

Replacing the HP2100 Computer in US Navy Test Sets

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Abstract - The DOD has a large investment in ATE which has become increasingly difficult and costly to repair due to non-availability of parts and trained maintenance personnel. One example is the AN/DPM-22 Guided Missile Components Test Station, a 1970 vintage test set based on the Hewlett Packard 9500 Automated Test System.

In order to increase the service life of the AN/DPM-22, the US Navy opted to replace the Hewlett Packard 2100S computer and its peripherals with an IBM-compatible 80486. One requirement was to retain the existing test equipment, which has an assortment of IEEE Standard 488 compatible and peculiar parallel interfaces. Another requirement was to minimize the software changes. This paper addresses the hardware and software designs which were implemented to achieve those goals.

I. INTRODUCTION

The AN/DPM-22, Guided Missile Components Test Station, is Automatic Test Equipment (ATE) developed for the US Navy by the Raytheon Company in 1973. It is capable of performing repair depot tests of the Guidance and Control sections of the Sparrow missile, versions AIM-7F and AIM/RIM-7M. The AN/DPM-22 was designed using the Hewlett Packard (HP) 9500 Automated Test System as its core equipment. The HP9500 version in the AN/DPM-22 is controlled by the HP2100S minicomputer, associated disk drive and other peripherals. Twenty-one years ago, the HP9500 with its HP-2100S computer and peripherals was state-of-the-art. Now, this equipment is costly to maintain, and, may be unrepairable if any of the non-available components fail. Several other US Navy missile test sets were developed using the HP9500, including the AN/DSM-127 (Harpoon missile test set) and the AN/DSM-130 (Phoenix missile test set).

In 1992, a new version of the Sparrow missile, the AIM/RIM-7P, was developed and required testing at the repair depot. Since the Consolidated Automated Support System (CASS) missile test set was not yet available, the Naval Air Systems Command directed that the AN/DPM-22 be modified to incorporate AIM/RIM-7P tests.

Replacing test set assemblies which were no longer

maintainable was a key to the success of this modification program. Analysis of repair records for the thirteen AN/DPM-22 test sets suggested that replacing the HP2100S computer and its peripherals would provide the best return on investment. [Previous modifications had replaced some of the original HP9500 instruments with IEEE Standard 488, General Purpose Interface Bus (GPIB) compatible instruments.]

The task of redesigning and modifying four AN/DPM-22 test sets was assigned to the Support Equipment Engineering Branch at Naval Air Warfare Center Weapons Division, Pt. Mugu, CA. The following sections describe the process of replacing the computer and its peripherals.

II. DESIGN GOALS

We were tasked to replace obsolete equipment while striving to achieve the following design goals:

- 1) Maximize compatibility with the existing AN/DPM-22 design.
- 2) Use readily-available, multiple-source, off-the-shelf, commercial components.
- 3) The programming language selected had to be compatible with the 500+ existing test programs written in HP TODS BASIC.
- 4) HP2100 assembly language subprograms were to be rewritten in a high level language for ease of software maintenance.

All aspects of the modification were to be documented. A set of engineering and logistics documentation for the new design was required.

III. HARDWARE DESIGN

A. Original Configuration

The following original computer system equipment was removed from the AN/DPM-22 during the redesign and replaced by a new computer and peripherals:

1) HP2100S Computer. Capabilities include: 1 MHz clock; 32768 16-bit words of magnetic core memory; interrupt driven; direct memory access (DMA) capable. (DMA is not implemented in the AN/DPM-22).

2) HP7900A Disk Drive. Capabilities include: 2.5M 16-bit words per disk; one fixed disk; one removable disk.

3) HP13215A Disk Drive Power Supply

4) HP5321B-K21 Digital Clock. Capabilities include: current date and time outputs; repetitive pulse generator with programmable pulse rate.

5) HP2645 Display Terminal. Capabilities include: keyboard; 24 row by 80 column text display.

6) Beehive Video Display. Capabilities include: 24 row by 80 column text display. Used to display messages to the operator when the HP2645 is not connected.

7) AN/DPM-22 System Control Panel. Capabilities include: Switches which provide operator input to the computer when the HP2645 is not connected.

8) AN/DPM-22 System Display Panel. Capabilities include: Display of measured data and test status using Light Emitting Diode character displays and illuminated discrete indicators.

9) HP85001A (Dicom) Tape Cassette Drive. Capabilities include: Storage of test data results.

The following original computer system equipment was modified and retained in the AN/DPM-22:

1) HP2155A Input-Output (IO) Extender. Capabilities include: Increases the maximum number of computer IO cards by 32 (see IO Extender Design).

Figure 1 shows the original computer system configuration. Figure 2 shows the new configuration.

B. Computer Design

A new IBM-PC compatible, rack-mountable computer system was designed to perform the functions of the original computer system. The new computer includes the following components. Except as noted, all components selected are commercial, off-the-shelf:

1) Rack-mountable case with power supply for IBM-PC compatible components.

2) Motherboard Printed Circuit Assembly (PCA) with eight 16-bit ISA input-output (IO) slots (three IO slots are also

VESA, local bus compatible), 80486 microprocessor with 33 MHz clock, 16 megabytes of random-access memory (RAM).

3) VESA local bus Windows accelerator and Super-VGA video interface IO PCA.

4) Multifunction IO PCA. This VESA local bus compatible PCA provides two Integrated Drive Electronics (IDE) hard drive interfaces, two floppy drive interfaces, two serial IO ports and a parallel printer port.

5) GPIB interface IO PCA.

6) Non-GPIB instrument interface IO PCA. This new PCA, known as the IOX486 PCA, was designed to provide the interface between the new computer and the modified IO Extender. It provides a 16-bit wide bidirectional data path, a 16-bit wide IO-slot address path, four output data strobes, data valid status and interrupt lines. It also implements three timers which are used to provide accurate timing of test events to the nearest millisecond. Two groups of eight Dual-In-Line (DIP) switches are provided for user defined input to the computer. One switch bank is used for storing a unique test set hardware identification number. The IOX486 PCA appears to the 80486 as sixteen 16-bit IO ports.

Software was developed to control the IOX486 PCA (See Software Design).

Cables connect the three connectors on this PCA to the three computer interface PCAs in the modified IO Extender.

7) MIL-STD-1553 bus interface IO PCA (AIM/RIM-7P test requirement).

8) AIM/RIM-7P memory loader verifier interface IO PCA.

9) Local Area Network (LAN) Interface IO PCA.

10) 540-megabyte IDE hard disk drive.

11) Removable tray assembly for hard disk drive mounting.

12) 250-megabyte tape backup unit.

13) Keyboard.

14) Mouse with serial interface.

15) Rack-mountable case for desktop style video monitor.

16) 17-inch Super-VGA color video monitor in desktop

case

C. Computer Design Criteria

The general selection criteria were: availability of multiple sources of computer components, cost of components, and availability of operator and maintenance documentation. The following criteria were used when selecting specific computer components:

1) The 80486 motherboard PCA was selected to provide proven current technology. A clock speed of 33 MHz was chosen to achieve reliable microprocessor (MPU) operation without an MPU cooling fan.

An MPU cooling fan is a requirement when operating at clock rates of 66 MHz and above. When a fan is installed on the MPU, is not possible to install IO PCAs exceeding half-length into two of the eight IO slots since the microprocessor (MPU) socket is in line with the IO slots. This design tradeoff was not compatible with the IO PCA configurations in the AN/DPM-22 computer.

2) RAM size of 16 megabytes was chosen to provide space for Microsoft Windows and the AN/DPM-22 paperless technical manual software, as well as growth potential for test programs.

3) The backup tape drive, a 250-megabyte model, was installed to provide a method of loading new software releases when the test stations are installed at the repair depot.

4) The LAN PCA was selected to be compatible with the Support Equipment Engineering Branch LAN. This allowed master software to reside on the LAN server and to be downloaded from the LAN into the test stations where the TPS software was being debugged.

D. Instrument Interfaces

Instrument interfaces are of two major types: (1) GPIB compatible and (2) non-GPIB compatible.

1) *GPIB-compatible instruments:* Seven GPIB-compatible instruments were originally connected to two Hewlett Packard GPIB interface IO PCAs installed in the HP2155A IO Extender.

There are eight GPIB instruments in the new configuration and those instruments are within the maximum GPIB interconnection distance allowed, so only one GPIB interface IO PCA is required. The instruments are connected to a commercial GPIB interface PCA installed in an IO slot of the new computer.

GPIB interfaces from two different manufacturers were investigated. However, one which had been used successfully in previous applications, was not completely compatible with the VBDOS-PRO programming language (see Software Design). The National Instruments GPIB interface performed satisfactorily and is being used.

2) *Non-GPIB Instruments:* Each of the non-GPIB instruments was connected via cable to an HP IO PCA in the HP2155A IO Extender (see IO Extender Design). These instruments have parallel digital interfaces however the interface designs are non-standard, differing in the number of data, control and status lines; logic voltage and current requirements; control and status line signal definitions; and timing requirements. The type of IO PCA in the HP2155A IO Extender had been selected to accommodate the peculiar IO requirements of each instrument.

Eleven non-GPIB instruments are connected to new instrument interface PCAs in the modified IO Extender (see IO Extender Design). No modifications to the instruments or their cables are required. Digital signals from the IO Extender to the instruments have not changed.

E. IO Extender Design

1) *HP2155A original configuration:* There is no processing capability in the HP2155A. When connected to an HP2100S computer, the HP2155A IO Extender provided the capability of adding up to thirty-two more instrument IO channels to the computer. The HP2155A contains 32 IO slots, compatible with HP2100S IO PCAs, and three slots for PCAs which interface to the HP2100S.

The HP2100S control of and communication with the HP2155A is performed via two (or three) PCAs in the HP2100S and two (or three) PCAs in the HP2155A connected by cables. The connection between the HP2100S and HP2155A implements the following buses:

- a) a 16-bit wide input data bus
- b) a 16-bit wide output data bus
- c) an IO-slot address bus
- d) read and write strobes
- e) interrupt signals
- f) direct memory access (DMA) signals
- g) other status and control signals

(Interrupts can be enabled via software and are enabled on four of the IO PCAs.)

Hewlett Packard supplied several configurations of instrument IO PCAs for the HP2155A of which the AN/DPM-22 employed the following four types:

- a) HP12551B, Relay Register interface
- b) HP12566B, 16-bit Parallel IO interface
- c) HP12604B, 32-bit Input Register interface
- d) HP12661A, interface to HP6131 Digital Voltage Source

Power supplies and logic circuits on PCAs do not conform to Transistor-Transistor-Logic (TTL) standards. The IO Extender backplane is wirewrapped.

2) *IO Extender Chassis Redesign:* Retaining the HP2155A IO Extender as the interface to the non-GPIB instrument cables was determined to be more cost effective than creating a new instrument interface. However, several modifications had to be made to the HP2155A.

a) *Power Supply:* The power supply was replaced with an off-the-shelf, IBM-PC tower-case compatible power supply.

b) *Backplane Wiring:* The wire wrap wiring of the IO Extender backplane was modified to accept the new interrupt system. This was easily implemented because the HP2155A backplane contains many wires which became unused in the new design. A few of these unused wires were assigned new functions.

3) *IO Extender PCA Designs:* All PCAs in the IO Extender were replaced. Three of the new PCAs interface to the computer while the remainder provide the parallel digital interfaces to instruments. The new PCAs are the same size as the HP PCAs replaced. To facilitate maintenance all PCAs are double sided, integrated circuits (ICs) are off-the-shelf TTL and all ICs are socketed.

a) *Computer Interface:* The two PCAs and cables that connected the IO Extender with the HP2100S were removed and replaced by three new PCAs and cables designed to connect with the new IOX486 PCA in the computer. The new computer interface PCAs function similarly to those in the original HP interface except that: DMA signals are not implemented, the HP interrupt system was replaced with one compatible with the IBM-PC and 80486 micro-processor, the backplane control signals were simplified for compatibility with new instrument interface PCA designs and two additional backplane address lines were defined to allow up to four IO ports on each instrument interface PCA.

b) *Instrument Interfaces:* New PCAs were designed to retain the original physical and electrical connections to the instruments. The connections to the backplane are similar to the original except that: the system interrupt circuitry was replaced with one compatible with the IBM-PC and 80486, the control signals for reading from and writing to the PCAs were simplified. The new 32-bit Input Register interface PCA was designed to be addressed as two IO ports.

IV. SOFTWARE DESIGN

A. Original Configuration

The HP Test Oriented Disk Operating System (TODS) is the operating system used with the HP2100S. Test programs were written in TODS BASIC, an interpreted version of the BASIC language, that allowed user developed subprograms to be linked into the language. The user developed subprograms were written in HP2100 assembly language. There were over 500 TODS BASIC test programs and 100 HP2100 assembly language subprograms to be analyzed and converted to an IBM-PC compatible language.

B. Programming Language Selection

Microsoft Visual BASIC for DOS - Professional Version (VB DOS-PRO) was selected after evaluation of several versions of BASIC and other programming languages. The programming language selection was based upon the following criteria:

1) *Compatibility with HP TODS BASIC test program syntax:* Maximum compatibility between the HP TODS BASIC test syntax and the new test syntax is required. VB DOS-PRO syntax is quite similar to that of TODS-BASIC. Maximized compatibility was required by the following:

a) Nine of the thirteen AN/DPM-22 test stations are not being modified. Therefore, both the old and new software configurations will be maintained.

b) Due to the large number of test programs, a syntax translator program that would be used to translate HP TODS BASIC syntax into the syntax of the new programming language.

2) *Capability to create multi-megabyte EXE files:* When all the individual test programs and subprograms required for each Test Program Set are linked into one MSDOS EXE file, the TPS EXE file size exceeds 1 megabyte. VB DOS-PRO supports large files with an overlay manager within the EXE file. The overlay manager moves overlay portions of the code to be

executed into the lower 1 megabyte of memory and moves inactive code overlays to available memory above 1 megabyte, thereby allowing multi-megabyte files to be executed.

3) *Easy integration of application specific interrupt handlers:* VBDOS-PRO allows subprograms (including interrupt drivers) to be written in VBDOS-PRO or another language and linked into the test EXE file. It also allows the test program to specify which subprogram to execute when an user defined interrupt (UEVENT) occurs. Sharing data between the VBDOS and non-VBDOS software modules is easily done under VBDOS-PRO.

4) *Graphical user interface is not required:* While Visual BASIC for Windows and other languages requiring MicroSoft Windows were considered, they were not selected because of the complexity of the Windows environment and the complexity of adding device drivers.

C. Test Program Translation to VBDOS-PRO

Due to the large number of existing test programs written in the TODS-BASIC programming language, it was essential that TODS-BASIC test program source files be automatically translated into VBDOS-PRO syntax. We created a translator program using VBDOS-PRO which identified and translated 95 per cent of the syntax differences. Syntax differences that occurred infrequently or were difficult to detect automatically were left for manual debugging. Where manual action was required, a flag was inserted in the VBDOS-PRO test program source file.

The 500-plus HP-TODS test programs were converted into 300 VBDOS-PRO source files which were compiled and linked into ten TPS executable test programs (EXE files).

An eleventh EXE file, unique to the new computer, provides a menu for selecting tests to perform, setting of system configuration data and selecting help displays.

D. Assembly Language Subprograms

During analysis, some subprograms were determined to be unnecessary, since their functions are performed by MSDOS and VBDOS-PRO. The remaining subprograms were flowcharted, in order to understand the functions performed and the algorithms implemented. Most of those subprograms were rewritten in VBDOS-PRO as were most new subprograms. A few subprograms were written in Microsoft MASM assembly language or Microsoft C, where VBDOS-PRO could not support a desired capability. C language subprograms were written to control the IOX486 PCA hardware (see IO Extender Design), and respond to IOX486 interrupts.

The operator interface subprograms were completely rewritten to use the new video monitor, keyboard and mouse. New code was written using VBDOS-PRO forms to display information to the operator.

E. Configuration Management

Software configuration during development is controlled by maintaining the master files on LAN. During the integrate and test phase, the master files are downloaded into the test stations which are all connected to the LAN. Errors identified during debugging, are documented, a corrected copy of the software is tested and then the master file on the LAN is corrected by the Configuration Manager, who is the only person with Write Access to the master files.

V. PROJECT STATUS

All hardware has been designed, procured and assembled. All software coding has been completed. Hardware and software have been integrated. Subprogram software has been debugged. Test program software is now being debugged.

VI. POTENTIAL APPLICATIONS

The modification process described can be adapted to upgrade the computers of other HP9500 Automated Test Systems. The following process is recommended:

- a) Replace/modify computer hardware as described. Hardware is either commercial off-the-shelf or assembled from complete design documentation.
- b) Translate test software from the TODS-BASIC syntax to VBDOS-PRO syntax using a variation of the translator program developed for the AN/DPM-22.
- c) Recode test set unique assembly language subprograms in VBDOS-PRO or other MSDOS compatible language, however some generic HP9500 subprograms will not have to be recoded, since they are unnecessary or replacements have already been developed.

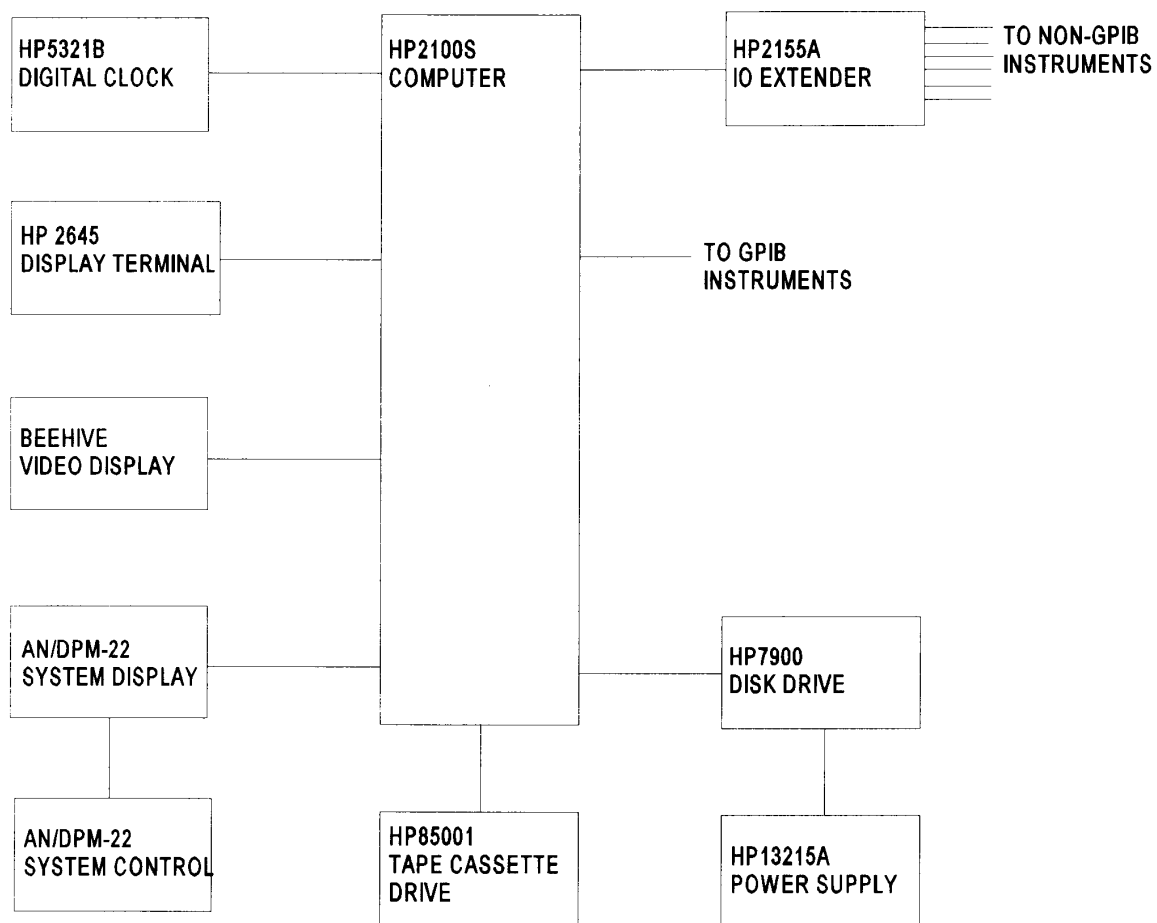


FIGURE 1. ORIGINAL COMPUTER SYSTEM CONFIGURATION

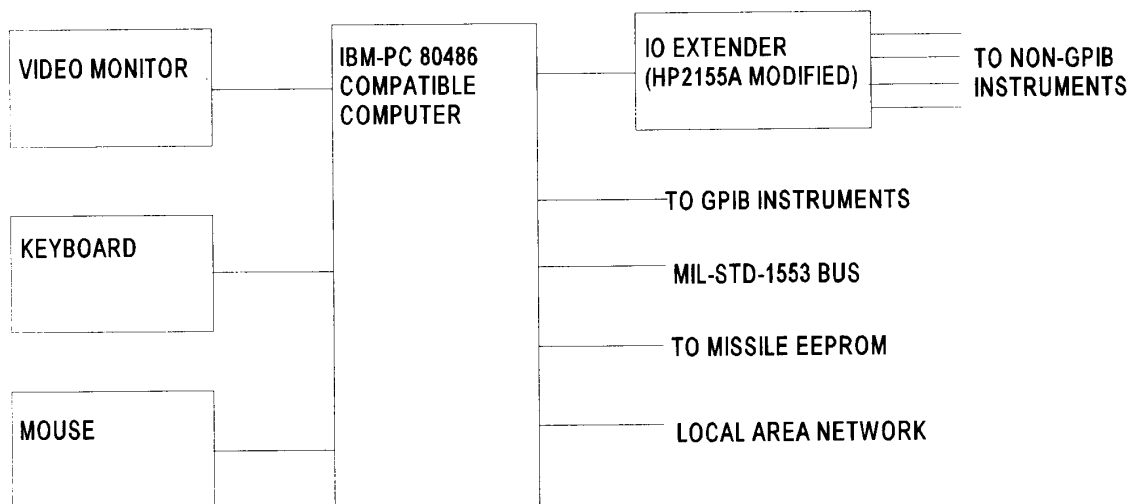


FIGURE 2. NEW COMPUTER SYSTEM CONFIGURATION