Keysight Technologies

M8196A 92 GSa/s Arbitrary Waveform Generator

Data Sheet

Version 2.1

M8196A in a 2-slot AXIe chassis

M8196A at a Glance

The Keysight Technologies, Inc. M8196A arbitrary waveform generator (AWG) has the highest sample rate and the widest bandwidth in its class with up to four synchronized channels operating simultaneously on one module.

- Sample rate up to 92 GSa/s (on up to 4 channels simultaneously)
- Analog bandwidth: 32 GHz (typical)
- 8 bits vertical resolution
- 512 kSa of waveform memory per channel
- 1, 2, or 4 differential channels per 1-slot AXIe module (number of channels is software upgradeable)
- Amplitude up to 1 Vpp(se) (2 Vpp(diff.)), voltage window –1.0 to +2.5 V
- $t_{rise/fall}$ (20%/80%) < 9 ps (typical)
- Ultra-low intrinsic jitter
- Built-in frequency and phase response calibration for clean output signals

Coherent Optical Applications

200G, 400G and 1 Terabit applications demand a new class of generators that provide high speed, precision and flexibility at the same time.

The M8196A is also ideally suited to address multi-level/multi-channel interfaces using any standard or custom data format, such as PAM-n (n = 3,4,5,...). The M8196A supports pattern lengths up to PRBS 2^{15-1} and baud rates up to 64 GBaud, including the necessary parameter changes, such as variable transition times, various pulse-shaping filters, adding distortions, and will also generate PAM-n signals with non-equidistant voltage levels.

With up to 4 channels per 1-slot AXIe module, each running at up to 92 GSa/s with 32 GHz of analog bandwidth, it allows dual polarization testing in a small form factor and the generation of complex signals with multiple modulation schemes (PAM-4,PAM-8, QPSK, nQAM) up to an outstanding speed of 64 GBaud and beyond.

Compensation for distortions generated e. g. by cables and amplifiers can be realized by embedding/de-embedding the S-parameters of the respective circuits or by performing an in-situ calibration using the Keysight Technologies vector signal analysis software.

Combined with the 81195A optical modulation generator software, the M8196A makes it easy to generate optical impairments (e.g. PMD) for stressing the optical receiver over multiple test scenarios.

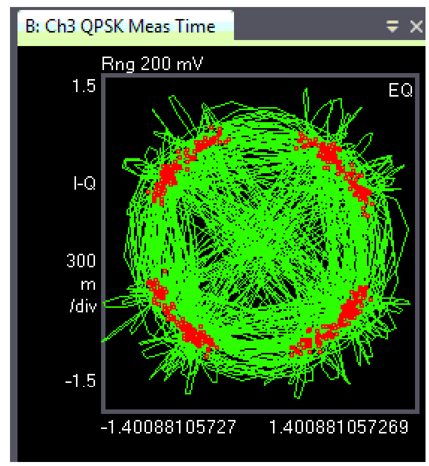


Figure 1. QPSK signal with emulated phase noise

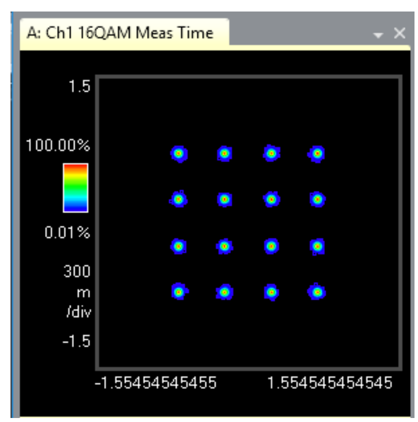


Figure 2. QAM16 at 64 GBaud

Multi-Level/Multi-Channel Digital Signals

The M8196A is also ideally suited to address multi-level/multi-channel interfaces using any standard or custom data format, for example high-speed backplane connections using PRBS pattern, can reach a pattern size upto $1x10^{-13}$. Other pattern methodology also available such as PAM-4 or PAM-8 format, as well as technologies in the mobile application space.

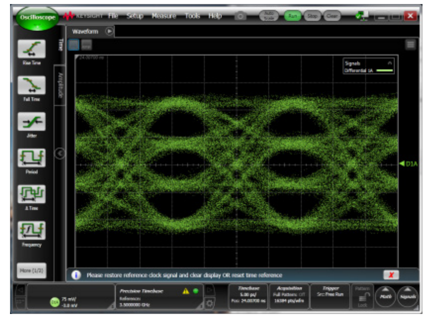


Figure 3. PAM-4 signal at 56 GBaud

The flexibility of the waveform generation at its highest speeds, combined with excellent intrinsic jitter performance makes the M8196A a truly future-proof instrument.

At data rates of multiple Gb/s, the effect of cables, board traces, and connectors etc. has to be taken into account in order to generate the desired signal at the test point of the device under test. The M8196A incorporates digital pre-distortion techniques for frequency- and phase-response compensation of the AWG output and any external circuit to generate the desired signal at the device under test. Channels can be embedded/de-embedded if the S-parameters of the respective circuits are provided.

In conjunction with the 81195A optical modulation generator software various kinds of distortions can be added to the signal.

The M8196A is now fully integrated into the M8070A BER System controller software. With its high channel density, it is well suited as an affordable pattern generator for multi-lane high-speed interfaces or as SI/RI source in conjunction with M8020A/ M8040A.

Physics, Chemistry and Electronics Research

With the M8196A AWG it is possible to generate any arbitrary waveform you can mathematically describe and download it directly to the M8196A. This includes ultra-short yet precise pulses down to 20 ps pulse width or extremely short, yet wideband RF pulses and chirps which are needed to investigate in live time chemical reactions and elementary particle excitation.

Figure 4. Emulation of chirps

Configuration

Product

Product number	Description	Comment
M8196A-001	Arbitrary waveform generator module 1 channel, 92 GSa/s, 512 kSa per channel	Including local start-up assistance and one 50 Ω termination for each channel
M8196A-002	Arbitrary waveform generator module 2 channels, 92 GSa/s, 512 kSa per channel	
M8196A-004	Arbitrary waveform generator module 4 channels, 92 GSa/s, 512 kSa per channel	
M8196A-BU2	Pre-configured system consisting of one M9505A 2-slot AXIe Chassis with USB Option	
M8196A-BU3	Pre-configured system consisting of one M9505A 2-slot AXIe Chassis with USB Option and one M9537A AXIe Embedded PC Controller	

Upgrade options

Product number	Description	Comment
M8196AU-U02	Upgrade from 1 channel to 2 channels	Software license
M8196AU-U04	Upgrade from 2 channels to 4 channels	Software license

Accessories

In order to be operational, an AXI chassis plus either an embedded controller or external PC or laptop are required in addition to one or more M8196A modules:
(See http://www.keysight.com/find/AXIe for more details)

Product number	Description	Comment
M9502A-U20	2-slot AXIe chassis with USB Option	
M9505A-U20	5-slot AXIe chassis with USB Option	
M9537A	AXIe embedded controller	
8121-1243	Cable assembly USB Type A-MINI B	
M9048A	PCIe® desktop card adapter Gen 2 x8	
Y1202A	PCIe cable for M9048A desktop adapter	
M8196A-810	Matched cable pair for M8196A AWG, 2.4 mm	
M8196A-820	Termination 50 Ω, 2.4 mm	

Software

Product number	Description	Comment
81195A	Optical Modulation Generator Software	Free to download
81195A-OSP	Optical Signal Properties	requires 81195A
M8070A-0TP	System Software for M8000 Series of BER Test Solutions, Transportable, Perpetual License	
M8070A-0NP	System Software for M8000 Series of BER Test Solutions, Network/Floating, Perpetual License	
M8070A-1TP	DUT Control Interface, Transportable, Perpetual License	
M8070A-1NP	DUT Control Interface, Network/Floating, Perpetual License	
N6171A-M02	MATLAB license (standard)	
N6171A-M03	MATLAB license (extended)	

Specifications

The following specifications are only valid with reference clock signal generated by internal synthesizer.

General characteristics

Sample rate	82.24 to 92 GSa/s
DAC resolution	8 bits
Number of channels per M8196A module	1, 2, or 4 (corresponds to Opt. 001, 002, and 004) Additional number of channels can be enabled via user-installable software license

Sample memory

Sample memory	512 kSa per channel. The waveforms in each channel can have different length
Waveform granularity	128 samples. The length of waveform segments must be a multiple of the granularity
Minimum waveform length	128 samples

Out 1, 2, 3, 4

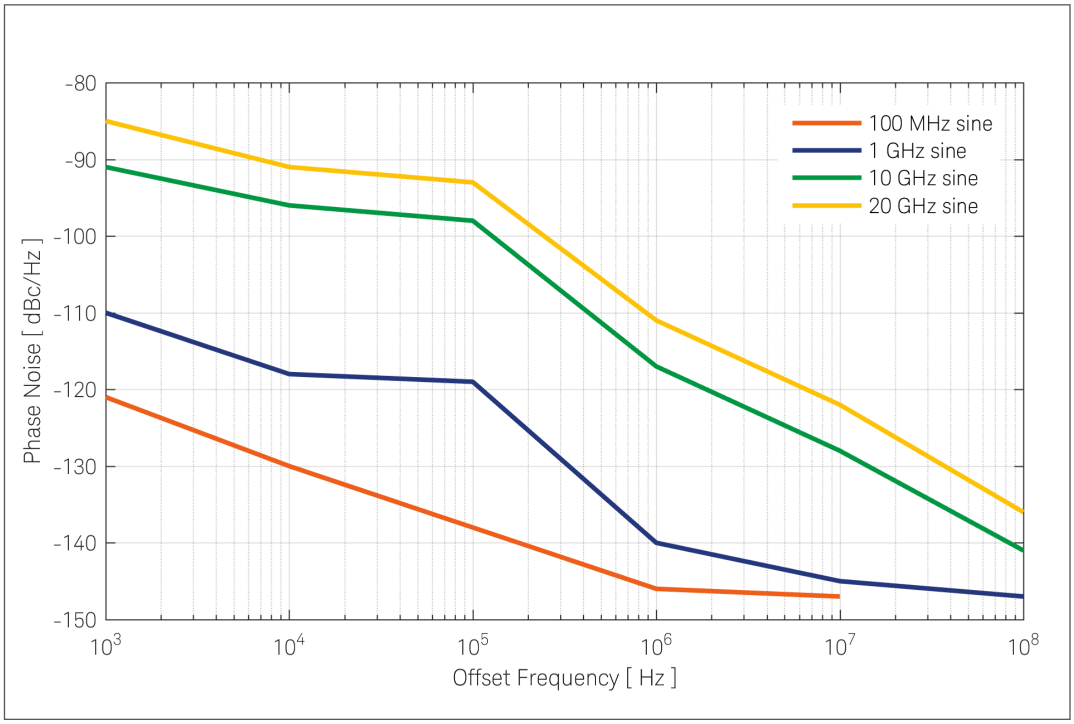
Output type	Single-ended[1] or differential
Analog bandwidth (3 dB, excl. sin(x)/x roll-off)	32 GHz (typ)
Rise/fall time (20%/80%)[2, 3]	9 ps (typ) corrected[2] 14 ps (typ) uncorrected
Impedance	50 Ω (nom)
Amplitude	75 $mV_{pp(se)}$ to 1 $V_{pp(se)}$ into 50 Ω 150 $mV_{pp(diff.)}$ to 2 $V_{pp(diff.)}$ into 50 Ω
Amplitude resolution	400 µV (nom)
DC amplitude accuracy[3]	±(2.5% +10 mV) (typ)
Voltage window	–1.0 to +2.5 V single-ended into 50 Ω
Offset resolution	400 µV (nom)
DC offset accuracy[4]	±20 mV (typ)
Differential offset	Adjustable
Termination voltage window	–1.5 to + 3.5 V (low level –500 mV) to (high level + 500 mV)
Termination voltage resolution	300 µV (nom)
Skew between any pair of outputs	0 ps ±7 ps (typ)
Skew between normal and complement	0 ps ±3 ps (nom)
Total Jitter, with pre-distortion	4 ps (pp) at 32 Gb/s PRBS (typ)[8]
Random jitter, RMS[7]	130 fs (typ)
Phase noise (f_{Sa} = 92 GHz)	< –115 dBc/Hz (typ) at 10 kHz offset, f_{out} = 1 GHz < –95 dBc/Hz (typ) at 10 kHz offset, f_{out} = 10 GHz
Harmonic distortions[5,6]	
2nd harmonic	–50 dBc (typ), f_{out} < 2 GHz, –45 dBc (typ), f_{out} = 2 GHz ... 4.5 GHz –38 dBc (typ), f_{out} = 4.5 GHz ... < 8 GHz –30 dBc (typ), f_{out} > 8 GHz
3rd harmonic	–45 dBc (typ), f_{out} < 2 GHz, –37 dBc (typ), f_{out} = 2 GHz ... 4.5 GHz –32 dBc (typ), f_{out} > 4.5 GHz
Two-tone IMD[6]	–47 dBc (typ), f_{out1} = 990 MHz, f_{out2} = 1010 MHz

SFDR[5] (excluding harmonic distortions)	
In-band	–73 dBc (typ), f_{out} = DC...400 MHz, measured DC to 400 MHz –57 dBc (typ), f_{out} = DC...4 GHz, measured DC to 4 GHz –58 dBc (typ), f_{out} = 4 GHz...6 GHz, measured 4 GHz to 6 GHz –54 dBc (typ), f_{out} = 6 GHz...8 GHz, measured 6 GHz to 8 GHz –60 dBc (typ), f_{out} = 8 GHz...10 GHz, measured 8 GHz to 10 GHz –43 dBc (typ), f_{out} = 10 GHz...12 GHz, measured 10 GHz to 12 GHz –53 dBc (typ), f_{out} = 12 GHz...14 GHz, measured 12 GHz to 14 GHz –46 dBc (typ), f_{out} = 14 GHz...16 GHz, measured 14 GHz to 16 GHz –54 dBc (typ), f_{out} = 16 GHz...18 GHz, measured 16 GHz to 18 GHz –53 dBc (typ), f_{out} = 18 GHz...20 GHz, measured 18 GHz to 20 GHz –50 dBc (typ), f_{out} = 20 GHz...22 GHz, measured 20 GHz to 22 GHz –35 dBc (typ), f_{out} = 22 GHz...24 GHz, measured 22 GHz to 24 GHz –48 dBc (typ), f_{out} = 24 GHz...26 GHz, measured 24 GHz to 26 GHz –53 dBc (typ), f_{out} = 26 GHz...28 GHz, measured 26 GHz to 28 GHz –53 dBc (typ), f_{out} = 28 GHz...30 GHz, measured 28 GHz to 30 GHz –39 dBc (typ), f_{out} = 30 GHz...32 GHz, measured 30 GHz to 32 GHz
Adjacent band	–57 dBc (typ), f_{out} = DC...4 GHz, measured DC to 8 GHz –58 dBc (typ), f_{out} = 4 GHz...6 GHz, measured 3 GHz to 8 GHz –54 dBc (typ), f_{out} = 6 GHz...8 GHz, measured 4 GHz to 10 GHz –53 dBc (typ), f_{out} = 8 GHz...10 GHz, measured 6 GHz to 12 GHz –43 dBc (typ), f_{out} = 10 GHz...12 GHz, measured 8 GHz to 14 GHz –39 dBc (typ), f_{out} = 12 GHz...14 GHz, measured 10 GHz to 16 GHz –46 dBc (typ), f_{out} = 14 GHz...16 GHz, measured 12 GHz to 18 GHz –53 dBc (typ), f_{out} = 16 GHz...18 GHz, measured 14 GHz to 20 GHz –48 dBc (typ), f_{out} = 18 GHz...20 GHz, measured 16 GHz to 22 GHz –40 dBc (typ), f_{out} = 20 GHz...22 GHz, measured 18 GHz to 24 GHz –35 dBc (typ), f_{out} = 22 GHz...24 GHz, measured 20 GHz to 26 GHz –37 dBc (typ), f_{out} = 24 GHz...26 GHz, measured 22 GHz to 28 GHz –46 dBc (typ), f_{out} = 26 GHz...28 GHz, measured 24 GHz to 30 GHz –45 dBc (typ), f_{out} = 28 GHz...30 GHz, measured 26 GHz to 32 GHz –36 dBc (typ), f_{out} = 30 GHz...32 GHz, measured 28 GHz to 34 GHz
Amplitude flatness (at RF output connector, compensated for sin(x)/x)[9]	±1 dB (typ), f_{out} = DC ... 10 GHz ±2 dB (typ), f_{out} = 10 GHz ... 25 GHz ±3 dB (typ), f_{out} = 25 GHz ... 32 GHz
Total Harmonic Distortion[5,6]	0.5% (typ), f_{out} = 1GHz 0.7% (typ), f_{out} = 2 GHz 1.3% (typ), f_{out} = 5 GHz 2.2% (typ), f_{out} = 10 GHz
Connector type	2.4 mm (female)

1. Unused output must be terminated with 50 Ω to GND.
2. Frequency response correction up to 43 GHz
3. Termination voltage = 0 V; adjusted at 23°C ambient temperature, amplitude increases by 0.4%/°C (typical) for ambient temperature below 23°C
4. Termination voltage = 0 V
5. Sample rate 92 GSa/s, output amplitude 500 mV_{pp}(se)
6. Measured with a balun (e.g. HL9405)
7. 9 GHz clock; 1 V ampl.; 90 GSa/s
8. at BER 10^{-12}, 32 Gb/s, $PRBS^{15}$, RC=1.0, 1 V_{pp}, measured with Keysight 86100D DCA
9. measured at DATA OUT

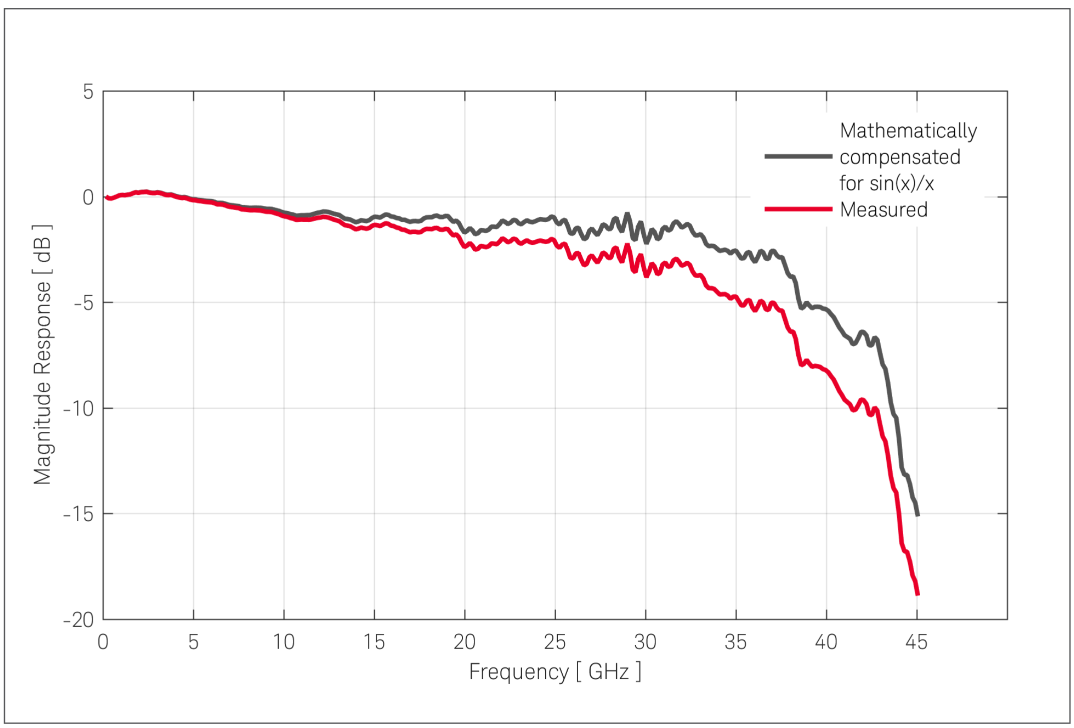
Phase noise

Phase noise measured with a sample rate of 92 GSa/s, single-ended, 500 mV amplitude, with internal synthesizer.



Frequency response

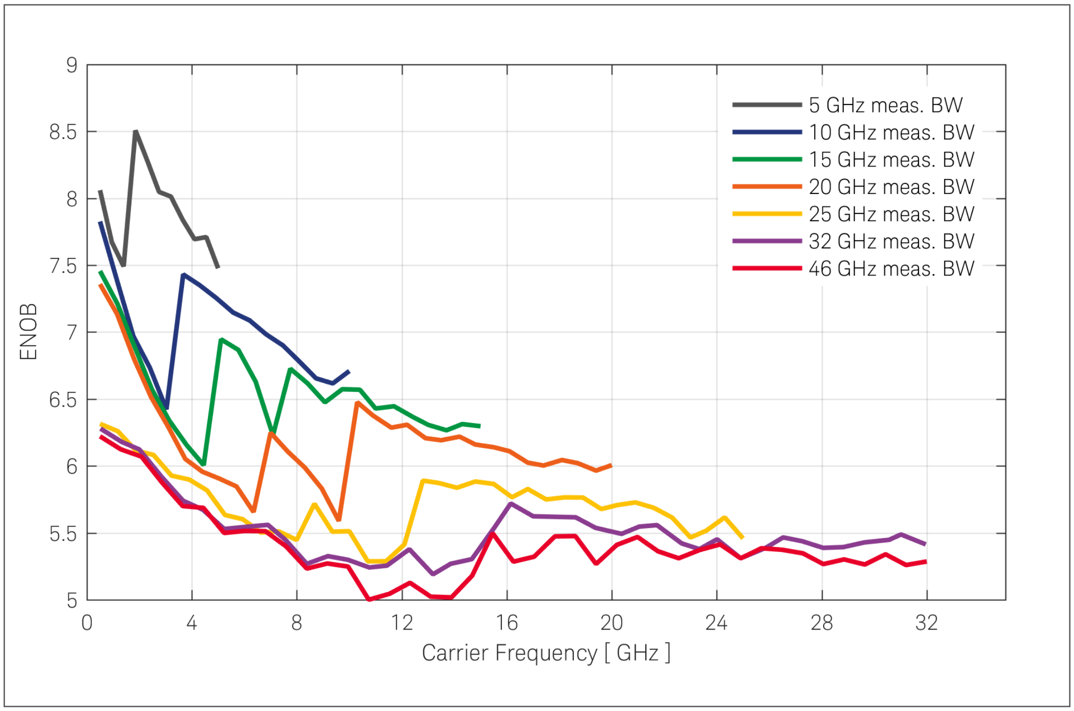
Frequency response measured with a sample rate of 92 GSa/s, single ended, 500 mV amplitude and a multi-tone signal containing frequencies from DC to 45 GHz with equal amplitudes.



ENOB

Effective Number of Bits measured according to IEEE 1658-2011. Noise and distortions are considered up to the respective bandwidth.

The measurement is performed on a differential signal combined by a balun with a sample rate of 92 GSa/s, internal clock and 500 mV single ended (1 V differential) amplitude at different bandwidths.



Marker

Two independent digital markers are available in single channel with markers and dual channel with markers mode. They are provided on channel 2 and 3 on normal and complement. In 4-channel mode no markers are available.

Markers do not reduce vertical resolution. The granularity of markers is one sample.

Run modes

Continuous	One waveform segment is continuously repeated
Triggered	One waveform segment is looped continuously after a trigger event is received

Trigger input

A trigger input is provided on the front panel of the M8196A.

Input Range	–4 V to +4 V
Threshold	
Range	–4 V to +4 V (typ)
Resolution	10 mV (nom)
Sensitivity	100 mV (typ)
Polarity	Selectable, positive or negative, either edge
Timing Uncertainty	8 ns (typ)
Trigger Latency	5.32 µs (typ)
Connector Type	SMA (female)

Variable Delay

The output channels can be jointly delayed with respect to the reference clock signal with high resolution. This can be used to align the M8196A outputs to external equipment, e.g. other M8196A modules.

Delay Range	0 to 10 µs
Delay Resolution	50 fs
Delay Accuracy	±10 ps (typ)

Reference clock input

A clock reference input is provided on the front panel of the M8196A and used as the clock reference for all four channels of that M8196A. Operation of M8196A requires a clean reference clock signal.

Input frequency ranges[11]	
Range 10 MHz to 300 MHz	Sample Rate 82.24 GHz to 93.4 GHz, adjustable
Range 162 MHz to 17 GHz	Sample Rate 82.24 GHz to 93.4 GHz, adjustable
Range 2.32 GHz to 3.0 GHz	Sample Rate 74 GHz to 96 GHz, fixed to 32x input frequency
Lock range	±1% (typ)
Input level	
10 MHz - 10 GHz 10 GHz - 17 GHz	250 mV_{pp} to 2 V_{pp} 500 mV_{pp} to 2 V_{pp}
Impedance	50 Ω (nom)
Connector	SMA (female)
Sample clock frequency resolution	1 ppm[10]

10. e.g. sample clock frequency = 92 GHz ≥ frequency resolution = 92 kHz
11. DAC operation only specified from 82.24 GSa/s to 92 GSa/s

Reference clock output

Source: Backplane	
Output frequency	$f_{out} = f_{Sa}$ / (32 * n) with n = 1 to 1024 or $f_{out} = f_{Sa}$ / 256
Frequency accuracy	±20 ppm
Source: Internal	
Output frequency	$f_{out} = f_{Sa}$ / (32 * n) with n = 1 to 1024 or $f_{out} = f_{Sa}$ / 256 or f_{out} = 100 MHz
Frequency accuracy	±2 ppm
Source: Reference Clock Input of M8196A	
f_{in} = 10 to 300 MHz	$f_{out} = f_{Sa}$ / (n * m) with n,m = 1 to 8
f_{in} = 2.570 to 2.920 GHz	$f_{out} = f_{in}$ / 8
f_{in} = 210 MHz to 17 GHz	$f_{out} = f_{Sa}$ / (32 * n) with n = 1 to 1024 or $f_{out} = f_{Sa}$ / 256
Output amplitude	0.9 V_{pp} (typ) up to 300 MHz, 0.4 V_{pp} (typ) up to 2.875 GHz into 50 Ω
Source impedance	50 Ω (nom), AC coupled
Connector	SMA (female)

Internal synthesizer clock characteristics

Frequency[11]	82.24 to 93.4 GHz
Accuracy	±2 ppm
Resolution	7 digits (for example: 9 kHz at 90 GHz)

Download speed

	USB using SCPI	PCIe using SCPI
Download Speed	~80 kSa/s (meas)	~1.6 MSa/s (meas)

Note: Loading 4 channels waveform memory requires 2 MSa download

Instrument software

The M8196A is controlled by a combined soft-front panel and firmware application that runs on an embedded AXIe controller or external PC or laptop.

Supported operating systems	Windows 7 (32 or 64 bit), Windows 8 / 8.1 (32 or 64 bit), Windows 10 (32 or 64 bit)
Required hard disk space	1 Gb
Interface to M8196A hardware	PCI Express® or USB
Application programming interfaces	SCPI, IVI-COM, LabView

General

Power consumption	50 W (nom) at 92 GSa/s
Operating temperature	0 to 40°C
Operating humidity	5% to 80% relative humidity, non-condensing
Operating altitude	Up to 2000 m
Storage temperature	–40 to +70°C
Stored states	User configurations and factory default
Interface to controlling PC	PCIe (see AXIe chassis specification) USB (see AXIe chassis specification)
Form factor	1-slot AXIe
Dimensions (W x H x D)	322.25 mm x 30 mm x 281.5 mm
Weight	3.15 kg
Safety designed to	IEC61010-1, UL61010, CSA22.2 61010.1 tested
EMC tested to	IEC61326
Warm-up time	30 min
Calibration interval	2 years recommended
Cooling requirements	When operating the M8196A choose a location that provides at least 80 mm of clearance at rear, and at least 30 mm of clearance at each side

Definitions

Specifications

The warranted performance of a calibrated instrument that has been stored for a minimum of two hours within the operating temperature range of 0 to 40°C and after a 45-minute warm-up period. All specifications include measurement uncertainty and were created in compliance with ISO-17025 methods.

Typical (typ)

The characteristic performance, which 80% or more of manufactured instruments will meet. This data is not warranted, does not include measurement uncertainty, and is valid only at room temperature (approximately 23°C).

Nominal (nom)

The mean or average characteristic performance, or the value of an attribute that is determined by design such as a connector type, physical dimension, or operating speed.
This data is not warranted and is measured at room temperature (approximately 23°C).

Measured (meas)

An attribute measured during development for purposes of communicating the expected performance. This data is not warranted and is measured at room temperature (approximately 23°C).

Accuracy

Represents the traceable accuracy of a specified parameter. Includes measurement error and timebase error, and calibration source uncertainty.

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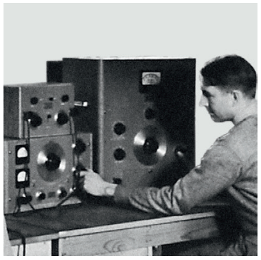
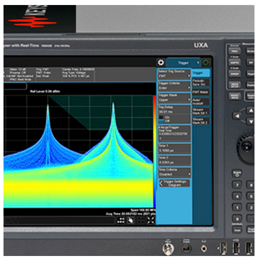


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