Application Note

Easy creation of customized multi-channel test and measurement systems

The trend for multi-channel testing has never been stronger as more electronic devices use array and parallelization methods to increase system speed and performance. Requirements can be found in almost every field, such as testing MIMO (Multiple-Input Multiple-Output) antennas that are used for radio links in communication, or the transmitter and receiver arrays employed in advanced radar, sonar, and ultrasound systems. Even in general electronics the need for multi-channel testing is expanding. Components continue to increase in complexity, coming with higher pin counts, while micro controller and processing systems utilize faster and more complex logic circuitry and bus systems.

Traditionally, most test and measurement products are designed for bench-top or hand-held operation. As a result, when it comes to multi-channel applications their form factor often limits the number of channels they can provide. For example, digital oscilloscopes typically offer two or four channels while signal sources are often limited to just one or two. Creating large multi-channel testing systems from these products then results in having to purchase multiple instruments. It's an approach that usually takes up a lot of space and also presents a challenge when it comes to system integration and software development. The alternative approach has been to use modular instrumentation. By choosing a suitable platform users can simply add modules to configure and create systems that match their specific multi-channel requirements. However, modular systems also have their own drawbacks. They're often expensive and sometimes the performance lags what's possible from the latest test instrumentation technology. Furthermore, modular systems can sometimes restrict the available choice of hardware and software.

Spectrum Instrumentation has taken a different approach to multi-channel test system creation, using modularity but connecting it directly to the latest in PC technology. With more than 30 years of experience in developing PC based instrumentation, the company has a complete line-up of PCIe cards that are specifically designed for multi-channel test and measurement applications. Being PCIe, the cards can be installed in almost any desktop PC, or a PCIe expansion chassis, to access the latest state-of-the-art technology (such as the fastest CPU and GPU processing platforms). In addition, Spectrum Instrumentation provides a number of hardware and software tools to make creating fully customized multi-channel test systems fast and easy.

39 Models to Mix and Match

The companies general purpose product family is known as the M2p series, and it consists of 39 different models. These PCIe cards all share a high level of commonality and interconnectivity, making it possible to easily configure them to create almost any desired multi-channel test system. Three major classes of instrument are available. It includes 24 different Digitizers, for analogue signal acquisition, 14 Arbitrary Waveform Generators (AWGs), for analogue signal generation, and a Digital I/O card that can both acquire or generate high speed digital signals.

Figure 1: The M2p.5968-x4 Digitizer is a half-size PCIe card with 8 channels all suited to acquiring analogue signals with frequency content up to 60 MHz.

To allow users to acquire or generate signals that best match the specific testing requirements the Digitizer and AWG cards are available with a choice of speed grades (sampling or output rates with matching bandwidth) all using high-resolution 16-bit technology. The digitizers offer speed grades with sampling rates up to 5, 20, 40, 80 and 125 MS/s, while the AWG's have maximum output rates up to 40, 80 or 125 MS/s. In addition, different models offer one, two, four or eight fully synchronized channels on a single card.

Figure 1 shows an M2p.5968-x4 Digitizer that provides eight input channels offering sampling rates up to 125 MS/s with 16-bit vertical resolution. All the channels have full front-end circuitry, for scope-like performance, that allows adjustment of parameters such as the input range, offset and impedance. The flexible front-end design makes it possible for the cards to acquire a very wide variety of electronic signals. While the 16-bit resolution means they do so with outstanding accuracy and dynamic range.

Each individual product in the M2p family is a tiny (168 mm x 107 mm x 30 mm) half-size PCIe card, allowing them to be installed in almost any PC. The design is such that the different models all share a common base board. On the base board different daughter boards are installed to produce the various products. By sharing common technology, the three classes of instrument all work well together. They offer similar features and have common programming. Sharing proven technology also lowers each products production costs and improves their overall reliability.

Modular Connectivity with Star-Hub

Another advantage of sharing a common base board is that each product can utilize similar clock and trigger circuitry. To take advantage of this the company has developed a clock and trigger distribution system, called Star-Hub, that allows all the cards connected by it to be synchronized with the same clock and trigger signals. Star-Hub works with any card from the M2p family and allows all three classes (Digitizer, AWG, Digital I/O) of instrument to be synchronized in a single system.

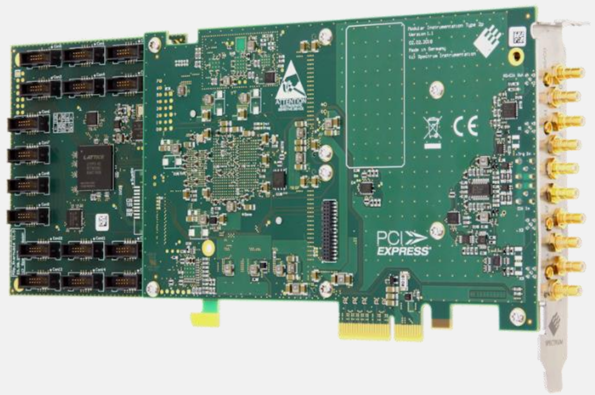

Figure 2: The Star-Hub option allows up to 6 or 16 M2p cards to be fully synchronized and can be mounted on the rear (as shown) or on top of the host card.

The Star-Hub module is available in two different configurations; a small version, that enables the synchronization of up to 6 cards, or a large version for up to 16 cards. The Star-Hub module consists of a board that can be mounted on any M2p product, to make it the system master. The other cards in the system are then connected together with small cables of the same length. Even the master card is connected in this way. It ensures there's a minimum phase delay and skew between all the channels of all the cards in the system. Figure 2 shows the Star-Hub module mounted on an M2p.xxxx card. Once Star-Hub is installed, the connection of the boards is automatically recognized and checked by the software driver whenever the system is started. With all the cards working as a single system, programming, and controlling the cards is greatly simplified.

For maximum trigger flexibility any card, or even several cards, can be used as trigger sources for the complete system. All the possible trigger modes (such as Channel, External, Software, Window, Pulse, Re-Arm, Spike, OR/AND, Delay) remain available when Star-Hub is used. Furthermore, the trigger source of all the cards can be combined with a logical OR operation for situations where multi-input logic triggering is required.

Creating Systems for Analogue Signal Acquisition with up to 128 Channels

For test situations that require multi-channel signal acquisition Star-Hub can be used with up to 16 M2p series Digitizer cards. This allows the creation of systems with almost any number of channels up to a maximum of 128. For example, six M2p.5923-x4 cards can be used to build a system with 48 channels, each offering sampling rates up to 20 MS/s. It's a speed grade that is well suited to several applications such as RADAR, ultrasonic imaging, mechanical measurements, Light Imaging and Ranging (LIDAR), fluid mechanics, seismic studies, and wind tunnel testing. Figure 3 shows such a system installed in a Supermicro PC, that can accommodate up to 6 PCIe cards, to make a compact, yet very powerful, test platform.

Even larger systems can be built using PCs with more slots (slot-CPU based PC systems are available with up to twenty slots) or by using an expansion chassis. Figure 4 shows a chassis from Supermicro that accommodates eight digitizer cards, one AWG card, one graphics card and still has a spare slot. By housing up 16 PCIe Digitizer cards in a single chassis it's possible to create very compact systems. It's a good solution when both system size and channel density are important. Furthermore, by using commercially available PC components, rather than a more proprietary modular instrumentation standard, it reduces system cost.

For applications requiring the capture and analysis of higher frequency signals simply select a digitizer with a faster speed grade. For example, 16 M2p.5943-x4 cards can be used together with Star-Hub to build a system with 128 fully synchronized channels, each sampling at rates up to 80 MS/s, or 16 M2p.5966-x cards can deliver 64 channels with 125 MS/s sampling. Fast systems like these are used in a wide variety of applications, including component testing, imaging systems, communications monitoring, surveillance, Optical Time Domain Reflectometry (OTDR), and large scientific experiments.

Multi-channel Analogue Signal Generation

In most test systems signal sources are required to provide analogue signals that are used as a device stimulus. In many situations the device under test does not generate signals on their own. Take for example an amplifier. Without a signal source to provide an appropriate input signal no significant electrical measurements can be made. It's the combination of measurement instruments and signal sources that make electrical testing possible. Using an AWG and Digitizer together makes it easy to build automated testing platforms for stimulus-response or closed-loop type measurements.

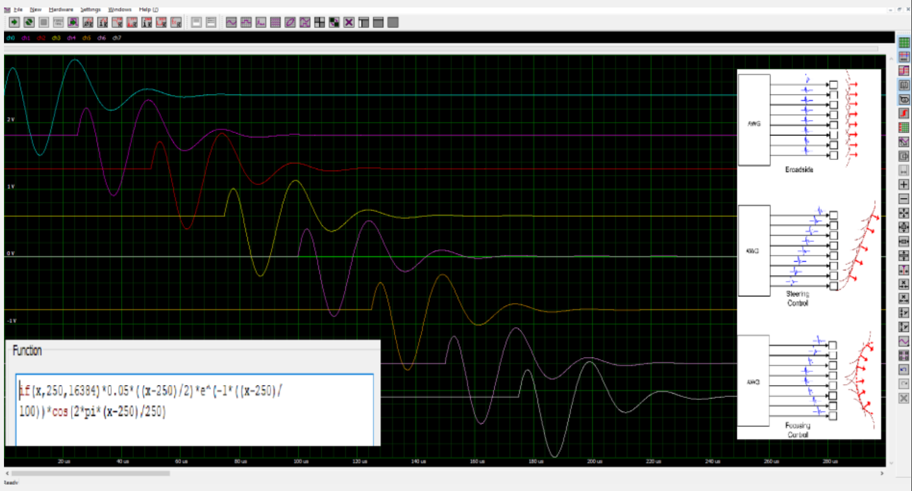

Figure 3: Multi-channel AWGs are perfect tools for driving Phased Array systems as they can produce almost any waveshape and users can easily control each signals amplitude and timing characteristics. Shown are the basic signal components of an eight-element ult

As a signal source the AWG comes as close as possible to being a universal product since it can produce almost any desired signal or waveshape. Waveforms can be created analytically with great precision using equations or captured using digitizers or digital oscilloscopes and then replayed. Additionally, modular AWG's offer compact size and highly integrated compatibility with their host computers, again making them ideal for automated test systems.

The M2p series AWG's can produce almost any waveshape with frequency content up to 60 MHz. A key feature of the products is a precise phase-locked loop circuit that is used to drive each channels output clock. The PLL design delivers high clocking accuracy (⩽ ±1.0 ppm) and stability. It allows the clock rate to be fully programmable, with 1 Hz resolution, and set anywhere from 1 kHz up to the maximum speed of each card. Similarly, amplitude swings can be programmed from ±1 mV up to ±6 V into 50 Ω termination, or ±12 V into high impedance loads.

Like the Digitizers, the AWG's can also be connected with Star-Hub to allow the creation of systems with almost any number of fully synchronized channels, up to a maximum of 80. The need for multichannel signal generation can be found in a variety of applications. For example, multichannel AWGs can provide the signals needed for driving Phased Array systems, be they antennas for RF signals or ultrasonic transducers. A feature of these systems is that they enable steering of the emitted signals. Figure 3 shows the basic signal components of an eight-element ultrasonic phased array transmission system.

By arranging the individual drive signals to be delayed sequentially, the transmitted signal from an ultrasonic acoustic transducer array can be steered in a direction or even focused to a specific point. AWG users have total control over the waveform's amplitude and timing characteristics, offering complete flexibility in controlling the emitted wave front. Figure 5 also shows examples (see the left side schematics) of how to direct the beam in a uniform or broadside wavefront, in a downward direction, or in a focused manner.

Other examples where multi-channel AWG systems can be deployed include in robotics and mechatronics, component testing, optical systems (transceiver testing) and as complete device simulators.

Interconnectivity and Multi-Purpose I/O

Each M2p series Digitizer and AWG card comes with several front panel connectors so that it can be easily integrated together with other test instrumentation devices. As standard, the units have connectors for external trigger and clock inputs, plus four additional connectors (one multi-function output (X0) and three multi-function I/O) that can be individually programmed to perform different functions. This includes clock and trigger I/O as well as card status flags. In addition, the multi-function connectors can be used for synchronous digital I/O (where the digital data is stored inside the analogue data samples), asynchronous I/O lines and for logic trigger inputs.

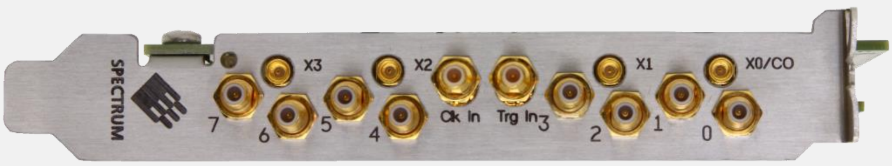

Figure 4: Shows the front panel of an 8-channel card with SMB type connectors for the analogue channels, external clock, and trigger, as well as 4 MMCX connectors for the multipurpose lines.

The multi-purpose connectors allow the Digitizer and AWG cards to be used in a variety of mixed (analogue and digital) signal testing situations. If more digital I/O lines are needed there's also an option available that adds another 16 synchronous digital lines to the analogue data. These additional lines effectively extend the four standard multi-purpose XIO lines to make a total of 20. Fully programmable, the lines can run as synchronous digital inputs for a digitizer, synchronous digital outputs for an AWG, or asynchronous I/O lines, status lines, or even as additional trigger inputs.

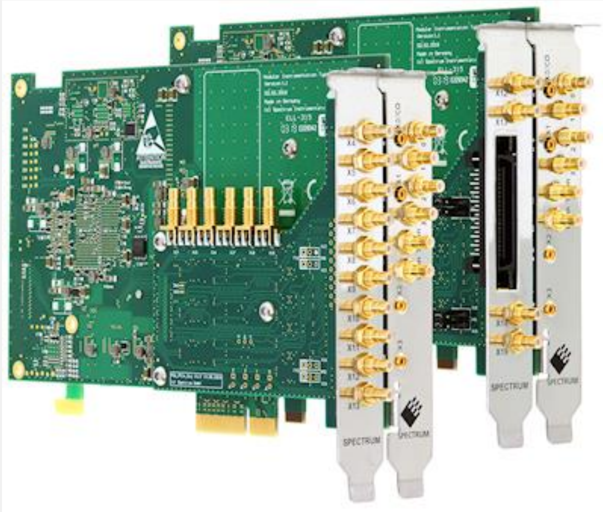

Figure 5: Mounted beside the card is the multi-purpose digital I/O option. Together the combination offers 4 analogue AWG channels and 20 programmable digital XIO lines.

Digital I/O for Logic Analysis and Pattern Generation

While the M2p series Digitizers and AWGs are primarily designed for acquiring and generating analogue signals, another product in the M2p family, the model M2p.75115-x4 card, does the same thing but for digital signals. The card has 32 parallel channels that can be programmed to either acquire, or generate, digital signals at clocking rates up to 125 MHz. When set for digital acquisition, the channels offer 3.3 V and 5 V TTL compatibility, making them suitable for use with a wide range of digital signals. In generation mode, the cards deliver output levels of 0.2 V for low states and 2.8 V for high states into high impedance.

Importantly, this Digital I/O card shares a common base board with the M2p series Digitizers and AWG's. As such it can also be used with Star-Hub, sharing the same clock and trigger signals with any other cards that are installed in the system. Using multiple M2p.75115-x4 cards together with Star-Hub also allows the creation of digital acquisition, or generation, with many more channels. For example, combining 16 cards together with Star-Hub creates a Digital I/O system with up to 512 fully synchronized channels. It makes a very cost-effective way for engineers and scientists to perform logic analysis, or make timing measurements, in situations where they need very high numbers of channels. Similarly, it's an economical way to build pattern generation capabilities into sophisticated control systems.

Software and Tools for System Integration

The M2p products are fully programmable and come with all the tools needed to build a system using almost any PC. The product drivers support both Windows and Linux operating systems, while programming examples and support is available for a host of languages, including C++, LabVIEW, MATLAB, Visual Basic.NET, Python, and Julia. This wide choice lets users create their own test programs in whatever language they're most comfortable with, speeding up development and efficiency.

If a turnkey solution is required, Spectrum offers its own control software -- SBench 6 –- that allows signal generation, acquisition, display, processing, storage, and reporting. The program is designed for multi-channel applications, with several features that help to make system setup and control fast and simple. Data sharing with other programs or devices, such as oscilloscopes, is also possible using built in import/export functions for transferring data in Binary, ASCII or Wave formats.

Processing Power for Demanding Signal Analysis Requirements

The M2p cards are based on the PCIe standard and use a 4 lane Gen 1 connection. This fast bus makes it possible for each card to transfer data at very high speeds (up to 700 MB/s) to and from the PC. For multi-channel applications the bus is ideal as each PCIe device has its own exclusive bandwidth and therefore it does not affect others in the system. This helps to overcome a common complaint in many multi-channel systems, where slow data transfer makes them unfriendly and sometimes even unusable. The M2p cards on the other hand shift data to the PC's processing system at high speed, maintaining data throughput and optimizing processing speed.

For applications requiring high powered signal and data processing the company even offers a special package called SCAPP (Spectrum CUDA Access for Parallel Processing). The SCAPP SDK allows a direct link between Spectrum digitizers or AWGs and CUDA based GPU cards. Once in the GPU users can harness the processing power of the GPU's multiple (up to 5000) processing cores and large (up to 24 GB) memories. SCAPP uses an RDMA process to send data at the cards full PCIe transfer speed to/from the GPU card.

The structure of a CUDA graphics card fits very well with the M2p series products as it is designed for parallel data processing, which is the same as most signal processing jobs. For example, the processing tasks of data conversion, filtering, averaging, baseline suppression, FFT window functions or even FFTs themselves can all be easily parallelized. The SCAPP SDK software is based on C/C++ and comes with tested and optimized parallel processing examples for basic functions like filtering, averaging, data de-multiplexing, data conversion or FFT. The examples can be easily modified and adapted for customer specific applications with normal programming skills.

Conclusion

Multi-channel testing is becoming more common while at the same time requiring higher system performance and lower cost. With the M2p product family Spectrum Instrumentation has created a cost-effective solution, for analogue and digital signal acquisition and generation, by creating a series of multi-channel instruments that all work together using the latest PC based technology. Careful product design and a choice of hardware and software options, make it easy to create almost any multi-channel test system and tailor it to match a specific applications requirement.