

# M8195A 65 GSa/s Arbitrary Waveform Generator M8197A Multi-Channel Synchronization Module

Version 3.1



## M8195A at a Glance

Go where you have never been able to test before: with real-time mode, sequencing and deep memory – explore your possibilities.

- Sample rate up to 65 GSa/s (on up to 4 channels)
- Analog bandwidth: 25 GHz
- 8 bits vertical resolution
- Up to 16 GSa of waveform memory per AXIe module
- 1, 2 or 4 differential channels per 1-slot high AXIe module (number of channels is software upgradeable)
- Multi-module synchronization
  - Up to 16 channels per 5-slot AXIe chassis<sup>1</sup>
- Advanced 3-level sequencing with external dynamic control<sup>1</sup>
- Load new waveforms on-the-fly without interrupting the playback of the previous one<sup>1</sup> (“memory ping-pong”)
- Amplitude up to  $1 V_{pp(se)}$ ,  $2 V_{pp(diff)}$ , voltage window  $-1.0 \dots +3.3 V$
- $t_{rise/fall}$  20%/80% 18 ps (typ). With pre-distortion applied 12 ps (typ)
- Ultra-low intrinsic jitter ( $RJ_{rms} < 200$  fs)
- Built-in frequency and phase response calibration for clean output signals
- Up to 64-tap FIR filter in hardware for frequency response compensation
- Up to 2 markers with 1 sample resolution (markers don't reduce vertical resolution)
- Embedded DSP enables real-time waveform and impairment generation

Speed your test by up to 100 times with unique real-time mode.

## Key Applications

As devices and interfaces become faster and more complex, the M8195A AWG gives you the versatility to create the signals you need for digital applications, optical and electrical communication, advanced research, wideband radar and satcom.

- Coherent optical – a single M8195A module can generate two independent I/Q baseband signals (dual polarization = 4 channels) at up to 32 GBaud (and beyond).
- Multi-level / multi-channel digital signals – generate PRBS<sup>2</sup>, NRZ, PAM4, PAM8, DMT, etc. signals of up to 32 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/ $\mu$ W – generate extreme wideband RF signals with an instantaneous bandwidth of DC to 25 GHz for aerospace/defense/communication applications

## Coherent optical applications

The M8195A supports leading edge research for 100 Gb/s, 400 Gb/s and 1 Tb/s optical transmission systems that require a very wideband electrical stimulus with a variety of complex modulation formats from QPSK to nQAM to OFDM at symbol rates up to 32 GBaud and beyond.

In order to drive dual-polarization systems, the M8195A has 4 independent, yet precisely synchronized analog output channels in a single module. Since all 4 channels are generated by the same instrument without any external circuitry, precise synchronization down to the femto-second-range can be achieved and maintained.

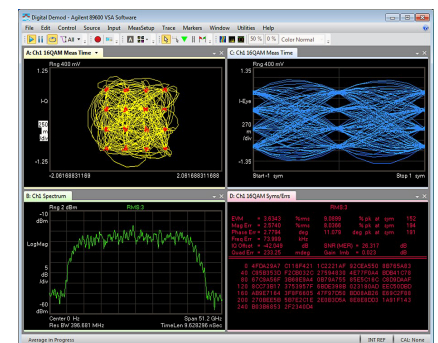


Figure 1. 16 QAM @ 32 GBaud.

1. Available with M8195A plus M8197A.
2. PRBS pattern size includes PRBS7, PRBS10, PRBS11, PRBS15. For PRBS23, 31 will require extended 16 GSa/s memory option.

The M8195A uses digital pre-distortion techniques for frequency- and phase-response compensation of the AWG output and any external circuits. These are required in order to achieve a clean signal at the device under test.

Distortions generated by cables, amplifiers, etc. can also be compensated by embedding /de-embedding the S-parameters of the respective circuits or by performing an in-situ calibration using Keysight 81195A Optical Modulation Generator software.

In conjunction with the 81195A Optical Modulation Generator software clean signals and signals stressed with impairment patterns can be generated both offline on a PC or in real-time using the hardware DSP block, which allows the parameters of the waveform (e.g., the pulse shaping filter coefficients) and impairment generation to be adjusted at run-time without downloading a new waveform.

## Multi-level/multi-channel digital signals

Increasing the data throughput on digital interfaces has traditionally been accomplished by increasing the data rate or by increasing the number of parallel signals. However, at a certain point, it is more cost-effective to consider multi-level signaling techniques. Examples are high-speed backplane connections using PAM4 or PAM8, and also technologies in the mobile application space.

The M8195A is ideally suited to address those multi-level/multi-channel interfaces using any standard or custom data format, such as PAM-n ( $n = 3, 4, 5, \dots$ ) or DMT. The M8195A supports pattern lengths up to PRBS  $2^{31}-1^*$  and baud rates up to 32 GBaud, including the necessary parameter changes, such as variable transition times, various pulse-shaping filters, adding distortions, and can also generate PAM-n signals with non-equidistant voltage levels. The flexibility of the waveform generation at highest speeds, combined with excellent intrinsic jitter performance makes the M8195A truly a future-proof instrument – independent of the direction technology is moving.

At data rates of multiple Gb/s, the effect of cables, board traces, connectors etc. have to be taken into account in order to generate the desired signal at the test point of the device under test. The M8195A 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.

With up to 4 differential output channels per 1-slot AXIe module and the ability to synchronize multiple modules, the M8195A is well-suited to stimulate multi-lane high-speed interfaces in a very economic fashion.

With the integration of the M8195A AWG into the M8000 Series of BER test solutions, Keysight allows you to address your high-speed digital receiver test needs with the M8070A software platform and choose the BERT or AWG that best meets your needs.

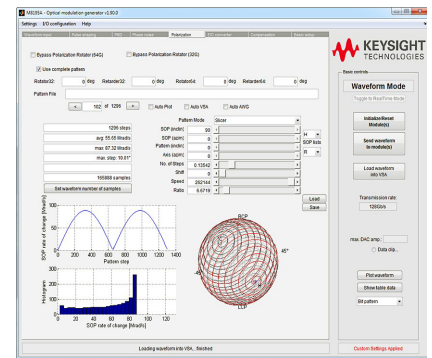


Figure 2. Optical Modulation Generator Software

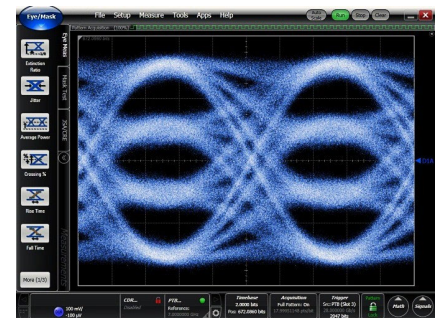


Figure 3. 4 PAM4 signal at 28 GBaud (= 56 Gbit/s).

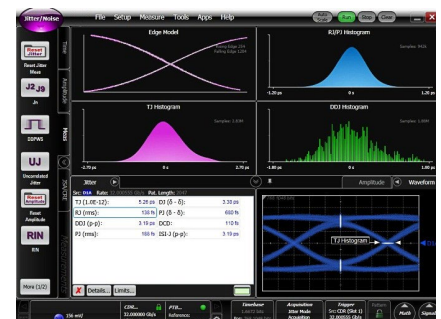


Figure 4. 32 Gb/s PRBS 211-1 showing 138 fs  $R_{jms}$ .

1. \* PRBS waveforms are calculated and upload into AWG's waveform memory by software. For PRBS lengths up to  $2^{15}-1$ , the download time is negligible but for a PRBS  $2^{31}-1$ , this will take several minutes.

## Physics, chemistry and electronics research

You can generate any arbitrary waveform that you can mathematically describe (e.g. in MATLAB) and download it directly to the M8195A. This includes ultra-short yet precise pulses down to ~100 ps pulse width or extremely short, yet wideband RF pulses and chirps.

In conjunction with the M8197A synchronization module, these signals can be triggered from external sources with very low jitter.

## Wideband RF/ $\mu$ W signals

The M8195A can address wideband wireless, EW and comms/satcom applications where extremely wide instantaneous bandwidth (DC to 25 GHz) and fast frequency hopping are critical parameters.

With built-in frequency and phase calibration, it is straight forward to generate wideband multi-tone signals with a flat frequency response up to 25 GHz.

Wideband wireless signals with any modulation scheme (e.g. nPSK, nQAM, APSK, OFDM, etc.) can be generated directly at carrier frequencies of up to 25 GHz. In many cases, this saves an additional up-conversion stage (e.g. in case of IEEE 802.11ad) or enables waveform generation directly at the carrier frequency.

Note that the available frequency range depends on the number of channels that are used simultaneously as well as the amount of memory per channel (see sample memory modes in this document).



Figure 5. 100 ps pulse with 17 ps risetime.

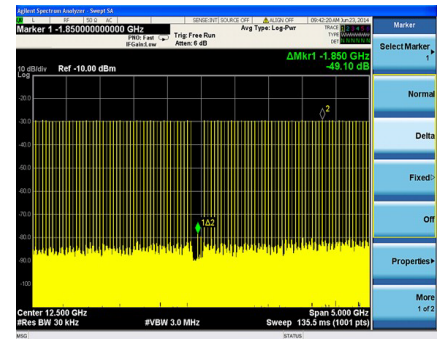


Figure 6. Multi-tone signal from 10 GHz to 15 GHz.

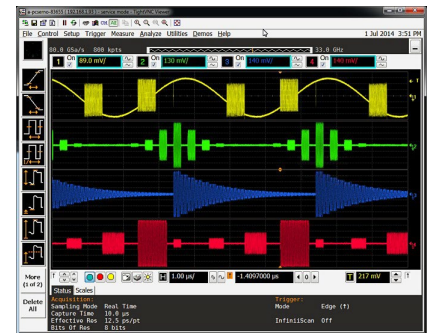


Figure 7. Four different pulsed signals up to 25 GHz.



## M8197A

The M8197A is a synchronization module for up to four M8195A modules. Using the M8197A, a fully synchronous system with up to 16 channels per AXIe 5-slot chassis can be realized. The M8197A also provides a dynamic control input/general purpose output that can be used with one or more M8195A modules. Trigger-to-output delay accuracy is improved when using the M8197A trigger input (see timing characteristics paragraph).



Figure 8. M8197A, front panel view and system with 16 synchronized channels (4x M8195A modules and 1x M8197A module).

## Software

The basic functionality of the M8195A is controlled from a soft front panel application running on the AXIe embedded controller or external PC or laptop. In addition to basic settings such as sample clock rate, output amplitudes, etc., the soft front panel offers functionality to:

- Load waveforms from files
- Generate standard waveforms (sine, square, etc.)
- Generate multi-tone waveforms
- Generate complex modulated waveforms (nPSK, nQAM, etc.)
- Generate binary and multi-level digital waveforms
- Generate serial data waveforms
- Control FIR filters

In addition to the soft front panel, the M8195A can be controlled via *SCPI* and *IVI-COM* remote programming interfaces.

External software applications that can be used to generate and download waveforms directly to the M8195A via SCPI or IVI-COM include MATLAB, LabView, C++, C# or any other .NET language.

- The M8195A is integrated into the following Keysight software applications:
- M8070A - system software for M8000 Series of BER test solutions
- M8085A - MIPI® receiver test solutions
- 81195A - optical modulation generator software
- M9099A - waveform creator application software
- W146xA - SystemVue electronic system-level design software

For additional information see the respective data sheets.

## Configuration

The following products/options are available.

| Product number | Description                                                                                                                   | Comment                                                                                                                                                                                                                 |
|----------------|-------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| M8195A-001     | 1 channel, 65 GSa/s, 2 GSa per module                                                                                         | Including local start-up assistance and one 50 $\Omega$ termination for each channel                                                                                                                                    |
| M8195A-002     | 2 channel, 65 GSa/s, 2 GSa per module                                                                                         |                                                                                                                                                                                                                         |
| M8195A-004     | 4 channel, 65 GSa/s, 2 GSa per module                                                                                         |                                                                                                                                                                                                                         |
| M8195A-16G     | Upgrade to 16 GSa per module                                                                                                  | Software license                                                                                                                                                                                                        |
| M8195A-SEQ     | Sequencer functionality per module                                                                                            | Software license                                                                                                                                                                                                        |
| M8195A-FSW     | Fast switching per module                                                                                                     | Software license                                                                                                                                                                                                        |
| M8195A-1A7     | ISO 17025 report                                                                                                              |                                                                                                                                                                                                                         |
| M8195A-Z54     | Z54 calibration report                                                                                                        |                                                                                                                                                                                                                         |
| M8195A-BU1     | Pre-configured system consisting of one M9505A 5-slot AXIe Chassis with USB Option and one M9537A AXIe Embedded PC Controller |                                                                                                                                                                                                                         |
| M8195A-BU2     | Pre-configured system consisting of one M9502A 2-slot AXIe Chassis with USB Option                                            |                                                                                                                                                                                                                         |
| M8195A-BU3     | Pre-configured system consisting of one M9502A 2-slot AXIe Chassis with USB Option and one M9537A AXIe Embedded PC Controller |                                                                                                                                                                                                                         |
| M8197A         | Synchronization module for up to four M8195A modules                                                                          | Including four synchronization cables                                                                                                                                                                                   |
| M8195S         | Pre-configured Arbitrary Waveform Generator System including one M8197A                                                       | In addition to the required modules, a local start-up assistance, one 50 $\Omega$ termination for each channel and an AXIe chassis with an embedded controller or external PC connectivity will automatically be added. |

## Upgrade options for M8195A

| Product number | Description                              | Comment          |
|----------------|------------------------------------------|------------------|
| M8195AU-U02    | Upgrade from 1 ch. to 2 ch.              | Software license |
| M8195AU-U04    | Upgrade from 2 ch. to 4 ch. <sup>1</sup> | Software license |
| M8195AU-16G    | Upgrade to 16 Gsa per module             | Software license |
| M8195AU-SEQ    | Sequencer functionality per module       | Software license |
| M8195AU-FSW    | Fast switching per module                | Software license |

1. For an upgrade from 1 to 4 channels, both M8195AU-002 and M8195AU-U04 are required.

## 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 M8195A/M8197A 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 28-AWG 5-Conductor 2-M-LG PVC |         |
| M9048A         | PCIe® desktop card adapter Gen 2 x 8                           |         |
| Y1202A         | PCIe cable for M9048A desktop adapter                          |         |
| M8195A-810     | Matched cable pair for M8195A AWG, 2.92 mm                     |         |
| M8195A-820     | Termination 50 $\Omega$ , 26.5 GHz                             |         |

## Software

| Product number | Description                                                                                                             | Comment                 |
|----------------|-------------------------------------------------------------------------------------------------------------------------|-------------------------|
| 81195A         | Optical Modulation Generator Software                                                                                   | Free to download        |
| 81195A-RSP     | Real-Time Signal Processing                                                                                             | Requires 81195A         |
| 81195A-OSP     | Optical Signal Properties                                                                                               |                         |
| M8070A-OTP     | System Software for M8000 Series of BER Test Solutions, Transportable, Perpetual License                                |                         |
| M8070A-ONP     | System Software for M8000 Series of BER Test Solutions, Network/Floating, Perpetual License                             |                         |
| M8070A-1TP     | DUT Control Interface, Transportable, Perpetual License                                                                 |                         |
| M8085A-CT1     | MIPI C-PHY <sup>sm</sup> Editor for M819xA AWG, transportable, perpetual License                                        |                         |
| M8085A-CN1     | MIPI C-PHY Editor for M819xA AWG, network/floating, perpetual License                                                   |                         |
| M8085A-CTA     | MIPI C-PHY Calibration, Conformance and Characterization Procedures for M819xA AWG, Transportable, Perpetual License    |                         |
| M8085A-CNA     | MIPI C-PHY Calibration, Conformance and Characterization Procedures for M819xA AWG, Network/Floating, Perpetual License | Requires M8070A license |
| M8085A-DT1     | MIPI D-PHY <sup>sm</sup> Editor for M819xA AWG, transportable, perpetual License                                        |                         |
| M8085A-DN1     | MIPI D-PHY Editor for M819xA AWG, network/floating, perpetual License                                                   |                         |
| M8085A-DTA     | MIPI D-PHY Calibration, Conformance and Characterization Procedures for M819xA AWG, transportable, perpetual License    |                         |
| M8085A-DNA     | MIPI D-PHY Calibration, Conformance and Characterization Procedures for M819xA AWG, Network/Floating, Perpetual License |                         |
| N6171A-M02     | MATLAB license (standard)                                                                                               |                         |
| N6171A-M03     | MATLAB license (extended)                                                                                               |                         |



# Specifications

## General characteristics

| M8195A                               |                                                                                                                                                  |
|--------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|
| Sample rate                          | 53.76 GSa/s to 65.00 GSa/s<br>or 26.88 GSa/s to 32.50 GSa/s (sample rate divider = 2)<br>or 13.44 GSa/s to 16.25 GSa/s (sample rate divider = 4) |
| DAC resolution                       | 8 bits                                                                                                                                           |
| Number of channels per M8195A module | 1, 2 or 4 (corresponds to Opt. 001, 002, 004)<br>Number of channels is software upgradable via license key                                       |

## Sample memory

| M8195A                                 |                                                                                                                                               |
|----------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|
| Internal sample memory                 | 1 MSa per module<br>(for modes of operation see Sample memory modes table below)                                                              |
| Extended sample memory                 | 2 GSa per M8195A module (standard) 16 GSa per M8195A module (with Option 16G)<br>(for modes of operation see Sample memory modes table below) |
| Waveform granularity <sup>1</sup>      |                                                                                                                                               |
| – Int. memory                          | 128 samples                                                                                                                                   |
| – Ext. memory, sample rate divider = 1 | 256 samples                                                                                                                                   |
| – Ext. memory, sample rate divider = 2 | 128 samples                                                                                                                                   |
| – Ext. memory, sample rate divider = 4 | 64 samples                                                                                                                                    |
| Minimum waveform length                |                                                                                                                                               |
| – Int. memory                          | 128 samples                                                                                                                                   |
| – Ext. memory, sample rate divider = 1 | 1280 samples                                                                                                                                  |
| – Ext. memory, sample rate divider = 2 | 640 samples                                                                                                                                   |
| – Ext. memory, sample rate divider = 4 | 320 samples                                                                                                                                   |

## Useable number of Channels with extended memory

| Option |     |     |                                       | Mode                                          | Sample rate divider                          |                                              |  |
|--------|-----|-----|---------------------------------------|-----------------------------------------------|----------------------------------------------|----------------------------------------------|--|
|        |     |     |                                       | 1                                             | 2                                            | 4                                            |  |
|        |     |     |                                       | 53.76 GSa/s to 65.00 GSa/s<br>max. 16G memory | 26.88 GSa/s to 32.50 GSa/s<br>max. 8G memory | 13.44 GSa/s to 16.25 GSa/s<br>max. 4G memory |  |
| 001    | 002 | 004 | Single channel <sup>2</sup>           | 1                                             | 1                                            | 1                                            |  |
|        |     |     | Single channel with marker            | 1                                             | 1                                            | 1                                            |  |
|        |     |     | Dual channel <sup>2</sup>             | 1                                             | 2                                            | 2                                            |  |
|        |     |     | Dual channel with marker <sup>2</sup> | 1                                             | 2                                            | 2                                            |  |
|        |     |     | Dual channel duplicate                | N/A                                           | 2                                            | 2                                            |  |
|        |     |     | Four channel <sup>2</sup>             | 1                                             | 2                                            | 4                                            |  |

1. The length of waveform segments must be a multiple of the granularity.
2. Unused channels can be used at full sample rate with internal memory.

## Sample memory modes

| Mode            | Available with option | Sample memory (standard) | Sample memory (with Opt. 16G) | Max. sample rate | Interpolation <sup>1</sup> | Max. output frequency <sup>2</sup> | Analog BW (typ) (3 dB) |
|-----------------|-----------------------|--------------------------|-------------------------------|------------------|----------------------------|------------------------------------|------------------------|
| 1 ch, ext.mem.  | 001, 002, 004         | 2 GSa                    | 16 GSa                        | 65 GSa/s         | None                       | > 25 GHz                           | 25 GHz                 |
| 1 ch, int. mem. | 001, 002, 004         | 1 MSa                    | 1 MSa                         | 65 GSa/s         | None                       | > 25 GHz                           | 25 GHz                 |
| 2 ch, ext.mem.  | 002, 004              | 1 GSa per ch.            | 8 GSa per ch.                 | 32.5 GSa/s       | 2 x                        | 12.8 GHz                           | 25 GHz                 |
| 2 ch, int.mem.  | 002, 004              | 512 KSa per ch.          | 512 KSa per ch.               | 65 GSa/s         | None                       | > 25 GHz                           | 25 GHz                 |
| 4 ch, ext.mem.  | 004                   | 0.5 GSa per ch.          | 4 GSa per ch.                 | 16.25 GSa/s      | 4 x                        | 6.4 GHz                            | 25 GHz                 |
| 4 ch, int.mem.  | 004                   | 256 KSa per ch.          | 256 KSa per ch.               | 65 GSa/s         | None                       | > 25 GHz                           | 25 GHz                 |

## Frequency switching characteristics

| M8195A                                          |               |
|-------------------------------------------------|---------------|
| Effective frequency switching time <sup>3</sup> |               |
| – with Option FSW                               | 38 ps         |
| – without Option FSW                            | > 505 $\mu$ s |

## Out 1, 2, 3, 4

| M8195A                                    |                                                                             |
|-------------------------------------------|-----------------------------------------------------------------------------|
| Output type                               | Single ended <sup>4</sup> or differential                                   |
| Bandwidth (3 dB, excl. sin(x)/x roll-off) | 25 GHz (typ)                                                                |
| Rise/fall time <sup>5</sup> (20% / 80%)   | 18 ps (typ)                                                                 |
| Impedance                                 | 50 $\Omega$ (nom)                                                           |
| Amplitude                                 | 75 mV <sub>pp</sub> to 1.0 V <sub>pp</sub> , single-ended into 50 $\Omega$  |
|                                           | 150 mV <sub>pp</sub> to 2.0 V <sub>pp</sub> , differential                  |
| Amplitude resolution                      | 200 $\mu$ V (nom)                                                           |
| DC amplitude accuracy <sup>6</sup>        | $\pm$ (2.5% +10 mV) (typ)                                                   |
| Voltage window                            | -1.0 V to +3.7 V single-ended into 50 $\Omega$                              |
| Offset resolution                         | 200 $\mu$ V (nom)                                                           |
| DC offset accuracy <sup>7</sup>           | $\pm$ 20 mV (typ)                                                           |
| Differential offset                       | In system adjustable to 0 mV                                                |
| Termination voltage window                | -1.0 V to + 3.7 V                                                           |
|                                           | V <sub>OL</sub> $\leq$ 1.5 V: (low level - 500 mV) to (high level +1000 mV) |
|                                           | V <sub>OL</sub> > 1.5 V: low level to (high level +1000 mV)                 |
| Total jitter, with pre-distortion         | 6 ps (pp) at 32 Gb/s PRBS (nom)                                             |
| Random jitter, RMS <sup>8</sup>           | 200 fs (typ)                                                                |

- Interpolation is performed by FIR filters in hardware. For 2x (4x) interpolation, samples are read from memory at a rate up to 32.5 GSa/s (16.25 GSa/s) and interpolated to a DAC sample rate of up to 65 GSa/s. For interpolation = none, the sample rate from memory is the same as the DAC sample rate.
- With default FIR configuration the maximum sample rate is calculated as 80% of Nyquist. With custom FIR configurations higher output frequencies can be achieved.
- Effective switching frequency is determined as  $1/f_{\max}$ , with  $f_{\max} = f_{\text{Sa}}(\max) / 2.5$
- Unused output must be terminated with 50  $\Omega$  to GND. In case the termination voltage is not GND, the unused output must be terminated to V<sub>Term</sub>.
- Sample rate 64 GSa/s, output amplitude 500 mV<sub>pp(se)</sub>.
- Termination voltage = 0 V; adjusted at 23 °C ambient temperature, amplitude increases by 0.2%/°C (typ) for ambient temperature below 23 °C.
- Termination voltage = 0 V.
- 10 GHz clock; 1 V ampl.; 60 GSa/s.

## Out 1, 2, 3, 4 (Continued)

| M8195A                                                                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|----------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Harmonic distortions <sup>1,2</sup>                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| – 2nd harmonic                                                                   | -45 dBc (typ), $f_{out} < 3$ GHz<br>-35 dBc (typ), $f_{out} = 3$ GHz... 6 GHz<br>-30 dBc (typ), $f_{out} > 6$ GHz                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| – 3rd harmonic                                                                   | -45 dBc (typ), $f_{out} < 1$ GHz<br>-40 dBc (typ), $f_{out} = 1$ GHz... 3 GHz<br>-35 dBc (typ), $f_{out} = 3$ GHz... 6 GHz<br>-30 dBc (typ), $f_{out} > 6$ GHz                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| Two-tone IMD <sup>1</sup>                                                        | -45 dBc (typ), $f_{out1} = 990$ MHz, $f_{out2} = 1010$ MHz                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| SFDR <sup>1</sup> (excluding harmonic distortions)                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| – In-band                                                                        | -80 dBc (typ), $f_{out} = 100$ MHz, measured DC to 1 GHz<br>-70 dBc (typ), $f_{out} =$ DC...400 MHz, measured DC to 400 MHz<br>-48 dBc (typ), $f_{out} =$ DC...4 GHz, measured DC to 4 GHz<br>-53 dBc (typ), $f_{out} = 4$ GHz...6 GHz, measured 4 GHz to 6 GHz<br>-53 dBc (typ), $f_{out} = 6$ GHz...8 GHz, measured 6 GHz to 8 GHz<br>-50 dBc (typ), $f_{out} = 8$ GHz...10 GHz, measured 8 GHz to 10 GHz<br>-46 dBc (typ), $f_{out} = 10$ GHz...12 GHz, measured 10 GHz to 12 GHz<br>-50 dBc (typ), $f_{out} = 12$ GHz...14 GHz, measured 12 GHz to 14 GHz<br>-42 dBc (typ), $f_{out} = 14$ GHz...16 GHz, measured 14 GHz to 16 GHz<br>-42 dBc (typ), $f_{out} = 16$ GHz...18 GHz, measured 16 GHz to 18 GHz<br>-42 dBc (typ), $f_{out} = 18$ GHz...20 GHz, measured 18 GHz to 20 GHz<br>-48 dBc (typ), $f_{out} = 20$ GHz...21 GHz, measured 20 GHz to 21 GHz<br>-42 dBc (typ), $f_{out} = 21$ GHz...22 GHz, measured 21 GHz to 22 GHz<br>-40 dBc (typ), $f_{out} = 22$ GHz... 24 GHz, measured 22 GHz to 24 GHz<br>-40 dBc (typ), $f_{out} = 24$ GHz ... 26 GHz, measured 24 GHz to 26 GHz |
| – Adjacent band                                                                  | -48 dBc (typ), $f_{out} =$ DC...4 GHz, measured DC to 8 GHz<br>-48 dBc (typ), $f_{out} = 4$ GHz...6 GHz, measured 3 GHz to 8 GHz<br>-34 dBc (typ), $f_{out} = 6$ GHz...8 GHz, measured 4 GHz to 10 GHz<br>-34 dBc (typ), $f_{out} = 8$ GHz...10 GHz, measured 6 GHz to 12 GHz<br>-46 dBc (typ), $f_{out} = 10$ GHz...12 GHz, measured 8 GHz to 14 GHz<br>-42 dBc (typ), $f_{out} = 12$ GHz...14 GHz, measured 10 GHz to 16 GHz<br>-32 dBc (typ), $f_{out} = 14$ GHz...16 GHz, measured 12 GHz to 18 GHz<br>-30 dBc (typ), $f_{out} = 16$ GHz...18 GHz, measured 14 GHz to 20 GHz<br>-40 dBc (typ), $f_{out} = 18$ GHz...20 GHz, measured 16 GHz to 22 GHz<br>-35 dBc (typ), $f_{out} = 20$ GHz....22 GHz, measured 18 GHz to 24 GHz<br>-30 dBc (typ), $f_{out} = 22$ GHz....24 GHz, measured 20 GHz to 26 GHz<br>-28 dBc (typ), $f_{out} = 24$ GHz.... 25 GHz, measured 22 GHz to 27 GHz<br>-28 dBc (typ), $f_{out} = 25$ GHz.... 26 GHz, measured 23 GHz to 27 GHz                                                                                                                             |
| Amplitude flatness (at SMA connector, <sup>3</sup> compensated for $\sin(x)/x$ ) | $\pm 2$ dB (typ), $f_{out} =$ DC...10 GHz<br>+2 dB, -3 dB (typ), $f_{out} = 10$ ...25 GHz (typ)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| Connector type                                                                   | 2.92 mm "K-style" (female)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |

1. Sample rate 64 GSa/s, output amplitude 500 mV<sub>pp(se)</sub>.

2. Measured with a balun (e.g. HL 9405).

3. Measured at Data Out.

Phase noise

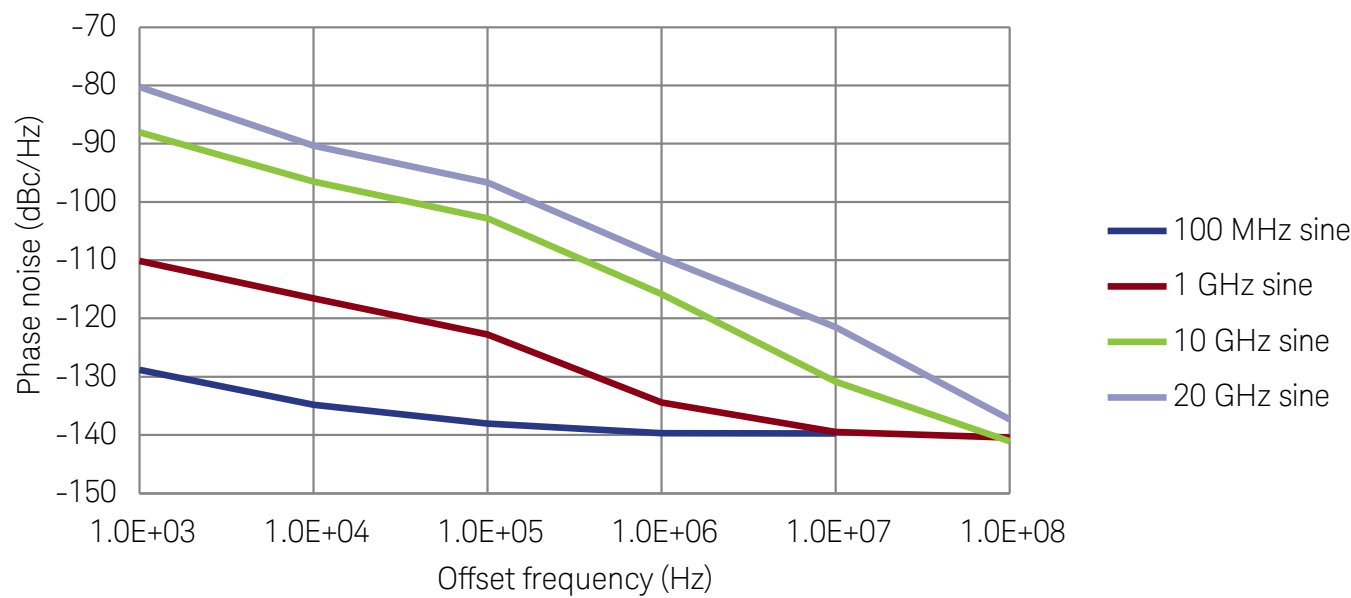


Figure 9. Nominal phase noise measured with a sample rate of 64 GSa/s, at Out 1, single ended, 500 mV amplitude

Frequency response

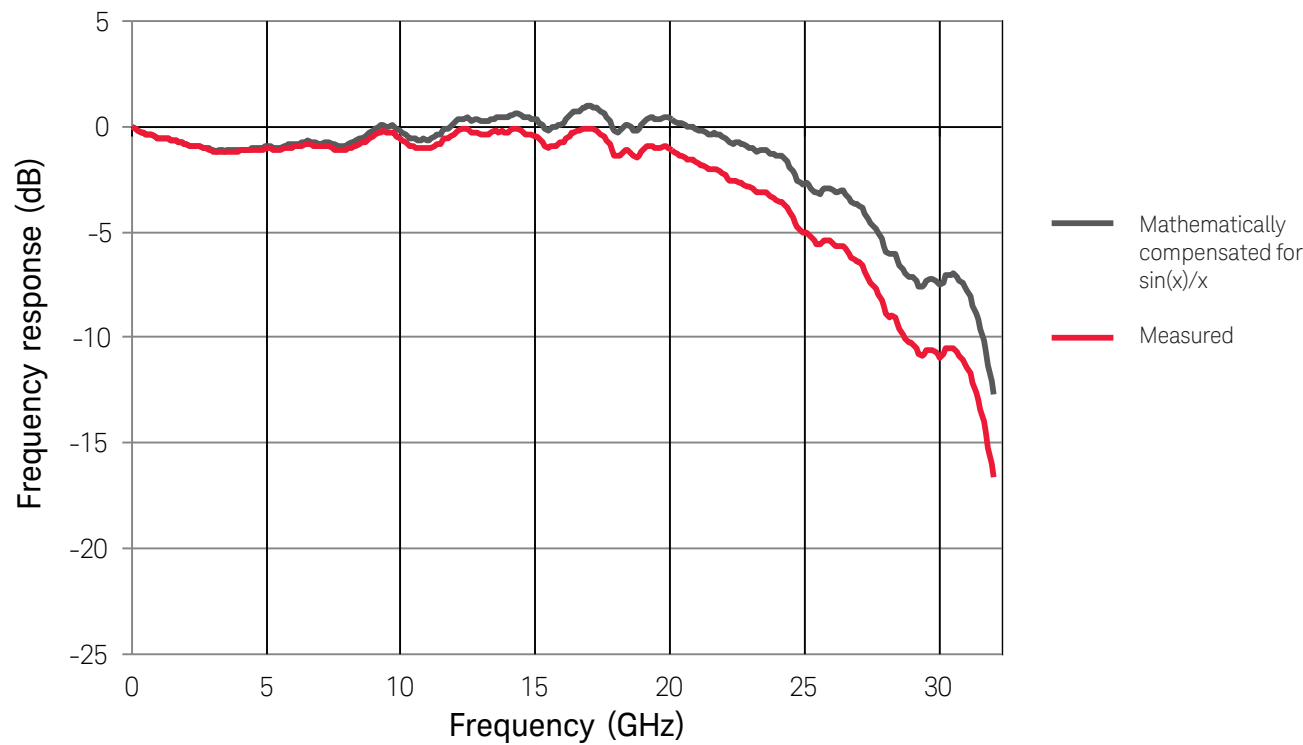


Figure 10. Nominal frequency response measured with a sample rate of 64 GSa/s and a multi-tone signal containing frequencies from DC to 32 GHz with equal amplitudes

## ENOB

ENOB measured at 64 GSa/s using the sine fit method according to IEEE Std 1658-2011 with a sampling scope. Bandwidth is limited to maximum tone frequency, except for the ones labeled with Nyquist.

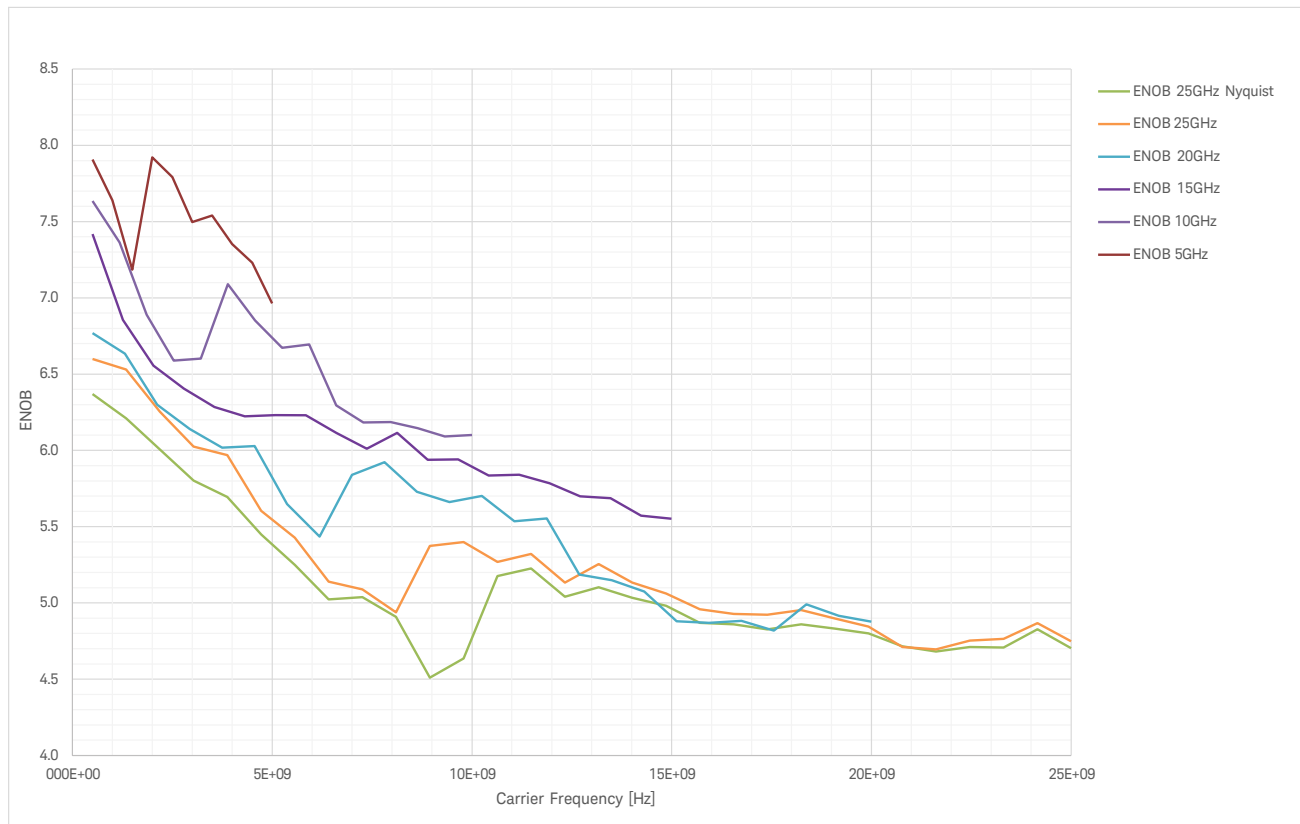


Figure 11. Nominal ENOB measured on a differential signal combined by a 50 GHz Balun Hyperlabs HL9405 with a sample rate of 64 GSa/s, internal clock and 500 mV amplitude at different bandwidths.

## Markers

Two independent digital markers and their complements are available in single channel with markers and dual channel with markers mode. The markers are available only for channels on extended memory. They are provided on channel 3 and 4 on normal and complement.

In all other modes, no markers are available.

Markers do not reduce vertical resolution.

The granularity of markers is one sample, a maximum of one rising and one falling edge of a marker are possible within 128 samples.

## Dual channel duplicate mode

In "Dual channel duplicate mode" the signal on channel 1 is duplicated on channel 2 and the signal on channel 4 is duplicated on channel 3.

This mode allows differential signals to be generated with adjustable skew between normal and complement.



## Run modes

| M8195A and M8197A |                                                                                             |
|-------------------|---------------------------------------------------------------------------------------------|
| Continuous        |                                                                                             |
| – Int. Memory     | A waveform segment is continuously repeated                                                 |
| – Ext. Memory     | A waveform segment/sequence/scenario is continuously repeated                               |
| Triggered         |                                                                                             |
| – Int. Memory     | A waveform segment is looped continuously after a trigger event is received                 |
| – Ext. Memory     | A waveform segment/sequence/scenario is generated once after a trigger event is received    |
| Gated             |                                                                                             |
| – Int. Memory     | A waveform segment is looped continuously after a rising edge of the trigger/gate input     |
| – Ext. Memory     | A waveform segment/sequence/scenario is generated as long as the trigger/gate input is high |

## Sequencer modes

The sample memory can be split into a maximum of 16 M waveform segments.

Waveform segments can have different sizes, but the segment size must be the same across channels.

The sequence table can contain up to 16 M entries (sequence IDs).

| M8195A                       |                                                                                                                                                                      |
|------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Arbitrary                    |                                                                                                                                                                      |
| – Int. Memory                | One waveform segment of arbitrary length is continuously looped                                                                                                      |
| – Ext. Memory                |                                                                                                                                                                      |
| Sequence (requires Opt. SEQ) |                                                                                                                                                                      |
| – Int. Memory                | Not available                                                                                                                                                        |
| – Ext. Memory                | One or more waveform segments are arranged in a linear sequence. Each segment can be repeated a programmable number of times or until an external event is signaled. |
| Scenario (requires Opt. SEQ) |                                                                                                                                                                      |
| – Int. Memory                | Not available                                                                                                                                                        |
| – Ext. Memory                | One or more sequences are arranged in a linear sequence. Each sequence can be repeated a programmable number of times or until an external event is signaled         |

## Trigger/gate input

A trigger/gate input is provided on the front panel of the M8195A and the M8197A. The trigger input is used to start/gate waveform playback.

- The trigger/gate input of the M8195A affects the channels of that M8195A.
- The trigger/gate input of the M8197A affects all channels of all M8195A that are combined in a multi-module system. To achieve best delay accuracy between trigger/gate input and the OUT signals, use the trigger/gate input of the M8197A. See timing characteristics below.

| M8195A and M8197A             |                                  |
|-------------------------------|----------------------------------|
| Input range                   | -4 V to +4 V                     |
| Threshold                     |                                  |
| – Range                       | -4 V to +4 V                     |
| – Resolution                  | 10 mV (nom)                      |
| – Sensitivity                 | 100 mV (typ)                     |
| Polarity                      | Selectable, positive or negative |
| Input impedance               | 50 $\Omega$ (nom), DC coupled    |
| Max. toggle rate <sup>1</sup> |                                  |
| – Sample rate divider = 1     | Sample rate/3584                 |
| – Sample rate divider = 2     | Sample rate/1792                 |
| – Sample rate divider = 4     | Sample rate/896                  |
| Connector type                | SMA (female)                     |

## Event input

An event input is provided on the front panel of the M8195A and the M8197A. It is used in conjunction with the sequencer to advance to the next waveform segment or sequence.

- The event input of the M8195A affects the channels of that M8195A.
- The event input of the M8197A affects all channels of all M8195A that are combined in a multi-module system.

| M8195A and M8197A |                                  |
|-------------------|----------------------------------|
| Input range       | -4 V to +4 V                     |
| Threshold         |                                  |
| – Range           | -4 V to +4 V                     |
| – Resolution      | 10 mV (nom)                      |
| – Sensitivity     | 100 mV (typ)                     |
| Polarity          | Selectable, positive or negative |
| Input impedance   | 50 $\Omega$ (nom), DC coupled    |
| Connector type    | SMA (female)                     |

1. Without option -FSW the trigger interval is limited as described under the 'Frequency switching characteristics'.

## Trigger output (M8195A only)

The “Trigger output” and “Event input” functions share the same connector on the front panel.

The “Trigger output” functionality is only used in conjunction with the 81195A Optical Modulation Generator Software. For details of using the “Trigger output” functionality, refer to the 81195A data sheet and user guide.

| M8195A                      |                                            |
|-----------------------------|--------------------------------------------|
| Output impedance            | 50 $\Omega$ (nom)                          |
| Level                       |                                            |
| – Voltage window            | –0.5 V to 2.0 V                            |
| – Amplitude                 | 200 mVpp to 2.5 Vpp                        |
| – Resolution                | 10 mV                                      |
| – Accuracy                  | $\pm$ (10% + 25 mV) (typ)                  |
| Rise/fall time (20% to 80%) | 150 ps (nom)                               |
| Width                       | 20 ns (1280 sample clock cycles @ 64 GS/s) |

## Dynamic control input/general purpose output (M8197A only)

A bidirectional parallel input and output port is provided on the front panel of the M8197A synchronization module. When the port is configured as input, it can be used as ‘dynamic control input’ for all channels of a synchronous system to control the sequencing by external hardware. The dynamic control input affects all channels of a synchronous system. When the port is configured as a parallel output, the 14 digital lines can be individually controlled by software to represent logical states zero or one.

A detailed description of the dynamic control input, including timing diagram and pin assignment, is shown in the M8195A User’s Guide.

| M8197A                           |                                                                   |
|----------------------------------|-------------------------------------------------------------------|
| Configuration as input           |                                                                   |
| – Input signals                  | Data[0..12]_In, Data_Select, Load                                 |
| – Number of addressable segments | $2^{24} = 16\,777\,216$                                           |
| – Data rate                      | DC to 1 MHz                                                       |
| – Setup time                     | 3.0 ns (‘Data[0..12]_In’, ‘Data_Select’ to rising edge of ‘Load’) |
| – Hold time                      | 0.0 ns (rising edge of ‘Load’ to ‘Data[0..12]_In’, ‘Data_Select’) |
| – Input range                    |                                                                   |
| – Low level                      | 0 V to +0.7 V                                                     |
| – High level                     | +1.6 V to 3.6 V                                                   |
| – Input impedance                | Internal 10 k $\Omega$ (nom) to GND                               |
| Configuration as output          |                                                                   |
| – Output signals                 | Data[0..13]_Out                                                   |
| – Output range                   |                                                                   |
| – Low level (–12 mA to 0 mA)     | 0 V to +0.4 V                                                     |
| – High level (0 mA to 12 mA)     | +2.4 V to 3.3 V                                                   |
| Connector type                   | 20 pin mini D ribbon (MDR) connector <sup>1</sup>                 |

1. Manufacturer: 3M. Manufacturer Part Number: N10220-52B2PC.

## Timing characteristics

The sequencing of a single M8195A can be controlled with the 'Trigger/Gate Input' as well as the 'Event Input' of the M8195A. In a synchronous system that consists of one M8197A and up to four M8195A, the sequencing of the entire synchronous system can be controlled with the 'Trigger/Gate Input' as well as the 'Event Input' of the M8197A. A single M8195A or a synchronous system can operate asynchronously or synchronously. In case of synchronous operation, a timing requirement between the Reference Clock Output and 'Trigger/Gate Input' or 'Event Input' must be met.

|                                        | M8195A                                                                | M8197A                                                                |
|----------------------------------------|-----------------------------------------------------------------------|-----------------------------------------------------------------------|
| Delay                                  |                                                                       |                                                                       |
| – Trigger/Gate Input to Data Out       | 40192 sample clock cycles + 0 ns (nom)                                | 45317 sample clock cycles + 8 ns (nom)                                |
| – Event Input to Data Out              | 40192 sample clock cycles + 0.15 ns (nom)                             | 45317 sample clock cycles + 8 ns (nom)                                |
| Delay accuracy, asynchronous operation |                                                                       |                                                                       |
| – Trigger/Gate Input to Data Out       | ± 100 ps (typ)                                                        | ± 20 ps (typ)                                                         |
| – Event Input to Data Out              | ± 100 ps (typ)                                                        | ± 100 ps (typ)                                                        |
| Synchronous operation                  |                                                                       |                                                                       |
| Delay accuracy                         | 1ps <sub>rms</sub> (typ) (Rising edge of 'REF CLK OUT' to 'DATA OUT') | 1ps <sub>rms</sub> (typ) (Rising edge of 'REF CLK OUT' to 'DATA OUT') |
| – Set-up time                          | -2.5 ns (typ) ('TRIG IN', 'EVENT IN' to rising edge of 'REF CLK OUT') | -1.9 ns (typ) ('TRIG IN', 'EVENT IN' to rising edge of 'REF CLK OUT') |
| – Hold time                            | 5.1 ns (typ) (Rising edge of 'REF CLK OUT' to 'TRIG IN', 'EVENT IN')  | 4.5 ns (typ) (Rising edge of 'REF CLK OUT' to 'TRIG IN', 'EVENT IN')  |
| Skew between normal and complement     | 0 ps ± 1 ps (nom)                                                     |                                                                       |
| Skew between any pair of outputs       |                                                                       |                                                                       |
| – Within one M8195A module             | 0 ps ± 5 ps (typ) <sup>1</sup>                                        |                                                                       |
| – Across multiple M8195A modules       | 0 ps ± 100 ps (typ) <sup>2</sup>                                      |                                                                       |

1. Can be adjusted to 0 ps using variable channel delay.

2. Can be adjusted to 0 ps using variable module delay and variable channel delay.

## Variable channel delay

In order to compensate for external cable length differences as well as the initial skew, channels 1, 2, 3 and 4 can be individually delayed with a very high timing resolution. There are two possibilities to adjust the variable channel delay:

- The sample clock delay can be changed in discrete steps. The step size is  $1 / \text{DAC Sample Frequency}$ . E.g. the step size is 15.625 ps for a DAC Sample Frequency of 64 GHz.
- The FIR delay can be used for sub sample delay adjust. Note: This delay functionality uses a digitally implemented FIR filter with limited length and accuracy. As a result the output signal may show some degradation when using the FIR delay adjust.

| M8195A                    |                        |
|---------------------------|------------------------|
| Sample clock delay range  | 0 ... 95 sample clocks |
| FIR delay range           |                        |
| – Sample Rate Divider = 1 | -50 ps...+50 ps        |
| – Sample Rate Divider = 2 | -100 ps...+100 ps      |
| – Sample Rate Divider = 4 | -200 ps...+200 ps      |
| FIR delay resolution      | 10 fs                  |

## Variable module delay

In order to compensate for external cable length differences as well as the initial skew, channels 1, 2, 3 and 4 can be jointly delayed with a very high timing resolution. In case the M8197A synchronization module is used to configure a synchronous system, the variable delay can be used to align the channels of multiple M8195A modules.

Modifying the variable delay always affects the delay of all four channels.

E.g. setting the variable delay to 10 ps has the following effect. Out 1, 2, 3 and 4 are delayed by 10 ps with respect to trigger/gate input and event input.

| M8195A           |                   |
|------------------|-------------------|
| Delay range      | 0 ns to 10 ns     |
| Delay resolution | 50 fs             |
| Delay accuracy   | $\pm 10$ ps (typ) |

## FIR filter

Each channel in the M8195A has an FIR filter with programmable coefficients in front of its respective DAC. The FIR filters are used to realize variable channel delay and waveform interpolation with sample rate divider 2 and 4. The following presets are available for the FIR filter coefficients: Nyquist, Low Pass, Linear Interpolation, Zero Order Hold and User Defined. The number of taps of each filter is 16 when internal memory is used and depends on the sample rate divider when extended memory is used as shown in the following table:

| Sample rate divider | Taps | Memory sample rate          | DAC sample rate             |
|---------------------|------|-----------------------------|-----------------------------|
| 1                   | 16   | 53.76 GSa/s ... 65.00 GSa/s | 53.76 GSa/s ... 65.00 GSa/s |
| 2                   | 32   | 26.88 GSa/s ... 32.50 GSa/s | 53.76 GSa/s ... 65.00 GSa/s |
| 3                   | 64   | 13.44 GSa/s ... 16.25 GSa/s | 53.76 GSa/s ... 65.00 GSa/s |

## Reference clock input

The clock reference input is provided on the front panel of each module. The clock reference input of the M8195A is used as the clock reference for all four channels of that M8195A. The clock reference input of the M8197A synchronization module is used as the clock reference for all channels of all M8195A that are combined in a synchronous system.

| M8195A and M8197A                 |                                                                              |
|-----------------------------------|------------------------------------------------------------------------------|
| Input frequency ranges            | 10 MHz to 300 MHz<br>210 MHz to 17 GHz                                       |
| Lock range                        | $\pm 1\%$ (typ)                                                              |
| Jitter                            | $< 2$ ps <sub>pp</sub>                                                       |
| Input level                       |                                                                              |
| – 10 MHz - 10 GHz                 | 250 mV <sub>pp</sub> to 2 V <sub>pp</sub>                                    |
| – 10 GHz - 17 GHz                 | 500 mV <sub>pp</sub> to 2 V <sub>pp</sub>                                    |
| Impedance                         | 50 $\Omega$ (nom), AC coupled                                                |
| Connector                         | SMA                                                                          |
| Sample clock frequency resolution | 1 ppm; e.g. sample clock frequency = 64 GHz => frequency resolution = 64 kHz |

## Reference clock output

The clock reference output is provided on the front panel of each module.

| M8195A and M8197A                                                            |                                                                                                                                                         |
|------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|
| AXIe backplane clock source                                                  |                                                                                                                                                         |
| – Output frequency                                                           | $f_{\text{Out}}^1 = f_{\text{Sa}} / (32 * n)$ with $n = 1 \dots 1024$ or<br>$f_{\text{Out}}^2 = f_{\text{Sa}} / 256$                                    |
| – Frequency accuracy                                                         | $\pm 20$ ppm                                                                                                                                            |
| Internal clock source                                                        |                                                                                                                                                         |
| – Output frequency                                                           | $f_{\text{Out}}^1 = f_{\text{Sa}} / (32 * n)$ with $n = 1 \dots 1024$ or<br>$f_{\text{Out}}^2 = f_{\text{Sa}} / 256$ or<br>$f_{\text{Out}}^2 = 100$ MHz |
| – Frequency accuracy                                                         | See internal synthesizer clock characteristic                                                                                                           |
| External reference clock input frequency $f_{\text{In}} = 10$ MHz to 300 MHz |                                                                                                                                                         |
| – Output frequency                                                           | $f_{\text{Out}}^2 = f_{\text{In}} / (n * m)$ with $n, m = 1 \dots 8$ or<br>$f_{\text{Out}}^2 = f_{\text{Sa}} / 256$                                     |
| – Frequency accuracy                                                         | Depends on external reference clock                                                                                                                     |
| External reference clock input frequency $f_{\text{In}} = 210$ MHz to 17 GHz |                                                                                                                                                         |
| – Output frequency                                                           | $f_{\text{Out}}^1 = f_{\text{Sa}} / (32 * n)$ with $n = 1 \dots 1024$ or<br>$f_{\text{Out}}^2 = f_{\text{Sa}} / 256$                                    |
| – Frequency accuracy                                                         | Depends on external reference clock                                                                                                                     |
| Output amplitude                                                             | 900 mV <sub>pp</sub> (nom) into 50 $\Omega$                                                                                                             |
| Source impedance                                                             | 50 $\Omega$ (nom), AC coupled                                                                                                                           |
| Connector                                                                    | SMA                                                                                                                                                     |

1. Reference clock output phase shifts when the variable delay is changed.
2. For M8195A: Reference clock output remains unchanged when the variable delay is changed.
3. Warm-up time 2 minutes min.
4.  $f_{\text{Sa}} = 64$  GHz; reference clock source: internal.

## Internal synthesizer clock characteristics

| M8195A                   |                                                         |
|--------------------------|---------------------------------------------------------|
| Frequency                | 53.76 GHz to 65.00 GHz                                  |
| Accuracy <sup>1</sup>    | ± 2 ppm (spec)                                          |
| Frequency resolution     | 7 digits, e.g. 100 Hz at 1 GHz                          |
| Phase noise <sup>2</sup> | < -115 dBc/Hz (typ) at 10 kHz offset, $f_{OUT} = 1$ GHz |
|                          | < -95 dBc/Hz (typ) at 10 kHz offset, $f_{OUT} = 10$ GHz |

## Download speed

Download speed is measured by transferring the samples from the controlling PC's memory into the M8195A.

|                | USB using SCPI or IVI | PCIe using SCPI <sup>3</sup> | PCIe using IVI <sup>3, 4</sup> |
|----------------|-----------------------|------------------------------|--------------------------------|
| Download Speed | ~8 MSa/s (meas)       | ~40 MSa/s (meas)             | ~400 MSa/s (meas)              |

## Instrument software

The M8195A and M8197A are controlled by a combined soft-front panel and firmware application that runs on an embedded AXIe controller or external PC or laptop.

| M8195A and M8197A                  |                                                                                     |
|------------------------------------|-------------------------------------------------------------------------------------|
| 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 hardware              | PCI Express® or USB                                                                 |
| Application programming interfaces | SCPI, IVI-COM, LabView                                                              |

## General

|                             | M8195A                                                                                                                                      | M8197A     |
|-----------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|------------|
| Power consumption           | 180 W (nom) @ 65 GSa/s                                                                                                                      | 60 W (nom) |
| Operating temperature       | 0 °C to 40 °C                                                                                                                               |            |
| Operating humidity          | 5% to 80% relative humidity, non-condensing                                                                                                 |            |
| Operating altitude          | Up to 2000 m                                                                                                                                |            |
| Storage temperature         | -40 °C to +70 °C                                                                                                                            |            |
| Stored states               | User configurations and factory default                                                                                                     |            |
| Interface to controlling PC | PCIe (see AXIe chassis specification) or USB                                                                                                |            |
| Form factor                 | 1-slot AXIe                                                                                                                                 |            |
| Dimensions (W x H x D)      | 322.25 mm x 30 mm x 281.5 mm                                                                                                                |            |
| Weight                      | 3.75 kg                                                                                                                                     | 2.7 kg     |
| Safety designed to          | IEC61010-1, UL61010, CSA22.2 61010.1 tested                                                                                                 |            |
| EMC tested to               | IEC61326-1                                                                                                                                  |            |
| Warm-up time                | 30 min                                                                                                                                      |            |
| Calibration interval        | 2 years recommended                                                                                                                         |            |
| Cooling requirements        | When operating the system choose a location that provides at least 80 mm of clearance at rear, and at least 30 mm of clearance at each side |            |

1. Warm-up time 2 minutes min.
2.  $f_{sa} = 64$  GHz; reference clock source: internal.
3. Using M9048A PCIe adapter.
4. Download of waveform samples without marker information.



# 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 after a 45-minute warm up period. 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 °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.

# 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                                                                                                                                                                                                                                                                                                                                                                                                                       |
|------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>KeysightCare</b><br> | 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 <a href="#">KeysightCare data sheet</a> 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.                                                                                                                                                                                                                                    |
| <b>Keysight Support Portal &amp; Knowledge Center</b>                                                      | 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.                                                                                                                                                                                                           |
| <b>Education Services</b>                                                                                  | Build confidence and gain new skills to make accurate measurements, with flexible Education Services developed by Keysight experts. Including Start-up Assistance.                                                                                                                                                                                                                                                             |
| Alternative product acquisition                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                |
| <b>KeysightAccess</b>                                                                                      | 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                                                     |
|-------------------------------|--------------------------------------------------------------|
| <b>KeysightCare Enhanced*</b> | <b>Includes Tech Support, Warranty and Calibration</b>       |
| 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)      |
| <b>KeysightCare Assured</b>   | <b>Includes Tech Support and Warranty</b>                    |
| 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                     |
| <b>Start-Up Assistance</b>    |                                                              |
| 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.

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