Control and Computation Module Development

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The control and computation module (CCM) project has selected on the basis of developed criteria the 8080A microprocessor as its first candidate CCM. Software development methods have been investigated and two test bed projects have been chosen to evaluate application techniques of the 8080A and support microcircuits which will satisfy DSN requirements. Final recommendations will reflect successful JPL applications experience.

I. Introduction

It has been recognized that digital technology in the areas of control and computation is having an ever widening impact on the development of Deep Space Network (DSN) ground support equipment. A result of this recognition is the formation of the control and computation module (CCM) development project, whose objective is the assessment and development of a standardized set of digital control and computation modules, useful as building blocks for DSN equipment and meeting the criteria of functionalism, high reliability, and constrained life cycle costs.

Consideration of DSN functional applications, taken together with the advent of large-scale integration (LSI) of digital circuitry into small packages, led to the decision that the initial set of CCMs would consist of individual commercial LSI microcircuits as opposed to special modules housing some aggregate of digital circuitry. Thus the construction of equipment using these CCMs could utilize packaging already developed for small-scale integration (SSI) microcircuits. Moreover, a relatively restricted set of CCMs could implement a large set of DSN applications such as listed in Table 1. Procurement of LSI devices selected as CCMs would be similar to current procurement of high-reliability SSI and medium-scale integration (MSI) devices for the DSN (Refs. 1 and 2).

Logistics considerations involving maintenance and sparing would also be similar to that of SSI and MSI devices. In the DSN station, maintenance would consist of the replacement of a circuit board containing many microcircuits, or on a higher level by replacement of a drawer or cage containing many circuit boards. These boards would then be repaired at the central maintenance depot serving the station complex. At the depot, the unit of replacement would be the individual microcircuit.

The first device type selected for use as a CCM was the microprocessor. This was industry's most visible effort in LSI, and was naturally suited for simple control and computation tasks. In addition, the high interest in these devices by engineers developing the DSN subsystems listed in Table 2, together with the profusion of devices offered by industry, lent some urgency to recommendation of a candidate device meeting suitable selection criteria. The device recommended is the 8080A microprocessor, first introduced by the Intel Corporation but now also available from several alternate sources.

Support microcircuits for the 8080A are listed in Table 3. A typical DSN controller would consist of the three devices of the CPU group, selected devices from the memory and input/output (I/O) groups, and required discrete logic. Such a controller is shown in Fig. 1. The I/O block to the standard interface contains discrete logic for a standard interface adapter (SIA) driven by an 8255 programmable I/O unit. Subsystem hardware is also driven by the 8255 and required drivers. A major portion of the subsystem development effort involves the design of the program residing in the read-only memory (ROM).

II. Selection Criteria

The criteria developed for the CCM selection process falls into two categories, namely usefulness criteria and life cycle cost criteria. Usefulness criteria include device speed and functional capability, software requirements and support, and the availability of support microcircuits. Microprogrammable bipolar bit slice devices were initially studied because of their speed advantage over metal oxide semiconductor (MOS) preprogrammed microprocessors. Consideration of these bipolar devices was terminated however when a close examination of DSN requirements revealed that the narrow range of applications insufficient for MOS speed but not requiring the ultimate speed of SSI devices did not warrant the increased complexity and cost of microprogramming.

Life cycle cost criteria include initial procurement costs, device reliability, software design and maintenance costs, and logistics costs. Primary emphasis was placed on device reliability. Unique to LSI is the fact that testing and screening for reliable devices is far more complicated than for SSI and MSI devices. Experience has shown that reliability is coincident with product maturity, involving continuous production of thousands of items monthly, after a startup period of several years during which time incremental changes in the production process have been iteratively made to increase yield. Two devices which meet this maturity process are the 8080A and the 6800. Selection of the 8080A over the 6800 was based on higher commercial usage of the 8080A, estimated to be 2 or 3 times the usage of the 6800.

The rapidly advancing state of LSI technology and the proliferation of microprocessor devices currently available have raised concern that future procurement of spares may be jeopardized due to obsolescence and subsequent lack of sources. In the past, large commercial usage of a component has resulted in a type of usage inertia wherein demand has made the component available long after its recognized obsolescence. It is believed that this same principle applies to the 8080A and is an additional reason for its selection.

III. Software Development

Development of software for a microprocessor controller requires a combination of special software development hardware and a software language system such as an assembly or higher level language. Complete development systems for the 8080A are available for less than \$20,000. During software development, the software development hardware is tied directly to the subsystem as shown in Fig. 2. The program resides in random access memory (RAM), where it may be easily modified as required. After the program has been successfully tested, it is programmed into programmable read-only memory (PROM) for use by the DSN subsystem.

If an external software facility is available, then the minimal 8080A development system shown in Fig. 3 may be purchased for less than \$500. Cross languages were developed under the CCM project for a software facility consisting of a Sigma 5 computer and a MAC 16 minicomputer. Software preparation on this facility is shown in Fig. 4. Here, the source code on punched cards is either assembled by the cross assembly language or compiled by the higher level PL/M cross compiler residing in the Sigma 5. Listings and diagnostics are output on the Sigma 5 line printer, and 8080A object code is output on binary punched cards. Information on the cards is punched on paper tape by the MAC 16 minicomputer. Software on the paper tape is then loaded into the development system via the paper tape reader shown in Fig. 3.

Objectives of the CCM project also include preparation of specifications useful in the procurement of the selected CCM and demonstration of the CCM utility in selected test bed projects. Specifications for the 8080A are currently being developed, and two test bed projects have been selected.

IV. Test Bed Projects

First of the two test bed projects to demonstrate 8080A application is a control unit for a 16000-point spectrum analyzer for radio frequency interference (RFI) indication.

This analyzer is being developed under another work unit and consists of discrete high-speed logic operating at a 10-MHz clock rate. The 8080A control unit will serve as an interface between the high-speed logic and the external environment to perform such functions as I/O, mode control, self testing, and automatic recovery procedures.

The second test bed project will demonstrate the use of more than one 8080A in a distributed control application. This application involves control of an ephemeris tuned receiver local oscillator. Several different control functions have been identified for this application including closed loop system control, ephemeris polynomial calculation, and system monitoring and I/O control.

Both projects meet the general criteria for test bed projects. Such criteria include the demonstration of CCM devices used to solve DSN requirements, the furtherance of specific DSN objectives, the development of equipment not easily available from industry, and the ability to complete the project in a one-year time span.

V. Conclusion

The concept of the CCM as being an LSI microcircuit is a natural extension of the current DSN high-reliability program for small- and medium-scale integrated microcircuits. Although initial emphasis is on high usage commercial devices, this emphasis does not preclude future consideration of in-house developed circuits for DSN-unique application. Selection of the 8080A as a candidate CCM also implies selection of the required support circuits. Final approval of the 8080A as a CCM will be based on successful JPL applications experience.

References

1. Zundel, E. F., "High-Reliability Microcircuit Procurement in the DSN," in *The Deep Space Network,* Technical Report 32-1526, Vol. XI, pp. 121-123, Jet Propulsion Laboratory, Pasadena, Calif., Oct. 15, 1972.
2. Zundel, E. F., "High-Reliability Microcircuit Procurement Program in the DSN," in *The Deep Space Network Progress Report 42-27,* pp. 124-125, Jet Propulsion Laboratory, Pasadena, Calif., June 15, 1975.

Table 1. DSN applications

Line sensing and activation for monitoring and configuration control
Data manipulation and formatting
Limit comparison
Message generation: Human-machine interface
Simple low-speed calculations
Analog/digital and digital/analog conversion
Fast Fourier transformation
Digital filtering
Phase detection
Frequency counting and synthesizing
Digital interfacing

Table 2. DSN subsystems and assemblies

Utility control system
Antenna control assembly
RF subsystem controller
Receiver-exciter controller
SDA controller
Transmitter controller
VLBI recorder controller
Microwave controller
Fourth harmonic analyzer
Frequency standard controller
Noise adding radiometer
Tuned oscillator controller
Station manager's console
Automatic test equipment

Table 3. 8080A and support microcircuits

CPU Group	
8080A	microprocessor
8224	clock generator
8228	system controller
Memory Group	
8111	4 x 256 static RAM
8708	8 x 1024 EPROM
I/O Group	
8212	8-bit buffer
8214	interrupt controller
8251	universal synchronous/asynchronous receiver/transmitter
8255	programmable I/O port

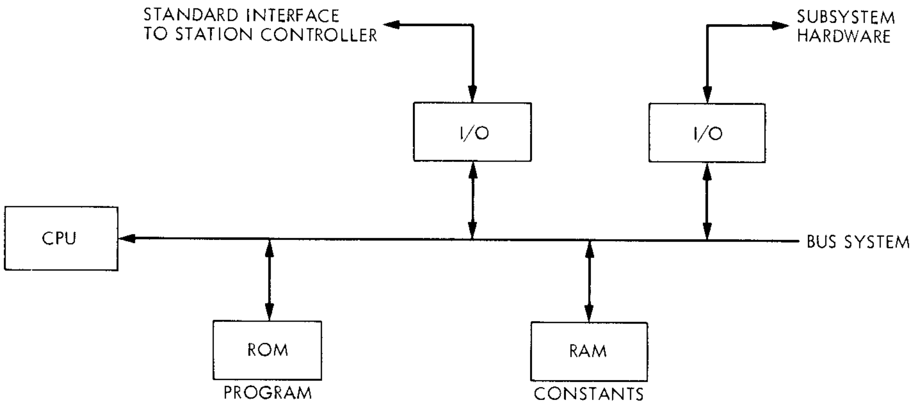

Fig. 1. Typical DSN controller

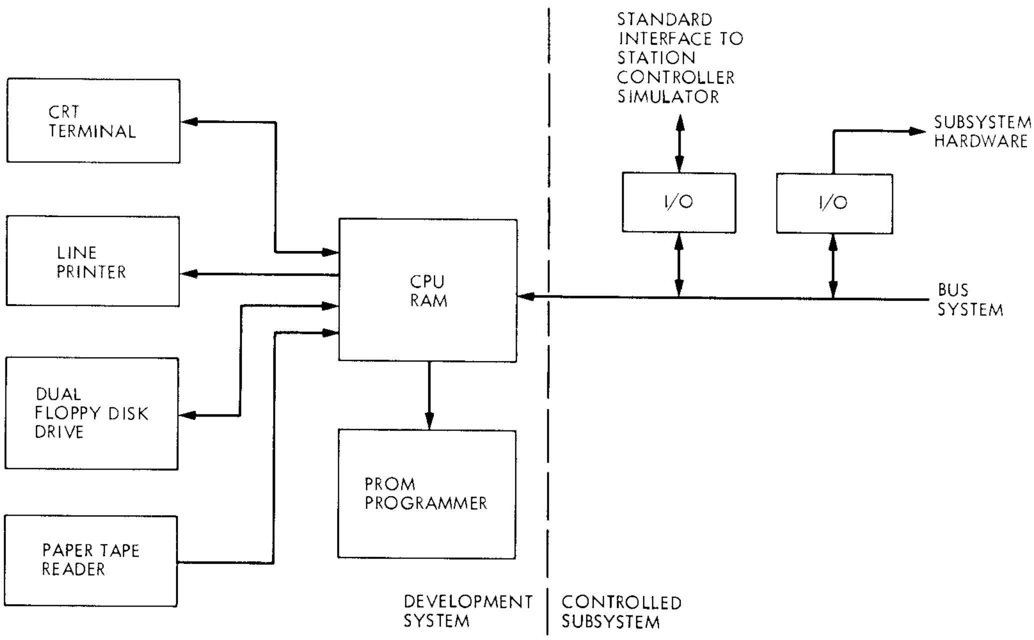

Fig. 2. Complete software development system

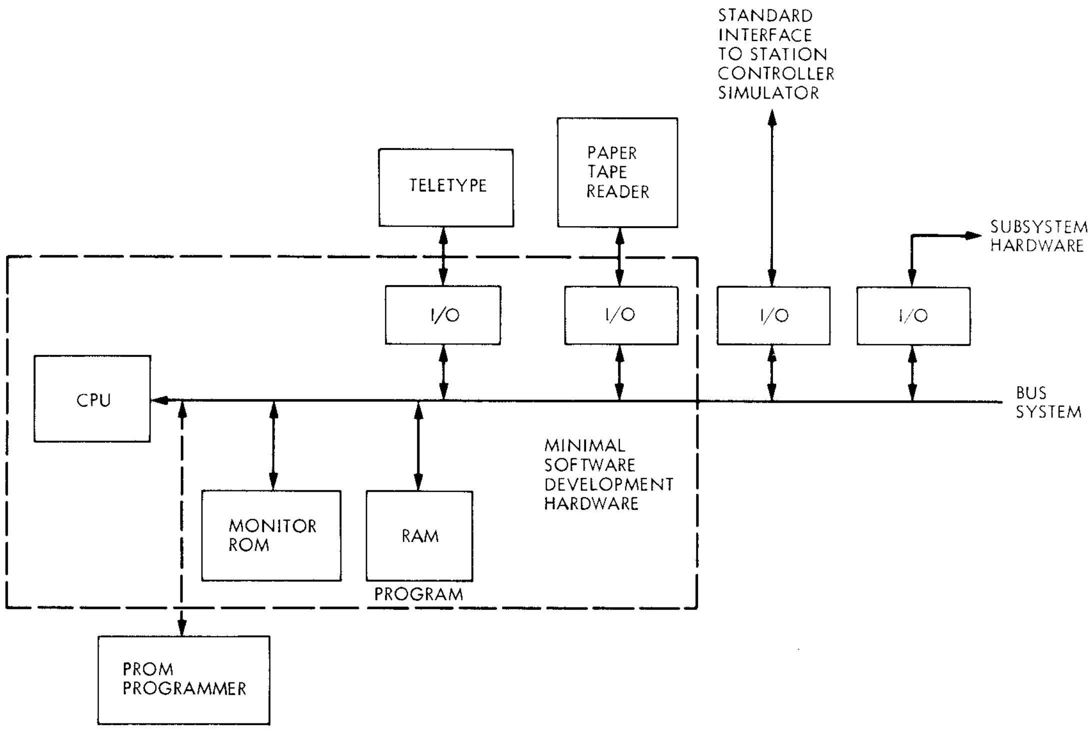

Fig. 3. Minimal software development system

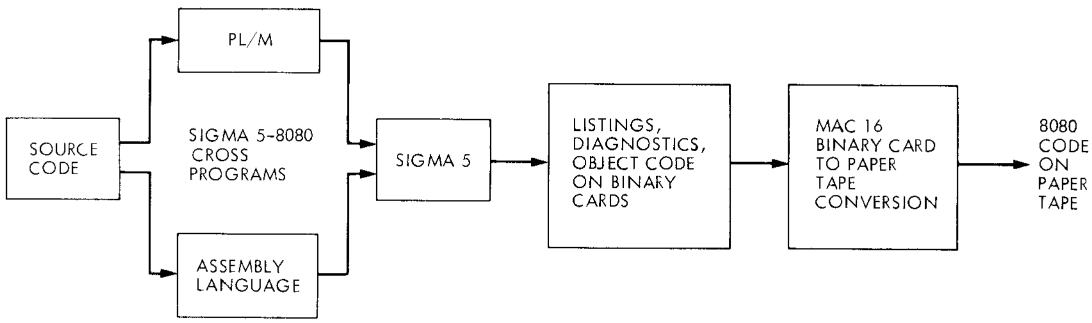

Fig. 4. Software preparation on external facility