Highly Accurate, Record/ Playback of Digitized Signal Data Serves a Variety of Applications

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Using FPGA-based filtering, precision timestamping and packet-inspection, a powerful recording and playback solution provides network data that exactly mirrors data captured from the real world.

In recent years, technology advancements in high-bandwidth signal acquisition have been truly astounding. Whether those signals are comprised of radar, RF, video or other form of data, sensor and receiver technologies keep pushing up the bandwidth of incoming information. The same is true of data going the other direction: broadcast signals in their various forms. At the same time, network technologies have kept pace enabling processing systems to distribute all that incoming data. 10 Gbit Ethernet networking is today considered mainstream, while 40 Gbit and 100 Gbit Ethernet are no longer considered exotic. These high-bandwidths and the deluge of incoming data in turn makes recording and playback of signal acquisitions more challenging. But even there, storage systems and FPGA technologies have likewise advanced to help record and playback systems keep up with the rest of the signal chain.

Benefits of High Accuracy Data Recording

There's a big difference, however, between ordinary recording and playback solutions versus the capability to do multi-port line rate record and playback at a high level of accuracy—in other words, accuracy close enough to the original data stream to be useful to system developers. Achieving such levels of accuracy is a huge advantage because it means captured data can be played back in a lab with the confidence that the data—in terms of both content and timing—looks exactly the same as it was when it was captured by the sensor front end in the field.

With just that in mind, New Wave DV offers its RapXG solution. The RapXG provides scalable, high-performance packet capture and playback. For networking density, the box supports multiple ports of 10, 40, and 100 Gbit Ethernet over Quad SFP+ (or QSFP+) ports supporting optical and copper connectors. The system's standard features include accurate time synchronization, programmable 5-tuple filters, PCAP Next Generation file format, a highly efficient PCI Express Gen3 host, a user-friendly GUI or command line interface and a full API for record and playback functions. Figure 1 shows a standard implementation of the RapXG system, capable of recording four 10Gb ports for 3 continuous hours. However, New Wave can customize several aspects of RapXG—including the number of network adapters, chassis size and temperature/vibration characteristics, RAID array size and drive choices—in order to meet exact bandwidth and storage needs of the user.

Figure 1: *The RapXG provides line rate network record and playback. Number of ports, speeds, chassis characteristics, RAID array size and drive choices are all configurable to user bandwidth and storage needs.*

Among the most powerful features of RapXG is its ability to play back recorded data exactly as it was captured. While other solutions simply send captured packets back onto the network, RapXG plays them back at the rate they were captured. The system employs hardware-controlled precision clocks and the recorded capture timestamp, to play back network data to within 20ns of captured time.

It's All on the Board

At the heart of the RapXG is the FPGA network card running New Wave's Capture IP Core (Figure 2). This board does all the network interfacing and, most importantly, the system's hardware filters, timestamping, regulated playback and customizable packet processing capabilities are all implemented on the board's FPGA.

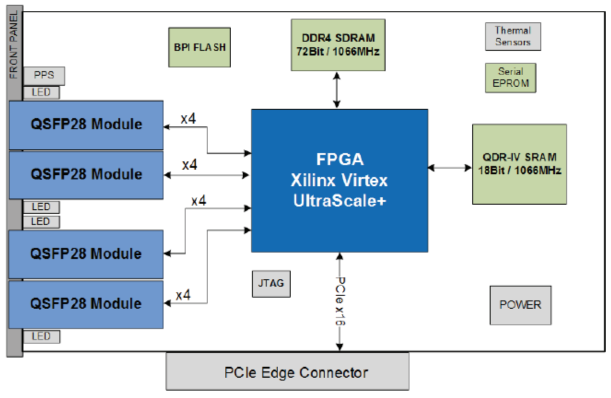

Figure 2: *The RapXG's hardware filters, timestamping, regulated playback and customizable packet processing capabilities are all implemented on the board's Xilinx UltraScale+ FPGA*

Two options are available covering the performance requirements needed. Option 1 is the V5031 PCIe card based on the Altera Stratix V FPGA, Quad 10 Gigabit Ethernet SFP/SFP+ ports also reside on the card along with an 8-lane PCI Express Gen 3 interface to the host interface. Option 2 is the V5052, which is based on the Xilinx UltraScale+ Virtex FPGA, offering up to sixteen 10Gb ports.....or four 40Gb ports.....or four 100Gb ports....using SFP+ or QSFP28 transceivers, on a card with a PCIe Gen 3 x 16 host interface.

New Wave remains FPGA-agnostic in terms of its roadmap for RapXG—or any of its products. The company employs the best available FPGA technologies from lending vendors such as Altera, MicroSemi and Xilinx. On most of its products New Wave supports user customization directly on its FPGA firmware. If there's special filter schemes or IP that's either classified or trade secret, users can embed firmware intended for their eyes only.

The RapXG can perform very accurate time synchronization. It supports a variety of time code formats including IRIG-A, B and G time codes as well as IEEE 1588 Precision Time Protocol (PTP) and others. The board very accurately timestamps data coming in. And it also uses that timestamp to hardware regulate when a packet egresses the box. This is in contrast to playback systems that simply push out data through the network port as fast as possible. In such systems, the data and its timing doesn't at all look on the network like it did when recorded. Even if the content of the data is all there, it's not necessarily moving as it did in the original stream—with the same spaces in between packets and so on. For some applications, that sort of recording is sufficient. But for applications like electronic warfare, signal intelligence, advanced communications or radar, it's critically important that the data played back look exactly like it did coming in.

Timestamps, PCAP and Filters

On the RapXG, all of the timing protocols and timestamping are implemented on the FPGA. As soon as the first bits of a packet enters the RapXG box, it captures the timestamp and appends it to the packet that's coming in. And then on playback, the RapXG system uses FPGAs to do hardware regulated playback. The hardware queues up packets and plays them back at the appropriate time based on the external timestamp.

The system stores the recorded data in the open source PCAP format. By using PCAP, the files can easily be shared with others. There are many open source tools for PCAP including text editors and viewers. By using this standard format, not everyone needs a RapXG box to be able to look at the recorded data.

On the RapXG FPGA there are some very powerful hardware filtering capabilities. A full set of four channels of 10 Gbit/s data equals 40 Gbit/s of incoming data—which is a lot of data. Many applications don't need all that information, so it's useful to filter out the data that isn't of interest. These filters let users record or playback only a subset of the data. A simple filter could for example look for the IP addresses found in the packets. Or a more complicated filter might for example look deep into the packet and look for some string of bytes that identifies it as data that's of interest.

In theory, you could do that kind of filtering in software. But theory doesn't mesh with reality in high-bandwidth data capture of this kind. A software based approach just couldn't keep pace with the speed and volume of data. Moreover, at these kinds of bandwidths, the data must move in and out of disk-drives and across PCI Express interconnects without causing bottlenecks. By adding more PCI Express channels and larger disk arrays you could compensate, but that adds more cost. In contrast, hardware filtering done at the FPGA level helps cut down the amount of data that needs to be recorded and does it in a much lower cost implementation. That can have significant impacts on many facets of system design—fewer drives, smaller rack-space, less power and so on. Meanwhile, there are some applications that do require full 40 Gbit/s of data. That's often the case when the user doesn't know what data they're looking for. Instead of filtering, they capture all the data, and go back and sift through it to find the event indicators of interest.

VITA 49 Provides 2nd Timestamp

Another significant feature of the RapXG architecture is VITA 49 support. The ANSI ratified VITA 49 provides an industry standard packet format for digitized signals. The standard can work with any kind of signal. It basically provides a standard packet format for the exchange between a front end and a processor. If one vendor for example makes a sensor front end that outputs 10 Gbit Ethernet, and another makes a processor system that accepts VITA 49 10 Gbit Ethernet data, the two systems can connect seamlessly and work together. Aside from the packet content, a VITA 49 standard packet organizes several key elements include the timestamp, frequency, size of each capture and so on.

Aside from the compatibility advantages, the support of VITA 49 has some important implications for New Wave's RapXG. Because it supports VITA 49, every packet has TWO timestamps—the one captured by the RapXG box system and the VITA 49 timestamp from when the data was originated. The RapXG's external time source ensures that its timestamp is extremely accurate. Users can now look at the delta between the two timestamps and thereby get a valuable determination of the network's latency between when the data was created and when it was recorded.

In a simple network, it's likely that the two timestamps will be the same—or very close to the same. But over complex networks, the data may travel through numerous switches, routers and hubs and therefore may add significant latency. By knowing the difference between the two timestamps, users can adjust or account for that latency, providing a better ability to replicate exactly how the signal stream really looks.

Having the VITA 49 timestamp also adds options for playback that other record/playback solutions do not. On playback, the RapXG system can play the data back based on the timestamp captured by the RapXG, or it can play the data back based on the VITA 49 timestamp. In essence, RapXG can make the data stream look just like it was when recorded in the network or make the data look like it's coming from the originator by playing it back based on the VITA 49 timestamp.

RapXG Record/Playback in Action

The diagram in Figure 3 illustrates how the RapXG system works. At the far left on the diagram you see a signal captured from the analog world—the signal could be anything including radar, RF, video, comms or other kind of data. Let's assume for example it's an RF signal. The sensor front end acquires the RF data and puts in through some analog to a digital conversion. Next, the front end may do some digital processing on it—maybe some

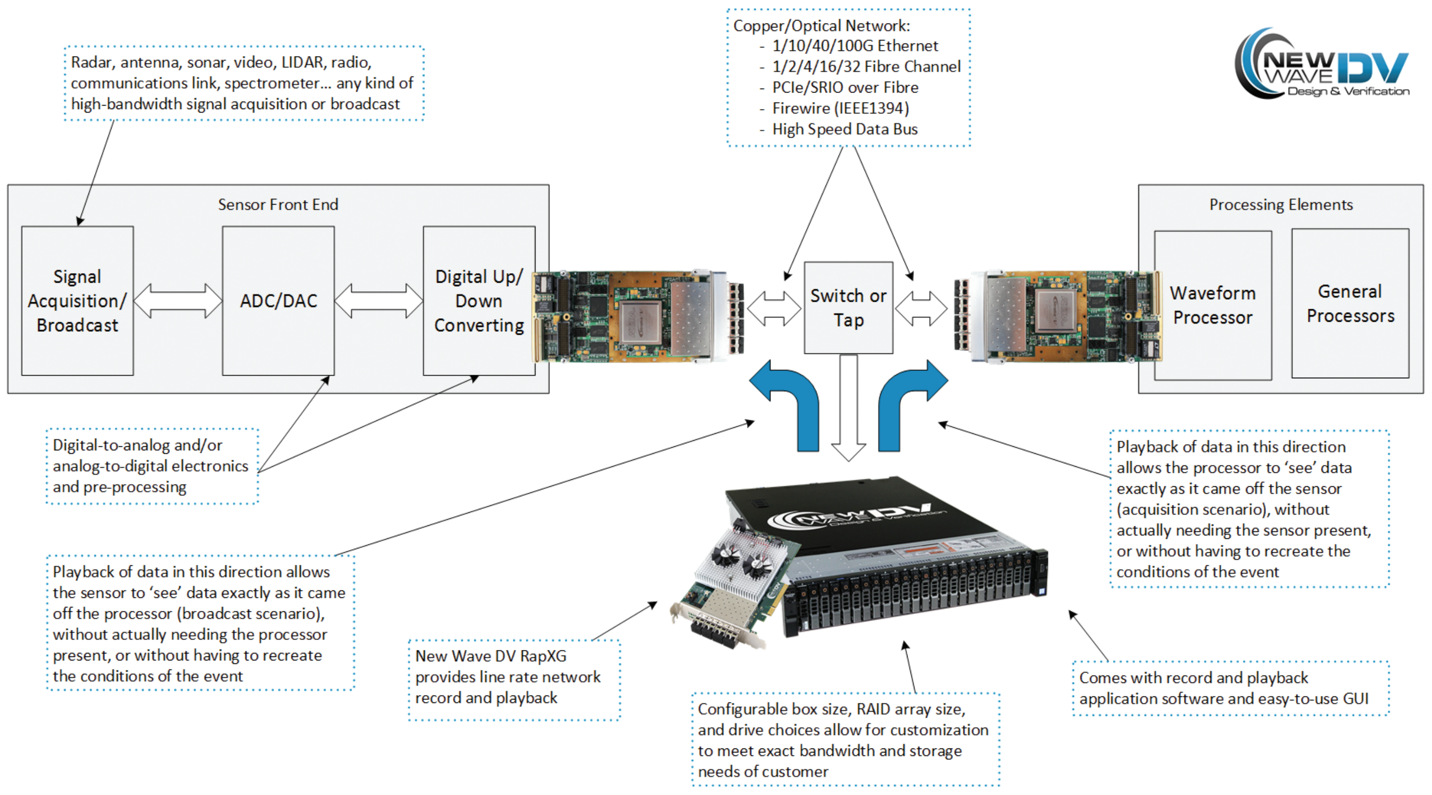
Radar, antenna, sonar, video, LIDAR, radio, communications link, spectrometer… any kind of high-bandwidth signal acquisition or broadcast
Copper/Optical Network:
- 1/10/40/100G Ethernet
- 1/2/4/16/32 Fibre Channel
- PCIe/SRIO over Fibre
- Firewire (IEEE1394)
- High Speed Data Bus
Sensor Front End
Signal Acquisition/ Broadcast
ADC/DAC
Digital Up/ Down Converting
Switch or Tap
Processing Elements
Waveform Processor
General Processors
Digital-to-analog and/or analog-to-digital electronics and pre-processing
Playback of data in this direction allows the processor to 'see' data exactly as it came off the sensor (acquisition scenario), without actually needing the sensor present, or without having to recreate the conditions of the event
Playback of data in this direction allows the sensor to 'see' data exactly as it came off the processor (broadcast scenario), without actually needing the processor present, or without having to recreate the conditions of the event
New Wave DV RapXG provides line rate network record and playback
Configurable box size, RAID array size, and drive choices allow for customization to meet exact bandwidth and storage needs of customer
Comes with record and playback application software and easy-to-use GUI

Figure 3: . *This data flow diagram illustrates where the RapXG interacts with any signal/data capture-processing application. No matter what the variety of captured data—radar, RF, video, etc.—RapXG provides highly accurate recording and playback in either direction.*

digital down-conversion, digital up-conversion, etc. Then that data streams onto the network. These days that's most often 10 Gb Ethernet, but 40 Gb is getting more prevalent too. RapXG supports 40 GbE as a solution. 100 GbE is also supported, and will soon be integrated into New Wave's recorders.

The white arrows in Figure 3 represent the data flow. There's either a network switch or a tap between the sensor front end and the system processing elements. And that switch or tap is where the RapXG box gets access to the data. The data flows into the RapXG box where it's recorded. For some applications, only recording is required. The white line into the RapXG box shows that flow of data into the recorder. As mentioned earlier, the data is all stored in a standard, open-source format, making it easy to share and analyze the recorded data as needed.

The blue lines in Figure 3 represent the stream during playback. Most typically, the RapXG box plays the recorded data back to the processing elements—the blue arrow blending to the right. A good example of where this is useful is radar algorithm development. Imagine a ship-based radar system where real-world radar data is captured and recorded aboard ship—radar data of flying objects like aircraft, drones, etc. Using the RapXG box, that data is recorded at sea. Then that same data gets played back onshore in the development lab. Radar algorithm developers can then apply new tweaked algorithms and test them out using the recorded radar data and observe how new algorithms perform right there in the lab. There are obviously huge cost savings and huge convenience to be able to access that real-world data without being out at sea or where the data was originated.

Data Flow the Other Way

Next, let's consider data moving in the other direction. A good example requiring that, is a signal jammer application. Here, you are PRODUCING your waveform on the processing element and then sending it out through the analog front end for transmission.

In that case, the RapXG box records the synthetically produced data coming from the processing element. Once the data is recorded, some applications may even want to play back the synthesized data from the RapXG box and out the front end without having the processing elements connected at all. That situation is represented in Figure 3 by the blue arrow bending to the left.

Remember that the recorded data is all stored in an industry standard format: PCAP. With that in mind, system developers can do some interesting things in these transmission/broadcast situations. A user could go in and tweak the data in the recorded data file and play it back, outputting to the analog front end. In such a case, the recorder is playing data that was actually never created by the processing elements. This essentially turns RapXG's playback engine into a signal generator able to transmit waveforms that you've never actually sent from the processing elements. And because of the highly accurate timing capabilities, these waveforms can easily appear as close to the real-world signal data as needed.

Offering maximum flexibility, three types of user interfacing are supported on the RapXG system. Users can choose between a graphical user interface (GUI) or a command line script-based interface. And the third option is a robust API that developers can use to actually create application software running on the RapXG system. That's particularly useful when you want to develop automated tests or run custom application software on the system. Because it's a true API, it enables a user's software to talk to RapXG's application software running on the box. Using the API enables application software to take advantage of the card's capabilities through a C++ library and allows applications to modify card settings easily. The RapXG system is also fully integrated with the Wireshark network protocol analyzer, enabling users to efficiency diagnose network issues.

Suited for a Broad Variety of Applications

The variety of applications that can benefit from RapXG are almost as broad as the imagination. Real-time systems ranging from electronic trading systems to military radar track distribution, all depend on the timely receipt of data for proper operation. Aside from using it for basic network data record and playback, RapXG can serve roles as an Ethernet based Sensor/Video recorder, a network traffic emulator, a network event logger or even as a network security monitor. In terms of markets, RapXG performs the same functions no matter what the incoming recorded data is. Whether its data downloaded from satellites, radar data captured from a ship-based radar, airborne electronic warfare jamming or industrial event logging in a smart factory, RapXG provides scalable, high-performance FPGA-based packet capture and playback—and does it all at extreme levels of accuracy.