select:
      - Waveform shape: **DC**
      - Amplitude: **0.0 V**
      - Frequency (MHz): **0**

- Phase: 0.00 degrees
- DC offset: 0.5 V

CAUTION When operating the I/Q Modulator Pin Switch, the control signal may leak into the RF Out and damage an amplifier if it is connected directly to the output of the RF Out connector. To help protect devices, it is recommended that a high-pass filter be connected on the RF Out connector with a cutoff frequency of at least 2 GHz.
(For example, a Mini-Circuits 15542 High-Pass Filter with a frequency range of 2010 to 10100 MHz.)

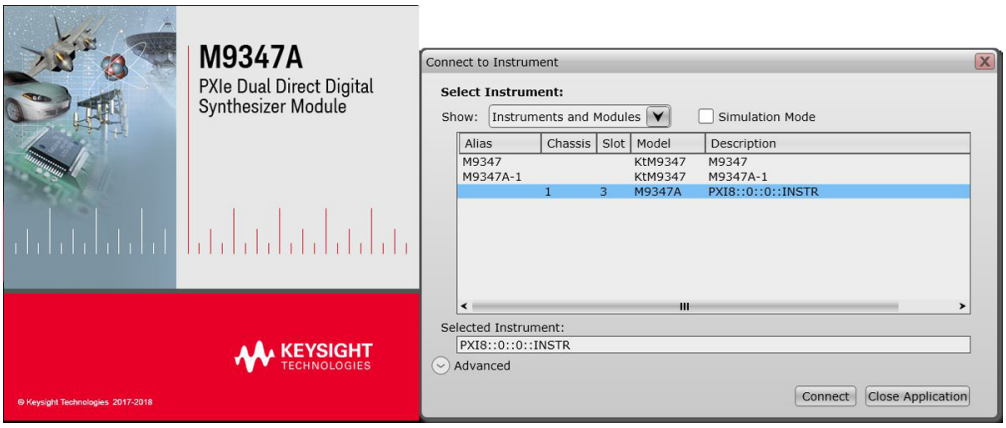
The actual high-pass filter model depends on the frequency range of the I/Q Modulator being used.

g. On Channel 1, 2, and 3, clear the HiZ check box to enable outputs.

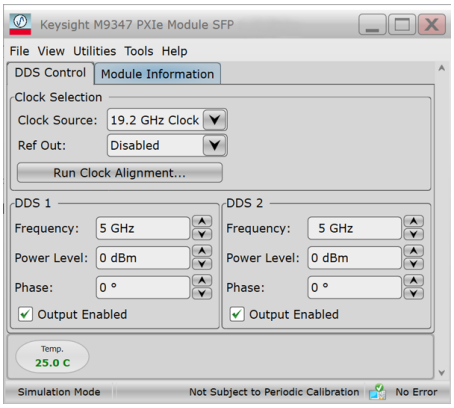
3. Configure Ch 1 and Ch 2 of the Digitizer to view the Frequency spectrum.
   a. Select the Frequency tab.
   b. Select the check box for Channel 1 and 2.
   c. Set Points: 5000
   d. Set each Channel to the following settings:
      - Impedance: 50 Ω
      - Full Scale: 1 V
      - Position: 0.000 V
      - Prescaler: 0

6. 0. 4. 4 Configure each M9347AH01 PXIe Dual DDS Module

1. Start the Soft Front Panel for each M9347AH01 PXIe Dual DDS module by selecting **Start** > **Keysight M9347 PCIe Module** > **M9347 SFP.**
2. From the **Connect to Instrument** dialog, select a M9347AH01 module. (If there is more than one M9347AH01 module in the system, use the physical **Chassis** and **Slot** number, displayed in the dialog box, to determine which M9347AH01 that is to be connected.)

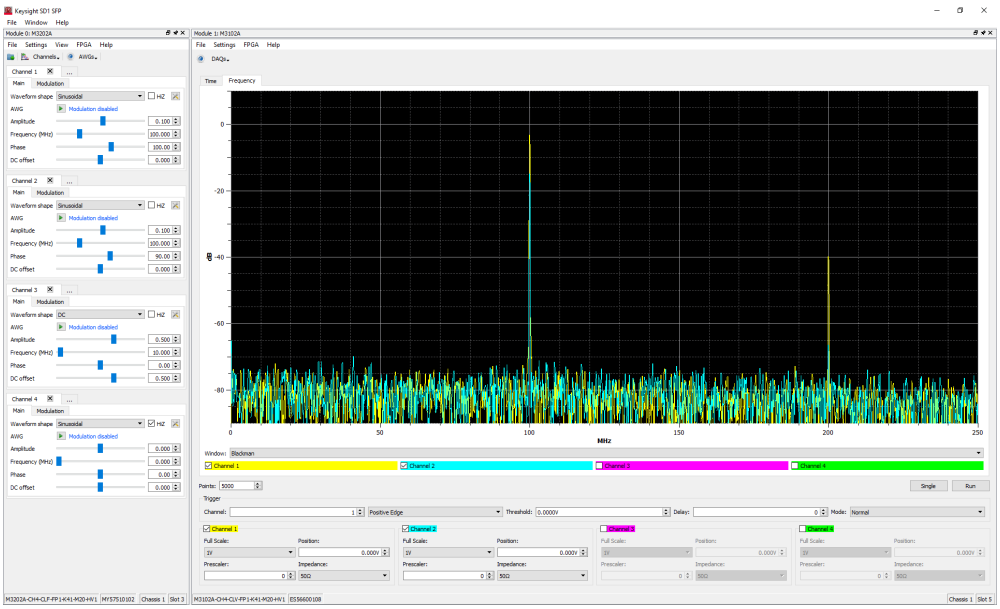


3. Using the Keysight M9347A PXIe Module SFP, select the **DDS Control** tab, and set the output settings for DDS 1 (Synth Out 1 connector) and DDS 2 (Synth Out 2 connector):
    a. Set **Clock Source** to 19.2 GHz Clock. (Should match **Clock In** frequency.)
    b. Set **Ref Out** to Disabled.
    c. Select **Run Clock Alignment**. (This performs an internal alignment to lock the DDS chips to the system Clock Source. This alignment must be performed each time system Clock Source is changed.)
    d. Set **Frequency** to 5 GHz for DDS 1 and DDS 2.
    e. Set **Power Level** to 0 dBm for DDS 1 and DDS 2.
    f. Set **Phase** to 0 degrees for DDS 1 and DDS 2.
    g. Select the check box, **Output Enabled**, for DDS 1 and DDS 2, to enable both the Synth Out 1 connector and the Synth Out 2 connector.



6. 0. 4. 5 Verify Operation of an I/Q Demodulator, Frequency Spectrum

1. Verify that there is a signal at 100 MHz and a harmonic at 200 MHz.
   Since AWG Ch 3 is driving the I/Q Modulator Pin Sw with a DC offset of 0.5 V, the I/Q Modulator is On (as shown below). When the AWG Ch 3 Pin Sw signal is set below 0.3 V, it sets the output of the I/Q Modulator to Off (not shown).



2. Verify the I/Q Modulator can be amplitude modulated by injecting a square wave signal into the Pin Sw connector, effectively turning the signal at the RF Out connector on and off. The settings on AWG Ch 3 can be used to control the rate that the I/Q Modulator is switched on and off.

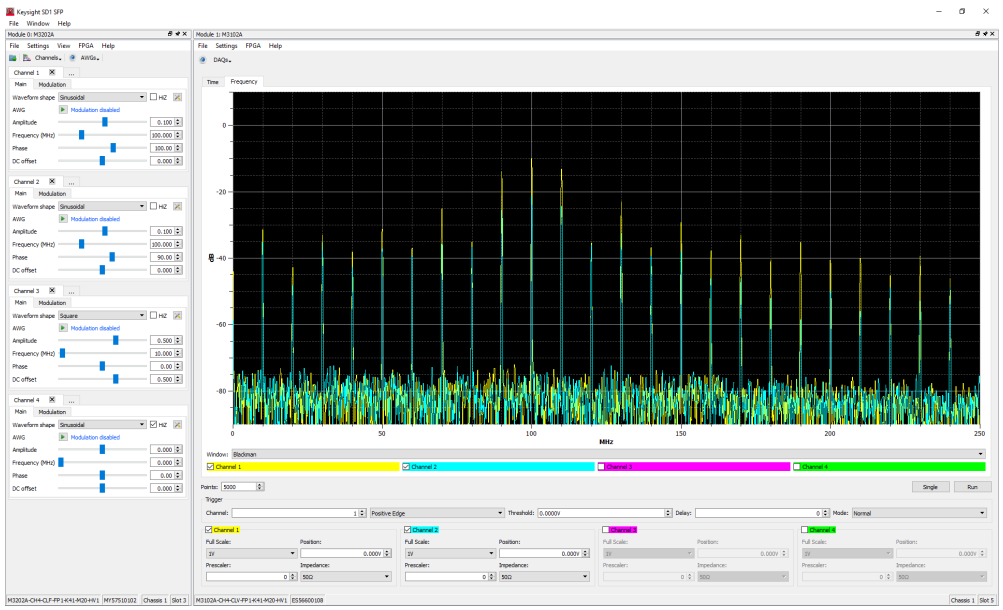
   For example, with AWG Ch 3 Out connected to I/Q Modulator Pin Sw, using an SMA (m) to SMA (m) cable with an SMA (f) to SMB (f) adapter, use the AWG Channel 3 SFP and select:

   a. Waveform shape: **Square**
   b. Amplitude: **0.5 V**
   c. Frequency (MHz): **10 MHz**
   d. Phase: **0.00 degrees**
   e. DC offset: **0.5 V**

   CAUTION When operating the I/Q Modulator Pin Switch, the control signal may leak into the RF Out and damage an amplifier if it is connected directly to the output of the RF Out connector. To help protect devices, it is recommended that a high-pass filter be connected on the RF Out connector with a cutoff frequency of at least 2 GHz. (For example, a Mini-Circuits 15542 High-Pass Filter with a frequency range of 2010 to 10100 MHz.)

   The actual high-pass filter model depends on the frequency range of the I/Q Modulator being used.

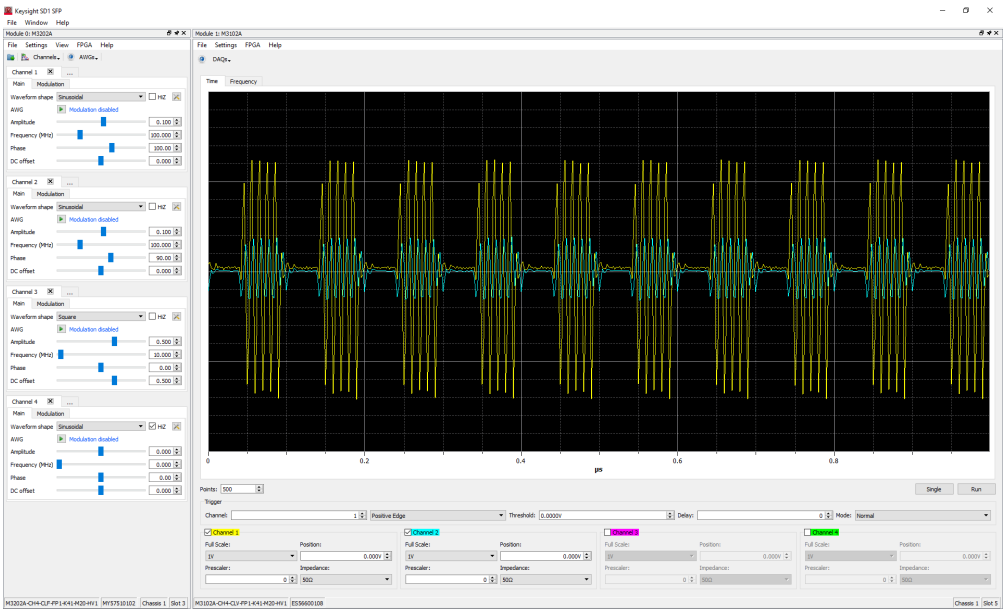


6. 0. 4. 6 Verify Operation of an I/Q Demodulator, Time Domain

- Configure channels 1 and 2 of the Digitizer to view the Time domain.
  a. Select the **Time** domain tab.
  b. Select the check box for Channel 1 and 2.
  c. Set Points: **500**
  d. Set each Channel to the following settings:
     a. Full Scale: **1 V**
     b. Position: **0.000 V**
     c. Prescaler: **0**
     d. Impedance: **50 Ω**

  e. Verify the frequency setting on AWG Ch 3 is controlling the rate that the I/Q Modulator is switched on and off.

     The following display shows how the I/Q Modulator can have a square wave applied that is used to amplitude modulate the output; it is on for 50% of the 10 MHz duty cycle (0.05 µs) and off for 50%.

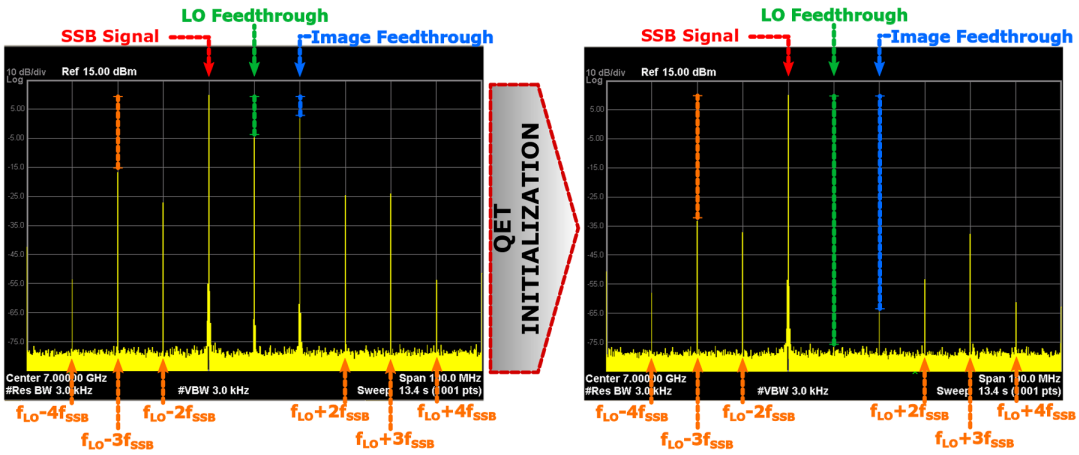


7 Run the QET Initialization Utility

The QET Initialization Utility is an IQ calibration software that minimizes undesired mixing products that can be introduced by the Keysight U3022AH37 I/Q Modulator/Demodulator Test Set on page 13. The result is a more stable and reliable system that can be used by researchers, when producing IQ waveforms, and can be applied to a Qubit Under Test.

As an example of minimizing undesired mixing products, local oscillator and mirror image feed-through signals can be minimized to improve spectral purity.

Improve Spectral Purity with the QET Initialization Utility



After running the QET Initialization Utility, a "Corrected" file (that contains all of the results that were corrected by pre-distorting a waveform prior to loading it into AWG memory), along with manual corrections made to settings on the AWG SFP and Local Oscillator SFP produces two corrected I and Q waveform files; these two files can then be loaded into AWG memory, queued, and played from the two AWG channels (AWG Ch 1 and AWG Ch 2). The final corrected IQ waveform, with improved spectral purity, can be applied to a Qubit Under Test.

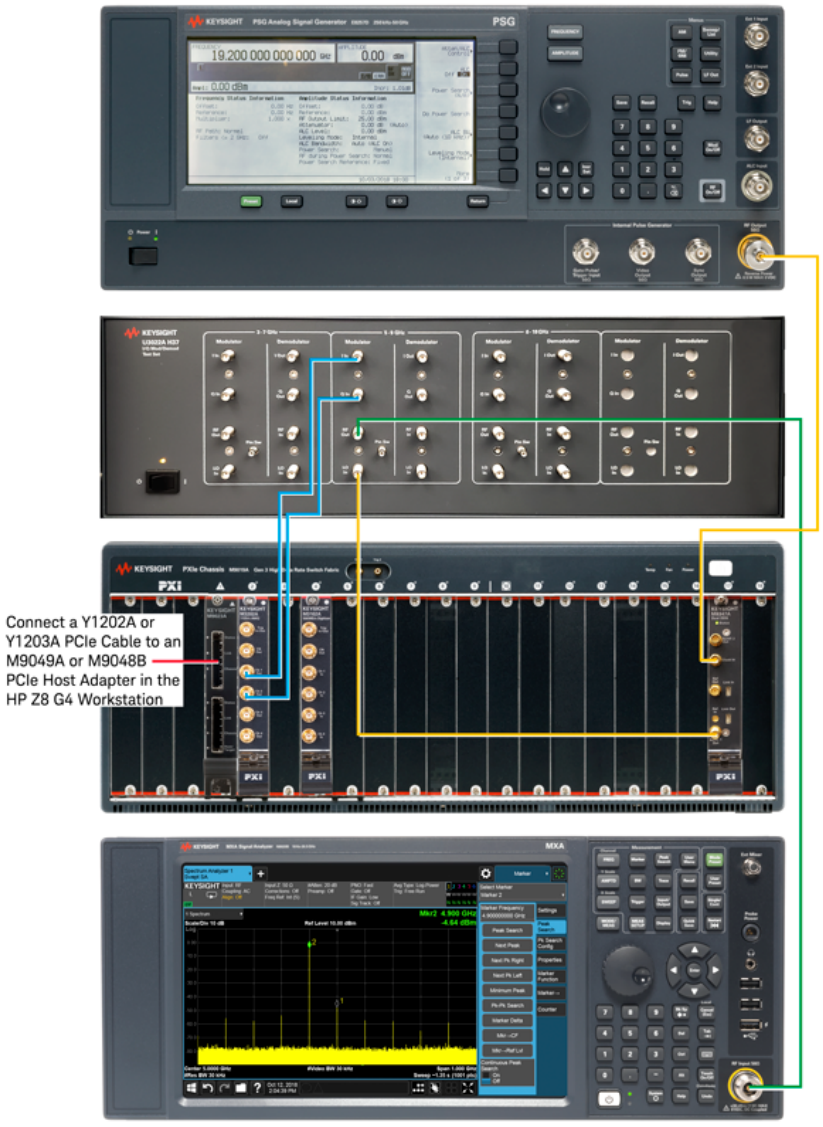
Summary of the QET Initialization Utility Process Flow

1. Install Hardware on page 60
    a. Connect Cables on page 61
    b. Configure a Frequency Reference on page 61
2. Start the QET Initialization Utility
   by selecting **Start** > **Keysight** > **QET Initialization Utility**.

3. Select the Equipment Setup Tab on page 62
    a. Select an AWG and a Waveform Type on page 62
        i. (Optional) Enter an AWG Alias.
        ii. Select an AWG model number.
        iii. Enter a waveform type and an AWG offset frequency.
        iv. Enter/confirm the AWG chassis and slot number.
        (The Resource Address is auto-filled from the Model Number, Chassis, and Slot Number.)
    b. Select one of the following as the Local Oscillator:
        - Select the M9347AH01 Dual DDS as the Local Oscillator on page 63
            i. (Optional) Enter a Local Oscillator Alias.
            ii. Select a Local Oscillator model number.
            iii. Enter a Resource Address for the Local Oscillator.
                a. Assign a valid VISA Alias to an M9347A. (M9347A-1)
                b. Start the SCPI Service.
                c. Enter the specific Resource Address.
                (TCPIP0::localhost::hislip1::INSTR)
            iv. Enter all Advanced Options for channel and power.
            (channel=1;level=0)
        - or Select the E8267D or N5182B as the Local Oscillator on page 65
            i. (Optional) Enter a Local Oscillator Alias.
            ii. Select a Local Oscillator model number.
            iii. Enter a Resource Address for the Local Oscillator.
            iv. Enter all Advanced Options for channel and power.
            (level=0)
    c. Select a Signal Analyzer on page 66
        i. (Optional) Enter a Signal Analyzer Alias.
        ii. Select a Signal Analyzer model number.
        iii. Enter a Resource Address for the Signal Analyzer.
        iv. Leave the Advanced Options entry box empty.
4. Select the Tx Mixer Initialization Tab on page 67
    a. Set the Stimulus and Select an Uncorrected Waveform File on page 67
        i. Set the Stimulus (Frequency of the LO).
        ii. Set the Stimulus (Channel Amplitude of the AWG).
        iii. Select an Uncorrected Waveform File.
        iv. Select a name for the Corrected Waveform File.
        The name is auto-filled by the program and based on the entry for the Uncorrected Waveform File.
        v. Select Execution to start the initialization.

7.1 Install Hardware

NOTE The following list of hardware components are the recommended models used with the Keysight Quantum Engineering Toolkit. The hardware configurations are shown using the Keysight M9019A PXIe Chassis; this chassis and many other hardware components may have optional or alternate models available. Refer to Review Hardware Components on page 9.



NOTE In all equipment setups throughout this document, all cables are the same and shown in different colors for clarity only.
See Cables, SMA (m) to SMA (m) on page 15.

7. 1. 1 Connect Cables

NOTE **In all equipment setups throughout this document, all cables are the same and shown in different colors for clarity only.**
See Cables, SMA (m) to SMA (m) on page 15.

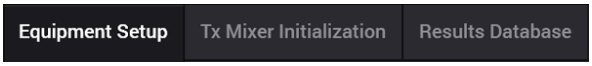
1. Connect a Y1202A or Y1203A PCIe cable to an M9049A or M9049B PCIe Host Adapter in the HP Z8 G4 Workstation.
2. Connect SMA (m) to SMA (m) cables from an AWG to the I/Q Modulator:
   a. Connect AWG Ch 1 Out to I/Q Modulator I In.
   b. Connect AWG Ch 2 Out to I/Q Modulator Q In.
3. Connect the E8267D PSG RF Output to the M9347AH01 Clock In.
   a. Connect a 3.5 mm (f) to 3.5 mm (f) adapter on the E8267D PSG RF Output with Option 520 or connect a 2.4 mm (f) to 3.5 mm (f) adapter on the E8267D PSG RF Output with Option 532 or 544.
   b. Connect one end of SMA (m) to SMA (m) cable to the 3.5 mm (f) adapter.
   c. Connect the other end of the SMA cable to the M9347AH01 Clock In.
4. Connect the M9347AH01 Synth Out 1 to I/Q Modulator LO In.
5. Connect the I/Q Modulator RF Out to the input of a spectrum analyzer.
   a. Connect a Type-N (m) to SMA (f) adapter on the spectrum analyzer input.
   b. Connect one end of an SMA (m) to SMA (m) cable to the SMA (f) adapter.
   c. Connect a high-pass filter directly to the I/Q Modulator RF Out.
   d. Connect the other end of the SMA cable to an I/Q Modulator RF Out.

7. 1. 2 Configure a Frequency Reference

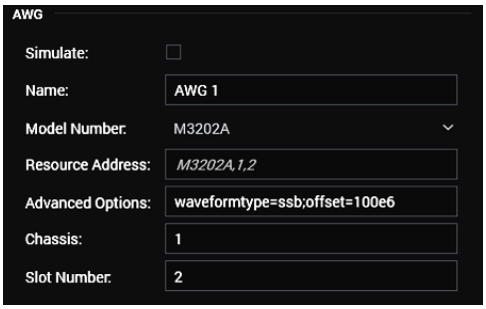
- If using the Keysight E8257D or E8267D PSG Signal Generator as the frequency reference, perform the following:
  a. Select [FREQUENCY] and enter 19.2 GHz.
  b. Select [AMPLITUDE] and enter 0.00 dBm.
  c. Select [RF On/Off] so that RF Output is On.

- If a different frequency reference is being used, refer to the user documentation for that product to learn how to set the frequency and power to the settings listed above.

7. 2 Select the Equipment Setup Tab



7. 2. 1 Select an AWG and a Waveform Type



1. (Optional) Enter an AWG Alias.
2. Select an AWG model number.
3. Enter a waveform type and an AWG offset frequency.
4. Enter/confirm the AWG chassis and slot number.

   The Resource Address is auto-filled from the Model Number, Chassis, and Slot Number.

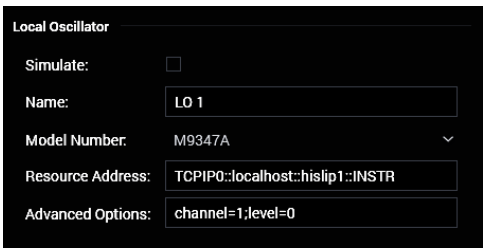
Name:	This entry box is optional, but can be used to assign an "Alias" (a user-friendly name) to the AWG that is used in the system. In this example, `AWG 1` is specified as the AWG Alias.
Model Number:	A drop-down menu is used to display AWG models (M3202A, M3201A, M8190A) that can be used with this software. Select the arrow for the drop-down menu and select an AWG model number. In this example, the `M3202A` is selected.
Resource Address:	This entry is auto-filled from the Model Number drop-down menu selection combined with values from the Chassis and Slot Number entries. In this example, `M3202A,1,2` is displayed.
Advanced Options:	Enter `waveformtype=ssb;offset=100e6` In this example, a single-sideband waveform type (ssb) is designated and has an offset from the local oscillator frequency of 100 MHz (`offset=100e6`). This 100 MHz offset entry must equal the frequency of the AWGs being used. The waveformtype can be either: `ssb or gaussian`.
Chassis:	This entry box is used to enter/confirm the chassis number housing the AWG. In this example, there is only one chassis being used, so `1` was entered.
Slot Number:	This entry box is used to enter/confirm the slot number, of the chassis, housing the AWG. In this example, the AWG is located in slot number two, so `2` was entered.

7. 2. 2 Select a Local Oscillator

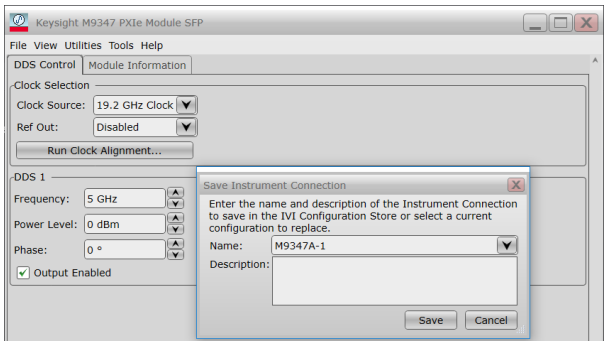
Select one of the following as the Local Oscillator:

- Select the M9347AH01 Dual DDS as the Local Oscillator on page 63
- Select the E8267D or N5182B as the Local Oscillator on page 65

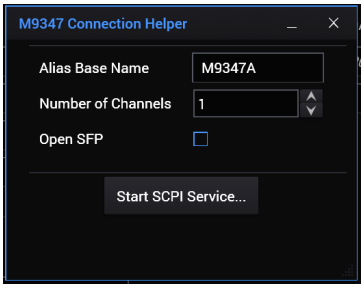
7. 2. 2. 1 Select the M9347AH01 Dual DDS as the Local Oscillator



1. (Optional) Enter a Local Oscillator Alias.
2. Select a Local Oscillator model number.
3. Enter a Resource Address for the Local Oscillator.
    a. Assign a valid VISA Alias to an M9347A.
    b. Start the SCPI Service.
    c. Enter the specific Resource Address.
4. Enter all Advanced Options for channel and power. (channel=1;level=0).

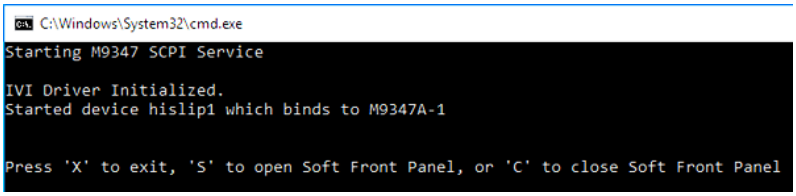
Name:	This entry box is optional, but can be used to assign an "Alias" (a user-friendly name) to the Local Oscillator that is used in the system. In this example, `LO 1` is specified as the Local Oscillator Alias.
Model Number:	A drop-down menu is used to display Local Oscillator models (E8267D, N5182B, M9347A) that can be used with this software. Select the arrow for the drop-down menu and select a Local Oscillator model number. In this example, the M9347A is selected.
Resource Address:	This entry box is used to enter the VISA address of the Local Oscillator is used in the system. If the M9347A is selected from the drop-down menu as the Local Oscillator, it must first be connected using a SCPI Service. The SCPI Service assigns a hislip socket to each module that has a valid VISA Alias defined.  To assign a valid VISA Alias to each M9347A 1. Start the Soft Front Panel for each M9347A PXIe Dual DDS module by selecting **Start** > **Keysight M9347A PCIe Module** > **M9347 SFP**.

2. From the **Connect to Instrument** dialog, select an M9347AH01 module. (If there is more than one M9347AH01 module in the system, use the physical Chassis and Slot number, displayed in the dialog box, to determine which M9347AH01 is being connected.)
3. Using the Keysight M9347 PXIe Module SFP, select **File** > **Save Connection...** and enter **M9347A-1** in the Name entry box.
   - Each valid VISA Alias must be of the form: `M9347A-X` where `X` is an integer number, starting at 1.
   - If only one M9347A is in the system, this would be `M9347A-1`.
   - If there are two or more M9347A modules in the system, each valid VISA Alias would be `M9347A-1`, `M9347A-2`, and so on.
4. Close the **M9347A SFP**. (The SCPI Service cannot start with this open.)



To start the SCPI Service

1. From QET Initialization Utility, select **Tools** > **M9347 Connection Helper**.
2. Enter **M9347A** in the Alias Base Number.
3. Select the **Up/Down** arrows to change the Number of Channels needed. (This corresponds to the number of VISA Alias addresses needed.)
4. Select **Start SCPI Service...**



Once the SCPI Service has started, connect to it using the host name (`localhost`) and hislip socket number (`hislip1`) as follows:

`TCPIP0::localhost::hislip1::INSTR`

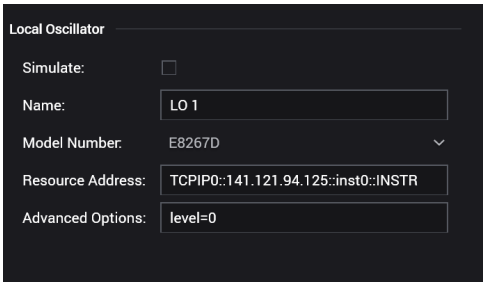
In this example, if the M9347A-1 is selected, it requires a connection string in the form of: `TCPIP0::localhost::hislipX::INSTR`

where `X=1`, so: `TCPIP0::localhost::hislip1::INSTR` is the specific Resource Address.

If selecting M9347A-2, `X=2`, `TCPIP0::localhost::hislip2::INSTR` would be the specific Resource Address. Close the **M9347A SFP**.

Advanced Options:	This entry box is used to enter the channel number (1 or 2 for the M9347A) and power level of the Local Oscillator used in the system. In this example, `channel=1` of the M9347A refers to Synth 1 Out and `level=0` refers to the Power Level, in dBm, of the Synth 1 Out. (Enter channel=1;level=0.) To designate the Synth 2 Out of the M9347A, enter `channel=2.`

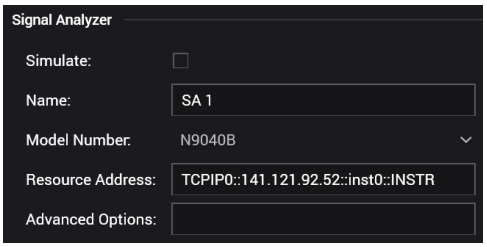
7. 2. 2. 2 Select the E8267D or N5182B as the Local Oscillator



1. (Optional) Enter a Local Oscillator Alias.
2. Select a Local Oscillator model number.
3. Enter a Resource Address for the Local Oscillator.
4. Enter all Advanced Options for channel and power. (level=0)

Name:	This entry box is optional, but can be used to assign an "Alias" (a user-friendly name) to the Local Oscillator used in the system. In this example, `LO 1` is specified as the Local Oscillator Alias.
Model Number:	A drop-down menu is used to display Local Oscillator models (E8267D, N5182B, M9347A) that can be used with this software. Select the arrow for the drop-down menu and select a Local Oscillator model number. In this example, the `N8267D` is selected.
Resource Address:	This entry box is used to enter the Resource Address (IP Address) of the Local Oscillator used in the system. In this example, since we are selecting to use an E8267D, it is addressed as: `TCPIP0::141.121.94.125::inst0::INSTR` The IP address of the E8267D, represented here as `xxx.xxx.xxx.xxx` was replaced with the actual IP address of the E8267D. To determine the IP address of the Keysight E8267D – Select [Utility] > I/O Config > LAN Setup > and read the IP address displayed in the form= `xxx.xxx.xxx.xxx`
Advanced Options:	This entry box is used to enter the power level of the Local Oscillator used in the system. In this example, `level=0` refers to the Power Level, in dBm, of the RF Output.

7. 2. 3 Select a Signal Analyzer



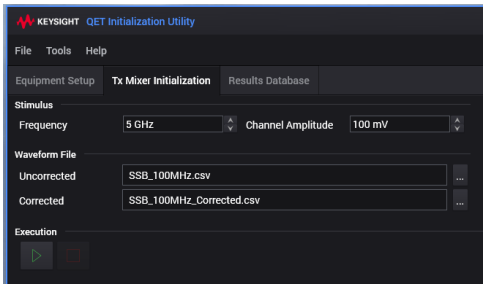
1. (Optional) Enter a Signal Analyzer Alias.
2. Select a Signal Analyzer model number.
3. Enter a Resource Address for the Signal Analyzer.
4. Leave the Advanced Options entry box empty.

   There are currently no Advanced Options needed.

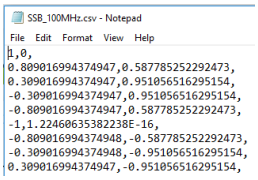
Name:	This entry box is optional, but can be used to assign an "Alias" (a user-friendly name) to the Signal Analyzer used in the system. In this example, `SA 1` is specified as the Alias.
Model Number:	A drop-down menu is used to display Signal Analyzer models (N9010A, N9020A, N9030A, N9040A, N9040B) that can be used with this software. Select the arrow for the drop-down menu and select a Signal Analyzer model number. In this example, the `N9040B` is selected.
Resource Address:	This entry box is used to enter the Resource Address (IP Address) of the Signal Analyzer used in the system. In this example, since we are selecting to use an N9040B, it is addressed as: `TCPIP0::141.121.92.52::inst0::INSTR` The IP address of the N9040B, represented here as `xxx.xxx.xxx.xxx` was replaced with the actual IP address of the N9040B. To determine the IP address of the Keysight N9040B UXA Signal Analyzer – Select the Settings Icon ⚙ – Select **System** > **Show System** > and read the IP address being displayed in the form= `xxx.xxx.xxx.xxx`
Advanced Options:	Leave the Advanced Options entry box empty. There are currently no Advanced Options needed for the Signal Analyzer.

7. 3 Select the Tx Mixer Initialization Tab

7. 3. 1 Set the Stimulus and Select an Uncorrected Waveform File



1. Set the **Stimulus** (Frequency of the LO).
2. Set the **Stimulus** (Channel Amplitude of the AWG).
3. Select an **Uncorrected** Waveform File.
4. Select a name for the **Corrected** Waveform File.
   The name is auto-filled by the program and based on the entry for the Uncorrected Waveform File.
5. Select **Execution** to start the initialization.

Frequency	This entry box is used to enter the Stimulus frequency of the Local Oscillator. Refer to Select a Local Oscillator on page 63. In this example, `5 GHz` is specified as the frequency of the Local Oscillator.
Channel Amplitude	This entry box is used to enter the Stimulus AWG Channel Amplitude. In this example, `100 mV` is specified as the Channel Amplitude and corresponds to AWG Ch 1 Out and AWG Ch 2 Out; both AWG outputs must be the same.
Waveform File Uncorrected	This selection box is used to select the Uncorrected Waveform File used when running the QET Initialization Utility. To select an Uncorrected Waveform File  1. Select the folder icon ... and navigate to the Waveforms folder: `C:\Program Files\Keysight\Quantum Engineering Toolkit\Waveforms` 2. Select an the Uncorrected Waveform File; this file is used during the QET Initialization Utility. In this example, `SSB_100MHz.csv` was selected. Note that each row contains two values separated by a comma. In line one, the first entry starts with a value of 1 and the second entry starts with a value of 0. The first entry (which is used to play on AWG Ch 1), is the Cosine waveform and the second entry (which is used to play on AWG Ch 2) is the Sine waveform.
Waveform File Corrected	This entry box is used to select a name for the Corrected Waveform File. The name for the Corrected Waveform File is auto-filled by the program; the name is based on the filename used in the Uncorrected Waveform File entry.

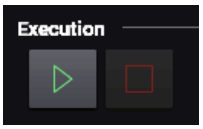
To select a name for the Corrected Waveform File

1. Select the folder icon ... and navigate to the Documents folder: `\This PC\Documents`
2. Select the name filled by the program or change it to a custom name.

   In this example, the name that is auto-filled by the program is: `SSB_100MHz_Corrected.csv`.

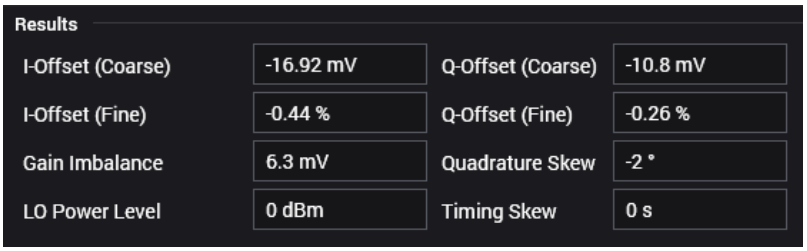
   The Corrected Waveform File adds the Correction Results for:
   - I-Offset (Fine), Q-Offset (Fine), Quadrature Skew, and Timing Skew.
   - The Correction Results for I-Offset (Coarse), Q-Offset (Coarse), and Gain Imbalance must still be corrected using the Keysight SD1 SFP for AWG Ch 1 and AWG Ch 2.
   - The Correction Result for LO Power Level must still be corrected using the selected LO.
     - If the M9347AH01 was used, the M9347 SFP can be used to change the DDS Power Level.
     - If the E8267D or N5182B was used, adjust the Power Level using their specific front panel [AMPLITUDE] control.

7. 3. 2 Execution of the QET Initialization Utility



Execution Button	The Execution button (green) is used to start the QET Initialization Utility.
Stop Button	The Stop button (red) is used to stop execution of the QET Initialization Utility.

7. 3. 3 Review Results after Execution of the QET Initialization Utility



NOTE

Three of these Results can be corrected using the AWG SFP and one can be corrected using the Local Oscillator SFP.

- The **I-Offset (Coarse)**, **Q-Offset (Coarse)**, and **Gain Imbalance** can be corrected using the AWG SFP.
- The **LO Power Level** can be corrected using the Local Oscillator SFP.
- Programming commands can also be used in place of the SFP controls. See the AWG User's Guide (M3201-90001).

The remaining correction Results are made by pre-distorting the uncorrected waveform prior to loading it into AWG memory.

7. 3. 3. 1 Results, Corrected Using the AWG SFP and LO SFP

The following results can be corrected using the AWG SFP and LO SFP; they are not currently being corrected by pre-distorting the waveform prior to loading it into AWG memory.

I-Offset (Coarse)	This correction value is the amount of DC offset needed from AWG Ch 1 Out. This correction can be made using the SD1 SFP for AWG Ch 1.
Q-Offset (Coarse)	This correction value is the amount of DC offset needed from AWG Ch 2 Out. This correction can be made using the SD1 SFP for AWG Ch 2.
Gain Imbalance	This correction value is the Gain-Imbalance of the Q-Channel relative to the I-Channel and is applied by adding a correction value to the Q-Channel amplitude. This correction can be made using the SD1 SFP for AWG Ch 2.
LO Power Level	This correction value is the LO Power Level applied during the calibration. The correction must be made using the selected local oscillator. – If the M9347AH01 was used as the local oscillator, the M9347 SFP can be used to change the DDS Power Level. – If the E8267D or N5182B was used as the local oscillator, adjust the LO Power Level using their specific front panel [AMPLITUDE] control.

7. 3. 3. 2 Results, Corrected by Pre-distorting the Waveform

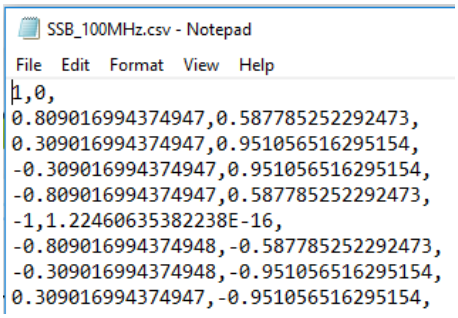
The following results cannot be corrected using the AWG SFP and LO SFP; these results are corrected by pre-distorting the waveform prior to loading it into AWG memory.

I-Offset (Fine)	This correction value is a finer adjustment than the I-Offset (Coarse) correction value of DC offset needed from AWG Ch 1 Out. Since the resolution needed to make this adjustment cannot be accomplished using SD1 SFP for AWG Ch 1 or the channelOffset command, the correction is instead applied by predistorting the target waveform prior to loading it into memory. This correction value is represented as a percentage of the full scale DAC value.
Q-Offset (Fine)	See the explanation for the I-Offset (Fine) correction value. Q-Offset (Fine) also does not have the resolution needed.
Quadrature Skew	This correction value is the Quadrature Skew-Imbalance of the Q-Channel relative to the I-Channel and is applied by adding a correction value to the Q-Channel Phase. In this example, AWG Ch 1 is applying a Cosine wave (In-Phase) and AWG Ch 2 is applying a Sine wave (90 degrees out of phase with AWG Ch 1; this is also referred to as Quadrature.) The Quadrature Skew is the amount of correction needed for AWG Ch 2 so that it is 90 degrees out of phase with AWG Ch 1.
Timing Skew	This correction needs to be applied to AWG Ch 2 so that its waveform starts at precisely the same time that the waveform from AWG Ch 1 starts. For example, if the output of Ch 2 must be delayed and since an M3202A is being used as the AWG, each waveform step is 1 ns. By placing a 0 in the first entry, the start of the waveform for Ch 2 is delayed by 1 ns. This effectively makes a correction of `-1E-09 s` so that the Sine wave from AWG Ch 2 is delayed and starts after the Cosine wave from AWG Ch 1. This correction value is applied to AWG Ch 2 by pre-distorting the waveform prior to loading it into memory.

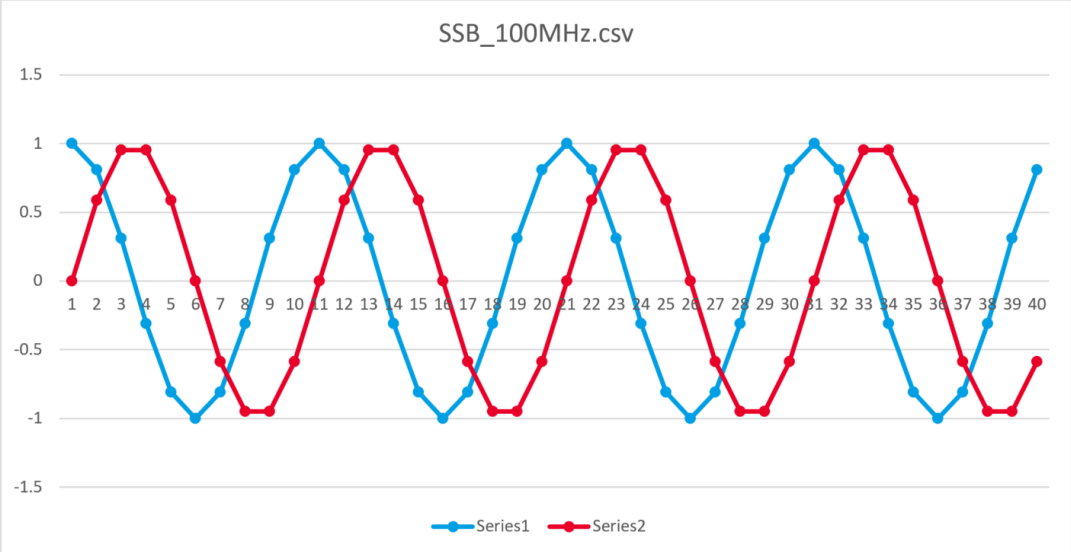
7. 3. 4 Review and Play Corrected I and Q Waveform Files

7. 3. 4. 1 Review the Uncorrected Waveform File

Continuing with the example, `SSB_100MHz.csv` was the Uncorrected Waveform File. Use a text editor (such as Notepad) to open this file and see that each row contains two values separated by a comma. In line one, the first entry starts with a value of 1 and the second entry starts with a value of 0. The first entry of each line (which is later used to play on AWG Ch 1), is the Cosine waveform and the second entry of each line (which is later used to play on AWG Ch 2) is the Sine waveform.



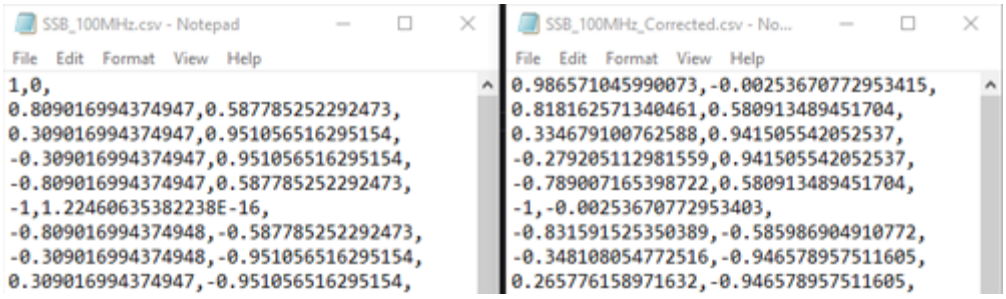
Plotting these points show that they approximately represent a Cosine waveform and a Sine waveform that are 90 degrees out of phase. (Cosine waveform points are shown in blue and Sine waveform points are shown in red.)



After Execution (running the QET Initialization Utility), the contents of SSB_100MHz.csv (Uncorrected) vs. SSB_100MHz_Corrected.csv (Corrected) can be viewed and compared.

7. 3. 4. 2 Review the Uncorrected vs. Corrected Waveform File

- The Corrected file adds the Correction Results for: **I-Offset (Fine)**, **Q-Offset (Fine)**, **Quadrature Skew**, and **Timing Skew**.



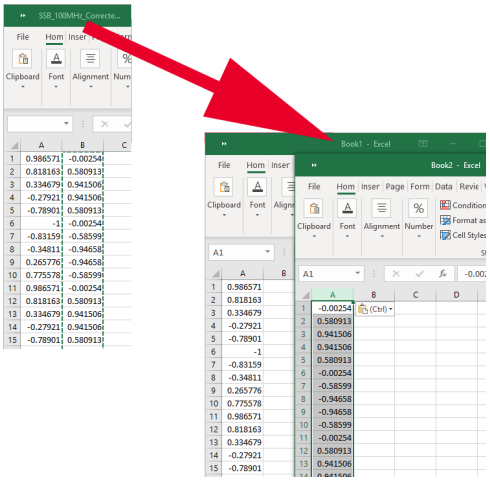
- The Correction Results for **I-Offset (Coarse)**, **Q-Offset (Coarse)**, and **Gain Imbalance** must still be corrected using the Keysight SD1 SFP for AWG Ch 1 and AWG Ch 2.
- The Correction Result for **LO Power Level** must still be corrected using the selected LO. If the M9347AH01 was used, the M9347 SFP can be used to change the DDS Power Level. If the E8267D or N5182B was used, adjust the Power Level using their specific front panel [AMPLITUDE] control.

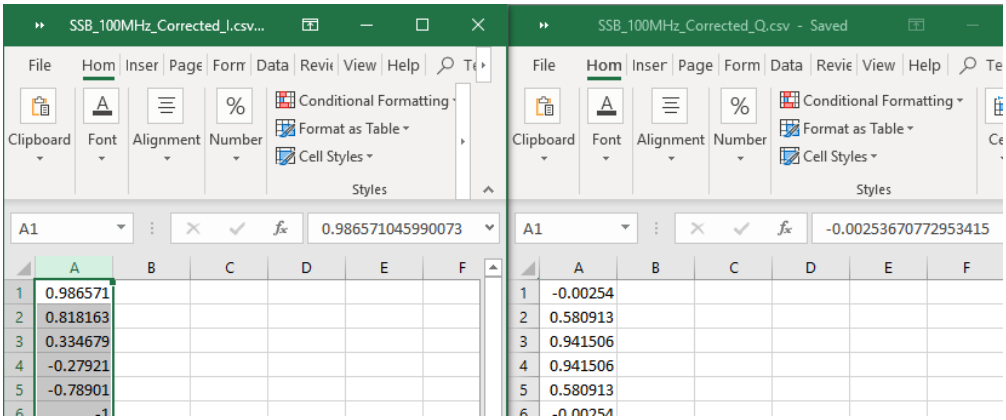
7. 3. 4. 3 Play AWG and LO Corrections with Corrected Waveform File

The following process starts with a "Corrected" file. (This file contains all of the Results that were corrected by pre-distorting the waveform prior to loading it into AWG memory.) The "Corrected" file is split into two files (so that it can be played on AWG Ch 1 and AWG Ch 2). Corrections are then applied to each channel using the AWG SFP. If the LO Power Level must be corrected, the LO SFP or the specific front panel [AMPLITUDE] control of the LO is adjusted so that the AWG waveforms, from AWG Ch 1 and AWG Ch 2, contain all of the corrections.

1. Using any .csv editor (such as Excel), open the `SSB_100MHz_Corrected.csv` file and create two additional files that are going to be played using SD1 SFP for AWG Ch 1 and AWG Ch 2.
   (This splits the "Corrected" file into two files.)

   Name the new files:
   - SSB_100MHz_Corrected_I.csv
   - SSB_100MHz_Corrected_Q.csv





2. Using a text editor (such as Notepad), add text to the header and save these new .csv files as follows:

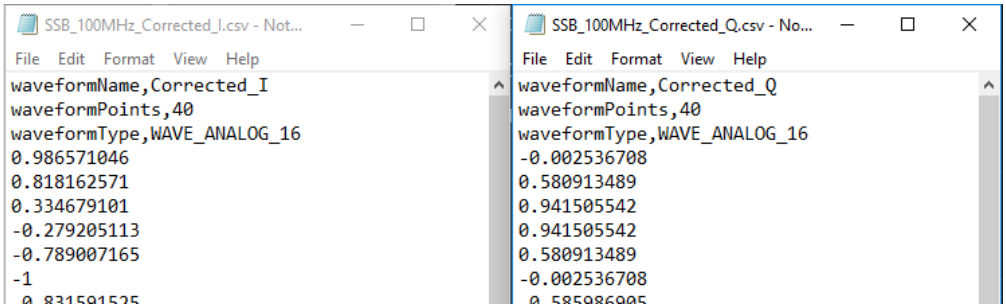
   ```
   waveformName,Corrected_I

   waveformPoints,40

   waveformType,WAVE_ANALOG_16
   ```

   and

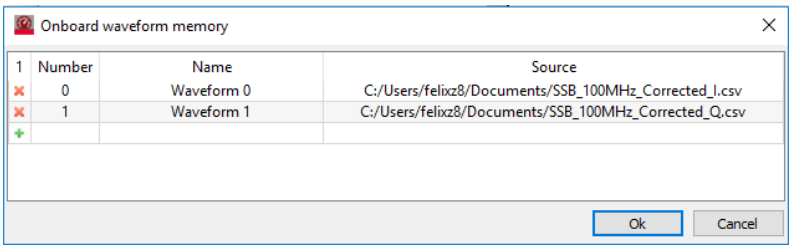
   ```
   waveformName,Corrected_Q

   waveformPoints,40

   waveformType,WAVE_ANALOG_16
   ```

   NOTE The entry `waveformPoints,40` was used in this example because there are 40 sample points in the file. If the number of samples is different in the file being used, this number would be different; for example, if there are 100 sample points in the file, this line should be: `waveformPoints,100`.

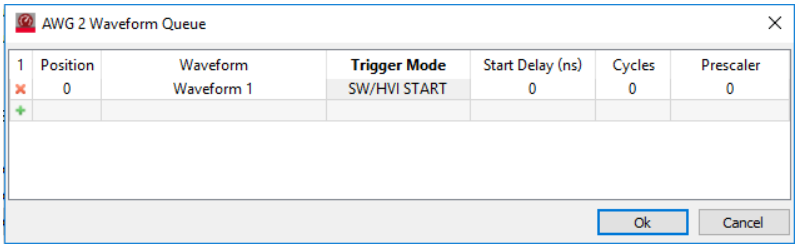
3. Save the edits so that the files look like the following:



4. Open **SD1 SFP** > **Settings** > **AWG Memory.**
5. On the AWG **Onboard waveform memory** dialog box, select the small red x next to any waveforms that may have been listed from previous examples.
6. On this AWG **Onboard waveform memory** dialog box, select the small green + on the left to open a window and navigate to the folder that the newly edited I and Q waveform files are saved in and select **Ok**.



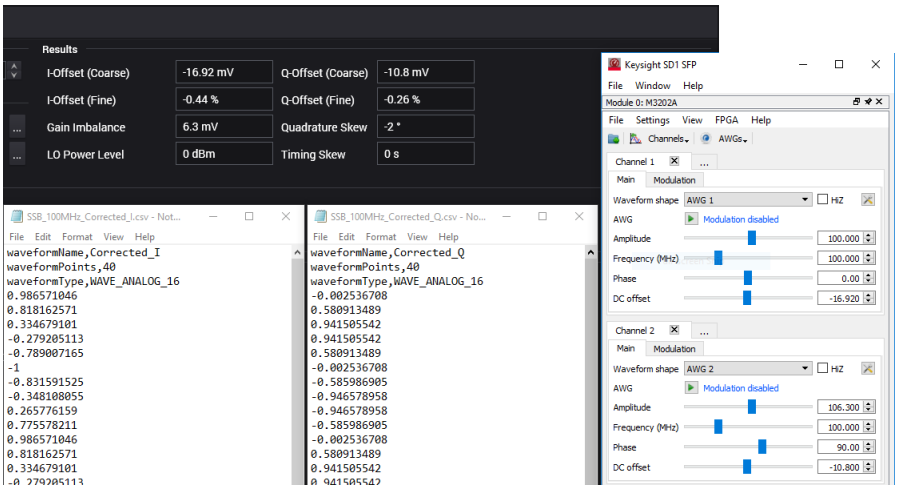
7. With **SD1 SFP** open, select **Settings** > **AWG Queue**> **AWG 2**.
8. Select **Trigger Mode Auto** and change the drop-down menu to `SW/HVI START` and select **Ok**.



NOTE **When making the changes through the AWG SFP, to enter values in millivolts, select the tool icon.** 

The tool icon must be selected to allow the entries to be changed to the millivolts scale; the AWG SFP will not have the needed resolution if the millivolts scale is not selected.

9. Using the SD1 SFP for Channel 1, adjust the **DC offset** by the amount shown in the **I-Offset (Coarse)** result (in this example, the value is -16.92 mV).
10. Using the SD1 SFP for Channel 2, adjust the **DC offset** by the amount shown in the **Q-Offset (Coarse)** result (in this example, the value is -10.8 mV).
11. Using the SD1 SFP for Channel 2, adjust the **Amplitude** by the amount shown in the **Gain Imbalance** result (in this example, the value is 6.3 mV). Since the Amplitude level was already 100 mV, it will have to be changed to 106.3 mV (100 mV + 6.3 mV).



The corrected I and Q waveform files are loaded into AWG memory, queued, and played from the two AWG channels. The final result is a corrected IQ waveform being played from AWG Ch 1 and AWG Ch 2; this final resultant IQ waveform has been corrected and can be applied to a Qubit Under Test.

8 Error Codes

8. 1 Error Codes for SD1 Programming Libraries

SD1 Error	Error No	Refer to keysightSD1.py for Definition.
SD_Error.OPENING_MODULE	-8000	Opening module
SD_Error.CLOSING_MODULE	-8001	Closing module
SD_Error.OPENING_HVI	-8002	Opening HVI
SD_Error.CLOSING_HVI	-8003	Closing HVI
SD_Error.MODULE_NOT_OPENED	-8004	Module not opened
SD_Error.MODULE_NOT_OPENED_BY_USER	-8005	Module not opened by user
SD_Error.MODULE_ALREADY_OPENED	-8006	Module already opened

SD_Error.HVI_NOT_OPENED	-8007	HVI not opened, see SD1 commands:
		`assignHardwareWithIndexAndSerialNumber()`
		`assignHardwareWithIndexAndSlot()`
		`assignHardwareWithUserNameAndSerialNumber()`
		`assignHardwareWithUserNameAndSlot()`
		`assignHardwareWithUserNameAndModuleID()`
		`compile()`
		`compilationErrorMessage()`
		`getNumberOfModules()`
		`getModuleIndex()`
		`getModuleByIndex()`
		`getModuleByName()`
		`load()`
		`pause()`
		`readIntegerConstantWithIndex()`
		`readIntegerConstantWithUserName()`
		`readDoubleConstantWithIndex()`
		`readDoubleConstantWithUserName()`
		`reset()`
		`resume()`
		`start()`
		`stop()`
		`writeIntegerConstantWithIndex()`
		`writeIntegerConstantWithUserName()`
		`writeDoubleConstantWithIndex()`
		`writeDoubleConstantWithUserName()`

SD_Error.INVALID_OBJECTID	-8008	Invalid objectID
SD_Error.INVALID_MODULEID	-8009	Invalid moduleID, see `getType()`.
SD_Error.INVALID_MODULEUSERNAME	-8010	Invalid moduleUsername
SD_Error.INVALID_HVIID	-8011	Invalid HVIID
SD_Error.INVALID_OBJECT	-8012	Invalid object
SD_Error.INVALID_NCHANNEL	-8013	Invalid channelNumber
SD_Error.BUS_DOES_NOT_EXIST	-8014	Bus does not exist
SD_Error.BITMAP_ASSIGNED_DOES_NOT_EXIST	-8015	Any input assigned to the bitMap does not exist

SD1 Error	Error No	Refer to keysightSD1.py for Definition.
SD_Error.BUS_INVALID_SIZE	-8016	Input size does not fit on this bus
SD_Error.BUS_INVALID_DATA	-8017	Input data does not fit on this bus
SD_Error.INVALID_VALUE	-8018	Invalid value, see `newFromArrayDouble()`.
SD_Error.CREATING_WAVE	-8019	Creating waveform
SD_Error.NOT_VALID_PARAMETERS	-8020	Invalid parameters
SD_Error.AWG	-8021	AWG failed
SD_Error.DAQ_INVALID_FUNCTIONALITY	-8022	DAQ invalid functionality
SD_Error.DAQ_POOL_ALREADY_RUNNING	-8023	DAQ buffer pool is already running
SD_Error.UNKNOWN	-8024	Unknown error
SD_Error.INVALID_PARAMETERS	-8025	Invalid parameters, see `FFT()`.
SD_Error.MODULE_NOT_FOUND	-8026	Module not found
SD_Error.DRIVER_RESOURCE_BUSY	-8027	Driver resource busy
SD_Error.DRIVER_RESOURCE_NOT_READY	-8028	Driver resource not ready
SD_Error.DRIVER_ALLOCATE_BUFFER	-8029	Driver cannot allocate buffer
SD_Error.ALLOCATE_BUFFER	-8030	Cannot allocate buffer
SD_Error.RESOURCE_NOT_READY	-8031	Resource not ready
SD_Error.HARDWARE	-8032	Hardware error
SD_Error.INVALID_OPERATION	-8033	Invalid operation
SD_Error.NO_COMPILED_CODE	-8034	No compiled code in the module
SD_Error.FW_VERIFICATION	-8035	Firmware verification failed
SD_Error.COMPATIBILITY	-8036	Compatibility error
SD_Error.INVALID_TYPE	-8037	Invalid type
SD_Error.DEMO_MODULE	-8038	Demo module
SD_Error.INVALID_BUFFER	-8039	Invalid buffer
SD_Error.INVALID_INDEX	-8040	Invalid index
SD_Error.INVALID_NHISTOGRAM	-8041	Invalid histogram number
SD_Error.INVALID_NBINS	-8042	Invalid number of bins
SD_Error.INVALID_MASK	-8043	Invalid mask
SD_Error.INVALID_WAVEFORM	-8044	Invalid waveform
SD_Error.INVALID_STROBE	-8045	Invalid strobe
SD_Error.INVALID_STROBE_VALUE	-8046	Invalid strobe value
SD_Error.INVALID_DEBOUNCING	-8047	Invalid debouncing
SD_Error.INVALID_PRESCALER	-8048	Invalid prescaler
SD_Error.INVALID_PORT	-8049	Invalid port
SD_Error.INVALID_DIRECTION	-8050	Invalid direction
SD_Error.INVALID_MODE	-8051	Invalid mode
SD_Error.INVALID_FREQUENCY	-8052	Invalid frequency
SD_Error.INVALID_IMPEDANCE	-8053	Invalid impedance
SD_Error.INVALID_GAIN	-8054	Invalid gain
SD_Error.INVALID_FULLSCALE	-8055	Invalid full scale
SD_Error.INVALID_FILE	-8056	Invalid file
SD_Error.INVALID_SLOT	-8057	Invalid slot

SD1 Error	Error No	Refer to keysightSD1.py for Definition.
SD_Error.INVALID_NAME	-8058	Invalid name
SD_Error.INVALID_SERIAL	-8059	Invalid serial number
SD_Error.INVALID_START	-8060	Invalid start
SD_Error.INVALID_END	-8061	Invalid end
SD_Error.INVALID_CYCLES	-8062	Invalid cycles
SD_Error.HVI_INVALID_NUMBER_ MODULES	-8063	Invalid number of modules on HVI
SD_Error.DAQ_P2P_ALREADY_RUNNING	-8064	DAQ P2P is already running
SD_Error.OPEN_DRAIN_NOT_SUPPORTED	-8065	Open drain not supported
SD_Error.CHASSIS_PORTS_NOT_ SUPPORTED	-8066	Chassis port not supported
SD_Error.CHASSIS_SETUP_NOT_ SUPPORTED	-8067	Chassis setup not supported
SD_Error.OPEN_DRAIN_FAILED	-8068	Open drain failed
SD_Error.CHASSIS_SETUP_FAILED	-8069	Chassis setup failed
SD_Error.INVALID_PART	-8070	Invalid part
SD_Error.INVALID_SIZE	-8071	Invalid size
SD_Error.INVALID_HANDLE	-8072	Invalid handle

9 References

Keysight PXIe Chassis Family, Startup Guide (M9019-90001)

- Keysight M9019A PXIe Chassis: 18-slot, 3U, 24 GB/s, Gen 3
- Keysight M9018B PXIe Chassis: 18-slot, 3U, 8 GB/s, Gen 2
- Keysight M9010A PXIe Chassis: 10-slot, 3U, 24 GB/s, Gen 3

Keysight M3202A PXIe Arbitrary Waveform Generator, User's Guide (M3201-90001)

- Keysight M3202A PXIe Arbitrary Waveform Generator: 1 GSa/s, 14 bit, 400 MHz
- Keysight M3201A PXIe Arbitrary Waveform Generator: 500 MSa/s, 16 bit, 200 MHz

Keysight M3102A PXIe Digitizer: 500 MSa/s, 14 bit, 200 MHz

- Keysight M3100A PXIe Digitizer: 100 MSa/s, 14 bit, 100 MHz
- Keysight M3300A PXIe AWG and Digitizer Combination, 500 MSa/s, 16 bit and 100 MSa/s, 14 bit
- Keysight M3302A PXIe AWG and Digitizer Combination 500 MSa/s, 16 bit, and 500 MSa/s, 14 bit

Keysight M9347AH01 PXIe Dual Direct Digital Synthesizer: 9 kHz to 12 GHz

- Keysight M9347AH01 PXIe Dual Direct Digital Synthesizer, Getting Started Guide (M9347-90001)

Keysight M9300A PXIe Frequency Reference: 10 MHz and 100 MHz

Keysight Y1212A Qty 1 Slot blocker kit: 5 slots

Keysight Y1213A Qty 1 PXI EMC filler panel kit: 5 slots

Keysight U3022AH37 I/Q Modulator/Demodulator Test Set

- Keysight U3022AH37 I/Q Modulator/Demodulator Test Set, User's and Service Guide (U3022-90011)
- Keysight 8493A-30 Coaxial Fixed Attenuator: DC to 12.4 GHz, 30 dB
- Keysight 8493B-30 Coaxial Fixed Attenuator: DC to 18 GHz, 30 dB

Keysight E8267D PSG Vector Signal Generator: 250 kHz to 20 GHz

Keysight E8257D PSG Analog Signal Generator: 250 kHz to 20 GHz

- PULSAR MICROWAVE CORPORATION, PS8-53-454/4S, 8-Way Power Divider

Keysight Instrument Rack Cabinet, User Manual (5967-9318)

- Keysight E3662B Rack Cabinet, 2.0 m
- Keysight E3661B Rack Cabinet, 1.6 m
- Keysight E3663AC System Rail Kit (E3663-90001)

Software

Keysight Quantum Engineering Toolkit Setup Wizard includes:

- Microsoft .NET Framework
- Keysight IO Libraries Suite
- Keysight M902x PXIe System Module
- Keysight PXIe Chassis Family
- Keysight M9347 PXI LO Drivers
- Keysight SD1 SFP [Soft Front Panels] Software
- Keysight SD1 Programming Libraries
- Keysight M3601A Hard Virtual Instrument (HVI) Design Environment Software
- Keysight M3602A FPGA Design Environment Software
- Keysight QET Initialization Utility

Tested PCs and External Controllers

Tested PC and PXI/AXIe Chassis Configurations (5990-7632EN)

- HP Z8 G4 Workstation (Recommended Model) - See HP website.
- Keysight M9049A PCIe Performance Host Adapter: Dual Port (x16), Gen 3
- Keysight M9048B PCIe Host Adapter: Single Port, x8, Gen 3
- Keysight M9023A PXIe Performance System Module: Dual Port (x16), Gen 3
- Keysight M9022A PXIe System Module: Single Port, x8, Gen 3
- Keysight Y1202A PCIe Cable: x8, 2.0 m
- Keysight Y1203A PCIe Cable: x8, 0.5 m

Keysight M9037A PXIe Performance Embedded Controller: 4-slot, 3U, Gen 3

Keysight M9036A PXIe Embedded Controller: 3-slot, 3U, Gen 2

(Optional) Test Equipment

Keysight N9040B UXA Signal Analyzer (Frequency option depends on U3022AH37.)

Keysight DSA90254A Infiniium High Performance Oscilloscope: 2.5 GHz

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