M2p.65xx-x4 - 16 bit 125 MS/s Arbitrary Waveform Generator

- **Up to 125 MS/s on four channels**
- **Up to 80 MS/s on eight channels**
- **One, two, four and eight channel versions**
- **Versions with 40 MS/s and 125 MS/s**
- **Ultra Fast PCI Express x4 interface**
- **Simultaneous signal generation on all channels**
- **Standard output max. ±3 V into 50 Ohm (±6 V into 1 MOhm)**
- **high-voltage output max. ±6 V into 50 Ohm (±12 V into 1 MOhm)**
- **Features: Single-Shot, Loop, FIFO, Gated Replay, Sequence Replay**
- **512 MiSamples on-board memory**
- **Synchronization of up to 16 cards per system**
- **Fixed trigger to output delay**
- **Direct data transfer from CUDA GPU using SCAPP option**

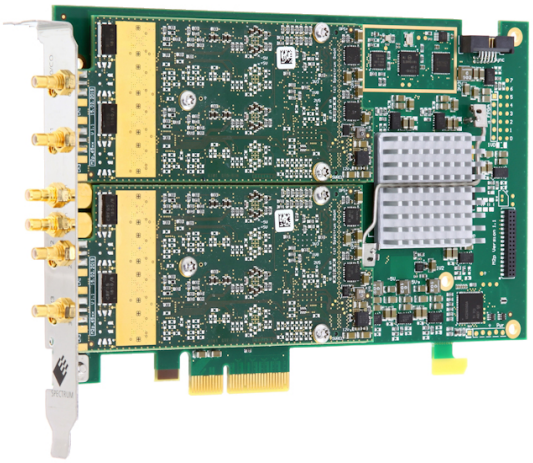
Multi-Tone DDS Option

The DDS firmware option adds a new output mode with 16 individually programmable DDS cores. Each DDS core can be routed to different outputs allowing up to 16 DDS cores for a single output forming a multi-carrier, or multi-tone, signal source.
Each core can be programmed for frequency, amplitude and phase. DDS commands can be issued with 8.0 ns spacing. Advanced commands like frequency slope, amplitude slope or digital outputs can be programmed. A programmable timer as well as external trigger can be used to advance DDS-commands.

SCAPP
Spectrum's CUDA Access – Parallel Processing

M2p series

- PCIe x4 Gen1 Interface
- Works with x4/x8/x16* PCIe slots
- Sustained streaming mode up to 700 MB/s**
- Half-length PCIe Form Factor



Operating Systems
- Windows 7 (SP1), 8, 10, 11 Server 2008 R2 and newer
- Linux Kernel 5.x, 6.x, 7.x
- Windows/Linux 32 and 64 bit

Programming Languages
- C, C++, C#, Python
- Julia, Java, VB.NET, Delphi
- IVI

Supported Software
- SBench 6
- MATLAB
- LabVIEW

Model	Analog Bandwidth	Output rate / channels 1 ch	2 ch	4 ch	8 ch	Output Level in 50 Ω	in 1 MΩ
M2p.6530-x4	70 MHz	40 MS/s				±3 V	±6 V
M2p.6531-x4	70 MHz	40 MS/s	40 MS/s			±3 V	±6 V
M2p.6536-x4	70 MHz	40 MS/s	40 MS/s	40 MS/s		±3 V	±6 V
M2p.6533-x4	70 MHz	40 MS/s	40 MS/s	40 MS/s	40 MS/s	±3 V	±6 V
M2p.6540-x4	70 MHz	40 MS/s				±6 V	±12 V
M2p.6541-x4	70 MHz	40 MS/s	40 MS/s			±6 V	±12 V
M2p.6546-x4	70 MHz	40 MS/s	40 MS/s	40 MS/s		±6 V	±12 V
M2p.6560-x4	70 MHz	125 MS/s				±3 V	±6 V
M2p.6561-x4	70 MHz	125 MS/s	125 MS/s			±3 V	±6 V
M2p.6566-x4	70 MHz	125 MS/s	125 MS/s	125 MS/s		±3 V	±6 V
M2p.6568-x4	70 MHz	125 MS/s	125 MS/s	125 MS/s	80 MS/s	±3 V	±6 V
M2p.6570-x4	70 MHz	125 MS/s				±6 V	±12 V
M2p.6571-x4	70 MHz	125 MS/s	125 MS/s			±6 V	±12 V
M2p.6576-x4	70 MHz	125 MS/s	125 MS/s	125 MS/s		±6 V	±12 V

Analog bandwidth gives the range of frequencies the analog signal can occupy, while the **max. signal (sine) frequency** is limited by the Nyquist-theorem to half of the **output rate**, e.g., 40 MS/s gives 20 MHz.

General Information

The M2p.65xx series offers different versions of arbitrary waveform generators for PCI Express with a maximum output rate of 125 MS/s. These boards allow to generate freely definable waveforms on several channels synchronously.

With one of the synchronization options the setup of synchronous multi channel systems is possible as well as the combination of arbitrary waveform generators with digitizers of the M2p product family.

The 512 MiSample on-board memory can be used as arbitrary waveform storage or as a FIFO buffer continuously streaming data via the PCIe interface.

The high-resolution 16-bit DACs deliver four times the resolution of AWGs using 14-bit technology.

*Some x16 PCIe slots are for the use of graphic cards only and can't be used for other cards. **Throughput measured with a motherboard chipset supporting a TLP size of 256 bytes.

Software Support

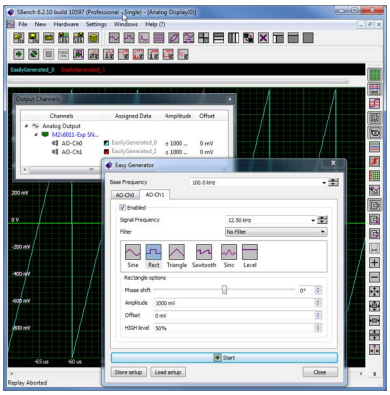
Windows drivers

The cards are delivered with drivers for Windows 7, Windows 8, Windows 10 and Windows 11 (each 32 bit and 64 bit). Programming examples for Visual C++, Delphi, Visual Basic, VB.NET, C#, Python, Java, Julia and IVI are included.

Linux Drivers

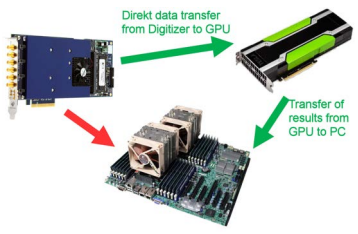
All cards are delivered with full Linux support. Pre compiled kernel modules are included for the most common distributions like Fedora, Suse, Ubuntu LTS or Debian. The Linux support includes SMP systems, 32 bit and 64 bit systems, versatile programming examples for GNU C++, Python and Julia, as well as the possibility to get the kernel driver sources for your own compilation.

SBench 6



A base license of SBench 6, the easy-to-use graphical operating software for Spectrum cards, is included in the delivery. The base license makes it is possible to test the card, generate simple signals or load and replay previously stored SBench 6 signals. It's a valuable tool for checking the cards performance and assisting with the units initial setup. The cards also come with a demo license for the SBench6 professional version. This license gives the user the opportunity to test the additional features of the professional version with their hardware. The professional version contains several advanced measurement functions, such as FFTs and X/Y display, import and export utilities as well as support for all replay modes including data streaming. Data streaming allows the cards to continuously replay data and transfer it directly from the PC RAM or hard disk. SBench 6 has been optimized to handle data files of several GBytes. SBench 6 runs under Windows as well as Linux (KDE and GNOME) operating systems. A test version of SBench 6 can be downloaded directly over the internet and can run the professional version in a simulation mode without any hardware installed. Existing customers can also request a demo license for the professional version from Spectrum. More details on SBench 6 can be found in the SBench 6 data sheet.

SCAPP – CUDA GPU based data processing



For applications requiring high performance signal and data processing Spectrum offers SCAPP (Spectrum's CUDA Access for Parallel Processing). The SCAPP SDK allows a direct link between Spectrum digitizers, AWGs (AWG mode only, not usable for DDS mode) or Digital Data Acquisition Cards and CUDA based GPU cards. Once in the GPU users can harness the processing power of the GPU's multiple (up to 10000) processing cores and large (up to 48 GB) memories. SCAPP uses an RDMA (Linux only) process to send data at the full PCIe transfer speed to and from the GPU card. The SDK includes a set of examples for interaction between the Spectrum card and the GPU card and another set of CUDA parallel processing examples with easy building blocks for basic functions like filtering, averaging, data de-multiplexing, data conversion or FFT. All the software is based on C/C++ and can easily be implemented, expanded and modified with normal programming skills.

Third-party products

Spectrum supports the most popular third-party software products such as LabVIEW or MATLAB. All drivers come with detailed documentation and working examples are included in the delivery.

Hardware features and options

PCI Express x4

The M2p series cards use a PCI Express x4 Gen1 connection. They can be used in PCI Express x4, x8 and x16 slots with hosts supporting Gen1, Gen2, Gen3, Gen4 or Gen5. The maximum sustained data transfer rate is more than 700 MByte/s (read direction) or 700 MByte/s (write direction) per slot. Physically supported slots that are electrically connected with only x1 or x2 can also be used with the M2p series cards, but with reduced data transfer rates.

Connections

The cards are equipped with SMB connectors for the analog signals as well as for the external trigger and clock input. In addition, there are four MMCX connectors: one multi-function output (X0) and three multi-function I/O connectors (X1, X2, X3). These multi-function connectors can be individually programmed to perform different functions:

- Clock output (X0 only)
- Trigger output
- Status output (armed, triggered, ready, ...)
- Synchronous digital inputs, being stored inside the analog data samples
- Asynchronous I/O lines
- Logic trigger inputs

Singleshot output

When singleshot output is activated the data of the on-board memory is played exactly one time. The trigger source can be either one of the external trigger inputs or the software trigger. After the first trigger additional trigger events will be ignored.

Repeated output

When the repeated output mode is used the data of the on-board memory is played continuously for a programmed number of times or until a stop command is executed. The trigger source can be either one of the external trigger inputs or the software trigger. After the first trigger additional trigger events will be ignored.

Single Restart replay

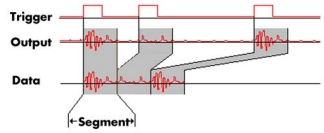
When this mode is activated the data of the on-board memory will be replayed once after each trigger event. The trigger source can be either the external trigger or software trigger.

FIFO mode

The FIFO or streaming mode is designed for continuous data transfer between the card and the PC memory. When mounted in a PCI Express x4 Gen1 interface both, read and write streaming speeds of up to 700 MByte/s are possible. The control of the data stream is done automatically by the driver on interrupt request basis. The

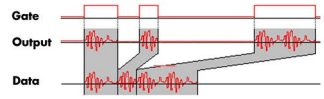
complete installed on-board memory is used to buffer the data, making the continuous streaming process extremely reliable.

Multiple Replay



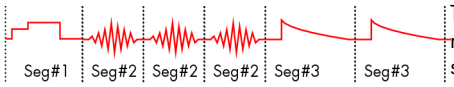
The Multiple Replay mode allows the fast output generation on several trigger events without restarting the hardware. With this option very fast repetition rates can be achieved. The on-board memory is divided into several segments of the same size. Each segment can contain different data which will then be played with the occurrence of each trigger event.

Gated Replay



The Gated Sampling mode allows data replay controlled by an external gate signal. Data is only replayed if the gate signal has attained a programmed level.

Sequence Mode



The sequence mode allows to split the card memory into several data segments of different length. These data segments are chained up in a user chosen order using an additional sequence memory. In this sequence memory the number of loops for each segment can be programmed and trigger conditions can be defined to proceed from segment to segment. Using the sequence mode it is also possible to switch between replay waveforms by a simple software command or to redefine waveform data for segments simultaneously while other segments are being replayed. All trigger-related and software-command-related functions are only working on single cards, not on star-hub-synchrnonized cards.

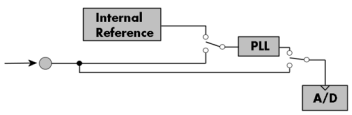
External trigger input

All boards can be triggered using an external analog or digital signal. The external trigger input has one comparator that can be used for standard edge and level triggers.

External clock input and output

Using a dedicated connector a sampling clock can be fed in from an external system. Additionally it's also possible to output the internally used sampling clock on a separate connector to synchronize external equipment to this clock.

Reference clock



The option to use a precise external reference clock (typically 10 MHz) is necessary to synchronize the instrument for high-quality measurements with external equipment (like a signal source). It's also possible to enhance the stability of the sampling clock in this way. The driver automatically generates the requested sampling clock from the fed in reference clock.

Star-Hub

The Star-Hub is an additional module allowing the phase stable synchronization of up to 16 boards in one system. Two versions are available: one with up to 6 cards and the large version supports up to 16 cards in one system. Both versions can be mounted in two different ways, to either extend the cards length to ¾ PCIe length occupying one slot, or extend its width to two slots whilst keeping the ½ PCIe length.

Independent of the number of boards there is no phase delay between the channels. The Star-Hub distributes trigger and clock information between all boards. As a result all connected boards are running with the same clock and the same trigger. All trigger sources can be combined with OR/AND. For digitizers that means all channels of all cards to be trigger source at the same time.

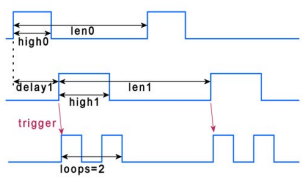
Multi-Purpose I/O 4 Standard + 16 Option

As standard each card has 4 multi-purpose I/O lines (3 x I/O and 1 x Output). As an option a piggy-back module carries additional 16 mutli-purpose I/O lines making up to 19 digtal inputs or 20 digital outputs.

This option is available with SMB connectors or with FX/2 connector for flat-ribbon cable, with pin-compatibility with previous hardware versions.

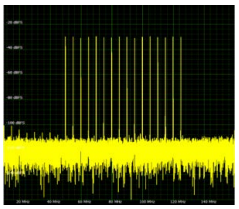
All I/O lines can be used for synchronous digital data acquisition (digitizer), synchronous digital data output/marker output (AWG), asynchronous digital I/O, can carry additional status information or can be used as trigger inputs

Firmware Option Digital Pulse Generator



The digital pulse generator option adds 4 internal independent digital pulse generators with programmable duty cycle, output frequency, delay and number of loops. These digital pulse generators can be triggered by software, hardware trigger or can trigger each other allowing to form complex pulse schemes to drive external equipment or experiments. The digital pulse generators can be output on the existing multi-XIO lines (X0, X1, ...), to trigger other pulse generators or can be used to trigger the instrument's main trigger internally. Time resolution of the pulse generator depends on the cards type and the selected sampling rate and can be found in the technical data section.
The pulse generator option is a firmware option and can be later installed on all shipped cards.

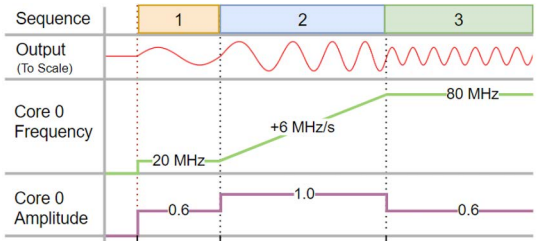
Firmware Option Multi-Tone DDS



DDS - Direct Digital Synthesis - is a method for generating arbitrary periodic waveforms from a single, fixed-frequency reference clock and is widely used in signal generation applications. The DDS functionality implemented on Spectrum Instrumentation's AWGs is based on the principle of adding multiple "DDS cores" to generate a multi-carrier (multi-tone) signal, with each carrier having its own well-defined frequency, amplitude and phase. The frequency plot shows 16 tones. In addition to these static parameters, there are also built in dynamic parameters like slopes for frequency and amplitude to allow for intrinsic linear changes for multiple cores.

Below, the example sequence of three commands for a single core, shows a fixed 20 MHz frequency with 60% amplitude in step 1, a

10 second frequency ramp with 6 MHz/s slope and full 100% amplitude in step 2 and finally, in step 3, a fixed 80 MHz frequency with 60% amplitude. Each step consists of only 3 to 4 single line commands to set the mode, frequency, amplitude and timing.



Each of the cores can either be added together and output, or specific groups of cores can be added together and output on a specific hardware output channel. A fast DMA mode allows the use of individual DDS command sequences for programming more advanced frequency changes, like shaped slopes or modulated sine signals.

The DDS option is a firmware option that can be field installed on all shipped cards and generatorNETBOX products. Each single internal AWG card of the generatorNETBOX can get this option with the full set of DDS cores for each AWG card.

DDS Control

DDS Control is a free to use software for operating the Direct Digital Synthesis (DDS) firmware option available for Spectrum's Arbitrary Waveform Generator and DDS product lines. It is a good starting tool to familiarize yourself with the Spectrum DDS functionality of your card. With DDS, the card can output a certain number of sine waves (carriers), that are generated with the firmware DDS cores. DDS control can program these DDS cores statically with DDS dialogs, or it allows the user to program full sequences (or patterns) of commands in an exact timed manner. It can setup the cards for specific core and hardware setups. The parameters lists can loop either infinitely long or a specific number of times. Saving and loading of setups and sequences is possible.

Calibration factory/ISO/IEC 17025

All of the channels are calibrated in factory before the board is shipped. Depending on the QM needs the card can shipped to factory for a complete re-calibration against external traceable calibration sources. As an option a ISO/IEC17025-compliant certificate is available with new cards and after recalibration.

Technical Data

Definitions

Specifications (spec)
Figures are valid for products stored for at least 2 hours inside the specified operating temperature range, after a 30 minute warm-up, after running an on-board calibration and with properly cooled products. Data published in this document are specifications (spec) only where specifically indicated. Figures marked with (spec) are calibrated to the specification during production and during factory calibrations.

Typical (typ)
Figures marked with (typ) are a characteristic performance that most of the manufactured instruments will meet due to design. Typical figures are measured during production but cannot be calibrated.

Measured (meas)
A figure measured during development to communicate expected performance. The figure is measured in lab environment with an environmental temperature between 20°C and 25°C and an altitude of less than 100 m.

Nominal (nom)
The value of this figure is determined by design and is not measured nor calibrated.

Analog Outputs

Resolution (nom)		16 bit	
D/A Interpolation		no interpolation	
Output amplitude (nom)	software programmable	653x and 656x:	±1 mV up to ±3 V in 1 mV steps into 50 Ω termination (resulting in ±2 mV up to ±6 V in 2mV steps into high impedance loads)
		653x and 656x	Gain values below ±300 mV into 50 Ω are generated by reduction of digital samples
		654x and 657x:	±1 mV up to ±6 V in 1 mV steps into 50 Ω termination (resulting in ±2 mV up to ±12 V in 2mV steps into high impedance loads)
		654x and 657x:	Gain values below ±300 mV and between ±1000 mV and ±2000 mV into 50 Ω are generated by reduction of digital samples
Output Amplifier Path Selection (nom)	automatically by driver	Low Power path:	Selected Gain of ±1 mV to ±960 mV (into 50 Ω)
		High Power path:	653x and 656x: Selected Gain of ±940 mV to ±3 V (into 50 Ω) 654x and 657x: Selected Gain of ±940 mV to ±6 V (into 50 Ω)
Output Amplifier Setting Hysteresis (nom)	automatically by driver	940 mV to 960 mV (if output is using low power path it will switch to high power path at 960 mV. If output is using high power path it will switch to low power path at 940 mV)	
Output amplifier path switching time (meas)		1.2 ms (output disabled while switching)	
Output offset Low Power Path (nom)	software programmable	±960 mV in 1 mV steps into 50 Ω (±1920 mV in 2 mV steps into 1 MΩ)	
Output offset High Power Path (nom)	software programmable	653x and 656x: ±3 V in 1 mV steps into 50 Ω (±6V in 2 mV steps into 1 MΩ) 654x and 657x: ±6 V in 1 mV steps into 50 Ω (±12V in 2 mV steps into 1 MΩ)	
Filters	software programmable	One of 4 different filters (refer to „Bandwidth and Filters" section)	
DAC Differential non linearity (nom)	DNL, DAC only	±2.0 LSB typical	
DAC Integral non linearity (nom)	INL, DAC only	±4.0 LSB typical	
Output resistance (nom)		50 Ω	
Output coupling		DC	
Minimum output load (nom)		653x and 656x: 0 Ω (short circuit safe by design) 654x and 657x: 50 Ω (short circuit safe by hardware supervisor, outputs will turn off)	
Max output swing in 50 Ω (nom)		653x and 656x: ±3.0 V (offset + amplitude) 654x and 657x: ±6.0 V (offset + amplitude)	
Max output swing in 1 MΩ (nom)		653x and 656x: ±6.0 V (offset + amplitude) 654x and 657x: ±12.0 V (offset + amplitude)	
Max output current (nom)		653x and 656x: ±100 mA 654x and 657x: ±200 mA	
Slewrate using Filter 0 (meas)		Low power path (0 to 900 mV): 250 mV/ns 653x and 656x: High power path (0 to 3000 mV): 850 mV/ns 654x and 657x: High power path (0 to 6000 mV): 1700 mV/ns	
Rise/Fall time 10% to 90% using Filter 0 (meas)		653x and 656x: ±3 V square wave: 5.3 ns 654x and 657x: ±3 V square wave: 5.4 ns 654x and 657x: ±6 V square wave: 5.4 ns	
Crosstalk @ 1 MHz signal ±3 V (meas)	1 to 4 ch standard AWG	95 dB (M2p.6530, M2p.6531, M2p.6536, M2p.6560, M2p.6561, M2p.6566)	
Crosstalk @ 1 MHz signal ±3 V (meas)	8 channel AWG	84 dB (M2p.6533, M2p.6568)	
Crosstalk @ 1 MHz signal ±6 V (meas)	1 to 4 ch high-voltage AWG	99 dB (M2p.6540, M2p.6541, M2p.6546, M2p.6540, M2p.6541, M2p.6546)	
Output accuracy (spec)		±1 mV ±0.5% of programmed output amplitude ±0.1% of programmed output offset	
Calibration	External	External calibration calibrates the on-board references. All calibration constants are stored in non-volatile memory. A yearly external calibration is recommended.Optional ISO/IEC17025-compliant certificate.	

Trigger

Available trigger modes	software programmable	External, Software, Pulse, Or/And, Delay
Trigger edge	software programmable	Rising edge, falling edge or both edges
Trigger pulse width	software programmable	0 to [4Gi - 1] samples in steps of 1 sample
Trigger delay	software programmable	0 to [4Gi - 1] samples in steps of 1 samples
Trigger hold-off (for Multi, Gate)	software programmable	0 to [4Gi - 1] samples in steps of 1 samples
Multi, Gate: re-arming time (nom)		< 24 samples (+ programmed hold-off)
Trigger input to output delay (meas)	Firmware version ≥ V30	63 sample clocks + 7 ns (valid for all modes except SPCSEQ_ENDLOOPONTRIG)
Trigger input pipeline delay to internal trig (meas)		22 sample clocks
Trigger input to trigger output delay (meas)	Firmware version ≥ V30	63 sample clocks
Memory depth	software programmable	16 up to [installed memory / number of active channels] samples in steps of 8
Multiple Replay segment size	software programmable	16 up to [installed memory / number of active channels] samples in steps of 8
External trigger accuracy		1 sample

		Ext	**X1, X2, X3**
External trigger			
External trigger type		Single level comparator	3.3V LVTTL logic inputs
External trigger impedance (typ)	software programmable	50 Ω / 5 kΩ	For electrical specifications refer to „Multi Purpose I/O lines" section.
External trigger input level (nom)		±5 V (5 kΩ), ±2.5 V (50 Ω),	
External trigger over voltage protection (nom)		±20 V (5 kΩ), 5 Vrms (50 Ω)	
External trigger sensitivity, min signal swing (nom)		200 mVpp	
External trigger level	software programmable	±5 V in steps of 10 mV	
External trigger bandwidth (typ)	50 Ω 5 kΩ	DC to 400 MHz DC to 300 MHz	n.a. DC to 125 MHz
Minimum external trigger pulse width		≥ 2 samples	≥ 2 samples

Multi Purpose I/O lines

Number of multi purpose output lines	one, named X0
Number of multi purpose input/output lines	three, named X1, X2, X3

Multi Purpose line		**X0**	**X1, X2, X3**
Input: available signal types	software programmable	n.a.	Asynchronous Digital-In, Logic trigger
Input: signal levels		n.a.	3.3 V LVTTL (Low ≤ 0.8 V, High ≥ 2.0 V)
Input: impedance		n.a.	10 kΩ to 3.3 V
Input: maximum voltage level		n.a.	-0.5 V to +4.0 V
Input: maximum bandwidth		n.a.	125 MHz
Output: available signal types	software programmable	Run-, Arm-, Trigger-Output, Marker-Output, Synchronous Digital-Out, Asynchronous Digital-Out ADC Clock Output,	Run-, Arm-, Trigger-Output, Marker-Output, Synchronous Digital-Out, Asynchronous Digital-Out,

Output: impedance	50 Ω
Output: drive strength	Capable of driving 50 Ω loads, maximum drive strength ±48 mA
Output: type / signal levels	3.3V LVTTL, TTL compatible for high impedance loads
Output: update rate (synchronous modes)	sampling clock

Option M2p.65xx-DDS16 (16 tone DDS firmware)

Number of available DDS cores per AWG card		16		
DDS core routing options	software programmable	The 16 cores can be equally distributed over the activated channels, hence: 16 cores on 1 channel 8 cores on 2 channels each 4 cores on 4 channels each 2 cores on 8 channels each		
DDS commands	individual for each core	Frequency, Amplitude, Phase, Frequency Slope, Amplitude Slope		
DDS commands	for all cores	Reset, Execute Now, Execute at Trigger/Timer		
DDS command transfer mode		single or DMA		
DDS time resolution (nom)		125 MS/s 8.0 ns		
DDS single command time resolution (nom)		8.0 ns		
		Minimum	**Maximum**	**Step**
DDS timer resolution (nom)	software programmable	80 ns	1125900 s > 13 d 8 ns × (2^{47}-1)	8 ns
DDS frequency range (nom)	per core programmable	0 Hz	125 MHz	Max Samplerate/2^{32}
DDS amplitude range (nom)	per core programmable	-1.0	+1.0	0.0000305 (1/(2^{15}-1))
DDS phase range (nom)	per core programmable	0°	359.824°	0.17578° (360°/2^{11})
DDS command buffer	single mode DMA mode	4Ki commands 128Mi commands in on-board RAM. More commands can reside in DMA buffer in PC-RAM.		
Min user software to analog output latency (meas)	single mode DMA mode	approx. 4 us approx. 160 us		
Max continuous DDS command rate (meas)	single mode DMA mode	TBD		
External trigger to DDS output change (meas)		approx. 775 ns		
Maximum external re-trigger rate (meas)		12.5 MHz		
Number of DDS options per generatorNETBOX		Each generatorNETBOX DNx.65x contains one or more AWGs. The user can individually decide how many of these internal AWGs should be equipped with the DDS option. Each single internal AWG needs a separate license.		

Option M2p.xxxx-PulseGen

Number of internal pulse generators	4
Number of pulse generator output lines	4 (Existing multi-purpose outputs X0 to X3)
Time resolution of pulse generator	Selected Sampling Rate, max is 125 MS/s (8 ns)
Programmable output modes	Single-shot, multiple repetitions on trigger, gated
Programmable trigger sources	Software, Card Trigger, Other Pulse Generator, XIO lines.
Programmable trigger gate	None, ARM state, RUN state
Programmable length (frequency)	2 to 4Gi samples in steps of 1 (32 bit)
Programmable width (duty cycle)	1 to 4Gi samples in steps of 1 (32 bit)
Programmable delay	0 to 4Gi samples in steps of 1 (32 bit)
Programmable loops	0 to 4Gi samples in steps of 1 (32 bit) with 0 = infinite loops
Output level of digital pulse generators	Please see section of multi-purpose I/O lines.

Option M2p.xxxx-DigFX2 / M2p.xxxx-DigSMB common

Input: signal levels (meas)		3.3 V LVTTL
Input: impedance (meas)		10 kΩ to 3.3 V
Input: maximum voltage level (nom)		-0.5 V to +4.0 V
Input: maximum bandwidth (meas)		125 MHz
Input: available signal types	software programmable	Synchronous Digital-In (M2p.59xx only), Asynchronous Digital-In
Output: available signal types	software programmable	Run-, Arm-, Trigger-Output, Synchronous Digital-Out (M2p.65xx only), Asynchronous Digital-Out
Output: update rate synchronous modes (meas)		sampling clock
Output: type / signal levels (meas)		3.3V LVTTL, TTL compatible for high impedance loads

Option M2p.xxxx-DigFX2 specific

Number of additional multi-purpose I/O lines	16 (X4 to X19)
Card width with installed option	Requires one additional slot left of the main card's bracket, on „solder side" of the PCIe card
Connector	1 x 40 pole half pitch (Hirose FX2 series, one adapter cable to IDC connector in standard 2.54mm pitch included (Cab-d40-xx-xx). 4 x SMB male, (jumper selectable between FX2/SMB for: X12, X13, X18 and X19)) Connector on card: Hirose FX2B-40PA-1.27DSL Flat ribbon cable connector: Hirose FX2B-40SA-1.27R
Output: impedance (meas)	FX2: 90 Ω , SMB: 50 Ω
Output: drive strength (meas)	Capable of driving 90 Ω loads (FX2), 50 Ω loads (SMB), maximum drive strength ±48 mA
Compatibility	Pinning compatible with M2i.xxxx-dig option and M2i.70xx connectors

Option M2p.xxxx-DigSMB specific

Number of additional multi purpose I/O lines	16 (X4 to X19)
Card width with installed option	Requires one additional slot left of the main card's bracket, on „solder side" of the PCIe card
Connectors on bracket	10 x SMB male (X4 to X13)
Internal connectors	6 x SMB male (X14 to X19)
Output: impedance (meas)	50 Ω
Output: drive strength (meas)	Capable of driving 50 Ω loads, maximum drive strength ±48 mA

Sequence Replay Mode

Number of sequence steps	software programmable	1 up to 4096 (sequence steps can be overloaded at runtime)
Number of memory segments	software programmable	2 up to 64Ki (segment data can be overloaded at runtime)
Minimum segment size	software programmable	32 samples in steps of 8 samples.
Maximum segment size	software programmable	512 MiS / active channels / number of sequence segments (round up to the next power of two)
Loop Count	software programmable	1 to (1Mi - 1) loops
Sequence Step Commands	software programmable	Loop for #Loops, Next, Loop until Trigger, End Sequence
Special Commands	software programmable	Data Overload at runtime, sequence steps overload at runtime, readout current replayed sequence step
Limitations for synchronized products		Software commands changing the sequence as well as „Loop until trigger" are not synchronized between cards. This also applies to multiple AWG modules in a generatorNETBOX.

Clock

Clock Modes	software programmable	internal PLL, external clock, external reference clock, sync
Internal clock range (PLL mode)	software programmable	see „Clock Limitations" table below
Internal clock accuracy (spec)	after warm-up	≤ ±1.0 ppm (at time of calibration in production)
Internal clock aging (spec)		≤ ±0.5 ppm / year
PLL clock setup granularity (internal reference)		1 Hz
External reference clock range (nom)	software programmable	128 kHz up to 125 MHz
Direct external clock to internal clock delay (meas)		4.3 ns
Direct external clock range		see „Clock Limitations and Bandwidth" table below
External clock type		Single level comparator
External clock input level (nom)		±5 V (5 kΩ), ±2.5 V (50 Ω),
External clock input impedance (typ)	software programmable	50 Ω / 5 kΩ
External clock over voltage protection (nom)		±20 V (5 kΩ), 5 Vrms (50 Ω)
External clock sensitivity, min signal swing (nom)		200 mVpp
External clock level (nom)	software programmable	±5 V in steps of 1mV
External clock edge		rising edge used
External reference clock input duty cycle (nom)		45% - 55%
Clock output electrical specification		Available via Multi Purpose output X0. Refer to „Multi Purpose I/O lines" section.
Synchronization clock multiplier „N" for different clocks on synchronized cards	software programmable	N being a multiplier (1, 2, 3, 4, 5, ... Max) of the card with the currently slowest sampling clock. The card maximum (see „Clock Limitations and Bandwidth" table below) must not be exceeded.
Channel to channel skew on one card (meas)		< 200 ps (typical)
Skew between star-hub synchronized cards (meas)		< 100 ps (typical)

Connectors

Analog		SMB male (one for each single-ended input/output)	Cable-Type: Cab-3f-xx-xx
Trigger Input		SMB male	Cable-Type: Cab-3f-xx-xx
Clock Input		SMB male	Cable-Type: Cab-3f-xx-xx
Standard Multi Purpose I/O		MMCX female (4 lines)	Cable-Type: Cab-1m-xx-xx
Option M2p.xxxx-DigSMB	on extra bracket	SMB male	Cable-Type: Cab-3f-xx-xx
Option M2p.xxxx.DigFX2	on extra bracket	40-pole half pitch (Hirose FX2)	Cable-Type: Cab-d40-xx-xx

Connection Cycles

All connectors have an expected lifetime as specified below. Please avoid to exceed the specified connection cycles or use connector savers.

SMB connector (nom)	500 connection cycles
MMCX connecto (nom)r	500 connection cycles
Hirose FX2 connecto (nom)r	500 connection cycles
PCIe connector (nom)	50 connection cycles

Environmental and Physical Details

Dimension (Single Card) type M2p.65x3, M2p.65x8, M2p.654x or M2p.657x	8 channel AWG or High power AWG	L x H x W: 168 mm (½ PCIe length) x 107 mm x 30 mm. Requires one additional slot right of the main card's bracket, on „component side" of the PCIe card.
Dimension (all other single cards)		L x H x W: 168 mm (½ PCIe length) x 107 mm x 20 mm (single slot width)
Dimension (with -SH6tm or -SH16tm installed)		Extends W by 1 slot right of the main card's bracket, on „component side" of the PCIe card.
Dimension (with -SH6ex or -SH16ex installed)		Extends L to 245 mm (¾ PCIe length) at the back of the PCIe card
Dimension (with -DigSMB or -DigFX2 installed)		Extends W by 1 slot left of the main card's bracket, on „solder side" of the PCIe card.
Weight (M2p.59xx, M2p.75xx series)	maximum	215 g
Weight (M2p.65x0, M2p.65x1, M2p.65x6 series)	maximum	195 g
Weight (M2p.65x3, 65x8, 654x, 657x series)	maximum	305 g
Weight (Star-Hub Option -SH6ex, -SH6tm)	including 6 sync cables	65 g
Weight (Star-Hub Option -SH16ex, -SH16tm)	including 16 sync cables	90 g
Weight (Option -DigSMB)		50 g
Weight (Option -DigFX2)		60 g
Warm up time (meas)		30 minutes
Operating temperature (nom)		0 °C to 40 °C
Storage temperature (nom)		-10 °C to 70 °C
Humidity (nom)		10% to 90%
Dimension of packing	1 or 2 cards	470 mm x 250 mm x 130 cm
Volume weight of packing	1 or 2 cards	4 kg

PCI Express specific details

PCIe slot type	x4, Generation 1 (Gen1)
PCIe slot compatibility (physical)	x4, x8, x16
PCIe slot compatibility (electrical)	x1, x2, x4, x8, x16 with PCIe Gen1, Gen2, Gen3, Gen4 or Gen5
Sustained streaming mode (meas) (Card-to-System: M2p.59xx or M2p.75xx)	> 700 MB/s (measured with a chipset supporting a TLP size of 256 bytes, using PCIe x4 Gen1)
Sustained streaming mode (meas) (System-to-Card: M2p.65xx or M2p.75xx)	> 700 MB/s (measured with a chipset supporting a TLP size of 256 bytes, using PCIe x4 Gen1)

Certification, Compliance, Warranty

Conformity Declaration	EN 17050-1:2010	General Requirements
EU Directives	2014/30/EU	EMC - Electromagnetic Compatibility
	2014/35/EU	LVD - Electrical equipment designed for use within certain voltage limits
	2011/65/EU	RoHS - Restriction of the use of certain hazardous substances in electrical and electronic equipment
	2006/1907/EC	REACH - Registration, Evaluation, Authorisation and Restriction of Chemicals
	2012/19/EU	WEEE - Waste from Electrical and Electronic Equipment
Compliance Standards	EN 61010-1: 2010	Safety regulations for electrical measuring, control, regulating and laboratory devices - Part 1: General requirement
	EN 61187:1994	Electrical and electronic measuring equipment - Documentation
	EN 61326-1:2021	Electrical equipment for measurement, control and laboratory use
	EN 61326-2-1:2021	EMC requirements - Part 1: General requirements
		EMC requirements - Part 2-1: Particular requirements - Test configurations, operational conditions and performance criteria for sensitive test and measurement equipment for EMC unprotected applications
	EN IEC 63000:2018	Technical documentation for the assessment of electrical and electronic products with respect to the restriction of hazardous substances
Product warranty	5 years starting with the day of delivery	
Software and firmware updates	Life-time, free of charge	

Power Consumption

		3.3V	12 V	Total
M2p.6530-x4 (meas)	Typical values: All channels activated, Sample rate: 40 MSps	0.1 A	0.8 A	10 W
M2p.6531-x4 (meas)	Output signal: 10 MHz sine wave, Output level: +/- 3.0 V into 50 Ω load	0.1 A	0.9 A	11 W
M2p.6536-x4 (meas)		0.1 A	1.2 A	15 W
M2p.6533-x4 (meas)		0.1 A	1.8 A	23 W
M2p.6540-x4 (meas)	Typical values: All channels activated, Sample rate: 40 MSps	0.1 A	1.0 A	13 W
M2p.6541-x4 (meas)	Output signal: 10 MHz sine wave, Output level: +/- 6.0 V into 50 Ω load	0.1 A	1.4 A	17 W
M2p.6546-x4 (meas)		0.1 A	2.2 A	27 W
M2p.6560-x4 (meas)	Typical values: All channels activated, Sample rate: 125 MSps	0.1 A	0.8 A	10 W
M2p.6561-x4 (meas)	Output signal: 10 MHz sine wave, Output level: +/- 3.0 V into 50 Ω load	0.1 A	0.9 A	11 W
M2p.6566-x4 (meas)		0.1 A	1.2 A	15 W
M2p.6568-x4 (meas)		0.1 A	1.9 A	23 W
M2p.6570-x4 (meas)	Typical values: All channels activated, Sample rate: 125 MSps	0.1 A	1.0 A	13 W
M2p.6571-x4 (meas)	Output signal: 10 MHz sine wave, Output level: +/- 6.0 V into 50 Ω load	0.1 A	1.4 A	17 W
M2p.6576-x4 (meas)		0.1 A	2.2 A	27 W

MTBF

MTBF (typ)	400000 hours

Clock Limitations

	M2p.653x DNx.653-xx M2p.654x DNx.654-xx DNx.803-xx DNx.813-xx	M2p.656x DNx.656-xx M2p.657x DNx.657-xx DNx.806-xx DNx.816-xx
max internal clock (non-synchronized cards)	40 MS/s	125 MS/s
min internal clock (non-synchronized cards)	1 kS/s	1 kS/s
max internal clock (cards synchronized via star-hub)	40 MS/s	125 MS/s
min internal clock (cards synchronized via star-hub)	128 kS/s	128 kS/s
max direct external clock	40 MS/s	125 MS/s
min direct external clock	DC	DC
min direct external clock LOW time	4 ns	4 ns
min direct external clock HIGH time	4 ns	4 ns

Bandwidth and Filters

	Filter	- 3dB bandwidth	Filter characteristic
Analog bandwidth does not include Sinc response of DAC (typ)	Filter 0	70 MHz	third-order Butterworth
	Filter 1	20 MHz	fifth-order Butterworth
	Filter 2	5 MHz	fourth-order Bessel
	Filter 3	1 MHz	fourth-order Bessel

Dynamic Parameters

	M2p.653x/DNx.653-xx/DNx.803-xx			
Test - Samplerate	40 MS/s		40 MS/s	
Output Frequency	800 kHz		4 MHz	
Output Level in 50 Ω	±900mV	±3000mV	±900mV	±3000mV
Used Filter	1 MHz		5 MHz	
NSD (typ)	-142 dBm/Hz	-132 dBm/Hz	-142 dBm/Hz	-132 dBm/Hz
SNR (typ)	90.7 dB	91.1 dB	83.7 dB	84.1 dB
THD (typ)	-74.0 dB	-74.0 dB	-70.5 dB	-70.5 dB
SINAD (typ)	73.9 dB	73.9 dB	69.8 dB	69.8 dB
SFDR excl harmonics (typ)	97.0 dB	95.0 dB	88.0 dB	88.0 dB
ENOB based on SINAD (typ)	12.0	12.0	11.3	11.3
ENOB based on SNR (typ)	14.7	14.8	13.5	13.6

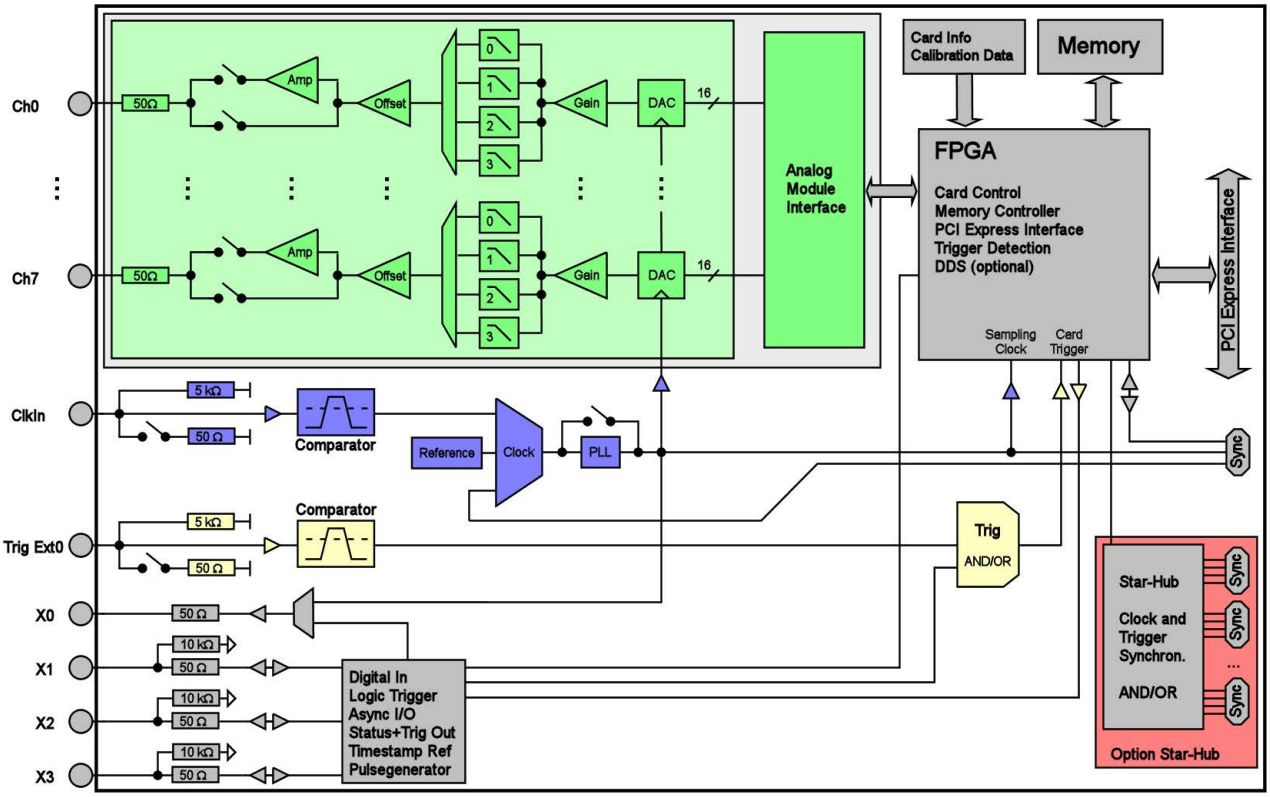
	M2p.654x/DNx.654-xx/DNx.813-xx			
Test - Samplerate	40 MS/s		40 MS/s	
Output Frequency	800 kHz		4 MHz	
Output Level in 50 Ω	±900mV	±6000mV	±900mV	±6000mV
Used Filter	1 MHz		5 MHz	
NSD (typ)	-138 dBm/Hz	-129 dBm/Hz	-142 dBm/Hz	-126 dBm/Hz
SNR (typ)	86.7 dB	88.1 dB	83.7 dB	84.2 dB
THD (typ)	-74.0 dB	-74.0 dB	-74.0 dB	-74.0 dB
SINAD (typ)	73.8 dB	73.8 dB	73.6 dB	73.6 dB
SFDR excl harmonics (typ)				
ENOB based on SINAD (typ)	12.0	12.0	11.9	11.9
ENOB based on SNR (typ)	14.1	14.3	13.6	13.7

	M2p.656x/DNx.656-xx/DNx.806-xx					
Test - Samplerate	125 MS/s		125 MS/s		125 MS/s	
Output Frequency	800 kHz		4 MHz		16 MHz	
Used Filter	1 MHz		5 MHz		20 MHz	
Output Level in 50 Ω	±900mV	±3000mV	±900mV	±3000mV	±900mV	±3000mV
NSD (typ)	-142 dBm/Hz	-132 dBm/Hz	-142 dBm/Hz	-132 dBm/Hz	-142 dBm/Hz	-132 dBm/Hz
SNR (typ)	90.7 dB	91.1 dB	83.7 dB	84.1 dB	77.7 dB	78.1 dB
THD (typ)	-74.0 dB	-74.0 dB	-70.5 dB	-70.5 dB	-66.0 dB	-61.9 dB
SINAD (typ)	73.9 dB	73.9 dB	69.8 dB	69.8 dB	65.7 dB	60.9 dB
SFDR excl harmonics (typ)	97.0 dB	95.0 dB	88.0 dB	88.0 dB	90.0 dB	89.0 dB
ENOB based on SINAD (typ)	12.0	12.0	11.3	11.3	10.6	9.8
ENOB based on SNR (typ)	14.7	14.8	13.5	13.6	12.5	12.6

	M2p.657x/DNx.657-xx/DNx.816-xx					
Test - Samplerate	125 MS/s		125 MS/s		125 MS/s	
Output Frequency	800 kHz		4 MHz		16 MHz	
Used Filter	1 MHz		5 MHz		20 MHz	
Output Level in 50 Ω	±900mV	±6000mV	±900mV	±6000mV	±900mV	±6000mV
NSD (typ)	-138 dBm/Hz	-129 dBm/Hz	-142 dBm/Hz	-126 dBm/Hz	-142 dBm/Hz	-127 dBm/Hz
SNR (typ)	86.7 dB	88.1 dB	83.7 dB	84.2 dB	77.7 dB	79.1 dB
THD (typ)	-74.0 dB	-74.0 dB	-74.0 dB	-74.0 dB	-70.5 dB	-63.1 dB
SINAD (typ)	73.8 dB	73.8 dB	73.6 dB	73.6 dB	69.7 dB	63.0 dB
SFDR excl harmonics (typ)						
ENOB based on SINAD (typ)	12.0	12.0	11.9	11.9	11.3	10.2
ENOB based on SNR (typ)	14.1	14.3	13.6	13.7	12.6	12.8

THD and SFDR are measured at the given output level and 50 Ohm termination with a high resolution M3i.4860/M4i.4450-x8 data acquisition card and are calculated from the spectrum. Noise Spectral Density is measured with built-in calculation from an HP E4401B Spectrum Analyzer. All available D/A channels are activated for the tests. SNR and SFDR figures may differ depending on the quality of the used PC. NSD = Noise Spectral Density, THD = Total Harmonic Distortion, SFDR = Spurious Free Dynamic Range. Phase Noise and Jitter is measured with a Holzworth HA7062C Phase Noise Analyzer.

Hardware block diagram



Order Information

The card is delivered with 512 MiSample on-board memory and supports standard replay, FIFO replay (streaming), Multiple Replay, Gated Replay, Continuous Replay (Loop), Single-Restart as well as Sequence. Operating system drivers for Windows/Linux 32 bit and 64 bit, examples for C/C++, LabVIEW (Windows), MATLAB (Windows and Linux), IVI, .NET, Delphi, Java, Python, Julia and a Base license of the measurement software SBench 6 are included.

Adapter cables are not included. Please order separately!

PCI Express x4

Standard Version
with ±3V output in 50Ω

Order no.	D/A Resolution	Standard mem	Single-Ended Outputs		Output Level
M2p.6530-x4	16 Bit	512 MiSample	1 channel	40 MS/s	±3 V (50Ω) or ±6 V (1 MΩ)
M2p.6531-x4	16 Bit	512 MiSample	2 channels	40 MS/s	±3 V (50Ω) or ±6 V (1 MΩ)
M2p.6536-x4	16 Bit	512 MiSample	4 channels	40 MS/s	±3 V (50Ω) or ±6 V (1 MΩ)
M2p.6533-x4	16 Bit	512 MiSample	8 channels	40 MS/s	±3 V (50Ω) or ±6 V (1 MΩ)
M2p.6560-x4	16 Bit	512 MiSample	1 channel	125 MS/s	±3 V (50Ω) or ±6 V (1 MΩ)
M2p.6561-x4	16 Bit	512 MiSample	2 channels	125 MS/s	±3 V (50Ω) or ±6 V (1 MΩ)
M2p.6566-x4	16 Bit	512 MiSample	4 channels	125 MS/s	±3 V (50Ω) or ±6 V (1 MΩ)
M2p.6568-x4	16 Bit	512 MiSample	4 channels 8 channels	125 MS/s 80 MS/s	±3 V (50Ω) or ±6 V (1 MΩ)

PCI Express x4

High Voltage Version
with ±6V output in 50Ω

Order no.	D/A Resolution	Standard mem	Single-Ended Outputs		Output Level
M2p.6540-x4	16 Bit	512 MiSample	1 channel	40 MS/s	±6 V (50Ω) or ±12 V (1 MΩ)
M2p.6541-x4	16 Bit	512 MiSample	2 channels	40 MS/s	±6 V (50Ω) or ±12 V (1 MΩ)
M2p.6546-x4	16 Bit	512 MiSample	4 channels	40 MS/s	±6 V (50Ω) or ±12 V (1 MΩ)
M2p.6570-x4	16 Bit	512 MiSample	1 channel	125 MS/s	±6 V (50Ω) or ±12 V (1 MΩ)
M2p.6571-x4	16 Bit	512 MiSample	2 channels	125 MS/s	±6 V (50Ω) or ±12 V (1 MΩ)
M2p.6576-x4	16 Bit	512 MiSample	4 channels	125 MS/s	±6 V (50Ω) or ±12 V (1 MΩ)

Options

Order no.	Option
M2p.xxxx-SH6ex [1]	Synchronization Star-Hub for up to 6 cards incl. cables, only one slot width, card length 245 mm
M2p.xxxx-SH6tm [1]	Synchronization Star-Hub for up to 6 cards incl. cables, two slots width, standard card length
M2p.xxxx-SH16ex [1]	Synchronization Star-Hub for up to 16 cards incl. cables, only one slot width, card length 245 mm
M2p.xxxx-SH16tm [1]	Synchronization Star-Hub for up to 16 cards incl. cables, two slots width, standard card length
M2p.xxxx-DigFX2	16 additional multi-purpose I/O lines on separate slot bracket, FX2 connector (incl. Cab-d40-idc-100)
M2p.xxxx-DigSMB	16 additional multi-purpose I/O lines, 10 on separate slot bracket, 6 internal connectors
M2p-upgrade	Upgrade for M2p.xxxx: Later installation of options Star-Hub or Dig.

Firmware Options

Order no.	Option
M2p.xxxx-PulseGen	Firmware Option: adds 4 freely programmable digital pulse generators that use the XIO lines X0 to X3 for output (later installation by firmware upgrade available)
M2p.65xx-DDS16	Firmware Option: adds DDS firmware with 16 fully independently programmable DDS cores.

Services

Order no.	
Recal	Recalibration at Spectrum incl. calibration protocol
Card-Prot-17025	ISO 17025 Calibration Certificate for one card; add-on for new cards or for recalibration

Cables

		Order no.					
for Connections	Length	to BNC male	to BNC female	to SMA male	to SMA female	to SMB female	
Analog/Clock/Trig/Dig	80 cm	Cab-3f-9m-80	Cab-3f-9f-80	Cab-3f-3mA-80	Cab-3f-3fA-80	Cab-3f-3f-80	
Analog/Clock/Trig/Dig	200 cm	Cab-3f-9m-200	Cab-3f-9f-200	Cab-3f-3mA-200	Cab-3f-3fA-200	Cab-3f-3f-200	
Probes (short)	5 cm		Cab-3f-9f-5				
Clk-Out/Trig-Out/Extra	80 cm	Cab-1m-9m-80	Cab-1m-9f-80	Cab-1m-3mA-80	Cab-1m-3fA-80	Cab-1m-3f-80	
Clk-Out/Trig-Out/Extra	200 cm	Cab-1m-9m-200	Cab-1m-9f200	Cab-1m-3mA-200	Cab-1m-3fA-200	Cab-1m-3f-200	
Information	The standard adapter cables are based on RG174 cables and have a nominal attenuation of 0.3 dB/m at 100 MHz.						

		to 2x20 pole IDC	to 40 pole FX2			
M2p.xxxx-DigFX2	100 cm	Cab-d40-idc-100	Cab-d40-d40-100			

Software SBench6

Order no.	
SBench6	Base version included in delivery. Supports standard mode for one card.
SBench6-Pro	Professional version for one card: FIFO mode, export/import, calculation functions, ...
SBench6-Multi	Option multiple cards: Needs SBench6-Pro. Handles multiple synchronized cards in one system.
Volume Licenses	Please ask Spectrum for details.

Software Options

Order no.	
SPc-RServer	Remote Server Software Package - LAN remote access for M2i/M3i/M4i/M4x/M2p/M5i cards
SPc-SCAPP	Spectrum's CUDA Access for Parallel Processing - SDK for direct data transfer between Spectrum card and CUDA GPU. Includes RDMA activation and examples. Only working for Data Acquisition or AWG mode, not usable for DDS mode

[1] : Just one of the options can be installed on a card at a time.

Technical changes and printing errors possible

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