M5i.63xx-x16 - 16 bit 10 GS/s Arbitrary Waveform Generator

- **Fast 16 bit arbitrary waveform generator**
- **Up to 10 GS/s on one or 5 GS/s on two channels**
- **Output signal bandwidth up to 3.9 GHz**
- **Differential or single-ended output**
- **Single-ended output 1 Vpp/4 dBm into 50 Ω (2 Vpp into high impedance)**
- **Differential output 2 Vpp/7 dBm into 100 Ω (4 Vpp into high impedance)**
- **Fixed trigger to output delay**
- **Ultra Fast PCI Express x16 Gen 3 interface**
- **2 GiSample (8 GiSample as option) on-board memory**
- **FIFO mode continuous streaming output**
- **Modes: Single-Shot, Repeated, Loop, FIFO, Multiple Replay**
- **Direct data transfer from CUDA GPU using SCAPP option**
- **Synchronization of up to 8 cards per system using Star-Hub**

Multi-Tone DDS Option

The DDS firmware option adds a new output mode with 64 individually programmable DDS cores per card or internal module. Each core can be programmed for frequency, amplitude and phase. DDS commands can be issued with 3.2 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

M5i series

- PCIe x16 Gen 3 Interface
- Sustained streaming mode up to 10.0 GByte/s*
- Included advanced cooling with dual fans for sufficient airflow

Operating Systems	Programming Languages	Supported Software
• 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	• C, C++, C#, Python • Julia, Java, VB.NET, Delphi • IVI	• SBench 6 • MATLAB • LabVIEW

Model	Analog Bandwidth	Output rate / channels 1 ch	2 ch
M5i.6320-x16	1.4 GHz	3.2 GS/s	
M5i.6321-x16	1.4 GHz	3.2 GS/s	3.2 GS/s
M5i.6350-x16	2.5 GHz	10 GS/s	
M5i.6357-x16	2.5 GHz	10 GS/s	5 GS/s
M5i.6360-x16	3.9 GHz	10 GS/s	
M5i.6367-x16	3.9 GHz	10 GS/s	5 GS/s

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., 5 GS/s gives 2.5 GHz.

General Information

The 63xx series arbitrary waveform generators deliver the highest performance in both speed and resolution. The series includes products with one or two channel and can be extended up to 16 synchronous channels using the star-hub. The 63xx products offer best AWG performance for multiple channels and signal frequencies up to 2.5 GHz with a high output level of up 1 Vpp single-ended into 50 Ohm or 2 Vpp differential into 100 Ohm.

The M5i series is based on the common API from Spectrum and uses the same software interface like all Spectrum products released since 2005.

*Throughput measured with a motherboard chipset supporting a TLP size of 512 bytes.

SPECTRUM INSTRUMENTATION GMBH · AHRENSFELDER WEG 13-17 · 22927 GROSSHANSDORF · GERMANY
PHONE: +49 (0)4102-6956-0 · FAX: +49 (0)4102-6956-66 · E-MAIL: info@spec.de · INTERNET: www.spectrum-instrumentation.com

Software Support

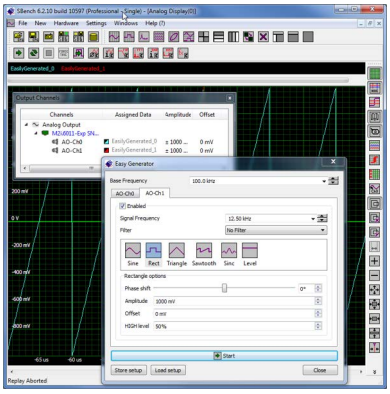
Windows drivers

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

Linux Drivers

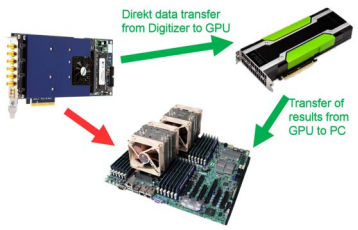
All cards are delivered with full Linux support. Pre compiled kernel modules are included for the most common distributions like Fedora, Suse, Ubuntu LTS or Debian. The Linux support includes SMP systems, 32 bit and 64 bit systems, versatile programming examples for GNU C++, Python and Julia, as well 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 x16

The M5i series cards use a PCI Express x16 Gen3 connection. They can be used in PCI Express x16 slots with hosts supporting Gen1 and newer. Gen3 or newer is needed to get full performance. The maximum sustained data transfer rate is more than 12.8 GiByte/s (read direction) or 10.0 GiByte/s (write direction) per slot on systems with a PCIe payload size of 512 bytes. Physically supported slots that are electrically connected with less lanes can also be used with the M5i series cards, but with reduced data transfer rates.

Connections

The cards are equipped with SMA connectors for the single-ended or differential analog output signals as well as for clock input and output, trigger input and four multi-purpose I/O connectors (X0, X1, X2, X3). These multi-purpose connectors can be individually programmed to perform different functions:

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

Calibration on-board/factory/ISO/IEC 17025

All of the channels are calibrated in factory before the board is shipped. To compensate for different variations like PC power supply, temperature and aging, the software driver provides routines for an automatic on-board offset and gain calibration of output gain and offset. All the cards contain a high precision on-board calibration reference. As an option a ISO/IEC17025-compliant certificate is available with new cards and after recalibration.

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.

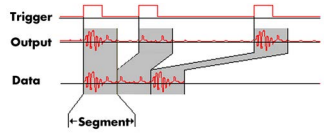
Single Restart replay

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 mode is designed for continuous data transfer between PC memory or hard disk and the generation board. The control of the data stream is done automatically by the driver on an interrupt request basis. The complete installed on-board memory is used for buffering data, making the continuous streaming 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.

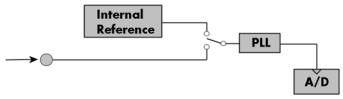
External trigger input

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

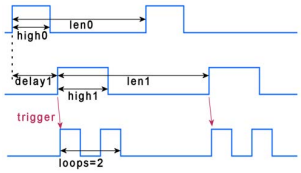
Using a dedicated connector a sampling clock can be fed in from an external system. Additionally it's also possible to output the internally used sampling clock on a separate connector to synchronize external equipment to this clock.

Reference clock



The option to use a precise external reference clock (normally 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 quality of the sampling clock in this way. The driver automatically generates the requested sampling clock from the fed in reference clock.

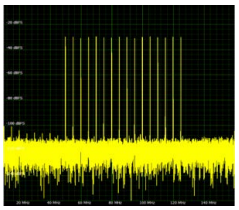
Firmware Option Digital Pulse Generator



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, ...) or can be used to trigger other pulse generators 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.

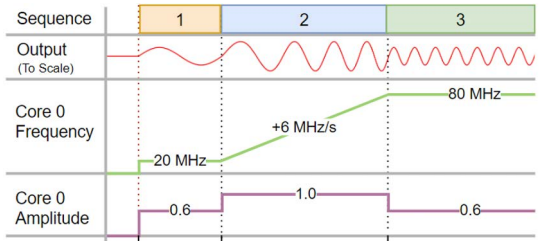
The pulse generator option is a firmware option and can be later installed on all shipped cards.

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 right-hand frequency plot shows 16 tones. In addition to these static parameters, there are also built in dynamic parameters like frequency and amplitude slope 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 seconds 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 50% 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.

Star-Hub

The Star-Hub is an additional module allowing the phase stable synchronization of up to 8 boards of one series and with same speed grade in one system. Independent of the number of boards there is no phase delay between all channels. The Star-Hub distributes trigger and clock information between all boards to ensure all connected boards are running with the same clock and trigger. All trigger sources can be combined with a logical OR allowing all channels of all cards to be the trigger source at the same time.

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 Mode	software programmable	Single-Ended or Differential	
Output Enable/Disable (nom)	software programmable	Output disable cuts connection to DAC and terminates connector with 50 Ω to GND	
Single-Ended		**into 50 Ω**	**into high impedance**
Output amplitude (nom)	software programmable	±1 mV up to ±500 mV	±2 mV up to ±1 V
		Amplitude values below ±100 mV into 50 Ω (±200 mV into high impedance) are generated by reduction of digital samples.	
Stepsize of output amplitude (nom)		1 mV	2 mV
Output offset (nom)	software programmable	±500 mV	±1.0 V
Maximum output voltage, offset + amplitude (nom)		±750 mV	±1.5 V
Differential		**into 100 Ω**	**into high impedance**
Output amplitude, differential signals (nom)	software programmable	±2 mV up to ±1 V	±4 mV up to ±2 V
		Amplitude values below ±200 mV into 100 Ω (±400 mV into high impedance) are generated by reduction of digital samples.	
Stepsize of output amplitude (nom)		2 mV	4 mV
Common Mode Voltage (nom)	software programmable	±500 mV	±1.0 V
Max common mode + single-ended amp (nom)		±750 mV	±1.5 V
DAC Differential non linearity (nom)	DNL, DAC only	±2.2 LSB typical	
DAC Integral non linearity (nom)	INL, DAC only	±9 LSB typical	
Output resistance (nom)		50 Ω	
Output coupling (nom)		DC	
Minimum output load (nom)		0 Ω (short circuit safe)	
Output amplitude accuracy DC (spec)		±2 mV ±1% of programmed output amplitude	
Output offset accuracy DC (spec)		±2 mV ±1% of programmed offset	
Offset temperature drift (meas)	after warm-up and calibration	TBD	
Gain temperature drift (meas)	after warm-up and calibration	TBD	
Calibration	Internal	Self-calibration is done on software command and corrects against the on-board references. Self-calibration should be issued after warm-up time.	
Calibration	External	External calibration calibrates the on-board references used in self-calibration. All calibration constants are stored in non-volatile memory. Optional ISO/IEC17025-compliant certificate. A yearly external calibration is recommended.	

Trigger

Available trigger modes	software programmable	External, Software, Or/And, Delay
Trigger edge	software programmable	Rising edge, falling edge or both edges
Trigger delay	software programmable	0 up to (256 GiS - 32) in steps of 32
Trigger holdoff (for Multi)	software programmable	0 up to (256 GiS - 32) in steps of 32
Memory depth	software programmable	64 up to (Installed memory / channels) in steps of 64
Multiple Recording segment size	software programmable	64 up to (Installed memory / channels) in steps of 64
Internal/External trigger accuracy		1 sample
Multiple Replay re-arming time (nom)	single card star-hub synchronized card	64 samples 800 samples

Trigger edge	software programmable	Rising edge, falling edge or both edges	
Trigger to Output Delay (meas)	M5i.635x/636x (10 GS/s) M5i.633x (3.2 GS/s)	~470 ns ~710 ns	
External trigger		**Ext**	**X0, X1, X2, X3**
External trigger type		single level comparator	3.3V LVTTL logic inputs
External trigger impedance (typ)	software programmable	50 Ω or 3 kΩ	For electrical specifications refer to the „Multi Purpose I/O lines" section.
External trigger input level (nom)		±5 V	
External trigger over voltage protection (nom)	50 Ω termination	±20 V	
	3 kΩ termination	7 Vrms	
External trigger sensitivity, mini signal swing (nom)		200 mVpp	
External trigger level (nom)	software programmable	±5 V with a stepsize of 10 mV	
External trigger bandwidth (typ)	50 Ω	DC to 2 GHz	DC to 125 MHz
	3 kΩ	DC to 750 MHz	n.a.
	10 kΩ	n.a.	DC to 125 MHz
Minimum external trigger pulse width		≥ 2 samples	≥ 2 samples
Resulting max detectable trigger frequency		[Current Samplerate]/2	[Current Samplerate]/2

Clock

Clock Modes	software programmable	internal PLL, external reference clock, star-hub synchronization clock
Internal clock accuracy (spec)		≤ ±1 ppm
Clock setup range		base frequency or divided base frequency
Clock setup base frequencies	M5i.632x	3.2 GS/s
	M5i.635x	10 GS/s
	M5i.636x	10 GS/s
Clock setup divider		power of 2: 2, 4, 8, 16, 32, ... , 524288, 1048576
Clock setup examples	M5i.632x	3.2, 1.6 GS/s, 800, 400, 200, 100 MS/s, ..., 1.6 kS/s
	M5i.635x	10.0, 5.0, 2.5, 1.25 GS/s, 625, 312.5 MS/s, ..., 5 kS/s
	M5i.636x	10.0, 5.0, 2.5, 1.25 GS/s, 625, 312.5 MS/s, ..., 5 kS/s
External reference clock range (nom)	software programmable	≥ 2 MHz and ≤ 750 MHz in steps of 2 MHz
External reference clock input impedance (typ)		50 Ω fixed
External reference clock input coupling (nom)		AC coupling
External reference clock input edge		Rising edge
External reference clock input type		Single-ended, sine wave or square wave
External reference clock input swing (nom)	min max	200 mVpp 3 Vpp
External reference clock input max DC voltage (nom)		±10 V (with max 3.0 V difference between low and high level)
External reference clock input duty cycle (nom)		45 % to 55 %
Clock setup granularity when using reference clock		divider: maximum sampling rate divided by: TBD
Internal reference clock output type		Single-ended, AC-coupled, LVPECL, 720 mVpp (typ)
Internal reference clock output frequency		clock setup base frequency / 64 (example: clock 3.2 GS/s -> output 50.000 MHz)
Star-Hub synchronization clock modes	software programmable	Internal clock, External reference clock
Channel to channel skew on one card (meas)		TBD ns
Skew between star-hub synchronized cards (nom)	software programmable	skew adjustable up to ±127 ps

Option M5i.63xx-DDS64 (64 tone DDS firmware)

Number of available DDS cores per AWG card	635x, 636x	64 @ 2.5 GS/s 32 @ 5 GS/s 16 @ 10 GS/s		
	632x	64 @ 1.6 GS/s 32 @ 3.2 GS/s		
DDS core routing options	software programmable	Routed cores can be individually activated for output Ch0: 64 or 32 cores Ch1: 32 cores		
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)		10 GS/s (100 ps)		
DDS single command time resolution (nom)	635x, 636x 632x	3.2 ns 5 ns		
DDS timer resolution (nom)	software programmable	Minimum	Maximum	Step
	635x, 636x	38.4 ns	450360 s > 5 d 3.2 ns × (2^{47}-1)	3.2 ns
	632x	60 ns	703687 s > 8 d 5 ns × (2^{47}-1)	5 ns
DDS frequency range (nom)	per core programmable	min: 0 Hz, max: [Current Samplerate], step: [Current Samplerate]/2^{32}		
DDS amplitude range (nom)	per core programmable	min: -1.0, max: +1.0, step: 0.0000305 (1/(2^{15}-1))		
DDS phase range (nom)	per core programmable	min: 0°, max: 359.912°, step: 0.08789° (360°/2^{12})		
DDS command buffer	single mode DMA mode	4Ki commands 512Mi commands in on-board RAM. More commands can reside in DMA buffer in PC-RAM. 2Gi commands with memory option.		
Min user software to analog output latency (meas)	single mode DMA mode	4 µs 26 µs		
Max continuous DDS command rate (meas)	single mode DMA mode	TBD 3.3 MCommands/s		
External trigger to DDS output change (meas)	635x, 636x 632x	approx. 735 ns approx. 1060 ns		
Maximum external re-trigger rate (meas)	635x, 636x 632x	35.2 ns 55 ns		
Number of DDS options per generatorNETBOX		Each generatorNETBOX DN6.63x contains multiple AWGs with either one or two channels. 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.		

Multi Purpose I/O lines (front-plate)

Number of multi purpose lines		four, named X0, X1, X2, X3
Input: available signal types	software programmable	Logic Trigger, Asynchronous Digital-In, Synchronous Digital-In (Digitizer only), Timestamp Reference Clock (Digitizer only)
Input: impedance (nom)	software programmable	10 kΩ to 3.3 V or 50 Ω to GND
Input: maximum voltage level (nom)		-0.5 V to +4.0 V
Input: signal levels (nom)		3.3 V LVTTL (Low ≤ 0.8 V, High ≥ 2.0 V)
Input: bandwidth (typ)		125 MHz
Output: available signal types	software programmable	Asynchronous Digital-Out, Trigger Output, Run, Arm, System Clock, Synchronous Digital-Out (AWG only)
Output: impedance (nom)		50 Ω
Output: signal levels (nom)		3.3 V LVTTL
Output: type (nom)		3.3 V LVTTL, TTL compatible for high impedance loads
Output: drive strength (nom)		Capable of driving 50 Ω loads, maximum drive strength ±48 mA
Output: internal update rate	M5i.332x, M5i.333x, DNx.332-xx, DNx.333-xx	Current sampling clock ≤ 3.2 GS/s: 1/4 of sampling clock Current sampling clock > 3.2 GS/s: 1/8 of sampling clock
Output: internal update rate	M5i.335x, M5i.336x, DNx.335-xx	Current sampling clock ≤ 5.0 GS/s: 1/4 of sampling clock Current sampling clock > 5.0 GS/s: 1/8 of sampling clock
Output: internal update rate	M5i.63xx, DNx.63xx DNx.63x-xx	Current sampling clock ≤ 5.0 GS/s: 1/4 of sampling clock Current sampling clock > 5.0 GS/s: 1/8 of sampling clock
Output: min high/low time (nom)		4 ns
Output: max signal frequency (typ)		125 MHz

Option M5i.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	Pulse generator's sampling rate is derived from instrument's sampling rate and value can be read out. Pulse generator update rate are: 33xx: Base Sampling Rate x Channels / 32 (max 10 GS/s x 1 ch / 32) = 312.5 MS/s (3.2 ns) 63xx: Sampling Rate x Channels / 32 (max 10 GS/s x 1 ch / 32) = 312.5 MS/s (3.2 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.

Bandwidth, Flatness and Slewrate

	Output Mode	Single-Ended Amplitude	Differential Amplitude	M5i.636x DNx.636-xx	M5i.635x DNx.635-xx	M5i.632x DNx.632-xx
Maximum Output Rate				10 GS/s	10 GS/s	3.2 GS/s
-3dB Bandwidth (typ)		±250 mV	±500 mV	3.9 GHz	2.5 GHz	1.4 GHz
-3dB Bandwidth (typ)		±500 mV	±1 V	2.9 GHz	2.5 GHz	1.4 GHz
Amplitude Flatness 0.5 dB (typ)				DC to 2.0 GHz	DC to 2.0 GHz	DC to 1.2 GHz
Slew rate (meas)	Single-Ended			4.1 V/ns	3.5 V/ns	2.3 V/ns
Slew rate (meas)	Differential			8.2 V/ns	7.0 V/ns	4.6 V/ns
Rise/Fall time 20% to 80% (meas) (step response)				150 ps	170 ps	260 ps
Rise/Fall time 10% to 90% (meas) (step response)				200 ps	245 ps	380 ps

Dynamic Parameters

Noise		Single-Ended Output		Differential Output	
Output Level in 50 Ω / 100 Ω		±250 mV	±500 mV	±500 mV	±1000 mV
NSD (typ)		-151 dBm/Hz		-157 dBm/Hz	
SNR (typ)	636x	53.1 dBc	59.1 dBc	65.1 dBc	71.1 dBc
	635x	56.0 dBc	61.0 dBc	67.0 dBc	73.0 dBc
	632x	58.5 dBc	64.5 dBc	69.5 dBc	75.5 dBc
SFDR excl. Harmonics (typ)		-90.0 dBc		-90.0 dBc	
ENOB based on SNR (typ)	636x	8.5 bit	9.5 bit	10.5 bit	11.5 bit
	635x	8.8 bit	9.8 bit	10.8 bit	11.8 bit
	632x	9.4 bit	10.4 bit	11.3 bit	12.3 bit

Harmonics	Single-Ended Output											
Output Frequency	20 MHz		100 MHz		500 MHz		1000 MHz		1500 MHz		2000 MHz	
Output Level into 50 Ω	±250 mV	±500 mV	±250 mV	±500 mV	±250 mV	±500 mV	±250 mV	±500 mV	±250 mV	±500 mV	±250 mV	±500 mV
THD (typ)	-64.4 dB	-58.7 dB	-60.6 dB	-54.2 dB	-46.8 dB	-40.8 dB	-38.8 dB	-31.9 dB	-36.9 dB	-26.1 dB	-31.8 dB	-21.7 dB
HD2 (typ)	-66.5 dB	-59.0 dB	-60.6 dBc	-54.5 dBc	-46.8 dBc	-41.1 dBc	-38.8 dBc	-32 dBc	-37.7 dBc	-27.8 dBc	-32.2 dBc	-24.6 dBc
HD3 (typ)	-79.4 dB	-75.1 dB	-79.5 dBc	-68.5 dBc	-67.9 dBc	-55.7 dBc	-62.9 dBc	-49.1 dBc	-44.4 dBc	-31.1 dBc	-42.7 dBc	-24.6 dBc
HD4 (typ)	-95.0 dB	-92.0 dB	-90.5 dBc	-81.8 dBc	-90.0 dBc	-63.7 dBc	-98 dBc	-50.4 dBc	-78 dBc	-46.1 dBc	-	-
	Differential Output											
Output Level into 100 Ω			±500 mV	±1 V	±500 mV	±1 V	±500 mV	±1 V	±500 mV	±1 V	±500 mV	±1 V
THD (typ)			-76 dB	-67.5 dB	-66.6 dB	-53.3 dB	-60.2 dB	-48.3 dB	-46.2 dB	-33.1 dB	-42.1 dB	-27.6 dB
HD2 (typ)			-77.4 dBc	-76.7 dBc	-82 dBc	-93 dBc	-63.9 dBc	-56.8 dBc	-73.2 dBc	-52.7 dBc	-45.6 dBc	-41.1 dBc
HD3 (typ)			-82 dBc	-68.2 dBc	-66.8 dBc	-53.2 dBc	-64.1 dBc	-49.3 dBc	-46.2 dBc	-33.1 dBc	-44.8 dBc	-27.8 dBc
HD4 (typ)			-94 dBc	-100 dBc	-95 dBc	-93 dBc	-68.7 dBc	-68.9 dBc	-93 dBc	-70.1 dBc	-	-

Intermodulation Distortion	Single-Ended Output or Differential Output					
Output Frequency	500 MHz ±0.5 MHz		1 GHz ±1.0 MHz		1.5 GHz ±5.0 MHz	
Output Level in 50 Ω	±250 mV	±500 mV	±250 mV	±500 mV	±250 mV	±500 mV
IMD3 (typ)	-76.0 dBc	-66.5 dBc	-67.4 dBc	-53.8 dBc	-55.4 dBc	-39.4 dBc

Phase Noise and Jitter	Single-Ended Output or Differential Output				
Output Frequency	20 MHz	125 MHz	500 MHz	1 GHz	1.5 GHz
Output Level in 50 Ω	±500 mV	±500 mV	±500 mV	±500 mV	±500 mV
Offset 10 Hz (typ)	-95 dBc/Hz	-79 dBc/Hz	-67 dBc/Hz	-61 dBc/Hz	-57 dBc/Hz
Offset 100 Hz (typ)	-117 dBc/Hz	-104 dBc/Hz	-94 dBc/Hz	-85 dBc/Hz	-81 dBc/Hz
Offset 1 kHz (typ)	-128 dBc/Hz	-113 dBc/Hz	-101 dBc/Hz	-96 dBc/Hz	-91 dBc/Hz
Offset 10 kHz (typ)	-148 dBc/Hz	-128 dBc/Hz	-116 dBc/Hz	-110 dBc/Hz	-107 dBc/Hz
Offset 100 kHz (typ)	-155 dBc/Hz	-144 dBc/Hz	-133 dBc/Hz	-127 dBc/Hz	-124 dBc/Hz
Offset 1 MHz (typ)	-156 dBc/Hz	-153 dBc/Hz	-146 dBc/Hz	-140 dBc/Hz	-137 dBc/Hz
Offset 10 MHz (typ)	-156 dBc/Hz	-154 dBc/Hz	-154 dBc/Hz	-155 dBc/Hz	-153 dBc/Hz
Offset 40 MHz (typ)	-156 dBc/Hz	-154 dBc/Hz	-154 dBc/Hz	-155 dBc/Hz	-153 dBc/Hz
Jitter - Integration range 1 kHz - 10 MHz (typ)	200 fs	200 fs	180 fs	180 fs	170 fs

All the dynamic parameter measurements were done at maximum output rate, i.e. 10 GS/s (for the 636x and 635x family) and 3.2 GS/s (for the 632x family).
THD, SFDR and NSD are measured at the given output level and 50 Ohm termination, differential outputs are measured with a Balun. Calculations are done with built-in calculations from an Siglent SVA1032X 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 using a measuring range from 10 Hz to 40 MHz and an integration range for the jitter measurement of 1 kHz to 10 MHz.

Connectors

Analog Inputs (one for each single-ended input)	33xx		SMA female	Cable-Type: Cab-3mA-xx-xx
Analog Outputs (two for each differential output)		63xx	SMA female	Cable-Type: Cab-3mA-xx-xx
Trigger Input	33xx	63xx	SMA female	Cable-Type: Cab-3mA-xx-xx
Clock Input	33xx	63xx	SMA female	Cable-Type: Cab-3mA-xx-xx
Clock Output	33xx	63xx	SMA female	Cable-Type: Cab-3mA-xx-xx
Multi Purpose I/O	33xx	63xx	SMA female	Cable-Type: Cab-3mA-xx-xx
Power Connector	33xx	63xx	PCIe 6-pin power +12V+GND	Must be supplied by PC power supply.

Connection Cycles

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

SMA connector	500 connection cycles
PCIe connector	50 connection cycles
PCIe power connector	30 connection cycles

Environmental and Physical Details

Dimension (Card, including rear fans)		L x H x W: 241 mm x 107 mm x 40 mm (double slot width)
Dimension (Card, rear fans, option star-hub)		L x H x W: 241 mm x 107 mm x 60 mm (three slots width)
Weight single M5i card	maximum	780 g
Weight (Option Star-hub, including 8 cables)	maximum	150 g
Warm up time (meas)		30 minutes (running acquisition at full speed)
Operating temperature (nom)		0°C to 50°C
Storage temperature (nom)		-10°C to 70°C
Humidity (nom)		10% to 90%
Dimension of packing	1 card	470 mm x 250 mm x 130 cm
Volume weight of packing	1 card	4 kg

PCI Express specific details

PCIe connector type		x16 Generation 3 (Gen3)
PCIe slot compatibility (physical)		x16
PCIe slot compatibility (electrical)		x1, x2, x4, x8, x16 with PCIe Gen1, Gen2, Gen3, Gen4 or Gen5
Sustained streaming mode Card-to-System (meas)	M5i.33xx	> 13.9 GB/s (measured on PCIe x16 Gen3 with a chipset supporting a 512 bytes TLP) > 11.2 GB/s (measured on PCIe x16 Gen3 with a chipset supporting a 256 bytes TLP)
Sustained streaming mode System-to-Card (meas)	M5i.63xx	> 11.7 GB/s (measured on PCIe x16 Gen3 with a chipset supporting a 512 bytes TLP) > 10.3 GB/s (measured on PCIe x16 Gen3 with a chipset supporting a 256 bytes TLP)
PCIe max card controller TLP		512 (lower values will limit maximum streaming speed)

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

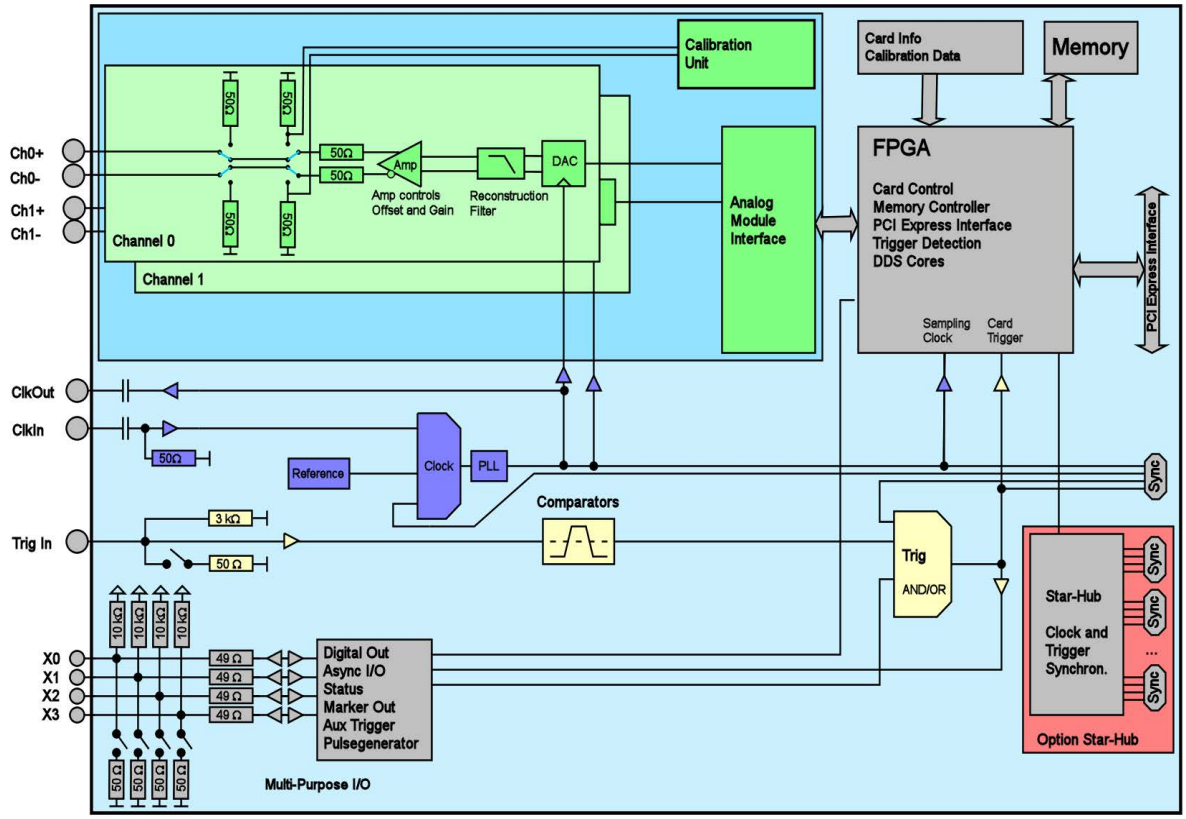
		Bus Connector		Power Connector*	
		3.3V	**12 V**	**12 V**	**Total**
M5i.6367-x16 (meas)	All channels active, differential output with maximum output level possible, 10 MHz sine signal	0.3 A	n.a.	3.1 A	38 W
M5i.6360-x16 (meas)		0.3 A	n.a.	3.1 A	38 W
M5i.6357-x16 (meas)		0.3 A	n.a.	3.1 A	38 W
M5i.6350-x16 (meas)		0.3 A	n.a.	3.1 A	38 W
M5i.6321-x16 (meas)		0.3 A	n.a.	3.1 A	38 W
M5i.6320-x16 (meas)		0.3 A	n.a.	3.1 A	38 W
M5i.xxxx-SH8 (meas)		n.a.	n.a.	0.42 A	5 W

*A separate power connection to the card is mandatory. The card cannot be powered solely by the PCIe bus connector

MTBF

MTBF (typ)	TBD hours

Hardware block diagram



Order Information

The card is delivered with 2 GiSamples on-board memory (8 GiSamples as option) and supports standard replay, FIFO replay (streaming), Multiple Replay, Continuous Replay (Loop) and Single-Restart. 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 x16

Order no.	Bandwidth	Standard mem	Optional mem	1 channel	2 channels
M5i.6320-x16	1.4 GHz	2 GiSample	8 GiSamples	3.2 GS/s	
M5i.6321-x16	1.4 GHz	2 GiSample	8 GiSamples	3.2 GS/s	3.2 GS/s
M5i.6350-x16	2.5 GHz	2 GiSample	8 GiSamples	10 GS/s	
M5i.6357-x16	2.5 GHz	2 GiSample	8 GiSamples	10 GS/s	5 GS/s
M5i.6360-x16	3.9 GHz	2 GiSample	8 GiSamples	10 GS/s	
M5i.6367-x16	3.9 GHz	2 GiSample	8 GiSamples	10 GS/s	5 GS/s

Options

Order no.	Option
M5i.xxxx-MEM8GS	Optional memory extension to 8 GiSamples (16 GiBytes)
M5i.xxxx-SH8-C2	Synchronization star-hub for up to 8 cards in one system, 2 synchronization cables included
M5i.xxxx-SH8-C4	Synchronization star-hub for up to 8 cards in one system, 4 synchronization cables included
M5i.xxxx-SH8-C8	Synchronization star-hub for up to 8 cards in one system, 8 synchronization cables included
Card-Upgrade	Upgrade for M5i.xxxx: Later installation of star-hub
M5i.xxxx-SyncCable	Additional synchronization cable for connecting star-hub to one card

Firmware Options

Order no.	Option
M5i.63xx-DDS64	Firmware Option multi-carrier DDS mode: adds 64 programmable DDS cores. Each core can be programmed with single commands for frequency, amplitude, phase, frequency slope, amplitude slope.
M5i.xxxx-PulseGen	Firmware Option: adds 4 freely programmable digital pulse generators that use the XIO lines for output (later installation by firmware-upgrade available)

Standard Cables

		Order no.			
for Connections	Length	to BNC male	to BNC female	to SMA male	to SMB female
Analog/Clk/Trig/XIO	80 cm	Cab-3mA-9m-80	Cab-3mA-9f-80	Cab-3mA-3mA-80	Cab-3f-3mA-80
Analog/Clk/Trig/XIO	200 cm	Cab-3mA-9m-200	Cab-3mA-9f-200	Cab-3mA-3mA-200	Cab-3f-3mA-200
Probes (short)	5 cm		Cab-3mA-9f-5		
Information	The standard adapter cables are based on RG174 cables and have a nominal attenuation of 0.3 dB/m at 100 MHz and 0.5 dB/m at 250 MHz. For high speed signals we recommend the low loss cables series CHF				

Low Loss Cables

Order No.	Option
CHF-3mA-3mA-200	Low loss cables SMA male to SMA male 200 cm
CHF-3mA-9m-200	Low loss cables SMA male to BNC male 200 cm
Information	The low loss adapter cables are based on MF141 cables and have an attenuation of 0.3 dB/m at 500 MHz and 0.5 dB/m at 1.5 GHz. They are recommended for signal frequencies of 200 MHz and above.

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

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

Technical changes and printing errors possible

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