Capturing Events of Long Duration or High Data Volume

Application Note

Four approaches enable gap-free acquisition of continuous and triggered signals

Numerous test scenarios require gap-free or continuous acquisition of digitized data for minutes, hours or days. In all cases, the data is stored in memory or on disk for detailed processing and analysis during or after the acquisition.

A variety of system configurations will enable effective continuous data acquisition along with the required processing and analysis of the captured data. The most effective arrangement depends on the details of your application: the number of signals; the frequency range and signal bandwidth; the required sampling rate and resolution; the expected duration of the acquisition; and more.

The remainder of this application note describes four system configurations that support continuous data acquisition, the potential bottlenecks in those configurations, and possible solutions to the bottlenecks. Throughout the note, sidebars highlight Agilent digitizers and data converters that can be used to create effective solutions for continuous acquisition of data.

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Capturing gap-free data for detailed analysis

There are two types of continuous data acquisition. One is the capture of a single, continuous data stream, which is commonly called streaming. The other is the gap-free capture of a series of contiguous data bursts (Figure 1).

Recordings of the first type require either no or just one trigger event to begin the capture session. Example applications that require streaming capture of digitized data include microwave astrophysics, atmospheric research, plasma research, signal monitoring, software defined radio, aerospace and defense SIGINT and COMINT.

Acquisitions of the second type rely on multiple trigger events that define the beginning of each burst. There may be gaps of undetermined length between the end of one event and the beginnings of the next. A series of contiguous events may repeat indefinitely with the recording system capturing each data burst without missing any of the events. Example applications include the analysis of particle-beam steering in cyclotron accelerators, medical and biomolecular imaging, signal monitoring, pulsed radar and telemetry systems.

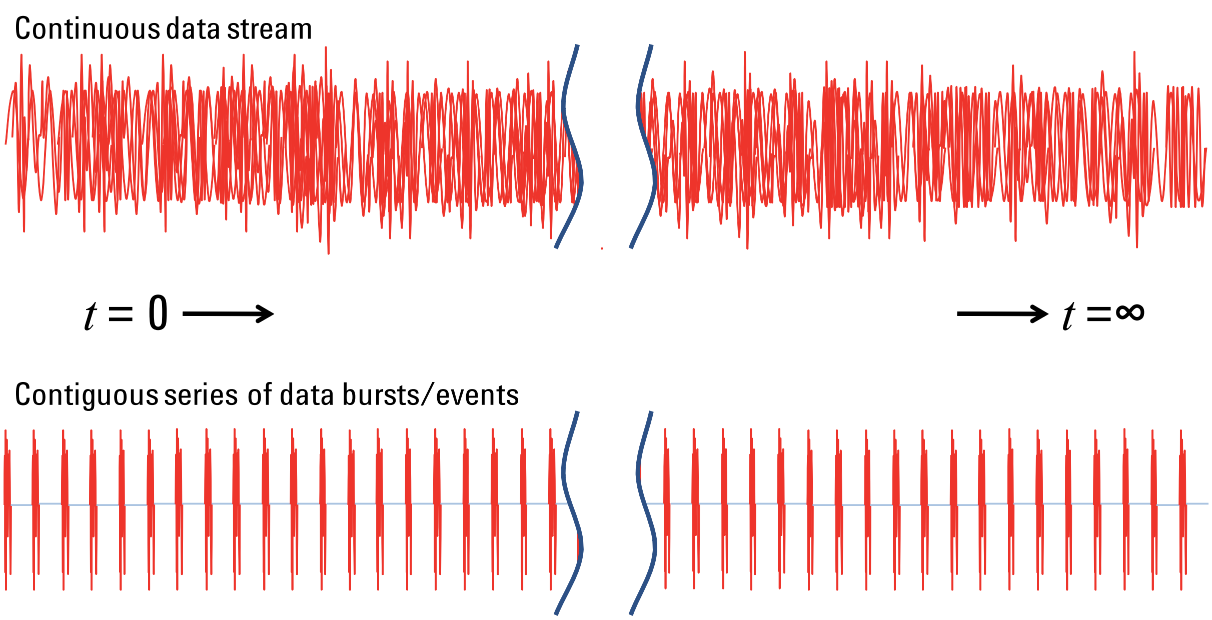

Figure 1. These examples highlight the differences between a continuous data stream and a series of contiguous data bursts.

Examining four possible configurations

Four system configurations are especially effective for data streaming, processing and analysis. The most effective approach will depend on the details of your application:

- the number of signals or data channels to be acquired
- the required frequency range and signal bandwidth
- the required sampling rate and resolution
- the required types of processing and analysis
- the expected duration of the acquisition
- the type of signal acquired

The next section describes the four configurations and their respective strengths, weaknesses and potential bottlenecks.

As with the configuration of any product requiring high-speed ADC or measurement system, there are tradeoffs. When configuring an acquisition system for continuous data recording, the tradeoffs occur between four key factors: overall performance, system complexity, system software and total cost.

A variety of PCI-based Agilent modular digitizers can be used to create an effective solution for continuous data acquisition. This application note presents block diagrams that support four techniques:

- Recording of data to the host processor (e.g., system recording PC)
- Recording of data directly from a digitizer to a disk drive
- Recording of data to a disk array through a RAID controller
- Recording of data to a digital signal processing (DSP) engine through the backplane

Unfortunately, the choice of a system configuration isn't always clear cut. The good news: The gray area includes a few readily available solutions that can address the bottlenecks in any of these configurations.

Configuration 1: Recording to the host processor

This is the simplest and most common approach, and it is most effective with modest requirements: few channels; lower frequencies or bandwidths; and duration measured in seconds or minutes.

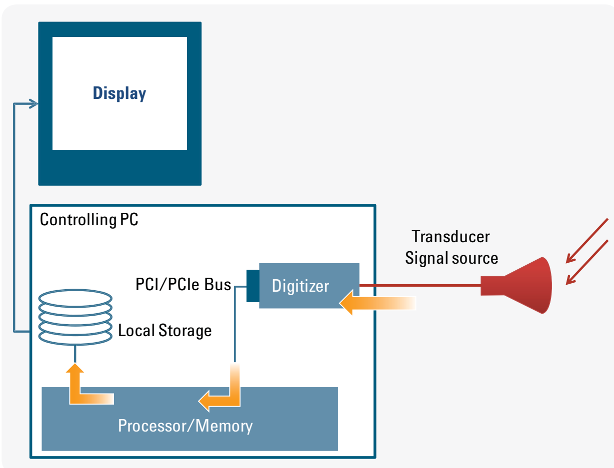

Figure 2. Recording to the host processor is the simplest approach, even if multiple digitizers are required.

The basic block diagram is shown in Figure 2. Each signal of interest is captured by a digitizer that is connected to the PCI or PCI Express® (PCIe®) bus or backplane. The digitized data is sent directly to the host PC where it is stored in memory, on disk or both.

The main strength of this approach is its simplicity: It uses standard, off-the-shelf digitizers, PCs and hard disks. As a result, it also offers the advantage of low cost compared to the other three approaches described below.

One potential weakness is the overall performance of the system itself. Any shortcoming in characteristics such as processing power, disk speed or data-transfer speed will limit the datacapture performance of the system. These problems become more significant as the number of digitizers increases.

Another source of possible issues is the PC operating system. Some generate interrupts that can block data transfers for several tenths of a second.

See pages 6-8 for details of data reduction and buffering methods.

Configuration 2: Recording directly to a disk drive

To enable extremely high performance, Agilent Acqiris U1080A digitizers bypass the backplane bottlenecks and provide a direct optical connection to external disk drives (Figure 3). Today, this is the second most commonly used approach among Agilent customers performing continuous data capture.

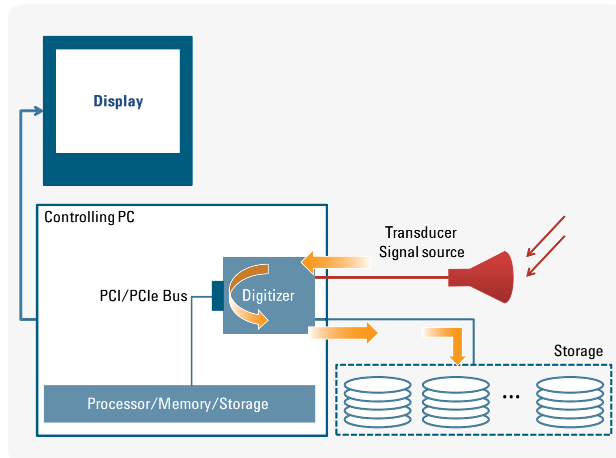

Figure 3. Recording directly to an external disk drive provides maximum performance in streaming applications.

The main strength of this configuration is its performance, and the greatest performance is achieved when each digitizer is connected to its own dedicated disk drive. If multiple digitizers share a single drive, then the effective bandwidth is reduced in direct proportion to the number of digitizers.

This configuration has two noteworthy shortcomings: cost and complexity. Both can become an issue if many signals of long duration must be acquired. However, this approach often offers the best possible solution in highly demanding applications.

This configuration needs a software application that can access the disk, process the data and provide analysis capabilities. Vendors can create custom software that meets these needs through direct links to the storage system.

See page 9 for details of methods to choose the best data bus.

Configuration 3: Recording to a RAID array

Adding an off-the-shelf RAID controller enables relatively high performance with lower cost and less complexity than configuration 2. In configuration 3, the digitizers and the RAID controller reside on the backplane and digitized data is stored in the RAID array (Figure 4).

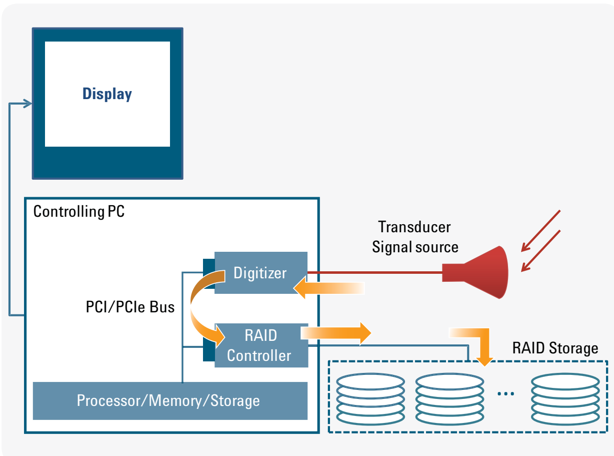

Figure 4. Recording to a RAID array can provide tremendous capacity when large volumes of data must be acquired.

The best possible performance is achieved if the array is configured for RAID 0, which is block-level striping of data across all array drives. This approach has zero redundancy, which has risks but enables high performance. Bandwidth is a function of the number of drives in the array.

The performance of the RAID controller and the disks in the RAID array are possible bottlenecks. As with configuration 1, the speed of the bus or backplane is another possible limiting factor in top-end performance.

See pages 6-8 for details of data reduction and buffering methods.

Configuration 4: Recording to DSP

System performance can be enhanced by adding a digital signal processing (DSP) card to the system (Figure 5). A high-performance DSP card that resides on the backplane can pre-process data, thereby reducing the volume of data that is transferred to the system host.

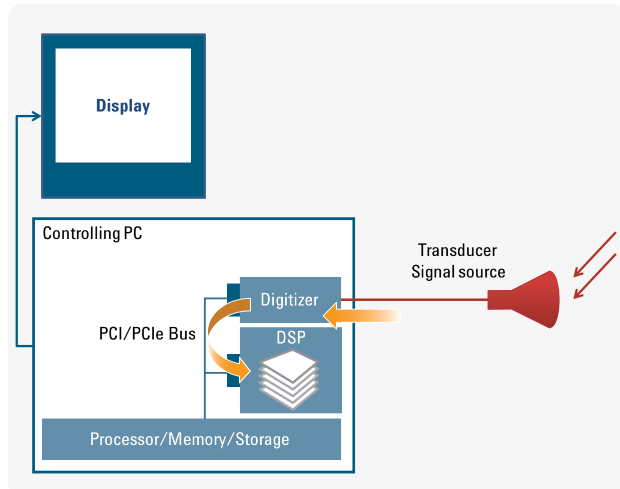

Figure 5. A DSP card can enhance the performance of continuous acquisition by reducing the volume of data that must be transferred to the host.

This approach has one crucial complication: The digitizer, DSP card and PC CPU must be able to share data via direct memory access (DMA). Without DMA support, overall system performance will be insufficient for effective data capture. Even with DMA support, the speed of the bus or backplane is another possible limiting factor in top-end performance (as in configurations 1 and 3).

See pages 6-8 for details of data reduction and buffering methods.

Addressing the common bottlenecks

The shortcomings of the four recommended configurations have three constant themes: data volume, system performance, and backplane speed. Three techniques can address these issues: apply data reduction methods, utilize data buffers, and choose the best data bus for the application.

Apply data reduction methods

If the volume of raw data is too high for the available system, it may be possible to pre-process the data before transferring it to the storage media. The enabling technology is either a DSP card that resides on the backplane (configuration 4) or an FPGA built into the digitizer, which is the case with many Agilent Acqiris digitizers.

Data reduction is a broad topic that encompasses methods such as gating, peak detection, digital downconversion, averaging and the fast Fourier transform (FFT). Gating and peak detection reduce the volume of data by selecting points that satisfy specific criteria. As the name suggests, peak detection passes along only those points that either exceed a user-specified threshold or satisfy a hysteresis-based peak-localization algorithm. Digital downconversion reduces the needed transfer bandwidth by applying decimation techniques that separate intermediate frequency (IF) signals into their complex baseband components. Averaging and the FFT reduce data volume through computations that provide an intermediate result that can be further processed and analyzed to create a desired final result.

In the context of continuous acquisition, gating is perhaps the most useful method—especially if the signals of interest occur in well-defined bursts. As the name suggests, the measurement system initiates the acquisition (i.e., opens a gate) only when certain criteria such as trigger level and direction are satisfied. In an Agilent modular digitizer, the gate is left open for either a specified time or as long as a user-defined threshold is met. The system will capture finite-length data blocks until additional criteria are met (e.g., number of blocks, period of time). The data from the concatenated series of gated measurements can be processed with averaging, peak detection, FFTs, and so on, to produce the required final result.

This technique is especially useful with configurations 1, 3 and 4. It is less applicable to configuration 2, which emphasizes speed and is typically used in applications that require acquisition of raw data.

Featured module: M9202A PXIe IF digitizer

The M9202A is a single-slot 3U 12-bit PXIe wideband IF digitizer running at 2 GSa/s, with up to 1 GHz instantaneous analog bandwidth. The M9202A features a Xilinx Virtex-6 FPGA that can implement various firmware options. With the DDC option, the unit implements a real-time digital downconversion (DDC) algorithm in the 300 MHz to 700 MHz band, enabling improved analog performance and reducing data flow through the PXIe backplane.

www.agilent.com/find/M9202A

Utilize data buffers

Buffering is a common solution whenever data rates are high enough to exceed the performance of the transmission medium and the storage media. In contiguous-burst acquisition, the most effective approach is to perform buffering within the digitizer. As a result, many Agilent digitizers support two techniques: sustained sequential recording (SSR) and simultaneous multi-buffer acquisition and readout (SAR).

SSR is sometimes called "ping-pong mode" because it automatically switches data between two memory banks within a digitizer. In a digitizer such as the Agilent Acqiris U1082A or U1084A, the embedded FPGA can be programmed to perform this operation. The ping-pong action writes a waveform (or sequence of waveforms) to one memory bank while the other memory bank is being read out over the bus to the host PC at high sustained trigger and data rates. The SSR firmware also provides a data-gating mode to reject unwanted data, reduce data volume (as described above) and further maximize the transfer rate (Figure 6).

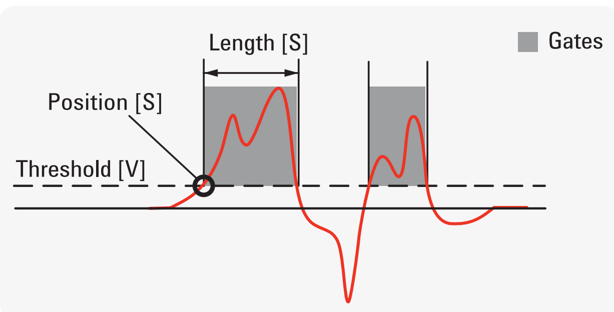

Figure 6. Threshold data gating enhances throughput performance by passing along only data of interest.

Featured module:
U1084A high-speed PCIe Digitizer with On-Board Signal Processing

This module provides 8-bit resolution on one or two channels and is available with 1.5 GHz bandwidth for the 2-4 GSa/s and 1-2 GSa/s sample rate versions, or 500 MHz bandwidth for the 0.5-1 GSa/s version. The on-board, high-speed FPGA handles real-time data processing tasks. Firmware options that support high-speed digitization, simultaneous acquisition and readout, signal averaging, and peak analysis can be easily uploaded to the FPGA under program control. A combination of any two firmware options can be loaded at once. Hot switch between these two firmware options is then possible.

www.agilent.com/find/U1084A

Utilize data buffers, continued

With simultaneous multi-buffer acquisition and readout (SAR), acquired data is stored in the standard digitizer memory (e.g., 256 kSa), which can be segmented. The acquired data is read out through the bus while another segment is filled with new data (Figure 6). This provides a dramatic increase in data throughput while also increasing the maximum trigger rate for lossless acquisition.

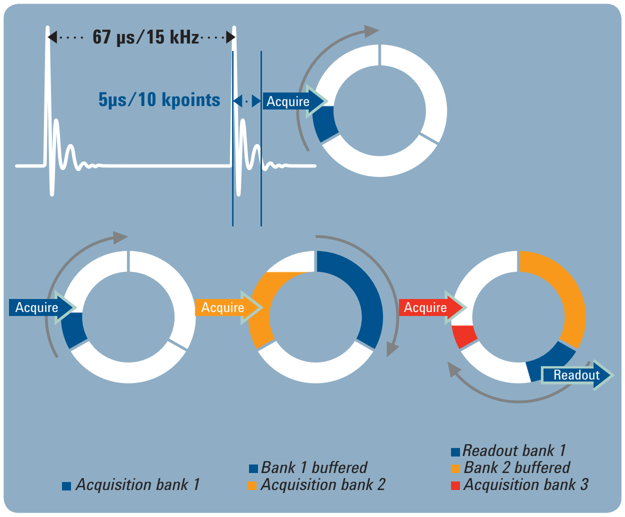

Figure 7. In this example a digitizer is running at 2 GSa/s and a 5 µs event is saved into a 10-kSa memory segment. The event has a 15 kHz repetition rate and the digitizer can acquire data continuously, capturing all events.

SAR is similar to the first-in/first-out (FIFO) method. FIFO works with individual samples while SAR operates on a buffered collection of samples.

Featured module: U1071A high-speed PCI digitizer

This module provides 8-bit resolution on one or two channels and is available with 1 GHz bandwidth or 500 MHz bandwidth at 1-2 GSa/s, and 150 MHz bandwidth at 0.5-1 GSa/s. The on-board, high-speed FPGA handles real-time data processing tasks. A firmware option supports SAR-based data buffering.

www.agilent.com/find/U1071A

Choose the best data bus

The most demanding applications require an imposing combination of high channel counts, wide bandwidths, long durations and a potentially massive volume of data. In such cases a solution can be streaming directly to disk via high speed backplane or optical data links.

The Agilent Acqiris U1080A cPCI digitizer includes front-panel optical data links that can connect to an external disk through a fiber optic link. When using these optical data links, the U1080A firmware allows streaming of all acquired data with no dead time and no loss of data at rates of up to 2 GB/s using the Serial FDPD protocol.

Featured module: U1080A high-speed cPCI digitizer with on-board FPGA processing

This module provides 8-bit resolution on one or two channels and is available with 1 GHz bandwidth at 1-2 GSa/s and optional optical connections for data streaming. The on-board, high-speed FPGA is reconfigurable for on-the-fly real-time analysis.

www.agilent.com/find/U1080A

Conclusion

The system configurations and bottleneck remedies described here can help you achieve gap-free recordings of continuous or triggered signals from one or more digitizers. A detailed analysis of your application, its requirements and the available technology can lead to the creation of well-tailored and dedicated solution.

An alternative approach is to factor in the maximum requirements in all dimensions—number of signals, frequency range, sampling rate, duration, and so on—and pad those values with headroom for future needs. The next step is to then configure a high-performance system that can be easily enhanced or expanded through the addition of, for example, faster digitizers and larger disk drives. Eventually, even this system may struggle to keep up with your measurement needs. At that point, the techniques mentioned earlier—apply data reduction, use data buffers, avoid the backplane, choose a more suitable bus—may once again prove useful.

www.agilent.com/find/digitizers

Related information

More information is available online at www.agilent.com/find/digitizers. A few key products are especially relevant to the creation of solutions for applications that require continuous recording of data:

- Agilent M9202A: 12-bit PXIe IF digitizers, Agilent publication 5990-6302EN
  http://cp.literature.agilent.com/litweb/pdf/5990-6302EN.pdf
- Agilent U1071A: Acqiris 8-bit high-speed PCI digitizer, Agilent publication 5989-7100EN
  http://cp.literature.agilent.com/litweb/pdf/5989-7100EN.pdf
- Agilent U1080A: Acqiris 8-bit high-speed cPCI digitizer with on-board signal processing, Agilent publication 5989-7122EN
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The Modular Tangram

The four-sided geometric symbol that appears in this document is called a tangram. The goal of this seven-piece puzzle is to create identifiable shapes—from simple to complex. As with a tangram, the possibilities may seem infinite as you begin to create a new test system. With a set of clearly defined elements—hardware, software—Agilent can help you create the system you need, from simple to complex.

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Revised: October 14, 2010

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Printed in USA, May 20, 2011
5990-7734EN

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