

INTERFACING LABORATORY INSTRUMENTS TO MULTIUSER, VIRTUAL MEMORY COMPUTERS

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INTRODUCTION

Computers based on virtual memory, multiuser architecture have recently become economically available to medium sized research groups (about 25 members). These new computers offer advantages to the experimentalist, though acceptance has been sometimes limited. One of the most important advantages of a virtual memory machine is the capability of fast access to arrays having dimensions greater than 64 kbytes. Arrays larger than 64 kbytes were available on some older computers based on physical memory. The access time to the memory beyond 64 kbytes is extremely slow for these systems. Fast access to large arrays is particularly important now where large data sets are required for research systems.

Many researchers are accustomed to a dedicated computer running a single-user operating and data acquisition system. When there are several experimentalists in a research group, the advantage of a multiuser system becomes important. The resources a computer provides can be shared among the users at a much lower cost than that of maintaining a separate dedicated computer and peripherals for each project. Software routines for instrument control and data acquisition as well as data bases are sharable resources. Expensive hardware resources, such as array processors, images processors, terminals, printers and color plotters can also be shared.

There are difficulties in assembling the hardware and software facilities required for a multiuser, experimental research oriented system. The single-user operating systems typically use built-in commands for easy instrument communication and other functions well suited for the experimenter's needs. A multiuser computer's input-output capabilities are more powerful but harder to understand. The user is left with the responsibility for bridging the gap between the capabilities provided and his particular needs for data acquisition and communication with devices.

The general purpose interface bus (GPIB) is used extensively in single-user computer systems for data acquisition and instrument control. For single-user systems the software for data acquisition and instrument control is often provided by the manufacturer of the system. This same bus can be used in a multiuser system; however, the necessary software is not provided. This lack of software has been a major obstacle for researchers and has prevented them from moving from a single to a multiuser virtual memory system.

In this work we will provide the reader with the information required for developing a multiuser computer system that meets the needs of a medium sized research group. The basic computer system and its components are described. Specific examples of GPIB instrument control and data acquisition with a multiuser system are described for use in both BASIC and FORTRAN programming. Additionally, a collection of high and low level subroutines for computer controls of instruments have been cited in the references.

COMPUTER SYSTEM AND INSTRUMENTS

Computer System

A computer system for a research group has several components. Figure 1 shows a block diagram of a balanced computer system specifically designed for an experimentally intensive research group. There are three central processing units (CPU's) in this configuration, each with 16 Mbyte memory, and two, 474 Mbyte, hard disks attached. The second hard disk is for backup of system and user software. Generally 16 Mbytes of memory is required for the processing of large data arrays. Each CPU (subsystem) has a major specific function. CPU 1 is designed for data analysis and contains an array processor for fast Fourier transformations. In addition, CPU 1 shares an image processor with CPU 2 for display images viewed with the image processor. CPU 2 is designed for image analysis and display. The 32 Gbyte optical disk drive provides easy access and storage of images. CPU 3 is designed for data acquisition and contains eight GPIB channels (ports) and an analog to digital (A/D) input/output interface with 16 channels. Up to nine users can use the third CPU simultaneously for data acquisition. Of course A/D interfaces may be added for additional users. Alternatively, fewer users could run multiple experiments simultaneously.

It is important to note that, although each CPU subsystem has been designed for a specific function, it is not limited to that function. Therefore, CPU's 1 and 2 also have GPIB and A/D interfaces. As shown a total of 15 researchers may acquire data or control instruments simultaneously via the GPIB or A/D interfaces. Equally important to the number of users working with the instruments is that additional users may be simultaneously analyzing data, image processing, developing software and generating reports.

The three CPU's are connected via an Ethernet connection for easy transfer of files between systems. A terminal server connected to the Ethernet allows for multiuser, remote access to each of the CPU's. This remote access allows researchers to have terminals and instruments placed at different locations throughout the site. Off-site access to the system is permitted via modems attached directly to the CPU or Ethernet. Modems are used for initiating, stopping or checking the status of an experiment on evenings or weekends.

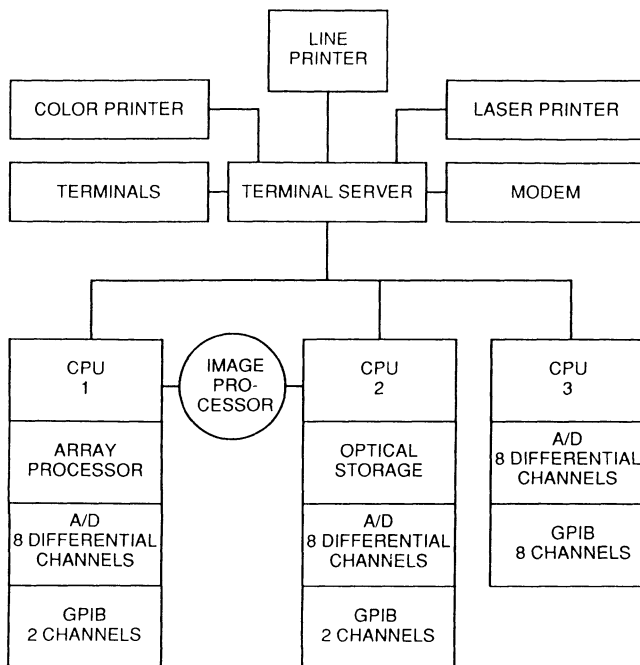


Figure 1. - Computer system.

INSTRUMENTS

A variety of instruments may be attached to the GPIB interface. It is this interface that is often the stumbling block in meeting the researchers' needs. The problem is two-fold for a multiuser system. First, the GPIB has a limit on total length of 29 m. One cannot expect to have all experiments taking place in one location (i.e., room, building, etc.); therefore, the need arises to extend the GPIB beyond this limit. Second, friendly software for multiuser, virtual memory, GPIB based instrument control and data acquisition is not available.

A typical configuration for a nondestructive evaluation research group is shown in Figure 2. Several research instruments including ultrasonic, x-ray tomographic, and tunneling scanners are attached to the computer system. Recently, GPIB extenders have been made available from several manufacturers. By using bus extenders, these instruments may be placed at locations remote from the CPU's. The GPIB extenders are transparent to the researchers' software so that no software modifications are needed.

The software required to control these instruments and for data acquisition is the most complicated of the two problems and for this reason it will be presented in detail.

Programming the components of the precision acoustic scanner system (PASS) covers a wide range of software problems encountered when connecting instruments to a computer via the GPIB. We will focus on this system, as it represents the most common problems.

The components of the precision acoustic scanning system (PASS) are shown in Figure 3. The specimen to be interrogated is mounted on an X-Y-Z

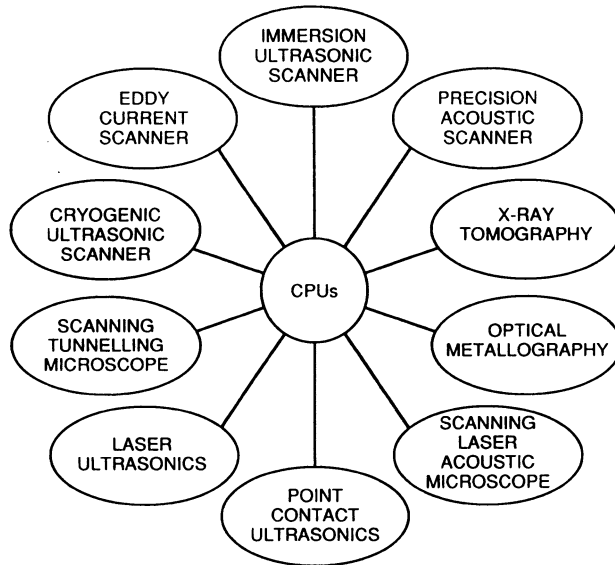


Figure 2. - Instrument configuration for a nondestructive evaluation research group.

positioning table. In contact with the sample is an ultrasonic transducer mounted on a displacement pressure gauge. A couplant is used between the transducer and the sample to provide good acoustic coupling. During operation the positioning table is moved to a series of points that describe an array. A vibrator (made from a modified electric scribing tool) attached to the transducer is excited during movement of the X and Y axes. This vibration allows free movement of the transducer over the sample while maintaining intimate contact between transducer and sample. This is done while maintaining a constant pressure between the transducer and specimen. At each point ultrasonic waveforms are selected, digitized and stored for later analysis.

The PASS has the following six components that communicate over the GPIB: three positioning tables, waveform digitizer with a time base and voltage base, time delay and voltmeter. The programming for this rather complex scanning system contains all of the features needed for adaptation to other computer controlled systems.

PROGRAMMING FOR INSTRUMENT CONTROL AND DATA ACQUISITION

In this section a fundamental program, written in FORTRAN, is presented that operates the PASS. The subroutines for this program are provided in [1].

Initially a GPIB channel is assigned to the precision acoustic scanner. Here a channel represents a physical GPIB port on the CPU.

The FORTRAN statement

```
CALL STRTGPIB (0)
```

initializes channel 0. Any instrument addressed subsequently in the program will communicate through channel 0. Next each component of the scan-

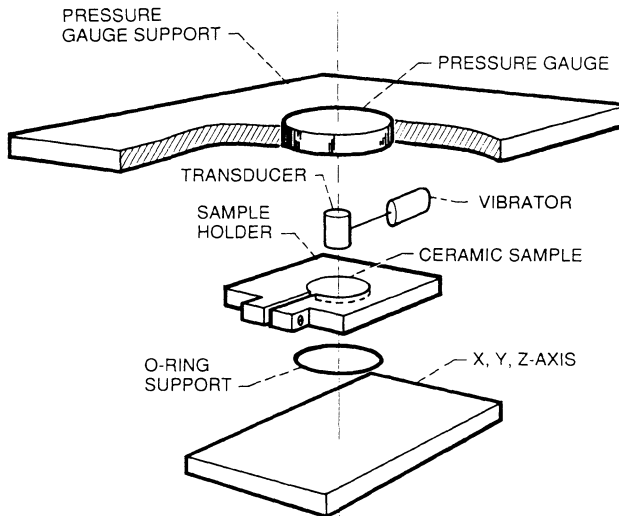
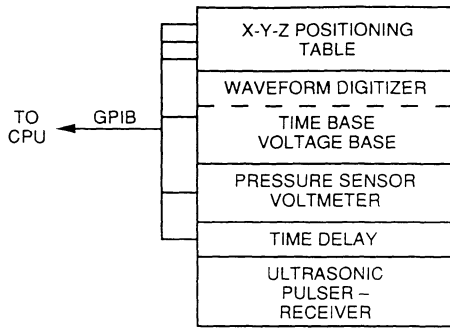


Figure 3. - Precision acoustic scanning system (PASS).

ning system must be initialized. There are six components, and their physical addresses have been adjusted to be contiguous from 32 to 37. These are also called addresses 0 to 5 where it is implied that the standard base GPIB address of 32 is to be added. The physical addresses for the digitizer, time delay, X-axis, Y-axis, Z-axis and voltmeter are set by the researcher at 0, 1, 2, 3, 4 and 5, respectively.

```
DO 10 NUMBER = 0, 5
CALL INITINSTR (NUMBER)
10 CONTINUE
```

As indicated earlier, the specimen is scanned in an organized array in the X-Y plane. The step size in the X,Y and Z directions are stipulated by the user as

```
XSTEP = 100
YSTEP = 100
ZSTEP = 10      ! the Z-axis will not be used for this
                ! template. But an argument is
                ! required for these subroutines.
```

and sent to the X-, Y- and Z-axis of the positioning table

```
CALL SETXYZ (2, XSTEP, 3, YSTEP, 4, ZSTEP)
```

where 2, 3 and 4 correspond to the X, Y and Z positioner axes. The ultrasonic waveform needs to be digitized and stored. The ultrasonic wave occurs at a specific time and is set by the time delay subroutine

```
CALL SETDELAY (1, DELAY(1))
```

where the first argument is the address of the time delay. DELAY(1) is the time delay required to place the ultrasonic wave within the digitizing window. The volts and time per division of the time and voltage base are set

```
CALL PUTTIME (0, SETTING)  
CALL SETVOLTDIV (0, SETTINGS(1))
```

where the first argument is the primary address of digitizer that contains the time and voltage bases. The SETTING and SETTINGS(1) are the proper time and voltages per division for displaying the ultrasonic wave in the digitizing window. The actual digitization of the ultrasonic waveform occurs with the command

```
CALL GETSA (0, 64, 320, A)
```

where the first argument is the address of the digitizer and 64 is the number of samples that are to be averaged, 320 is the intensity of the writing beam in the digitizer and "A" is the array that will contain the digitized waveform. The waveform is saved to a file opened as unit 6 with

```
WRITE (6) A
```

After a waveform is collected at one point, another point is selected with the X-Y-Z positioning table with

```
CALL MOVXYZ (2, 1, 1)
```

where the first argument corresponds to the address of the X-axis. The second argument corresponds to the axis to be moved one step (1, 2 and 3 for the X-, Y- and Z-axis, respectively). If the third argument is greater or less than zero, then the motion is in the positive or negative direction, respectively.

This program would loop back to the CALL SETDELAY statement to complete a scan line. The above FORTRAN source code gives a template for writing other source code. The complete source code for scanning a 5- by 5-mm square area with the PASS is given in [1]. Typical ultrasonic images obtained by use of the PASS are shown in [2] to [4].

Reference 1 also contains a listing and description of each of the user callable high level subroutines used for instrument control. The low level source code for these routines is provided. This source code may be adapted for writing other instrument control subroutines for additional instruments not covered in this work.

The complete program SCAN.FOR must be compiled first

```
$ FORTRAN SCAN
```

and linked

```
$ LINK SCAN, SYS$SYSROOT:[SYSLIB]IMAGELIB/LIB -  
SYS$SYSROOT:[SYSLIB]IEXSUI,OBJ
```

then run with

```
$ RUN SCAN
```

The subroutines provided as well as this and other data acquisition and instrument control programs may be shared with other users. Researchers may also write programs for operating instruments attached to other GPIB channels. With this capability, several researchers may be operating instruments and acquiring data simultaneously. A considerable amount of time is saved by sharing these developed programs.

We have found that, when programs and instruments are easily shared, program development occurs at a rapid rate. This rapid growth occurs because researchers modify each control program to meet their particular needs. In doing so, the fundamental program expands and is fine tuned by all the researchers to form a very versatile system.

SUMMARY

A multiuser, virtual memory computer system was devised and programmed for use by a medium sized research group. Problems associated with optimizing the system for shared, multiuser applications were resolved. Particular attention was given to hardware interfacing and development and compilation of subroutines. The result is a straightforward operating network for instrument control, data acquisition and processing. A comprehensive example program is provided for illustrative purposes.

REFERENCES

1. Generazio, E.R., Stang, D.B. and Roth, D.J., "Interfacing Laboratory Instruments to Multiuser, Virtual Memory Computers," NASA TM-4106, March 1989.
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