Product Note

Designing PCIe Digitizers for very high precision measurements

Comparison of mid range 10 to 100 MS/s 16 bit digitizer M2p.59xx with predecessor M2i.49xx

Introduction

For nearly 30 years Spectrum Instrumentation has been designing and manufacturing PC based instruments, typically digitizer and generator products, for the electronics Test and Measurement market. The company recently decided that it was time to replace its popular M2i.49xx series of digitizer cards, that were first designed over ten years ago. As the M2i.49xx series products have aged parts sourcing now becomes more difficult.

The challenge for the Spectrum engineers was not just to match the specifications of the older products but to deliver something that set new industry standards for performance; specifically measurement speed, accuracy and precision. Furthermore, the goal was to pack all the new technology into one ½ size PCIe card so that it could be used in more PC systems. That meant a reduction in the products overall size by a factor of two.

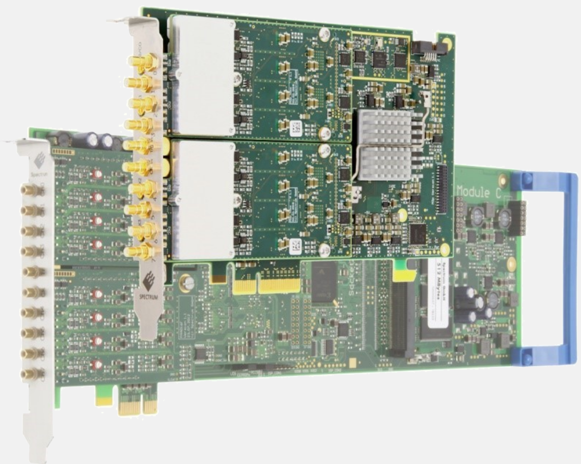

Figure 1. The M2p.59xx series (top) is a half size PCIe card measuring just 168 mm in comparison to the older M2i.49xx products (bottom) which measure 312 mm and occupy a full length PCIe slot.

Figure 1 shows the M2p.59xx series is half the size of the older M2i.49xx digitizers. However, the new products deliver more accuracy, sampling rate, bandwidth, memory and data transfer speed.

Modular Modules

All Spectrum digitizers are modular in design, with products consisting of a base board (that typically incorporates the digitizers clocking system, power supply, memory, memory management system and the PCIe interface controller) and daughter boards for the acquisition (ADC and amplifiers) as well as other peripherals. This modular approach allows one base board to support a number of different acquisition boards with differing performance levels; creating a range of products that all share

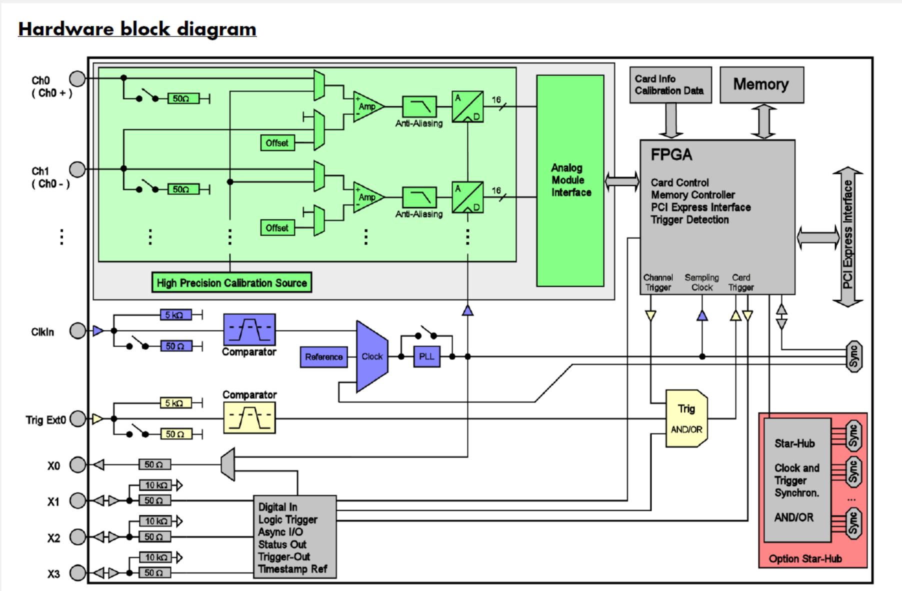

Figure 2 shows the block diagram of the M2p.59xx series products where the base card can accommodate a variety of different acquisition daughter boards and peripherals (such as Star-Hub).

common technology.

To reduce the products size an entirely new base card was designed. Special attention was paid to the clock design, where a pure low-jitter differential clock was employed rather than a conventional single-ended one. The differential clock helps to reduce jitter by ensuring that the ADC doesn't collect clock noise from the surrounding environment. The clocking scheme also utilizes a Phase-Locked-Loop architecture (PLL) with better than ± 1 ppm accuracy and high stability. The design incorporates flexibility, with internal or external clocking modes, and it also ensures good synchronization between channels. Another feature is that the clock can be easily shared, via Spectrum's Star-Hub clock and trigger distribution system, between other digitizers. In fact Star-Hub can synchronize the clock and trigger of up to 16 cards, allowing the creation of digitizer systems with up to 128 fully synchronized channels.

Figure 2 shows the simple block diagram for the M2p.59xx series products. The parts shaded green and red are daughter boards. Green shows the acquisition boards and red is the Star-Hub option. All of the other components reside on the main base board.

Selecting the ADC

The heart of any digitizer is the ADC. For the M2p.59xx series Spectrum identified next generation ADC technology that provides cost effective multi-channel performance, while at the same time can handle a wide range of input signal frequencies. The company chose a 16-bit ADC family from Linear Technology that has variants with sampling rates from 20 MS/s up to 125 MS/s, pin compatibility and an LVDS interface. The ADCs also offered fairly low power consumption, making them perfect for multi-channel card designs.

As can be seen from the block diagram, the Spectrum design always features an ADC and independent signal conditioning circuitry on each acquisition channel. This combination allows the accurate capture of signals with different amplitudes. For the M2p.59xx series products, the channels have six different signal input ranges (from ±200 mV up to ±10 V full scale), signal offset, selectable impedance (50 Ω and 1 MΩ), over voltage protection, and calibration. The channels also have the additional capability of being able to be configured in either single-ended or true differential modes.

Reducing sources of noise

In order to reduce the effects of unwanted noise and crosstalk, and to maximize measurement quality, special attention was given to the shielding on the acquisition daughter boards. Figure 3 shows the custom designed shields that help to prevent noise being collected from other PC components, or potential on-board sources (such as the fast asynchronous clocks used by the cards FPGA). Similarly, possible EMC issues are reduced by taking special care of inter-module connections and using differential clock signals for synchronization.

To help ensure good performance the Spectrum engineers also decided to remove other potential problems that can be caused by low quality PC power supplies. The base card includes a better power design,

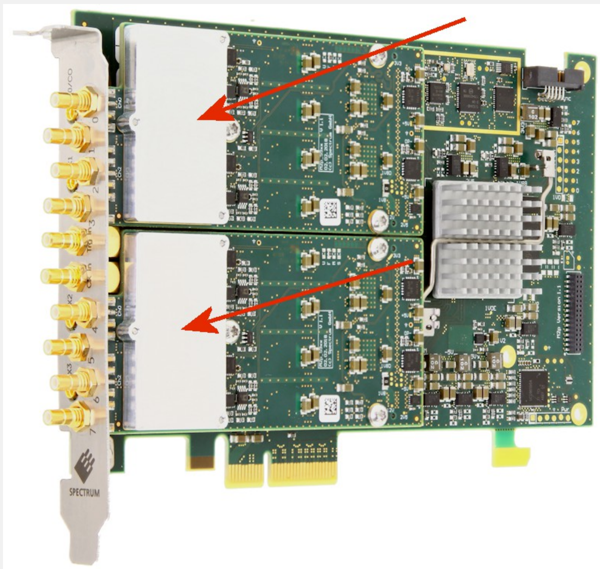

Figure 3 shows an eight channel M2p.59xx series digitizer. The arrows point to the shielding that protects the high-resolution ADCs and wideband amplifiers from unwanted sources of noise.

with all power lines being filtered and DC converted. This prevents the on-board analog components of the cards from collecting any noise that may exist on the power lines of the ATX motherboard.

Delivering Performance and Choice

With twenty new models, compared to the older M2i.49xx series' eight models, the M2p.59xx digitizer family gives customers more choice and performance. Models are available with one, two, four and eight channels and sampling rates of 20, 40, 80 and 125 MS/s. Most importantly, the new products deliver excellent dynamic measurement performance for parameters such as signal-to-noise ratio (SNR), spurious free dynamic range (SFDR), total harmonic distortion (THD) and effective number of bits (ENOB).

Table 1 shows a comparison of the base and top level products from both the old M2i.49xx series and the new M2p.59xx family. Despite the new products having significantly higher sampling rates and bandwidths their dynamic performance can be seen to match or exceed the older products overall capabilities.

Specification	M2p.592x-x4	M2i.491x-exp	M2p.596x-x4	M2i.496x-exp
Channels	2-8 Single Ended 2-4 Differential	4-8 Single Ended 2-4 Differential	1-8 Single Ended 1-4 Differential	2-8 Single Ended 2-4 Differential
Maximum Sampling Rate	20 MS/s	10 MS/s	4 x 125 MS/s 8 x80 MS/s	4 x 60 MS/s 8 x 30 MS/s
Resolution	16 bits	16 bits	16 bits	16 bits
Memory	1 GB	512 MB	1 GB	512 MB
Bandwidth	10 MHz	5 MHz	60 MHz	30 MHz
Bus Type and Speed	PCIe 4 lane	PCIe 1 lane	PCIe 4 lane	PCIe 1 lane
Bus Transfer Speed	700 MB/s	160 MB/s	700 MB/s	160 MB/s
GPU Support	SCAPP direct DMA transfer	No	SCAPP direct DMA transfer	No
Card Size	168 x 107 mm (Half size PCIe board)	312 mm x 107 mm (Full size PCIe board)	168 x 107 mm (Half size PCIe board)	312 mm x 107 mm (Full size PCIe board)
Gain Accuracy	≤ 0.1%	≤ 0.1%	≤ 0.1%	≤ 0.1%
Time Base Accuracy	≤ 1.0 ppm	≤ 20 ppm	≤ 1.0 ppm	≤ 20 ppm
SNR	>81 dB	>77.1 dB	>73.3 dB	>74.5 dB
SFDR	≥ 105 dB	>94.3 dB	≥ 98.5 dB	>92.2 dB
THD	≤ -89.5 dB	<-80 dB	≤ -83.3 dB	<-80 dB
ENOB	≥ 13.2 LSB	>12.5 LSB	≥ 11.8 LSB	>12.1 LSB

Table 1 compares the entry and top level M2p.59xx and M2i.49xx digitizers. Despite having higher sampling rate and bandwidth the dynamic performance of the new cards matches or exceeds that of the old.

Faster Automated Testing and Data Streaming

The table also shows the benefit of using a faster PCIe bus; with data transfer speed being increased from 160 MB/s to over 700 MB/s. As such, the newer cards can stream data to PC RAM, or storage devices such as SSD's, more than four times faster than the older units. For applications that require the acquisition of long continuous signals, the faster streaming rate also enables the digitizers to run at higher sampling rates. For example, a two channel digitizer sampling at 125 MS/s can stream data continuously without losing any information. Similarly, a four channel digitizer could run at up to 90 MS/s and eight channel cards at up to 45 MS/s.

Another feature of the Spectrum cards is that they also support data streaming to the latest graphical processing units (GPU's). The cards include Spectrum's Cuda Access for Parallel Processing (SCAPP) capability that allows a CUDA-based GPU to be used directly between any Spectrum digitizer and the PC. The big advantage with SCAPP is that data is passed directly from the digitizer to the GPU where high-speed parallel processing is possible using the GPU board's multiple (up to 5000) processing cores. GPU's are the perfect place to perform data imaging and complex signal analysis (such as FFT's, averaging, filtering and pulse characterization).

Finally, the combination of a faster PCIe bus and SCAPP offers the possibility for users to dramatically reduce automated test and measurement times.

Conclusion

The Spectrum engineers set out to replace the aging M2i.49xx series digitizers with a new line up of high precision products. The resulting M2p.59xx family is smaller, can handle a wider range of input frequencies, and also makes faster measurements with better accuracy and precision. The software API-interface is 100% compatible making a transition from old to new card very easy. Furthermore, the old series will be available to existing OEM customers for several years to come. The modular design of the new digitizers allowed the creation of twenty new models; enabling users to choose the sampling rate, bandwidth and number of channels that best matches their specific application. The results also show that a well-designed PCIe card can match or outperform most conventional bench top products as well as other modular instruments.