

# M5000 Series

High-Performance PXI System



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# Meet the M5000 Series

Welcome to the all-new Keysight M5000 Series. With an RF AWG, digitizer, digital I/O, and downconverter modules, the M5000 Series is a high-performance PXI system that enables the latest innovations in quantum, aerospace defense, and more.

## M5000 Series overview

Model	Description
M5200A	PXIe Digitizer 4 Channels, 2 GHz BW, 12-bit
M5201A	PXIe Down Converter 4 Channels, 2-16 GHz RF, 0.01-2.4 GHz IF
M5300A	PXIe RF AWG 4 Channels, DC-16 GHz RF, 2 GHz IBW, 14-bit
M5301A	PXIe Precision AWG 4 Channels, 400 MHz, 14-bit
M5302A	PXIe Digital I/O 28 LVDS Channels, 8 Trigger Channels

## Related products

Model	Description
M9046A	PXIe Chassis: High power, 18 slots, 24 GB/s, Requires option -QS2
M9032A	PXIe System Synchronization Module, 2-port
M9033A	PXIe System Synchronization Module, 5-port
M9038A	PXIe Embedded Controller
M9614A	PXIe 5-channel Source/Measure Unit
M9615A	PXIe 5-channel Precision Source/Measure Unit
P5000B	Streamline Vector Network Analyzer
UXR0164A	Infiniium UXR-Series Oscilloscope: 16 GHz, 4 Channels

# Enabling the Latest Innovations

## Quantum control

The M5000 Series forms the backbone for the Keysight Quantum Control System (QCS) – complete digital solution that eliminates the need to design custom control solutions.

Analog LOs and mixers in traditional hardware used for quantum control require frequent calibration, introduce leakage noise, and contribute to slow drifts in the performance of the system. The Keysight M5000 Series fully eliminates the need for these components leading to enhanced ease-of-use, unrivaled noise performance, and improved long-term stability.



# M5000 Series Modules

## M5200A Digitizer

The M5200A is a single-slot PXIe four-channel, high-speed digitizer. It is a high-performance digitizer with easy-to-use programming libraries, real-time sequencing technology, and FPGA programming.

The digitizer module supports four 2 GHz channels with 4.8 GSa/s sampling rate and 12-bits of resolution for high-definition sampling in quantum computing and aerospace applications. Users can create IP and processing algorithms in the FPGA. Users also have the ability for data usage outside of the module with the ability to transfer data directly over the PCIe backplane.



## M5201A Downconverter

The M5201A is a single-slot PXIe low-IF downconverter module with four pairs of RF/IF channels and a single, shared, internal local oscillator (LO). The RF input frequency range is 2 to 16 GHz. The intermediate frequency (IF) ranges from 10 MHz to 2.4 GHz.

The clock generator on the M5201A provides a reference which is then used to generate the Local Oscillator (LO) frequency required for the application. Inputs to the clock generator include the front panel 2.4 GHz clock input, the 100 MHz PXIe clock, and DSTAR clock from the chassis. When used with the -QS1 option on the M9046A chassis, the 2.4 GHz clock provides minimal phase noise and drift.



## M5300A RF AWG

The M5300A is a two-slot PXIe module with four high-speed AWG outputs, clock input and output, and eight triggers. It provides high-performance with easy-to-use programming libraries, real-time sequencing technology, and FPGA programming.

The M5300A RF AWG module supports four directly synthesized RF channels in 2 PXIe slots with up to 16 GHz of RF and 2 GHz of instantaneous bandwidth using direct digital I/Q modulation. The M5300A provides a waveform memory per channel of 1 GSample – half real (I) samples and half imaginary (Q) samples.

The M5300A includes a PathWave FPGA with user-customizable customer accessible area. The FPGA resource reserved for the customer configurable area is approximately 25% of the total XVCU35P FPGA resources. The customer configurable area in the M5300A reserves approximately 98% of CLB registers and 98% of LUTs for the user application.



## M5301A Baseband AWG

The M5301A is a single-slot PXIe module with four baseband AWG outputs, clock input and output, and four triggers. It provides high-performance with easy-to-use programming libraries, real-time sequencing technology, and FPGA programming.

The M5301A Baseband AWG module supports analog waveforms from 0 to 400 MHz with 400 MHz of bandwidth. The waveforms can be played from onboard memory as part of an HVI sequence.

The M5301A includes a PathWave FPGA with user-customizable customer accessible area. The FPGA resource reserved for the customer configurable area is approximately 25% of the total XVCU35P FPGA resources. The customer configurable area in the M5301A reserves approximately 98% of CLB registers and 98% of LUTs for the user application.



## M5302A Digital I/O

The M5302A is a single-slot Digital I/O PXIe module with 28 programmable LVDS channels and 8 single-ended channels. The LVDS channels can be used to communicate to the device under test or can be used to control other devices by emulating protocols. The single-ended channels are suitable for event triggers or other general-purpose I/O applications.

There are 28 bidirectional differential channels included on a 100-pin, front panel connector. These differential signals are LVDS (meant to drive 100-ohm differential load) and have a 1.2 Gbps maximum toggle rate. The Dig connector also includes +5 V power that is available to the user to power external interface circuitry (maximum current load is 0.5 A).

Eight SMBs are available for instrument triggers or other general purpose I/O signals. These channels are single-ended with a voltage swing of 0 – 3.3 V when driving High Impedance loads (the voltage levels at the DUT are halved when connected to a 50  $\Omega$  load). These signals can toggle up to 150 MHz when used as outputs, and 75 MHz when used as inputs.



## Distributed processing with FPGA

The M5000 Series has individual FPGAs in each module. Featuring the Kintex UltraScale+ FPGA in the M5201A and M5302A, and the Virtex UltraScale+ FPGA in the M5200A, M5300A, and M5301A, which allow for fast, distributed processing. The FPGA configurable region utilizes Xilinx FPGA partial reconfiguration technology to design and configure a defined section of the FPGA without the need to power down or reboot the cards or host computer.

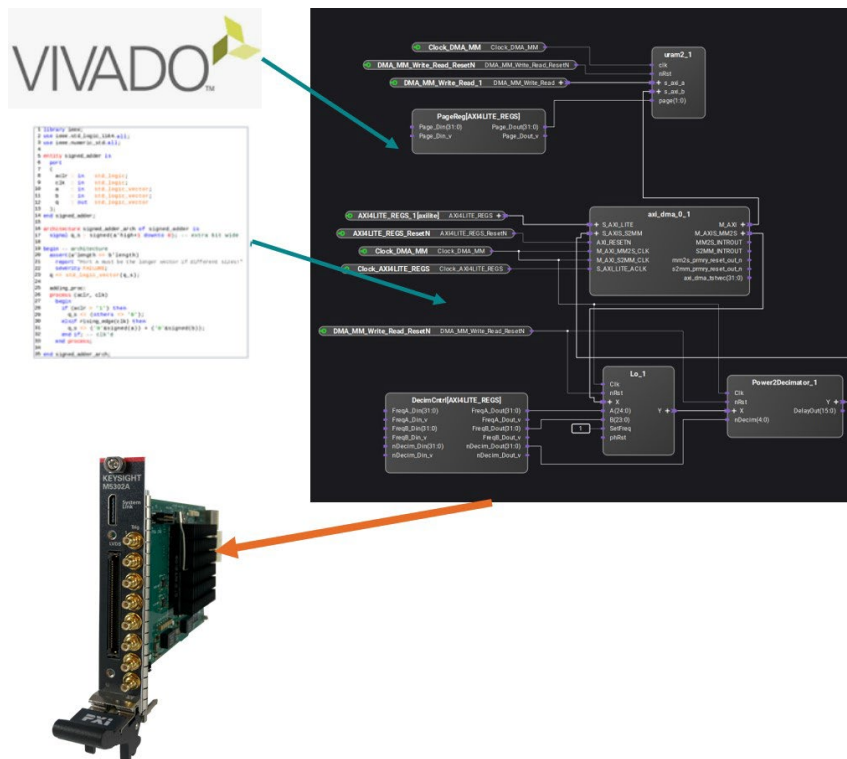


# PathWave FPGA

PathWave FPGA is a graphical environment that provides the ability to rapidly develop FPGA designs on many Keysight instruments. An IP library includes Logic/Math, Memory and DSP blocks that can be included in an FPGA design. PathWave FPGA supplies components to create custom design flows to go quickly from schematic to bitfile generation with the press of a button.

PathWave FPGA ships with a rich set of built-in library elements that can be dropped into a schematic. Easily modify the default template by importing Vivado IP, HDL IP, or by using the PathWave FPGA IP library. Key benefits:

- Visualize application flows and insert custom blocks
- Streamline the design process with full native FPGA-code compatibility
- Quickly compile the bitfile to program the FPGA model embedded in the instrument
- Easily target different instrument FPGAs using Board Support Packages (BSPs)

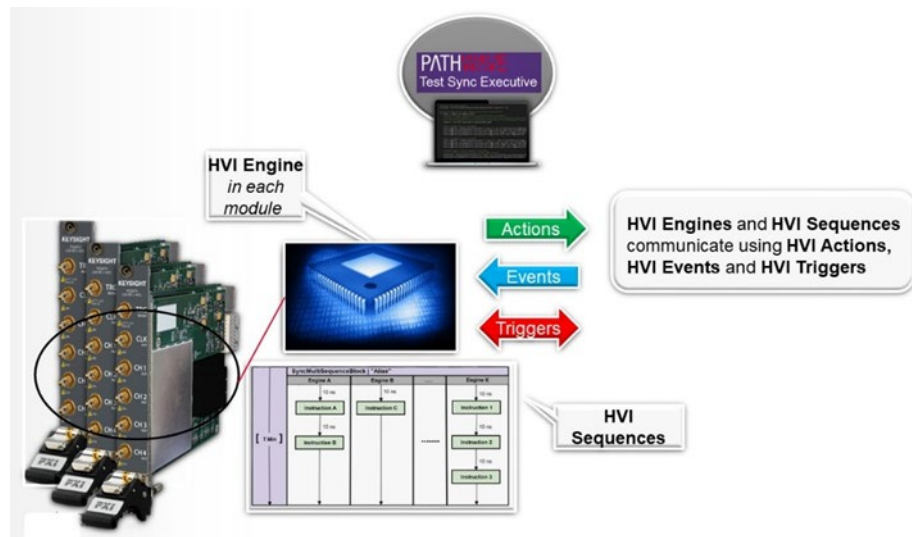


# PathWave Test Sync Executive

PathWave Test Sync Executive enables rapid development of high performance, multi-channel and multi-instrument, real-time synchronous solutions. This powerful software tool is critical in applications requiring tight synchronization, control, and feedback, including quantum control, radar, communication systems, and more.

With seamless integration of PathWave FPGA supported by the M5000 Series modules, you can now achieve:

- Transparent multi-module synchronization by precisely time aligning multiple channels in the same module or across several modules
- Real-time synchronous execution including sequencing, branching, and looping
- Time-deterministic hardware-based execution





# Technical Specifications and Characteristics<sup>1</sup>

## M5200A characteristics

### General characteristics

Description	PXIe high-speed digitizer
Bus interface and compatibility	PXIe peripheral module (x8 Gen 3)
Number of slots	1
PXIe chassis compatibility	M9046A
Front panel connectors	
RF Input connectors	SMA (4)
Trigger I/O	SMB (4)
2.4 GHz in	MCX
2.4 GHz out	MCX
Mechanical (nom)	
Size	3U/1-slot PXIe standard 130.1 x 21.7 x 210 mm; includes connectors and handle extensions
Weight	419 g (0.9 lb)

### Digitizer characteristics

Sampling rate	4.8 GSa/s
Resolution	12-bit
Input impedance (warranted spec)	50 Ohm, $\pm 1$ Ohm
DC gain accuracy (warranted spec)	$\pm 2\%$
DC offset accuracy (warranted spec)	$\pm 1.5\%$
3 dB bandwidth (warranted spec)	$\geq 2$ GHz
Coupling	DC
Bandwidth	DC-2 GHz
Input voltage full-scale range	900 mV pk-pk (module default gain setting)
RMS noise (at nominal full-scale range)	< 800 $\mu$ V
Effective Number of Bits (ENOB)	8
Memory Depth	1 GSa/Ch
Spurious free dynamic range (SFDR) (50% Full-Scale)	65 dBc
Spurious free dynamic range (SFDR) (80% Full-Scale)	65 dBc up to 1 GHz 40 dBc up to 2 GHz

<sup>1</sup> All characteristics are typical unless noted otherwise.

## Clock and I/O characteristics

Module reference clock	
Clock sources	Front panel, PXI_CLK100
Front panel clock frequency	2.4 GHz
Nominal input clock power	+15 dBm
Module self-clocking	Yes
Accuracy	Chassis dependent
Input/output triggers	
Trigger sources	Software, PXI_TRIG, PXI_STAR, and front panel I/O
Trigger destinations	PXI_TRIG and front panel I/O
Trigger polarity	Active high or active low (programmable)
Max PXI trigger toggle rate	100 MHz

## Trigger channel characteristics

Number of channels	4
Channel type	Single-ended, bidirectional, ground reference
Default state	1 M $\Omega$ nominal, input
Output characteristics (typ)	
Output voltage	
50 $\Omega$ load	0 V - 1.6 V
High impedance load	0 V - 3.2 V
Maximum output channel toggle rate	150 MHz
Input characteristics (typ)	
Input voltage range	0 - 5 V
Maximum low voltage threshold	0.8 V
Maximum high voltage threshold	2 V
Load impedance	1 M $\Omega$
Maximum input channel toggle rate	75 MHz

## Module power requirements

Total power dissipation	45 W <sup>2</sup>	
Supply voltage	+3.3 V	+12 V
Supply current	5.8 A	2.2 A

## FPGA characteristics

FPGA type	Xilinx Virtex Ultrascale+ (XCVU35P)
FPGA sandbox size	1/4 of FPGA resources
Timebase frequency	300 MHz (phase-locked to 100 MHz chassis clock)
Timebase source	PXI_CLK100 or DSTARA

<sup>2</sup> Nominal power without application specific gateware

## FPGA resource estimates

Site type	Available	Used	% Utilized	Available to user
CLB LUTs	244936	9424	3.85	235512
LUT as logic	244936	9369	3.83	235567
LUT as memory	113192	55	0.05	113137
CLB registers	489872	10028	2.05	479844
Register as flip flop	489872	10028	2.05	479844
Register as latch	489872	0	0	489872
CARRY8	30617	162	0.53	30455
F7 Muxes	122468	242	0.20	122226
F8 Muxes	61234	119	0.19	61115
F9 Muxes	30617	0	0	30617
CLB	30617	3647	11.91	26970
CLBL	16468	1971	11.97	14497
CLBM	14149	1676	11.85	12473
Unique control sets	61234	1144	1.87	60090
Block RAM tile	360	0.5	0.14	359.5
RAMB36/FIFO	360	0	0	360
RAMB18	720	1	0.14	719
URAM	240	0	0	240
DSPs	1872	0	0	1872

## M5201A characteristics

### General characteristics

Description	PXIe down converter
Bus interface and compatibility	PXIe peripheral module (x4 Gen 3)
Number of slots	1
PXIe chassis compatibility	M9046A
LO source	Internal
Front panel connectors	
RF in	SMA (4)
IF out	SMA (4)
2.4 GHz in	MCX
2.4 GHz out	MCX
Mechanical (nom)	
Size	3U/1-slot PXIe standard 130.1 x 21.7 x 210 mm; includes connectors and handle extensions
Weight	387 g (0.85 lb)

### Channel characteristics

RF in characteristics	
Frequency range	2 GHz to 16 GHz
Max input power	0 dBm
Input power damage level	+10 dBm
Port match	S11 < -10 dB up to 10 GHz S11 < -5 dB up to 16 GHz
IF out characteristics	
Channel bandwidth	10 MHz - 2400 MHz
Port match	< -10 dB
Performance characteristics	
Conversion gain (warranted spec) 2 GHz 14 GHz	>0 dB
Conversion gain (typ) 2 GHz (high-side mixing) 4 GHz 10 GHz 14 GHz 16 GHz 18 GHz (low-side mixing)	+2 dB +5 dB +3 dB +1 dB 0 dB 0 dB
LO frequency range	1 GHz to 18 GHz
LO Frequency resolution	$5 \times 10^{-6}$ Hz
LO Phase resolution	$84 \times 10^{-9}$ degrees
Input referred noise	-166 dBm/Hz
Noise figure	8 dB
Phase noise	-130 dBc/Hz at 12 GHz, 10 kHz offset
Channel to channel isolation	> 60 dB

### Module power requirements

Total power dissipation	32 W <sup>3</sup>	
Supply voltage	+3.3 V	+12 V
Supply current	3.6 A	1.7 A

### Clock and I/O characteristics

Module reference clock	
Clock sources	Front panel, PXI_CLK100
Front panel clock frequency	2.4 GHz
Nominal input clock power	+15 dBm
Module self-clocking	Yes
Accuracy	Chassis dependent
Input/output triggers	
Trigger sources	Software, PXI_TRIG, and PXI_STAR
Trigger destinations	PXI_TRIG and front panel I/O
Trigger polarity	Positive and negative support
Max PXI trigger toggle rate	100 MHz

### FPGA characteristics

FPGA type	Xilinx Kintex Ultrascale+ (KU15P)
FPGA sandbox size	1/6 of FPGA resources
Timebase frequency	300 MHz (phase-locked to 100 MHz chassis clock)
Timebase source	PXI_CLK100 or DSTARA

<sup>3</sup> Nominal power without application specific gateware

# M5300A characteristics

## General characteristics

Description	PXIe RF AWG
Bus interface and compatibility	PXIe peripheral module (x8 Gen 3)
Number of slots	2
PXIe chassis compatibility	M9046A
Front panel connectors	
Trigger channels	SMB (8)
RF connector	SMA
2.4 GHz in	MCX
2.4 GHz out	MCX
Mechanical (nom)	
Size	3U/2-slot PXIe standard 130.8 x 42.2 x 210 mm; includes connectors and handle extensions
Weight	649 g (1.4 lb)

## Channel characteristics

RF characteristics	
Frequency range (warranted spec)	-3 dB at 15 GHz
Frequency range (typ)	-3 dB at 16 GHz -5 dB at 17 GHz -6 dB at 18 GHz
Output power (typ)	> -2 dBm from 0 to 14 GHz -6 dBm from 14-16 GHz -10 dBm from 16-18 GHz
Port match	S22 < -10 dB to 6 GHz S22 < -4 dB to 16 GHz
Performance characteristics	
Baseband/Information bandwidth	2 GHz
DAC resolution	14-bit
Baseband sample rate, per-channel	4.8 GSa/s (2.4 GSa/s I/Q)
Waveform memory depth, per channel	1 GSa (500 MSa I and 500 MSa Q)
Number of waveforms, per channel	4096
DAC output sample rate	38.4 GSa/s
Minimum waveform length, per channel	64 Samples (I+Q), 13.3 ns
Maximum waveform length, per channel	1 GSamples (I+Q), 223 ms
NCO frequency coverage	0-18 GHz
NCO Frequency resolution	$5 \times 10^{-6}$ Hz
NCO Phase resolution	$84 \times 10^{-9}$ degrees
Noise floor (NSD)	-157 dBm/Hz
Phase noise <sup>4</sup>	-130 dBc/Hz at 8 GHz, 10 kHz offset -125 dBc/Hz at 16 GHz, 10 kHz offset
Channel to channel isolation	80 dB to 16 GHz
Spurious Free Dynamic Range (SFDR) <sup>5</sup> Excluding harmonics and DAC interleave spurs	-70 dBc to 16 GHz
Spurious Free Dynamic Range (SFDR) <sup>5</sup> Excluding harmonics, including DAC interleave spurs <sup>6</sup>	-45 dBc to 16 GHz

<sup>4</sup> When used with M9046A-QS1

<sup>5</sup> As measured +/- 500 MHz around the output frequency.

<sup>6</sup> Including DAC interleave spurs near 9.6 GHz



### Module power requirements

Total power dissipation	110 W <sup>7</sup>	
Supply voltage	+3.3 V	+12 V
Supply current	6.3 A	2.4 A

### Clock and I/O characteristics

Module reference clock	
Clock sources	Front panel, PXI_CLK100
Front panel clock frequency	2.4 GHz
Nominal input clock power	+15 dBm
Module self-clocking	Yes
Accuracy	Chassis dependent
Input/output triggers	
Trigger sources	Software, PXI_TRIG, PXI_STAR, and front panel I/O
Trigger destinations	PXI_TRIG and front panel I/O
Trigger polarity	Active high or active low (programmable)
Max PXI trigger toggle rate	100 MHz

### Trigger channel characteristics

Number of channels	8
Channel type	Single-ended, bidirectional, ground reference
Default state	1 M $\Omega$ nominal, input
Output characteristics (typ)	
Output voltage	
50 $\Omega$ load	0 V - 1.6 V
High impedance load	0 V - 3.2 V
Maximum output channel toggle rate	150 MHz
Input characteristics (typ)	
Input voltage range	0 - 5 V
Maximum low voltage threshold	0.8 V
Maximum high voltage threshold	2 V
Load impedance	1 M $\Omega$
Maximum input channel toggle rate	75 MHz

### FPGA characteristics

FPGA type	Xilinx Virtex Ultrascale+ (XCVU35P)
FPGA sandbox size	1/6 of FPGA resources
Timebase frequency	300 MHz (phase-locked to 100 MHz chassis clock)
Timebase source	PXI_CLK100 or DSTARA

<sup>7</sup> Nominal power without application specific gateware

## FPGA resource estimates

Site type	Available	Used	% Utilized	Available to user
CLB LUTs	244936	9424	3.85	235512
LUT as logic	244936	9369	3.83	235567
LUT as memory	113192	55	0.05	113137
CLB registers	489872	10028	2.05	479844
Register as flip flop	489872	10028	2.05	479844
Register as latch	489872	0	0	489872
CARRY8	30617	162	0.53	30455
F7 Muxes	122468	242	0.20	122226
F8 Muxes	61234	119	0.19	61115
F9 Muxes	30617	0	0	30617
CLB	30617	3647	11.91	26970
CLBL	16468	1971	11.97	14497
CLBM	14149	1676	11.85	12473
Unique control sets	61234	1144	1.87	60090
Block RAM tile	360	0.5	0.14	359.5
RAMB36/FIFO	360	0	0	360
RAMB18	720	1	0.14	719
URAM	240	0	0	240
DSPs	1872	0	0	1872

# M5301A characteristics

## General characteristics

Description	PXIe Baseband AWG
Bus interface and compatibility	PXIe peripheral module (x8 Gen 3)
Number of slots	1
PXIe chassis compatibility	M9046A
Front panel connectors	
RF Input connectors	SMA (4)
Trigger I/O	SMB (4)
2.4 GHz in	MCX
2.4 GHz out	MCX
Mechanical (nom)	
Size	3U/1-slot PXIe standard 130.1 x 21.7 x 210 mm; includes connectors and handle extensions
Weight	420 g (0.9 lb)

## Channel characteristics

Performance characteristics	
DAC resolution	14-bit
Bandwidth	400 MHz, -3 dB
Usable frequency range <sup>8</sup>	0-450 MHz, $\pm 1.5$ V 0-350 MHz, $\pm 2.0$ V 0-275 MHz, $\pm 2.5$ V
Waveform memory depth, per channel	1 GSa
Waveform sample rate	2.4 GS/s
Output voltage	$\pm 2.5$ V into 50 Ohms
Settling time (to 99%)	< 200 ns
Settling time (to 99.999%)	< 1 $\mu$ s
Temperature stability	20 $\mu$ V/ $^{\circ}$ C
Output impedance	50 $\Omega$
Noise floor (NSD)	-145 dBm/Hz
Phase noise <sup>9</sup>	-142 dBc at 100 MHz, 10 kHz offset
Spurious Free Dynamic Range (SFDR) Including harmonics, at 0 dBm	0-120 MHz: -50 dBc 120-320 MHz: -40 dBc 320-450 MHz: -50 dBc
Spurious Free Dynamic Range (SFDR) Excluding harmonics, at full scale output	0-450 MHz: -70 dBc

<sup>8</sup> Non-linear behavior of spectral content may occur outside of the useable frequency range

<sup>9</sup> When used with M9046A-QS1

### Clock and I/O characteristics

Module reference clock	
Clock sources	Front panel, PXI_CLK100
Front panel clock frequency	2.4 GHz
Nominal input clock power	+15 dBm
Module self-clocking	Yes
Accuracy	Chassis dependent
Input/output triggers	
Trigger sources	Software, PXI_TRIG, PXI_STAR, and front panel I/O
Trigger destinations	PXI_TRIG and front panel I/O
Trigger polarity	Active high or active low (programmable)
Max PXI trigger toggle rate	100 MHz

### Trigger channel characteristics

Number of channels	4
Channel type	Single-ended, bidirectional, ground reference
Default state	1 M $\Omega$ nominal, input
Output characteristics (typ)	
Output voltage	
50 $\Omega$ load	0 V - 1.6 V
High impedance load	0 V - 3.2 V
Maximum output channel toggle rate	150 MHz
Input characteristics (typ)	
Input voltage range	0 - 5 V
Maximum low voltage threshold	0.8 V
Maximum high voltage threshold	2 V
Load impedance	1 M $\Omega$
Maximum input channel toggle rate	75 MHz

### Module power requirements

Total power dissipation	77 W <sup>10</sup>	
Supply voltage	+3.3 V	+12 V
Supply current	4.2 A	5.3 A

### FPGA characteristics

FPGA type	Xilinx Virtex Ultrascale+ (XCVU35P)
FPGA sandbox size	1/6 of FPGA resources
Timebase frequency	300 MHz (phase-locked to 100 MHz chassis clock)
Timebase source	PXI_CLK100 or DSTARA

<sup>10</sup> Nominal power without application specific gateware

## FPGA resource estimates

Site type	Available	Used	% Utilized	Available to user
CLB LUTs	244936	9424	3.85	235512
LUT as logic	244936	9369	3.83	235567
LUT as memory	113192	55	0.05	113137
CLB registers	489872	10028	2.05	479844
Register as flip flop	489872	10028	2.05	479844
Register as latch	489872	0	0	489872
CARRY8	30617	162	0.53	30455
F7 Muxes	122468	242	0.20	122226
F8 Muxes	61234	119	0.19	61115
F9 Muxes	30617	0	0	30617
CLB	30617	3647	11.91	26970
CLBL	16468	1971	11.97	14497
CLBM	14149	1676	11.85	12473
Unique control sets	61234	1144	1.87	60090
Block RAM tile	360	0.5	0.14	359.5
RAMB36/FIFO	360	0	0	360
RAMB18	720	1	0.14	719
URAM	240	0	0	240
DSPs	1872	0	0	1872

## M5302A characteristics

### General characteristics

Description	PXle Digital I/O
Bus interface and compatibility	PXle peripheral module (x8 Gen 3)
Number of slots	1
Volatile module memory	8 GB (DDR4)
Non-volatile flash memory	1 GB
Front panel connectors	
LVDS	ERF8-050
Trigger channels	SMB male (8)
System sync	Reserved for future use
Mechanical (nom)	
Size	3U/1-slot PXle standard 130.1 x 21.7 x 210 mm; includes connectors and handle extensions
Weight	365 g (0.8 lb)

### Module power requirements

Total power dissipation	42 W	
Supply voltage	+3.3 V	+12 V
Supply current	1.8 A	3 A

### LVDS connector characteristics

Channels	
Functionality	LVDS plus auxiliary DUT power supply
Channel type	Differential, bidirectional
Number of channels	28
Channel impedance	100 $\Omega$ differential (nominal)
LVDS output characteristics (typ)	
Output voltage range	1.25 V $\pm$ 175 mV (100 $\Omega$ differential termination)
Maximum output short circuit current	20 mA
Maximum output channel toggle rate	1.2 Gbps
LVDS input characteristics (typ)	
Differential input voltage range	0.3 - 1.4 V (DC coupled) 0.6 - 1.1 V (AC coupled)
Input common mode voltage threshold	0.1 - 0.6 V
Maximum input toggle rate	1.2 Gbps



### LVDS channel skew characteristics (typical) <sup>11</sup>

Maximum skew adjustment range	$\pm 1667 \text{ ps (user)} + \pm 1667 \text{ ps (system)} = \pm 3333 \text{ ps (total)}$
Maximum skew adjustment resolution	50 ps
Maximum edge polarity skew	$\pm 50 \text{ ps}$
Maximum uncalibrated inter-channel skew error <sup>12,13</sup>	$\pm 150 \text{ ps}$
Maximum inter-channel skew drift ( $\pm 5^\circ\text{C}$ )	$\pm 200 \text{ ps}$
Input/output triggers	
Max uncalibrated inter-module skew error <sup>14,15</sup>	$\pm 250 \text{ ps}$
Maximum inter-module skew drift ( $\pm 5^\circ\text{C}$ )	$\pm 300 \text{ ps}$
HVI action/event time resolution	3.33 ns

### DUT power supply (typical)

Output voltage	5 V $\pm 5\%$
Maximum output current	0.5 A

### Trigger channel characteristics

Number of channels	8
Channel type	Single-ended, bidirectional, ground reference
Default state	1 M $\Omega$ nominal, input
Output characteristics (typ)	
Output voltage	
50 $\Omega$ load	0 V - 1.6 V
High impedance load	0 V - 3.2 V
Maximum output channel toggle rate	150 MHz
Input characteristics (typ)	
Input voltage range	0 - 5 V
Maximum low voltage threshold	0.8 V
Maximum high voltage threshold	2 V
Load impedance	1 M $\Omega$
Maximum input channel toggle rate	75 MHz

<sup>11</sup> Note that a 1.2 Gbps data valid window = 833 ps

<sup>12</sup> Total uncalibrated skew error between any two channels on same module over  $\pm 5^\circ\text{C} \leq 2 \times (\text{Max Uncalibrated Inter-Channel Skew Error} + \text{Max Inter-Channel Skew Drift} + \text{Max Edge Polarity Skew}) = 800 \text{ ps}$

<sup>13</sup> Total user-calibrated skew error between any two channels on same module over  $\pm 5^\circ\text{C} \leq 2 \times (\text{Max Skew Adjustment Resolution} / 2 + \text{Max Inter-Channel Skew Drift} + \text{Max Edge Polarity Skew}) = 550 \text{ ps}$

<sup>14</sup> Total uncalibrated skew error between any two channels across separate modules over  $\pm 5^\circ\text{C} \leq 2 \times (\text{Max Uncalibrated Inter-Module Skew Error} + \text{Max Inter-Module Skew Drift} + \text{Max Edge Polarity Skew}) = 1200 \text{ ps}$

<sup>15</sup> Total user-calibrated skew error between any two channels across separate modules over  $\pm 5^\circ\text{C} \leq 2 \times (\text{Max Skew Adjustment Resolution} / 2 + \text{Max Inter-Module Skew Drift} + \text{Max Edge Polarity Skew}) = 750 \text{ ps}$

### Trigger channel skew characteristics (typical) <sup>16</sup>

Maximum skew adjustment range	$\pm 1667 \text{ ps (user)} + \pm 1667 \text{ ps (system)} = \pm 3333 \text{ ps (total)}$
Maximum skew adjustment resolution	50 ps
Maximum edge polarity skew	$\pm 250 \text{ ps}$
Maximum uncalibrated inter-channel skew error <sup>17,18</sup>	$\pm 500 \text{ ps}$
Maximum inter-channel skew drift ( $\pm 5^\circ\text{C}$ )	$\pm 200 \text{ ps}$
Performance with Option KS2201A	
Max uncalibrated inter-module skew error <sup>19,20</sup>	$\pm 250 \text{ ps}$
Maximum inter-module skew drift ( $\pm 5^\circ\text{C}$ )	$\pm 300 \text{ ps}$
HVI action/event time resolution	3.33 ns

### Module timing and trigger characteristics

Module reference clock	
Frequency	100 MHz
Reference clock source	PXI_CLK100
Accuracy	Chassis dependent
Input/output triggers	
Trigger sources	Software, PXI_TRIG, PXI_STAR, and front panel I/O
Trigger destinations	PXI_TRIG and front panel I/O
Trigger polarity	Active high or active low (programmable)
LVDS input characteristics (typical)	
Differential input voltage range	0.3 - 1.425 V (DC coupled) 0.6 - 1.1 V (AC coupled)
Input common mode voltage threshold	0.1 - 0.6 V
Maximum input toggle rate	1.2 Gbps

### FPGA characteristics

FPGA type	Xilinx Virtex Ultrascale+ (XCVU35P)
FPGA sandbox size	1/6 of FPGA resources
Timebase frequency	300 MHz (phase-locked to 100 MHz chassis clock)
Timebase source	PXI_CLK100 or DSTARA
Available FPGA resources	
CLB registers	502320
CLB LUTs	251160
Block RAM tiles (Mb)	480
UltraRAM (Mb)	80
DSP blocks	960

<sup>16</sup> Note that a 300 Mbs Gbps data valid window = 3333 ps

<sup>17</sup> Total uncalibrated skew error between any two channels on same module over  $\pm 5^\circ\text{C} \leq 2 \times (\text{Max Uncalibrated Inter-Channel Skew Error} + \text{Max Inter-Channel Skew Drift} + \text{Max Edge Polarity Skew}) = 2500 \text{ ps}$

<sup>18</sup> Total user-calibrated skew error between any two channels on same module over  $\pm 5^\circ\text{C} \leq 2 \times (\text{Max Skew Adjustment Resolution} / 2 + \text{Max Inter-Channel Skew Drift} + \text{Max Edge Polarity Skew}) = 1550 \text{ ps}$

<sup>19</sup> Total uncalibrated skew error between any two channels across separate modules over  $\pm 5^\circ\text{C} \leq 2 \times (\text{Max Uncalibrated Inter-Module Skew Error} + \text{Max Inter-Module Skew Drift} + \text{Max Edge Polarity Skew}) = 3500 \text{ ps}$

<sup>20</sup> Total user-calibrated skew error between any two channels across separate modules over  $\pm 5^\circ\text{C} \leq 2 \times (\text{Max Skew Adjustment Resolution} / 2 + \text{Max Inter-Module Skew Drift} + \text{Max Edge Polarity Skew}) = 2050 \text{ ps}$

## Environmental and regulatory characteristics<sup>21,22</sup>

### Environmental characteristics

Operating and storage conditions	Operating	Storage
Temperature	0°C to 40°C	-40°C to 70°C
Altitude	Up to 10,000 ft (3048 m)	Up to 15,000 ft (4573 m)
Humidity	Type-tested at 95%, +40°C (non-condensing)	
Warm-up time	30 minutes	
Vibration		
Operating random vibration	Type-tested at 5 to 500 Hz, 0.21 g rms	
Survival random vibration	Type-tested at 5 to 500 Hz, 2.09 g rms	

### Regulatory characteristics

#### Safety

Complies with the current versions of the following standards (dates and editions are cited in the Declaration of Conformity):

- IEC/EN 61010-1
- Canada: CSA C22.2 No. 61010-1
- USA: UL std no. 61010-1

#### EMC

Complies with the essential requirements of the European EMC Directive as well as the current editions of the following standards (dates and editions are cited in the Declaration of Conformity):

- IEC/EN 61326-1
- CISPR Pub 11 Group 1, class A
- AS/NZS CISPR 11
- ICES/NMB-001

This ISM device complies with Canadian ICES-001.

Cet appareil ISM est conforme à la norme NMB-001 du Canada

#### South Korean class A EMC declaration

Information to the user:

This equipment has been conformity assessed for use in business environments. In a residential environment this equipment may cause radio interference.

- This EMC statement applies to the equipment only for use in business environment.

<sup>21</sup> Samples of this product have been type tested in accordance with the Keysight Environmental Test Manual and verified to be robust against the environmental stresses of Storage, Transportation, and End-use; those stresses include but are not limited to temperature, humidity, shock, vibration, altitude, and power line conditions.

<sup>22</sup> Test methods are aligned with IEC 60068-2 and levels are similar to MIL-PRF-28800F Class 3.

# Ordering Guide and Upgrade Information

Contact your Keysight representative or authorized partner for more information, or to place an order:

[www.keysight.com/find/contactus](http://www.keysight.com/find/contactus)

## Cabling

When configuring with the M9046A-QS1 option, all cables must be the same length to ensure proper functioning of the clocking mechanism.

Model	Description
Y1320A	System Sync/Link cable, x4-x4, 0.5m
Y1321A	System Sync/Link cable, x4-x4, 1.0m
Y1323A	System Sync/Link cable, x8-2, x4, 0.5m
Y1324A	System Sync/Link cable, x8-2, x4, 1.0m
Y1326A	System Sync/Link cable, x8-x8, 0.5m
Y1327A	System Sync/Link cable, x8-x8, 1.0m
Y1329A	System Sync/Link cable, x8-x8, 2.0m
71330A	MCX(m) to MCX(m) cable, phase stable, 0.3m
Y1331A	MCX(m) to MCX(m) cable, phase stable, 1.0m
Y1332A	MCX(m) to MCX(m) cable, phase stable, 2.0m
Y1333A	SMA(m)-SMP(f) cable, 0.3m

## Software upgrades

Model	Description
M5200A-BPS	Back plane streaming option for RF Digitizer
M5300A-BPS	Back plane streaming option for RF AWG
M5000AU-001	Upgrade - Backplane streaming option for RF AWG
M5000AU-002	Upgrade - Backplane streaming option for RF digitizer

## Additional software

Model	Description
M5401LUNA	Labber Quantum Software License
KS2201A	PathWave Test Sync Executive License
KF9001B	PathWave FPGA Run Time License
M5400B	Quantum FPGA IP Library for M5xxx Control Hardware

## For more information

For more insights on how to accelerate innovation in quantum computing, visit the [Quantum Control System Solution Brief](#).

To combine additional PXIe products, visit our [PXI Product Portfolio](#).

For more information on software offerings, visit [PathWave FPGA](#), [PathWave Test Sync Executive](#), and [Labber](#).

# Definitions

## **Specification (spec)**

Describes the performance of parameters covered by the product warranty and are valid for the unit's operation within the stated environmental range unless otherwise noted. Specifications include production guardbands to account for the expected statistical performance distribution, measurement uncertainties, and changes in performance due to environmental conditions. Standard calibration services offered by Keysight will ensure all these specifications are measured and a related statement of compliance with specification provided in the resulting calibration report.

## **Characteristic**

Characteristics describe product performance that is useful in the application of the product, but that is not covered by the product warranty. Characteristics are often referred to as nominal or typical values.

## **Typical (typ)**

Intended to provide additional information including the expected performance of an average unit that is not covered by the product warranty. These characteristics are shown in italics or labeled as 'typical'. Performance of a customer unit to typical specifications may or may not be measured during a calibration service.

## **Nominal (nom)**

A general, descriptive term that does not imply a level of performance. It is not covered by the product warranty. Represents the value of a parameter that is most likely to occur; the expected mean or mode of all instruments at room temperature (approximately 23 °C). These characteristics are shown in italics or labeled as 'nominal'. Performance of a customer unit to nominal specifications may or may not be measured during a calibration service.

## **Additional information**

The data contained in this document is subject to change.




## 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> 	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.
<b>Alternative acquisition options</b>	
<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.