High Speed Data Recording for Defense Systems

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The High Speed Data Recorder was designed to address the high speed, high channel count data acquisition needs of the Defense Threat Reduction Agency (DTRA). In the interest of national security, the United States Department of Defense pooled its resources, expertise and capabilities to create DTRA. The role of DTRA is to ensure that the United States remains capable of deterring, reducing and countering the present and future threats from Weapons of Mass Destruction. One of the many roles of DTRA is to evaluate the lethality of conventional, biological, chemical, and other advanced weapons against a broad spectrum of target types in real-world scenarios.

Introduction

DTRA issued a request for proposal for developing a high-speed data recorder for recording the data from explosive events. The requirements stated that the system be a Windows-based rack-mountable system that would allow them to acquire simultaneously triggered and sampled 16-bit data at one million samples per channel per second from 64 channels for at least 30 minutes. All sampled channels were to be over-sampled at up to 8x with an input signal impedance of 10k .

In addition, it was required that the system accept Global Positioning System (GPS) and/or IRIG B input signals so as to provide highly accurate data time-stamping. It was also essential that the system be fully programmable to incorporate any future modifications and so as to accommodate additional data acquisition cards for expanded channel counts and/or software functionality expansion. With a variety of proposals submitted for review, B & B Technologies, Inc (now NTS Test Systems Engineering (TSE) was chosen for having the most technically acceptable solution at the lowest offered price.

The solution was to use National Instruments' LabVIEW version 6.1 programming language to talk to and control a variety of hardware from a number of different manufacturers. NTS TSE assembled a system consisting of two high-speed PCI analog data acquisition cards from Interactive Circuits and Systems, Ltd (ICS) coupled together with a PCI based high speed digital data management and recording device manufactured by Conduant Corporation aptly named StreamStor. In addition to the aforementioned cards, a KSI Corporation PCI GPS card was implemented to accomplish the time stamping of the data.

All of the aforementioned hardware was enclosed in a product also manufactured by Conduant called the (Tape Killer) TK200, which is sold in conjunction with the StreamStor product to provide a versatile digital alterative to using analog tape recorders. The TK200 consists of a standard high-performance PC motherboard with two removable drive banks each capable of housing eight IDE hard drives. All hardware will be explained in greater detail under the Solution heading of this document.

The Challenge

Prior to the inception of this system, DTRA had been using high speed analog tape to record test data which was cumbersome to operate for storage, retrieval and archiving and couldn't provide the same reliability, speed or archiving ability as today's digital technology.

With a data acquisition rate of 1MHz per channel on 64 16-bit channels for a minimum of 30 minutes, the biggest challenge was collecting and storing all of the data to disk. With a data throughput of 128MB/s (64 channels*1,000,000 samples/sec*2 bytes/sample) from the data acquisition cards, it was clear that standard PC architecture would not be a feasible solution. In addition, the storage of data at that rate for a minimum of 30 minutes would require at least 230GB of data storage.

With a standard test day involving several tests, calibration routines and other validation procedures, it was essential that all stored data be easily retrievable with respect to the test start time. For this reason, GPS time stamping of events was mandatory to provide an easy method of retrieving data from any point in the entire run of test data.

The NTS Solution

DTRA's requirement of recording phase synchronized, simultaneously triggered, high frequency vibration data on 64 channels with GPS time stamping of events required that NTS TSE seek out and implement the latest technology in data acquisition and storage devices.

Hardware

The time stamping of events was accomplished using the TPRO-PCI GPS card from KSI which allowed for a TTL level input signal to be input to its Time Tag Input function thereby buffering a GPS timestamp for every TTL pulse received.

Providing an accurate GPS timestamp was essential for rapid retrieval of various events during the data acquisition and recording process as there were to be various stages of the test such as a calibration routine or one of the explosive events. At the start of acquisition, a TTL pulse is issued to the GPS card to record the start time and then additional pulses are issued for each subsequent event in the recording process. Due to the extremely short duration of the events, the lengthy recording time and the precision required, it was essential that the operator be able to pinpoint each event in the data stream.

On the acquisition side, the system required 64 16-bit channels that could be simultaneously triggered and sampled at rates of at least 1 MHz. NTS TSE found that ICS manufactured an ADC card called the ICS-645 which provided 32 channels of simultaneously sampled 16 bit data driven by ADC clocks capable of running at speeds up to 20MHz. The ICS cards contained a local port data port (called the P4 port), which could be used to pass timing and triggering signals to other ICS-645 cards over a 26-pin ribbon cable.

The P4 port allows the user to connect multiple ICS-645 cards together in a Master, Mid-Slave and End-Slave configuration where the Master boards shares its timing and triggering signals with each of the other cards in the system. This creates a seamless array of data acquisition channels all running off the same ADC clock and trigger signal thereby meeting the requirement that all channels be sampled and triggered simultaneously.

Being able to acquire the data at such a high rate was the easiest hurdle to overcome, but getting the data off the boards and stored to disk was a much more challenging task. The ICS card and supporting drivers provided the user with two options for data retrieval. The first option available is to pull the data off the PCI bus, into system memory and then to disk; but with the quantity of data required; this was not possible even with the fastest of computers. The ICS-645 card also provides an additional 80 pin port called the Front Panel Data Port (FPDP) which provided the ability to transfer 32 bit (4 byte) words at rates of up to 40 MHz resulting in a maximum data throughput of 160MB/s.

With each sample from each channel requiring 2 bytes of memory, the user can specify that the ICS boards "pack" the data where two samples from adjacent channels are sent in each 32-bit word transferred on the FPDP bus. When configuring the ICS-645 cards, the user can also specify the cards in a Master, Mid-Slave and End Slave configuration as with the P4 local port. This permits the Master ICS-645 to control the transfer of the data from both of the data acquisition cards thereby meeting our throughput requirement for getting the data off the card.

With the availability of the FPDP bus to transfer data at the required rate, the most important task was to find a means to read and store this data from the FPDP bus. This led us to Conduant's StreamStor PCI-816XF digital recorder, which can read data off the PCI bus or directly from its FPDP data port at sustained rates of up to 200MB/s. The StreamStor is a digital data recorder which records to disk any and all data it receives, in the order in which it receives it, to an array of up to 16 standard IDE disk drives.

The StreamStor recorder is located at the end of the 80pin FPDP cable and with the ICS boards managing the data packaging; the recorder receives and stores this data to its array of disk drives. The StreamStor device, specifically designed for real-time data recording and playback, acts as an extremely efficient Hard Disk Drive (HDD) controller to stripe the data to as many drives as are hooked up to the card. In this application, 16 120GB IDE drives were connected to the data recorder card providing just under 2 Terabytes of storage or at the prescribed data throughput rate of 128MB/s; just over 4 hours of consecutive storage. Of note is that with the advent of 200GB disk drives, the test duration can be extended to almost 7 hours.

With all core components selected, the Conduant TK200 chassis was chosen to house the hardware, disk drives and other components. The TK200 consists of a standard Windows-based high-performance PC complete with CD-RW and floppy drives, USB ports, six open PCI slots for data acquisition, data storage, GPS or any other required devices. The TK200 also provides two bays to house the data storage drives all in a convenient rack-mountable chassis. Each drive bank contains 8 drives and is easily removed from the system for data archiving and can be seamlessly re-inserted into the system to access a previous run of data.

In addition to the aforementioned components, NTS TSE assembled several BNC patch panels to provide easy connection and access for the input signals as well as an integrated LCD display, keyboard and mouse to create the complete system as shown in Figure 1 below.

Figure 1

Software

With all hardware components selected, National Instruments' LabVIEW software was chosen to talk to and control the entire test process. DTRA did not specify any significant requirements for the user interface or system functionality, other than to provide the ability to specify several key test parameters and allow for the retrieval of data. It is significant to note that the capabilities (and subsequently the complexity) of this system were greatly reduced by assuming many test parameters as constants to meet the very specific test needs specified by DTRA.

Some of the more obvious parameters that NTS TSE intentionally excluded from the LabVIEW software and that the user was not given control over include the number of channels to acquire, internal or external triggering, scaling in addition to many others. In subsequent software written for similar systems, NTS TSE has incorporated the ability to manage many of these features in a customized user interface. An example of added functionality is applications with user-specified scan rates approaching the ICS-645 maximum scan rate of 20MHz with a reduced channel count while permitting hardware (external) or software (internal) triggering.

Upon launching the software, a great deal of card initialization and setup is performed that is transparent to the user and then the main panel appears as shown in Figure 2 providing the user with
the means to setup and initiate a test.

Figure 2: Software Main Panel

From the main panel, the user is given the ability to initialize the KSI GPS card that launches a new screen and a procedure to ensure that the TTL input to the GPS card is functioning properly and that the queue of triggered events is empty. After initializing the GPS card, the user proceeds to the System Setup, which allows the user to specify a scan rate, over-sampling, file path location for the event time stamps and several other key test parameters. Once performed, the software returns to the main panel for the user to then arm the system to await an external trigger.

Once triggered, the system begins acquiring data at the prescribed rate and the data is written to the StreamStor device. It is significant to note that even with data streaming to disk at such high rates over the FPDP bus; data can also be viewed real-time without interrupting the data stream to disk. This is done by setting up the system to stream the data over the FPDP bus to the StreamStor device while also setting the system to read data from the PCI bus. In essence, the ICS-645 can be set up to send the same data at the same moment to both the FPDP bus and the PCI bus.

One of the outstanding feature of the TK200 system is that there is no burden placed on the PC even with the massive amount of data (128MB/s) being transferred to disk during a recording. Once the acquisition boards are triggered and data is flowing over the FPDP bus; no further operating system or software intervention is required to maintain the data flow until the user wishes to stop acquiring data. This permits the operating system to perform other tasks or for software to be written to analyze or display real-time data pulled off the PCI bus without interrupting the data flow to disk.

While data is streaming to disk, the user is given an indication on the main panel, in MB (or test time elapsed), how much data has been collected since the trigger was received. During the test, the user can issue further TTL pulses to the GPS card to mark important instances during the recording process. With the desired amount of data collected, the user can then stop the test from the main panel by pressing the Stop Acquisition button which returns all cards to their default state and prepares them to run another test.

With the data collection completed, the user is able to retrieve data from the recorder and store it to the system disk(s). Upon pressing the Fetch Data button, the software launches the Fetch Utility shown in Figure 3 which gives the user the ability to retrieve any amount of data from any location in the record and store it to as many files on the system disk as desired. The data is fetched from the StreamStor device in its raw form and simply written byte by byte to the specified file.

The Fetch Utility provided to DTRA provides no ability to extract data from individual channels, but software has been recently written in LabVIEW by BBT using the Application Programming Interface (API) tools provided by Conduant to extract data with greater ease. For example, knowing the event times, a user interface can be created to extract certain segments, from specified channels, from a particular event with only a few mouse clicks. By providing this functionality, the user can avoid having to calculate the specific byte (using the scan rate and elapsed test time) corresponding to the event in question.

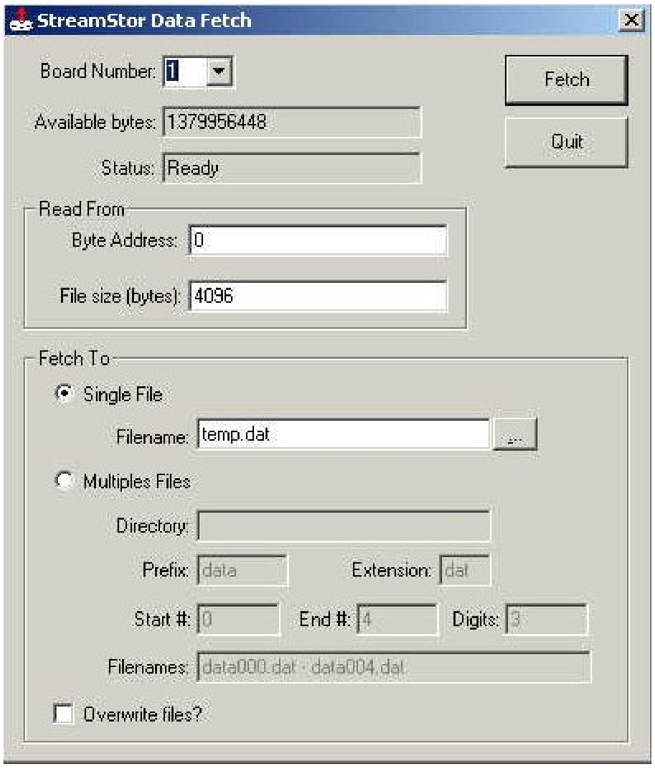

Figure 3: Fetch Utility

After fetching the desired data to the system drive for post-processing, the user can then run a new test or view the retrieved data on a simple graph by pressing the View Data button from the main panel. Once pressed, the Data Viewer (shown in Figure 4 below) is launched to allow the user to view the data from any of the retrieved data files. At the customers' request, the Data Viewer provides no data analysis tools and is merely a display of the data contained in the specified file as a tool to verify that data was accurately recorded.

As previously mentioned, the data is written in its raw form to disk and as a result, when reading data into any software package such as LabVIEW, the programmer must write an extensive algorithm to convert this raw data. Since the data is written as unsigned 32 bit words containing two channels worth of signed data, the programmer must extract each channel and scale the data to the desired voltage or signal levels.

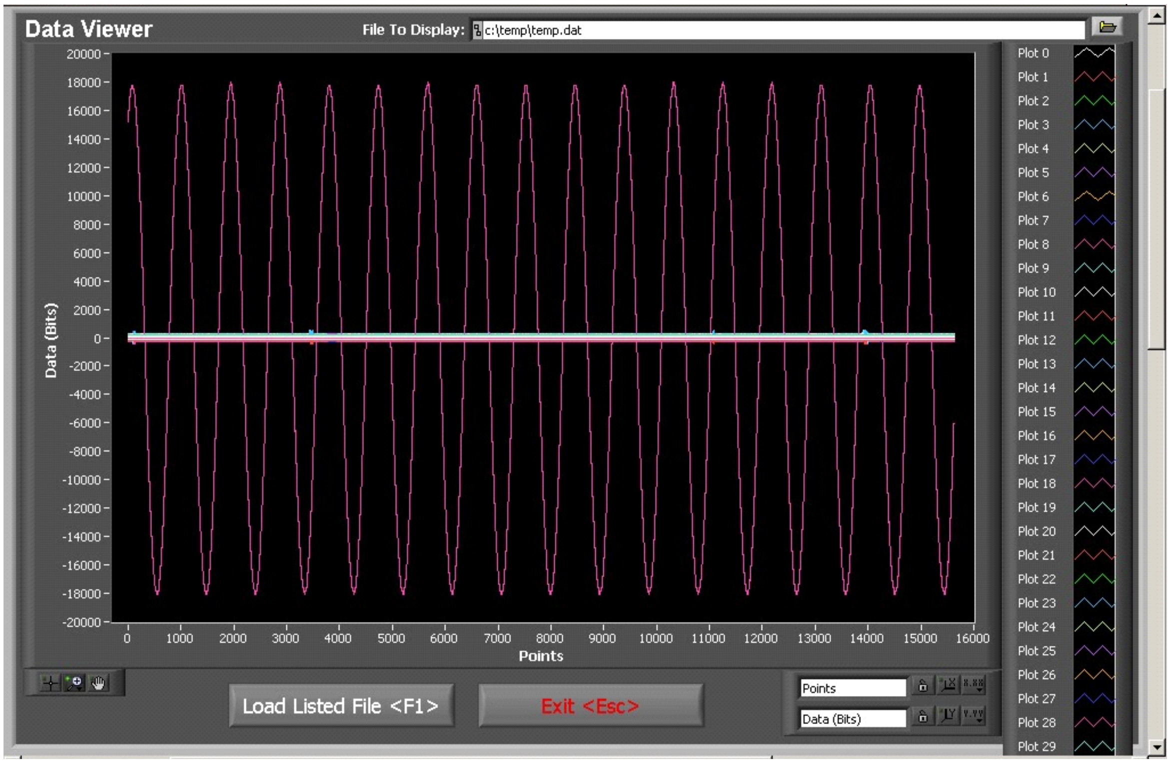

Figure 4: Data Viewer

Conclusions

After a great deal of testing and debugging, two identical High Speed Data Recorders were successfully delivered to DTRA. Each system was capable of scanning 64 16 bit channels at 1MHz for over 4 hours. With the implementation of these systems, DTRA has replaced its old analog tape systems and now has an easy-to-use, robust solution that allows them to confidently acquire and digitally store accurate, synchronized test data. Furthermore, DTRA is now able to maintain and archive digital test results that can be rapidly called upon at any time for further analysis or review.

The system and all devices discussed in this article met our customers' needs, but it is important to realize that this system has a great deal more potential than was utilized in this application. NTS Test Systems Engineering can and has successfully implemented similar systems utilizing and expanding upon the immense processing and acquisition potential of this system. Additional LabVIEW software can be written to tailor this system to nearly any application while providing a great deal of functionality in an easy-to-use software package.

About NTS Test Systems Engineering

NTS TSE, located in Albuquerque, NM, designs and integrates test, measurement, automation, data acquisition and control systems utilizing diverse hardware platforms, operating systems, and instrumentation standards. Our expertise involves projects ranging from LabVIEW instrument drivers to full-blown automated turnkey systems. The dedicated staff of electrical and mechanical engineers, project managers and technicians of NTS are well versed in designing, integrating and programming real world solutions for industrial applications for a diverse set of operating systems and standards.

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