Portable Multichannel / Multi-Module Streaming / Recording Solutions Using M9203A and PXIe RAID Storage

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M9203A Streaming / Recording Bundles

Keysight Technologies M9203A is a PXIe high-speed digitizer / wideband digital receiver, providing 12-bits of ADC resolution and a sampling rate of up to 1.6 GS/s in two channel mode, or 3.2 GS/s in single channel interleaved mode.

M9203A also offers two different streaming / recording bundles, both based on the continuous simultaneous acquisition and readout architecture (for gapless acquisition) and implementing a real time digitizer data recorder.

This application note gives a brief overview of the purpose / content of both bundles, provides a practical example of setting up a PXIe storage card as a RAID0 volume, and suggests solutions that would maximize streaming / recording performance for up to 8 channels.

Common Features

The features common to the M9203A-CB0 and M9203A-CB2 bundles are:

- Guaranteed recording specification of up to 1.7 GB/s per module (or 850 MB/s per channel if both channels are being used) Support for up to four M9203A modules in a single chassis
- Data can be streamed to a storage device, or to the host controller (if data throughput is below the maximum limit of host storage)
- An intuitive command line application
- A data viewer with a graphical user interface
- Streaming option -CB0 or -CB2 is added to a pre-configured M9203A that consists of:
    - o 1.6 GS/s sampling rate (option -SR2)
    - o Full bandwidth (option -F10)
    - o 4 GB acquisition memory (option -M40)
    - o Digitizer firmware (option -DGT)

M9203A-CB0: Streaming / Recording Real Sample Data

This enables solutions that require real sample data at up to 1.6 GS/s:

- The sample rate can be decimated by 2, 4, or 8; equivalent to 800 MS/s, 400 MS/s, and 200 MS/s respectively when using the internal clock
- By default, samples are stored as 12-bit raw data in 16-bits, but can also be stored using 12-bit, 10-bit, or 8-bit modes to optimize data throughput

M9203A-CB2: Streaming / Recording I/Q Data

This enables solutions that require digital down-conversion, with the samples stored as I/Q data:

- Real time multichannel phase coherent digital down-converter (DDC)
- Guaranteed recording specification up to 320 MHz, with tunable intermediate frequency
- Decimation ratio can be changed from the default value of 4 to 8, 16, 32, 64 or 128; maximum decimation reduces the sample rate to 12.5 MS/s when using the internal clock, providing an intermediate bandwidth (IBW) of 10 MHz
- Multichannel recording to disk of all I/Q samples for later analysis
- By default, samples are stored as 16-bit or 32-bit I/Q data, depending on the decimation ratio, but can also be stored as 12-bit I/Q data to optimize data throughput

Command Line Application

The streaming / recording process is setup and controlled via two intuitive command line applications, one for -CB0 (real sample data) and another for -CB2 (I/Q data). The following setup parameters are common to both applications:

- VISA address for the Master module, and up to 3 Slave modules
- Individual full-scale range (FSR) setting for each channel being streamed
- Clock source (internal clock, external clock, or external reference)
- Trigger parameters (trigger source, slope direction, and level)
- File size of the data recorded per channel (GB)
- Path names and file names for the recorded data

Figure 1: Command Line Application

The -CB0 application (streamRecorder_64.exe) has the following specific setup parameters:

- Sample rate decimation ratio (decimate by 2, 4, or 8)
- Enable/disable interleaved mode (can only be enabled if option -INT is also present)
- Data optimization mode to reduce real sample data throughput (12-bit, 10-bit, or 8-bit mode)

The -CB2 application (streamRecorderDDC_64.exe) has the following specific setup parameters:

- DDC sample decimation ratio (decimate by 4, 8, 16, 32, 64 or 128)
- DDC intermediate frequencies (DDCA defines Channel 1, DDCB defines Channel 2)
- Data optimization mode to reduce I/Q data throughput (12-bit mode)

Data Viewer Software

The -CB0 and -CB2 bundles also include a permanent license for the Wave Cut data viewing software.

This software is used to:

- Browse the actual recorded data, which could be greater than several TB in size, in a very fast manner with full resolution

- Provide a quick partial preview of the data, allowing rapid location of the region of interest

- Select and zoom into the region of interest

- Export/save the selected data to the required file format; raw, VSA, or HDF5

Note that data saved as a VSA file can be imported to Keysight's 89600 VSA Software for further analysis
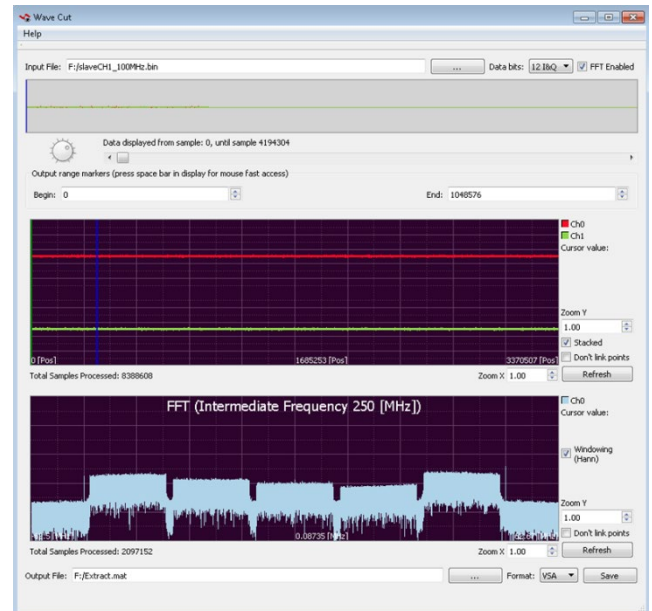
Figure 2: Wave Cut Data Viewer Software

Data Storage Solutions

External Workstation Storage

Historically Keysight has recommended the use of a high-power external workstation in conjunction with a PCIe® interface (M9021A), cable (Y1202A), and interface adapter (M9048A) to stream the data to eight SSDs configured as a RAID0 array.

The primary benefit of this type of configuration is the cost associated with the RAID controller and memory. However, it does require a larger footprint.
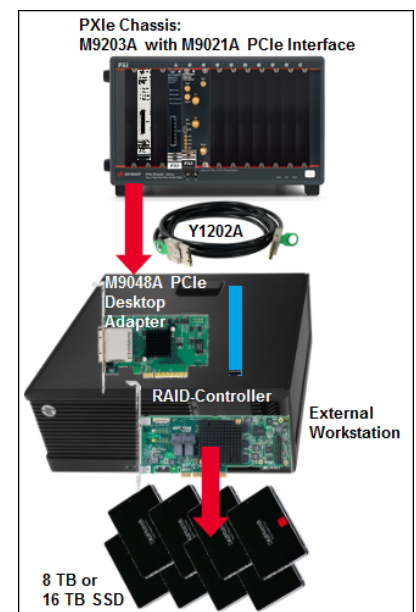
Figure 3: Workstation Storage

PXIe Chassis Storage

PXIe storage cards, when populated with NVM Express™ (NVMe™) solid state drives, enable streaming / recording solutions to be integrated in the same chassis as the digitizer.

A solution with integrated PXIe storage provides:

- Compact physical footprint in the work area.
- Portable solution.
- Reduced risk of controller obsolescence.
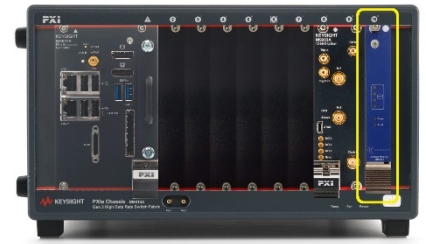
Figure 4: PXIe Chassis Storage

PXIe Chassis Compatibility

With regards to form factor, two chassis slots are required per M9203A module, and one is required per storage card. If more than two M9203A modules are present, then data throughput can be maximized by installing an additional storage card for use by the third and fourth modules.

M9203A Multi-Module Mode

The -CB0 and -CB2 bundles support up to four M9203A modules in a single chassis. If multiple modules are being used, then they must share a common clock and a common external trigger (if applicable).

Note that multi-module mode has two basic requirements with regards to chassis layout:

- The modules must be positioned in adjacent slots (i.e. no gaps between modules).
- When using more than 2 modules, one of the center modules must be designated as the Master.

M9010A: 10-slot, 24 GB/s, Gen 3

The M9010A provides a compact fully contained recording solution which can provide up to 6 channels with 16 TB of PXIe storage, with high data throughput via the PCIe Gen 3 backplane.

- Provides nine x8 slots plus a PXIe system slot.
- The PCIe switch fabric divides them into two bus segments – slots 2-5 and slots 6-10.
- If possible, data being streamed from an M9203A module should be recorded to a storage card in the same bus segment.
- Streaming data from two or more M9203A modules across the PCI to PCI bridge to the other segment could have an adverse effect on performance.
- See Appendices A and B for a comprehensive list of possible recording configurations.
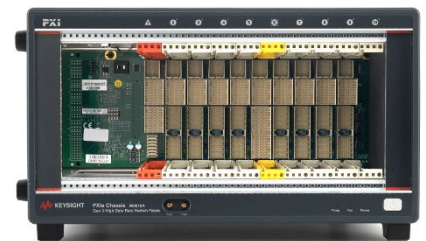
Figure 5: M9010A Chassis

M9019A: 18-slot, 24 GB/s, Gen 3

For more channels or memory requirements, the M9019A provides a flexible and powerful fully contained recording solution which can provide up to 8 channels with 16 TB of PXIe storage, again with high data throughput via the PCIe Gen 3 backplane.

Figure 6: M9019A Chassis

- Provides seventeen x8 slots plus a PXIe system slot.
- The PCIe switch fabric divides them into two bus segments – slots 2-9, and slots 10-18.
- If possible, data being streamed from an M9203A module should be recorded to a storage card in the same bus segment.
- Streaming data from two or more M9203A modules across the PCI to PCI bridge to the other segment could have an adverse effect on performance.
- See Appendices A and B for a comprehensive list of possible recording configurations.

M9018B: 18-slot, 8 GB/s, Gen 2

M9018B can be configured with a maximum of three M9203A modules and one storage card. While it can be used in streaming applications, the Gen 2 backplane limits the maximum data throughput that can be achieved, especially in multi-module applications.

- Provides thirteen x4 slots, four x8 slots (positions 2, 6, 11, 15), and a PXIe system slot.
- Only x8 chassis slots can be used, due to high data throughput.
- A maximum of three M9203A modules can be installed, as the fourth chassis slot is required for the storage card.
- It is not possible to install multiple modules in adjacent slots, which is a basic requirement for operating in multi-module mode.
- The PCIe Gen 2 backplane can impact performance, especially if one or more modules is operating at the maximum data throughput of 1.7 GB/s.
- Due to these limitations, M9018B is not recommended – consider using M9010A or M9019A instead.

PXIe Data Storage

PXIe Storage Card

For this example, and for the solutions suggested later in this document, we will consider the Conduant Corporation DM-4M.2-3U card.

This card supports up to four 2 TB NVMe M.2 form factor solid state drive modules, which can be configured as four standalone volumes, or combined to create a single 8 TB RAID0 volume.

Windows 8.1 and Windows 10 both natively support this card – for older versions of Windows, refer to the Conduant web site for the appropriate driver software.

Figure 7: Conduant DM-4M.2-3U

- Product Page: https://conduant.com/products/product/dm-4m/
- Data Sheet: https://conduant.com/wp-content/uploads/2017/04/DM4-M2-3UDatasheet.pdf

NVMe M.2 Solid State Drive Modules

For this example, and for the solutions suggested later in this document, we will consider the Samsung 970 EVO M.2 SSD module.

This module supports sequential read/write speeds of up to 3,500/2,500 MB/s respectively and is available in capacities up to 2 TB.

Capacities below 1 TB should be avoided, as the data sheet indicates that sequential write performance is much lower beyond the Intelligent TurboWrite region (a buffering technology used by Samsung to enable faster write speeds).

Figure 8: NVMe SSD Modules

For optimum performance, ensure you are using the latest Samsung NVMe driver.

- Product Page: https://www.samsung.com/semiconductor/minisite/ssd/product/consumer/970evo/
- NVMe Driver: https://www.samsung.com/semiconductor/minisite/ssd/download/tools/

Suggested Streaming / Recording Solutions

This section suggests practical chassis configurations for multichannel and multi-module streaming / recording solutions. They also include the sample rate and data packing settings that would provide maximum data throughput per channel, and the settings that would provide maximum recording duration. Refer to Appendices A and B for a comprehensive list of settings versus performance.

Note that the -CB2 examples in this section are all based on setups that use 12-bit I/Q data packing.

One / Two Channel(s) with 8 TB of Storage

Suggested Chassis Configuration	Description
	- M9010A chassis with M9037A in system slot 1 - M9203A in slots 8/9 8 TB PXIe storage card in slot 10 2-Ch from 8/9 streamed to slot 10
	- M9019A chassis with M9037A in system slot 1 - M9203A in slots 6/7 8 TB PXIe storage cards in slot 5 2-Ch from 6/7 streamed to slot 5

-CB0 Streaming	Data Throughput Per Channel / Maximum Recording Duration
1 Channel	2.266 GHz external clock, decimation ratio 1 = 1.133 GS/s **12-bit mode at 1.133 GS/s = 1.7 GB/s for 78 minutes**
	2.72 GHz external clock, decimation ratio 1 = 1.36 GS/s **10-bit mode at 1.36 GS/s = 1.7 GB/s for 78 minutes**
	1.8 GHz external clock, decimation ratio 8 = 112.5 MS/s **8-bit mode at 112.5 MS/s = 0.113 GB/s for 1179 minutes**
2 Channels	2.266 GHz external clock, decimation ratio 2 = 566.5 MS/s **12-bit mode at 566.5 MS/s = 0.85 GB/s for 78 minutes**
	2.72 GHz external clock, decimation ratio 2 = 680 MS/s **10-bit mode at 680 MS/s = 0.85 GB/s for 78 minutes**
	1.8 GHz external clock, decimation ratio 8 = 112.5 MS/s **8-bit mode at 112.5 MS/s = 0.113 GB/s for 589 minutes**

-CB2 Streaming	Data Throughput Per Channel / Maximum Recording Duration
1 Channel	Internal clock, decimation ratio 4 = 400 MS/s = 320 MHz IBW **12-bit I/Q mode with 320 MHz IBW = 1.2 GB/s for 111 minutes**
	1.8 GHz external clock, decimation ratio 128 = 7.03125 MS/s = 5.625 MHz IBW **12-bit I/Q mode with 5.625 MHz IBW = 0.021 GB/s for 6349 minutes**
2 Channels	2.266 GHz external clock, decimation ratio 4 = 283.25 MS/s = 226.6 MHz IBW **12-bit I/Q mode with 226.6 MHz IBW = 0.85 GB/s for 78 minutes**
	1.8 GHz external clock, decimation ratio 128 = 7.03125 MS/s = 5.625 MHz IBW **12-bit I/Q mode with 5.625 MHz IBW = 0.021 GB/s for 3174 minutes**

Three / Four Channels with 8 TB of Storage

Suggested Chassis Configuration	Description
	- M9010A chassis with M9037A in system slot 1 - M9203A in slots 6/7 and 8/9 - Multi-Module Master: Either M9203A - 8 TB PXIe storage cards in slot 10 - 2-Ch from 6/7 and 2-Ch from 8/9 streamed to slot 10
	- M9019A chassis with M9037A in system slot 1 - M9203A in slots 6/7 and 8/9 - Multi-Module Master: Either M9203A - 8 TB PXIe storage card in slot 5 - 2-Ch from 6/7 and 2-Ch from 8/9 streamed to slot 5

-CB0 Streaming	Data Throughput Per Channel / Maximum Recording Duration
3 Channels	2.266 GHz external clock, decimation ratio 2 = 566.5 MS/s **12-bit mode at 566.5 MS/s = 0.85 GB/s for 52 minutes** 2.72 GHz external clock, decimation ratio 2 = 680 MS/s **10-bit mode at 680 MS/s = 0.85 GB/s for 52 minutes** 1.8 GHz external clock, decimation ratio 8 = 112.5 MS/s **8-bit mode at 112.5 MS/s = 0.113 GB/s for 393 minutes**
4 Channels	2.266 GHz external clock, decimation ratio 2 = 566.5 MS/s **12-bit mode at 566.5 MS/s = 0.85 GB/s for 39 minutes** 2.72 GHz external clock, decimation ratio 2 = 680 MS/s **10-bit mode at 680 MS/s = 0.85 GB/s for 39 minutes** 1.8 GHz external clock, decimation ratio 8 = 112.5 MS/s **8-bit mode at 112.5 MS/s = 0.113 GB/s for 294 minutes**

-CB2 Streaming	Data Throughput Per Channel / Maximum Recording Duration
3 Channels	2.266 GHz external clock, decimation ratio 4 = 283.25 MS/s = 226.6 MHz IBW **12-bit I/Q mode with 226.6 MHz IBW = 0.85 GB/s for 52 minutes** 1.8 GHz external clock, decimation ratio 128 = 7.03125 MS/s = 5.625 MHz IBW **12-bit I/Q mode with 5.625 MHz IBW = 0.021 GB/s for 2116 minutes**
4 Channels	2.266 GHz external clock, decimation ratio 4 = 283.25 MS/s = 226.6 MHz IBW **12-bit I/Q mode with 226.6 MHz IBW = 0.85 GB/s for 39 minutes** 1.8 GHz external clock, decimation ratio 128 = 7.03125 MS/s = 5.625 MHz IBW **12-bit I/Q mode with 5.625 MHz IBW = 0.021 GB/s for 1587 minutes**

Five / Six Channels with 16 TB of Storage

Suggested Chassis Configuration	Description
	• M9010A chassis with M9037A in system slot 1 • M9203A in slots 4/5, 6/7 and 8/9 • Multi-Module Master: M9203A in slots 6/7 • 8 TB PXIe storage cards in slots 3 and 10 • 2-Ch from 4/5 and 1-Ch from 6/7 streamed to slot 3 • 2-Ch from 8/9 and 1-Ch from 6/7 streamed to slot 10
	• M9019A chassis with M9037A in system slot 1 • M9203A in slots 6/7, 8/9, and 10/11 • Multi-Module Master: M9203A in slots 8/9 • 8 TB PXIe storage cards in slots 5 and 12 • 2-Ch from 6/7 and 1-Ch from 8/9 streamed to slot 5 • 2-Ch from 10/11 and 1-Ch from 8/9 streamed to slot 12

-CB0 Streaming	Data Throughput Per Channel / Maximum Recording Duration
5 Channels	2.266 GHz external clock, decimation ratio 2 = 566.5 MS/s **12-bit mode at 566.5 MS/s = 0.85 GB/s for 52 minutes**
	2.72 GHz external clock, decimation ratio 2 = 680 MS/s **10-bit mode at 680 MS/s = 0.85 GB/s for 52 minutes**
	1.8 GHz external clock, decimation ratio 8 = 112.5 MS/s **8-bit mode at 112.5 MS/s = 0.113 GB/s for 393 minutes**
6 Channels	2.266 GHz external clock, decimation ratio 2 = 566.5 MS/s **12-bit mode at 566.5 MS/s = 0.85 GB/s for 52 minutes**
	2.72 GHz external clock, decimation ratio 2 = 680 MS/s **10-bit mode at 680 MS/s = 0.85 GB/s for 52 minutes**
	1.8 GHz external clock, decimation ratio 8 = 112.5 MS/s **8-bit mode at 112.5 MS/s = 0.113 GB/s for 393 minutes**

-CB2 Streaming	Data Throughput Per Channel / Maximum Recording Duration
5 Channels	2.266 GHz external clock, decimation ratio 4 = 283.25 MS/s = 226.6 MHz IBW **12-bit I/Q mode with 226.6 MHz IBW = 0.85 GB/s for 52 minutes**
	1.8 GHz external clock, decimation ratio 128 = 7.03125 MS/s = 5.625 MHz IBW **12-bit I/Q mode with 5.625 MHz IBW = 0.021 GB/s for 2116 minutes**
6 Channels	2.266 GHz external clock, decimation ratio 4 = 283.25 MS/s = 226.6 MHz IBW **12-bit I/Q mode with 226.6 MHz IBW = 0.85 GB/s for 52 minutes**
	1.8 GHz external clock, decimation ratio 128 = 7.03125 MS/s = 5.625 MHz IBW **12-bit I/Q mode with 5.625 MHz IBW = 0.021 GB/s for 2116 minutes**

Seven / Eight Channels with 16 TB of Storage

Suggested Chassis Configuration	Description
	• M9019A chassis with M9037A in system slot 1 • M9203A in slots 6/7, 8/9, 10/11, and 12/13 • Multi-Module Master: M9203A in slots 8/9 or 10/11 • 8 TB PXIe storage cards in slots 5 and 14 • 2-Ch from 6/7 and 2-Ch from 8/9 streamed to slot 5 • 2-Ch from 10/11 and 2-Ch from 12/13 streamed to slot 14

-CB0 Streaming	Data Throughput Per Channel / Maximum Recording Duration
7 Channels	2.266 GHz external clock, decimation ratio 2 = 566.5 MS/s **12-bit mode at 566.5 MS/s = 0.85 GB/s for 39 minutes** 2.72 GHz external clock, decimation ratio 2 = 680 MS/s **10-bit mode at 680 MS/s = 0.85 GB/s for 39 minutes** 1.8 GHz external clock, decimation ratio 8 = 112.5 MS/s **8-bit mode at 112.5 MS/s = 0.113 GB/s for 294 minutes**
8 Channels	2.266 GHz external clock, decimation ratio 2 = 566.5 MS/s **12-bit mode at 566.5 MS/s = 0.85 GB/s for 39 minutes** 2.72 GHz external clock, decimation ratio 2 = 680 MS/s **10-bit mode at 680 MS/s = 0.85 GB/s for 39 minutes** 1.8 GHz external clock, decimation ratio 8 = 112.5 MS/s **8-bit mode at 112.5 MS/s = 0.113 GB/s for 294 minutes**

-CB2 Streaming	Data Throughput Per Channel / Maximum Recording Duration
7 Channel	2.266 GHz external clock, decimation ratio 4 = 283.25 MS/s = 226.6 MHz IBW **12-bit I/Q mode with 226.6 MHz IBW = 0.85 GB/s for 39 minutes** 1.8 GHz external clock, decimation ratio 128 = 7.03125 MS/s = 5.625 MHz IBW **12-bit I/Q mode with 5.625 MHz IBW = 0.021 GB/s for 1587 minutes**
8 Channels	2.266 GHz external clock, decimation ratio 4 = 283.25 MS/s = 226.6 MHz IBW **12-bit I/Q mode with 226.6 MHz IBW = 0.85 GB/s for 39 minutes** 1.8 GHz external clock, decimation ratio 128 = 7.03125 MS/s = 5.625 MHz IBW **12-bit I/Q mode with 5.625 MHz IBW = 0.021 GB/s for 1587 minutes**

Summary

M9203A can be used to build portable streaming / recording solutions for real sample data or I/Q data, that are scalable from 1 to 8 channels, and can provide up to 16 TB of integrated PXIe storage in a single chassis. Performance is highly configurable via the setup parameters, making it ideal for a wide range of streaming / recording applications.

Keysight can configure and deliver a fully integrated solution specific to your requirements. Contact your local sales representative to engage with an application expert on your specific need.

Appendix A – Suggested Recording Configurations

The information provided in this appendix is based on the chassis configurations shown in the "Suggested Streaming / Recording Solutions" section.

For M9203A-CB0, these tables provide:

- All setup combinations that can be achieved using the internal clock, taking into consideration:
    - o Default 16-bit mode
    - o Data optimization via 12-bit, 10-bit and 8-bit modes
    - o Decimation ratios 2, 4, 8
- External clock settings that maximize data throughput
- External clock settings that provide maximum recording duration

Each setup provides information on sample rate, data throughput, and recording duration.

For M9203A-CB2, these tables provide:

- All setup combinations that can be achieved using the internal clock, taking into consideration:
    - o Default 16-bit mode for decimation ratio 4
    - o Default 32-bit mode for decimation ratios greater than 4
    - o Data optimization via 12-bit modes
    - o Decimation ratios 4, 8, 16, 32, 64 and 128
- External clock settings that maximize data throughput
- External clock settings that provide maximum recording duration

Each setup provides information on intermediate bandwidth, data throughput, and recording duration.

Note that the tables exclude any setup that would exceed the M9203A maximum data throughput limit of 1.7 GB/s.

For example:

- M9203A-CB0: Streaming 2 channels at 800 MS/s in 16-bit mode would require 3.2 GB/s
- M9203A-CB2: Streaming 2 channels with 320 MHz IBW in 16-bit mode would require 3.2 GB/s

Also note that an external clock can be used to obtain sample rate and IBW configurations that would not be achievable via the internal clock.

- The external clock range is 1.8 GHz to 3.2 GHz
- This provides a sample rate range of 900 MHz to 1.6 GHz (i.e. external clock setting divided by 2)
    - o This sample rate can be reduced further via the -CB0 and -CB2 decimation ratios
- For -CB2, the IBW is calculated as the sample rate multiplied by 0.8
    - o For example, 40 MS/s provides an IBW of 32 MHz

M9203A-CB0: Suggested Recording Configurations

Number of Channels	Data Packing (Bits)	Clock Source	Clock Frequency (GHz)	Decimation Ratio	Sample Rate (GS/s)	Channel Data Rate (GB/s)	Module Data Rate (GB/s)	Recording Duration (Mins)
1	16	Internal	-	2	0.8	1.6	1.6	83
		Internal	-	4	0.4	0.8	0.8	166
		Internal	-	8	0.2	0.4	0.4	333
		External	1.8	8	0.1125	0.225	0.225	592
	12	External	2.266	1	1.133	1.7	1.7	78
		Internal	-	2	0.8	1.2	1.2	111
		Internal	-	4	0.4	0.6	0.6	222
		Internal	-	8	0.2	0.3	0.3	444
		External	1.8	8	0.1125	0.169	0.169	788
	10	External	2.72	1	1.36	1.7	1.7	78
		Internal	-	2	0.8	1	1	133
		Internal	-	4	0.4	0.5	0.5	266
		Internal	-	8	0.2	0.25	0.25	533
		External	1.8	8	0.1125	0.141	0.141	945
	8	Internal	-	1	1.6	1.6	1.6	83
		Internal	-	2	0.8	0.8	0.8	166
		Internal	-	4	0.4	0.4	0.4	333
		Internal	-	8	0.2	0.2	0.2	666
		External	1.8	8	0.1125	0.113	0.113	1179
2	16	Internal	-	4	0.4	0.8	1.6	83
		Internal	-	8	0.2	0.4	0.8	166
		External	1.8	8	0.1125	0.225	0.45	296
	12	External	2.266	2	0.5665	0.85	1.7	78
		Internal	-	4	0.4	0.6	1.2	111
		Internal	-	8	0.2	0.3	0.6	222
		External	1.8	8	0.1125	0.169	0.338	394
	10	External	2.72	2	0.68	0.85	1.7	78
		Internal	-	4	0.4	0.5	1	133
		Internal	-	8	0.2	0.25	0.5	266
		External	1.8	8	0.1125	0.141	0.282	472
	8	Internal	-	2	0.8	0.8	1.6	83
		Internal	-	4	0.4	0.4	0.8	166
		Internal	-	8	0.2	0.2	0.4	333
		External	1.8	8	0.1125	0.113	0.226	589

M9203A-CB0: Suggested Recording Configurations (Continued)

Number of Channels	Data Packing (Bits)	Clock Source	Clock Frequency (GHz)	Decimation Ratio	Sample Rate (GS/s)	Channel Data Rate (GB/s)	Module Data Rate (GB/s)	Recording Duration (Mins)
3	16	Internal	-	4	0.4	0.8	1.6	55
		Internal	-	8	0.2	0.4	0.8	111
		External	1.8	8	0.1125	0.225	0.45	197
	12	External	2.266	2	0.5665	0.85	1.7	52
		Internal	-	4	0.4	0.6	1.2	74
		Internal	-	8	0.2	0.3	0.6	148
		External	1.8	8	0.1125	0.169	0.338	262
	10	External	2.72	2	0.68	0.85	1.7	52
		Internal	-	4	0.4	0.5	1	88
		Internal	-	8	0.2	0.25	0.5	177
		External	1.8	8	0.1125	0.141	0.282	315
	8	Internal	-	2	0.8	0.8	1.6	55
		Internal	-	4	0.4	0.4	0.8	111
		Internal	-	8	0.2	0.2	0.4	222
		External	1.8	8	0.1125	0.113	0.226	393
4	16	Internal	-	4	0.4	0.8	1.6	41
		Internal	-	8	0.2	0.4	0.8	83
		External	1.8	8	0.1125	0.225	0.45	148
	12	External	2.266	2	0.5665	0.85	1.7	39
		Internal	-	4	0.4	0.6	1.2	55
		Internal	-	8	0.2	0.3	0.6	111
		External	1.8	8	0.1125	0.169	0.338	197
	10	External	2.72	2	0.68	0.85	1.7	39
		Internal	-	4	0.4	0.5	1	66
		Internal	-	8	0.2	0.25	0.5	133
		External	1.8	8	0.1125	0.141	0.282	236
	8	Internal	-	2	0.8	0.8	1.6	41
		Internal	-	4	0.4	0.4	0.8	83
		Internal	-	8	0.2	0.2	0.4	166
		External	1.8	8	0.1125	0.113	0.226	294

M9203A-CB0: Suggested Recording Configurations (Continued)

Number of Channels	Data Packing (Bits)	Clock Source	Clock Frequency (GHz)	Decimation Ratio	Sample Rate (GS/s)	Channel Data Rate (GB/s)	Module Data Rate (GB/s)	Recording Duration (Mins)
5	16	Internal	-	4	0.4	0.8	1.6	55
		Internal	-	8	0.2	0.4	0.8	111
		External	1.8	8	0.1125	0.225	0.45	197
	12	External	2.266	2	0.5665	0.85	1.7	52
		Internal	-	4	0.4	0.6	1.2	74
		Internal	-	8	0.2	0.3	0.6	148
		External	1.8	8	0.1125	0.169	0.338	262
	10	External	2.72	2	0.68	0.85	1.7	52
		Internal	-	4	0.4	0.5	1	88
		Internal	-	8	0.2	0.25	0.5	177
		External	1.8	8	0.1125	0.141	0.282	315
	8	Internal	-	2	0.8	0.8	1.6	55
		Internal	-	4	0.4	0.4	0.8	111
		Internal	-	8	0.2	0.2	0.4	222
		External	1.8	8	0.1125	0.113	0.226	393
6	16	Internal	-	4	0.4	0.8	1.6	55
		Internal	-	8	0.2	0.4	0.8	111
		External	1.8	8	0.1125	0.225	0.45	197
	12	External	2.266	2	0.5665	0.85	1.7	52
		Internal	-	4	0.4	0.6	1.2	74
		Internal	-	8	0.2	0.3	0.6	148
		External	1.8	8	0.1125	0.169	0.338	262
	10	External	2.72	2	0.68	0.85	1.7	52
		Internal	-	4	0.4	0.5	1	88
		Internal	-	8	0.2	0.25	0.5	177
		External	1.8	8	0.1125	0.141	0.282	315
	8	Internal	-	2	0.8	0.8	1.6	55
		Internal	-	4	0.4	0.4	0.8	111
		Internal	-	8	0.2	0.2	0.4	222
		External	1.8	8	0.1125	0.113	0.226	393

M9203A-CB0: Suggested Recording Configurations (Continued)

Number of Channels	Data Packing (Bits)	Clock Source	Clock Frequency (GHz)	Decimation Ratio	Sample Rate (GS/s)	Channel Data Rate (GB/s)	Module Data Rate (GB/s)	Recording Duration (Mins)
7	16	Internal	-	4	0.4	0.8	1.6	41
		Internal	-	8	0.2	0.4	0.8	83
		External	1.8	8	0.1125	0.225	0.45	148
	12	External	2.266	2	0.5665	0.85	1.7	39
		Internal	-	4	0.4	0.6	1.2	55
		Internal	-	8	0.2	0.3	0.6	111
		External	1.8	8	0.1125	0.169	0.338	197
	10	External	2.72	2	0.68	0.85	1.7	39
		Internal	-	4	0.4	0.5	1	66
		Internal	-	8	0.2	0.25	0.5	133
		External	1.8	8	0.1125	0.141	0.282	236
	8	Internal	-	2	0.8	0.8	1.6	41
		Internal	-	4	0.4	0.4	0.8	83
		Internal	-	8	0.2	0.2	0.4	166
		External	1.8	8	0.1125	0.113	0.226	294
8	16	Internal	-	4	0.4	0.8	1.6	41
		Internal	-	8	0.2	0.4	0.8	83
		External	1.8	8	0.1125	0.225	0.45	148
	12	External	2.266	2	0.5665	0.85	1.7	39
		Internal	-	4	0.4	0.6	1.2	55
		Internal	-	8	0.2	0.3	0.6	111
		External	1.8	8	0.1125	0.169	0.338	197
	10	External	2.72	2	0.68	0.85	1.7	39
		Internal	-	4	0.4	0.5	1	66
		Internal	-	8	0.2	0.25	0.5	133
		External	1.8	8	0.1125	0.141	0.282	236
	8	Internal	-	2	0.8	0.8	1.6	41
		Internal	-	4	0.4	0.4	0.8	83
		Internal	-	8	0.2	0.2	0.4	166
		External	1.8	8	0.1125	0.113	0.226	294

M9203A-CB2: Suggested Recording Configurations

Number of Channels	I/Q Data Packing (Bits)	Clock Source	Clock Frequency (GHz)	Decimation Ratio	Intermediate Bandwidth (MHz)	Channel Data Rate (GB/s)	Module Data Rate (GB/s)	Recording Duration (Mins)
1	16	Internal	-	4	320	1.6	1.6	83
	32	Internal	-	8	160	1.6	1.6	83
		Internal	-	16	80	0.8	0.8	166
		Internal	-	32	40	0.4	0.4	333
		Internal	-	64	20	0.2	0.2	666
		Internal	-	128	10	0.1	0.1	1333
		External	1.8	128	5.625	0.056	0.056	2380
	12	Internal	-	4	320	1.2	1.2	111
		Internal	-	8	160	0.6	0.6	222
		Internal	-	16	80	0.3	0.3	444
		Internal	-	32	40	0.15	0.15	888
		Internal	-	64	20	0.075	0.075	1777
		Internal	-	128	10	0.038	0.038	3508
		External	1.8	128	5.625	0.021	0.021	6349
2	32	Internal	-	16	80	0.8	1.6	83
		Internal	-	32	40	0.4	0.8	166
		Internal	-	64	20	0.2	0.4	333
		Internal	-	128	10	0.1	0.2	666
		External	1.8	128	5.625	0.056	0.112	1190
	12	External	2.266	4	226.6	0.85	1.7	78
		Internal	-	8	160	0.6	1.2	111
		Internal	-	16	80	0.3	0.6	222
		Internal	-	32	40	0.15	0.3	444
		Internal	-	64	20	0.075	0.15	888
		Internal	-	128	10	0.038	0.076	1754
		External	1.8	128	5.625	0.021	0.042	3174

M9203A-CB2: Suggested Recording Configurations (Continued)

Number of Channels	I/Q Data Packing (Bits)	Clock Source	Clock Frequency (GHz)	Decimation Ratio	Intermediate Bandwidth (MHz)	Channel Data Rate (GB/s)	Module Data Rate (GB/s)	Recording Duration (Mins)
3	32	Internal	-	16	80	0.8	1.6	55
		Internal	-	32	40	0.4	0.8	111
		Internal	-	64	20	0.2	0.4	222
		Internal	-	128	10	0.1	0.2	444
		External	1.8	128	5.625	0.056	0.112	793
	12	External	2.266	4	226.6	0.85	1.7	52
		Internal	-	8	160	0.6	1.2	74
		Internal	-	16	80	0.3	0.6	148
		Internal	-	32	40	0.15	0.3	296
		Internal	-	64	20	0.075	0.15	592
		Internal	-	128	10	0.038	0.076	1169
		External	1.8	128	5.625	0.021	0.042	2116
4	32	Internal	-	16	80	0.8	1.6	41
		Internal	-	32	40	0.4	0.8	83
		Internal	-	64	20	0.2	0.4	166
		Internal	-	128	10	0.1	0.2	333
		External	1.8	128	5.625	0.056	0.112	595
	12	External	2.266	4	226.6	0.85	1.7	39
		Internal	-	8	160	0.6	1.2	55
		Internal	-	16	80	0.3	0.6	111
		Internal	-	32	40	0.15	0.3	222
		Internal	-	64	20	0.075	0.15	444
		Internal	-	128	10	0.038	0.076	877
		External	1.8	128	5.625	0.021	0.042	1587

M9203A-CB2: Suggested Recording Configurations (Continued)

Number of Channels	I/Q Data Packing (Bits)	Clock Source	Clock Frequency (GHz)	Decimation Ratio	Intermediate Bandwidth (MHz)	Channel Data Rate (GB/s)	Module Data Rate (GB/s)	Recording Duration (Mins)
5	32	Internal	-	16	80	0.8	1.6	55
		Internal	-	32	40	0.4	0.8	111
		Internal	-	64	20	0.2	0.4	222
		Internal	-	128	10	0.1	0.2	444
		External	1.8	128	5.625	0.056	0.112	793
	12	External	2.266	4	226.6	0.85	1.7	52
		Internal	-	8	160	0.6	1.2	74
		Internal	-	16	80	0.3	0.6	148
		Internal	-	32	40	0.15	0.3	296
		Internal	-	64	20	0.075	0.15	592
		Internal	-	128	10	0.038	0.076	1169
		External	1.8	128	5.625	0.021	0.042	2116
6	32	Internal	-	16	80	0.8	1.6	55
		Internal	-	32	40	0.4	0.8	111
		Internal	-	64	20	0.2	0.4	222
		Internal	-	128	10	0.1	0.2	444
		External	1.8	128	5.625	0.056	0.112	793
	12	External	2.266	4	226.6	0.85	1.7	52
		Internal	-	8	160	0.6	1.2	74
		Internal	-	16	80	0.3	0.6	148
		Internal	-	32	40	0.15	0.3	296
		Internal	-	64	20	0.075	0.15	592
		Internal	-	128	10	0.038	0.076	1169
		External	1.8	128	5.625	0.021	0.042	2116

M9203A-CB2: Suggested Recording Configurations (Continued)

Number of Channels	I/Q Data Packing (Bits)	Clock Source	Clock Frequency (GHz)	Decimation Ratio	Intermediate Bandwidth (MHz)	Channel Data Rate (GB/s)	Module Data Rate (GB/s)	Recording Duration (Mins)
7	32	Internal	-	16	80	0.8	1.6	41
		Internal	-	32	40	0.4	0.8	83
		Internal	-	64	20	0.2	0.4	166
		Internal	-	128	10	0.1	0.2	333
		External	1.8	128	5.625	0.056	0.112	595
	12	External	2.267	4	226.7	0.85	1.7	39
		Internal	-	8	160	0.6	1.2	55
		Internal	-	16	80	0.3	0.6	111
		Internal	-	32	40	0.15	0.3	222
		Internal	-	64	20	0.075	0.15	444
		Internal	-	128	10	0.038	0.076	877
		External	1.8	128	5.625	0.021	0.042	1587
8	32	Internal	-	16	80	0.8	1.6	41
		Internal	-	32	40	0.4	0.8	83
		Internal	-	64	20	0.2	0.4	166
		Internal	-	128	10	0.1	0.2	333
		External	1.8	128	5.625	0.056	0.112	595
	12	External	2.266	4	226.6	0.85	1.7	39
		Internal	-	8	160	0.6	1.2	55
		Internal	-	16	80	0.3	0.6	111
		Internal	-	32	40	0.15	0.3	222
		Internal	-	64	20	0.075	0.15	444
		Internal	-	128	10	0.038	0.076	877
		External	1.8	128	5.625	0.021	0.042	1587

Appendix B – Alternative Recording Configurations; Single Channel Per Module

This appendix considers an alternative method that only uses 1 channel of each M9203A, thereby limiting the streaming / recording solution to a maximum of 4 channels.

This method maximizes data throughput for every channel, enabling a multi-channel solution to perform at the level associated with a single channel solution.

As before, if more than two M9203A modules are present then an additional storage card is required for use by the third and fourth modules.

M9203A-CB0: Alternative Recording Configurations; Single Channel Per Module

Number of Channels	Data Packing (Bits)	Clock Source	Clock Frequency (GHz)	Decimation Ratio	Sample Rate (GS/s)	Channel Data Rate (GB/s)	Module Data Rate (GB/s)	Recording Duration (Mins)
2, 3, or 4	16	Internal	-	2	0.8	1.6	1.6	41
		Internal	-	4	0.4	0.8	0.8	83
		Internal	-	8	0.2	0.4	0.4	166
		External	1.8	8	0.1125	0.225	0.225	296
	12	External	2.266	1	1.133	1.7	1.7	39
		Internal	-	2	0.8	1.2	1.2	55
		Internal	-	4	0.4	0.6	0.6	111
		Internal	-	8	0.2	0.3	0.3	222
		External	1.8	8	0.1125	0.169	0.169	394
	10	External	2.72	1	1.36	1.7	1.7	39
		Internal	-	2	0.8	1	1	66
		Internal	-	4	0.4	0.5	0.5	133
		Internal	-	8	0.2	0.25	0.25	266
		External	1.8	8	0.1125	0.141	0.141	472
	8	Internal	-	1	1.6	1.6	1.6	41
		Internal	-	2	0.8	0.8	0.8	83
		Internal	-	4	0.4	0.4	0.4	166
		Internal	-	8	0.2	0.2	0.2	333
		External	1.8	8	0.1125	0.113	0.113	589

M9203A-CB2: Alternative Recording Configurations; Single Channel Per Module

Number of Channels	I/Q Data Packing (Bits)	Clock Source	Clock Frequency (GHz)	Decimation Ratio	Intermediate Bandwidth (MHz)	Channel Data Rate (GB/s)	Module Data Rate (GB/s)	Recording Duration (Mins)
2, 3, or 4	16	Internal	-	4	320	1.6	1.6	41
	32	Internal	-	8	160	1.6	1.6	41
		Internal	-	16	80	0.8	0.8	83
		Internal	-	32	40	0.4	0.4	166
		Internal	-	64	20	0.2	0.2	333
		Internal	-	128	10	0.1	0.1	666
		External	1.8	128	5.625	0.056	0.056	1190
	12	Internal	-	4	320	1.2	1.2	55
		Internal	-	8	160	0.6	0.6	111
		Internal	-	16	80	0.3	0.3	222
		Internal	-	32	40	0.15	0.15	444
		Internal	-	64	20	0.075	0.075	888
		Internal	-	128	10	0.038	0.038	1754
		External	1.8	128	5.625	0.021	0.021	3174

Appendix C – Setting Up PXIe Data Storage

Windows 10 provides two methods for creating a RAID0 volume (also known as a striped volume).

- **Storage Spaces**: This method must <u>not</u> be used, as the resulting volume is unsuitable for streaming / recording applications.

- **Disk Management**: This is a component of Windows Control Panel that can be found/run by typing "disk management" into the Windows search toolbar. This method <u>must</u> be used.

Using Disk Management:

1. Ensure all disks (modules) to be combined are "unallocated". Any disk not listed as "unallocated" must be fixed before proceeding – right-click on the disk and select "delete volume".
   Note: This will irretrievably erase any data stored on the disk

2. Right-click on the gray area to the left of any of the four disks and select "New Striped Volume" to launch the setup wizard.

3. **Select Disks**: Move all four disks from the "Available" panel to the "Selected" panel before advancing to the next step.

4. **Assign Drive Letter**: Select the preferred drive letter from the drop-down list before advancing to the next step.

5. **Format Volume**: Change "Allocation unit size" from "Default" to "64K", enter the preferred volume label, and check the box to "Perform a quick format" before proceeding to the "Completing the Wizard" step.

6. After approximately 20 seconds, the Disk Management screen will refresh to indicate the disks have been setup as dynamic volumes with the same label, and the summary panel at the top will indicate they are in a striped configuration.

7. **Optional**: Use disk benchmarking software, such as the free CrystalDiskMark utility, to verify RAID0 performance. The critical requirement is that sequential read/write operations must both be greater than 3,500 MB/s – the maximum data throughput from two M9203A modules is 3.4 GB/s.
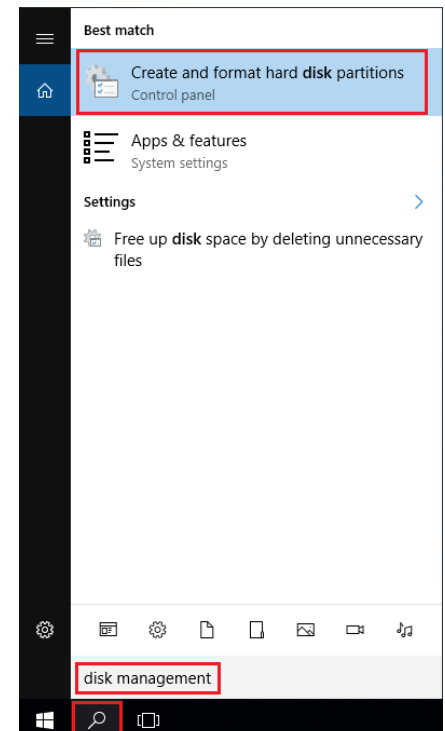   - CrystalDiskMark:
     https://crystalmark.info/en/software/crystaldiskmark/
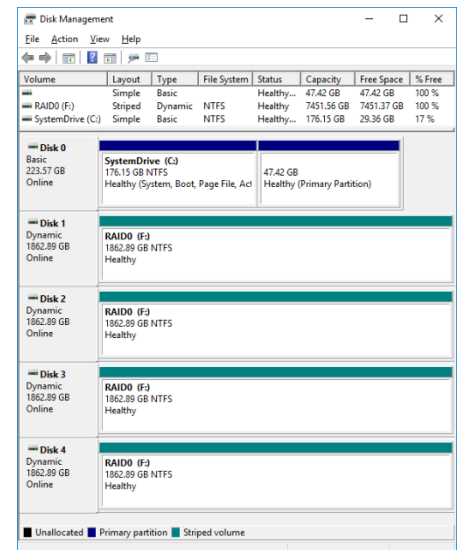

Figure B1: Run Disk Management

Figure B2: RAID0 Volume

Appendix D - Troubleshooting Operational and Performance Issues

Operational Issues

If the streaming / recording application does not operate as expected, then there are several factors to consider.

Instrument Software

- Verify the latest version of Keysight IO Libraries Suite is being used.
    - Keysight IO Libraries Suite: http://keysight.com/find/iolibs
- Verify the latest version of the MD2 High-Speed Digitizer Instrument Driver is being used.
    - MD2 Instrument Driver: http://keysight.com/find/md2

Command Line Application

- Verify the command line application is being executed from the correct folder.
    - -CB0:   C:\Program Files\Keysight\StreamerRecorderDGT\bin
    - -CB2:   C:\Program Files\Keysight\StreamerRecorderDDC\bin
- Use the "help" switch to verify the command syntax is correct.
    - -CB0:   streamRecorder_64.exe –help
    - -CB2:   streamRecorderDDC_64.exe –help
- Verify the M9203A VISA address(es).
    - This can be checked via Connection Expert (a component of IO Libraries Suite).
- Verify chosen file names are correct.
    - Ensure drives and path names exist.
    - Ensure filenames are not using any illegal characters (e.g. ^ % & * / { } :).
    - A filename can include a space if the drive/path/name is enclosed in double-quotes.

Hardware

- Refer to the M9203A user manual for information on hardware troubleshooting
    - User Manual Library:
      https://www.keysight.com/main/techSupport.jspx?pid=2670205&nid=-35502.1171760&pageMode=PL&t=79915.g.3&co=205920.i.4&cc=GB&lc=eng&sm=g
- M9203A operation can also be verified using the Soft Front Panel (SFP) graphical interface that is provided with the MD2 software.
    - This allows the user to explore the capabilities and features of the digitizers. The SFP user manual is available via the above link.

Performance Issues

Streaming / recording requires continuous capture and storage of data, with throughput limits of:

- M9203A: 1.7 GB/s per module
- PXIe Storage: 3.4 GB/s per card

If the solution meets these design limits, but a memory overflow error still occurs, then this must be caused by other services and/or applications running on the embedded controller.

Troubleshooting tips to improve performance:

- Avoid using additional applications while streaming / recording is in progress.
    o Unnecessary applications/processes will consume resources that might be required by the command line application.
    o Check the Windows system tray to ensure applications have actually been closed and are not running in the background.

- Avoid Windows Updates:
    o A simple method to avoid this is to disconnect the embedded controller from the network. This prevents the automatic checking, downloading, and installation of any pending updates.
    o If the embedded controller must be connected to the network, then consider disabling the Windows Update service. Before disabling it, ensure this does not breach your company security policy.

- Avoid interrupts that could be caused by virus/malware scans:
    o The method for doing this varies, as it depends on the virus/malware software being used.
    o For Windows Defender, this can be achieved via the "exclusions" feature:
        ▪ Exclude a folder – specify the drive letter of the RAID0 volume
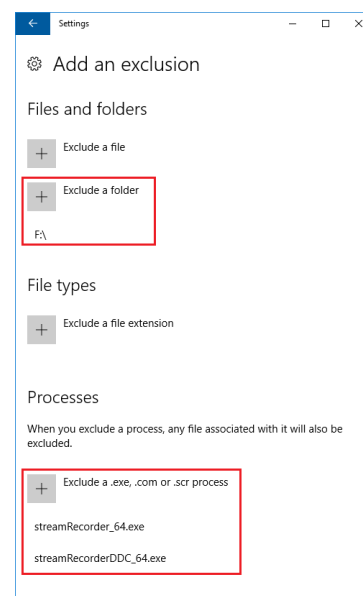   ▪ Exclude a process – specify the EXE file names for the CB0 and CB2 command line applications

Figure C1: Windows Defender

Acronym Glossary

ADC	Analog-to-Digital Converter
AXIe	AdvancedTCA Extensions for Instrumentation and Test
DDC	Digital Down-Converter
FSR	Full Scale Range
HDF	Hierarchical Data Format – an open source file format for storing numerical data
HDF5	The latest version of HDF
I/Q	In-phase data / Quadrature data
IBW	Intermediate Bandwidth
M.2	A specification for internally mounted computer expansion cards
MD2	The Keysight IVI driver that provides access to digitizer functions
NVMe™	Non-Volatile Memory Express
PCI	Peripheral Component Interconnect
PCIe®	PCI Express
PXI	PCI eXtensions for Instrumentation
PXIe	PXI Express
RAID	Redundant Array of Independent Disks
RAID0	RAID configuration that splits data evenly across multiple disks with no redundancy
SFP	Soft Front Panel
SSD	Solid State Hard Drive
VISA	Virtual Instrument Software Architecture
VSA	Vector Signal Analyzer

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