M8199B 256 GSa/s Arbitrary Waveform Generator

Version 1.2

Introduction

The M8199B is an arbitrary waveform generator that provides R&D engineers a high-performance signal source for arbitrary signals, enabling development of designs of 160 GBaud and above.



KEYSIGHT

Key Benefits

- Up to 8 synchronized channels at 256 GSa/s with nominal **analog bandwidth exceeding 80 GHz**
- Provides R&D engineers a high-performance signal source for arbitrary signals, enabling development of designs **of higher-order QAM (e.g., 64QAM) at 160 GBaud and above**
- First arbitrary waveform generator enabling **400+ Gb/s per lane in IM/DD** or **1.6+ Tb/s per carrier in coherent optical communications**
- Integrated, ready-to-use instrument, works with M8008A clock module
- Operates with well-known software, including MATLAB, Keysight IQtools, and SCPI programming interfaced based on M8070B

M8199B at a Glance

The Keysight M8199B arbitrary waveform generator (AWG) has the highest sample rate and the widest bandwidth in its class with up to eight synchronized channels operating simultaneously.

- Analog bandwidth exceeding 80 GHz
- Up to 2 Vpp differential output voltage at 160 GBaud
- Continuous sample rate range: 200 to 256 GSa/s
- Channel-to-channel skew adjustment with 25 fs resolution
- < 140 dBc wideband phase noise > 1 MHz
- 1 MSa of waveform memory per channel
- Synchronization of up to 8 channels across 4 modules
- Built-in frequency and phase response calibration for clean output signals

Applications

Coherent optical applications

Applications beyond 128 GBaud demand a new class of generators that provide high speed, precision, and flexibility at the same time. The M8199B is the ideal solution to test various optical systems from discrete components like optical power amplifiers to more complex dual polarization systems such as optical modulators or optical receivers. The M8199B also provides stress signals to test next generator digital signal processor ASICs and new algorithm concepts.

Distortions generated (e.g., by cables and amplifiers) can be compensated 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.

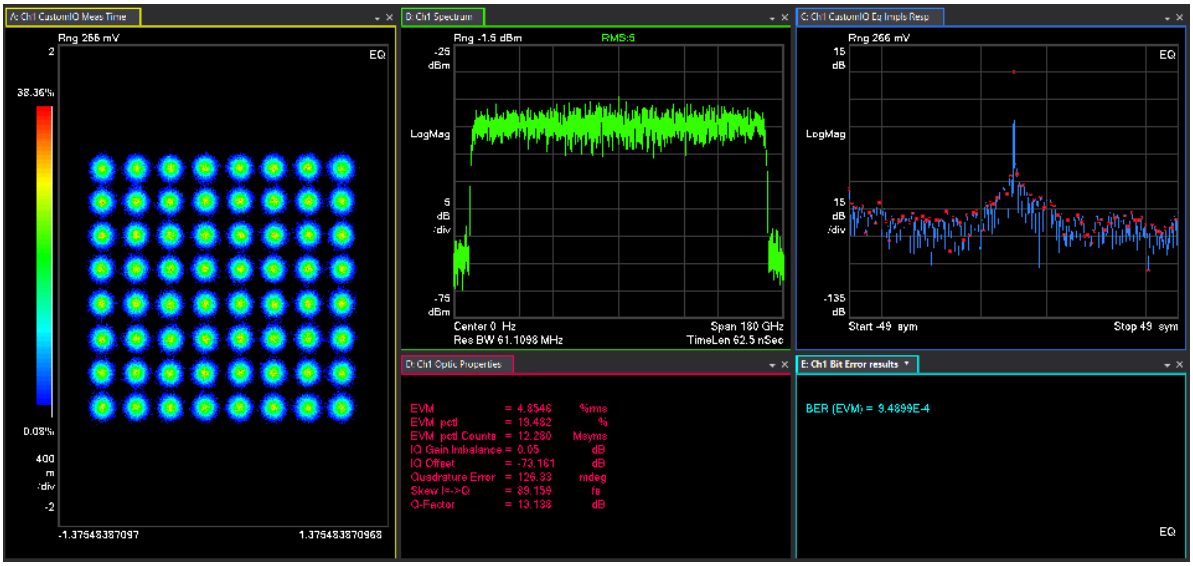


Figure 1. 64QAM at 160 GBaud (1.92 Tb/s using a 4-channel system)

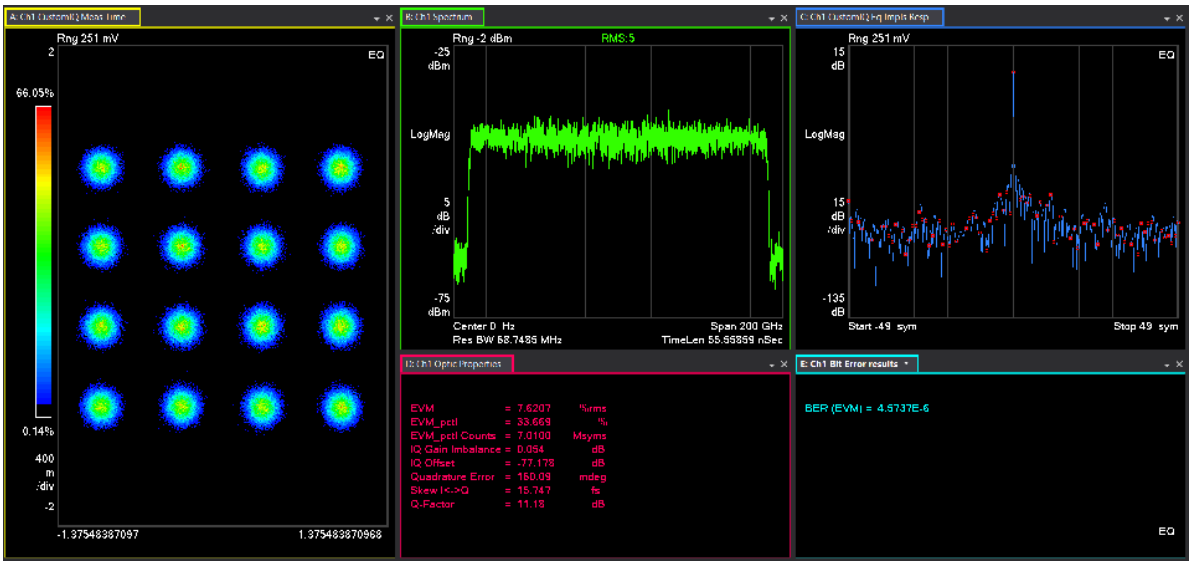


Figure 2. 16QAM at 180 GBaud (1.44 Tb/s using a 4-channel system)

Intensity-Modulation/Direct-Detect (IM/DD) optical applications

With increasing data rates in servers and computers, the trace loss increases, which reduces the signal-to-noise ratio, therefore, standard modulation formats, such as NRZ and PAM-4, may not be sufficient. The M8199B is the right tool for these applications to provide the flexibility needed for advanced research on new modulation formats to boost transmission rates to the next level. For example, high-speed research is already experimenting using PAM-3, PAM-6, PAM-8, and other proprietary modulation formats at data rates of 160 GBaud and beyond.

The flexibility of the waveform generator with high speeds, combined with excellent intrinsic jitter performances makes the M8199B a truly unique and versatile instrument.

At data rates of multiple Gb/s, the effects of cables, board traces, connectors, etc., must be considered in order to generate the desired signal at the test point of the device under test. The M8199B incorporates digital correction 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.

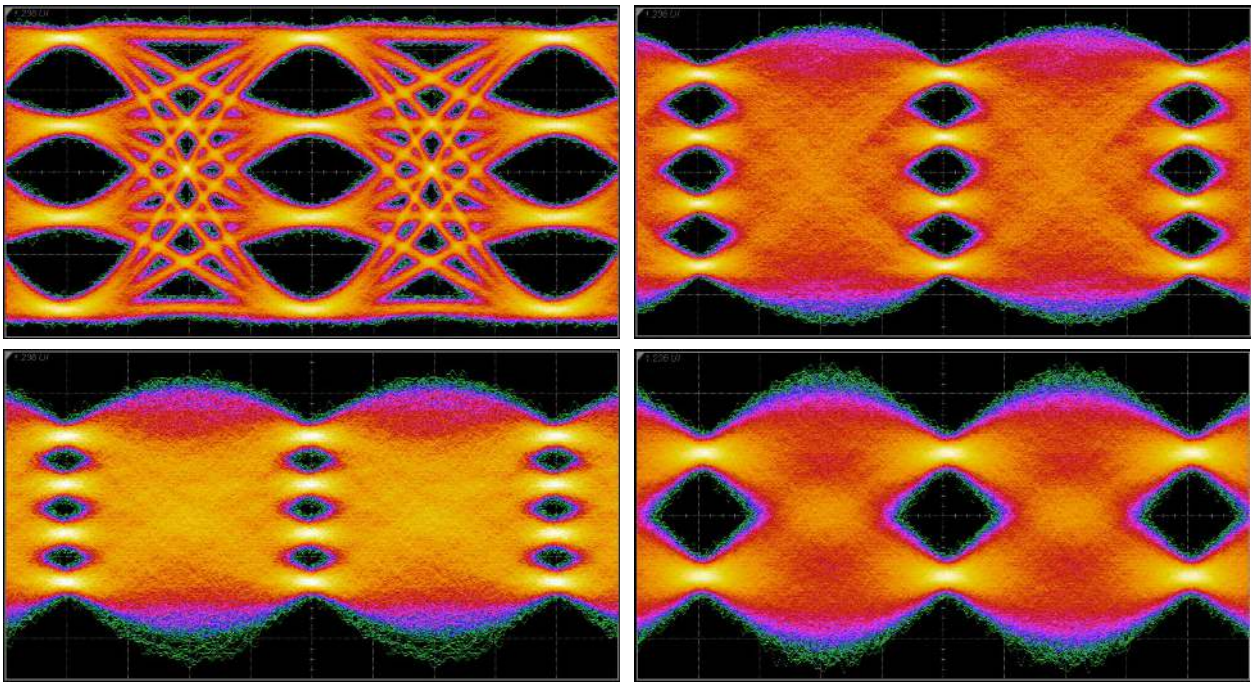


Figure 3. PAM-4 at 112 GBaud (224 Gb/s) on the top-left, PAM-4 at 160 GBaud (320 Gb/s) on the top-right, PAM-4 at 200 GBaud (400 Gb/s) on the bottom-left, NRZ at 200 GBaud (200 Gb/s) on the bottom-right

Wideband RF signal generation in wireless and aerospace/defense applications

The latest developments in radar and wireless technologies require signals with modulation bandwidths beyond 10 GHz, in some cases up to 30 GHz, with good signal quality. Generating those signals on an IF rather than I/Q is another important capability to support these applications.

With samples rates of 256 GSa/s, the M8199B has enough oversampling gain to generate extremely broad bandwidth, yet high fidelity RF signals.

Physics, chemistry, and general-purpose electronics research

The M8199B AWG allows users to generate any arbitrary waveform that can be mathematically described. For example, a signal calculated in Python or MATLAB can be downloaded directly into the M8199B. This includes ultra-short, yet precise pulses down to 5 ps pulse width or extremely short, wideband RF pulses and chirps which are needed to investigate in applications such as chemical reactions, elementary particle excitation, and quantum effects.

Software

The M8199B is controlled by the M8070B systems application software. In addition, the MATLAB based utility IQtools is included with the instrument software. IQtools provides a large number of waveform generation functionalities as well as an option to download user-defined waveforms. IQtools also supports “in-system calibration” to measure and compensate the frequency and phase response of the AWG and any external circuitry.

Hardware

Clocking and multi module operation

The M8199B has a single sample clock input connector that drives the 2 channels. The sample clock signal must be provided from a M8008A clock module. The M8008A clock module can drive up to four M8199B AWG modules, hence up to 8 fully synchronized channels at 256 GSa/s.

Front panel connections



Figure 4. M8199B Front Panel

- **Data Out, Data Out** – differential AWG output channels (1 mm female connectors)
- **Sync In** – connected to Sync Out of the M8008A clock module
- **Sample Marker Out** – differential sample marker output
- **Sync Marker Out A/B** – two single ended sync marker outputs
- **Clk In** – Sample clock input, connected to Clock Out of M8008A clock module
- **LB In, LB Out** – reserved for future use

Configuration

Product numbers	Description	Comments
M8199B-001	Arbitrary waveform generator module, 1 channel, 256 GSa/s, 2-slot AXIe module	Number of channels from 1 to 2 is upgradeable with the option M8199BU-U02
M8199B-002[1]	Arbitrary waveform generator module, 2 channel, 256 GSa/s, 2-slot AXIe module	
M8199B-S01	Arbitrary waveform generator module, 1 channel, 224 GSa/s, 2-slot AXIe module	Number of channels from 1 to 2 is upgradeable with the option M8199BU-U02
M8199B-S02[1]	Arbitrary waveform generator module, 2 channel, 224 GSa/s, 2-slot AXIe module	
M8008A-064	Clock generator 32-64 GHz, 1-slot AXIe module	One M8008A clock generator module required to operate up to four M8199B

1. A 4-channel system consists of two M8199B-002/S02 modules and one M8008A (plus chassis and accessories)

Upgrade options

Product numbers	Description	Comments
M8199BU-U02	Upgrade from 1-channel to 2-channels	Software license
M8199BU-256	Upgrade M8199B-S0x (224 GSa/s) to M8199B-00x (256 GSa/s)	Software license

Accessories

Product numbers	Description	Comments
M8199B-801	RF cable matched pair, 150 mm, 1.0 mm. male/male	Recommended for connecting AWG outputs to device under test. Must be ordered separately
M8199B-802	50 Ohm termination, 1.0 mm	1 termination included in M8199B-001, 2 terminations included in M8199B-002
M8199B-803	RF cable matched pair, 300 mm, 1.0 mm. male/male	Recommended for connecting AWG outputs to device under test. Must be ordered separately
M8199A-810	Replacement channel clock cable	All necessary clock cables are included with the M8199B module. These accessories are available as replacements
M8199A-811	Replacement M-clock cable	
M8199A-812	Multi-coax local bus cable	Only required for multi-chassis setups
M8008A-801	Clock module extension cable	Only required with more than one clock module
N6171A-M02	MATLAB license (standard)	Required to run/view/edit source code version of IQtools
N6171A-M03	MATLAB license (extended)	

In order to be operational, an AXIe chassis plus either an embedded controller or external PC or laptop are required in addition to one or more M8199B modules:

Product numbers	Description
M9505A-U20	5-slot AXIe chassis with USB option
M9537A	AXIe embedded controller
8121-1243	Cable assembly USB type A-MINI B
M9048B	PCIe host adapter: single port (x8), Gen 3
Y1202A	PCIe cable for M9048B host adapter



See http://keysight.com/find/AXIe for more details.

Specifications

General characteristics

Sample rate	200 to 256 GSa/s
DAC resolution	8 bits
Number of channels per M8199B module	1 channel (-001/S01 option) or 2 channels (-002/S02 option)
Sample memory	1024 kSa per channel The waveforms in each channel can have different lengths
Waveform granularity	512 samples The length of waveform segments must be a multiple of the granularity

Output characteristics (DataOut Channel 1, 2)

Output type	Single-ended or differential (Terminate unused output with 50 Ohm in single ended mode)
Coupling	AC coupled
Impedance	50 Ω (nom)
Amplitude range (valid at 400 MHz, at higher Frequencies please consider achievable amplitudes shown below)	300 $mV_{pp,\ se}$ to 2.5 $V_{pp,\ se}$ into 50 Ω 600 $mV_{pp,\ diff}$ to 5.0 $V_{pp,\ diff}$ into 50 Ω
Amplitude accuracy (measured peak-to-peak with 400 MHz square wave)	±(10 mV +7.5%) (typ)
Connector type	1.00 mm (female)

Timing characteristics

Skew between any pair of channels within the same M8199B module	0 ps +/- 1 ps (typ.)
Skew between any pair of outputs across different M8199B modules	Can be adjusted to 0 ps with user calibration (iqtools)
Random Jitter with M8008A	75 fs rms (typ)
Skew adjustment range	± 25 ns
Skew adjustment resolution	25 fs

RF characteristics

Analog bandwidth (including sin(x)/x roll-off, measured single-ended output, smoothed graph)		
	256 GSa/s	**224 GSa/s**
3 dB	75 GHz (typ)	65 GHz (typ)
6 dB	80 GHz (typ)	75 GHz (typ)
10 dB	90 GHz (typ)	80 GHz (typ)
Rise/fall time (20/80)	3 ps (meas)[1]	3 ps (meas)[1]
Achievable output amplitudes with digital correction applied		
	256 GSa/s	**224 GSa/s**
128 GBaud	1.3 $V_{pp,se}$ (typ) 2.6 $V_{pp,diff}$ (meas)	1.1 $V_{pp,se}$ (typ) 2.2 $V_{pp,diff}$ (meas)
144 GBaud	1.15 $V_{pp,se}$ (typ) 2.3 $V_{pp,diff}$ (meas)	0.9 $V_{pp,se}$ (typ) 1.8 $V_{pp,diff}$ (meas)
160 GBaud	1.1 $V_{pp,se}$ (typ) 2.2 $V_{pp,diff}$ (meas)	0.8 $V_{pp,se}$ (typ) 1.6 $V_{pp,diff}$ (meas)

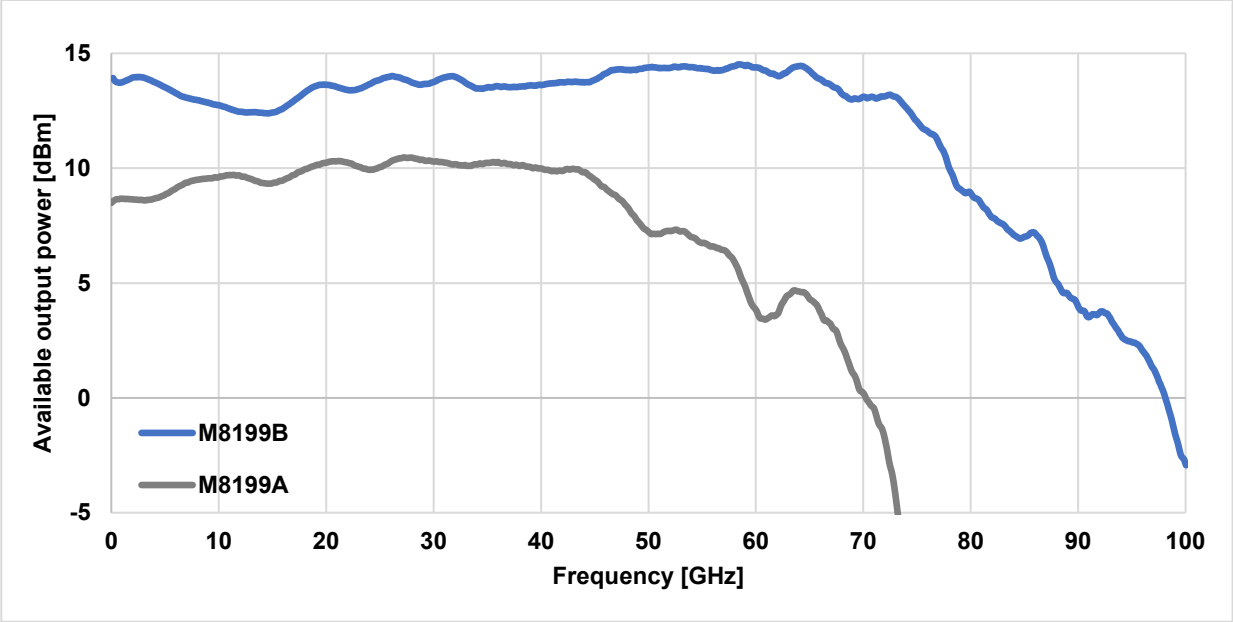


Figure 5. M8199B vs M8199A: available output power vs frequency with sinc-rolloff

[1] With frequency response correction applied. Amplitude reduced by 6 dB

Spectral Purity[2]: SINAD, SFDR, SNR, THD and ENOB

Spectral noise and distortions are measured with a single tone and 1 Vpp,diff output amplitude. A 10 dB attenuator is connected between AWG (M8199B) and sampling oscilloscope (N1046A).

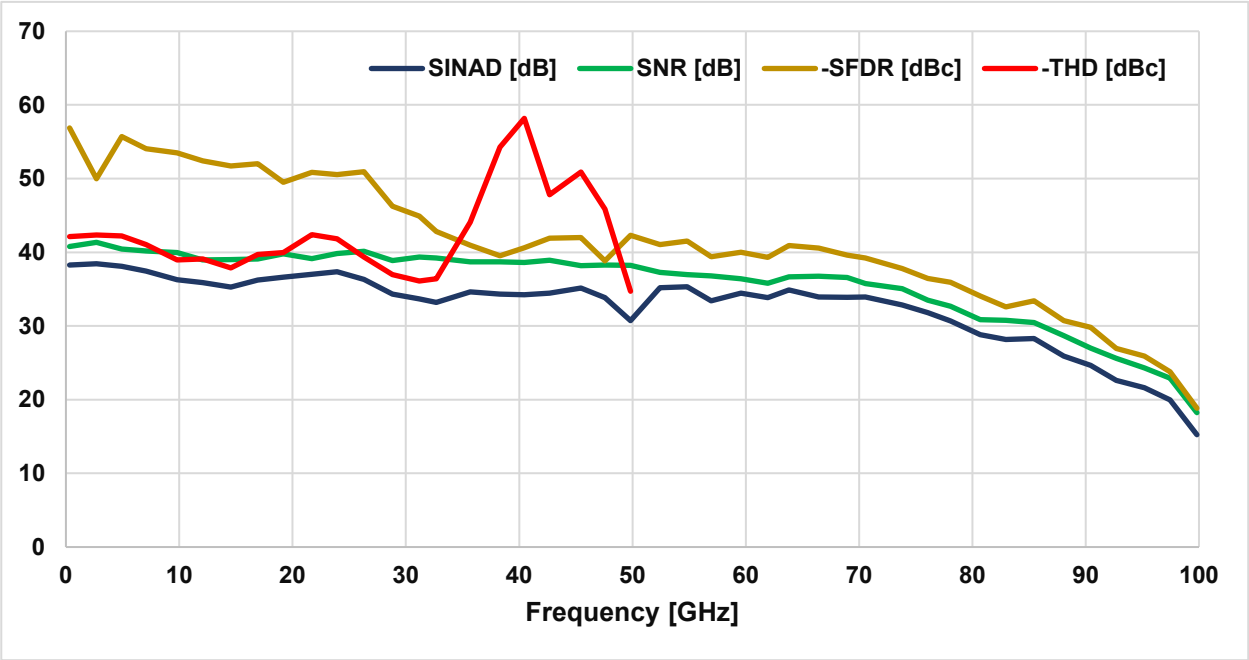


Figure 6. Combined spectral performance: typical values for M8199B operated at 256 GSa/s

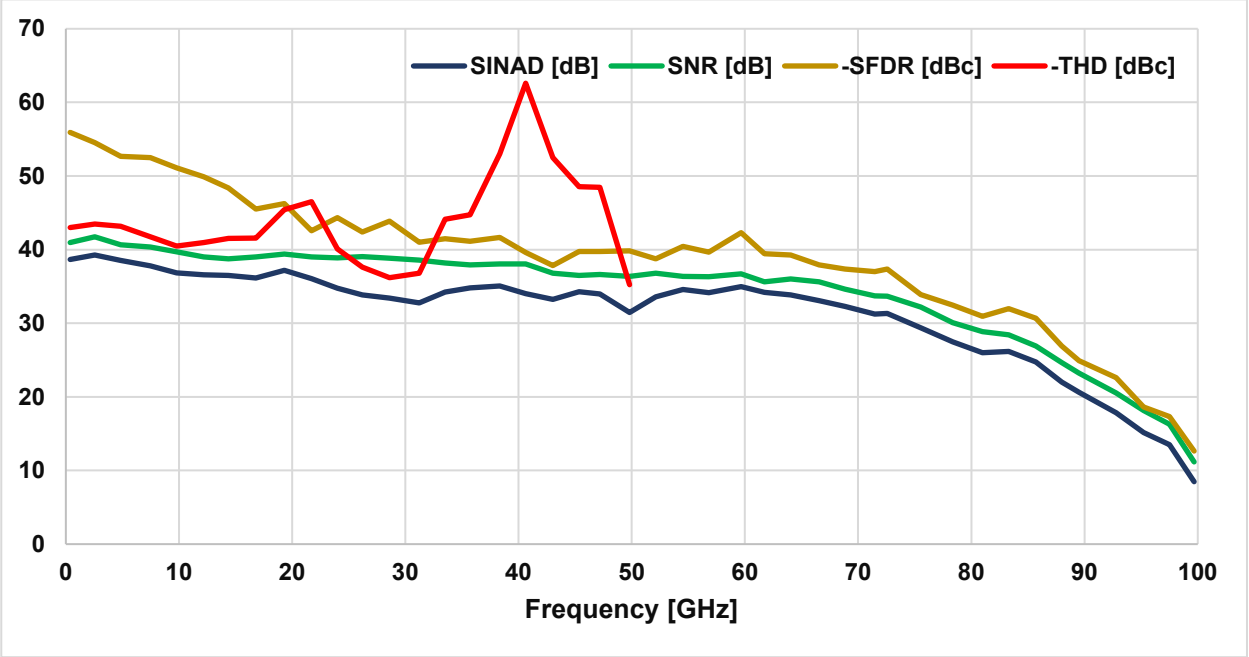


Figure 7. Combined spectral performance, typical values for M8199B operated at 224 GSa/s

[2] Parameters measured using an input sine wave, as defined in "IEEE Standard for Digitizing Waveform Recorders," in IEEE Std 1057-2017 (Revision of IEEE Std 1057-2007), Jan. 2018, doi: 10.1109/IEEESTD.2018.8291741.

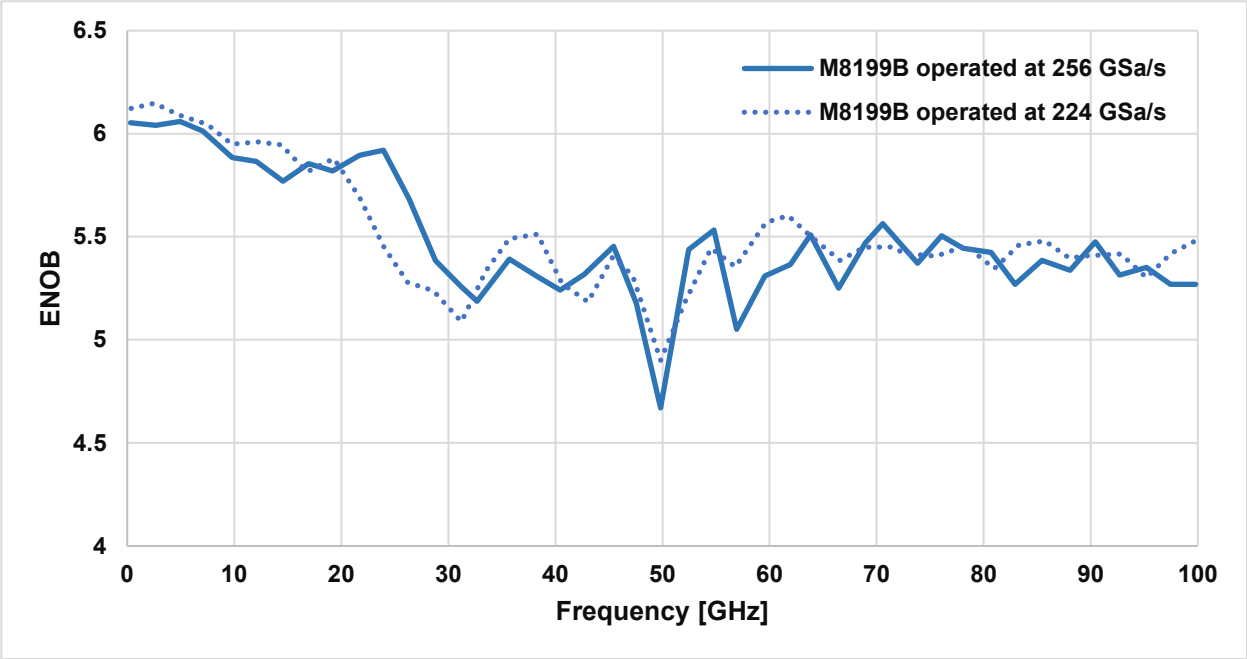


Figure 8. Typical ENOB (measured according to IEEE 1658-2011) for M8199B operated at 256 GSa/s or 224 GSa/s

Broadband Signal Quality: SNR of the received signal [dB]

The SNR of the received NRZ signal is measured transmitting a PRBS13 and 1 Vpp,diff output amplitude. A 10 dB attenuator is connected between AWG (M8199B) and sampling oscilloscope (N1046A). This measurement is based on the NRZ eye analysis considering a 2% central window of the symbol period. The frequency response correction is applied in the AWG.

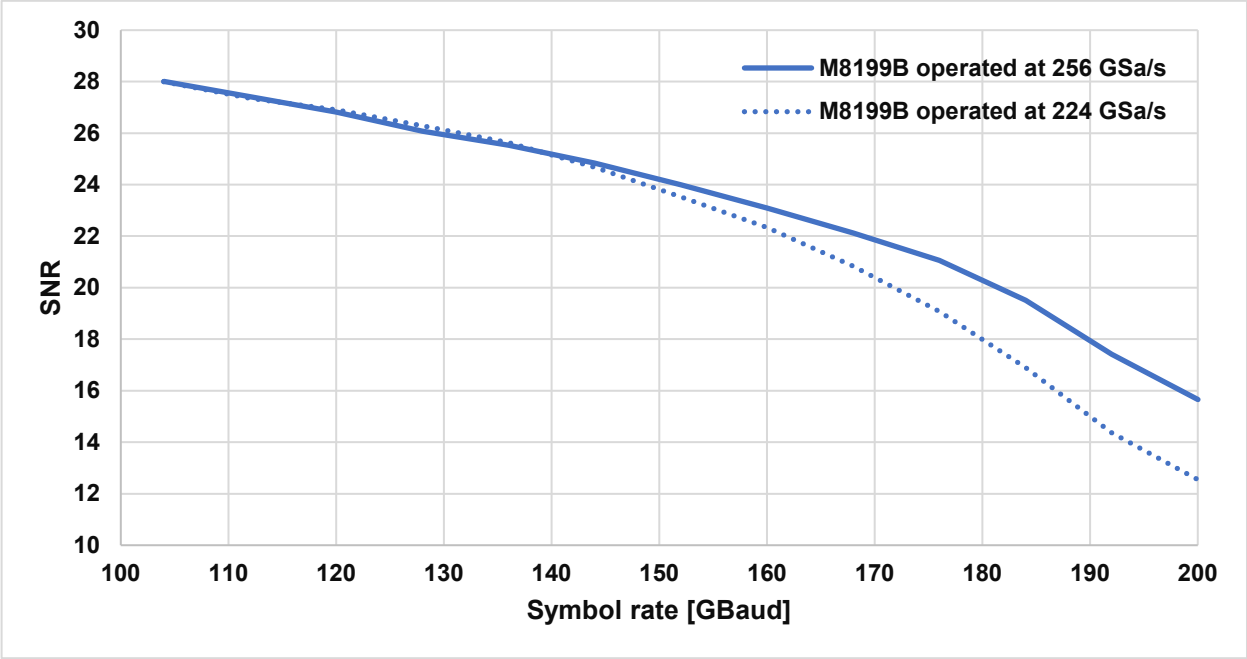


Figure 9. Typical achievable SNR, measured with a broadband NRZ signal, for M8199B operated at 256 GSa/s or 224 GSa/s.

CLK In

CLK In must be connected to *Sample Clock Out* of the M8008A clock module.

Sync In

Sync In must be connected to *Sync Out* of the M8008A clock module.

Sync Marker Out A/B	
Output type	Single ended
Coupling	DC
Impedance	50 Ohm (nom)
Amplitude	0.1 V … 2 V (nom) into 50 Ohm
Voltage window	-0.5 V … 1.75 V (nom) into 50 Ohm
Rise/fall time (20/80)	85 ps (typ) measured at 0.5 V
Connector type	3.5 mm, female

Sample Marker Out

Output type	Single ended[3] or differential
Coupling	DC
Impedance	50 Ohm (nom)
Amplitude	0.1 $V_{pp, se}$ … 1 $V_{pp, se}$ (nom) into 50 Ohm
Static offset accuracy[4]	± (25 mV + 10%)
Voltage window	-1.0 V … 3.7 V (nom) into 50 Ohm
Rise/fall time (30/70)	<30 ps (typ) measured at 0.5 V
Connector type	3.5 mm, female

Environmental characteristics

Power consumption	220 W (nom)
Operating temperature	0 ºC to 40 ºC
Operating humidity	15% to 95% relative humidity at 40 ºC, non-condensing
Operating altitude	Up to 2000m
Storage temperature	-40 ºC to +70 ºC
Storage humidity	24% to 90% relative humidity at 65 ºC, non-condensing
Stored states	User configurations and factory default
Interface to controlling PC	PCIe (see AXIe chassis specifications) or USB
Form factor	2-slot AXIe
AXIe dimensions (W x H x D)	351 mm x 60 mm x 309 mm
Weight	5.95 kg
Safety designed to	IEC 61010-1. UL 61010, CSA 22.2 61010.1 tested
EMC tested to	IEC 613226-1
Warm-up time	30 min
Calibration interval	2 years recommended
Cooling requirements	Slot air flow direction is from right to left. When operating the system, choose a location that provides at least 80 mm of clearance at rear and at least 50 mm of clearance at each side

[3] Unused outputs must be terminated with 50 Ohm to GND. In case the termination voltage is not GND, the unused output must be either terminated AC coupled or terminated to V_{Term}
[4] Measured with N1045B DCA and 10 dB attenuator

Definitions

Specification (spec)

The warranted performance of a calibrated instrument that has been stored for a minimum of 2 hours within the operating temperature range of 0 °C to 40 °C and a 15-minute warm up period. Within +/- 10 °C after auto calibration. All specifications include measurement uncertainty and were created in compliance with ISO-17025 methods. Data published in this document are specifications (spec) only where specifically indicated.

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 ºC).

Measured (meas)

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

Accuracy

Represents the traceable accuracy of a specific parameter. Includes measurement error, time base error, and calibration source uncertainty.

Confidently Covered by Keysight Services

Prevent delays caused by technical questions and reduce system downtime due to instrument maintenance and repairs with Keysight Services. Keysight Services are here to support your test needs with expert technical support, instrument repair and calibration, software support, training, alternative acquisition program options, and more.

A KeysightCare agreement provides dedicated, proactive support through a single point of contact for instruments, software, and solutions. KeysightCare covers an extensive group of instruments, application software, and solutions and ensures optimal uptime, faster response, faster access to experts, and faster resolution.

Keysight Services

Offering	Benefits
KeysightCare 	KeysightCare provides elevated support for Keysight instruments and software, with access to technical support experts who respond within a specified time and ensure committed repair and calibration turnaround times (TAT). KeysightCare offers multiple service agreement tiers, including KeysightCare Assured, Enhanced, and Application Software Support. See the KeysightCare data sheet for details.
KeysightCare Assured	KeysightCare Assured goes beyond basic warranty with repair services that include committed TAT and unlimited access to technical experts.
KeysightCare Enhanced	KeysightCare Enhanced includes all the benefits of KeysightCare Assured plus Keysight's accurate and reliable Calibration Services, accelerated, and committed TAT, and technical response.
Keysight Support Portal & Knowledge Center	All KeysightCare tiers include access to the Keysight Support Portal where you can manage support and service resources related to your assets such as service requests, and status, or browse the Knowledge Center.
Education Services	Build confidence and gain new skills to make accurate measurements, with flexible Education Services developed by Keysight experts. Including Start-up Assistance.
Alternative acquisition options	
KeysightAccess	Reduce budget challenges with a leased-based subscription service, that offers low monthly payments, enabling you to get the instruments, software, and technical support you want for your test needs.

Recommended services

Maximize your test system up-time by securing technical support, repair, and calibration services with committed response and turnaround times. 1-year KeysightCare Assured is included in every new instrument purchase. Obtain multi-year KeysightCare upfront to eliminate the need for lengthy and tedious paperwork and yearly requests for maintenance budget. Plus, you benefit from secured service for 2, 3, or 5 years.

Service	Function
KeysightCare Enhanced*	**Includes tech support, warranty and calibration**
R-55B-001-1	KeysightCare Enhanced – Upgrade 1 year
R-55B-001-2	KeysightCare Enhanced – Extend to 2 years
R-55B-001-3	KeysightCare Enhanced – Extend to 3 years (Recommended)
R-55B-001-5	KeysightCare Enhanced – Extend to 5 years (Recommended)
KeysightCare Assured	**Includes tech support and warranty**
R-55A-001-2	KeysightCare Assured – Extend to 2 years
R-55A-001-3	KeysightCare Assured – Extend to 3 years
R-55A-001-5	KeysightCare Assured – Extend to 5 years
Start-Up Assistance	
PS-S40-01	Included – instrument fundamentals and operations starter
PS-S40-04	Recommended – instrument fundamentals and operations starter
PS-S40-02	Optional, technology & measurement science standard learning

* Available in select countries. For details, please view the datasheet. R-55B-001-2/3/5 must be ordered with R-55B-001-1.

Keysight enables innovators to push the boundaries of engineering by quickly solving design, emulation, and test challenges to create the best product experiences. Start your innovation journey at www.keysight.com.

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