AXIe Data Streaming Drives Mil/Aero and Wireless Applications

By [Lauri Viitas], [Guzik Test and Measurement]

AXIe is a modular instrument standard, abbreviated from AdvancedTCA Extensions for Instrumentation and Test. AXIe is often referred to as the "big brother" of PXI because, despite its much larger module envelope, it acts logically as a PXIe (PXI Express) system. Communication is performed over a 4-lane PCIe (PCI Express) bus on the backplane either through external or embedded controllers. To a controller, an AXIe system is just another PXI chassis, though one with much larger board area and power capability. Specifically, an AXIe module offers eight times the volume of a 3U PXI module, and typically can support up to 200 watts per each chassis slot compared to PXI's 30 watts.

While AXIe is well known for offering very high speed digitizers and AWGs (arbitrary waveform generators), it also excels at streaming long data records to or from these devices. Example applications include wireless communication, radar emulation and test, and electronic warfare. These long data records are typically used to search for rare or infrequent events, often in the development phase of a product or system, but also for monitoring deployed systems.

This article will describe three methods for streaming in AXIe, and the advantages and limitations of each. The Guzik ADC 6000 series of AXIe Digitizers deploys all three methods, and will be used as an illustration of each technique along with actual results. The ADC 6000 series is essentially a family of single slot AXIe digitizing modules offering a single channel at 40GS/s, two channels at 20GS/s, or four channels at 10GS/s. All modules have 8-bits of resolution. The three techniques are PCIe streaming, local bus streaming, and massive on-board memory.

PCIe Streaming

The most straightforward method is to stream data over the PCIe fabric to a controller or large storage array. This method is nearly identical to the same operation in a PXI system, and many of the same storage products may be used. A diagram is shown in Figure 1:

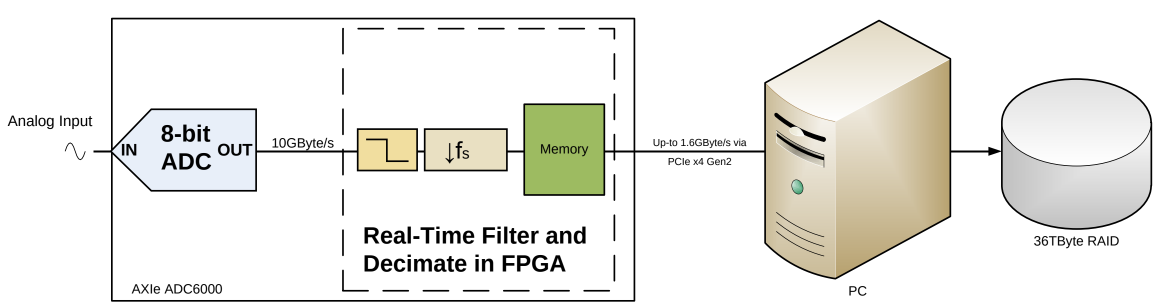

Figure 1. *After the signal is digitized and (optionally) processed and managed in memory, it is streamed to the PC controller via PCI Express. On-board the PC, it is streamed to another PCI Express port where a RAID array of 36TByte or more may be storing the gapless data.*

The advantage of this approach is its flexibility and reliance on industry standard products. Many RAID storage systems can be interfaced to via PCIe, so the sky is the limit when looking at total stored data.

The main constraint of this approach is the ultimate bandwidth or streaming speed. A PCIe Gen 1 lane has a theoretical bandwidth of 2Gb/s after the encoding overhead. The standard AXIe PCIe fabric is 4 lanes wide, which leads to 8Gb/s, or simply 1GB/s (8 bits in a byte). Since most AXIe modules and chassis actually work at Gen 2 speeds, the streaming throughput is increased to 2GB/s. If PCIe Gen 3 is deployed in the future, the aggregate bandwidth will nearly double again.

These speeds will look comparable to those in a PXI system, because AXIe and PXI use the same PCIe fabric. However, PXI allows up to 8 lanes to each module, doubling the throughput speeds again. AXIe has reserved backplane pins for creating a similar 8-lane system, and is already implemented on the Guzik ADC 6000 digitizers.

Due to small latencies, top performance may be 20 percent under theoretical peak speeds, leading to 1.6GB/s for the typical 4-lane Gen 2 system. Since each sample is a single byte (8 bits) for ADC 6000 series digitizers, this translates simply to up-to 1.6GS/s (Giga Samples / second). For ADC data streams, this correlates with up-to 640MHz bandwidth, when using 2.5 times oversampling, which exceeds all cellular and Wi-Fi bandwidths.

Guzik is currently working on a streaming application requiring 1.25GS/s, which is readily attained. It should be noted that the acquisition rate is actually much higher, at 10GS/s. On-board signal processing decimates the signal to the 1.25GS/s rate in real time. The advantage of this approach over simply lowering the sampling rate, is that processing gain actually improves the ENOB (effective number of bits). An 8-bit ADC (analog to digital converter) can achieve much higher signal fidelity using this technique than would be predicted by the ADC alone, rivaling higher resolution ADCs.

Local Bus Streaming

The local bus is a unique bus structure that brings many hidden benefits. Local buses are a set of short copper segments that connect pins between adjacent slots. This is why they are called "local" buses. For example, the right side of slot 2 is connected to the left side of slot 3. Then the right side of slot 3 is connected to the left side of slot 4, and so forth. See Figure 2:

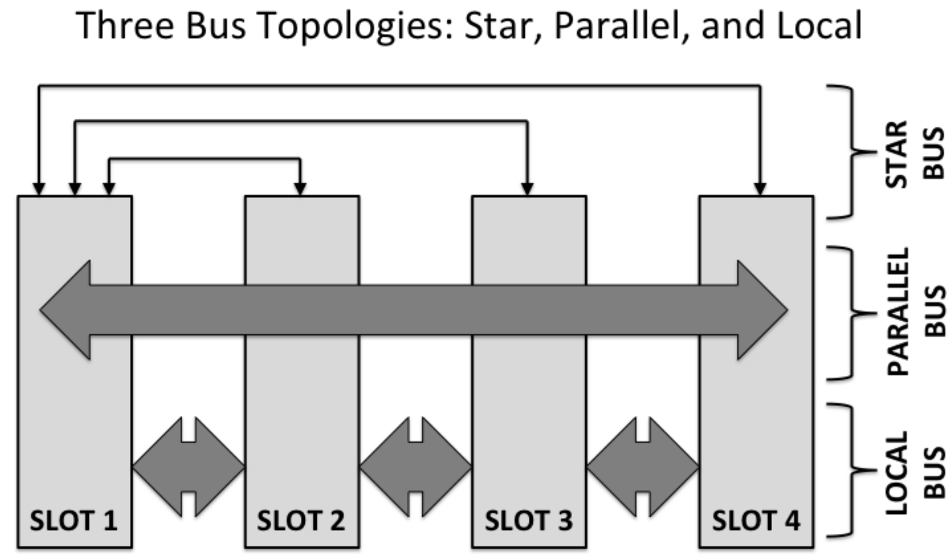

Figure 2. *Parallel buses such as trigger buses traverse all slots, and serial buses such as PCI Express are arranged in a star configuration to each slot. Local buses, however, connect only between adjacent slots. The short length enables very high data rates.*

Because the copper path lengths are short, only a few centimeters, very high-speed signals can be routed from slot to slot. Local buses enable high-speed private communication between related modules of an instrument set. Since the local bus begins and ends between the modules of an instrument set, another set of modules may use their local buses completely differently. This way, instrument sets from different vendors may co-exist in the same chassis, each exploiting the unique capabilities of the local bus.

The AXIe local bus consists of 124 lines organized as 62 high-speed differential pairs. With 60 pairs dedicated to the data path, and using fairly common FPGA (field programmable gate array) SERDES (Serializer/Deserializer) technology, the aggregate bus bandwidths can total 40GB/s from one slot to the next. This is an order of magnitude beyond other bus structures. Since AXIe only defines the topology of the local bus, the aggregate bandwidth potentially could increase proportionally with the interface bus speeds deployed.

The Guzik ADC 6000 family deploys local bus as a streaming option. The 40GB/s speed matches exactly the peak rates of 40GS/s of the digitizers, and Guzik internally has shown that local bus speeds can be significantly higher. Guzik uses the local bus to share memory between digitizers, through a special order configuration. That is, multiple digitizers may be inserted in adjacent slots, and a single module may use all the available memory on all the modules. Essentially, local bus allows a user to expand the available memory at very high speeds.

While the bus speeds have increased by a factor of over 20 compared to PCIe, there are some limitations. There are no commercial storage solutions that use the AXIe local bus, so a user will be limited by instrument vendor offerings. Each Guzik digitizer can have up to 128GB of on-board memory. A 5-slot AXIe slot chassis will then support up to 640GB of memory. Not a trivial amount by any means, but also not the multiple Terabytes available from commercial PCIe storage. There is a direct speed and storage depth tradeoff between local bus and PCIe systems.

Massive On-board Memory

As stated in the previous paragraph, each Guzik digitizer supports 128GB of memory, operating at the full 40GS/s bandwidth. That is 3 seconds at peak data rates, and is often sufficient for transient capture of an event. It should be noted that the 3 second capture depth remains true whether the digitizer is a single channel at 40GS/s, two channels at 20GS/s, or four channels at 10GS/s, as the aggregate sample rate remains at 40GS/s.

This data rate and depth is state of the art, and is directly enabled by the AXIe architecture. The large AXIe board size, along with robust power and cooling, allows this density of high-speed solid-state memory. Smaller module sizes simply cannot support this amount of memory. Furthermore, the memory can be deployed on a single coplanar printed circuit board, enabling high signal integrity, which directly enables higher speed designs.

To achieve this density and speed, Guzik uses the new 16GB DDR3 SO-DIMM modules from Intelligent Memory. It replaces the earlier 8GB modules, allowing the memory to double from 64GB to 128GB. While the examples shown here illustrate 40GS/s, there is no fundamental architectural limit to the speed possible.

Figure 3. *This 16GB DDR3 SO-DIMM allowed the AXIe digitizer to double available memory to 128GB, enabling 3 second gapless recording times at 40GS/s. The power and cooling capability of AXIe allows dense high speed memory directly onto the module, bypassing any speed limitations of an external bus.*

The limitation of this approach is clear- it is difficult to expand the memory beyond the amount on-board. For speeds up to 40GB/s, the local bus can expand the available memory by the number of slots available.

Applications

Most applications for deep streaming occur in research, development, or monitoring. Wireless communications, radar, and electronic warfare dominate today's streaming applications. Each of the three techniques makes a different tradeoff between total memory depth and speed. A good rule of thumb is to identify the simplest technique that meets the application's speed requirement, and then configure the system with the needed memory.

Streaming depth is not infinite. Even RAID systems have memory limits. A critical element of a streaming system is to start and stop streaming. Starting streaming is straight forward enough; instruments typically receive a command to begin. Stopping is more complicated. Here, there must be a detection of an event that halts the streaming. This is very application dependent. Sometimes the instrument itself, such as the digitizer, is looking for values that indicate an event of interest has occurred. With modern FPGAs, a calculated result may halt the acquisition. External circuitry can also generate a trigger signal that halts the acquisition. With deep enough memory, even the controller can send a command to stop acquiring data.

Once the record is acquired, the data can be analyzed. Typically this is done offline, below real time speeds. In the case of the Guzik digitizers, the Keysight 89600 VSA software is often used for signal analysis, but MATLAB and LabVIEW could also be used. In other applications the captured data may be played back on one or more AWGs to reproduce the captured signals. This is a method of Record-Playback real world RF signals.

Summary

AXIe delivers the board area, power, cooling and tight timing synchronization required by very high performance instrumentation. It also delivers three robust methods for capturing long data records: through PCIe, using on-board memory, and extending the memory through the local bus.

AXIe systems can now deploy real time streaming performance an order of magnitude beyond traditional techniques. The speed and flexibility is unprecedented, and not achievable through traditional bus architectures. These features enable new applications in wireless communications and mil/aero. Recent AXIe products from Guzik Test and Measurement show that these breakthrough performance levels may be achieved using today's technologies.