MICROCOMPUTERS FOR NUCLEAR INSTRUMENTATION

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MICROCOMPUTERS FOR NUCLEAR INSTRUMENTATION*

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SUMMARY

Small, desk-top Commodore PET® computers are being used to solve nuclear instrumentation problems at the Savannah River Laboratory (SRL). The ease of operating, programming, interfacing, and maintaining the PET computer makes it a cost-effective solution to many real-time instrumentation problems that involve both data acquisition and data processing. The IEEE-488 GPIB (General Purpose Instrument Bus) is an integral part of the PET hardware.

This paper reviews GPIB design concepts and discusses SRL applications that use the PET computer as a GPIB controller.

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INTRODUCTION

Since the development and the commercial introduction of the Intel* 8008 8-bit microprocessor in 1972, SRL has used programmed microprocessor-based digital systems to solve laboratory instrumentation problems. The initial cost of $200 per unit for the Intel 8008 module made it an attractive design component for sophisticated digital systems. Several systems1-3 were designed with this module. Those systems are still used daily and have operated reliably and required very little maintenance.

During the next few years, more sophisticated microprocessors (Intel* 8080, Motorola** 6800, etc.) and supporting large-scale integration (LSI) interface modules and memory modules were available to design engineers. Industry competition and improved manufacturing techniques rapidly reduced the cost of LSI devices. By 1974 many "home" and "hobby" computer systems became commercially available. These ranged in price from several hundred to several thousand dollars depending on capability. These computer systems generally lacked manufacturer software support and peripheral device support. The "home computer" description was somewhat misleading since users needed expertise in both hardware and software. We evaluated several of these systems for laboratory applications, but we concluded that special purpose in-house designs met our instrumentation needs better.4-5

** Motorola, Inc., Box 20912, Phoenix, AZ 85036.
In 1977 self-contained, desk-top microcomputers appeared in the electronics industry market. Commodore Business Machines, Inc., began delivering its PET-2001 computer, which was the first "affordable" integral single package unit for the home computer novice. The single package unit costs $795. The specifications, such as an advanced BASIC* interpreter, were also attractive. Integral input/output hardware and software to support the IEEE-488 GPIB make the PET computer a versatile controller and data processor for laboratory experiments.

DISCUSSION

The PET Computer

The PET computer is designed around the MOS Technology** 6502 8-bit microprocessor. It has a cathode ray tube (CRT) display, compressed keyboard, and cassette tape transport; all three peripherals are integrated into a single desk-top package (Figure 1). Its firmware package (built-in programs) occupies 14K memory addresses which consist of a BASIC interpreter, operating system, and peripheral utility programs. The standard RAM (random access memory) occupies 8K addresses; expansions up to 32K are supported by the firmware.7

* BASIC (Beginners All-purpose Symbolic Instruction Code).

** MOS Technology, Inc. is owned by Commodore Business Machines, Inc., Palo Alto, CA.
- Inexpensive IEEE-488 Bus Controller
- Integral CRT (Cathode Ray Tube) Display
- Integral Keyboard (Compact)
- Built-in Cassette Tape
- 8K (8 × 1024) 8-Bit Random Access Memory
- 14K (14 × 1024) Firmware
  - BASIC Interpreter
  - Utility Programs
- Expansion I/O Port
- $795.00

FIGURE 1. Commodore PET-2001 Characteristics
The PET has three ports to connect I/O peripheral devices (Figure 2). A portion of a peripheral interface LSI module (MOS Technology 6522) is dedicated to a user "hobby" port that allows an 8-bit exchange of data with I/O devices. Also, that port can supply a programmed frequency square wave signal to external peripherals. An expansion port for memory and I/O devices has buffered central processing unit (CPU) signals (data and handshake controls) and decoded 4K page addressing signals. Both the expansion and "hobby" port can be controlled by "peeking" and "poking" from a BASIC program or by a custom machine language program that resides in memory. A short machine program might be loaded from cassette via a BASIC program (for example, as a DATA STATEMENT) or more complex machine programs may be installed as permanent additions to firmware.

The IEEE-488 GPIB port is supported by the BASIC and operating system firmware as the primary peripheral I/O port. It is controlled from BASIC with file structured "print," "get," and "input" commands. Commodore peripherals (printer, disk, etc.) are "intelligent" GPIB devices.

The IEEE-488 GPIB

In December 1974 the IEEE Standards Board approved what is now known as IEEE Standard 488\textsuperscript{9,10} that describes a general purpose instrument bus (GPIB) for programmable instruments. The GPIB is an improved version of HP-IB (Hewlett-Packard Instrument Bus) used with a family of instruments from Hewlett-Packard Co. GPIB uses a
IEEE-488 BUS (GPIB)

PERIPHERAL INTERFACE ADAPTER

CENTRAL PROCESSOR UNIT
6502
MOS TECHNOLOGY, INC.

PERIPHERAL ADAPTER

MEMORY & I/O EXPANSION PORT
- 8-bit data I/O, buffered
- address lines, 10 4K pages
- controls

USER "HOBBY" PORT
- 8-bit data I/O
- controls

FIGURE 2. PET Input/Output Ports
party-line bus structure to which a maximum of 15 devices may be connected. Sixteen signal lines (Figure 3) provide communication of 8-bit commands and data bytes between a bus controller (such as PET and "listener" and/or "talker" devices connected to the bus via a standard cable.

Over 50 manufacturers (Table I) now have GPIB instruments in their standard product lines. For noncompatible instruments, general purpose GPIB couplers are available, such as ICS 4880 Series* that convert RS-232-C** or parallel data to GPIB format. For special purpose "intelligent" interface designs,¹¹⁻¹³ several component manufacturers are marketing LSI GPIB modules (Table II).

SRL Applications

The versatility of the PET computer/GPIB controller makes it a cost-effective solution to many SRL instrumentation problems (Figures 4 and 5). Although our problems encompass a variety of widely different requirements and constraints, one (and sometimes all three) of the PET interface ports can be used to connect the PET to real-time I/O peripheral devices.

A simple application uses a PET and the IEEE-488 bus to control two commercial devices, an Aston*** event scaler and a

* ICS Electronics Corp., San Jose, CA 95112.
*** The Aston Company, Atlanta, GA.
FIGURE 3. IEEE-488 Bus Diagram
TABLE I
Manufacturers of GPIB Instruments

Hewlett-Packard Co.
Systron-Donner Co.
ICS/Fairchild Instrument Co.
Guideline Instrument Co.
Tektronix, Inc.
Fluke Mfg. Co.
Lamda Electronics Corp.
Aston Co.

TABLE II
GPIB Design Components

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Part Number/Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motorola:</td>
<td>MC68488 (6800 Family GPIB Adapter)</td>
</tr>
<tr>
<td></td>
<td>MC3447 (Octal GPIB Transceiver)</td>
</tr>
<tr>
<td>Intel:</td>
<td>8291 (GPIB Peripheral Interface)</td>
</tr>
<tr>
<td></td>
<td>8292 (GPIB Controller Interface)</td>
</tr>
<tr>
<td>Phillips:</td>
<td>HEF 4738V (GPIB Instrument Interface)</td>
</tr>
<tr>
<td>Fairchild:</td>
<td>96LS488 (GPIB Instrument Interface)</td>
</tr>
<tr>
<td>Texas Instruments:</td>
<td>SN75160/161 (Octal Bus Transceivers)</td>
</tr>
</tbody>
</table>
FIGURE 4. PET Computer Connected to IEEE-488 Bus

FIGURE 5. PET/GPIB System
printer (Figures 6 and 7). Events from a gamma ray detection system are automatically counted; sample concentration of Krypton-85 is computed; a formal test report is printed. All programming is in BASIC. Data are also archived on cassette tape so that a more complex data processing program on selected data could be run on the PET later.

A PET is used to control an SRL pulse height analyzer (PHA) via GPIB (Figures 8 and 9). An ICS 4884 serial coupler is used for the 2400-baud communications control link to and from the PHA instrument. Histogram data from the PHA consist of Gaussian peaks representing various gamma emitting nuclear elements superimposed on a background noise baseline. A 5K byte BASIC program provides operational control of the PHA (off, on, selected channels readout, clearing data in memory, etc.) and a brief analysis of data (peak baseline normalization, integration under peak, computation of energy levels and concentration of selected elements). Raw data and results may be printed by the typewriter or saved on cassette tape.

A system has been designed and partially implemented to control and collect data, compute results, and print reports on information from a Princeton Applied Research* (PAR) electrochemical instrument (Figures 10 and 11). The complete system will use GPIB and the memory I/O expansion ports of the PET. Currently, PET monitors and controls a PAR 179/173D instrument and a digital panel.

* Princeton Applied Research Corp., Box 2565, Princeton, NJ 08540.
FIGURE 6. $^{85}$Kr Monitor

FIGURE 7. PET with Krypton Experiment
FIGURE 8. SRL Pulse Height Analysis System (PHA)
FIGURE 10. Electrochem DAS

FIGURE 11. PET/PAR System
meter and an ICS 4883 parallel data coupler. A 9K byte BASIC program operates the system. At a future date, high speed data from a PAR 174 instrument will be monitored by PET over a "direct memory access" channel into the I/O expansion port.

Future applications currently in development phase will use PET with a microprocessor-based analog data acquisition subsystem on the GPIB.

CONCLUSIONS

PET computers are inexpensive, effective GPIB bus controllers. Using GPIB instruments, in-house engineering development is minimized, and therefore, reduces systems cost and implementation time. BASIC programming is easy and final system program is usually written by the experimenter; engineering support will provide I/O subprograms either in BASIC or machine language.
REFERENCES


