M8198A Arbitrary Waveform Generator

Version 1.1

Introduction

The M8198A is a flexible arbitrary waveform generator that offers a unique combination of high-sample rate, high-bandwidth, deep memory, and advanced functionalities. Whether performing breakthrough 6G research, testing the discrete components of an optical system, addressing deep memory or wide bandwidth application in aerospace/defense, or experimenting with high-speed transmission, you need precision and flexibility to deliver your next generation technology needs. Keysight's M8198A AWG accelerates your innovation with more accurate and realistic signals in one instrument.

KEYSIGHT

Key Benefits

- Integrated, ready-to-use instrument.
- Up to **2 differential channels per module** at **128 GSa/s** with **analog bandwidth of 58 GHz.**
- Up to **8 GSa memory per channel** allowing generation of longer data streams.
- **One differential Sample Marker per channel**, programmable as sub-rate clock up to 8 GHz or pulse on an arbitrary sample of the waveform. Markers don't reduce vertical resolution.
- Works with the M8008A clock module, with the **possibility of direct clocking** from an external source (i.e., 12.5…16 GHz as input to the M8008A), and providing additional auxiliary outputs such as a **reference clock output at ¼ of Clock In of M8198A** (i.e., 12.5…16 GHz)
- Operates with well-known software, including MATLAB, Keysight IQtools, **PathWave Signal Generation (PWSG) Advanced Waveform Utility (AWU)** and SCPI programming interfaced based on M8070B.

Applications

Wideband RF signal generation

Latest developments in wireless, satellite and radar technologies require signals with modulation bandwidths beyond 10 GHz, in some cases up to 50 GHz, with uncompromised signal quality. Generating those signals on an IF rather than I/Q is another industry's unique capability of the M8198A to support these applications.

With sample rates of 128 GSa/s, the M8198A has enough oversampling gain to generate extremely broad bandwidth, yet high fidelity RF signals. As an example, figure 1 shows a QAM-64 signal with 10 GHz of modulation bandwidth on a 15 GHz carrier signal generated directly by the M8198A.

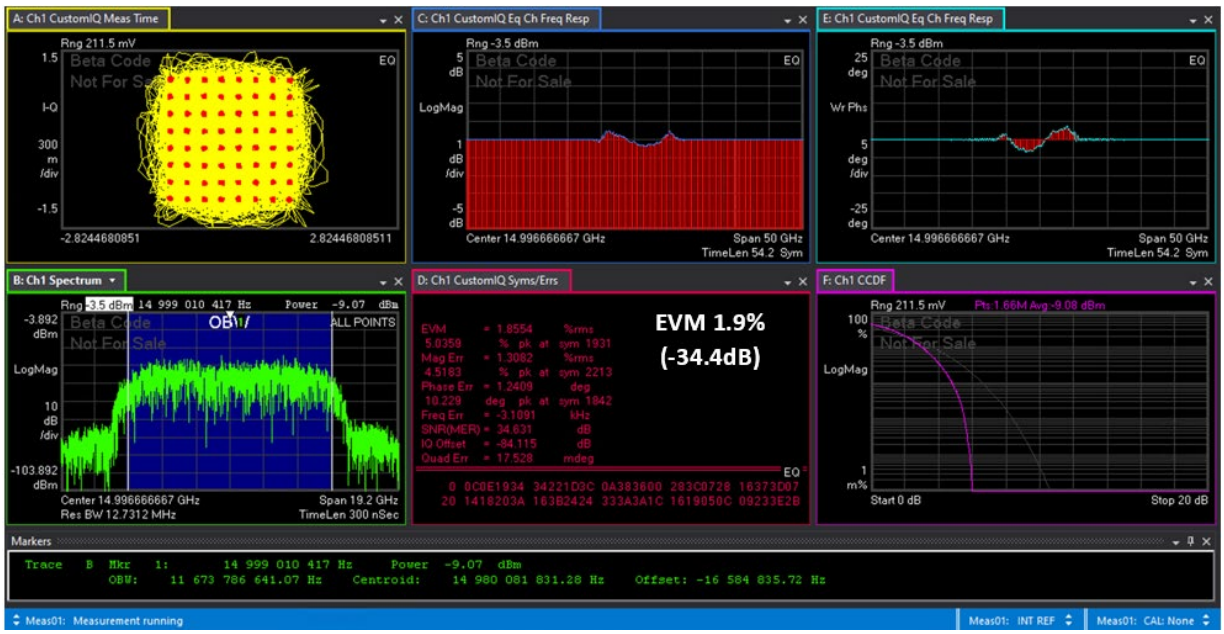

Figure 1. Example of 10 GBd QAM64 output signal, measured at sample rate of 128 GSa/s, and 1 Vpp,diff amplitude. Measured with a real-time oscilloscope (UXR) including 50 cm RF cable between M8198A AWG and UXR.

Multi-level digital signal generation

With increasing data rates in datacenters, servers and computers, R&D engineers face multiple design challenges due to increased sensitivity to channel impairments, channel losses and reduction in signal-to-noise ratio. The flexibility of the waveform generation with high speeds digital to analog converter and deep memory, combined with excellent intrinsic jitter performance makes the M8198A a truly unique and versatile instrument. The M8198A enables advanced research allowing for customization of modulation formats and data patterns to boost transmission rates to the next level.

In addition, the M8198A incorporates digital correction techniques for frequency and phase-response compensation of the AWG output and any external circuit such as cables, board traces, connectors etc. This allows the AWG to generate the desired signal at the device under test input. Any channels can be embedded/de-embedded if the S-parameters of the respective circuits are provided.

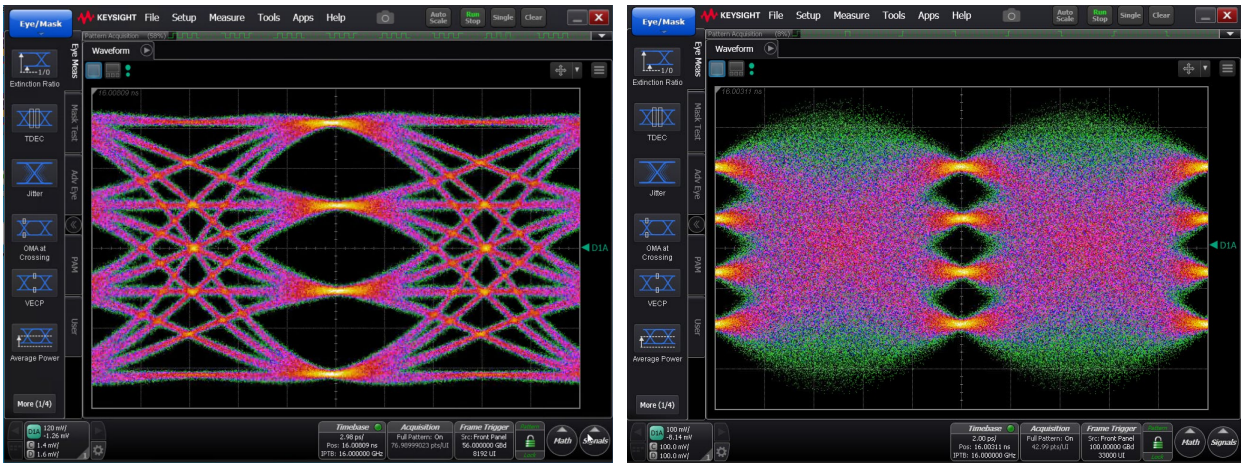

Figure 2. Example of 56 GBd PAM4 (left) and 100 GBd PAM4 (right) output signals with PRBS 2^{15-1}, measured at sample rate of 128 GSa/s, and 1 Vpp,diff amplitude. Measured with a sampling oscilloscope (N1046A).

General-purpose: research in electronics, physics, chemistry

The M8198A AWG allows users to generate any arbitrary waveform that can be mathematically described, e.g. a signal calculated in MATLAB can be downloaded directly into the M8198A.

This includes ultra-short, yet precise pulses down to ~7 ps pulse width or extremely short, wideband RF pulses and chirps which are needed to investigate in chemical reactions, elementary particle excitation and quantum effects.

Software

The M8198A is controlled by the M8070B systems application software. In addition, the free MATLAB based utility IQtools is included with the instrument software. IQtools provides many waveform generation utilities 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. It can compensate skew between all channels.

The M8198A can also be operated by using PathWave Signal Generation (PWSG) Advanced Waveform Utility (AWU).

Hardware

Clocking

The M8198A has one clock input connector for each channel. The sample clock signal must be provided from a companion clock module (M8008A).

With the clock input directly fed into the Digital-to-Analog converter (DAC), all DAC clocks are fully synchronous, i.e. any jitter on the clock will be passed through to the AWG output 1:1.

With the M8008A as a clock source, channels will be automatically de-skewed.

The M8008A gives the possibility of direct clocking from an external source (i.e., 12.5…16 GHz as input to the M8008A), and provides additional auxiliary outputs such as a reference clock output at ¼ of Clock In of M8198A (i.e., 12.5…16 GHz)

Front panel connections

Figure 4. M8198A connected to M8008A clock module.

- **Data Out Channel 1** – differential AWG Data Output (1.85 mm female connectors).
- **Data Out Channel 2** – differential AWG Data Output (1.85 mm female connectors).
- **Sync In** – connect to Sync Output of the M8008A clock module.
- **Sample Marker Out 1/2** – differential Sample Marker Output.
- **Event In A/B** –can be used to start or gate waveform playback.
- **Event Out A/B** – outputs a pulse at the start of the endless waveform loop.
- **Remote Head 1/2** – reserved for future use.
- **Ch 1 Clk In** – Channel 1 Clock Input needs to be connected to one of the connectors of the Sample Clock Out 1 of the M8008A clock module.
- **Ch 2 Clk In** – Channel 2 Clock Input needs to be connected to the other available connector of the Sample Clock Out 1 of the M8008A clock module (see Figure 4 for reference).
- **LB In, LB Out** – reserved for future use.

Configuration

Product numbers	Description	Comments
M8198A-001	Arbitrary waveform generator module, 1 channel, 128 GSa/s, 3-slot AXIe module	Number of channels from 1 to 2 is upgradeable with the option M8198AU-U02
M8198A-002	Arbitrary waveform generator module, 2 channel, 128 GSa/s, 3-slot AXIe module	
M8198A-08G	8 GSa memory per channel	
M8008A-064	Clock generator 32-64 GHz, 1-slot AXIe module	

Upgrade options

Product numbers	Description	Comments
M8198AU-U02	Upgrade M8198A AWG from 1 to 2 Channels, 128 GSa/s	Software license
M8198AU-U8G	Upgrade M8198A AWG from 1 GSa to 8 GSa Memory per channel	Software license

Accessories

Product numbers	Description	Comments
M8199A-801	RF cable matched pair, 150 mm, 1.85 mm. connectors, male/male	*Recommended for connecting AWG outputs to device under test. Must be ordered separately*
M8199A-802	50 Ω termination, 2.4 mm	*1 termination included in M8198A-001, 2 terminations included in M8198A-002*
M8198A-803	RF cable matched pair, 500 mm, 1.85 mm. connectors, 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 M8198A module. These accessories are available as replacements*
M8199A-811	Replacement M-clock cable	
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 for the system to be operational, an AXIe chassis plus either an embedded controller or external PC or laptop are required in addition to the M8198A AWG and M8008A Clock module:

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

Data Out 1/2 General characteristics

Sample rate	100 to 128 GSa/s
DAC resolution	8 bits
Number of channels per M8198A module	1 channel (option -001) or 2 channels (option -002)
Sample memory	Up to 1 GSa per channel standard Up to 8 GSa per channel with option -0G8 The waveforms in each channel can have different lengths
Waveform granularity	256 samples The length of waveform must be a multiple of the granularity

Data Out Channel 1/2 characteristics

Output type	Single-ended or differential (Terminate unused output with 50 Ω to GND in single-ended mode)
Coupling	Selectable, DC or AC
Impedance	50 Ω (nom.)
Amplitude range (valid at 400 MHz, at higher frequencies please consider achievable amplitudes shown below)	100 $mV_{pp,se}$ to 0.83 $V_{pp,se}$ into 50 Ω 200 $mV_{pp,diff}$ to 1.66 $V_{pp,diff}$ into 100 Ω
Amplitude resolution	1 mV_{se} (nom.)
Amplitude accuracy (measured peak-to-peak with 400 MHz square wave)	± (10 mV + 7.5 %) (typ.)
Output voltage window	-1.0 to +3.0 V, depends on external termination voltage[1]
DC offset accuracy	± (10 mV + 2 %) (typ.)
Common mode voltage accuracy[2]	± (25 mV + 12.5 %) (spec.)
Termination voltage (V_{Term}) window	-1.0 to +3.0 V
Connector type	1.85 mm (female)

Data Out Channel 1/2 Timing characteristics

Skew between Data Out Channel 1 and Data Out Channel 2	0 ps ± 5ps (nom.)[3] Can be adjusted to 0 ps using in-system calibration
Random Jitter with M8008A	75 fs RMS (typ.)[4]
Delay adjustment range	±10.0 ns
Delay adjustment resolution	25 fs

[1] High level voltage range = 2/3* V_{Term} - 0.9 V < HIL < V_{Term} + 2 V
Low level voltage range = 2/3 * V_{Term} - 1 V < LOL < V_{Term} + 1.9 V
[2] Common mode voltage = 0.5 * (measured offset at norm. + measured offset at com.). Measured with DCA N1046A and 10 dB attenuator, constant DAC value 0, termination voltage: 0 V, amplitude 0.5 $V_{pp,se}$
[3] Measured single ended at front panel.
[4] Calculated from SNR at f_{Out} = 40.09 GHz, f_{Sa} = 128 GSa/s

Data Out Channel 1/2 RF characteristics

Analog bandwidth	
3 dB	58 GHz (typ.) @ 128 GSa/s, without compensating for the sin(x)/x roll-off
Rise/fall time (20% / 80%)	7 ps (typ.)[5]

Data Out Channel 1/2 RF characteristics[6]

ENOB, (measured according to IEEE 1658-2011)	6.0 bit (typ.), f_{out} = DC…5 GHz 5.5 bit (typ.), f_{out} = 5 GHz…20 GHz 5.0 bit (typ.), f_{out} = 20 GHz…58 GHz
SINAD	37 dB (typ.), f_{out} = DC…5 GHz 36 dB (typ.), f_{out} = 5 GHz…10 GHz 34 dB (typ.), f_{out} = 10 GHz…20 GHz 31 dB (typ.), f_{out} = 20 GHz…58 GHz
SNR (excluding harmonic distortions and SFDR spur)	40 dB (typ.), f_{out} = DC…10 GHz 38 dB (typ.), f_{out} = 10 GHz…20 GHz 36 dB (typ.), f_{out} = 20 GHz…30 GHz 35 dB (typ.), f_{out} = 30 GHz…40 GHz 34 dB (typ.), f_{out} = 40 GHz…50 GHz 31 dB (typ.), f_{out} = 50 GHz…58 GHz
SFDR (excluding harmonic distortions)	- 54 dBc (typ.), f_{out} = DC…5 GHz - 48 dBc (typ.), f_{out} = 5 GHz…10 GHz - 46 dBc (typ.), f_{out} = 10 GHz…15 GHz - 42 dBc (typ.), f_{out} = 15 GHz…20 GHz - 37 dBc (typ.), f_{out} = 20 GHz…30 GHz - 35 dBc (typ.), f_{out} = 30 GHz…58 GHz
Total Harmonic Distortion	- 41 dBc (typ.), f_{out} = DC…5 GHz - 38 dBc (typ.), f_{out} = 5 GHz…10 GHz - 36 dBc (typ.), f_{out} = 10 GHz…25 GHz - 34 dBc (typ.), f_{out} = 25 GHz…34 GHz
2nd harmonic	- 47 dBc (typ.), f_{out} = DC…5 GHz - 42 dBc (typ.), f_{out} = 5 GHz…10 GHz - 39 dBc (typ.), f_{out} = 10 GHz…15 GHz - 35 dBc (typ.), f_{out} = 15 GHz…25 GHz - 33 dBc (typ.), f_{out} = 25 GHz…34 GHz
3rd harmonic	- 41 dBc (typ.), f_{out} = DC…5 GHz - 39 dBc (typ.), f_{out} = 5 GHz…10 GHz - 38 dBc (typ.), f_{out} = 10 GHz…20 GHz

[5] No frequency/phase correction applied.

[6] Measured at amplitude 500 $mV_{pp,se}$ or 1.0 $V_{pp,diff}$; f_{sa} = 128 GSa/s

Ch 1/2 Clk In

Ch 1/2 Clk In must be connected to Clk Out of the M8008A clock module.

Input type	Single ended
Coupling	AC
Input impedance	50 Ω (nom.)
Input power	+4 dBm … +8 dBm
Frequency range	50 GHz … 64 GHz
Connector type	1.85 mm, female

Sync In

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

Sample Marker Out 1/2

The Sample Marker Output allows generation of a sub-rate clock or a pulse on an arbitrary sample of the waveform.

Output type	Single ended[7] or differential
Coupling	DC
Impedance	50 Ω (nom.)
Amplitude	0.1 $V_{pp,se}$ … 1 $V_{pp,se}$ into 50 Ω
DC amplitude accuracy	± (15 mV + 2 %) (typ.)
Output voltage window	-0.5 V … 3.0 V, depends on external termination voltage[8]
Termination voltage (V_{Term}) window	-1.0 to +3.0 V
Rise/fall time (20% / 80%)	< 50 ps (typ.)
Sub-rate frequency	Sample rate / Sample Rate Divider
Sample rate divider range	16…65000
Connector type	3.5 mm, female

Run Modes

The M8198A AWG can be run in Continuous, Triggered or Gated mode.

Continuous / Sequencer Controlled	A waveform segment is continuously repeated
Triggered	A waveform segment is looped continuously after a trigger event is received
Gated	A waveform segment is looped continuously gated by the level of the trigger signal

[7] 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}

[8] High level voltage range = 2/3* V_{Term} - 0.9 V < HIL < V_{Term} + 2 V
Low level voltage range = 2/3 * V_{Term} - 1 V < LOL < V_{Term} + 1.9 V

Event In A/B

In Triggered Mode, Event In A/B can be used to start waveform playback in an endless loop on one or both channels after a trigger event is detected. The trigger event can be rising or falling edge and it is user configurable.

In Gated Mode, Event In A/B can be used for waveform playback in an endless loop on one or both channels if the gate is in open state. When the gate goes to closed state, waveform playback stops. If high- level or low- level means “gate open” or “gate closed” is user configurable.

Event In A/B characteristics

Input type	Single-ended
Coupling	DC
Input impedance	50 Ω (nom.)
Input voltage range	–1.0 V to +3.0 V
Minimum pulse width	512 sample clock periods
Threshold	Range: –1.0 V to +3.0 V Accuracy: ± 50 mV (typ.)
Absolute delay to data output	< 25 µs
Connector type	3.5 mm, female

Event Out A/B

A pulse is output at Event Out A/B at the start of the endless waveform loop.

Output type	Single ended
Coupling	DC
Impedance	50 Ω (nom.)
Amplitude	0.1 V … 2.0 V into 50 Ω
DC amplitude accuracy	± (15 mV + 2 %) (typ.)
Output voltage window	-0.5 V … 1.75 V into 50 Ω
Rise/fall time (20% / 80%)	125 ps (nom.) with 0.5 V amplitude
Pulse width	256 sample clock periods (typ.)
Delay between Event Out to Data Out	±512 sample clock periods (typ.)
Connector type	3.5 mm, female

Download Speed

Download speed is measured by transferring the samples from PC’s internal memory into the M8198A using the SCPI interface.

The download speed varies depending on the interface used.

USB interface	~7 MSa/s (meas.)
PCIe or TBT interface	~9 MSa/s (meas.)

Frequency Response

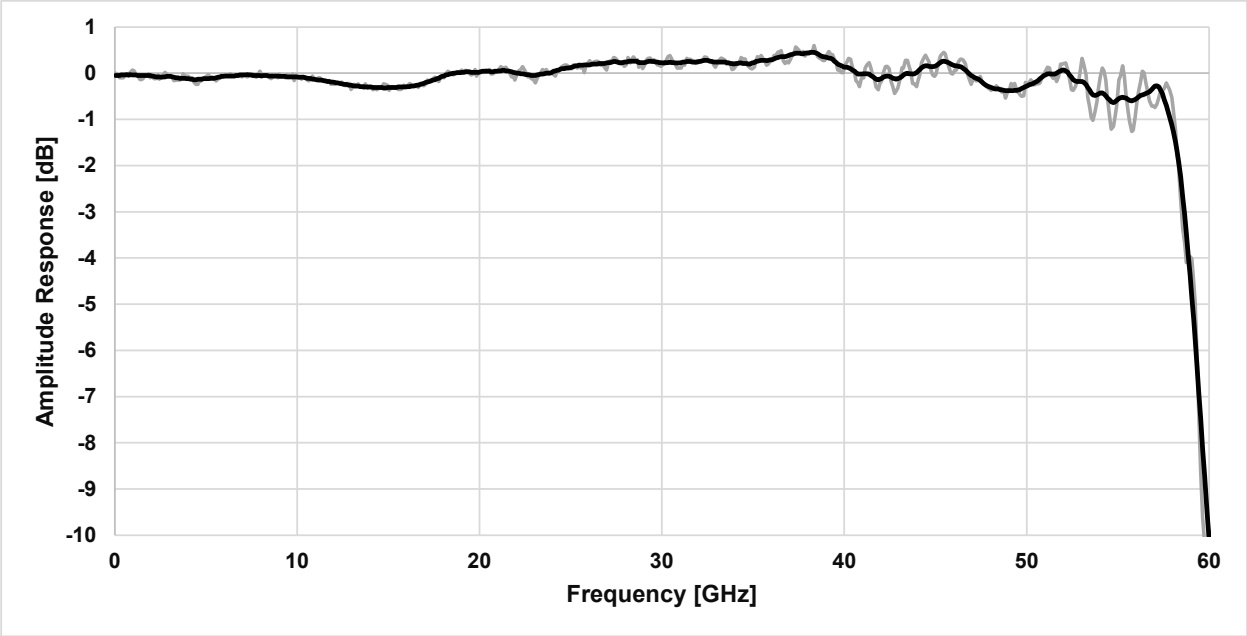

Figure 5. Frequency response at Data Out 1/2, measured at sample rate of 128 GSa/s, and 1 Vpp,diff amplitude. Sin(x)/x roll-off not compensated. Black: Savitzky–Golay filters polynomial fit, window size: 5%, grey: measured data.

ENOB

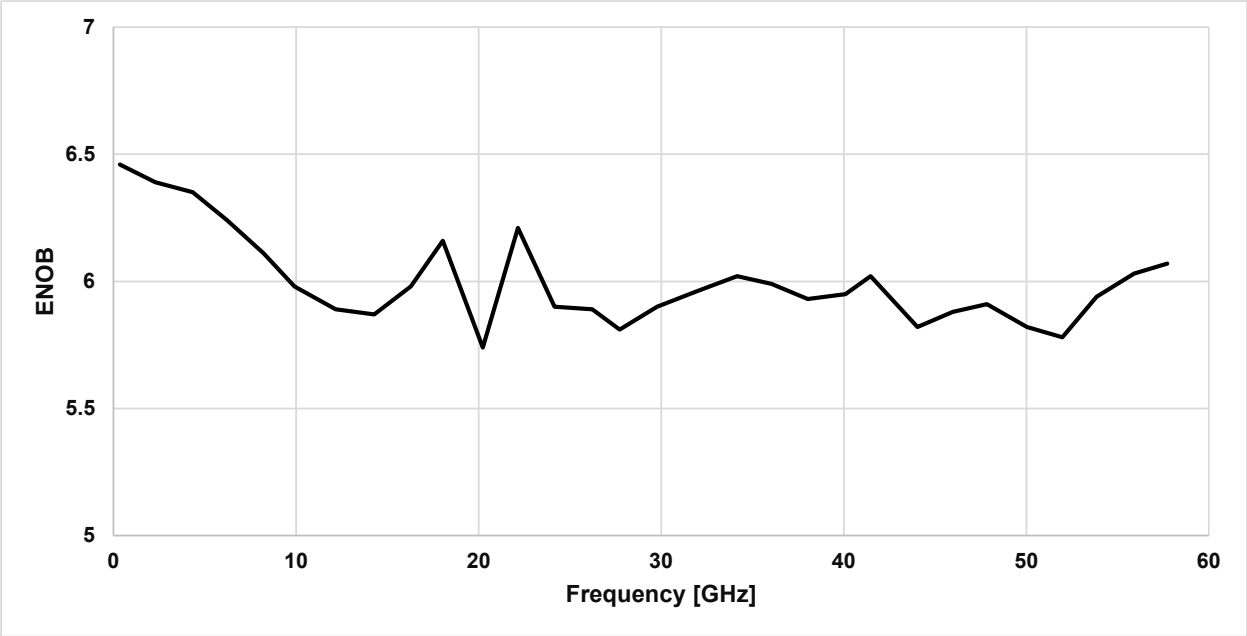

Figure 6. Typical ENOB at Data Out 1/2, measured at sample rate of 128 GSa/s, and 1 Vpp,diff amplitude. ENOB measured using the sine fit method according to IEEE Std 1658-2011 with a sampling oscilloscope (N1046A). The frequency response of the oscilloscope has been de-embedded in FlexDCA.

Environmental characteristics

Power consumption	600 W (nom.) @ 128 GSa/s
Operating temperature	5 ºC to 40 ºC
Operating humidity	15% to 95% relative humidity at 40 ºC, non-condensing
Operating altitude	Up to 2000 m
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	3-slot AXIe
Dimensions (W x H x D)	351 mm x 92 mm x 315 mm
Weight	8.5 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

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 5 °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, or 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	KeysightCare provides elevated support for Keysight instruments and software, with access to technical support experts that 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 subscription service 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-S10	Included – instrument fundamentals and operations starter
PS-S20	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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