
Keysight M8196A

Arbitrary Waveform Generator

Notices

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ESD Sensitive Device

All front-panel connectors of the M8196A are sensitive to Electrostatic discharge (ESD). We recommend to operate the instrument in an electrostatic safe environment.

There is a risk of instrument malfunction when touching a connector.

Please follow this instruction:

Before touching the front-panel connectors, discharge yourself by touching the properly grounded mainframe.

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Safety Information

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.

Safety Summary

General Safety Precautions	The following general safety precautions must be observed during all phases of operation of this instrument. Failure to comply with these precautions or with specific warnings elsewhere in this manual violates safety standards of design, manufacture, and intended use of the instrument. For safe operation the general safety precautions for the M9502A and M9505A AXIe chassis, must be followed. See: http://www.keysight.com/find/M9505A Keysight Technologies Inc. assumes no liability for the customer's failure to comply with these requirements. Before operation, review the instrument and manual for safety markings and instructions. You must follow these to ensure safe operation and to maintain the instrument in safe condition.
Initial Inspection	Inspect the shipping container for damage. If there is damage to the container or cushioning, keep them until you have checked the contents of the shipment for completeness and verified the instrument both mechanically and electrically. The Performance Tests give procedures for checking the operation of the instrument. If the contents are incomplete, mechanical damage or defect is apparent, or if an instrument does not pass the operator's checks, notify the nearest Keysight Technologies Sales/Service Office. WARNING To avoid hazardous electrical shock, do not perform electrical tests when there are signs of shipping damage to any portion of the outer enclosure (covers, panels, etc.).
General	This product is a Safety Class 3 instrument. The protective features of this product may be impaired if it is used in a manner not specified in the operation instructions.
Environment Conditions	This instrument is intended for indoor use in an installation category II, pollution degree 2 environment. It is designed to operate within a temperature range of 0 °C – 40 °C (32 °F – 105 °F) at a maximum relative humidity of 80% and at altitudes of up to 2000 meters. This module can be stored or shipped at temperatures between -40 °C and +70 °C. Protect the module from temperature extremes that may cause condensation within it.
Before Applying Power	Verify that all safety precautions are taken including those defined for the mainframe.
Line Power Requirements	The Keysight M8196A operates when installed in an Keysight AXIe mainframe.
Do Not Operate in an Explosive Atmosphere	Do not operate the instrument in the presence of flammable gases or fumes.
Do Not Remove the Instrument Cover	Operating personnel must not remove instrument covers. Component replacement and internal adjustments must be made only by qualified personnel. Instruments that appear damaged or defective should be made inoperative and secured against unintended operation until they can be repaired by qualified service personnel.

Safety Symbols

Table 1: Safety symbol

Symbol	Description
	Indicates warning or caution. If you see this symbol on a product, you must refer to the manuals for specific Warning or Caution information to avoid personal injury or damage to the product.
	C-Tick Conformity Mark of the Australian ACA for EMC compliance.
N10149 	CE Marking to state compliance within the European Community: This product is in conformity with the relevant European Directives.
	General Recycling Mark

Table 2: Compliance and environmental information

Symbol	Description
	This product complies with the WEEE Directive (2002/96/EC) marketing requirements. The affixed label 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 Annexure I, this product is classed as a "Monitoring and Control instrumentation" product.
	Do not dispose in domestic household waste. To return unwanted products, contact your local Keysight office, or see http://about.keysight.com/en/companyinfo/environment/takeback.shtml for more information.

Contents

1 Introduction

1.1	Document History	14
1.2	Options	15
1.3	Upgrade Options	15
1.4	Installing Licenses	16
1.5	The Front Panel of the M8196A	18
1.5.1	Status LED	19
1.5.2	DATA Out LED	20
1.5.3	Trigger IN LED	21
1.5.4	Ref CLK IN LED	21
1.6	Theory of Operation	22
1.6.1	M8196A Block Diagram	22
1.6.2	Delay Adjust	24
1.6.3	Instruments Modes	25

2 M8196A User Interface

2.1	Introduction	27
2.2	Launching the M8196A Soft Front Panel	28
2.3	M8196A User Interface Overview	30
2.3.1	Title Bar	30
2.3.2	Menu Bar	30
2.3.3	Status Bar	32
2.3.4	Clock/Output/Standard Waveform/Multi-Tone Waveform/Complex Modulated Waveform/Serial Data Waveform/Import Waveform Tabs	32
2.3.5	Run / Stop Button	33
2.3.6	Numeric Control Usage	33
2.4	Driver Call Log	34
2.5	Errors List Window	35
2.6	Clock Tab	36
2.7	Output Tab	38
2.8	Trigger Tab	40
2.9	Standard Waveform Tab	42
2.10	Multi-Tone Waveform Tab	47
2.11	Complex Modulated Waveform Tab	53
2.12	Serial Data Waveform Tab	62
2.12.1	Bitmapping for Binary Data to PAM Signals	69

	2.13	Import Waveform Tab	71
	2.14	Correction File Format	77
3		Markers	
	3.1	Introduction	79
	3.2	Dealing with Markers	79
4		General Programming	
	4.1	Introduction	82
	4.2	IVI-COM Programming	83
	4.3	SCPI Programming	83
	4.3.1	AgM8196SFP.exe	84
	4.4	Programming Recommendations	86
	4.5	System Related Commands (SYSTem Subsystem)	87
	4.5.1	:SYSTem:ERRor[:NEXT]?	87
	4.5.2	:SYSTem:HELP:HEADers?	87
	4.5.3	:SYSTem:LIcense:EXTended:LIST?	88
	4.5.4	:SYSTem:SET[?]	88
	4.5.5	:SYSTem:VERSion?	89
	4.5.6	:SYSTem:COMMunicate:*?	89
	4.6	Common Command List	93
	4.6.1	*IDN?	93
	4.6.2	*CLS	93
	4.6.3	*ESE	93
	4.6.4	ESR?	93
	4.6.5	*OPC	93
	4.6.6	*OPC?	94
	4.6.7	*OPT?	94
	4.6.8	*RST	94
	4.6.9	*SRE[?]	94
	4.6.10	*STB?	94
	4.6.11	*TST?	94
	4.6.12	*LRN?	95
	4.6.13	*WAI?	95
	4.7	Status Model	96
	4.7.1	:STATus:PRESet	98
	4.7.2	Status Byte Register	98
	4.7.3	Questionable Data Register Command Subsystem	99
	4.7.4	Operation Status Subsystem	101
	4.7.5	Voltage Status Subsystem	102
	4.7.6	Frequency Status Subsystem	103
	4.7.7	Connection Status Subsystem	104
	4.7.8	Run Status Subsystem	104

4.8	:ARM/TRIGger Subsystem	105
4.8.1	:ABORt[1 2 3 4]	105
4.8.2	:ARM[:SEquence][:START][:LAYer]:MDELay[?] <module_delay> MINimum MAXimum	105
4.8.3	:INITiate:IMMediate[1 2 3 4]	106
4.8.4	:INITiate:CONTinous[:STATe][?] OFF ON 0 1	106
4.8.5	:ARM[:SEquence][:START][:LAYer]:TRIGger:LEVel[?] <level> MINimum MAXimum	106
4.8.6	:ARM[:SEquence][:START][:LAYer]:TRIGger:SLOPe[?] POSitive NEGative EITHer	107
4.8.7	:TRIGger[:SEquence][:START]:BEGin:HWDisable[:STATe][?] 0 1 OFF ON	107
4.8.8	:TRIGger[:SEquence][:START]:BEGin[:IMMediate]	108
4.9	:INSTrument Subsystem	109
4.9.1	:INSTrument:SLOT[:NUMBer]?	109
4.9.2	:INSTrument:IDENtify [<seconds>]	109
4.9.3	:INSTrument:IDENtify:STOP	110
4.9.4	:INSTrument: HWRevisiOn?	110
4.9.5	:INSTrument:DACMode[?] SINGLE DUAL FOUR MARKer DCMarker	111
4.10	:MMEMory Subsystem	112
4.10.1	:MMEMory:CATalog? [<directory_name>]	112
4.10.2	:MMEMory:CDIRectory [<directory_name>]	113
4.10.3	:MMEMory:COPY <string>,<string>[,<string>,<string>]	113
4.10.4	:MMEMory:DELeTe <file_name>[,<directory_name>]	114
4.10.5	:MMEMory:DATA <file_name>,<data>	114
4.10.6	:MMEMory:DATA? <file_name>	115
4.10.7	:MMEMory:MDIRectory <directory_name>	115
4.10.8	:MMEMory:MOVE <string>,<string>[,<string>,<string>]	116
4.10.9	:MMEMory:RDIRectory <directory_name>	116
4.10.10	:MMEMory:LOAD:CSTate <file_name>	117
4.10.11	:MMEMory:STORe:CSTate <file_name>	117
4.11	:OUTPut Subsystem	118
4.11.1	:OUTPut[1 2 3 4][:STATe][?] OFF ON 0 1	118
4.11.2	:OUTPut: ROSCillator:SOURce[?] INTernal EXTernal SCLK1 SCLK2	118
4.11.3	:OUTPut: ROSCillator:SCD[?] <sample_clock_divider>	119
4.11.4	:OUTPut: ROSCillator:RCD1[?] <reference_clock_divider1>	119
4.11.5	:OUTPut: ROSCillator:RCD2[?] <reference_clock_divider2>	120
4.11.6	:OUTPut[1 2 3 4]:DIOFset[?] <value> MINimum MAXimum	120
4.11.7	:OUTPut[1 2 3 4]:VPCorr[?] <value> MINimum MAXimum	121
4.12	Sample Frequency Commands	123
4.12.1	[:SOURce]:FREQuency:RASTer[?] <frequency> MINimum MAXimum	123
4.12.2	[:SOURce]:FREQuency:INT RNG1 RNG2 RNG3:RASTer[?] <frequency> MINimum MAXimum	123

4.13	Reference Oscillator Commands	125
4.13.1	[:SOURce]:ROSCillator:SOURce[?] EXTeRnal AXI INTeRnal	125
4.13.2	[:SOURce]:ROSCillator:SOURce:CHECK? EXTeRnal AXI INTeRnal	125
4.13.3	[:SOURce]:ROSCillator:FREQuency[?] <frequency> MINimum MAXimum	126
4.13.4	[:SOURce]:ROSCillator:RANGe[?] RANG1 RANG2 RANG3	126
4.13.5	[:SOURce]:ROSCillator:RNG1 RNG2 RNG3:FREQuency[?] <frequency> MINimum MAXimum	127
4.14	:VOLTage Subsystem	128
4.14.1	[:SOURce]:VOLTage[1 2 3 4][:LEVel][:IMMediate][:AMPLitude][?] <level> MINimum MAXimum	128
4.14.2	[:SOURce]:VOLTage[1 2 3 4][:LEVel][:IMMediate]:OFFSet[?] <level> MINimum MAXimum	128
4.14.3	[:SOURce]:VOLTage[1 2 3 4][:LEVel][:IMMediate]:HIGH[?] <level> MINimum MAXimum	129
4.14.4	[:SOURce]:VOLTage[1 2 3 4][:LEVel][:IMMediate]:LOW[?] <level> MINimum MAXimum	129
4.14.5	[:SOURce]:VOLTage[1 2][:LEVel][:IMMediate]:TERMination[?] <level> MINimum MAXimum	130
4.15	Frequency and Phase Response Data Access	131
4.15.1	[:SOURce]:CHARacteris[1 2 3 4][:VALue]? [<amplitude>[,<sample_frequency>]]	131
4.16	:TRACe Subsystem	132
4.16.1	Waveform Data Format	132
4.16.2	Arbitrary Waveform Generation	133
4.16.3	:TRAC[1 2 3 4]:DEF	133
4.16.4	:TRAC[1 2 3 4]:DEF:NEW?	134
4.16.5	:TRAC[1 2 3 4]:DEF:WONL	134
4.16.6	:TRAC[1 2 3 4]:DEF:WONL:NEW?	135
4.16.7	:TRAC[1 2 3 4]:DATA[?]	135
4.16.8	:TRAC[1 2 3 4]:IMP	136
4.16.9	:TRAC[1 2 3 4]:DEL	142
4.16.10	:TRAC[1 2 3 4]:DEL:ALL	143
4.16.11	:TRAC[1 2 3 4]:CAT?	143
4.16.12	:TRAC[1 2 3 4]:NAME[?]	144
4.16.13	:TRAC[1 2 3 4]:COMM[?]	144
4.16.14	:TRAC[1 2 3 4]:MARK[?]	145
4.17	:TEST Subsystem	146
4.17.1	:TEST:PON?	146
4.17.2	:TEST:TST?	146

5 Examples

5.1	Introduction	147
5.2	Remote Programming Examples	147
5.3	Example Files for Import	147

	5.4	Example Correction Files	148
	5.5	Example Custom Modulation Files	148
6		Appendix	
	6.1	Resampling Algorithms for Waveform Import	149
	6.1.1	Resampling Requirements	149
	6.1.2	Resampling Methodology	150

1 Introduction

1.1	Document History	/	14
1.2	Options	/	15
1.3	Upgrade Options	/	15
1.4	Installing Licenses	/	16
1.5	The Front Panel of the M8196A	/	18
1.6	Theory of Operation	/	22

Introduction

The Keysight M8196A is a 92 GSa/s Arbitrary Waveform Generator with highest bandwidth and channel density. It offers up to 4 x 512 kSa waveform memory. The M8196A is ideally suited to address following key applications:

- Coherent optical – a single M8196A module can generate 2 independent I/Q baseband signals (dual polarization = 4 channels) at 64 Gbaud and beyond.
- Multi-level / Multi-channel digital signals – generate NRZ, PAM4, PAM8, DMT, etc. signals at up to 56 Gbaud. Embed/De-embed channels, add Jitter, ISI, noise and other distortions.
- Physics, chemistry, and electronics research – generate any mathematically defined arbitrary waveforms, ultra-short yet precise pulses and extremely wideband chirps.
- Wideband RF/ μ W – generate extremely wideband RF signals with an instantaneous bandwidth of DC to 32 GHz for aerospace/defense/communication applications.

Features and Benefits	The M8196A is an arbitrary waveform generator with highest sample rate, bandwidth, and channel density: • Sample rate up to 92 GSa/s (on each channel) • Analog bandwidth: 32 GHz (typ.) • Vertical resolution: 8 bits • 1, 2, or 4 differential channels per 1-slot high AXIe module (number of channels is software upgradable) • Built-in frequency and phase response calibration • Amplitude up to 1 Vpp (single ended) (2 Vpp (differential)) • $T_{\text{Rise},20\% \dots 80\%} \quad T_{\text{Fall},20\% \dots 80\%} : 9 \text{ ps (typ.)}$ • Ultra low intrinsic Random Jitter $RJ_{\text{rms}} < 130 \text{ fs}$ • Form factor: 1-slot AXIe module controlled via external PC or embedded AXIe system controller M9536A
Supporting Operating System	The Keysight M8196A supports the following operating systems: • Windows 7 (32 bit or 64 bit) • Windows 8 (32 bit or 64 bit) • Windows 8.1 (32 bit or 64 bit) • Windows 10 (32 bit or 64 bit)
Control M8196A from M8070A System Software for BER Test Solutions	For digital applications that require multi-level signaling like NRZ, PAM-4, the M8196A arbitrary waveform generator will be integrated with the M8070A System Software for M8000 Series of BER Test Solutions. Once integrated, M8196A will be visible in the module view of M8070A GUI, just like any other M8000 Series module. For M8196A integration with M8070A, following must be installed: • Keysight IO Libraries Suite 16.3 or higher • M8196A software version 2.0 or later • M8070A software version 3.4 or later Once the M8196A module is mounted on to the chassis and relevant connections are made, it will be visible in the Module View of the M8070A GUI. Please see the M8070A User Guide and Online Help for further information. Click the following link for latest version of the mentioned documents: http://www.keysight.com/find/M8000 Please note that Keysight M8070A can only be installed on 64 bit operating system for Windows 7, 8, and 8.1.

NOTE

M8196A Soft Front Panel must not be launched while using the instrument with M8070A.

NOTE

The M8070A is a licensed software, and thus requires a license to communicate with the J-BERT M8020A hardware. You can either purchase an M8070A license to install on a dedicated host computer (M8070A-OTP) or one that can be installed on a network server that will be used as a license server for operating over a company network (M8070A-ONP, floating/networked).

Please see the M8020A Getting Started Guide for further information about licensing. Click the following link for latest version of the mentioned document:

<http://www.keysight.com/find/M8020A>

**Control M8196A from
81195A Optical
Modulation Generator
Software for Coherent
Test Solutions**

For coherent optical transmission applications that require dual polarization quaternary amplitude modulation formats like DP-QAM16, the M8196A arbitrary waveform generator will be integrated with the 81195A Optical Modulation Generator Software.

The 81195A Optical Modulation Generator software allows you to generate dual-IQ, complex modulated signals, as well as emulate optical signal properties and signal impairments such as phase noise, polarization rotation, and polarization mode dispersion (PMD).

For M8196A integration with 81195A, the following must be installed:

- Keysight IO Libraries Suite 16.3 or higher
- M8196A software version 1.0 or later
- 81195A software version 2.1 or later

Once the M8196A module is mounted on to the chassis and relevant connections are made, it will be accessible from the 81195A GUI.

Please see the 81195A User Guide for further information. Click the following link for latest version of the mentioned documents:

<http://www.keysight.com/find/81195A>

Please note that Keysight 81195A can be installed on 32 and 64 bit operating systems for Windows 7, 8, and 8.1.

NOTE

M8196A Soft Front Panel must first be launched before using the instrument with the 81195A.

NOTE

The 81195A is a licensed software. Please see the 81195A User Guide for further information about licensing.

Click the following link for latest version of the mentioned document:

<http://www.keysight.com/find/81195A>

Additional Documents

Additional documentation can be found at:

- <http://www.keysight.com/find/M9514A> for 14-slot chassis related documentation.
- <http://www.keysight.com/find/M9505A> for 5-slot chassis related documentation.
- <http://www.keysight.com/find/M9502A> for 2-slot chassis related documentation.
- <http://www.keysight.com/find/M9047A> for PCIe desktop adapter card related documentation.
- <http://www.keysight.com/find/M9536A> for embedded AXIe controller related documentation.
- <http://www.keysight.com/find/M8196A> for AXIe based AWG module related documentation.

1.1 Document History

Edition 1.0 (January, 2016)	This edition of the user's guide describes the functionality of the M8196A Version 1.0.
Edition 2.0 (May, 2016)	This edition of the user's guide describes the functionality of the M8196A Version 2.0.
Edition 3.0 (May, 2019)	This edition of the user's guide describes the functionality of the M8196A Version 2.1.1.0.

1.2 Options

For the M8196A , following product options are available.

Table 3: Options provided by M8196A

Product Number	Description	Available as SW upgrade?	Comment
M8196A-001	Arbitrary waveform generator module 1 channel, 92 GSa/s, 512 kSa per channel	N/A (minimum configuration)	Must order either: 001, 002, or 004
M8196A-002	Arbitrary waveform generator module 2 channels, 92 GSa/s, 512 kSa per channel	Yes	Must order either: 001, 002, or 004
M8196A-004	Arbitrary waveform generator module 4 channels, 92 GSa/s, 512 kSa per channel	Yes	Must order either: 001, 002, or 004
M8196A-BU2	Bundle consisting of one M9502A 2-slot AXIe chassis with USB option		
M8196A-BU3	Bundle consisting of one M9502A 2-slot AXIe chassis with USB option and one M9536A AXIe embedded PC controller		

Option -001, -002, or -004

With this option the number of channels is selected. The M8196A is available in a one channel (-001), two channel (-002) or 4 channel (-004) version. A software upgrade from one to two channels is possible by installing option U02. A software upgrade from two to four channels is possible by installing option U04. In order to upgrade from one to four channels, first option -U02 and next -U04 must be installed.

1.3 Upgrade Options

For the M8196A , following upgrade options are available.

Table 4: Upgrade options provided by M8196A

Product Number	Description	Available as SW upgrade?	Comment
M8196AU-U02	Upgrade from 1 channel to 2 channels	Yes	User-installable software license
M8196AU-U04	Upgrade from 2 channels to 4 channels	Yes	User-installable software license

1.4 Installing Licenses

After you purchase a license and you acquire the corresponding license file, you need to install the license on M8196A.

You can install the new license in the following ways:

1. In Keysight License Manager, click the **File** menu, and then select **Install....** An **Install License File(s)** window appears. In this window, browse to the location where you saved the license file. Select the license file, and then click the **Open** button.
2. To manually install a license by entering the appropriate license file information, click the **Tools** menu, click **Enter License Text....** The **License Text Entry and Installation** dialog box appears.

Type in the license data exactly as you received from Keysight. Click the **Install** button to install the license.

3. On Windows-based systems, you can install the license by copying the license file into the license directory
C:\Program Files\Keysight\licensing.

Once the licenses are installed, you can use the Keysight License Manager to view all licenses for the local system as depicted in the following figure.

Options U02 and U04 are upgradable using the Keysight License Manager (KLM); see [Table 4](#).

Observe following steps while installing licenses:

1. Close the firmware of the M8196A
2. Install the licenses using KLM
3. Start the firmware of the M8196A. The firmware finds the new licenses in KLM and installs them in the M8196A.

In case of an upgrade from one channel (-001) to four channels (-004) following steps must be observed:

1. Close the firmware of the M8196A
2. Install license -U02 using KLM
3. Start the firmware of the M8196A. The firmware finds the new license -U02 in KLM and installs it in the M8196A.
4. Close the firmware of the M8196A
5. Install license -U04 using KLM
6. Start the firmware of the M8196A. The firmware finds the new license -U04 in KLM and installs it in the M8196A.

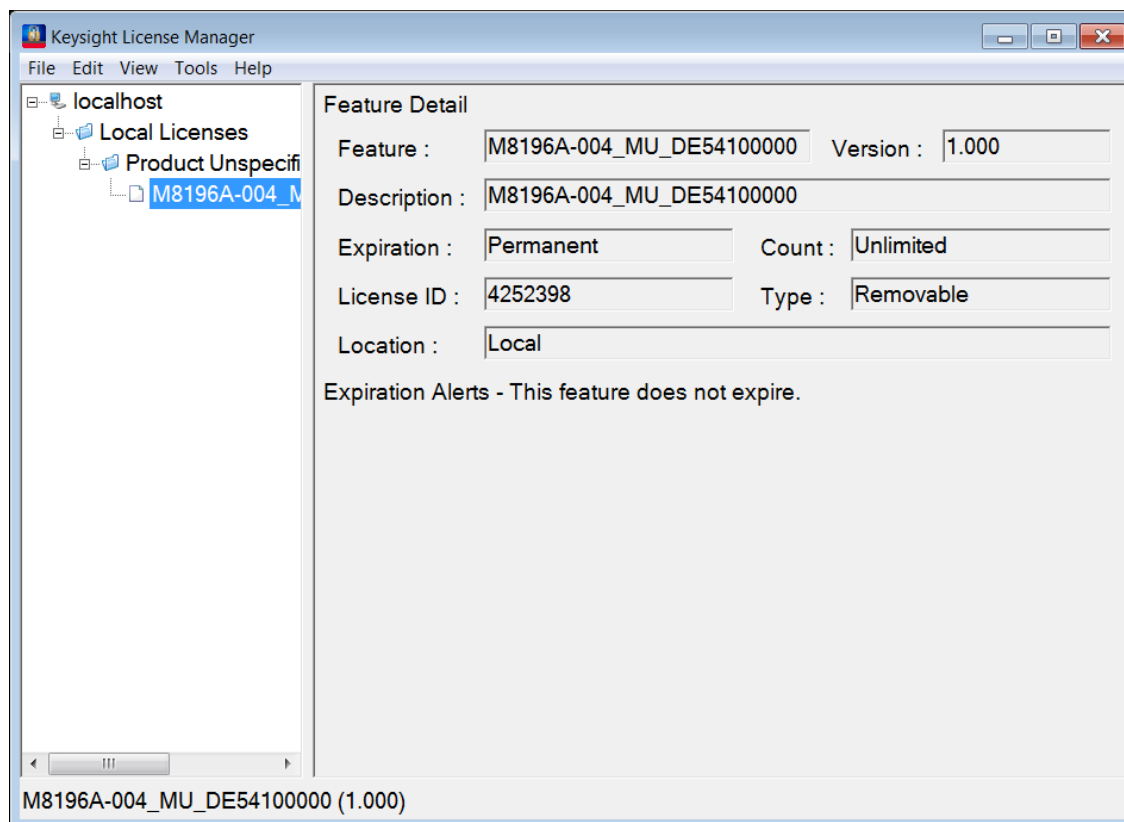


Figure 1: Using Keysight License Manager to view installed licenses

NOTE

Licenses for instrument options are transferred to the M8196A module. They are later no longer visible in the Keysight License Manager.

1.5 The Front Panel of the M8196A

The Front Panel of the M8196A is shown in the figure below.



Figure 2: Front panel of M8196A

Data Outputs

The M8196A is always delivered with four physically available differential Data Outputs of the Digital to Analog Converter (DAC). The analog DAC outputs are labelled with DATA OUT CHANNEL 1, DATA OUT CHANNEL 2; DATA OUT CHANNEL 3, DATA OUT CHANNEL 4. Depending on the channel option (-001 or -002 or -004) that has been installed, the M8196A one, two, or four differential analog outputs of the Digital to Analog Converters (DAC) are enabled for data generation.

Option -001: The differential output DATA OUT CHANNEL 1 is enabled for analog data generation. Also, one or two digital markers can be generated at DATA OUT CHANNEL 2 and DATA OUT CHANNEL 3.

Option -002: The selected Instrument Mode (see section [Error! Reference source not found.](#)) determines, which channels are enabled for analog data and marker generation.

- In 'Dual Channel' mode the differential outputs DATA OUT CHANNEL 1 and DATA CHANNEL 4 are enabled for analog data generation. DATA OUT CHANNEL 2 and DATA OUT CHANNEL 3 are disabled.
- In 'Dual Channel with Marker' mode the differential outputs DATA OUT CHANNEL 1 and DATA OUT CHANNEL 4 are enabled for analog data generation. One or two digital markers can be generated at DATA OUT CHANNEL 2 and DATA OUT CHANNEL 3.

Option -004: The differential output DATA OUT CHANNEL 1, DATA OUT CHANNEL 2, DATA OUT CHANNEL 3 and DATA CHANNEL 4 are enabled for analog data generation.

Note: The Data Outputs can be used differentially or single-ended. In case the output is used single-ended, the unused output must be terminated with 50 Ohm to GND to achieve optimum signal quality.

TRIG IN

The Trigger Input is used to start the M8196A by an external signal.

REF CLK IN

The Reference Clock Input can be used to synchronize to an external clock. The input frequency can vary between 10 MHz and 17 GHz.

REF CLK OUT

The Reference Clock Output can be used to synchronize a DUT to the M8196A. The adjustable output frequency covers a large frequency range.

1.5.1 Status LED

Following LEDs are available at the front panel to indicate the status of the AWG module:

- The green **'Access'** LED:
 - o It indicates that the controlling PC exchanges data with the AWG module.
- The red **'Fail'** LED has following functionality:
 - o It is 'ON' for about 30 seconds after powering the AXle chassis.
 - o After about 30 seconds the LED is switched 'OFF'. If an external PC is used to control the AXle chassis, this PC can be powered after this LED has switched OFF.
 - o During normal operation of the module this LED is 'OFF'. In case of an error condition such as e.g. a self-test error, the LED is switch 'ON'.

1.5.2 DATA Out LED

Table 5: Data out LED

Color	Meaning	Description
Off	Output disabled	Represents the state 'Disable'. Selectable from SFP or SCPI. The output amplifier is not powered After Power-On the LED is off. After successful initialization of the M8196A, the LED turns to its default state which is OFF.
ON, green	Output enabled	Represents the state 'Enable'. Selectable from SFP or SCPI - Output amplitude is equal to the adjusted amplitude - Offset is equal to the adjusted amplitude - External Termination voltage is equal the adjusted termination voltage
On, red	Protection circuit active	Error condition such as - The externally applied termination voltage significantly differs from the adjusted termination voltage - External termination resistor significantly differs from 50 Ohm The protection circuit overwrites amplifier settings (amplitude, offset) such that the amplifier's output stage will not be destroyed => Amplifier is not powered User interaction is required to remove the externally applied error condition. After removal, the user must actively enable the output again.

NOTE

The DATA Output LED does not represent the RUN / Stop Status. Also, the Output LED does not indicate whether a valid pattern is loaded in a certain channel.

1.5.3 Trigger IN LED

Table 6 Trigger IN LED

Color	Meaning	Description
Off	Trigger IN disabled	The trigger input is disabled. The waveform is started immediately after pressing Run/Stop.
BLINKING, green	Module armed	The module is armed and waiting for a valid trigger to occur.
ON, green	Module triggered	The module detected a valid trigger and the waveform output has been started.

1.5.4 Ref CLK IN LED

Table 7: Ref CLK IN LED

Color	Meaning	Description
Off	Applied Clock cannot be used	In case the clock reference is not set to Ref CLK IN, this LED is OFF.
ON, green	Valid signal at Ref CLK IN detected	- CDR has locked on Ref CLK In and - The externally applied frequency is correct and - Ref CLK In has been selected as the clock reference
ON, red	No valid signal at Ref CLK IN	- Ref CLK In has been selected as the clock reference - The externally applied clock signal is not valid. E.g. the frequency does not match the adjusted value or the amplitude is outside the specified range

1.6 Theory of Operation

1.6.1 M8196A Block Diagram

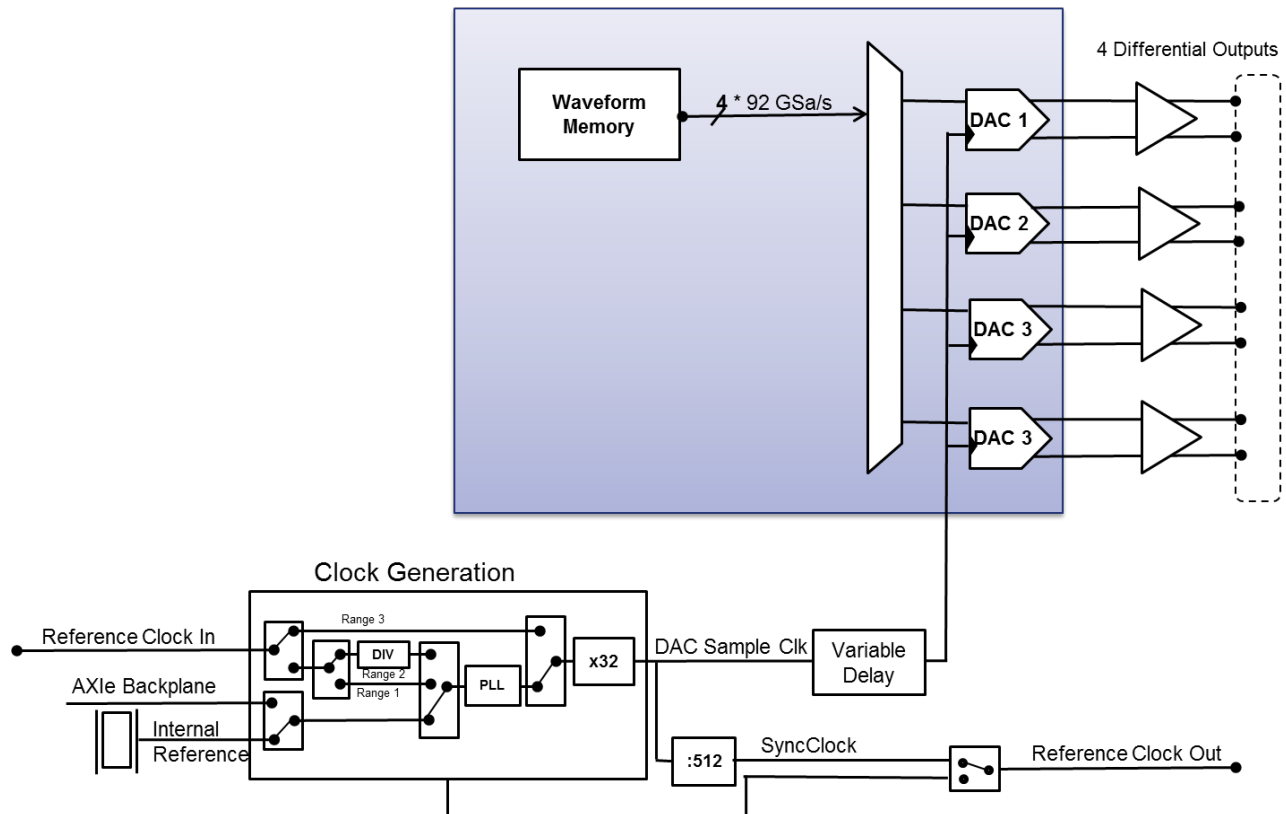


Figure 3: M8196A block diagram

The drawing below shows a block diagram of the instrument.

The level of detail is chosen to provide a general high level understanding of how the instrument is working. Therefore, not all of ports are shown in the block diagram.

The M8196A can operate in different modes: 'Single Channel', 'Single Channel with markers', 'Dual Channel', 'Dual Channel with markers', or 'Four Channel'.

The Sample Rate of all four Digital to Analog Converters (DAC) is always identical and can be selected between 82.24 GSa/s ... 93.4 GSa/s with internal reference clock.

With external reference clock in the range of 2.32 GHz to 3 GHz (Range 3) the Sample Rate range can be extended to typically 74 to 96 GSa/s.

The DAC specification is valid from 82.24 GSa/s to 92 GSa/s.

Definitions

DAC Sample Rate:

The DAC Sample rate generated by internal clock is always in the range of 82.24 GSa/s ... 93.4 GSa/s. The DAC sample rate indicates how many samples per seconds the DAC can generate. The unit of the sample rate is Sa/s

DAC Sample Frequency:

The DAC Sample frequency with internal clock is always in the range of 82.24 GHz ... 93.4 GHz. As the DAC sample frequency references to a clock, the unit of the sample frequency is Hz.

DAC Sample CLK:

The DAC Sample CLK is the clock signal that sources the four DAC of the M8196A. There is a variable delay element between the clock generation block and the DAC.

SyncClock:

$\text{SyncClock} = \text{DAC Sample Rate} / 512$

The SyncClock is the timing reference for the M8196A. The Sync Clock is an internal clock signal that can be output at the Reference Clock Out in order to accurately align the timing with an external DUT or additional test equipment.

Waveform Sample Rate:

The Waveform Sample Rate corresponds to the DAC Sample Rate.

Waveform Granularity:

The waveform granularity is 128. This means that the waveform length must be a multiple of this granularity. The minimum waveform length is 128 samples.

Operation

Delay Alignment:

The Synch Clock is the internal timing reference of the M8196A. After power on and after each DAC sample rate change, the M8196A performs an internal delay alignment. The resolution of this delay alignment is better than 1ps.

External clock handling:

Clock signal sources for AWG are generated by internal reference oscillator, provided by AXI backplane or by applying an external reference clock signal.

Sequencing:

Sequencing is not supported by the M8196A. For compatibility with M8195A in the M8196A the segment number is 1.

1.6.2 Delay Adjust

The variable delay is used in order to compensate for e.g. external cable length differences as well as the initial skew. The variable delay has a very high timing resolution. Modifying the variable delay always affects the delay of all four Data Outputs.

Setting the variable delay to e.g. 10 ps has following effects:

- Data Out 1, Data Out 2, DataOut 3, and Data Out 4 are delayed by 10 ps with respect to the output at Ref Clk out.
- In case the M8196A is sourced from Ref CLk In (or the AXIe backplane), Data Out1, Data Out 2, Data Out 3, and Data Out 4 are delayed by 10 ps with respect to Ref CLk In (or the AXIe backplane).

1.6.3 Instruments Modes

The following chapter provides an overview of all available instrument modes.

The instrument modes are associated with the instrument options:

Option -001 allows the selection of the instrument mode 'Single Channel' or 'Single Channel with Marker'.

The waveform is always sent at channel 1. The digital markers are always sent at channel 2 and 3.

Option -002 allows the selection of the Instrument Mode 'Single Channel', 'Single Channel with Marker', 'Dual Channel with Marker' or 'Dual Channel'.

In Instrument mode 'Dual Channel', no digital markers are available.

Each channel can be enabled and disabled independently from other channels.

Option -004 allows the selection of the Instrument Mode 'Single channel', 'Single Channel with Marker', 'Dual Channel with Marker', 'Dual Channel', or 'Four Channel'.

In Instrument mode 'Four Channel', no digital markers are available.

Each Channel can be enabled and disabled independently from other channels.

Table 8: Instrument modes

Instrument mode	Waveform source	Sample memory size	Waveform memory access rate	Mapped to channel
Single channel	Memory 1	Mem 1: 512 kSa	82.24 GSa/s ... 93.4 GSa/s	Ch 1: Waveform 1 Ch 2,3,4: Inactive
Single channel with marker	Memory 1	Mem 1: 512 kSa	82.24 GSa/s ... 93.4 GSa/s	Ch 1: Waveform 1 Ch 2: Marker 1 Ch 3: Marker 2 Ch 4: Inactive
Two channels	Memory 1 Memory 4	Mem 1: 512 kSa Mem 4: 512 kSa	82.24 GSa/s ... 93.4 GSa/s 82.24 GSa/s ... 93.4 GSa/s	Ch 1: Waveform 1 Ch 2,3: Inactive Ch 4: Waveform 4
Two channel with marker	Memory 1 Memory 4	Mem 1: 512 kSa Mem 4: 512 kSa	82.24 GSa/s ... 93.4 GSa/s 82.24 GSa/s ... 93.4 GSa/s	Ch 1: Waveform 1 Ch 2: Marker 1 Ch 3: Marker 2 Ch 4: Waveform 2
Four channels	Memory 1 Memory 2 Memory 3 Memory 4	Mem 1: 512 kSa Mem 2: 512 kSa Mem 3: 512 kSa Mem 4: 512 kSa	Mem 1 = Mem 2 = Mem 3 = Mem 4: 82.24 GSa/s ... 93.4 GSa/s	Ch 1: Waveform 1 Ch 2: Waveform 2 Ch 3: Waveform 3 Ch 4: Waveform 4

NOTE

Sample rate is always identical on all channels.

2 M8196A User Interface

2.1	Introduction	/ 27
2.2	Launching the M8196A Soft Front Panel	/ 28
2.3	M8196A User Interface Overview	/ 30
2.4	Driver Call Log	/ 34
2.5	Errors List Window	/ 35
2.6	Clock Tab	/ 36
2.7	Output Tab	/ 38
2.8	Trigger Tab	/ 40
2.9	Standard Waveform Tab	/ 42
2.10	Multi-Tone Waveform Tab	/ 47
2.11	Complex Modulated Waveform Tab	/ 53
2.12	Serial Data Waveform Tab	/ 62
2.13	Import Waveform Tab	/ 71
2.14	Correction File Format	/ 77

2.1 Introduction

This chapter describes the M8196A Soft Front Panel.

2.2 Launching the M8196A Soft Front Panel

Follow the step to launch the M8196A Soft Front Panel:

- Select **Start > All Programs > Keysight M8196 > Keysight M8196 Soft Front Panel**

NOTE

To control the instrument through SCPI:
From the Keysight Connection Expert, select the discovered M8196 module, and click **Send Commands To This Instrument**.

The following screen will appear:

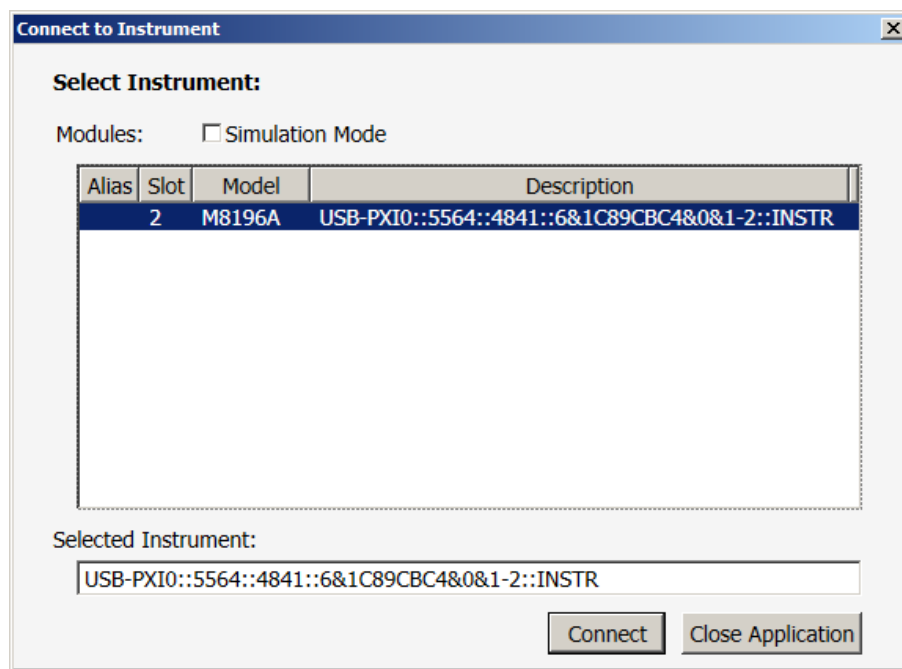


Figure 4: M8196A connected to PC

The instrument selection dialog shows the addresses of the discovered M8196A modules. Select a module from the list and press “Connect”.

If no M8196A module is connected to your PC, you can check “Simulation Mode” to simulate an M8196A module.

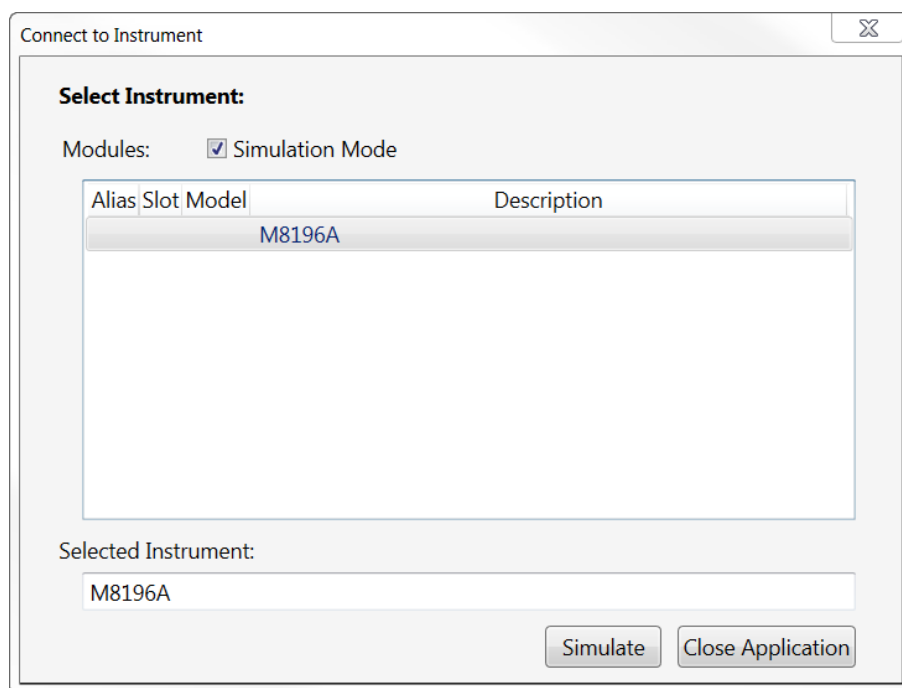


Figure 5: M8196A connected in simulation mode

2.3 M8196A User Interface Overview

The M8196A user interface includes the following GUI items:

- Title Bar
- Menu Bar
- Status Bar
- Tabs (Clock, Output, Trigger Standard Waveform, Multi-Tone Waveform, Complex Modulated Waveform, Serial Data Waveform and Import Waveform)
- Run / Stop Button

The detailed information on these GUI items is described in the sections that follow.

2.3.1 Title Bar

The title bar contains the standard Microsoft Windows elements such as the window title and the icons for minimizing, maximizing, or closing the window.

2.3.2 Menu Bar

The menu bar consists of various pull down menus that provide access to the different functions and launch interactive GUI tools.

The menu bar includes the following pull down menu:

- File
- View
- Utilities
- Tools
- Help

Each menu and its options are described in the following sections.

2.3.2.1 File Menu

The File menu includes the following selections:

- File – Connect...
Opens the instrument selection dialog.
- File – Save Configuration As...
Saves configuration as a text file.
- File – Load Configuration...
Load the previously saved configuration file.
- File – Exit
Exits the user interface.

2.3.2.2 View Menu

The View menu includes the following selections:

- View – Refresh
Reads the instrument state and updates all fields.
- View – Hide
Minimizes GUI to notify icon

2.3.2.3 Utilities Menu

The Utility menu includes the following selections:

- Utility – Identify
Identify the instrument by flashing the green “Access” LED on the front panel for a certain time.
- Utility – Reset
Resets the instrument, reads the state and updates all fields.
- Utility – Self Test...
Opens a window to start the self-test and display the result after completion.

2.3.2.4 Tools Menu

The Tools menu includes the following selections:

- Tools – Monitor Driver Calls
Opens the **Driver Call Log** window.

2.3.2.5 Help Menu

The Help menu includes the following selections:

- Help – User Guide
Opens the instrument's user's guide.
- Help – Driver Help
Opens the instrument's driver help (available with later FW release)
- Help – Online Support
Opens the instrument's product support web page.
- Help – About
Displays revision information for hardware, software and firmware. Displays the serial number of the connected module.

2.3.3 Status Bar

The Status Bar contains three fields from left to right:

- Connection state
“Not Connected” – No instrument is connected.
“Connected: <Instrument resource string>” – An instrument is connected. The resource string, for example PXI36::0::0::INSTR is displayed.
“Simulation Mode” – No real instrument is connected. The user interface is in simulation mode.
Click this field to open the Instrument Selection Dialog.
- Instrument status
Displays the instrument status, for example “Reset complete” after issuing a reset command. In case of error it displays additional error information.
- Error status
“Error” – The connected instrument reported an error.
“No Error” – No errors occurred.
Click this field to open the Report Error Window.

2.3.4 Clock/Output/Standard Waveform/Multi-Tone Waveform/Complex Modulated Waveform/Serial Data Waveform/Import Waveform Tabs

These tabs are used to configure the most important parameters of the M8196A module. They are described in detail in the sections that follow.

2.3.5 Run / Stop Button

The Run/Stop button is used to switch between Run and Program mode. When pressed the waveform generation is started and the "Run" turns green. When pressed again the output sends a zero-waveform and the "Stop" turns red. Output voltage offset remains active as long as output port is enabled.

2.3.6 Numeric Control Usage

The numeric control is used to adjust the value and units. Whenever you bring the mouse pointer over the numeric control, a tooltip appears which shows the possible values in that range.

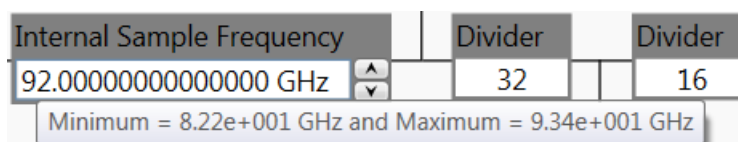


Figure 6: Tooltip showing possible values in the range

The numeric controls can be used in the following ways:

- Use the up/down arrows to change the value. The control automatically stops at the maximum/minimum allowed value.
- You can increase or decrease the value starting at a specific portion of the value. To do this, place the cursor to the right of the targeted digit and use the up/down arrows. This is especially useful when changing a signal characteristic that is immediately implemented, and observing the result in another instrument. For example, you can change the signal generator's frequency by increments of 10 MHz and observe the measured result in a signal analyzer:

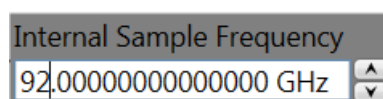


Figure 7: Typing directly into the field

- Type directly into the field and press the Enter key. If you enter a value outside the allowed range, the control automatically limits the entered value to the maximum or minimum allowed value.
- When you type the value, you can type the first letter of the allowed unit of measure to set the units. For example, in the Frequency control you can use "H", "K", "M", or "G" to specify hertz, kilohertz, megahertz, or gigahertz, respectively. (The control is not case sensitive.)

The controls allow scientific notation if it is appropriate to the allowed range. Type the first decimal number, enter an "E", and omit any trailing zeroes. For example, in the Frequency control you can type 2.5e+9 and press [Enter] to set the frequency to 2.5 GHz. (The plus sign is automatically inserted if it is omitted.)

2.4 Driver Call Log

Use this window to inspect the sequence of IVI driver calls and SCPI commands used to configure the M8196A module. (IVI COM driver will be available with a later FW release.)

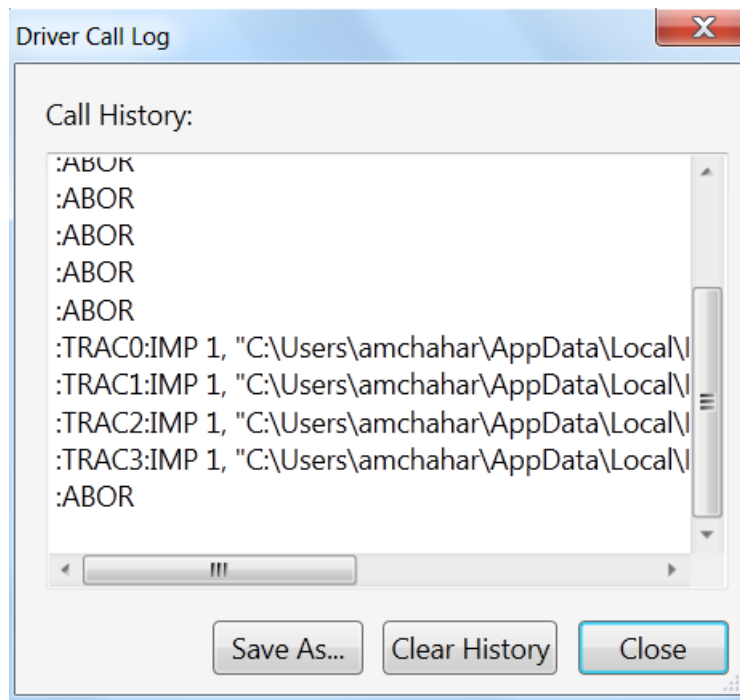


Figure 8: Driver call log window

It has the following buttons:

- Save As...
Saves the Driver Call Log as a text file.
- Clear History
Clears the Driver Call Log.
- Close
Exits the window.

2.5 Errors List Window

Use this window to view errors, warnings, and information.

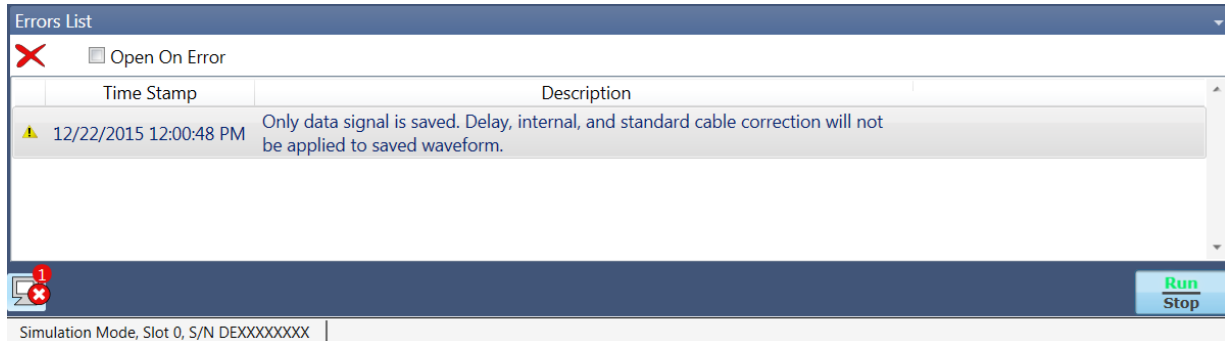


Figure 9: Errors list window

It has the following controls, signs, and columns:

- ☐ Open On Error
Select this check box to automatically open the errors list window whenever an error occurs. This window will show error details i.e. time stamp and description.
-  (Clear All)
Use this option to clear all the errors from the errors list window.
-  or  (Hide Errors List Window or Show Errors List Window)
Use this toggle option to respectively show or hide the errors list window. It also shows total number of errors in the list. When the window has no errors, the green tick icon will appear.
-  (Error)
This icon represents an error.
-  (Warning)
This icon represents a warning.
-  (Information)
This icon represents an information.
- Time Stamp
This column lists the time stamp of individual errors in the format DD/MM/YYYY HH:MM:SS.
- Description
This column provides the description of individual errors.
-  (Window Controls)
This drop down list provides window control options like:
 - Float
 - Dock
 - Auto Hide
 - Close

2.6 Clock Tab

Use this tab to configure the sample clock and the reference clock of M8196A module. The sample clock for all four Digital to Analog Converters (DAC) of the four channels is identical. It allows user to configure clock source, reference clock range and frequency, and DAC sample frequency.

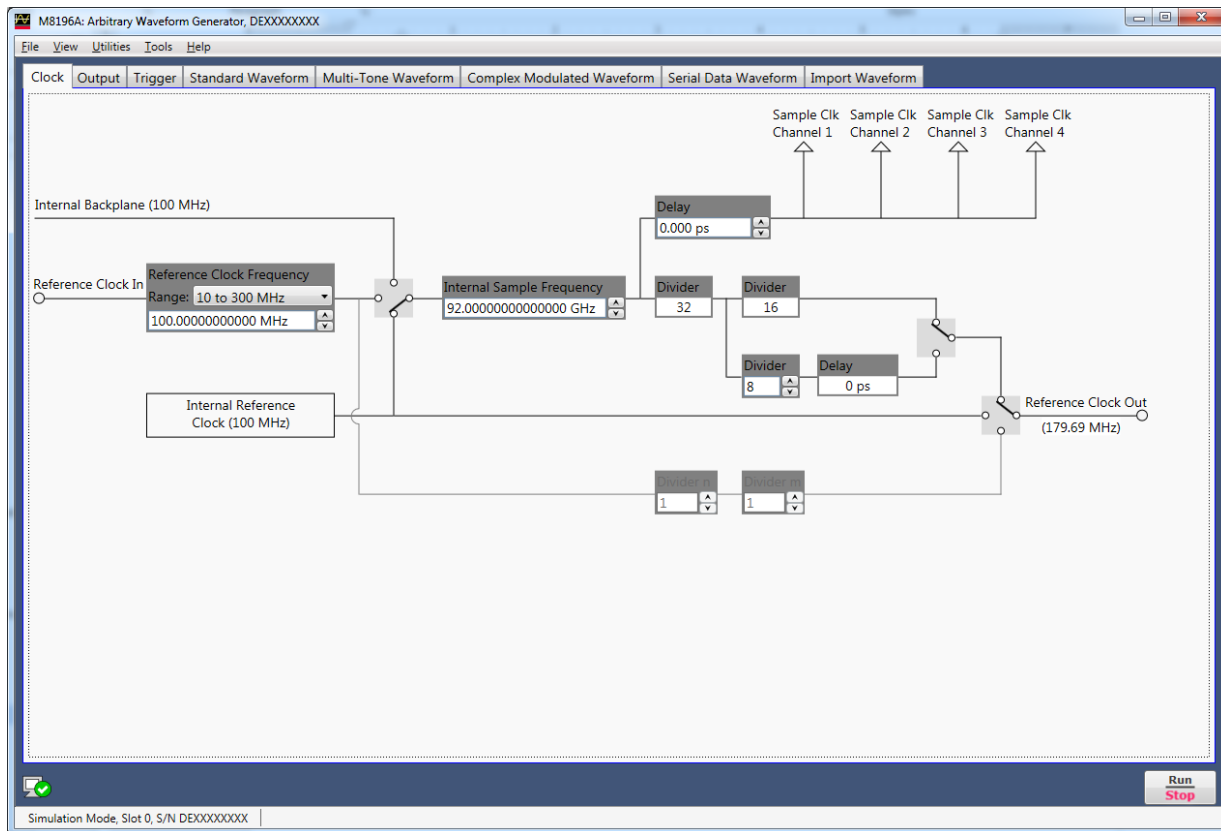


Figure 10: Clock tab

1. Reference Clock Selection Switch

This switch selects between the different reference clock sources.

- Internal 100 MHz: Reference from internal oscillator
- Internal Backplane 100 MHz: Reference from AXIe Backplane
- External: Reference from Ref Clock In

2. DAC Sample Frequency

This field sets the DAC sample frequency for all the channels.

The range is $8.224 \text{ e } +001$ to $9.340 \text{ e } +001$ GHz.

3. Sample Clock Out Delay

This field specifies the sample clock out delay in ps for all the channels.

The range is 0 ps to 10ns.

4. Reference Clock Frequency and Range

This field allows to select a reference clock frequency range among the three options 10 to 300 MHz (Range 1), 162 MHz to 17 GHz (Range 2), and 2.32 GHz to 3.0 GHz (Range 3). Further, it provides a field to enter the frequency value within the selected range. Using a high precision external clock source the clock range 2.32 GHz to 3.00 GHz allows the M8196A to be operated at sample rates of 74 GHz to 96 GHz.

Please note that the M8196A is specified for a sample rate range of 82.24 GHz to 92 GHz.

5. Reference Clock Out Switch

It allows selecting reference clock out source depending on reference clock input source.

2.7 Output Tab

Use this tab to configure the Data Outputs (Channel 1, Channel 2, Channel 3, and Channel 4) of the M8196A AWG module.

The M8196A has five different modes of operation:

- **Single Channel:** If this mode is selected, Channel 1 is used to generate data; Channel 2, Channel 3, and Channel 4 are disabled. This mode is available with option 001,002, or 004 only.
- **Single Channel with Markers:** If this mode is selected, Channel 1 is used to generate data, and channel 2 and 3 are used to generate digital markers. Channel 4 is disabled.
- **Dual Channel:** If this mode is selected, Channel 1 and Channel 4 are used to generate data. Channel 2 and Channel 3 are disabled. This mode is selectable, if option 002 or 004 is present
- **Dual Channel with Markers:** If this mode is selected, Channels 1 and 4 are used to generate a signal. Channel 1 has two markers output on channel 2 and 3. Channel 4 can generate a signal without markers.
- **Four Channel:** This mode is only selectable, if option 004 is installed. If this mode is selected, all four channels can be used to generate data.

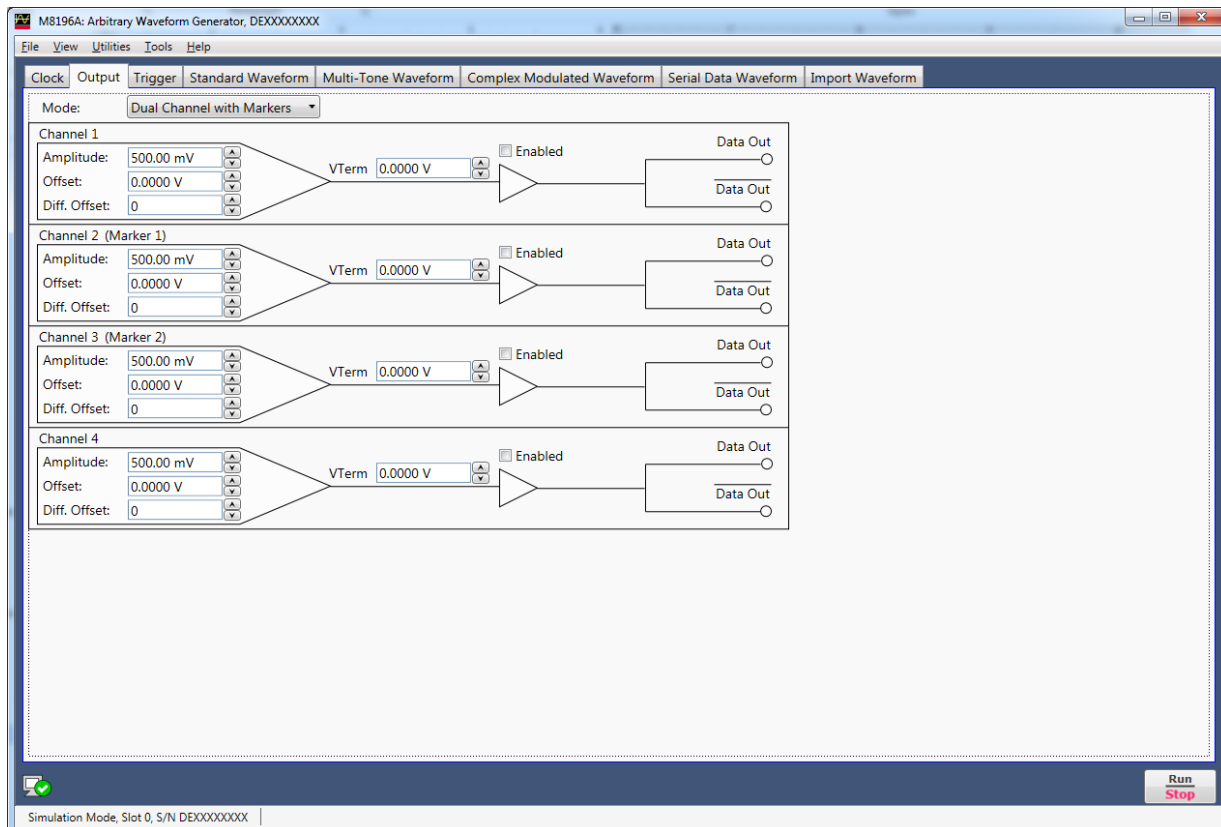


Figure 11: Output tab

Each channel has the following input fields:

- Amplitude
Sets the single-ended, peak-to-peak amplitude of the output signal.
- Offset
Sets the common mode offset voltage of the output signal.
- Diff. Offset (Differential Offset)
Sets the differential offset of the output signal.
- V Term (Termination Voltage)
Sets the termination voltage.
- Output status indicator. This indicator reflects the color of the 'Channel' LED on the front panel:
 - It is 'OFF' when the channel is disabled and no overload condition at this channel has been detected.
 - It is 'GREEN' if the channel is enabled and no overload condition at this channel has been detected.
 - It is 'RED' if the internal protection circuit of that channel has detected an overload condition. Potential overload conditions are e.g. an external short to GND or 50 Ohm termination to a wrong externally applied termination voltage V_{Term} . In case an overload condition is detected, remove the overload condition of the test set-up and enable the channel.
- Output enable switch
 - If set to enabled position, the generated signal is present at the output.

When pressing the Stop button the the output voltage offset remains active as long as the output port is enabled.

2.8 Trigger Tab

Use this tab to configure the triggering of the M8196A AWG module. The M8196A supports only a single trigger event which will start the waveform output. Once the waveform output has been started, the waveform will play indefinitely until the output is stopped manually by pressing Run/Stop.

The M8196A supports two different modes of operation:

- Continuous: If running in continuous mode, the waveform output is started immediately after pressing Run/Stop. The Trigger In controls and the 'Force Trigger' button are out of action in this mode. To stop the waveform output again, press Run/Stop again.
- Triggered: In triggered mode, the waveform output is started only after the module has received a valid trigger signal at its TRIG IN input. To initiate the module press Run/Stop. This will bring the M8196A into armed mode indicated by a blinking TRIG IN LED on the front panel. After receiving a valid trigger edge, the module will start playing the waveform pattern from its internal memory and the front panel LED will turn on permanently. To stop the waveform output again, press Run/Stop again.

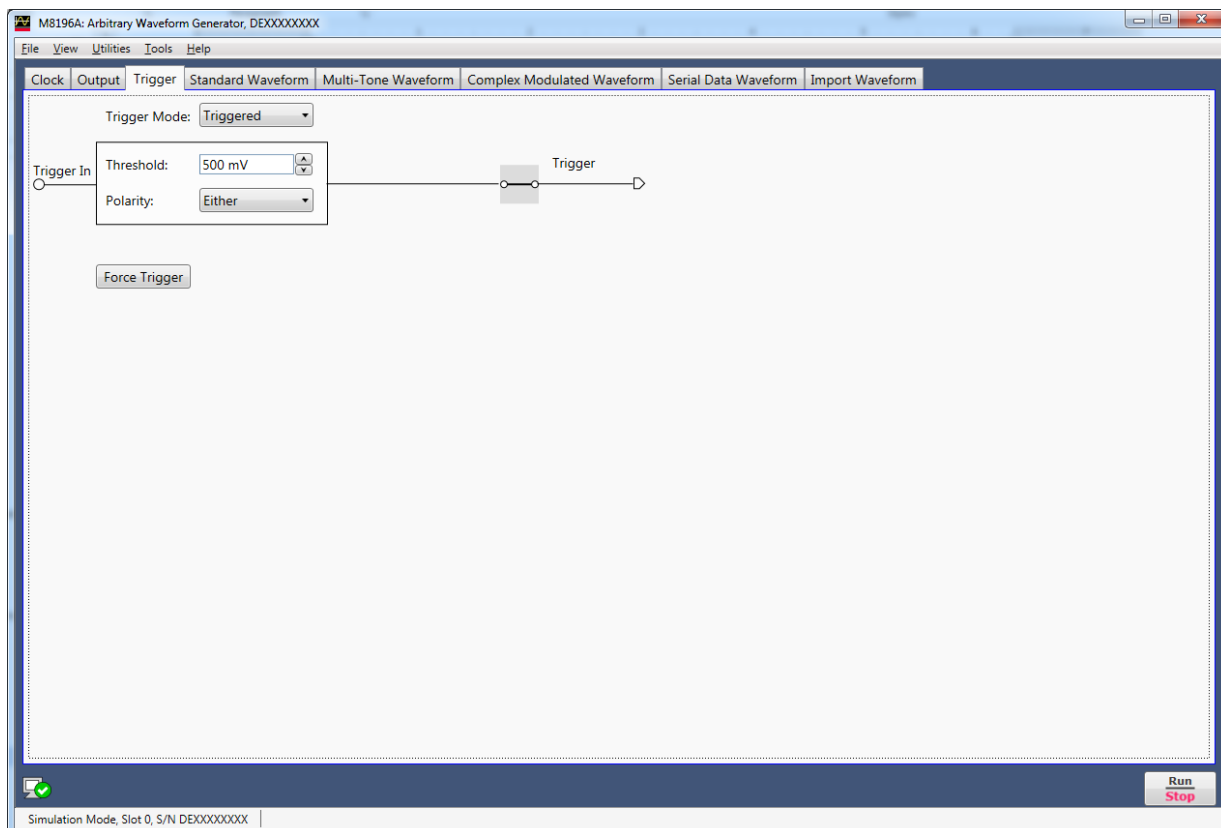


Figure 12 Trigger tab

The tab contains the following controls:

- Trigger Mode
Sets the the module in either continuous or triggered mode.
- Threshold
Sets the threshold of the trigger input.
- Polarity
Sets the signal edge on which to trigger. Choices are positive (rising), negative (falling) or either edge.
- Trigger (Switch)
Allows to manually disable the hardware trigger input.
- Force Trigger
Manually trigger the module when in triggered mode.

2.9 Standard Waveform Tab

Use this tab to create a variety of standard waveform types. It provides the controls which allow the complete definition of signal generation parameters for the following waveform shapes:

- Sinusoidal
- Square with linear transitions
- Square with cosine-shaped transitions
- Triangle
- Sinc (Sin x/x)
- Bandwidth-limited Gaussian noise

The standard waveform tab allows you to generate signals for both direct and I/Q data generation modes. It also provides a graphic waveform preview functionality, which can be used to validate created signals before sending them to the instrument. The created signals can also be stored in a file for later use. The application takes care of handling the requirements and limits of the target hardware in aspects such as maximum and minimum record lengths and sampling rate and record length granularity. As a result, the signals designed in this tab will be always feasible to be generated by the instrument and free of distortions such as wrap-around or timing artifacts, even if the signal is generated in looped mode.

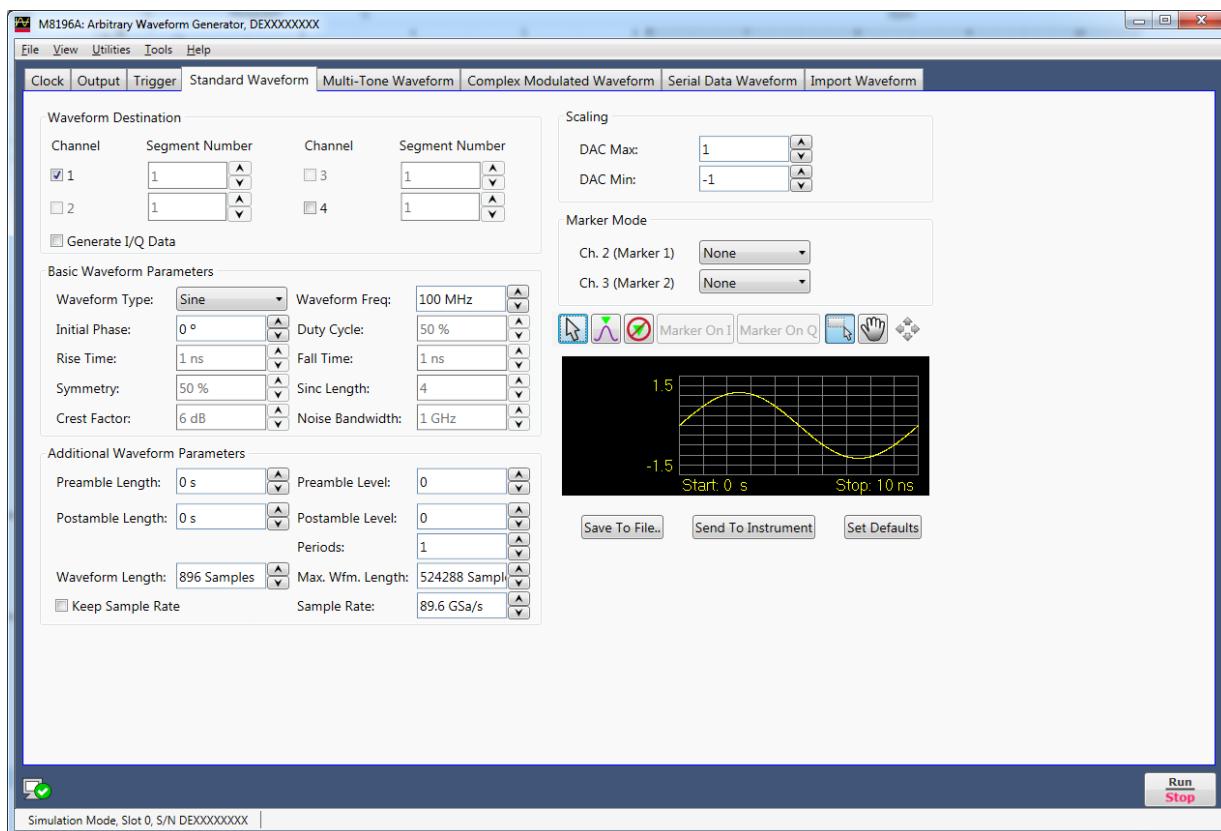


Figure 13: Standard waveform tab

This tab has the following controls:

Waveform Destination Section

- Channel
Independent checkboxes allow the definition of standard waveforms for Channel 1, Channel 2, Channel 3, or Channel 4. One of the boxes is always checked. When pressing the 'Send To Instrument' button, the waveform is sent to all channels that are checked.
- Generate I/Q Data
If checked, baseband (I/Q) signals will be generated. The effect of this control depends on the selected signal type. For Sinusoidal waves, the resulting complex signal will be a single spectral line located at positive or negative frequencies. This implies that users can type negative numbers into the "Waveform Freq." field. For noise, the resulting complex signal will be a limited-bandwidth Gaussian noise with uncorrelated positive and negative frequency components. All the other waveform types result in the same signal being generated by both I and Q assigned channels. I/Q selection toggle buttons for each channel will be shown when the Generate I/Q Data checkbox is checked. In-Phase (I) and Quadrature (Q) components can be independently assigned to each channel.
- Segment Number
The segment number is 1.

NOTE

The segment number section is only kept for compatibility to M8195A AWG.

Basic Waveform Parameters Section

- Waveform Type:
The following waveform types are available:
 - Sine: Sinusoidal waveform. Frequency and Initial Phase parameters can be defined for this waveform type using the corresponding controls. If the Generate I/Q checkbox is checked, two sine waves with a 90° phase difference will be assigned to the I and Q components.
 - Square_Linear: Square signal with linear transitions. Frequency, Rise Time, Fall Time, Duty Cycle, and Initial Phase parameters can be defined for this waveform type using the corresponding controls.
 - Square_Cos: Square signal with cosine shaped transitions. Frequency, Rise Time, Fall Time, Duty Cycle, and Initial Phase parameters can be defined for this waveform type using the corresponding controls.
 - Triangle: Triangular waveform with linear transitions. Frequency, Symmetry, and Initial Phase parameters can be defined for this waveform type using the corresponding controls.
 - Sinc: Sin x/x waveform. Frequency, Symmetry, Sinc Length, and Initial Phase parameters can be defined for this waveform type using the corresponding controls.
 - Noise: Gaussian noise with limited bandwidth. Frequency, Crest Factor, and Noise Bandwidth parameters can be defined for this waveform type using the corresponding controls. If the Generate I/Q checkbox is

checked, two uncorrelated noise waveforms will be assigned to the I and Q components.

- **Waveform Frequency**
Repetition rate for one cycle of the standard waveform. It is always a positive number except when Signal Type is set to Sine and the Generate I/Q Data checkbox is checked. In this case, frequency may be negative so the resulting SSB (Single-Side Band) will be located over or below the carrier frequency.
- **Initial Phase**
The phase within a normalized cycle of the standard waveform for the first sample in the segment.
- **Duty Cycle**
The relative width as a percentage of the mark and the space sections of square waves.
- **Rise Time**
The transition time (10%-90%) for the rising edge in square waveforms.
- **Fall Time**
The transition time (10%-90%) for the falling edge in square waveforms.
- **Symmetry**
For both triangular and sinc waveforms, it marks the location as a percentage of the positive highest peak within a period of the basic signal.
- **Sinc Length**
The number of zero crossings in a single period for the sinc waveform type.
- **Crest Factor**
The peak-to-average power ratio in dBs for Noise samples before low-pass filtering. Actual crest factor in the final signal after filtering will be higher.
- **Noise Bandwidth**
Baseband noise bandwidth for Noise waveforms. For IQ modes, noise bandwidth around the carrier frequency will be twice this parameter.

Additional Waveform Parameters Section

- **Preamble Length**
The duration of a DC section before the defined Standard waveform starts.
- **Preamble Level**
The level for the DC section before the defined Standard waveform starts. Acceptable range for this parameter is $-1/+1$, being the full dynamic range of the instrument's DAC.
- **Postamble Length**
The duration of a DC section after the defined Standard waveform stops.
- **Postamble Level**
The level for the DC section after the defined Standard waveform stops. Acceptable range for this parameter is $-1/+1$, being the full dynamic range of the instrument's DAC.
- **Keep Periods**
This checkbox is only available when "Keep Sample Rate" is selected. When this option is selected, the waveform calculation algorithm preserves the user-defined number of periods.

- **Set WL to Max**
This checkbox is only available when “Keep Sample Rate” is selected. When this option is selected, the waveform calculation algorithm always takes the maximum waveform length as defined in the “Max. Wfm. Length”.
- **Periods**
The number of repetition of single periods of the standard waveform within the target segment. This parameter is set automatically when Frequency is changed and preamble and postamble lengths are set to zero in order to obtain the best timing accuracy and meet the record length granularity requirements.
- **Waveform Length**
The length in samples of the resulting segment. It may be set within acceptable limits and it may be calculated automatically to properly implement other signal and instrument parameters such as sampling rate.
- **Max. Wfm. Length**
Maximum waveform length must be used to force the resulting waveform to be shorter than or equal to a user-set limit.
- **Keep Sample Rate**
This check box preserves the sampling rate to a user-defined value no matter how any other signal parameters may be defined. Keeping the sampling rate to a fixed value may be necessary when multiple waveforms are created to be used in a sequence or scenario. The “Set WL to Max” check box gets activated when this check box is checked.

Set WL to Max. This check box forces the usage of the number of samples defined in the “Max. Wfm. Length” numeric entry field. Some waveform parameters may be adjusted to make sure that continuous play-back of the waveform is seamless.

Marker Mode

These controls are available when the “Single Channel with Marker” or “Dual Channel with Marker” mode is selected in the Output tab.

- **Ch. 2 (Marker 1)**
Marker 1 is output on Channel 2. Signaling the beginning of the Channel 1 waveform may be activated (Segment selection) and deactivated (None selection).
- **Ch. 3 (Marker 2)**
Marker 2 is output on Channel 3. Signaling the beginning of the Channel 1 waveform may be activated (Segment selection) and deactivated (None selection).

Scaling Section

- **DAC Max**
Standard waveforms may occupy a limited range of the DAC’s full scale. This parameter sets the maximum level. If set to a lower level than DAC Min, this will be automatically set to the same level. Acceptable range for this parameter is -1/+1, being the full dynamic range of the instrument’s DAC.

- DAC Min

Standard waveforms may occupy a limited range of the DAC's full scale. This parameter sets the minimum level. If set to a higher level than DAC Max, this will be automatically set to the same level. Acceptable range for this parameter is -1/+1, being the full dynamic range of the instrument's DAC.

Preview Section

- Waveform Preview Toolbar

The waveform preview toolbar includes the icons to preview the waveform. The following icons are available:

	Uses the mouse to control the marker. The respective position of marker at X and Y axis are displayed on the top of waveform.
	Takes the marker to the peak position
	Sets the marker on the I data part of the waveform
	Sets the marker on the Q data part of the waveform
	Turns off the marker
	Provides zoom functionality. Use the mouse pointer to select the area on waveform that you want to zoom. Once done, you can click Auto scale icon to zoom out the waveform.
	Uses the mouse pointer to move the waveform around. You can also use the pan tool when the waveform is zoomed in.
	Auto scale the waveform

- Save To File...

Signals can be stored in files in whether BIN (for non IQ modes) or IQBIN (for IQ modes) formats. These files may be reused within the Import Waveform tab.

- Send To Instrument

Signal will be transferred to the selected segments of the selected channels. The previous running status for the target instrument will be preserved but sampling rate may be modified depending on the waveform requirements.

- Set Default

All the standard waveform parameters are set automatically to their corresponding default values.

2.10 Multi-Tone Waveform Tab

Use this tab to create signals made-up of multiple tones, either equally or arbitrarily spaced. It also allows for the definition of a frequency interval without tones (or notch) for NPR (Noise Power Ratio) testing. Amplitudes and phases of the individual tones can be corrected through correction factor files defined by the user. The Multi-Tone tab allows you to generate both RF and baseband (I/Q Data) signals. It also provides a graphic waveform preview functionality, which can be used to validate the location and amplitudes of the tones in the signal before sending it to the instrument or be stored in a file for later use. The signal's crest factor or Peak-to-Average Power Ratio (PAPR) is also shown. The application handles requirements and limits of the target hardware in aspects such as maximum and minimum record lengths, sampling rate, and record length granularity. As a result, generation of signals designed in this tab will always be feasible through the instrument, and they will be free of distortions such as wrap-around or timing artifacts, even if they are generated in looped mode.

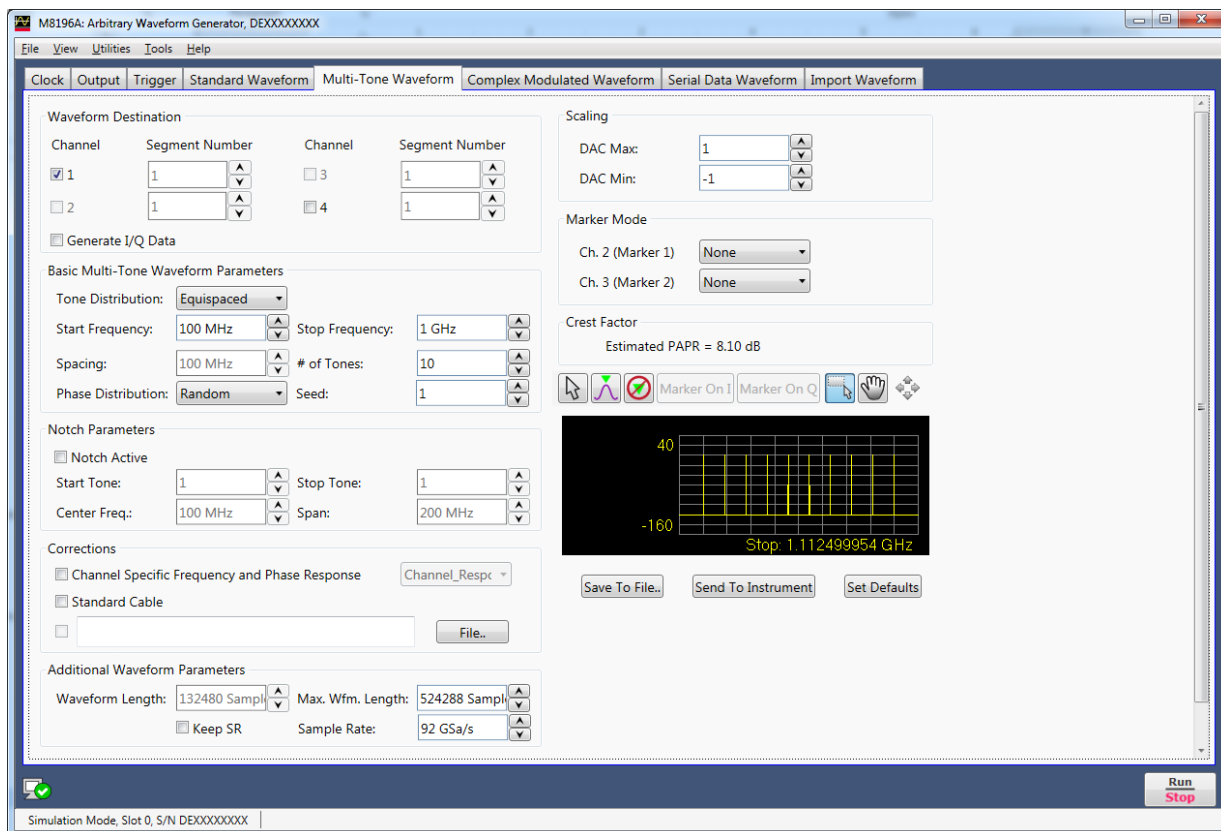


Figure 14: Multi-Tone waveform tab

There are two basic operation modes for the definition of equally spaced or arbitrarily distributed tones respectively. The selection between the two modes is made through the “Tone Distribution” drop-down list. This control affects the contents of the “Basic Multi-Tone Waveform Parameters” section of the user interface and the presence of the “Notch Parameter” section, which only makes sense in case of equally spaced tones. However, controls in the other control groups are valid and operative for both operating modes. Equally spaced tones are defined on the basis of their common parameters such as start and stop frequencies, and tone spacing or number of tones or both. Arbitrarily distributed tones are defined through a table. In order to simplify the creation of complex scenarios, the tones defined in the equally spaced mode are loaded into the tone table every time the user switches to the arbitrary mode and the tone table is empty. In this way, any number of tones may be easily defined in the equally spaced mode, and then the resulting table may be edited for frequency, amplitude, or phase for each individual tone. Tones may also be deleted or added.

This tab has the following controls:

Waveform Destination Section

- **Generate I/Q Data**
If checked, baseband (I/Q) signals will be generated. The resulting complex signal will be a series of tones located at positive and/or negative frequencies. As a consequence, negative values can be typed into any waveform frequency edition field in this panel when this checkbox is checked.
- **I/Q Toggle buttons**
I/Q selection toggle buttons for each channel will be shown when the Generate I/Q Data checkbox is checked. In-Phase (I) and Quadrature (Q) components can be independently assigned to each channel.
- **Channel Independent checkboxes** allow the definition of Multi-Tone waveforms for Channel 1, Channel 2, Channel 3 or Channel 4. One of the boxes is always checked. When pressing the ‘Send To Instrument’ button, the waveform is sent to all channels that are checked.
- **Segment Number**
The segment number is 1. Please note that the segment number section is only kept for compatibility to M8195A AWG.

Corrections Section

- **File...**
Open a correction file selection dialog box. Default file extensions match the File Format selection. The name of the successfully loaded correction factors file is shown in the field located at the left of this button. The accepted format for correction files may be found in the [Correction File Format](#) section.
- **Channel Specific Frequency and Phase Response**
This checkbox activates the application of corrections based on frequency-domain calibration data stored in the target instrument in an internal non-volatile memory. It improves flatness and linear phase distortion.

- **Standard Cable**
This checkbox activates the application of correction factors based on a typical 2.4mm connector, high-quality, high-bandwidth 0.85m microwave cable (Huber+Suhner type N4910-61601).

Additional Waveform Parameters Section

- **Waveform Length**
It is indicator only. The length is in samples of the resulting segment.
- **Max. Wfm. Length**
Maximum waveform length must be used to force the resulting waveform to be shorter than or equal to the limit set by the user.
- **Keep Sample Rate**
This check box preserves the sampling rate to a user-defined value irrespective of the manner in which other signal parameters may be defined. Keeping the sampling rate to a fixed value may be necessary when multiple waveforms are created for usage in a sequence or scenario. The "Set WL to Max" checkbox shows up when this check box is checked.
- **Set WL to Max**
This checkbox is only available when "Keep Sample Rate" is selected. When this option is selected, the waveform calculation algorithm always takes the maximum waveform length as defined in the "Max. Wfm. Length".
- **Sample Rate**
Final DAC conversion rate for the resulting signal. It may be set by the user or automatically calculated depending on other signal parameters.

Marker Mode

These controls are available when the "Single Channel with Marker" or "Dual Channel with Marker" mode is selected in the Output tab.

- **Ch. 2 (Marker 1)**
Marker 1 is output on Channel 2. Signaling the beginning of the Channel 1 waveform may be activated (Segment selection) and deactivated (None selection).
- **Ch. 3 (Marker 2)**
Marker 2 is output on Channel 3. Signaling the beginning of the Channel 1 waveform may be activated (Segment selection) and deactivated (None selection).

Scaling Section

- **DAC Max**
Multi-Tone waveforms may occupy a limited range of the DAC's full scale. This parameter sets the maximum level. If set to a lower level than DAC Min, this will be automatically set to the same level. Acceptable range for this parameter is -1/+1, being the full dynamic range of the instrument's DAC.

- **DAC Min**
Multi-Tone waveforms may occupy a limited range of the DAC's full scale. This parameter sets the minimum level. If set to a higher level than DAC Max, this will be automatically set to the same level. Acceptable range for this parameter is -1/+1, being the full dynamic range of the instrument's DAC.

Crest Factor Section

- **It is an indicator only.**
It shows the estimated PAPR for the current waveform in dB. Although the definition of the PAPR parameter is always the ratio between the peak and the average power for a signal, results change depending on the working mode. For the I/Q Data Generation mode, the result reflects the PAPR of the envelope of the resulting signal while for direct generation it reflects the overall signal. The difference between the former and the latter values is close to +3dBs in most cases.

Preview Section

- **Multi-Tone Preview Toolbar**
The waveform preview toolbar includes the icons that provide different functionality to preview the waveform. For details, see [Preview Section Waveform Preview Toolbar](#).

Compilation and Panel Control Section

- **Save To File...**
Signals can be stored in files either in BIN (for non IQ modes) or IQBIN (for IQ modes) formats. These files may be reused within the Import Waveform tab.
- **Send To Instrument**
Signal will be transferred to the selected segments of the selected channels. The previous running status for the target instrument will be preserved but sampling rate may be modified depending on the waveform requirements.
- **Set Default**
All the Multi-Tone waveform parameters are set automatically to their corresponding default values. Entries in the Arbitrary Tone table are not modified by this button.
- **Two control sections show-up for equally spaced tone definition ("Equispaced" selected in the Tone Distribution drop-down list): "Basic Multi-Tone Waveform Parameters" and "Notch Parameters".**

Basic Multi-Tone Waveform Parameters Section

- **Start Frequency**
It is the frequency of the first tone. If it is set to a value higher than the one in the Stop Frequency field, this is changed back to the previous Start Frequency.

- Stop Frequency
It is the frequency of the last tone. If it is set to a value lower than the one in the Stop Frequency field, this is changed back to the previous Stop Frequency.
- Spacing
It is an indicator only.
$$\text{Spacing} = (\text{Stop Frequency} - \text{Start Frequency}) / (\# \text{ of Tones} - 1).$$
- # of Tones
It is the total number of tones in the Multi-Tone signal including the ones in the notch, if any.
- Phase Distribution
Phase for each tone can be set in the three different modes: constant, random, and parabolic. While constant phase Multi-Tone signals show a high crest factor, a random phase distribution results in a much lower value for this parameter while a parabolic distribution results in a close to optimal (or minimum) crest factor.
- Seed
This parameter is associated to the random phase distribution and allows generating the same or different random sequences for the phases of each tone. It is also useful to look for a distribution resulting in a desired crest factor value.

Notch Parameters Section

- Notch Active
This check box activates or deactivates the generation of a notch in the equally spaced Multi-Tone signal.
- Start Tone
It is the index of the first tone to be removed in a notch. Acceptable indexes start with 1.
- Stop Tone
It is the index of the last tone to be removed in a notch. Acceptable indexes start with 1.
- Center Frequency
It is an indicator only. The central frequency for the notch is computed and shown in this field.
- Span
It is an indicator only. The tone-free frequency span for the notch is computed and shown in this field.

Arbitrary Tones Section

Alternatively, an edition table shows-up for arbitrarily spaced tones definition ("Arbitrary" selected in the Tone Distribution drop-down list). When not previously edited (or empty), the table is automatically loaded with the parameters of the tones defined in the equally spaced tone section. This allows for easy edition of individual tones or the creation of multiple notches, or both. Parameters for each tone include its frequency (in Hz), its relative amplitude (in dB), and phase (in degrees). Entries in the table may be added, edited, and deleted. Entries in the table may be also sorted in

ascending or descending order of any parameter by clicking in the corresponding field name.

Addition of a new entry in the table must be done by editing the empty edition field located at the bottom of the table. Deletion of any number of entries can be performed by selecting the ones to be deleted and then hitting the key of the keyboard. Meaningful numeric values must be typed into the edition fields. Otherwise an error condition is triggered. While a valid frequency entry must be always entered, any of the amplitude and phase edition fields may kept empty so they take the default values (0.0 dB for Amplitude and 0.0 degrees for Phase).

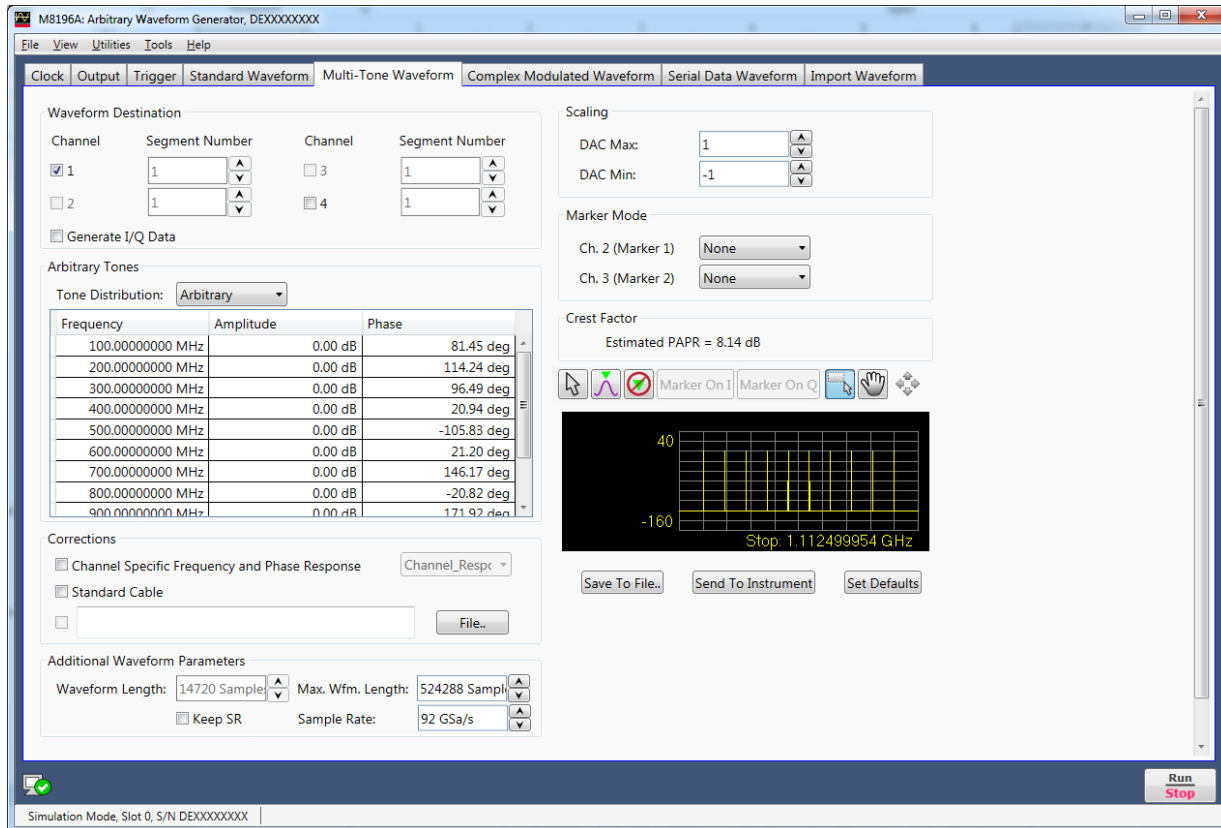


Figure 15: Multi-Tone waveform tab, arbitrary tone distribution

2.11 Complex Modulated Waveform Tab

Use this tab to create baseband and IF/RF digitally modulated signals. User-defined corrections may be applied to signals to compensate for (or emulate) instrument, interconnections and channel linear distortions. The complex modulation tab allows you to generate both RF and Baseband (I/Q) signals. It directly supports a large variety of signal-carrier modulation schemes. This is a list of the currently supported standards, modulation orders, and modulation parameters:

- ASK (Amplitude Shift Keying): Modulation Index (0%-100%).
- PSK (Phase Shift Keying): BPSK, QPSK, $\pi/4$ -DQPSK, Offset-QPSK (OQPSK), 8PSK, and $3\pi/8$ 8PSK (EDGE).
- QAM (Quadrature Amplitude Modulation): 8QAM, 16QAM, 32QAM, 64QAM, 128QAM, 256QAM, 512QAM, AND 1024QAM.
- MSK (Minimum Shift Keying)
- APSK (Amplitude-Phase Shift Keying): 16APSK and 32 APSK. R2/R1 and R3/R1 can be set by the user to any desired value.
- STAR: STAR16 and STAR32. The R2/R1 parameter may be set for the STAR16 modulation scheme.
- VSB (Vestigial Side Band): 8VSB and 16VSB.
- FSK (Frequency Shift Keying): 2FSK, 4FSK, 8FSK, and 16FSK. Peak deviation frequency may be set by the user to any desired value.
- Custom: Users may define arbitrary constellations through simple ASCII files that may be read by the SFP application. Modulations with offset (Q delayed by half a symbol time) and rotating constellations may be also defined.
(Refer to the section)

Pulse Shaping type, characteristics, and different data options may be selected by the user. The panel provides a constellation preview functionality, which can be used to validate the selected modulation scheme and the corresponding modulation parameters. The application takes care of handling the requirements and limits of the target hardware with respect to maximum and minimum record lengths, sampling rate, and record length granularity. As a result, generation of the signals designed in this tab will always be feasible by the instrument and free of distortions such as wrap-around or timing artifacts at any signal domain (time, frequency, and modulation), even if the signal is generated in looped mode.

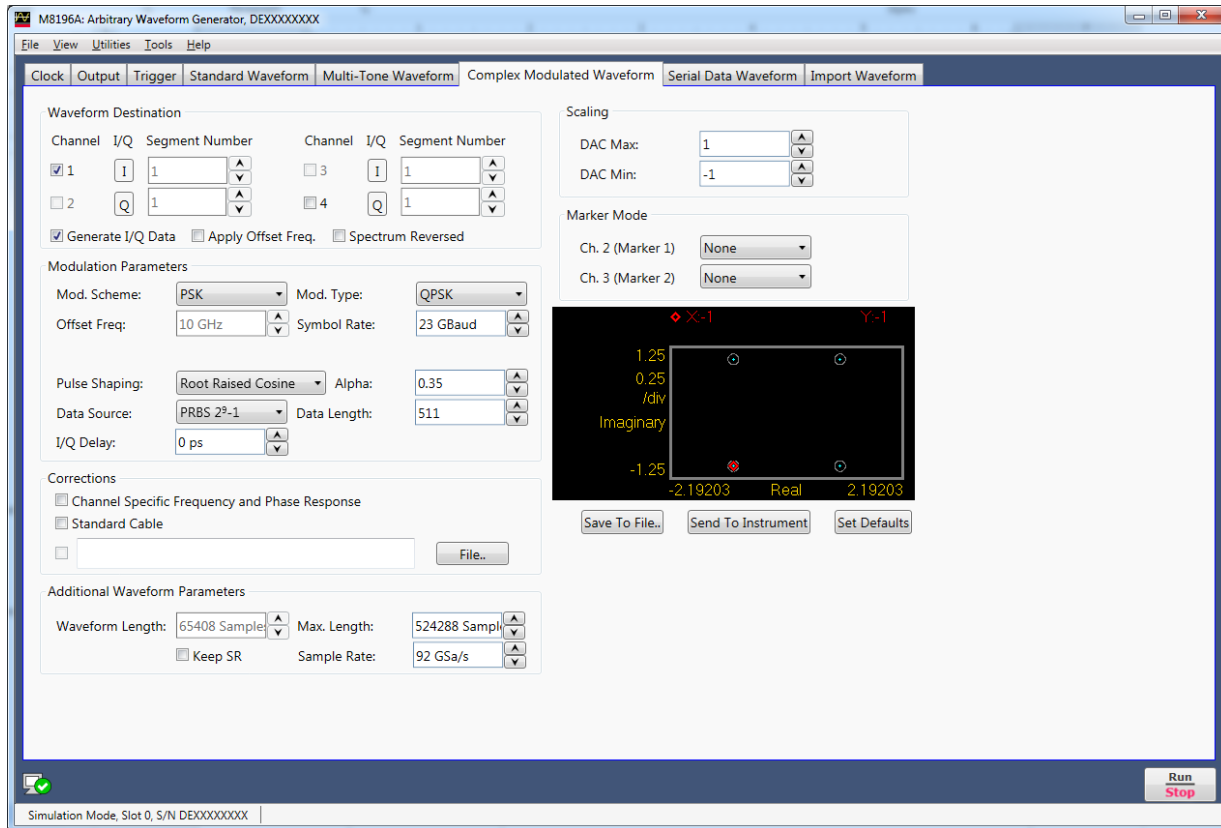


Figure 16: Complex modulated waveform tab

Only relevant parameters and edition fields are shown in the GUI at any time depending on the selected generation mode (RF or I/Q) and modulation scheme.

Waveform Destination Section

- **Generate I/Q Data**
If checked baseband (I/Q) signals will be generated.
- **I/Q Toggle buttons**
I/Q selection toggle buttons for each channel will be shown when the Generate I/Q Data checkbox is checked. In-Phase (I) and Quadrature (Q) components can be independently assigned to each channel.
- **Apply Offset Freq.**
This checkbox is only active for the I/Q Data Generation mode and it applies a frequency shift to the signal according to the 'Offset Freq.' edition field. Frequency shift, unlike carrier frequency, may be positive or negative.
- **Spectrum Reversed**
This checkbox must be selected for generation of signals in the second Nyquist band ($FS/2 - FS$). Its effect is the reversion of the fundamental signal (in the 1st Nyquist Band) in the frequency domain. It also reverses the effect of any correction so correction factors obtained for the second Nyquist band will be applied appropriately.

- Channel
Independent checkboxes allow the definition of waveforms for Channel 1, Channel 2, Channel 3 or Channel 4. One of the boxes will be always checked. When pressing the 'Send To Instrument' button, the waveform is sent to all channels that are checked.
- Segment Number
The segment number is 1. Please note that the segment number section is only kept for compatibility to M8195A AWG.

Modulation Parameters Section

- Mod. Scheme
This drop-down list selects the different modulation scheme categories that are supported (see list above).
- Mod. Type/Mod. Order
This drop-down list selects the different modulation orders or modulation scheme sub-types for the selected modulation scheme category.
- Carrier Freq. / Offset Freq.
The purpose and labeling of this edition field changes depending on the generation mode. For the direct RF generation mode, it handles the carrier frequency while for the I/Q Data Generation mode it deals with the offset frequency (see the [Apply Offset Freq.](#) control). Units in both cases are in Hz.
- Symbol Rate
This edition field must be used to enter the signaling speed (or baud rate) for the modulated signal expressed in Bauds (1 Baud = 1 Symbol/s).
- Mod. Index(%)
This edition field only shows up when the ASK modulation scheme is selected. It sets the modulation index as a percentage for the signal.
- R2/R1 Ratio
This edition field only shows up when the 16APSK, 32APSK, and 16STAR modulation schemes are selected. It sets the ratio between the radius of the two inner symbol rings in the constellation.
- R3/R1 Ratio
This edition field only shows up when the 32APSK modulation scheme is selected. It sets the ratio between the radius of the outer and the most internal symbol rings in the constellation.
- Freq. Dev.
This edition field only shows up when the FSK modulation schemes are selected. It sets the peak frequency deviation in Hz.
- Mod. File..
This button only shows up when 'Custom' modulation scheme is selected. It opens a file selection window where modulation definition files may be selected. If a valid file is selected, its name will show up in the text field located at the left of this button. Otherwise, a "File Loading Error" message is shown.

- Pulse Shaping

This drop-down list can select different pulse shaping to be applied to the baseband symbols; choices are 'Root Raised Cosine', 'Raised Cosine', 'Gaussian', 'Rectangular', 'None', 'EDGE', and 'Half Sine'.

Notes:

- The default pulse shape is 'Gaussian'.
- The filter types 'None' and 'Rectangular' define the pulse shape in time domain. These filter types can only be applied for integer oversampling. Examples: Filter type 'None' with 4 times oversampling generates one sample with the actual value followed by 3 samples with a value of zero (Dirac-Pulse). The filter type 'Rectangular' with 4 times oversampling generates 4 identical sample values.
- The filter types 'Root Raised Cosine', 'Raised Cosine', 'Gaussian', 'EDGE', and 'Half Sine' describe the filter shape in frequency domain.

- Alpha / BT

The meaning and labeling of this edition field depends on the selected pulse shaping. For "Nyquist" filters (Raised Cosine and Square Root of Raised Cosine) it is the 'Alpha' parameter (or roll-off factor) of the filter. For Gaussian filters it is the BT (Bandwidth/symbol period product) parameter. Some filter types do not require an additional filter parameter.

- Data Source

This drop-down list allows the selection of different pseudo random binary sequences as data sources for modulation. Choices are PRBS7 (Polynomial x^7+x^6+1), PRBS10 (Polynomial $x^{10}+x^7+1$), PRBS11 (Polynomial $x^{11}+x^9+1$), PRBS15 (Polynomial $x^{15}+x^{14}+1$), PRBS23 (Polynomial $x^{23}+x^{18}+1$), PRBS23p (Polynomial $x^{23}+x^{21}+x^{18}+x^{15}+x^7+x^2+1$), and PRBS31 (Polynomial $x^{31}+x^{28}+1$).

- Data Length

This edition field may be used to set a given data length to be implemented by the modulated signal. This field defaults to the maximum non-repeating length of the selected PRBS. It also defaults to this value if the user types '0' (Zero). Otherwise, the sequence will be truncated when the number of bits set by this control is reached. If this number is longer than the PRBS maximum length, the sequence will be re-started as many times as necessary.

- I/Q Delay

This numeric edition field allows for the definition of the time skew between the I and the Q baseband components. It can be used to compensate or emulate timing misalignments caused by cabling, external modulators and other devices. This control is activated only when the Generate I/Q Data checkbox is selected. Delay is applied differentially to both components.

- Gray Coding

This checkbox enables gray coding for the applicable modulation modes.

Corrections Section

- File...

Opens a correction file selection dialog box. Default file extension is CSV (Comma-Separated Values). The name of the successfully loaded correction factors file is shown in the field located at the left of this button. The accepted format for correction files may be found in the [Correction File Format](#) section.

- **Channel Specific Frequency and Phase Response**
This checkbox activates the application of corrections based on frequency-domain calibration data stored in the target instrument in non-volatile memory. It improves flatness and linear phase distortions.
- **Standard Cable**
This checkbox activates the application of correction factors based on a typical 2.4 mm connector, high-quality, high-bandwidth 0.85m cable (Huber+Suhner type N4910-61601).

Additional Waveform Parameters Section

- **Waveform Length**
It is an indicator only. The length is in samples of the resulting segment.
- **Max. Length**
Maximum waveform length must be used to force the resulting waveform to be shorter or equal to a limit set by the user.
- **Keep Sample Rate**
This check box preserves the sampling rate to a user-defined value irrespective of any other defined signal parameter. Keeping the sampling rate to a fixed value may be necessary when multiple waveforms are created for usage in a sequence or scenario. The "Set WL to Max" check box gets activated when this check box is checked
- **Set WL to Max**
This checkbox is only available when "Keep Sample Rate" is selected. When this option is selected, the waveform calculation algorithm always takes the maximum waveform length as defined in the "Max. Wfm. Length".
- **Sample Rate**
It is the final DAC conversion rate for the resulting signal. It may be set by the user or automatically calculated depending on other signal parameters.

Marker Mode

These controls are available when the "Single Channel with Marker" or "Dual Channel with Marker" mode is selected in the Output tab.

- **Ch. 2 (Marker 1)**
Marker 1 is output on Channel 2. Signaling the beginning of the Channel 1 waveform may be activated (Segment selection) and deactivated (None selection).
- **Ch. 3 (Marker 2)**
Marker 2 is output on Channel 3. Signaling the beginning of the Channel 1 waveform may be activated (Segment selection) and deactivated (None selection).

Scaling Section

- **DAC Max**
Standard waveforms may occupy a limited range of the DAC's full scale. This parameter sets the maximum level. If set to a lower level than DAC Min, this will be automatically set to the same level. Acceptable range for this parameter is $-1/+1$, being the full dynamic range of the instrument's DAC.
- **DAC Min**
Standard waveforms may occupy a limited range of the DAC's full scale. This parameter sets the minimum level. If set to a higher level than DAC Max, this will be automatically set to the same level. Acceptable range for this parameter is $-1/+1$, being the full dynamic range of the instrument's DAC.

Constellation Diagram Section

The constellation diagram section shows a graphic representation of the ideal constellation corresponding to the selected modulation scheme and modulation parameters. It also shows the location of symbols from valid modulation definition files for validation. The line above the constellation diagram shows the following modulation parameters:

- BPS (Bits Per Symbol)
- Per symbol rotation angle (in degrees)
- I/Q delay (in symbol times)

Compilation and Panel Control Section

- **Save To File...**
Signals can be stored in files in whether BIN (for non IQ modes) or IQBIN (for IQ modes) formats. These files may be reused within the Import Waveform tab.
- **Send To Instrument**
Signal will be transferred to the selected segments of the selected channels. The previous running status for the target instrument will be preserved but sampling rate may be modified depending on the waveform requirements.
- **Set Default**
All the waveform parameters are set automatically to their corresponding default values.
- **Abort**
This button allows canceling signal calculation at any moment. It only shows up during signal compilation.

Custom Modulation File Format

A custom modulation file is an ASCII delimited file including all the information required to define a single carrier modulated signal based in quadrature (IQ) modulation. The file must be composed of a header including a series of lines with identifiers and parameters, and a list of numerical correction factors. For lines including more than one item (i.e. one identifier and one parameter), those must be separated using commas. Identifiers and parameters are not case sensitive. These are the significant fields for the header:

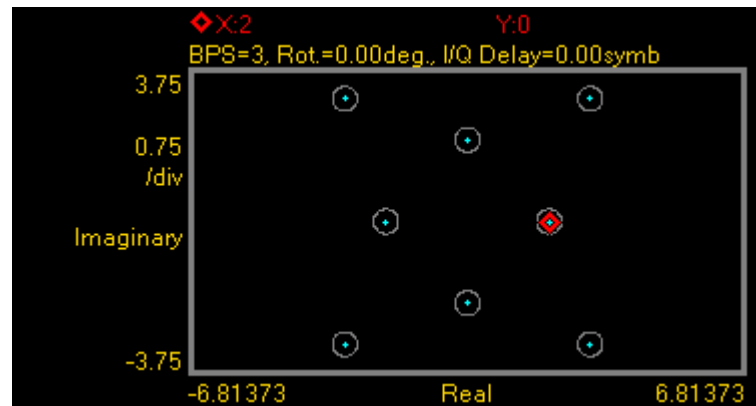
- #N: This is a mandatory field and it must be the first in the file. The N parameter is the bits per symbol parameter. $0 < N < 11$.
- Offset: It indicates if the Q component must be delayed by half a symbol time respect to the I component. Accepted parameters are 'yes' or 'no'. This parameter is optional. It defaults to 'no' if not included in the file.
- Rotation: It sets the rotation of the constellation for each consecutive symbol in degrees. This parameter is optional. It defaults to 0.0 if not included in the file.
- RotMode: Rotation mode. Parameter may be 'cont' (continuous) or 'alt' (alternate). This parameter is optional. It defaults to 'cont' if not included in the file.
- Vsb: It indicates that vestigial side band baseband filtering must be applied. Accepted parameters are 'yes' or 'no'. This parameter is optional. It defaults to 'no' if not included in the file.

The order of the above entries is not relevant except for the '#N' field that must be placed first in the file. The symbol location section starts with a line including the 'IQ' characters (not case-sensitive). Entries in this section are made by IQ pairs separated by commas. The number of entries must be at least 2^N although additional entries will be ignored. Data to symbol mapping depends on the order of the symbols in the file so its position expressed in binary format corresponds to the binary code assigned to that symbol. Comments must start with the '/' character sequence and may use a complete line or be located at the end of any valid line (including the first line). Empty lines are also valid.

The following example illustrates a simple example of a 3 bit per symbol QAM8 modulation with a particular constellation.

```
#3 // MyModulationFile
Iq
// Inner symbols
2.0, 0.0
0.0, -2.0
-2.0, 0.0
0.0, 2.0
// Outer symbols
3.0, 3.0
-3.0, 3.0
-3.0, -3.0
3.0, -3.0 // Final symbol
```

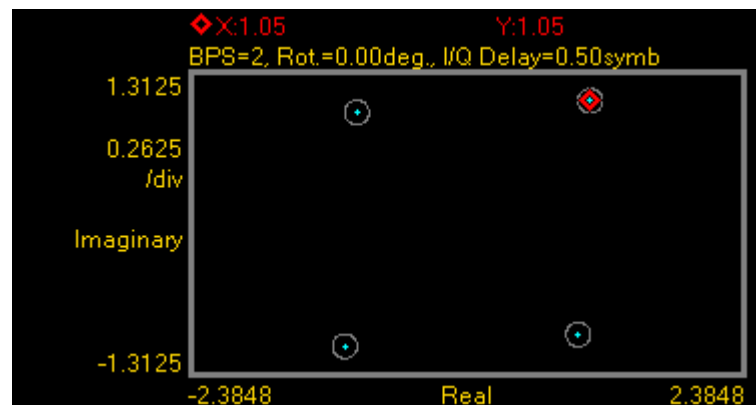
The above file does not include any unnecessary line in the header as it defines a non-rotating, non-offset modulation so default values for these fields are used instead. The resulting constellation after loading this file is shown as following:



The following example illustrates another possible use of custom modulation to define a distorted constellation. In this particular case, a O-QPSK modulation with a quadrature error (non-perpendicular I and Q axis) is defined:

```
#2
Offset, yes
iq
1.05, 1.05
-0.95, 0.95
-1.05, -1.05
0.95, -0.95
```

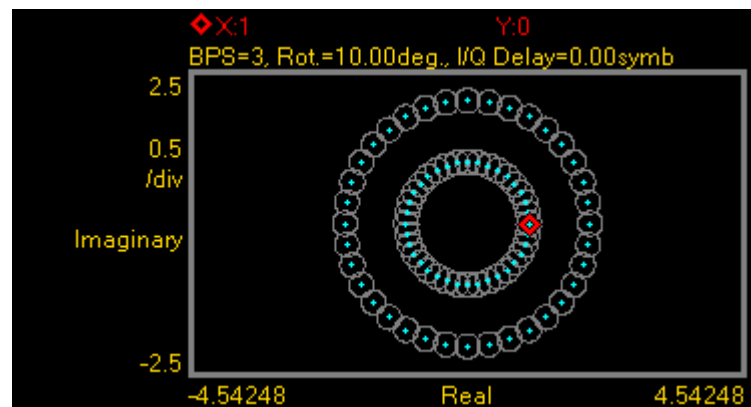
The above file includes a line to indicate that this is an offset modulation. The resulting constellation after loading this file is shown as following:



The following is a more complex example:

```
#3
Offset, no
Rotation, 10.0
RotMODE, cont
iq
1.0, 0.0
2.0, 0.0
0.0, 1.0
0.0, 2.0
-1.0, 0.0
-2.0, 0.0
0.0, -1.0
0.0, -2.0
```

The above file is composed of a header with relevant information. In this particular case, the file contains 8 (2^3) IQ pairs. The 'IQ' characters indicate the starting point for the symbol location list composed by 8 lines with I/Q pairs separated by commas. I and Q will not be delayed ('Offset, no') and constellation will rotate by 10.0 degrees ('Rotation, 10.0') in a continuous fashion ('RotMODE, cont'). In fact, the 'Offset' and 'RotMode' fields could be removed without any effect on the final signal as these fields take the default values. The resulting constellation after loading this file is shown as following:



2.12 Serial Data Waveform Tab

Use this tab to create single lane and multilane bi-level and multi-level high-speed digital serial signals and clocks. User-defined corrections may be applied to signals to compensate for (or emulate) instrument, interconnections and interconnect linear distortions. The serial data tab allows you to generate both data and clock signals. It directly supports a large variety of channel coding and modulation schemes. This is a list of the currently supported modulation and channel coding formats:

- NRZ (Not Return to Zero).
- Unipolar RZ (Return to Zero).
- Polar RZ (Return to Zero).
- PAM-4 (Pulse-Amplitude Modulation, 4 level)
- PAM-5 (Pulse-Amplitude Modulation, 5 level)
- PAM-8 (Pulse-Amplitude Modulation, 8 level)
- PAM-10 (Pulse-Amplitude Modulation, 10 level)
- PAM-12 (Pulse-Amplitude Modulation, 12 level)
- PAM-16 (Pulse-Amplitude Modulation, 16 level)

Users can set the bit/signaling rate, basic pulse shape characteristics, and transition time. Any AWG channel may be selected to generate either a serial signal or a :2 or :4 synchronous clock. A series of standard PRBS sequences with different lengths may be selected in order to produce realistic traffic and to allow bit-error rate testing with standard BER testers. Signals may be corrected for cabling and the AWG frequency response in a channel by channel basis. Additionally, external correction data may be applied to account for the distortions added by additional cabling, passive or active system blocks or test fixturing. Channel to channel skew can be also adjusted with resolutions as low as 100fs. The application takes care of handling the requirements and limits of the target hardware with respect to maximum and minimum record lengths, sampling rate, and record length granularity. As a result, generation of the signals designed in this tab will always be feasible by the instrument and free of distortions such as wrap-around or timing artifacts at any signal domain (time, frequency, and modulation), even if the signal is generated in looped mode.

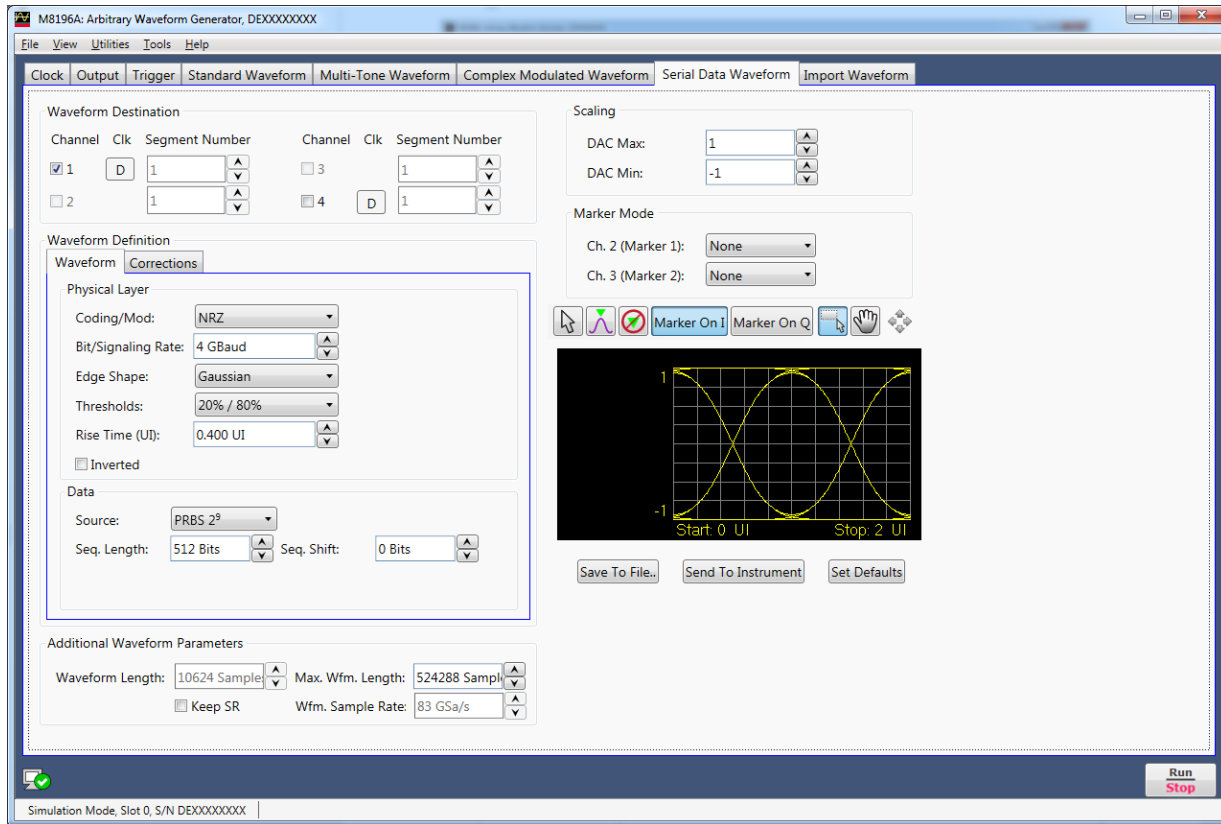


Figure 17: Serial data waveform tab

Only relevant parameters and edition fields are shown in the GUI at any time depending on the selected channel coding scheme.

Waveform Destination Section

- **Clock Toggle buttons**
Data/clock selection toggle buttons for each channel. The Data(D), Clock:2 (C/2), and Clock:4 (C/4) can be independently assigned to each channel. The nominal timing for the 50% level in the raising edge for the clock signals is located in the center of the eye for the current symbol.
- **Channel**
Independent checkboxes allow the definition of waveforms for Channel 1, Channel 2, Channel 3, or Channel 4. One of the boxes will be always checked. When pressing the 'Send To Instrument' button, the corresponding waveforms are sent to all channels that are checked.
- **Segment Number**
The segment number is 1. Please note that the segment number section is only kept for compatibility to M8195A AWG.

Waveform Definition Section

The Waveform Definition section is organized in two tabs in which controls are grouped by their functionality: Waveform, Data, and Corrections.

Waveform Definition

Waveform **Corrections**

Physical Layer

Coding/Mod: NRZ

Bit/Signaling Rate: 4 GBaud

Edge Shape: Gaussian

Thresholds: 20% / 80%

Rise Time (UI): 0.400 UI

☐ Inverted

Data

Source: PRBS 2⁹

Seq. Length: 512 Bits

Seq. Shift: 0 Bits

Waveform Tab:

- Physical Layer Section

Physical characteristics of the waveform can be set up in this tab. These include the following controls:

 - o Coding/Mod.

This drop-down list selects the different channel coding and modulation schemes that are supported (see list above). NRZ is the default selection.
 - o Bit/Signaling Rate

This edition field must be used to enter the signaling speed (or baud rate) for the modulated signal expressed in Bauds (1 Baud = 1 Symbol/s). Baud rate is equal to the bit rate for two-level line coding schemes. 4GBaud is the default value.
 - o Edge Shape

This drop-down list allows the selection of shape for the transitions (edges); choices are 'Rectangular', 'Trapezoidal' (linear), 'First Order' (RC network), 'Gaussian', 'Bessel Thompson' (4th order Bessel-Thomson reference receiver filter), 'Raised Cosine' and 'Root Raised Cosine' (Square Root Raised Cosine).'

Notes:

- The default edge shape is 'Gaussian'.
 - For clock signals (i.e. the Clock Toggle button is set to 'C/2' or 'C/4') the edge shape is always Gaussian.
- o Thresholds

This drop-down list sets the level threshold convention for the measure rise/fall time parameters. Choices are b_20_80 (20%-80%) and b_10_90 (10%-90%). 20%-80% is the default selection for this control.
 - o Rise Time (UI)

Rise/fall times can be set-up through this edition field. Time must be expressed in UIs (Unit Interval) as a fraction of the symbol duration. Rise time can be set up for all the edges shapes except for the Unfiltered, Raised-Cosine and Square Root of Raised-Cosine shapes. Rise time is fixed for clock signals to two sample periods in order to minimize clock jitter. 400mUI (0.4 UI) is the default value for this field.
 - o Alpha

This edition field only shows up when the Raised Cosine and Square-root of Raised Cosine edge shapes are selected. With it, the excess bandwidth parameter (alpha) of the isolated pulses can be set up. Alpha = 1.0 is the default value.
 - o Inverted

This checkbox (if checked) reverses the polarity of the output waveform. Default state is unchecked.
- Data Section

The sequence of data to be generated can be set up in this tab. To do so, the following control are available:

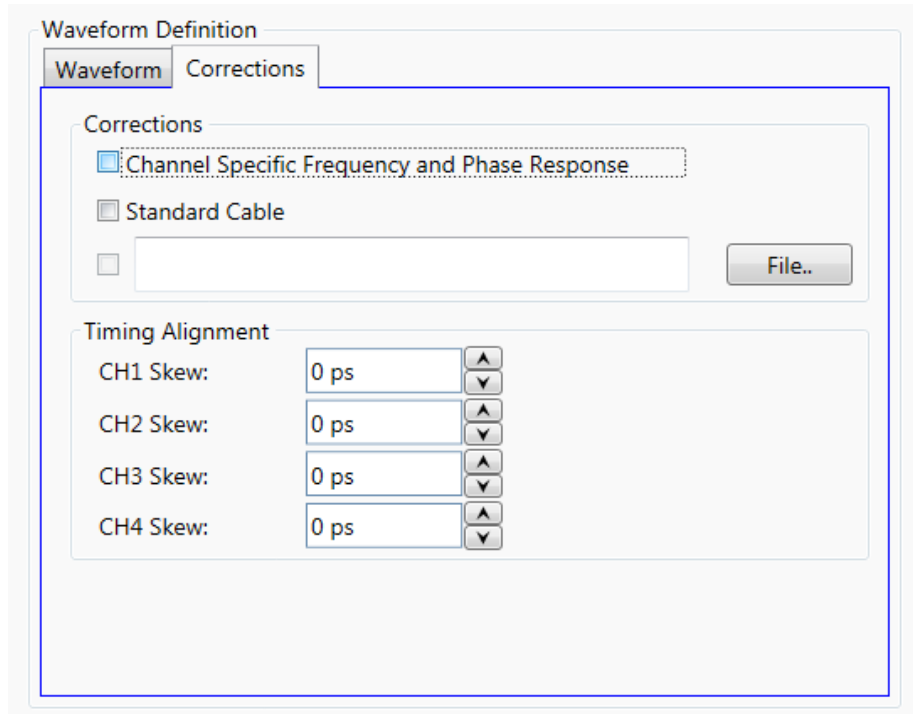
 - o Source

This drop-down list allows the selection of different pseudo random binary sequences as data sources for signal generation. Choices are PRBS 2^7-1 (Polynomial x^7+x^6+1), PRBS 2^9-1 (Polynomial x^9+x^5+1), PRBS $2^{10}-1$ (Polynomial $x^{10}+x^7+1$), PRBS 2^7 (Polynomial x^7+x^6+1), PRBS 2^9 (Polynomial x^9+x^5+1), PRBS 2^{10} (Polynomial $x^{10}+x^7+1$), PRBS 2^{11} (Polynomial $x^{11}+x^9+1$), and PRBS 2^{15} (Polynomial $x^{15}+x^{14}+1$). The sequences are identified by its non-repeating length. The 2^x sequences add an extra '0' to the longest sequence of consecutive '0' in the corresponding 2^x-1 sequence.
 - o Seq. Length

This edition field may be used to set a given data length to be implemented by the modulated signal. This field defaults to the maximum non-repeating length of the selected PRBS. It also defaults to this value if the user types '0' (Zero). Otherwise, the sequence will be truncated when the number of bits set by this control is reached. If this number is longer than the PRBS maximum length, the sequence will be re-started as many times as necessary. The actual number of symbols (and record length) in the waveform memory will depend on the line coding/modulation and record length granularity requirements. The simultaneous generation of a clock signal can also influence on the actual sequence length as an integer number of clock cycles must be accommodated to keep its integrity (i.e. ISI distortion free characteristics).

- o Seq. Shift

This numeric edition field adds a shift to the PRBS sequence being generated by each channel. In this way, uncorrelated data streams may be generated to simulate multi-lane links (i.e. to test the effects of crosstalk) or to emulate IQ baseband channels to feed electrical or optical coherent quadrature modulators. The shift added to each channel may be calculated (in bits) for each channel using the expression $\text{Shift} = (\text{Channel Number} - 1) * (\text{Seq. Shift})$. Unshifted PRBS sequences always start with the longest run of '1' for that particular sequence.



Corrections Tab:

The purpose of these controls is the correction (de-embedding) of different linear distortions and differential delays added by cabling and fixturing, PCB interconnections, etc. The following controls are included:

- **Channel Specific Frequency and Phase Response**
This checkbox activates the application of corrections based on frequency-domain calibration data stored in the target instrument in non-volatile memory. It improves flatness and linear phase distortions.
- **Standard Cable**
This checkbox activates the application of correction factors based on a typical 2.4 mm connector, high-quality, high-bandwidth 0.85m cable (Huber+Suhner type N4910-61601).
- **File...**
Opens a correction file selection dialog box. Default file extension is CSV (Comma-Separated Values). The name of the successfully loaded correction factors file is shown in the field located at the left of this button. The accepted format for correction files may be found in the [Correction File Format](#) section. In particular, adaptive equalizer models obtained through the Keysight 89600 VSA software can

be imported through this procedure to compensate for linear distortions added by any intermediate component, PCB trace, or cable. To obtain this model, apply a NRZ signal with sufficient bandwidth to an 89600 equipped oscilloscope and export the resulting equalizer model. Isolated pulse characteristics of the waveform must be known by the 89600 software so it is advisable to calibrate the SUT (System Under Test) using a Raised-Cosine signal with $\alpha = 1$ to maximize the nominal bandwidth for a given bitrate. The 89600 software must be set up to analyze a BPSK signal with the same baud rate and baseband filter characteristics.

- CH1 Skew / CH2 Skew / CH3 Skew / CH4 Skew

These numeric fields can be used to set-up the absolute delay for each channel in seconds. The valid range for them is -100ps ... +100ps. This feature may be used to control the skew of data and clock signals.

Additional Waveform Parameters Section

- Waveform Length

It is an indicator only. The length is in samples of the resulting segment.

- Max. Length

Maximum waveform length must be used to force the resulting waveform to be shorter or equal to a limit set by the user.

- Keep Sample Rate

This check box preserves the sampling rate to a user-defined value irrespective of any other defined signal parameter. Keeping the sampling rate to a fixed value may be necessary when multiple waveforms are created for usage in a sequence or scenario. The "Set WL to Max" check box gets activated when this check box is checked

- Set WL to Max

This checkbox is only available when "Keep Sample Rate" is selected. When this option is selected, the waveform calculation algorithm always takes the maximum waveform length as defined in the "Max. Wfm. Length" field. Record length are calculated to contain an integer number of complete PRBS sequences except when the "Set WL to Max" is checked. In this case the number of symbols in the resulting waveform will be the closest integer for the signaling rate set by the user. As a result, signaling rate will be adjusted, if necessary, so it is consistent with the resulting time window (Time Window = Record Length * Sampling Rate).

- Sample Rate

Indicator only. It is the final DAC conversion rate for the resulting signal. It is automatically calculated depending on other signal parameters if the "Keep Sample Rate" checkbox is not checked.

Marker Mode

These controls are available when the "Single Channel with Marker" or "Dual Channel with Marker" mode is selected in the Output tab.

- Ch. 2 (Marker 1)

Marker 1 is output on Channel 2. Signaling the beginning of the Channel 1 waveform may be activated (Segment selection) and deactivated (None selection).

- Ch. 3 (Marker 2)

Marker 2 is output on Channel 3. Signaling the beginning of the Channel 1 waveform may be activated (Segment selection) and deactivated (None selection).

Scaling Section

- **DAC Max**
Standard waveforms may occupy a limited range of the DAC's full scale. This parameter sets the maximum level. If set to a lower level than DAC Min, this will be automatically set to the same level. Acceptable range for this parameter is $-1/+1$, being the full dynamic range of the instrument's DAC.
- **DAC Min**
Standard waveforms may occupy a limited range of the DAC's full scale. This parameter sets the minimum level. If set to a higher level than DAC Max, this will be automatically set to the same level. Acceptable range for this parameter is $-1/+1$, being the full dynamic range of the instrument's DAC.

Compilation and Panel Control Section

- **Save To File...**
Signals can be stored in files in BIN format. These files may be reused within the Import Waveform tab.

NOTE

The waveform is always saved without applying corrections. Also, the waveform of the data signal (Clock Toggle button is set to 'D') and not the clock signal (Clock Toggle button is set to 'C/2' or 'C/4') is saved.

- **Send To Instrument**
Signal will be transferred to the selected segments of the selected channels. The previous running status for the target instrument will be preserved but sampling rate may be modified depending on the waveform requirements.
- **Set Default**
All the waveform parameters are set automatically to their corresponding default values.
- **Abort**
This button allows canceling signal calculation at any moment. It only shows up during signal compilation.

2.12.1 Bitmapping for Binary Data to PAM Signals

This section describes how the binary data of the data source (e.g. a PRBS) is mapped to the different levels of a PAM-4, PAM-5, PAM-8, PAM-10, PAM-12 or PAM-16 signal.

Definition:

- A PAM-n signal has n levels.
- The level number 1 is associated with the low level.
- The level number n is associated with the high level.

Table 9: PAM4

Level number	Binary data ('Inverted' not checked)	Binary data ('Inverted' checked)
4	11	00
3	10	01
2	01	10
1	00	11

Table 10: PAM8

Level number	Binary data ('Inverted' not checked)	Binary data ('Inverted' checked)
8	111	000
7	110	001
6	101	010
5	100	011
4	011	100
3	010	101
2	001	110
1	000	111

Table 11: PAM16

Level number	Binary data ('Inverted' not checked)	Binary data ('Inverted' checked)
16	1111	0000
15	1110	0001
14	1101	0010
13	1100	0011
12	1011	0100
11	1010	0101
10	1001	0110
9	1000	0111
8	0111	1000
7	0110	1001
6	0101	1010
5	0100	1011
4	0011	1100
3	0010	1101
2	0001	1110
1	0000	1111

- **PAM-5:** Two bits of the binary data are used. The same mapping as for the PAM-4 modulation is applied to get the 4 outer levels. The level in the middle is generated randomly with 1/5th probability.
- **PAM-10 (or PAM-12):** 4 bits of the binary data are used. This gives 16 possible levels. However, only 10 (or 12) values are needed. If the value is lower than 10 (or 12), direct mapping is applied. If the value is equal to or greater than 10 (or 12), random mapping is applied to any of the valid 10 (or 12) levels.

2.13 Import Waveform Tab

Use this tab to perform the functions such as importing, scaling, and resampling waveform files in a variety of formats for their generation by the M8196A arbitrary waveform generator. It provides the controls which allow the complete definition of signal processing parameters for the waveform file format (see [File Format](#)).

Depending on the file format and contents, information regarding the original sampling rate of the input waveforms can be extracted and re-used within the import tool. Resampling is performed so no images or aliases show up in the resampled waveform.

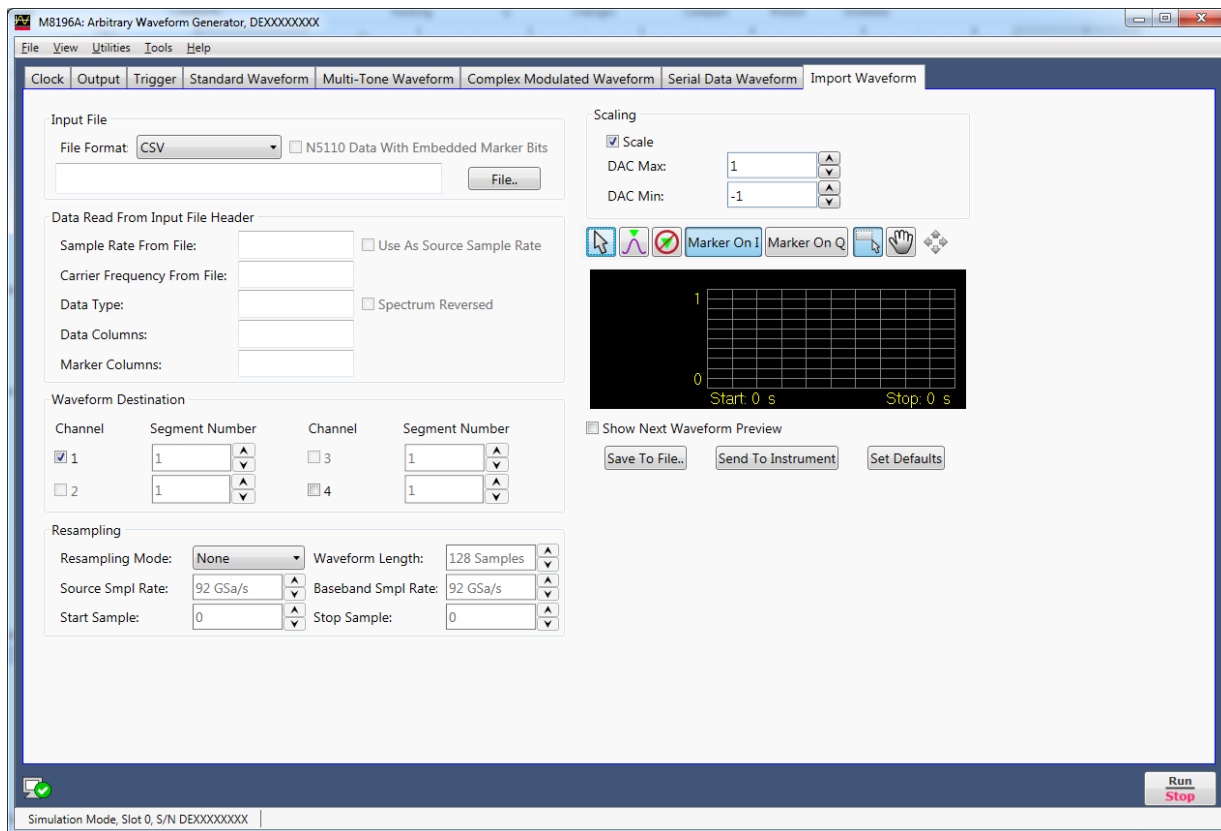


Figure 18: Import waveform tab

This tab has the following controls and indicators:

Input File Section

- File Format

For details on the available file format, see [File Format](#).

Sample waveform data files are available in different formats as listed in the [Table 12](#). The files can be simply imported using the Input File section and can be sent to the instrument to view the waveform preview. The sample waveform data can be found at the location: **Start > All Programs > Keysight M8196 > Keysight M8196 Examples**

Steps to view the sample data file waveform preview:

- 1 Select the Show Next Waveform Preview check box.
- 2 Select the required **File Format** from the drop-down list.
- 3 Click **File...**
- 4 In the **Open** dialog box, select the sample waveform file (as per selected file format)
- 5 Click **Open**.
- 6 Click Send to Instrument.

Table 12: Sample waveform data files

File format	Waveform data file
TXT	Sin10MHzAt64GHz.txt
BIN	Sin10MHzAt64GHz.bin
BIN8	Sin10MHzAt64GHz.bin8
BIN6030	Sin10MHzAt64GHz.bin6030
BIN5110	SinDelta10MHzIQ.bin5110
IQBIN	SinDelta10MHzIQ.iqbin
MAT89600	Sin10MHzAt64GHz.mat89600
CSV	Sin10MHzAt64GHz.csv
DSA90000	Sin10MHzAt64GHz.dsa90000

- N5110 Data With Embedded Marker Bits

This checkbox is only enabled, if the File Format is BIN5110. If checked, the BIN5110 format with 14-bit data for I and Q and embedded marker bits is used. If unchecked, the BIN5110 format with 16-bit data for I and Q and no marker bits is used.

- File...

Open a file selection dialog. Default file extensions match the File Format selection. Successful loading of a waveform updates multiple information fields through the panel reflecting the waveform settings and a graph of the waveform is shown in the preview display.

Data Read From Input File Header Section

- **Sample Rate From File**
Indicator only. It shows the input waveform sample rate, if any, contained in the loaded file. If no sample rate is specified "n.a." (not available) is shown.
- **Use As Source Sample Rate**
This checkbox assigns the sample rate specified in the file as the Source Sample Rate used for resampling.
- **Carrier Frequency From File**
Indicator only. It shows the input waveform carrier frequency, if any, contained in the loaded file. If no carrier frequency is specified "n.a." (not available) is shown.
- **Data Type**
This is the organization of samples within the file. It may be Single (real-only waveform) or IQ (complex waveforms).
- **Spectrum Reversed**
This checkbox is only active for complex (IQ) waveforms. It results in an imported signal which is the complex conjugate of the input signal, thus its spectrum will be reversed.
- **Data Columns**
It shows the internal organization of the file regarding waveforms. It can show from one column (Y1) up to 4 (Y1, Y2, Y3, Y4).
- **Marker Columns**
It shows the internal organization of the file regarding markers. It can show from one column (M1) up to 4 (M1, M2, M3, M4).

Waveform Destination Section

- **Channel**
Independent checkboxes allow to import waveforms for Channel 1, Channel 2, Channel 3 or Channel 4. One of the boxes is always checked. If the file contains only one waveform, when pressing the 'Send To Instrument' button, the waveform is sent to all channels that are checked.
If the file contains multiple waveforms (file types MAT89600 and CSV), they can be sent to multiple channels in one operation.

The following two tables show the standard column-to-channel mapping for the case of no additional data header in the CSV file or no reordering of the column names in the MAT89600 file.

Table 13: Standard column-to-channel mapping in four-channel mode

Number of columns in file for real values	Import and download to M8196A, when corresponding channel box is checked
1.	Column 1 to Ch 1 and Ch 2 and Ch 3 and Ch4
2.	Column 1 to Ch 1 and Column 2 to Ch 2
3.	Column 1 to Ch 1 and Column 2 to Ch 2 and Column 3 to Ch 3
4.	Column 1 to Ch 1 and Column 2 to Ch 2 and Column 3 to Ch 3 and Column 4 to Ch 4

Table 14: Standard Column to channel mapping in two-channel mode

Number of columns in file for real values	Import and download to M8196A, when corresponding channel box is checked
1.	Column 1 to Ch 1 and Ch4
2.	Column 1 to Ch 1 and Column 2 to Ch 4
3.	Column 1 to Ch 1 and Column 2 to Ch 4, Column 3 is ignored
4.	Column 1 to Ch 1 and Column 2 to Ch 4, Column 3 and 4 are ignored

For MAT89600 file and CSV file with data header, the mapping shown below applies:

Table 15: Modified column-to-channel mapping in four-channel mode

Name of column	Import and download to M8196A, when corresponding channel box is checked
Y1	Ch 1
Y2	Ch 2
Y3	Ch 3
Y4	Ch 4

Table 16: Modified column-to-channel mapping in two-channel mode

Name of column	Import and download to M8196A, when corresponding channel box is checked
Y1	Ch 1
Y2	Ch 4
Y3	ignored
Y4	Ch 4, if Y2 is not present; ignored, if Y2 is present

- **I/Q Toggle buttons**
I/Q selection toggle buttons for each channel will be shown when the file containing an I/Q waveform is selected for import. In-Phase (I) and Quadrature (Q) components can be independently assigned to each channel.
- **Segment Number**
The segment number is 1. Please note that the segment number section is only kept for compatibility to M8195A AWG.

Resampling Section

- **Resampling Mode**
It controls the way waveforms are imported and resampled. Please refer to the description of the [Resampling Methodology](#) in the Appendix chapter. The following modes are available:
 - **None:** Baseband Sample Rate will be the same as the Source Sampling Rate. The output waveform will use the same number of samples as the selected portion of the input waveform. Granularity requirements will be met by repeating the basic waveform the minimum number of times so

the combined length is a multiple of the granularity for the current DAC mode.

- Timing: The time window of the input signal (Waveform Length / Sample Rate) will be used to calculate the best value for the output record length being a multiple of the granularity for the current DAC mode according to the output sampling rate defined by the user. Final output sampling rate will be slightly adjusted to accurately keep the timing of the original signal.
- Output_SR: The user-defined output sampling rate will be used to calculate the best value for the output record length being a multiple of the granularity for the current DAC mode according to the time window of the input signal. Final time window will be slightly adjusted to keep the selected output sampling rate. This change is reflected in the Source Sampling Rate numeric entry field value.
- Output_RL: The user-defined output Waveform Length will be used to calculate the best value for the output Sample Rate according to the time window of the input signal. Waveform Length will be adjusted to the nearest multiple of the granularity for the current DAC mode according to the time window of the input signal.
- Zero_Padding: Output Waveform Length is calculated based on the input waveform time window and the user-defined output sampling rate. The resulting waveform length will not be, in general, a multiple of the granularity. To meet the granularity conditions, a number of zero samples are added until the combined number of samples is a multiple of the granularity. Output Sample Rate will be slightly adjusted to keep the input waveform time window.
- Truncate: Output Waveform Length is calculated based on the input waveform time window and the user-defined output sampling rate. The resulting waveform length will not be, in general, a multiple of the granularity. To meet the granularity conditions, a number of samples is removed until the resulting number of samples is a multiple of the granularity. Output Sample Rate will be slightly adjusted to keep the input waveform time window.
- Repeat: Output Waveform Length is calculated based on the input waveform time window and the user-defined output sampling rate. The resulting waveform length will not be, in general, a multiple of the granularity. To meet the granularity conditions, the base waveform is repeated the minimum number of times so the overall number of samples is a multiple of the granularity. Output Sample Rate will be slightly adjusted to keep the input waveform time window. The Waveform Length field will show the length of the combined waveform.

- Waveform Length

It shows the number of samples of the resampled output waveform. It can be set when Resampling Mode is Output_RL. Otherwise, this field is an indicator.

- Source Sample Rate

The speed at which samples in the input waveform are sampled. It can be set by typing a valid value unless the "Use As Source Sample Rate" checkbox is checked. In this particular case, the sampling rate information contained in the input waveform file will be always used.

- Baseband Sample Rate

The speed at which samples in the output waveform will be converted. It can be set in all Resampling Modes except for the Output_RL mode.

- **Start Sample**
This field can be used to select the starting sample of the section of the input waveform to be imported. It cannot be set to a value higher than the Stop Sample.
- **Stop Sample**
This field can be used to select the final sample of the section of the input waveform to be imported. It cannot be set to a value lower than the Start Sample.
- **Scale**
This checkbox controls the way the input output waveform will be scaled after resampling. If unchecked, the output waveform samples will not be re-scaled. Sample levels over +1.0 or under -1.0 will be clipped.

Scaling Section

- **DAC Max**
Imported waveforms may occupy a limited range of the DAC's full scale. This parameter sets the maximum level. If set to a lower level than DAC Min, this will be automatically set to the same level. Acceptable range for this parameter is -1/+1, being the full dynamic range of the instrument's DAC.
- **DAC Min**
DAC Max: Imported waveforms may occupy a limited range of the DAC's full scale. This parameter sets the minimum level. If set to a higher level than DAC Max, this will be automatically set to the same level. Acceptable range for this parameter is -1/+1, being the full dynamic range of the instrument's DAC.

Preview Section

- **Waveform Preview Toolbar**
The waveform preview toolbar includes the icons which provide different functionality to preview the waveform. For details, see [Preview Section](#)
Waveform Preview Toolbar.
- **Show Next Waveform Preview**
This checkbox affects the behavior of the preview for the next waveform. If selected, a preview of the imported waveform is displayed. Leave this checkbox unselected to speed up the import of large waveforms.
- **Save To File...**
Signals can be stored in files in whether BIN (for non IQ modes) or IQBIN (for IQ modes) formats. These files may be reused within the Import Waveform tab.
- **Send To Instrument**
Signal will be transferred to the selected segments of the selected channels. The previous running status for the target instrument will be preserved but sampling rate may be modified depending on the waveform requirements.
- **Set Default**
All the imported waveform parameters are set automatically to their corresponding default values.

2.14 Correction File Format

A correction file is an ASCII delimited file carrying all the information required to compensate or embed a given frequency response in the multi-tone or complex modulation signal. The file must be composed of a header including a series of lines with identifiers and parameters, and a list of numerical correction factors. In lines including more than one item (i.e., one identifier and one parameter), the items must be separated using commas. Identifiers and parameters are not case sensitive.

These are the significant fields for the header:

- **InputBlockSize:** It states the number of valid correction factors in the file. It is a mandatory field.
- **XStart:** It is frequency in Hz corresponding to the first entry in the correction factor section of the file. It is a mandatory field for multi-tone generation in direct mode and optional for multitone in upconverter mode and complex modulation.
- **XDelta:** It is frequency distance in Hz between consecutive entries in the correction factor section of the file. It is a mandatory field.
- **YUnit:** Units for the amplitude values in the correction factor section of the file. Parameter associated to it may be 'dB' (for logarithmic relative amplitudes) or 'lin' (for dimensionless linear relative amplitude). This parameter is optional and its default value is 'lin'. Phase unit must be always stated in radians.

The order of the above entries is not relevant. The correction factor section starts with a line including a single 'y' or 'Y' character. Entries in this section are made by Amp1(Fi), Phase1(Fi) pairs. In particular, this format is compatible with adaptive equalizer files exported in comma-separated value (CSV) format from the Keysight 89600 VSA software package. These files reflect the channel response corrected by the equalizer so they should be applied through the selection of the 'Channel_Response' option in the corresponding 'CorrectionMode' drop-down list in the 'Corrections' section of the 'Multi-Tone' or 'Complex Modulation' panel, respectively. Comments must start with the '/' character sequence and may use a complete line or be located at the end of any valid line. Empty lines are also valid.

This is an example correction file:

```
// MyCorrectionFile
InputBlockSize, 1024
XStart, 1.0E+09 // 1.0GHz
XDelta, 1.0E+06
YUnit, lin
Y
0.987, -0.2343
0.995, 0.5674
...
...
1.269, -0.765
```

The above files are composed of a header with relevant information. In these particular cases, the files contain 1024 linear correction factors spaced by 1 MHz and starting at 1 GHz. The 'Y' character indicates the starting point for the correction factor

list composed of 1024 lines with amplitude/phase pairs separated by commas. For one-channel files there is a amplitude/phase pair per line while for two channel files there are two pairs (Amp1, Phase1, Amp2, Phase2).

The way this information is applied by the Soft Front Panel software depends on the signal generation mode and the signal category. For direct conversion multi-tone RF generation modes ('Generate IQ Data' unchecked), corrections are applied directly to the tones based on their absolute frequency. For up-converted multi-tone baseband generation(I/Q) modes ('Generate IQ Data' checked), corrections are applied to the complex baseband signals. So, the internal or external carrier frequency is represented by the central entry in the list (i.e., entry #512 in the 1024 entries example shown above) regardless of the 'XStart' parameter. For Complex Modulated waveforms, corrections are always applied to the complex baseband signals regardless of the 'Generate IQ Data' checkbox setting so, as it happens with the correction of multi-tone baseband signals, the internal or external carrier frequency is represented by the central entry in the list.

3 Markers

[3.1 Introduction](#) / 79

[3.2 Dealing with Markers](#) / 79

3.1 Introduction

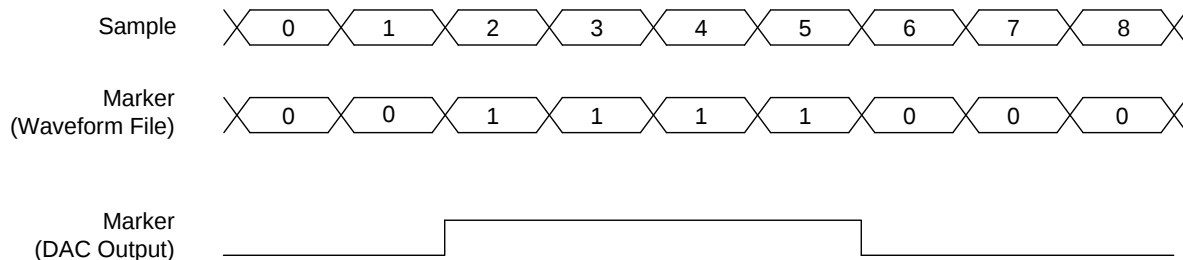
The instrument provides output signals with a defined timing relationship to the output sample stream. These signals are called markers.

There are up to 2 marker channels available:

The details of these markers are explained in the sections that follow.

3.2 Dealing with Markers

Depending on the data format, the input files for waveforms provide marker information directly related to the samples. This means that each sample has its own bit signaling whether this sample is marked or not.



The upper 3 rows show the sample data together with the corresponding marker bits and the expected output waveform of a marker channel.

Marker information (Marker 1 and Marker 2) is always linked to channel 1 waveform. If markers should be synchronized to channel 4 waveform then waveforms in channel 1 and 4 must be of equal length.

4 General Programming

- 4.1 Introduction / 82
- 4.2 IVI-COM Programming / 83
- 4.3 SCPI Programming / 83
- 4.4 Programming Recommendations / 86
- 4.5 System Related Commands (SYSTem Subsystem) / 87
- 4.6 Common Command List / 93
- 4.7 Status Model / 96
- 4.8 :ARM/TRIGger Subsystem / 105
- 4.9 :INSTrument Subsystem / 109
- 4.10 :MMEMory Subsystem / 112
- 4.11 :OUTPut Subsystem / 118
- 4.12 Sample Frequency Commands / 123
- 4.13 Reference Oscillator Commands / 125
- 4.14 :VOLTage Subsystem / 128
- 4.15 Frequency and Phase Response Data Access / 131
- 4.16 :TRACe Subsystem / 132
- 4.17 :TEST Subsystem / 146

4.1 Introduction

Introduction

The M8196A can be programmed like other modular instruments using IVI-COM driver. In addition classic instrument programming using SCPI commands is supported.

The following picture gives an overview about how things work together:

NOTE

Programming using IVI-COM driver is supported with later FW revision.

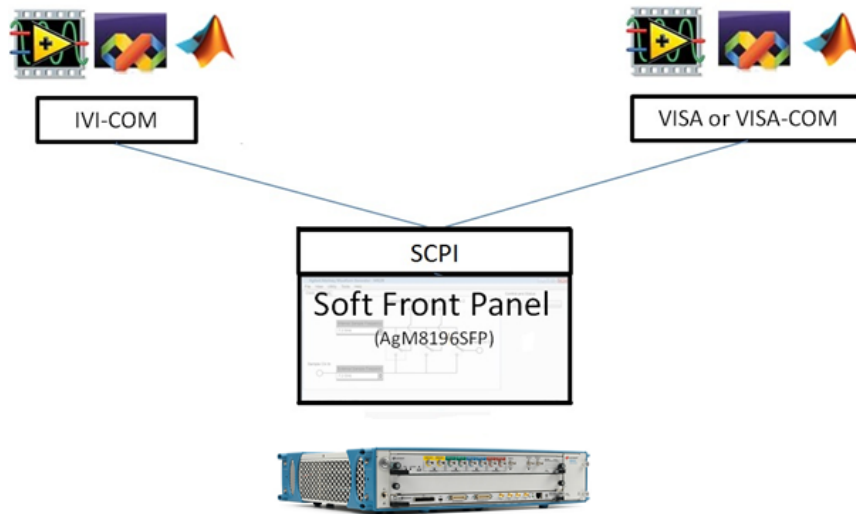


Figure 19: M8196A programming

The Soft Front Panel talks to the actual M8196A module using a PCI express or USB connection. I/O to the module is done using VISA library of Keysight I/O library. Addressing is done with PXI resource strings, e.g. "PXI36::0::0::INSTR" or USB resource strings, e.g. "USB-PXI0::5564::4819::DE00000001::INSTR". The purpose of the Soft Front Panel is to provide a classic instrument like SCPI interface that is exposed via LAN.

IVI-COM wraps the SCPI commands into an API based programming model. To select which module is programmed, the resource string of the module is used. The IVI-driver will automatically locate an already running Soft Front Panel that is handling the module. If no such Soft Front Panel exists, it is started automatically. This way it is completely hidden that the IVI driver actually needs the Soft Front Panel for programming the M8196A module.

VISA or VISA-COM are libraries from an installed I/O library such as the Keysight I/O library to program the instrument using SCPI command strings. The Soft Front Panel must be already running to connect to it.

The Soft Front Panel is also providing the user interface. It is used for interactively changing settings. In addition, it can log what IVI or SCPI calls need to be done when changing a setting. This can be activated with *Tools* → *Monitor Driver calls...*

4.2 IVI-COM Programming

The recommended way to program the M8196A module is to use the IVI drivers. See documentation of the IVI drivers how to program using IVI drivers. The connection between the IVI-COM driver and the Soft Front Panel is hidden. To address a module therefore the PXI or USB resource string of the module is used. The IVI driver will connect to an already running Soft Front Panel. If the Soft Front Panel is not running, it will automatically start it.

IVI drivers will be available with a later FW revision.

4.3 SCPI Programming

Introduction

In addition to IVI programming SCPI programming using a LAN connection is also supported. Three LAN protocols are supported. The correct resource strings are shown in the Soft Front Panel's About window. A context menu is provided to copy the resource strings.

- **VXI-11:** The Visa resource string is e.g. "TCPIP0::localhost::inst0::INSTR".
- **HiSLIP:** This protocol is recommended. It offers the functionality of VXI-11 protocol with better performance that is near socket performance. Visa resource strings look like "TCPIP0::localhost::hislip0::INSTR". To use the HiSlip protocol an I/O library such as the Keysight I/O Libraries Suite must be installed. Since the protocol is new it might not be supported by the installed I/O library. The Keysight I/O Libraries Suite 16.3 and above supports it. However, the Keysight I/O Libraries Suite might be installed as secondary I/O library. In this case, check if the primary I/O library supports HiSLIP. If it does not, the socket protocol must be used.
- **Socket:** This protocol can be used with any I/O library or using standard operating system socket functionality connecting to port 5025. This protocol must be used if the used I/O library is not supporting HiSLIP protocol. Visa resource string looks like "TCPIP0::localhost::5025::SOCKET", the exact resource string can be seen in the Ag8196 Soft Front Panel main window.

NOTE

AgM8196SFP.exe must be started prior to sending SCPI to the instrument. (See [AgM8196SFP.exe](#))

4.3.1 AgM8196SFP.exe

Before sending SCPI commands to the instrument, the Soft Front Panel (AgM8196SFP.exe) must be started. This can be done in the Windows Start menu (Start > All Programs > Keysight M8196 > Keysight M8196 Soft Front Panel).

4.3.1.1 Command Line Arguments

(See [Communication](#) for details about /Socket, /Telnet, /Inst, /HiSLIP, /AutoID, /NoAutoID, /FallBack).

Table 17: Command line arguments

Option	Description
/Socket socketPort	Set the socket port at which the Soft Front Panel waits for SCPI commands
/Telnet telnetPort	Set the telnet port at which the Soft Front Panel waits for SCPI commands
/Inst instrumentNumber	Set the instrument number (instN, hislipN) at which the Soft Front Panel waits for SCPI commands on VXI-11.3 and HiSLIP connections (if not specified with /HiSLIP).
/HiSLIP hislipNumber	Set the instrument number for HiSLIP SCPI communication. If not specified, the same number as for VXI-11.3 is used.
/AutoID	Automatically select ports and numbers for the connections (default behavior).
/NoAutoID	Disable the default behavior; i.e. do not automatically select ports and numbers for the connections.
/FallBack	Try to find unused ports and number if starting a server fails.
/NoSplash	Don't show the splash screen.
/Minimized	Start with the SFP window minimized to the Windows task bar.
/Title "title"	Additional information shown in the SFP window title.
/r resourceName	Visa PXI resource string of the module to connect to, e.g. PXI12::0::0::INSTR. "auto" selects the next free instrument.

4.3.1.2 Communication

Depending on the command line arguments `/Socket`, `/Telnet`, `/Inst`, `/AutoID`, `/NoAutoID`, `/FallBack`, the Soft Front Panel starts several servers to handle SCPI commands. (Refer to the table above.)

- **`/Socket`, `/Telnet`, `/Inst`, `/HiSLIP`:** If -1, don't start the respective servers
Defaults:
 - Socket port: 5025 (e.g. `TCPIP0::localhost::5025::SOCKET`)
 - Telnet port: 5024
 - HiSLIP: 0 (e.g. `TCPIP0::localhost::hislip0::INSTR`)
 - VXI-11.3: 0 (e.g. `TCPIP0::localhost::inst0::INSTR`)
- **`/FallBack`:** If starting a server fails because of a conflict, try using another port or number
 - **HiSLIP, VXI-11.3:** increase the index until a server can be started successfully
 - **Socket, Telnet:** start with port 60000, then increase it until the servers can be started successfully. If neither socket nor telnet is disabled the Soft Front Panel tries to start the servers on two consecutive ports (socket port = telnet port + 1)

- **`/AutoID`:** Automatically select ports and number for the connections, which are unique per instrument.

This is the default behavior; it is not necessary to specify this argument on the command line.

If only one AXIe module is connected to this PC and it is an M8196 module, first try to use the command line arguments `/Socket`, `/Telnet`, `/Inst`, or their respective default values if they are not specified. If starting the servers fails, proceed with the steps below.

`/Socket`, `/Telnet`, `/Inst`, `/HiSLIP` are ignored (unless they are -1 and a server is disabled)

If the Soft Front Panel detects more than one AXIe module, use a special mechanism to obtain a number for the HiSLIP and VXI-11.3 servers, which makes sure that the Soft Front Panel uses always the same VISA resource string per module

The socket and telnet port are then calculated from the HiSLIP index:

- telnet port = $60000 + 2 * \text{HiSLIP index}$
- socket port = $60000 + 2 * \text{HiSLIP index} + 1$

Note: Ports may already be in use by Windows or other applications, so they are not available for M8196A.

- **`/NoAutoID`:** Do not automatically select ports and number for the connections, use the values specified with `/Socket`, `/Telnet`, `/Inst`, `/HiSLIP` or their respective default values instead.

If both `/NoAutoID` and `/AutoID` are specified, `/AutoID` overrides `/NoAutoID`.

NOTE

The first port not assigned by IANA is 49152 (IANA, Internet Assigned Numbers Authority, <http://www.iana.org>)

4.4 Programming Recommendations

This section lists some recommendations for programming the instrument:

1. Start programming from the default setting. The common command for setting the default setting is:

```
*RST
```

2. Use the binary data format when transferring waveform data.

The SCPI standard defines a long and a short form of the commands. For fast programming speed, it is recommended to use the short forms. The short forms of the commands are represented by upper case letters. For example the short form of the command to set 10mV offset is:

```
:VOLT:OFFS 0.01
```

3. To improve programming speed it is also allowed to skip optional subsystem command parts. Optional subsystem command parts are depicted in square brackets, e.g.: Set amplitude `[ :SOURce ] :VOLTage [ 1 | 2 ] [ :LEVel ] [ :IMMediate ] [ :AMPLitude ]`

Sufficient to use:

```
:VOLT
```

4. M8196A is a 4 channel instrument. Parameters have to be specified for output 1, 2, 3, and 4. If there is no output specified the command will set the default output 1. So, for setting an offset of 10mV for output 1 and output 2 the commands are:

```
:VOLT:OFFS 0.01      # sets offset of 10mV at output 1
```

```
:VOLT1:OFFS 0.01     # sets offset of 10mV at output 1
```

```
:VOLT2:OFFS 0.01     # sets offset of 10mV at output 2
```

4. If it is important to know whether the last command is completed then send the common query:

```
*OPC?
```

5. It is recommended to test the new setting which will be programmed on the instrument by setting it up manually. When you have found the correct setting, then use this to create the program.

6. In the program it is recommended to send the command for starting data generation (:INIT:IMM) as the last command. This way intermediate stop/restarts (e.g. when changing sample rate or loading a waveform) are avoided and optimum execution performance is achieved.

```
*RST      # set default settings
```

```
...      # other commands to set modes
```

```
...      # and parameters
```

```
:OUTP1 ON # enable the output 1
```

```
:INIT:IMM # start data generation.
```

4.5 System Related Commands (SYSTem Subsystem)

4.5.1 :SYSTem:ERRor[:NEXT]?

Command	:SYST:ERR?
Long	:SYSTem:ERRor?
Parameters	None
Parameter Suffix	None
Description	Read and clear one error from the instrument's error queue. A record of up to 30 command syntax or hardware errors can be stored in the error queue. Errors are retrieved in first-in-first-out (FIFO) order. The first error returned is the first error that was stored. Errors are cleared as you read them. If more than 30 errors have occurred, the last error stored in the queue (the most recent error) is replaced with "Queue overflow". No additional errors are stored until you remove errors from the queue. If no errors have occurred when you read the error queue, the instrument responds with 0, "No error". The error queue is cleared by the *CLS command, when the power is cycled, or when the Soft Front Panel is re-started. The error queue is not cleared by a reset (*RST) command. The error messages have the following format (the error string may contain up to 255 characters): error number,"Description", e.g. -113,"Undefined header".
Example	Query :SYST:ERR?

4.5.2 :SYSTem:HELP:HEADers?

Command	:SYST:HELP:HEAD?
Long	:SYSTem:HELP:HEADers?
Parameters	None
Parameter Suffix	None

Description	The HEADers? query returns all SCPI commands and queries and IEEE 488.2 common commands and common queries implemented by the instrument. The response is a <DEFINITE LENGTH ARBITRARY BLOCK RESPONSE DATA> element. The full path for every command and query is returned separated by linefeeds. The syntax of the response is defined as: The <nonzero digit> and sequence of <digit> follow the rules in IEEE 488.2, Section 8.7.9. A <SCPI header> is defined as: It contains all the nodes from the root. The <SCPI program mnemonic> contains the node in standard SCPI format. The short form uses uppercase characters while the additional characters for the long form are in lowercase characters. Default nodes are surrounded by square brackets ([]).
Example	Query :SYST:HELP:HEAD?

4.5.3 :SYSTem:LIcense:EXTended:LIST?

Command	:SYST:LIC:EXT:LIST?
Long	:SYSTem:LIcense:EXTended:LIST?
Parameters	None
Parameter Suffix	None
Description	This query lists the licenses installed.
Example	Query :SYST:LIC:EXT:LIST?

4.5.4 :SYSTem:SET[?]

Command	:SYST:SET[?]
Long	:SYSTem:SET[?]
Parameters	<binary block data>
Parameter Suffix	None

Description	In query form, the command reads a block of data containing the instrument's complete set-up. The set-up information includes all parameter and mode settings, but does not include the contents of the instrument setting memories or the status group registers. The data is in a binary format, not ASCII, and cannot be edited. In set form, the block data must be a complete instrument set-up read using the query form of the command. This command has the same functionality as the *LRN command.
Example	Command <pre>:SYST:SET <binary block data></pre> Query <pre>:SYST:SET?</pre>

4.5.5 :SYSTem:VERSion?

Command	<code>:SYST:VERS?</code>
Long	<code>:SYSTem:VERSion?</code>
Parameters	None
Parameter Suffix	None
Description	This query returns a formatted numeric value corresponding to the SCPI version number for which the instrument complies.
Example	Query <pre>:SYST:VERS?</pre>

4.5.6 :SYSTem:COMMunicate:*?

Command	<code>:SYST:COMM:*?</code>
Long	<code>:SYSTem:COMMunicate:*?</code>
Parameters	None
Parameter Suffix	None

Description	These queries return information about the instrument Soft Front Panel's available connections. If a connection is not available, the returned value is -1. This is only useful if there is more than one Keysight module connected to a PC, otherwise one would normally use the default connections (HiSLIP and VXI-11 instrument number 0, socket port 5025, telnet port 5024) One can never be sure if a socket port is already in use, so one could e.g. specify a HiSLIP number on the command line (AgM8196SFP.exe /AutoID /Inst5 /Fallback /r ...) and let the Soft Front Panel find an unused socket port. Then this socket port can be queried using the HiSLIP connection.
Example	Query :SYST:COMM:*?

4.5.6.1 :SYSTem:COMMunicate:INSTR[:NUMBer]?

Command	:SYST:COMM:INST?
Long	:SYSTem:COMMunicate:INSTR?
Parameters	None
Parameter Suffix	None
Description	This query returns the VXI-11 instrument number used by the Soft Front Panel.
Example	Query :SYST:COMM:INST?

4.5.6.2 :SYSTem:COMMunicate:HiSLip[:NUMBer]?

Command	:SYST:COMM:HISL?
Long	:SYSTem:COMMunicate:HiSLip?
Parameters	None
Parameter Suffix	None
Description	This query returns the HiSLIP number used by the Soft Front Panel.
Example	Query :SYST:COMM:HISL?

4.5.6.3 :SYSTem:COMMunicate:SOCKet[:PORT]?

Command	:SYST:COMM:SOCK?
Long	:SYSTem:COMMunicate:SOCKet?
Parameters	None
Parameter Suffix	None
Description	This query returns the socket port used by the Soft Front Panel.
Example	Query :SYST:COMM:SOCK?

4.5.6.4 :SYSTem:COMMunicate:TELNet[:PORT]?

Command	:SYST:COMM:TELN?
Long	:SYSTem:COMMunicate:TELNet?
Parameters	None
Parameter Suffix	None
Description	This query returns the telnet port used by the Soft Front Panel.
Example	Query :SYST:COMM:TELN?

4.5.6.5 :SYSTem:COMMunicate:TCPIp:CONTrol?

Command	:SYST:COMM:TCP:CONT?
Long	:SYSTem:COMMunicate:TCPIp:CONTrol?
Parameters	None
Parameter Suffix	None
Description	This query returns the port number of the control connection. You can use the control port to send control commands (for example “Device Clear”) to the instrument.
Example	Query :SYST:COMM:TCP:CONT?

4.6 Common Command List

4.6.1 *IDN?

Read the instrument's identification string which contains four fields separated by commas. The first field is the manufacturer's name, the second field is the model number, the third field is the serial number, and the fourth field is a revision code which contains four numbers separated dots and a fifth number separated by a dash: Keysight Technologies, M8196A,<serial number>, x.x.x.x-h
 x.x.x.x= Soft Front Panel revision number, e.g. 2.0.0.0
 h= Hardware revision number

4.6.2 *CLS

Clear the event register in all register groups. This command also clears the error queue and cancels a ***OPC** operation. It doesn't clear the enable register.

4.6.3 *ESE

Enable bits in the Standard Event Status Register to be reported in the Status Byte. The selected bits are summarized in the "Standard Event" bit (bit 5) of the Status Byte Register. The ***ESE?** query returns a value which corresponds to the binary-weighted sum of all bits enabled decimal by the ***ESE** command. These bits are not cleared by a ***CLS** command. Value Range: 0–255.

4.6.4 ESR?

Query the Standard Event Status Register. Once a bit is set, it remains set until cleared by a ***CLS** (clear status) command or queried by this command. A query of this register returns a decimal value which corresponds to the binary-weighted sum of all bits set in the register.

4.6.5 *OPC

Set the "Operation Complete" bit (bit 0) in the Standard Event register after the previous commands have been completed.

4.6.6 *OPC?

Return “1” to the output buffer after the previous commands have been completed. Other commands cannot be executed until this command completes.

4.6.7 *OPT?

Read the installed options. The response consists of any number of fields separated by commas.

4.6.8 *RST

Reset instrument to its factory default state.

4.6.9 *SRE[?]

Enable bits in the Status Byte to generate a Service Request. To enable specific bits, you must write a decimal value which corresponds to the binary-weighted sum of the bits in the register. The selected bits are summarized in the “Master Summary” bit (bit 6) of the Status Byte Register. If any of the selected bits change from “0” to “1”, a Service Request signal is generated. The ***SRE?** query returns a decimal value which corresponds to the binary-weighted sum of all bits enabled by the ***SRE** command.

4.6.10 *STB?

Query the summary (status byte condition) register in this register group. This command is similar to a Serial Poll but it is processed like any other instrument command. This command returns the same result as a Serial Poll but the “Master Summary” bit (bit 6) is not cleared by the ***STB?** command.

4.6.11 *TST?

Execute Self Tests. If self-tests pass, a 0 is returned. A number larger than 0 indicates the number of failed tests.

To get actual messages, use **:TEST:TST?**

4.6.12 *LRN?

Query the instrument and return a binary block of data containing the current settings (learn string). You can then send the string back to the instrument to restore this state later. For proper operation, do not modify the returned string before sending it to the instrument. Use **:SYST:SET** to send the learn string. See [:SYSTem:SET\[?\]](#).

4.6.13 *WAI?

Prevents the instrument from executing any further commands until the current command has finished executing.

4.7 Status Model

Introduction

This section describes the structure of the SCPI status system used by the M8196A. The status system records various conditions and states of the instrument in several register groups as shown on the following pages. Each of the register groups is made up of several low level registers called Condition registers, Event registers, and Enable registers which control the action of specific bits within the register group.

These groups are explained below:

- A condition register continuously monitors the state of the instrument. The bits in the condition register are updated in real time and the bits are not latched or buffered. This is a read-only register and bits are not cleared when you read the register. A query of a condition register returns a decimal value which corresponds to the binary-weighted sum of all bits set in that register.
- An event register latches the various events from changes in the condition register. There is no buffering in this register; while an event bit is set, subsequent events corresponding to that bit are ignored. This is a read only register. Once a bit is set, it remains set until cleared by query command (such as STAT:QUES:EVEN?) or a *CLS (clear status) command. A query of this register returns a decimal value which corresponds to the binary-weighted sum of all bits set in that register.
- An enable register defines which bits in the event register will be reported to the Status Byte register group. You can write to or read from an enable register. A *CLS (clear status) command will not clear the enable register but it does clear all bits in the event register. A **STAT : PRES** command clears all bits in the enable register. To enable bits in the enable register to be reported to the Status Byte register, you must write a decimal value which corresponds to the binary weighted sum of the corresponding bits.
- Transition Filters are used to detect changes of the state in the condition register and set the corresponding bit in the event register. You can set transition filter bits to detect positive transitions (PTR), negative transitions (NTR) or both. Transition filters are read/write registers. They are not affected by *CLS.

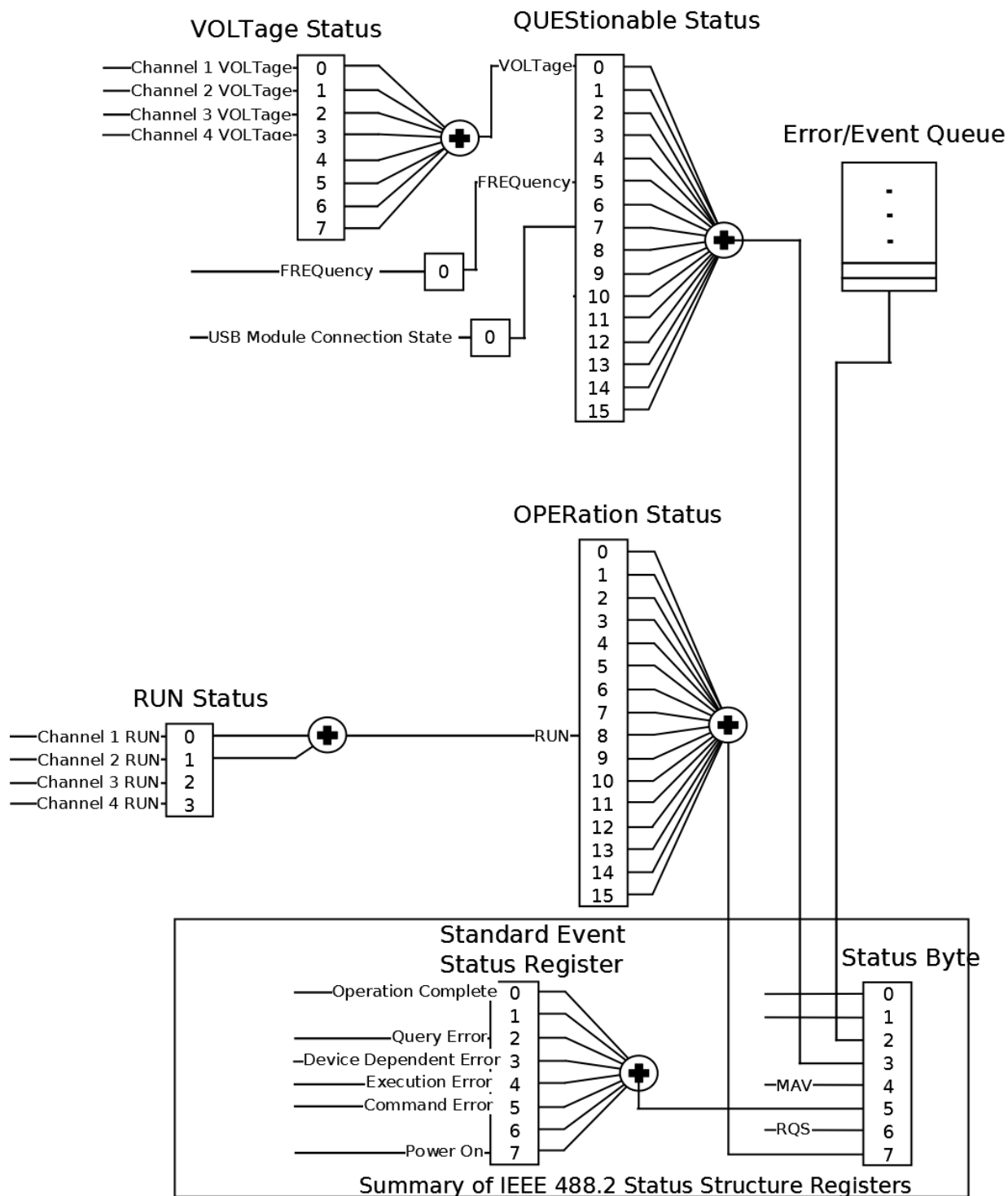


Figure 20: Status register structure

4.7.1 :STATus:PRESet

Clears all status group event registers. Presets the status group enables PTR and NTR registers as follows:

ENABle = 0x0000, PTR = 0xffff, NTR = 0x0000

4.7.2 Status Byte Register

The Status Byte summary register reports conditions from the other status registers. Data that is waiting in the instrument's output buffer is immediately reported on the "Message Available" bit (bit 4) for example. Clearing an event register from one of the other register groups will clear the corresponding bits in the Status Byte condition register. Reading all messages from the output buffer, including any pending queries, will clear the "Message Available" bit. To set the enable register mask and generate an SRQ (service request), you must write a decimal value to the register using the *SRE command.

Table 18: Status byte register

Bit Number	Decimal Value	Definition
0	1	Not Used. Returns "0"
Not used		
1	2	Not Used. Returns "0"
Not used		
2	4	One or more error are stored in the Error Queue
Error Queue		
3	8	One or more bits are set in the Questionable Data Register (bits must be enabled)
Questionable Data		
4	16	Data is available in the instrument's output buffer
Message Available		
5	32	One or more bits are set in the Standard Event Register
Standard Event		
6	64	One or more bits are set in the Status Byte Register
Master Summary		
7	128	One or more bits set in the Operation Data Register (bits must be enabled)
Operational Data		

4.7.3 Questionable Data Register Command Subsystem

The Questionable Data register group provides information about the quality or integrity of the instrument. Any or all of these conditions can be reported to the Questionable Data summary bit through the enable register.

Table 19: Questionable data register

Bit Number	Decimal Value	Definition
0 Voltage warning	1	Output has been switched off (to protect itself)
1 Not used	2	Returns "0"
2 Not used	4	Returns "0"
3 Not used	8	Returns "0"
4 Not used	16	Returns "0"
5 Frequency warning	32	Output signal is invalid, because of an instable or missing external reference clock.
6 Not used	64	Returns "0"
7 USB disconnected	128	USB module connection state
8 Not used	256	Returns "0"
9 Not used	512	Returns "0"
10 Not used	1024	Returns "0"
11 Not used	2048	Returns "0"
12 Not used	4096	Returns "0"
13 Not used	8192	Returns "0"
14 Not used	16384	Returns "0"
15 Not used	32768	Returns "0"

The following commands access the questionable status group.

4.7.3.1 :STATus:QUESTionable[:EVENT]?

Reads the event register in the questionable status group. It's a read-only register. Once a bit is set, it remains set until cleared by this command or the ***CLS** command. A query of the register returns a decimal value which corresponds to the binary-weighted sum of all bits set in the register.

4.7.3.2 :STATus:QUEStionable:CONDition?

Reads the condition register in the questionable status group. It's a read-only register and bits are not cleared when you read the register. A query of the register returns a decimal value which corresponds to the binary-weighted sum of all bits set in the register.

4.7.3.3 :STATus:QUEStionable:ENABle[?]

Sets or queries the enable register in the questionable status group. The selected bits are then reported to the Status Byte. A ***CLS** will not clear the enable register but it does clear all bits in the event register. To enable bits in the enable register, you must write a decimal value which corresponds to the binary-weighted sum of the bits you wish to enable in the register.

4.7.3.4 :STATus:QUEStionable:NTRansition[?]

Sets or queries the negative-transition register in the questionable status group. A negative transition filter allows an event to be reported when a condition changes from true to false. Setting both positive/negative filters true allows an event to be reported anytime the condition changes. Clearing both filters disable event reporting. The contents of transition filters are unchanged by ***CLS** and ***RST**.

4.7.3.5 :STATus:QUEStionable:PTRansition[?]

Set or queries the positive-transition register in the questionable status group. A positive transition filter allows an event to be reported when a condition changes from false to true. Setting both positive/negative filters true allows an event to be reported anytime the condition changes. Clearing both filters disable event reporting. The contents of transition filters are unchanged by ***CLS** and ***RST**.

4.7.4 Operation Status Subsystem

The Operation Status register contains conditions which are part of the instrument's normal operation.

Table 20: Operation status register

Bit Number	Decimal Value	Definition
0 Not used	1	Returns "0"
1 Not used	2	Returns "0"
2 Not used	4	Returns "0"
3 Not used	8	Returns "0"
4 Not used	16	Returns "0"
5 Not used	32	Returns "0"
6 Not used	64	Returns "0"
7 Not used	128	Returns "0"
8 Run Status	256	Indicates if system is running
9 Not used	512	Returns "0"
10 Not used	1024	Returns "0"
11 Not used	2048	Returns "0"
12 Not used	4096	Returns "0"
13 Not used	8192	Returns "0"
14 Not used	16384	Returns "0"
15 Not used	32768	Returns "0"

The following commands access the operation status group.

4.7.4.1 :STATus:OPERation[:EVENT]?

Reads the event register in the operation status group. It's a read-only register. Once a bit is set, it remains set until cleared by this command or *CLS command. A query of the register returns a decimal value which corresponds to the binary-weighted sum of all bits set in the register.

4.7.4.2 :STATus:OPERation:CONDition?

Reads the condition register in the operation status group. It's a read-only register and bits are not cleared when you read the register. A query of the register returns a decimal value which corresponds to the binary-weighted sum of all bits set in the register.

4.7.4.3 :STATus:OPERation:ENABLE[?]

Sets or queries the enable register in the operation status group. The selected bits are then reported to the Status Byte. A ***CLS** will not clear the enable register but it does clear all bits in the event register. To enable bits in the enable register, you must write a decimal value which corresponds to the binary-weighted sum of the bits you wish to enable in the register.

4.7.4.4 :STATus:OPERation:NTRansition[?]

Sets or queries the negative-transition register in the operation status group. A negative transition filter allows an event to be reported when a condition changes from true to false. Setting both positive/negative filters true allows an event to be reported anytime the condition changes. Clearing both filters disable event reporting. The contents of transition filters are unchanged by ***CLS** and ***RST**.

4.7.4.5 :STATus:OPERation:PTRansition[?]

Set or queries the positive-transition register in the operation status group. A positive transition filter allows an event to be reported when a condition changes from false to true. Setting both positive/negative filters true allows an event to be reported anytime the condition changes. Clearing both filters disable event reporting. The contents of transition filters are unchanged by ***CLS** and ***RST**.

4.7.5 Voltage Status Subsystem

The Voltage Status register contains the voltage conditions of the individual channels.

The following SCPI commands and queries are supported:

```
:STATus:QUESTionable:VOLTage[:EVENT]?
:STATus:QUESTionable:VOLTage:CONDition?
:STATus:QUESTionable:VOLTage:ENABLE[?]
:STATus:QUESTionable:VOLTage:NTRansition[?]
:STATus:QUESTionable:VOLTage:PTRansition[?]
```

Table 21: Voltage status register

Bit Number	Decimal Value	Definition
0 Voltage warning	1	Output 1 has been switched off (to protect itself)
1 Voltage warning	2	Output 2 has been switched off (to protect itself)
2 Voltage warning	4	Output 3 has been switched off (to protect itself)
3 Voltage warning	8	Output 4 has been switched off (to protect itself)
4 Not used	16	Returns "0"
5 Not used	32	Returns "0"
6 Not used	64	Returns "0"
7 Not used	128	Returns "0"

4.7.6 Frequency Status Subsystem

The Frequency Status register contains the frequency conditions of the module. The following SCPI commands and queries are supported:

```
:STATus:QUESTionable:FREQuency[:EVENT]?
:STATus:QUESTionable:FREQuency:CONDition?
:STATus:QUESTionable:FREQuency:ENABle[?]
:STATus:QUESTionable:FREQuency:NTRansition[?]
:STATus:QUESTionable:FREQuency:PTRansition[?]
```

Table 22: Frequency status register

Bit Number	Decimal Value	Definition
0 Frequency warning	1	Output signal is invalid, because of an instable or missing external reference clock.

4.7.7 Connection Status Subsystem

The Connection Status register contains the state of the USB connection to the M8196A module.

The following SCPI commands and queries are supported:

```
:STATus:QUEStionable:CONNection[:EVENt]?
:STATus:QUEStionable:CONNection:CONDition?
:STATus:QUEStionable:CONNection:ENABle[?]
:STATus:QUEStionable:CONNection:NTRansition[?]
:STATus:QUEStionable:CONNection:PTRansition[?]
```

Table 23: Connection status register

Bit Number	Decimal Value	Definition
0 USB disconnected	1	USB module connection state

4.7.8 Run Status Subsystem

The Run Status register contains the run status conditions of the individual channels.

The following SCPI commands and queries are supported:

```
:STATus:OPERation:RUN[:EVENt]?
:STATus:OPERation:RUN:CONDition?
:STATus:OPERation:RUN:ENABle[?]
:STATus:OPERation:RUN:NTRansition[?]
:STATus:OPERation:RUN:PTRansition[?]
```

Table 24: Run status register

Bit Number	Decimal Value	Definition
0 Run Status	1	Indicates if channel 1 is running
1 Run Status	2	Indicates if channel 2 is running
2 Run Status	4	Indicates if channel 3 is running
3 Run Status	8	Indicates if channel 4 is running

4.8 :ARM/TRIGger Subsystem

4.8.1 :ABORt[1|2|3|4]

Command	:ABOR[1 2 3 4]
Long	:ABORt[1 2 3 4]
Parameters	None
Parameter Suffix	None
Description	Stop signal generation on all channels. The channel suffix is ignored.
Example	Command :ABOR1

4.8.2 :ARM[:SEQuence][:STARt][:LAYer]:MDELay[?] <module_delay>|MINimum|MAXimum

Command	:ARM:MDEL[?]
Long	:ARM[:SEQuence] [:STARt][:LAYer]:MDELay[?]
Parameters	{<delay> MINimum MAXimum}
Parameter Suffix	[s ms us ns ps]
Description	Set or query the module delay settings. The unit is in seconds.
Example	Command :ARM:MDEL 1E-13 Query :ARM:MDEL?

4.8.3 :INITiate:IMMediate[1|2|3|4]

Command	:INIT:IMM[1 2 3 4]
Long	:INITiate:IMMediate[1 2 3 4]
Parameters	None
Parameter Suffix	None
Description	Start signal generation on all channels. The channel suffix is ignored
Example	Command :INIT:IMM

4.8.4 :INITiate:CONTinuous[:STATe][?] OFF|ON|0|1

Command	:INIT:CONT:STAT[?]
Long	:INITiate:CONTinuous:STATe[?]
Parameters	OFF ON 0 1
Parameter Suffix	None
Description	Set or query the continuous mode. 0/OFF – Continuous mode is off. The module is in triggered mode. 1/ON – Continuous mode is on.
Example	Command :INIT:CONT:STAT ON Query :INIT:CONT:STAT?

4.8.5 :ARM[:SEQuence][:START][:LAYer]:TRIGger:LEVel[?] <level>|MINimum|MAXimum

Command	:ARM:TRIG:LEV[?]
Long	:ARM:TRIGger:LEVel[?]
Parameters	<level> MINimum MAXimum

Parameter Suffix	None
Description	Set or query the trigger input threshold level. • <level> – Threshold level voltage.
Example	Command :ARM:TRIG:LEV 3e-9 Query :ARM:TRIG:LEV?

4.8.6 :ARM[:SEQuence][:START][:LAYer]:TRIGger:SLOPe[?] POSitive|NEGative|EITHer

Command	:ARM:TRIG:SLOP[?]
Long	:ARM:TRIGger:SLOPe[?]
Parameters	POSitive NEGative EITHer
Parameter Suffix	None
Description	Set or query the trigger input slope. • POSitive – rising edge • NEGative – falling edge • EITHer – both
Example	Command :ARM:TRIG:SLOP POS Query :ARM:TRIG:SLOP?

4.8.7 :TRIGger[:SEQuence][:START]:BEGin:HWDisable[:STATe][?] 0|1|OFF|ON

Command	:TRIG:BEG:HWD[?]
Long	:TRIGger:BEGin:HWDisable[?]
Parameters	0 1 OFF ON

Parameter Suffix	None
Description	Set or query the hardware input disable state for the trigger function. When the hardware input is disabled, a trigger can only be generated using the :TRIGger[:SEquence][:START]:BEGin[:IMMediate] command. When the hardware input is enabled, a trigger can be generated by command, by a signal present at the trigger input or the internal trigger generator.
Example	Command :TRIG:BEG:HWD ON Query :TRIG:BEG:HWD?

4.8.8 :TRIGger[:SEquence][:START]:BEGin[:IMMediate]

Command	:TRIG:BEG
Long	:TRIGger:BEGin
Parameters	None
Parameter Suffix	None
Description	In triggered mode send the start/begin event to the module.
Example	Command :TRIG:BEG

4.9 :INSTrument Subsystem

4.9.1 :INSTrument:SLOT[:NUMBer]?

Command	:INST:SLOT?
Long	:INSTrument:SLOT?
Parameters	None
Parameter Suffix	None
Description	Query the instrument's slot number in its AXIe frame.
Example	Query :INST:SLOT?

4.9.2 :INSTrument:IDENTify [<seconds>]

Command	:INST:IDEN
Long	:INSTrument:IDENTify
Parameters	<seconds>
Parameter Suffix	None
Description	Identify the instrument by flashing the green "Access" LED on the front panel for a certain time. <seconds> optional length of the flashing interval, default is 10 seconds.
Example	Command :INST:IDEN 5

4.9.3 :INSTrument:IDENtify:STOP

Command	:INST:IDEN:STOP
Long	:INSTrument:IDENtify:STOP
Parameters	None
Parameter Suffix	None
Description	Stop the flashing of the green “Access” LED before the flashing interval has elapsed.
Example	Command :INST:IDEN:STOP

4.9.4 :INSTrument: HWRevision?

Command	:INST:HWR?
Long	:INSTrument:HWRevision?
Parameters	None
Parameter Suffix	None
Description	Returns the M8196 hardware revision number.
Example	Query :INST:HWR?

4.9.5 :INSTrument:DACMode[?] SINGLE|DUAL|FOUR|MARKer|DCMarker

Command	:INST:DACM[?]
Long	:INSTrument:DACMode[?]
Parameters	SINGLE DUAL FOUR MARKer DCMarker • SINGLE – Channel 1 can generate a signal • DUAL – Channels 1 and 4 can generate a signal, channels 2 and 3 are unused • FOUR – Channels 1, 2, 3, and 4 can generate a signal • MARKer – Channel 1 with two markers output on channel 2 and 3 • DCMarker – Dual channel with marker: Channels 1 and 4 can generate a signal. Channel 1 has two markers output on channel 2 and 3. Channel 4 can generate signals without markers.
Parameter Suffix	None
Description	Use this command or query to set or get the operation mode of the DAC. The value of the operation mode determines, to which channels waveforms can be transferred and the format of the waveform data. In operation mode SINGLE, DUAL, or FOUR the data consists of 1-byte waveform samples only. In operation mode MARKer or DCMarker the data loaded to channel 1 consists of interleaved 1-byte waveform and 1-byte marker samples (see section :TRACe Subsystem).
Example	Command :INST:DACM DUAL

4.10 :MMEMory Subsystem

NOTE

MMEM commands requiring <directory_name> assume the current directory if a relative path or no path is provided. If an absolute path is provided, then it is ignored.

4.10.1 :MMEMory:CATalog? [<directory_name>]

Command	:MMEM:CAT?
Long	:MMEMory:CATalog?
Parameters	None
Parameter Suffix	None
Description	Query disk usage information (drive capacity, free space available) and obtain a list of files and directories in a specified directory in the following format: <numeric_value>,<numeric_value>,{<file_entry>} This command returns two numeric parameters and as many strings as there are files and directories. The first parameter indicates the total amount of storage currently used in bytes. The second parameter indicates the total amount of storage available, also in bytes. The <file_entry> is a string. Each <file_entry> indicates the name, type, and size of one file in the directory list: <file_name>,<file_type>,<file_size> As the Windows file system has an extension that indicates file type, <file_type> is always empty. <file_size> provides the size of the file in bytes. In case of directories, <file_entry> is surrounded by square brackets and both <file_type> and <file_size> are empty.
Example	Query :MMEM:CAT?

4.10.2 :MMEMory:CDIRectory [<directory_name>]

Command	:MMEM:CDIR
Long	:MMEMory:CDIRectory
Parameters	None
Parameter Suffix	None
Description	Changes the default directory for a mass memory file system. The <directory_name> parameter is a string. If no parameter is specified, the directory is set to the *RST value. At *RST, this value is set to the default user data storage area, that is defined as System.Environment.SpecialFolder.Personal e.g. C:\Users\Name\Documents MMEMory:CDIRectory? – Query returns full path of the default directory.
Example	Command :MMEM:CDIR "C:\Users\Name\Documents" Query :MMEM:CDIR?

4.10.3 :MMEMory:COPY <string>,<string>[,<string>,<string>]

Command	:MMEM:COPY
Long	:MMEMory:COPY
Parameters	<string>,<string>
Parameter Suffix	None
Description	Copies an existing file to a new file or an existing directory to a new directory. Two forms of parameters are allowed. The first form has two parameters. In this form, the first parameter specifies the source, and the second parameter specifies the destination. The second form has four parameters. In this form, the first and third parameters specify the file names. The second and fourth parameters specify the directories. The first pair of parameters specifies the source. The second pair specifies the destination. An error is generated if the source doesn't exist or the destination file already exists.
Example	Command :MMEM:COPY "C:\data.txt", "C:\data_new.txt"

4.10.4 :MMEMory:DELeTe <file_name>[,<directory_name>]

Command	:MMEM:DEL
Long	:MMEMory:DELeTe
Parameters	<file_name>
Parameter Suffix	None
Description	Removes a file from the specified directory. The <file_name> parameter specifies the file to be removed.
Example	Command :MMEM:DEL "C:\data.txt"

4.10.5 :MMEMory:DATA <file_name>, <data>

Command	:MMEM:DATA
Long	:MMEMory:DATA
Parameters	<file_name>, <data>
Parameter Suffix	None
Description	The command form is MMEMory:DATA <file_name>,<data> . It loads <data> into the file <file_name>. <data> is in 488.2 block format. <file_name> is string data.
Example	Command :MMEM:DATA "C:\data.txt", #14test

4.10.6 :MMEMory:DATA? <file_name>

Command	:MMEM:DATA?
Long	:MMEMory:DATA?
Parameters	<file_name>
Parameter Suffix	None
Description	The query form is MMEMory:DATA? <file_name> with the response being the associated <data> in block format.
Example	Query :MMEM:DATA? "C:\data.txt"

4.10.7 :MMEMory:MDIRectory <directory_name>

Command	:MMEM:MDIR
Long	:MMEMory:MDIRectory
Parameters	<directory_name>
Parameter Suffix	None
Description	Creates a new directory. The <directory_name> parameter specifies the name to be created.
Example	Command :MMEM:MDIR "C:\data_dir"

4.10.8 :MMEMory:MOVE <string>,<string>[,<string>,<string>]

Command	:MMEM:MOVE
Long	:MMEMory:MOVE
Parameters	<string>,<string>
Parameter Suffix	None
Description	Moves an existing file to a new file or an existing directory to a new directory. Two forms of parameters are allowed. The first form has two parameters. In this form, the first parameter specifies the source, and the second parameter specifies the destination. The second form has four parameters. In this form, the first and third parameters specify the file names. The second and fourth parameters specify the directories. The first pair of parameters specifies the source. The second pair specifies the destination. An error is generated if the source doesn't exist or the destination file already exists.
Example	Command <pre>:MMEM:MOVE "C:\data_dir","C:\newdata_dir"</pre>

4.10.9 :MMEMory:RDIRectory <directory_name>

Command	:MMEM:RDIR
Long	:MMEMory:RDIRectory
Parameters	<directory_name >
Parameter Suffix	None
Description	Removes a directory. The <directory_name> parameter specifies the directory name to be removed. All files and directories under the specified directory are also removed.
Example	Command <pre>:MMEM:RDIR "C:\newdata_dir"</pre>

4.10.10 :MMEMory:LOAD:CState <file_name>

Command	:MMEM:LOAD:CST
Long	:MMEMory:LOAD:CState
Parameters	<file_name >
Parameter Suffix	None
Description	Current state of instrument is loaded from a file.
Example	Command :MMEM:LOAD:CST "C:\data.txt"

4.10.11 :MMEMory:STOR:CState <file_name>

Command	:MMEM:STOR:CST
Long	:MMEMory:STOR:CState
Parameters	<file_name >
Parameter Suffix	None
Description	Current state of instrument is stored to a file.
Example	Command :MMEM:STOR:CST "C:\data.txt"

4.11 :OUTPut Subsystem

4.11.1 :OUTPut[1|2|3|4][:STATe][?] OFF|ON|0|1

Command	:OUTP[?]
Long	:OUTPut[?]
Parameters	OFF ON 0 1
Parameter Suffix	None
Description	Switch the amplifier of the output path for a channel on or off.
Example	Command :OUTP ON Query :OUTP?

4.11.2 :OUTPut:ROSCillator:SOURce[?] INTernal|EXTernal|SCLK1|SCLK2

Command	:OUTP:ROSC:SOUR[?]
Long	:OUTPut:ROSCillator:SOURce[?]
Parameters	INTernal EXTernal SCLK1 SCLK2
Parameter Suffix	None
Description	Select which signal source is routed to the reference clock output: INTernal: the module internal reference oscillator EXTernal: the external reference clock from REF CLK IN with two variable dividers SCLK1: DAC sample clock with variable divider and variable delay SCLK2: DAC sample clock with fixed divider

Example	Command
	:OUTP:ROSC:SOUR INT
	Query
	:OUTP:ROSC:SOUR?

4.11.3 :OUTPut: ROSCillator:SCD[?] <sample_clock_divider>

Command	:OUTP:ROSC:SCD[?]
Long	:OUTPut:ROSCillator:SCD[?]
Parameters	sample_clock_divider
Parameter Suffix	None
Description	Set or query the divider of the DAC sample clock signal routed to the reference clock output.
Example	Command
	:OUTP:ROSC:SCD 1
	Query
	:OUTP:ROSC:SCD?

4.11.4 :OUTPut: ROSCillator:RCD1[?] <reference_clock_divider1>

Command	:OUTP:ROSC:RCD1[?]
Long	:OUTPut:ROSCillator:RCD1[?]
Parameters	reference_clock_divider1
Parameter Suffix	None
Description	Set or query the first divider of the reference clock signal routed to the reference clock output.
Example	Command
	:OUTP:ROSC:RCD1 2
	Query
	:OUTP:ROSC:RCD1?

4.11.5 :OUTPut: ROSCillator:RCD2[?] <reference_clock_divider2>

Command	:OUTP:ROSC:RCD2[?]
Long	:OUTPut:ROSCillator:RCD2[?]
Parameters	reference_clock_divider2
Parameter Suffix	None
Description	Set or query the second divider of the external reference clock signal routed to the reference clock output.
Example	Command :OUTP:ROSC:RCD2 1 Query :OUTP:ROSC:RCD2?

4.11.6 :OUTPut[1|2|3|4]:DIOffset[?] <value>|MINimum|MAXimum

Command	:OUTP:DIOF[?]
Long	:OUTPut:DIOffset[?]
Parameters	<value> MINimum MAXimum
Parameter Suffix	None
Description	Differential Offset: The hardware can compensate for little offset differences between the normal and complement output. “<value>” is the offset to the calibrated optimum DAC value, so the minimum and maximum depend on the result of the calibration.
Example	Command :OUTP:DIOF MAX Query :OUTP:DIOF?

Table 25: Differential offset

Value	Normal Output	Complement Output
< 0	Offset decreased	Offset increased
0	No offset	
> 0	Offset increased	Offset decreased

Due to the use of DAC values, the granularity is 1. At the direct output (DAC) at 50 Ω :
 1 $\approx$ 1.526 μ V. At the DC output the resulting offset depends on the voltage settings.

4.11.7 :OUTPut[1|2|3|4]:VPCorr[?] <value>|MINimum|MAXimum

Command :OUTP[1|2|3|4]:VPC[?]

Long :OUTPut[1|2|3|4]:VPCorr[?]

Parameters <value>|MINimum|MAXimum

Parameter Suffix None

Description Set or query the peaking correction.
 The amplifier inside the M8196A applies a certain amount of “peaking” (i.e. boosting of high frequency components in the signal) to compensate for frequency roll-off of the DAC. If peaking correction is set to 0, the factory-calibrated amount of peaking is applied, which results in a 3 dB bandwidth of 32 GHz at the connector.
 Using the “:OUTPut[1|2|3|4]:VPCorr” command, the amount of peaking can be adjusted. Positive values boost higher frequencies even further, while negative values attenuate higher frequencies. An increase(decrease) of 1000 yields approximately 1 dB gain (loss) at 32 GHz.
 A positive peaking correction can be useful to compensate for loss in cables or other circuits connected to the AWG output. Too much peaking on the other hand can reduce overall signal quality.

NOTE

Since some amount of peaking is already used as a factory default, the available peaking range that is available for this command is not guaranteed. The range varies from instrument to instrument and from channel to channel. Use the MIN and MAX parameters in a query to find the minimum(maximum) value for a given channel.

NOTE

Adjusting the peaking is considered “over-programming”. The specifications of the instrument (e.g. bandwidth, rise-/fall-time, amplitude) are no longer valid if peaking is set to a non-zero value.

Example

Command

```
:OUTP1:VPC 3000 -- set peaking of channel 1 to 3000  
:OUTP3:VPC MAX  -- set peaking of channel 3 to the maximum allowed value
```

Query

```
:OUTP3:VPC?      -- query the current peaking of channel 3  
:OUTP4:VPC? MAX  -- query the maximum possible peaking for channel 4
```

4.12 Sample Frequency Commands

4.12.1 [:SOURce]:FREQuency:RASTer[?] <frequency>|MINimum|MAXimum

Command	:FREQ:RAST[?]
Long	:FREQuency:RASTer[?]
Parameters	<frequency> MINimum MAXimum
Parameter Suffix	None
Description	Set or query the sample frequency of the output DAC for the currently selected reference clock and reference clock range.
Example	Command :FREQ:RAST MIN Query :FREQ:RAST?

4.12.2 [:SOURce]:FREQuency:INT|RNG1|RNG2|RNG3:RASTer[?] <frequency>|MINimum|MAXimum

Command	:FREQ:INT RNG1 RNG2 RNG3:RAST[?]
Long	:FREQuency:INT RNG1 RNG2 RNG3:RASTer[?]
Parameters	<frequency> MINimum MAXimum
Parameter Suffix	None
Description	Set or query the sample frequency of the output DAC for a specific reference clock source and external reference clock range. Current reference clock source and external reference clock range remains unchanged. INT: internal or AXI reference clock RNG1: external reference clock and external reference clock range 1 RNG2: external reference clock and external reference clock range 2 RNG3 is not available since in range 3 the sample frequency is directly determined by the reference clock frequency and can not be set independently

Example

Command
:FREQ:INT:RAST MIN
Query
:FREQ:INT:RAST?

4.13 Reference Oscillator Commands

4.13.1 [:SOURce]:ROSCillator:SOURce[?] EXTeRnal|AXI|INTeRnal

Command	:ROSC:SOUR[?]
Long	:ROSCillator:SOURce[?]
Parameters	EXTeRnal AXI INTeRnal
Parameter Suffix	None
Description	Set or query the reference clock source. EXTeRnal: reference is taken from REF CLK IN. AXI: reference is taken from AXI backplane. INTeRnal: reference is taken from module internal reference oscillator. May not be available with every hardware. Command not supported with Revision 1 hardware.
Example	Command :ROSC:SOUR AXI Query :ROSC:SOUR?

4.13.2 [:SOURce]:ROSCillator:SOURce:CHECK? EXTeRnal|AXI|INTeRnal

Command	:ROSC:SOUR:CHEC?
Long	:ROSCillator:SOURce:CHECK?
Parameters	EXTeRnal AXI INTeRnal
Parameter Suffix	None
Description	Check if a reference clock source is available. Returns 1 if it is available and 0 if not.
Example	Query :ROSC:SOUR:CHEC? AXI

4.13.3 [:SOURce]:ROSCillator:FREQuency[?] <frequency>|MINimum|MAXimum

Command	:ROSC:FREQ[?]
Long	:ROSCillator:FREQuency[?]
Parameters	<frequency> MINimum MAXimum
Parameter Suffix	None
Description	Set or query the expected reference clock frequency, if the external reference clock source is selected.
Example	Command :ROSC:FREQ MIN Query :ROSC:FREQ?

4.13.4 [:SOURce]:ROSCillator:RANGe[?] RANG1| RANG2 | RANG3

Command	:ROSC:RANG[?]
Long	:ROSCillator:RANGe[?]
Parameters	RANG1 RANG2 RANG3
Parameter Suffix	None
Description	Set or query the reference clock frequency range, if the external reference clock source is selected. RANG1: 10...300 MHz RANG2: 162 MHz...17 GHz RANG3: 2.3125 GHz ... 3 GHz
Example	Command :ROSC:RANG RANG1 Query :ROSC:RANG?

4.13.5 [:SOURce]:ROSCillator:RNG1|RNG2|RNG3:FREQuency[?] <frequency>|MINimum|MAXimum

Command	:ROSC:RNG1 RNG2:FREQ[?]
Long	:ROSCillator:RNG1 RNG2 RNG3:FREQuency[?]
Parameters	<frequency> MINimum MAXimum
Parameter Suffix	None
Description	Set or query the reference clock frequency for a specific reference clock range. Current range remains unchanged. RNG1: 10...300 MHz RNG2: 210 MHz...17 GHz RNG3: 2.3125 GHz...3 GHz
Example	Command :ROSC:RNG1:FREQ MIN Query :ROSC:RNG1FREQ?

4.14 :VOLTage Subsystem

Set the output voltages for a channel.

4.14.1 [:SOURce]:VOLTage[1|2|3|4][:LEVel][:IMMediate][:AMPLitude][?] <level>|MINimum|MAXimum

Command	:VOLT[?]
Long	:VOLTage[?]
Parameters	<level>
Parameter Suffix	None
Description	Set or query the output amplitude.
Example	Command :VOLT 0.685 Query :VOLT?

4.14.2 [:SOURce]:VOLTage[1|2|3|4][:LEVel][:IMMediate]:OFFSet[?] <level>|MINimum|MAXimum

Command	:VOLT:OFFS[?]
Long	:VOLTage:OFFSet[?]
Parameters	<level>
Parameter Suffix	None
Description	Set or query the output offset.
Example	Command :VOLT:OFFS 0.02 Query :VOLT:OFFS?

4.14.3 [:SOURce]:VOLTage[1|2|3|4][:LEVel][:IMMediate]:HIGH[?] <level>|MINimum|MAXimum

Command	:VOLT:HIGH[?]
Long	:VOLTage:HIGH[?]
Parameters	<level>
Parameter Suffix	None
Description	Set or query the output high level.
Example	Command :VOLT:HIGH 3e-1 Query :VOLT:HIGH?

4.14.4 [:SOURce]:VOLTage[1|2|3|4][:LEVel][:IMMediate]:LOW[?] <level>|MINimum|MAXimum

Command	:VOLT:LOW[?]
Long	:VOLTage:LOW[?]
Parameters	<level>
Parameter Suffix	None
Description	Set or query the output low level.
Example	Command :VOLT:LOW -0.3 Query :VOLT:LOW?

4.14.5 [:SOURce]:VOLTage[1|2][:LEVel][:IMMediate]:TERMination[?] <level>|MINimum|MAXimum

Command	:VOLT:TERM[?]
Long	:VOLTage:TERMination[?]
Parameters	<level>
Parameter Suffix	None
Description	Set or query the termination voltage level.
Example	Command :VOLT:TERM -0.3 Query :VOLT:TERM?

4.15 Frequency and Phase Response Data Access

4.15.1 [:SOURce]: CHARacteris[1|2|3|4][:VALue]? [<amplitude>,<sample_frequency>]]

Command	:CHAR?
Long	:CHARacteris?
Parameters	<amplitude> the output amplitude <sample_frequency> the sample frequency
Parameter Suffix	None
Description	Query the frequency and phase response data for a channel. The query returns the data for the AWG sample frequency and output amplitude passed as parameters as a string of comma-separated values. If the sample frequency or both parameters are omitted, the currently configured AWG sample frequency and output amplitude are used. The frequency and phase response includes the sin x/ x roll-off of the currently configured AWG sample frequency. As a result the query delivers different results when performed at e.g. 88 GSa/s or 92 GSa/s. To achieve optimum frequency and phase compensation results, the frequency and phase response has been characterized individually per channel and for different output amplitudes. As a result, the query delivers different results when performed at e.g. 500 mV or 800 mV. The frequency and phase response refers to the 2.4 mm connector. In case external cables from the 2.4 mm connector to the Device Under Test (DUT) shall be mathematically compensated for as well, the corresponding S-Parameter of that cable must be taken into account separately. Format: The first three values are output frequency 1 in Hz, corresponding relative magnitude in linear scale, corresponding phase in radians. The next three values are output frequency 2, corresponding relative magnitude, corresponding phase, and so on.
Example	Query <pre>:CHAR2? "0,1.01068,0, 1e+008,1.00135,-6.11215e-005, 2e+008,0.993992,-0.000179762, ... 3.19e+010,0.0705237,-3.82659, 3.2e+010,0.0665947,-3.85028"</pre>

4.16 :TRACe Subsystem

Use the :TRACe subsystem to control the arbitrary waveforms and their respective parameters:

- Create waveform segments of arbitrary size with optional initialization.
- Download waveform data with or without marker data into the segments.
- Delete one or all waveform segments from the waveform memory.

4.16.1 Waveform Data Format

In the data formats shown below the fields have the following meanings:

DB7...DB0 – Sample as signed 8-bit value, valid range is -128 to +127.

M1, M2 – Marker bits for Marker 1 and 2 to be output on channel 2 and 3, respectively.

Table 26: Sample data format without markers

7	6	5	4	3	2	1	0
DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0
DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0
...							
DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0

Table 27: Sample data format with markers

7	6	5	4	3	2	1	0
DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0
X	X	X	X	X	X	M2	M1
DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0
X	X	X	X	X	X	M2	M1
...							
DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0
X	X	X	X	X	X	M2	M1

4.16.2 Arbitrary Waveform Generation

To prepare your module for arbitrary waveform generation follow these steps:

- Set instrument mode (number of channels)
- Define a segment using the various forms of the
 - :TRAC[1|2|3|4]:DEF command.
- Fill the segment with sample values using
 - :TRAC[1|2|3|4]:DATA.
- Signal generation starts after calling INIT:IMM.
- Use the :TRAC[1|2|3|4]:CAT? query to read the length of a waveform loaded into the memory of a channel. Use the :TRAC[1|2|3|4]:DEL:ALL command to delete a waveform from the memory of a channel.

4.16.3 :TRAC[1|2|3|4]:DEF

Command	:TRAC[1 2 3 4]:DEF
Long	:TRACe[1 2 3 4]:DEFine
Parameters	<segment_id>,<length>[,<init_value>] • <segment_id> – id of the segment • <length> – length of the segment in samples, marker samples do not count • <init_value> – optional initialization DAC value
Parameter Suffix	None
Description	Use this command to define the size of a waveform memory segment. If <init_value> is specified, all values in the segment are initialized. If not specified, memory is only allocated but not initialized.
Example	Commands Define a segment with id 1 and length 1280 samples on channel 1. Initialize all samples to 0. TRAC1:DEF 1,1280,0

4.16.4 :TRAC[1|2|3|4]:DEF:NEW?

Command	:TRAC[1 2 3 4]:DEF:NEW?
Long	:TRACe[1 2 3 4]:DEFine:NEW?
Parameters	<length> [,<init_value>] • <length> – length of the segment in samples, marker samples do not count • <init_value> – optional initialization DAC value
Parameter Suffix	None
Description	Use this query to define the size of a waveform memory segment. If <init_value> is specified, all values in the segment are initialized. If not specified, memory is only allocated but not initialized. If the query was successful, a new <segment_id> will be returned. This command is for compatibility with M8195A.
Example	Query Define a segment of length 1280 samples on channel 1. Returns the segment id. TRAC1:DEF:NEW? 1280

4.16.5 :TRAC[1|2|3|4]:DEF:WONL

Command	:TRAC[1 2 3 4]:DEF:WONL
Long	:TRACe[1 2 3 4]:DEFine:WONLy
Parameters	<segment_id>,<length>[,<init_value>] • <segment_id> – id of the segment • <length> – length of the segment in samples, marker samples do not count • <init_value> – optional initialization DAC value.
Parameter Suffix	None
Description	Use this command to define the size of a waveform memory segment. If <init_value> is specified, all values in the segment are initialized. If not specified, memory is only allocated but not initialized. The segment will be flagged write-only, so it cannot be read back or stored.
Example	Command Define a write-only segment with id 1 and length 1280 samples on channel 1. :TRAC1:DEF:WONL 1,1280

4.16.6 :TRAC[1|2|3|4]:DEF:WONL:NEW?

Command	:TRAC[1 2 3 4]:DEF:WONL:NEW?
Long	:TRACe[1 2 3 4]:DEFine:WONLy:NEW?
Parameters	<length>[,<init_value>] • <length> – length of the segment in samples, marker samples do not count • <init_value> – optional initialization DAC value
Parameter Suffix	None
Description	Use this query to define the size of a waveform memory segment. If <init_value> is specified, all sample values in the segment are initialized. If not specified, memory is only allocated but not initialized. If the query was successful, a new <segment_id> will be returned. The segment will be flagged write-only, so it cannot be read back or stored.
Example	Query Define a write-only segment with length 1280 samples on channel 1. Returns the segment Id. :TRAC1:DEF:WONL:NEW? 1280

4.16.7 :TRAC[1|2|3|4]:DATA[?]

Command	:TRAC[1 2 3 4]:DATA[?]
Long	:TRACe[1 2 3 4]:DATA[?]
Parameters	<segment_id>,<offset>,<length> <block> <numeric_values>) • <segment_id> – id of the segment • <offset> offset from segment start in samples (marker samples do not count) to allow splitting the transfer in smaller portions • <block> waveform data samples in the data format described above in IEEE binary block format • <numeric_values> waveform data samples in the data format described above in comma separated list format
Parameter Suffix	None
Description	Use this command to load waveform data into the module memory. If <segment_id> is already filled with data, the new values overwrite the current values. If length is exceeded error -223 (too much data) is reported.

This SCPI has the following syntax for command/query:

Command

:TRACe[1|2|3|4][:DATA] <segment_id>,<offset>,<block>|<numeric_values>

Query

:TRACe[1|2|3|4][:DATA][?] <segment_id>,<offset>,<length>

Example

Command

Load data consisting of 1280 samples as comma-separated list into previously defined segment 1 starting at sample offset 0.

:TRAC1:DATA 1,0,0,1,2,...,1279

Load data consisting of 1280 waveform data samples and same number of marker samples (interleaved waveform data and marker samples) as comma-separated list into previously defined segment 1 starting at sample offset 0.

:TRAC1:DATA 1,0,0,3,1,0,2,0,...,1279,0

The marker sample “3” corresponds to a high level for Marker 1 and 2 for the first sample of the waveform segment. Marker samples with value 0 correspond to a low level for Marker 1 and 2.

A marker value of 1 corresponds to high level for Marker 1 and low level for Marker 2.

A marker value of 2 correspond to low level for Marker 1 and high level for Marker 2.

Query

:TRAC:DATA? 1,0,1280

NOTE

If the segment is split in smaller sections, the sections have to be written in order of ascending <offset> values. If modification of the segment contents is necessary, the whole segment with all sections must be rewritten.

4.16.8 :TRAC[1|2|3|4]:IMP

Command

:TRAC[1|2|3|4]:IMP

Long

:TRACe[1|2|3|4]:IMPorT

Parameters

<segment_id>,<file_name>,TXT|BIN|BIN8|IQBIN|
BIN6030|BIN5110|MAT89600|DSA90000|CSV,IONLy|QONLy,ON|OFF|1|0,[ALENgtH|FI
LL][,<init_value>][,<ignore_header_parameters>]

File Format

Import segment data from a file. Different file formats are supported. An already existing segment can be filled, or a new segment can be created. This can be used to import real waveform data as well as complex I/Q data.

<segment_id> the number of the segment, into which the data will be written

<file_name> the complete path of the file.

TXT|BIN|BIN8|IQBIN|BIN6030|BIN5110|MAT89600|DSA90000|CSV. (See [File Type](#))

<data_type> IONLy|QONLy. This parameter is only used, if the file contains I/Q data.

<marker_flag> ON|OFF|1|0 (See [Marker Flag](#))

<padding> ALENgth|FILL (See [Padding](#))

<init_value> – optional initialization value. For non-I/Q format this is a DAC value. For I/Q file format this is the I-part or Q-part of an I/Q sample pair in binary format (int8). Defaults to 0 if not specified.

<ignore_header_parameters> ON|OFF|1|0 (See [Ignore Header Parameters](#))

File Type**TXT**

Compatibility: Keysight M8190A, Tek AWG 7000

One file contains waveform samples for one M8196A channel as normalized values (-1.0 .. +1.0) and (optionally marker values) separated by ‘,’ or ‘;’ or ‘\t’. Not given marker values are just set to 0. Space ‘ ’ and ‘\t’ are ignored. Line end can be \r or \r\n. The waveform samples can be imported to any of the four M8196A channels.

Example (US locale)

0.7,0,1

0.9,1

Example (German locale):

0,7;0;1

0,9;1

NOTE

In German locale it is recommended (but not required) to use ‘;’ or ‘\t’ as separator. But it must then be ensured that the double really has a decimal point (‘.’) or there is some space inserted to ensure correct parsing:

0,7,0,1

0 ,0,1

BIN

Compatibility: Keysight M8190A.

One file contains waveform samples for one channel. The waveform samples can be imported to any of the four M8196A channels. Samples consist of binary int16 values (in little endian byte order).

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
DB13	DB12	DB11	DB10	DB9	DB8	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0	SYNM	SMPM

When imported the MSBs DB13 to DB6 are used as 8-bit sample values. All other bits including marker bits SYNM and SMPM are ignored.

BIN8

BIN8 is the most memory efficient file format for the M8196A without digital markers. As a result, the fastest file download can be achieved. One file contains waveform samples for one channel. The waveform samples can be imported to any of the four M8196A channels. Samples consist of binary int8 values:

7	6	5	4	3	2	1	0
DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0

IQBIN

Compatibility: Keysight M8190A.
One file contains waveform samples for two M8190A channels plus optionally digital marker information.
Channel mapping
I is mapped to channel 1
Q mapped to channel 2
Sample Marker 1 is ignored
Sample Marker 2 is ignored

BIN6030

Compatibility: Keysight N6030
Binary int16 values (in little endian byte order). The Keysight N6030 has 15 bits and uses the most significant digits, ignoring the LSB. While importing, the 8 LSBs are used as sample values, all other bits are ignored.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
DB13	DB12	DB11	DB10	DB9	DB8	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0	X	X

BIN5110

Compatibility: Keysight 5110A
Binary int16 I/Q sample pairs (in little endian byte order). May contain full 16 bit DAC values without the marker bits or 14 bit value plus two markers.
When importing 16 bit values without markers the marker flag should be set to 'OFF' so that 8 LSB are ignored.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
I13	I12	I11	I10	I9	I8	I7	I6	I5	I4	I3	I2	I1	I0	X	SMPM
Q13	Q12	Q11	Q10	Q9	Q8	Q7	Q6	Q5	Q4	Q3	Q2	Q1	Q0	X	SYNM

MAT89600

Compatibility: Keysight 89600 VSA

One file contains waveform samples for one or two or three or four M8196A channels. It is a 89600 VSA recording file in MATLAB binary format (.mat) containing floating point values (without markers). Only MATLAB level 4.0 and 5.0 files are supported.

MATLAB binary files with one, two, three or four columns are supported. If the MATLAB file consists of one column, the data can be imported to channel 1 or channel 2 or channel 3 or channel 4. If it consists of multiple columns, column 1 can be imported to channel 1, column 2 to channel 2, column 3 to channel 3 and column 4 to channel 4.

If it consists of multiple columns, the handling depends on the number of available channels.

Four-channel mode: Column 1 can be imported to channel 1, column 2 to channel 2, column 3 to channel 3 and column 4 to channel 4,

Two-channel mode: Column 1 can be imported to channel 1, column 2 to channel 4. If column 2 is not present, column 4 can be imported to channel 4.

Both real and complex I/Q data formats are supported. For I/Q format the values are stored as array of complex numbers with the real part corresponding to I value and the imaginary part corresponding to Q value. The header variable 'XDelta' (1/XDelta) is used to set the currently selected sample frequency.

DSA90000

Compatibility: Keysight DSA90000 Oscilloscope

One file contains waveform samples for one M8196A channel. The waveform samples can be imported to any of the four M8196A channels.

DSA90000 waveform file in binary format (.bin) containing header and floating point data (without markers). Only waveform type 'Normal' is supported. If the file contains more than one waveform only the first waveform will be imported.

CSV

Compatibility: M8190A

One file contains waveform samples for one, two, three, or four M8196A channels.

Normalized values (-1.0 .. +1.0) and markers in comma delimited format. Without header information, the columns are pre-defined in the following way:

- 1 column: waveform data for channel 1
- 2 columns: waveform data for channel 1 & 2
- 3 columns: waveform data for channel 1 & 2 & 3
- 4 columns: waveform data for channel 1 & 2 & 3 & 4

If the file consists of one column, the data can be imported to channel 1 or channel 2 or channel 3 or channel 4. If it consists of multiple columns, the handling depends on the number of available channels.

Four-channel mode: Column 1 can be imported to channel 1, column 2 to channel 2, column 3 to channel 3 and column 4 to channel 4,

Two-channel mode: Column 1 can be imported to channel 1, column 2 to channel 4. If column 2 is not present (possible when a data header is used, see below), column 4 can be imported to channel 4.

Examples:

1 channel (without markers):

0.7

0.9

...

2 channel (without markers):

0.7,0.7

0.9,1.0

...

3 channels (without markers):

0.7,0.65,0.36

0.8,0.66,0.35

0.9,0.67,0.34

...

4 channels (without markers):

0.7,0.65,0.36,-0.1

0.8,0.66,0.35,-0.2

0.9,0.67,0.34,-0.33

...

The CSV format may contain optional header information as follows:

Parameter Header

The parameter header contains optional header parameters as name and value pairs separated by '='. Each parameter should be specified in a single line. This header is optional. There are following header parameters:

SampleRate

The sample rate.

SetConfig

Flag to indicate if the header parameters need to be set. This can be set to either 'true' or 'false'. If this flag is 'false' header parameters will not be set. If this flag is omitted header parameters are set.

Data Header

The data header contains the names of the data columns separated by ','. The waveform data are specified after the data header. This header is optional. If this header is not specified the data need to be defined similar to CSV files without the header (see above). The data columns are as follows:

Y1

Waveform data for channel 1.

Y2

Waveform data for channel 2.

Y3

Waveform data for channel 3.

Y4

Waveform data for channel 4.

SampleMarker1

Sample Marker for channel 2.

SampleMarker2

Sample Marker for channel 3.

Notes: If any of the marker columns (SampleMarker1 or Sample Marker2) is present for a channel the data header must contain the waveform data column (Y1 or Y2). It is possible to have only the data columns (Y1 , Y2, Y3, Y4 or any combination) without the marker columns though.

Examples:

SampleRate = 7.2 GHz

Y1, Y2, SampleMarker1, SampleMarker2

0.7,0.7,0,0

0.9,1.0,0,1

0.3,-0.3,1,1

...

Y1, SampleMarker1

0.7,0

0.9,1

0.3,0

...

Y1, SampleMarker1, SampleMarker2

0.7,0,0

0.9,0,1

0.3,1,1

...

Y1, Y2, Y4

0.7,0,65,0.36

0.8,0,66,0.35

0.9,0,67,0.34

...

Marker Flag	This flag is used to specify if the marker data need to be downloaded or not. If this flag is 'OFF' marker data will not be downloaded. Default value is 'ON'. This flag is applicable to BIN5110 format only. If BIN5110 format consists of full 16 bit DAC values (without markers) this flag should be set to 'OFF' so that 2 LSB's are ignored. Since M8196A does not support markers this flag should be set to 'OFF'.
Padding	ALENgth: Automatic LENgth : <segment_id> may or may not exist. After execution <segment_id> has exactly the length of the pattern in file or a multiple of this length to fulfill granularity and minimum segment length requirements. This behavior is default if <padding> is omitted. FILL: <segment_id> must exist. If pattern in file is larger than the defined segment length, just ignore excessive samples. If pattern in file is smaller than defined segment length, fill remaining samples with <init_value>. <init_value> defaults to 0 if it is not specified.
Ignore Header Parameters Flag	This flag is used to specify if the header parameters need to be set. If this flag is 'ON' header parameters will not be set. This flag is optional and the default value is 'OFF' i.e. by default the header parameters are set. This flag is applicable to formats (CSV and MAT89600) that contain header parameters.
Example	Command <pre>:TRAC1:IMP 1, "C:\Program Files (x86)\Keysight\M8196\Examples\WaveformDataFiles\ Sin10MHzAt64GHz.bin", BIN, IONLY, ON, ALEN</pre>

4.16.9 :TRAC[1|2|3|4]:DEL

Command	:TRAC[1 2 3 4]:DEL
Long	:TRACe[1 2 3 4]:DELeTe
Parameters	<segment_id> – id of the segment
Parameter Suffix	None
Description	Delete a segment. The command can only be used in program mode.
Example	Command <pre>:TRAC:DEL 1</pre>

4.16.10 :TRAC[1|2|3|4]:DEL:ALL

Command	:TRAC[1 2 3 4]:DEL:ALL
Long	:TRACe[1 2 3 4]:DELeTe:ALL
Parameters	None
Parameter Suffix	None
Description	Delete all segments. The command can only be used in program mode.
Example	Command :TRAC:DEL:ALL

4.16.11 :TRAC[1|2|3|4]:CAT?

Command	:TRAC[1 2 3 4]:CAT?
Long	:TRACe[1 2 3 4]:CATaLog?
Parameters	None
Parameter Suffix	None
Description	The query returns a comma-separated list of segment-ids that are defined and the length of each segment. So first number is a segment id, next length ... If no segment is defined, "0, 0" is returned.
Example	Query :TRAC1:CAT?

4.16.12 :TRAC[1|2|3|4]:NAME[?]

Command	:TRAC[1 2 3 4]:NAME[?]
Long	:TRACe[1 2 3 4]:NAME[?]
Parameters	<segment_id>,<name>
Parameter Suffix	None
Description	This command associates a name to a segment. The query gets the name for a segment. <segment_id> – the number of the segment <name> – string of at most 32 characters
Example	Command :TRAC:NAME 1, "ADY" Query :TRAC:NAME? 1

4.16.13 :TRAC[1|2|3|4]:COMM[?]

Command	:TRAC[1 2 3 4]:COMM[?]
Long	:TRACe[1 2 3 4]:COMMent[?]
Parameters	<segment_id>,<comment>
Parameter Suffix	None
Description	This command associates a comment to a segment. The query gets the comment for a segment. <segment_id> – the number of the segment <comment> – string of at most 256 characters
Example	Command :TRAC:COMM 1, "Comment" Query :TRAC:COMM? 1

4.16.14 :TRAC[1|2|3|4]:MARK[?]

Command	:TRAC[1 2 3 4]:MARK[?]
Long	:TRACe[1 2 3 4]:MARKer[?]
Parameters	OFF ON 0 1
Parameter Suffix	None
Description	Use this command to enable or disable markers. The query form gets the current marker state.
Example	Command :TRAC:MARK 1 Query :TRAC:MARK?

4.17 :TEST Subsystem

4.17.1 :TEST:PON?

Command	:TEST:PON?
Long	:TEST:PON?
Parameters	None
Parameter Suffix	None
Description	Return the results of the power on self-tests.
Example	Query :TEST:PON?

4.17.2 :TEST:TST?

Command	:TEST:TST?
Long	:TEST:TST?
Parameters	None
Parameter Suffix	None
Description	Same as *TST? but the actual test messages are returned.
Example	Query :TEST:TST?

NOTE

Currently same as :TEST:PON?

5 Examples

- 5.1 Introduction / 147
- 5.2 Remote Programming Examples / 147
- 5.3 Example Files for Import / 147
- 5.4 Example Correction Files / 148
- 5.5 Example Custom Modulation Files / 148

5.1 Introduction

In a standard installation the examples can be found in the folder “C:\Program Files (x86)\Keysight\M8196\Examples”.

5.2 Remote Programming Examples

The MATLAB IQtools are described in file “README.docx” in subfolder “MATLAB\iqtools”. The C++, C# and VB programs are provided as Visual Studio 2008 solutions. However, they can be easily converted to more recent Visual Studio versions. They show how to connect to the AWG, write a sine wave into the memory and start signal generation. They use the VISA or VISA-COM libraries.

5.3 Example Files for Import

The subfolder “WaveformDataFiles” contains examples for all supported import file formats. To import them use either the SFP Import Waveform panel or the SCPI command TRAC[1|2|3|4]:IMP.

5.4 Example Correction Files

The subfolder “CorrectionFiles” contains examples to be used in the SFP Multi-Tone and Complex Modulation panels.

5.5 Example Custom Modulation Files

The subfolder “CustomModulationFiles” contains examples to be used in the SFP Complex Modulation panel.

6 Appendix

6.1 Resampling Algorithms for Waveform Import / 149

6.1 Resampling Algorithms for Waveform Import

6.1.1 Resampling Requirements

Resampling is typically associated to a series of processes applied to a waveform sampled at a given sampling frequency to generate a new waveform with a different sampling rate while preserving all the original information contained in the signal within the Nyquist bandwidth corresponding to the output sampling rate. Processes involved in resampling may vary depending on the output to input sampling rate ratio (or resampling factor) and the integer nature of the ratio itself. Resampling calculations, when applied to arbitrary waveform generation, must meet additional constraints such as available record length boundaries, record length granularity requirements, or acceptable sampling rate range.

Typically, the characteristics of the input waveform (sampling rate, record length) are externally defined (i.e. by the horizontal settings of an oscilloscope used to capture the waveform). Users may be interested in resampling the signal to adapt the input waveform to the AWG requirements or the user desires. In some cases, it may be necessary to reduce the sampling rate if it has been captured at a higher sampling rate than the one allowed by the AWG or to reduce the record length required to generate it. The opposite is also true as oversampling may help to “smooth” the signal as increasing sampling rate will shift the images created by the DAC to a higher frequency. Finally, resampling may be also necessary to adapt the record length of the input waveform to a legal record length that can be applied to a real AWG (i.e. to meet the record length granularities) without applying truncation or “zero padding” to the input waveform.

6.1.2 Resampling Methodology

Generally speaking, resampling factors do not have to be an integer or a simple fractional ratio. Because of that, traditional methods based in upsampling/filtering/decimation techniques may not be suitable given the amount of calculations resulting from the typical input waveform sizes involved. Instead of this, a more straight forward approach has been chosen. This approach is based in the following principles:

- Only output samples will be calculated so there is not any up-sampling and/or down-sampling operations involved.
- Filtering calculations will be kept to a minimum by using a filter with a fast enough roll-off and sufficient stop band attenuation according to the target AWG dynamic range.
- Interpolation filter and anti-alias filters are exactly the same although the filter parameters will depend on the resampling parameters.
- The implemented algorithm does perform filtering and interpolation simultaneously so the number of calculations is greatly reduced. Additionally, filters are implemented as look-up tables so those are calculated only once during the process.
- Timing parameters are based in double precision floating-point numbers while amplitude related parameters are single precision numbers. Most calculations consist in multiplication/addition operations required by convolution processes and only involve amplitude related variables (input samples and filter coefficients). Single precision numbers will minimize calculation time while offering more than enough dynamic range.

Interpolators and anti-aliasing filters share most characteristics as they are required to be low-pass with good flatness, linear phase, fast roll-off, and high stop-band rejections ratio. Ideal interpolator filters show a “brick-wall” response. However, such filters require a very long “sinc-like” impulse response to obtain good-enough performance. Impulse response length has a direct effect on calculation times resulting of applying the filter. Roll-off characteristics are especially important when applying the filter as the anti-alias filter required for down-sampling. The filter implemented in these algorithms has been designed with the following objectives:

- Pass band flatness better than 0.01 dB
- Stop band attenuation better than 80 dB
- F80dB/F3dB ratio better than 1.15

The final filter consists in a sinc signal with a 41 sample periods length after applying a Blackman-Harris time-domain window.

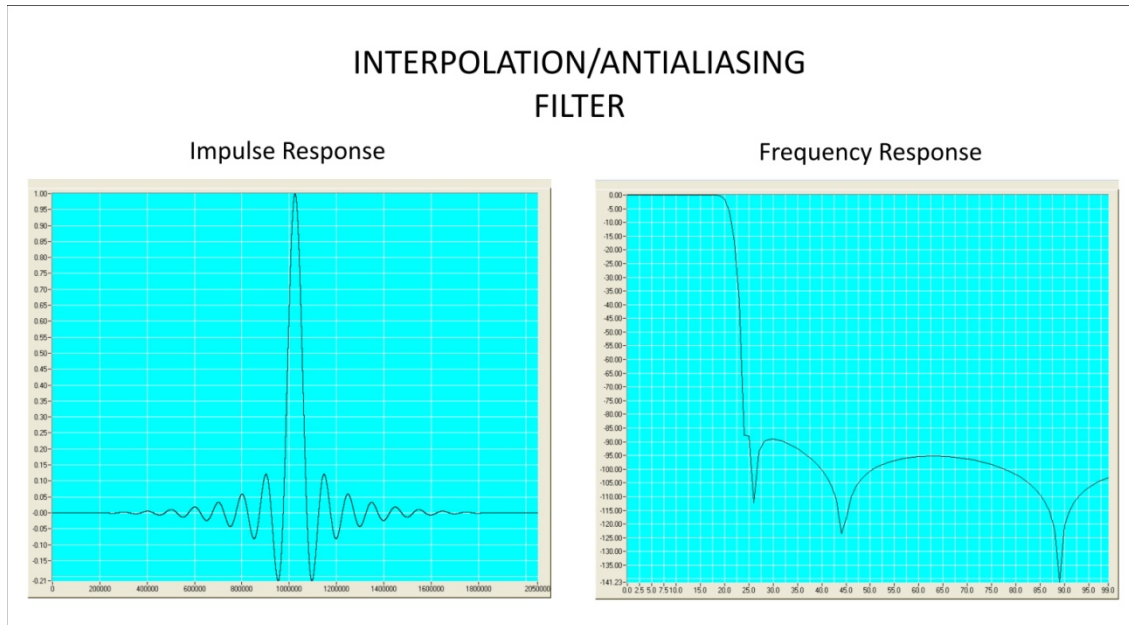


Figure 21: Interpolation/Antialiasing filter

The filter shape remains the same no matter the resampling characteristics. For resampling ratios greater than 1.0, filter will implement an interpolator so nulls in the impulse response must be located at multiples of the sampling period of the input signal. For ratios lower than 1.0 the filter will implement an antialiasing filter. In this case, distance between nulls will have to be longer than the output waveform sampling period so the filter reach the required attenuation (>80dB) at the output signal Nyquist frequency. For the implemented filter this is accomplished by choosing 0.89 ratio between the output sampling period and the distance between consecutive nulls in the filter's impulse response.

