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A Unique Portable Signal
Acquisition/Processing
Station

Robert D. Garron
Stephen G. Azevedo

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A UNIQUE PORTABLE SIGNAL ACQUISITION/PROCESSING STATION

Robert D. Geron
Stephen G. Asaveo

Lawrence Livermore National Laboratory
May 16, 1983

Summary

At Lawrence Livermore National Laboratory, there are experimental applications requiring digital signal acquisition as well as data reduction and analysis. A prototype Signal Acquisition/Processing Station (SAPS) has been constructed and is currently undergoing tests. The system employs an LSI-11/23 computer with Data Translation analog-to-digital hardware. SAPS is housed in a roll-around cart which has been designed to withstand most subtle EMI/RFI environments. A user-friendly name allows a user to access powerful data acquisition packages with a minimum of training. The software architecture of SAPS involves two operating systems, each being transparent to the user. Since this is a general purpose workstation with several units being utilized, an emphasis on low cost, reliability, and maintenance was stressed during conception and design. The system is targeted for mid-range frequency data acquisition; between a data logger and a transient digitizer.

Introduction

The data acquisition requirements at the Lawrence Livermore National Laboratory (LLNL) are many and varied. Data may have to be acquired in remote areas with harsh environments. Some data is collected in the presence of high electro-magnetic and/or radio-frequency (EMI/RFI) interference. In most cases, the data must be converted to digital form, archived, displayed, processed, reduced, and analyzed before becoming meaningful to the experimenter. Sometimes real-time processing or control is required. However, all of the time, the costs of the acquisition system must be minimized.

Currently, most data is collected on analog media (tape, chart recorders, oscilloscopes, and other devices) and digitized at a later time by a central data reduction facility. This is because it is costly and impractical to design new collection equipment for each "one-shot" experiment that takes place. With the cost of computer equipment and storage devices dropping rapidly, it is becoming much easier and less expensive to have dedicated computers handle the acquisition task. The "turnaround" is accelerated from weeks or sometimes months to minutes or seconds. In addition, the computer makes real-time control and processing available to the user.

We have designed and built a prototype Signal Acquisition and Processing Station (SAPS) to meet the needs mentioned above for most of the LLNL applications. The system is meant to be:

- (1) easy-to-use ("user-friendly", "turn-key") so experimenters may utilize its capabilities with minimal instruction,
- (2) portable to use anywhere without harm or data loss,
- (3) inexpensive to clone,
- and (4) contain the software tools to perform data display, storage, processing, reduction, and analysis.

This paper will first discuss the motive for the development of SAPS, followed by the philosophy overruling during its design. Some details of the design are highlighted to illustrate the design approach. The architecture and implementation considerations, both hardware and software, are then presented.

Reasons for Development

The impetus for the development of the Signal Acquisition and Processing Station was the lack of a commercially available unit which satisfied our specifications. The immediate need was for a data acquisition system which was capable of continuous mid-range (100 K samples per second) data collection. The term "system" is defined here as a turn-key unit which allows a novice to perform a function without having to write any code or to be a computer literate. Many companies exist which manufacture data acquisition hardware and even pseudo-systems, a unit which after purchase requires additional code and configuration, but there is no complete "off-the-shelf" system. Only recently are several companies addressing this problem with new technology.

Our requirement was to collect continuously to disk a minimum of 15 megasamples of data, distributed over 8 channels at a sample rate of 20,000 hertz per channel. After collecting the data, it had to be reduced and analyzed in the field. This mandated that a portable system, which included the proper signal conditioning capability, data acquisition hardware, operating system(s), and necessary data reduction/analysis software be available for the job.

General Design Philosophy

The design goal of the Signal Acquisition and Processing Station was to provide a general "tool" for data acquisition at LLNL. This idea stemmed from the fact that others at the Lab found themselves faced with similar requirements to those we had encountered. The tool concept was incorporated because it permits a particular function to be capitalized upon while allowing the implementation to be user transparent.

The station needed the ability to handle 128 channels of data capture in a multitude of configurations. For example, the user may configure the 128 channels to record at a rate of 2,000 samples per second, or a 128-channel configuration may have 120 channels recording at 10 samples per second, 4 channels at 1,000 samples per second, and the remaining channels at 10,000 samples per second.

The design approach was the top-down technique which provided the ability to view the system as the integration of many elements. This approach permitted consideration for the user interface and special attributes which were to be included in the

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Figure 1. This figure illustrates the architecture of SAPS, while the A/D configuration, filters, and slave design are highlighted. Note that all of the software, hardware, and attributes available to the LSI-11/23 computer can be utilized by SAPS.

design. The user interface was seen as an important factor in the success of the system, since many different operators would be responsible for the system's operation. Several constraints imposed upon the design, most notably cost, prevented the installation of the ideal user interface. In any case, a dynamic menu system was designed for use with the available hardware since it best satisfied our constraints.

The housing for this system was a considerable challenge. Several of the system's attributes required extra attention. EMI/RFI hardening was one such attribute because of the potential that a portable system has in operating in many different environments. The SAPS operating environments could include areas which have strong magnetic and electric fields, electromagnetic pulses (EMPs), and other radiated phenomena. This presented some acute problems to overcome during implementation. Another system attribute was the power distribution and the necessity for proper grounding. The philosophy here was to provide an environment which suppressed spikes, noise, brown-outs, and ground loops, and at the same time allowed precise regulation and even loading. Other considerations that affected the design of this structure were weight, size of components, heating limits, air flow, protection levels, safety, maintenance procedures, and portability.

As with any project, the desire to minimize cost was a criteria. The system was configured to provide a cost versus performance design which would promote further interest at LLNL. In the final analysis, the entire system was less than \$60,000 and was able to satisfy the desired specifications.

Architectural Overview

The architecture of SAPS is shown in Figure 1. This architecture is explored below from a hardware point of view followed by a software perspective.

Hardware

Two computers with 64 differential analog input channels in each form the base of SAPS. The signal lines pass through filters, which can range from single-pole noise filters to GP18 programmable multipole, multizero elliptic filters, and proceed into the A/D system. Computer B is slaved to Computer A by a clock line only. This architecture precluded the need for software to control a slave computer. An advantage of this configuration is that Computer B contains identical software and hardware to Computer A. This permits Computer B to operate as an independent 64 channel data acquisition system, like Computer A. Note that this ability allows for additional expansion. For example, any configuration may be realized with

either Computer A or Computer B or other SAPS posing as slaves.

The data acquisition subsystem used was Data Translation's Lab Data Unit. Their advanced architecture boards have proved to be the state of the art in digital computer data acquisition. The A/D boards have many desirable features such as the ability to specify the sampling frequency and signal gain on a per channel basis. Each computer also contains several D/A converters (not shown) which can provide real-time data output capability. Another advantage is that the software package included allows multiple real-time clocks. This feature provides the ability to operate up to four boards independent of one another. Note that each computer may contain 128 channels, but performance dictated that two computers be utilized to obtain the desired speed.

The storage system of each computer includes a permanent soft-sectored Winchester, a double-sided, double-density floppy, the capability of installing a tape unit, and 256 kilobytes of main memory.

The first step of implementation was to review the pseudo-systems in the marketplace and determine if an integration of the available components was feasible. This review of industry products acknowledged that off-the-shelf components were available to satisfy most of our requirements. For a variety of reasons, i.e., cost, compatibility with existing machines, available software, and others, the DEC LSI-11/23 was chosen as the computer of SAPS. The laboratory is well supplied with support and resources for DEC equipment. As new hardware is introduced, for example, a VAX on a chip or M68000 on a Q-BUS board, the SAPS system may be easily updated. By using the LSI-11, SAPS is capable of communicating with other SAPS in a nodal network via DECnet. This will prove to be useful in field operations.

Software

The heart of this system, as with any computer system, is the associated software. The architecture is composed of a shell which encompasses a layered inner structure. The menu system, mentioned earlier, masks the software packages, operating systems, and application programs from the user. Menus may be traversed in any particular order from any menu to any other menu by the touch of a button. This is realized because the menu system is a command processor and parser of text files merged into one package. This structure allows software growth with respect to features available to the menus, and user growth in that a user may define his own menu linking scheme.

SAPS employs several software engineering techniques that have proved successful over the past

decade: (1) the idea of an interactive menu, which may be easily altered by the user, (2) modularity throughout the system code, (3) memory and disk management techniques, such as space allocation and position allocation, (4) data base management techniques; for example, the signal analysis packages have their own data bases, and (5) proper selection of operating systems to complement the requirements and specifications requested.

SAPS has two operating systems supplied by DEC, RT-11FS and RXX-11N. There are two operating systems because several important signal analysis packages execute under RXX and the data acquisition software executes under RT-11. Having multiple operating systems definitely increased the complexity of the station, but obviated the necessity of redesigning and coding software to function under either operating system.

The Winchester disk is divided into four logical devices, with space allocated to match the projected usage, in order to accommodate the two operating systems and their associated data. The Scientific Micro Systems (SMS) floppy/Winchester device drivers used with each operating system were modified to allow multiple bootstraps to reside in any block on the disk. DEC drivers only allow a bootstrap to reside at block zero. An implementer should note that other software is affected by this alteration, such as the RXX file transfer utility (FLX). The reason for this is that DEC uses a device table in their utilities.

A desired feature for SAPS was to have the ability to reproduce other SAPS cheaply and easily. This was accomplished by further modification of the drivers and software in order to permit Winchester to Winchester copying. In essence, there are two software drivers to operate the two disks in question. Copying 40 megabytes may be achieved in less than ten minutes.

Application packages available for SAPS are: (1) advanced signal processing programs (SIG, ANALYZE), (2) control programs, (3) diagnostic programs, (4) test programs, (5) a learning program with examples, (6) setup and initialization programs, and (7) communication programs.

Conclusions

We have presented the design for a low-cost, portable signal acquisition and processing station to be used in a variety of applications at LLNL. The software and hardware have been assembled with an emphasis on low-cost, reliability, ease-of-use, and maintainability. SAPS is housed in a roll-around cart which has been designed to withstand most subtle EMI/RFI environments. The software is provided for data storage, graphical display, processing, reduction, and analysis.

Figure 2. Steve Azevedo exercising one of the Signal Analysis Packages included within the software library of SAPS.

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