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IBM System/7 and Plant Automation

Abstract: The recently announced IBM System/7 was developed for use in a broad range of data acquisition and control applications and provides the foundation for comprehensive plant automation applications. Its unique modular structure and broad spectrum of features satisfy the basic plant automation requirements described in the paper by Kinberg and Landeck in this issue. In the present paper the functional characteristics, important design features, and the basic architectural concepts of hardware and software are discussed. An example of the use of this new system in the automation of the System/7 manufacturing process itself is provided to illustrate its use in the testing of complex electronic assemblies as part of an integrated plant automation system.

Introduction

Experience with IBM plant automation applications, such as those described in other papers[1–5] in this issue, and with customer installations using IBM 1130's, 1800's, and System/360's pointed to the need for a flexible, modular system that could provide a broad range of computing power. Experience in process control, laboratory automation,[6] and data acquisition applications indicated similar requirements, although there are recognized differences in the relative importance of system parameters in the various applications. As a result, the design goal for the recently announced IBM System/7 was an architectural structure and functional capabilities that could satisfy this broad range of requirements.

Although it is difficult to quantify all of the requirements that served as design guides for the development of System/7, those identified in the paper by Kinberg and Landeck[7] provide a basis for examining the structure of this new system when applied to plant automation. Kinberg and Landeck list the following requirements and principles:

- The real-time capability on different levels of the computer system hierarchy should be commensurate with the activity required at that level.
- The system architecture should provide flexibility (and versatility) and modularity in terms of function, capability and computing power.
- The structure and features should provide for access to the computer system from practically any physical location in the plant.
- Special capability, such as microsecond response time to external interrupts, should be provided in the subsystem having the requirement.
- Implementation, expansion and maintenance of individual applications in an interconnected system should have minimum disruptive effect on total system operation.
- The structure should provide for the centralization of I/O units such as card equipment, high-speed printers and disk files that can be conveniently shared between applications. Similarly, common services, large computing power and extensive data bases should be shared whenever possible.

The purpose of the present paper is to briefly describe the System/7 structure and features and relate them to these plant automation requirements and principles. The

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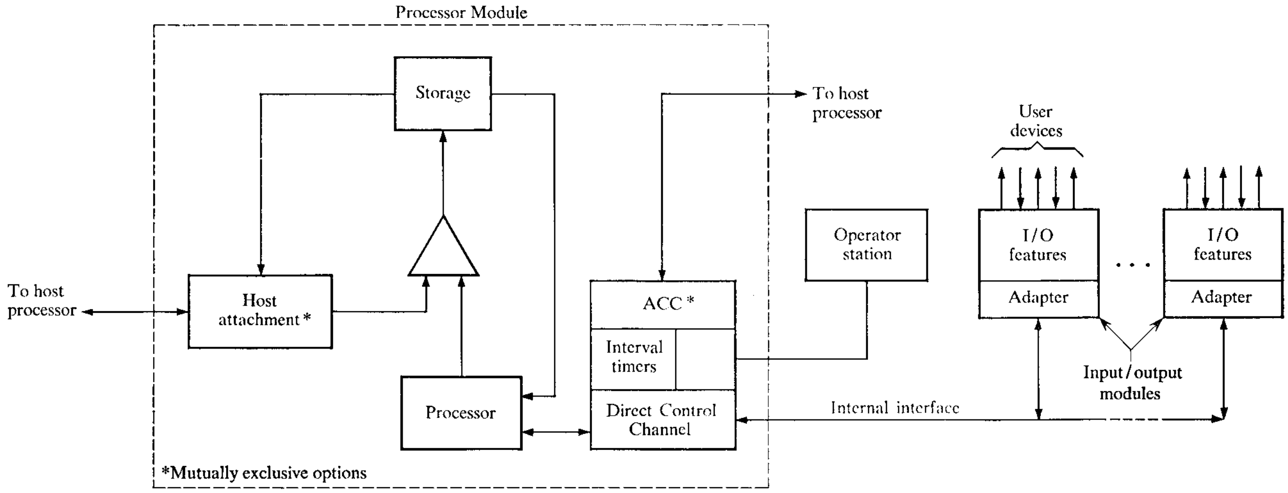

Figure 1 The over-all organization of IBM System/7.

modules and enclosures included in System/7 are described in terms of their function and basic organization. The interconnection of these units to provide a wide range of systems from a basic "starter set" to a comprehensive system utilizing direct channel or teleprocessing connection to a host processor is also considered. A proposed configuration to be used in the production of System/7 itself is described to illustrate the functional capabilities for production control of complex electronic equipment.

System/7 description

System/7 is a highly modular, flexible system designed for use in a broad range of applications including plant automation, laboratory automation and process control. To satisfy the many requirements of these applications, the design of the system emphasized functional and structural modularity, time responsiveness, expandability, and application compatibility with a range of host processors that provide a broad spectrum of computing power. The basic design approach depends heavily on the hierarchical concept of interconnected systems to provide the necessary computing power and other functions at the level where they are required. For example, the lowest level of the application system structure provides a high degree of real-time responsiveness and nominal computing power. Connection to a host processor, however, provides the first-level system with access to additional computing power and other resources.

Separating the system into functionally complete, separately packaged modules gives flexibility needed to customize the available features into an application system. The software for the system is similarly structured so that an efficient programming system of supervisory functions and user code can be implemented for the particular application. Among the benefits of this modular architecture is the ability to expand the configuration from a minimum stand-alone system to a comprehensive stand-alone system more powerful than many present day medium-sized computer control systems. In addition, or alternately, System/7 can be integrated into an interconnected computer information system to provide services for an entire company.

In the following sections the hardware is discussed and its important features are highlighted. A few of the possible system configurations and their associated software support are then described before the use of the system in a plant automation application is illustrated.

System organization

The over-all System/7 organization is shown schematically in Fig. 1, which illustrates the fundamental data flow in the system. The Processor Module, a functionally complete subsystem, consists of the processor, its associated storage, 1130 attachment, the Direct Control Channel, operator station control, interval timers and Asynchronous Communication Control (ACC). The communications and 1130 adapters are mutually exclusive options and are not required when the system is used in a stand-alone configuration. When connected to a host processor through one or the other type of adapter, a range of communication modes and speeds and a number of different system configurations are provided.

The processor and its associated storage provide the basic computational capability in System/7. As indicated in the figure, storage can be accessed by the processor or through the 1130 attachment.

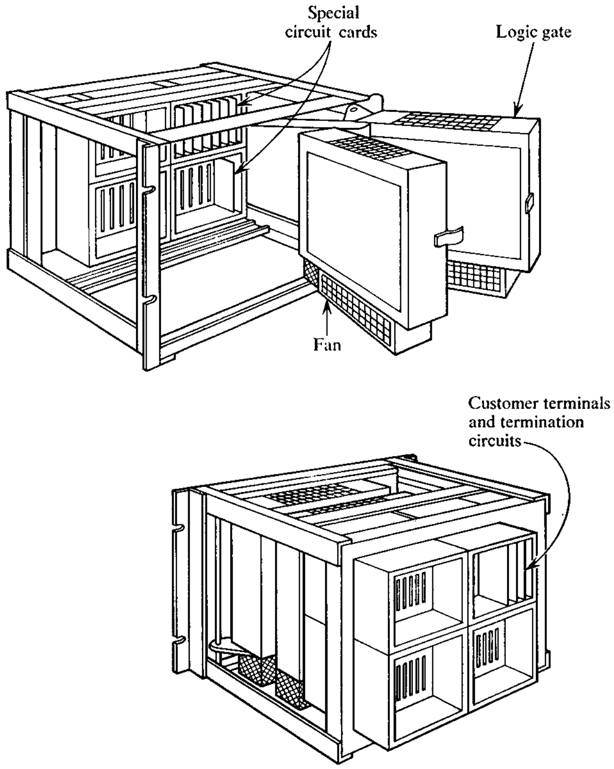

Figure 2 Input/output module construction.

The Direct Control Channel, in addition to providing the necessary control for the interval timers and I/O equipment, provides an internal interface to which separately packaged input/output modules are connected. Depending on the system configuration, from one to 11 input/output modules may be controlled. These modules house the feature controls and the hardware which provides the sensor-based and man/machine I/O capability required in a data acquisition and control system. Features providing a variety of analog and digital I/O functions are available as separate input/output modules or as features within a multifunction input/output module.

Physical structure

The packaging of System/7 is consistent with the objective of maximum modularity and flexibility. The Processor Module and each of the input/output modules are constructed as separate assemblies. Each assembly, approximately 15 × 22 × 20 inches in size, consists of a frame and up to four swinging gates. These gates contain the logic boards and cards, and a fan. When mounted in the enclosure described below, the swing-out gates provide two-sided access to the logic for servicing, as well as access to other equipment mounted in the module.

In the case of input/output modules which require a termination facility for customer wiring, one or two swing-out logic gates can be mounted in the module, as shown in Fig. 2. The back panel of the frame consists of a printed circuit card fitted with connectors for cards inserted into card guides on both sides of the back panel. The cards plugged into the module side of the back panel contain special circuits associated with the sensor I/O functions provided by the input/output module. For example, in the case of an analog input feature, these cards contain the multiplexing switches. The mating card, plugged into the back panel from the rear of the module, is a termination card which provides for signal conditioning, such as filtering, and also provides the terminal strips to which the signal wires are connected.

The Processor Module and the input/output modules are mounted in rack enclosures which also house power supplies, internal interface wiring, and the System/7 operator's console. Three basic enclosures are available, differing primarily in the number of modules that can be accommodated. The smallest of these enclosures provides mounting space, power and the operator console for one Processor Module and a single input/output module. The enclosure is approximately 48 inches high, 28 inches wide, and 31 inches in depth. It represents the smallest System/7 configuration and can be used in either a stand-alone or interconnected configuration. This enclosure is illustrated in Fig. 3.

Also shown in Fig. 3 are the three- and six-position module enclosures. The three-position module enclosure is approximately 60 × 38 × 31 inches in size and contains the power, internal interface, and operator console necessary for a Processor Module and two input/output modules. The six-position module enclosure adds a 24-inch bay accommodating three additional module positions. The enclosures provide for two-sided access to the modules housed within them.

As an optional feature for the three- and six-position module enclosures, an internal air isolation system is provided for use when the system is installed in areas subject to atmospheric contamination. The enclosure doors are completely gasketed with a flexible material. Heat generated within the enclosure is dissipated through an air-to-air heat exchanger mounted on the top of the enclosure. The exchanger has a capacity sufficient to allow the normal 122°F maximum temperature specified for the system. By this means, the cooling air inside the enclosure is effectively isolated from the contaminated environment, thereby significantly reducing the effect of the contaminants on the electronic components in the system.

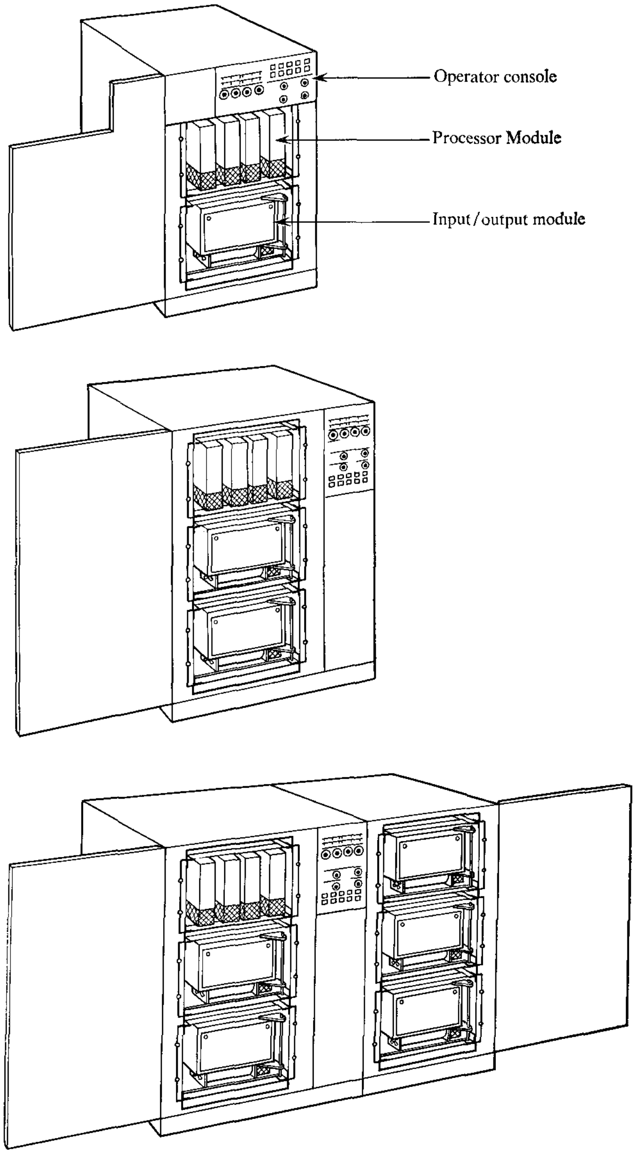

Figure 3 Enclosures for System/7.

Processor Module

The processor with its associated storage provides the computational and control functions required in the system. The monolithic storage has a 400-nsec cycle time and is available in sizes from 2K to 16K words in 2K-word increments. In addition, the storage and other Processor Module data paths contain two parity bits, one for each of the two 8-bit bytes in the basic computer word.

The processor is unique in that it provides an individual instruction address register, accumulator and seven index registers for each of the four available priority interrupt levels. This organization avoids the requirement for register store and restore programming upon priority interrupt entry and exit, normally a time consuming function. Coupled with automatic sublevel branching on priority interrupt entry, program level switching to any of the 64 interrupt sublevel service routines can be accomplished in as little as two storage cycle times after an interrupt is recognized. These features and the high speed monolithic storage provide a processing capability with extremely high time-responsiveness.

The selection criteria for the instruction set emphasized function, execution time, storage space and cost. It consists primarily of short (one word), single-cycle instructions; only four two-word instructions are included. It includes a class of register-accumulator operations (LOAD, STORE, ADD, SUBSTRACT, AND, OR, EXCLUSIVE OR), a wide range of arithmetic indicator tests, and shift instructions for all accumulator and index registers. There are no double operand, multiply, divide or compare instructions. This yields an instruction set that, for the most part, uses single storage locations and a maximum instruction execution time of three storage-access cycles, exclusive of the interface time in the case of the I/O instruction.

As indicated in the data flow in Fig. 1, the Processor Module also includes the Direct Control Channel, which provides the control and communication with the input/output modules. The internal interface, under the control of the Direct Control Channel, is distributed to all the input/output modules in the system. The interface provides selection of the addressed module, interrupt request polling, power failure detect, auto-restart and other functions.

Included with the Direct Control Channel are two independently controlled 16-bit interval timers having 50-μsec resolution with automatic interrupt on overflow. Also included is the native attachment for the IBM Operator Station, which provides independent operation of paper tape input and output, keyboard, and printer facilities.

An optional Asynchronous Communication Control (ACC) feature is provided. Adapters providing communication rates of 134.5 and 600 bps and a special adapter for rates up to 50 kbps are available. These communication facilities provide for teleprocessing interconnection between System/7 and the System/360 (Model 25 and above), System/370, the IBM 1800, and other systems having suitable asynchronous communication support. The use of an ACC preempts the 1130 attachment feature in the Processor Module.

The 1130 attachment in the Processor Module provides for a direct attachment to the IBM 1130 Storage Access Channel (SAC). This provides storage-to-storage transfers of programs and data limited only by the storage speed of the IBM 1130. All transfers are initiated by the 1130 and a "shoulder tap" interrupt system is used to request and maintain control of the data transfer.

Input/output modules

Three input/output modules provide System/7 with sensor-based and man/machine I/O capability. These modules can be mounted in any position in the enclosures described previously except for the position reserved for the Processor Module.

The Low Speed Analog Input Module provides a differential "flying capacitor" multiplexer, time-shared amplifier, 14-bit (plus sign) analog-to-digital converter (ADC), and the necessary controls for converting analog input signals into digital form. The multiplexer, utilizing mercury-wetted relays, has a maximum capacity of 128 two-wire inputs and a maximum scanning rate of 200 points per second (pps). The programmable or auto-range amplifier in the system provides seven ranges from ± 10 mV to ± 5.12 V full scale. An optional feature provides only the ± 5.12 V full-scale range. Common mode potentials of up to 250 V can be accommodated with a common-mode rejection ratio in excess of 120 dB. The total error on the various input ranges is less than 0.35% to 0.05% of full scale with corresponding repeatability specifications of 0.20% to 0.03% of full scale.

The Medium Speed Analog Input Module utilizes a differential MOSFET multiplexer, time-shared differential amplifier with programmable or automatic ranging, and the 14-bit ADC. An optional single-gain amplifier is also available. Each module accommodates up to 128 analog input signals. Seven input ranges are provided from ± 10 mV to ± 5.12 V. The scanning rate on low-level inputs (less than 640 mV) is 14 kpps in the programmable mode and 7 kpps when auto-ranging is selected by the program. The scanning rate on the 5.12-V range is 20 kpps in the programmable gain mode of operation. Total error and repeatability specifications are the same as in the low-speed feature. The maximum common-mode-plus-normal-mode voltage is limited to 11 V by the characteristics of the MOSFET multiplexer and amplifier. The common mode rejection ratio is up to 114 dB, depending on the resistive source unbalance and the range.

The Multifunction Module provides a number of options to provide analog input and output, digital input and output, and a 2790 Control in a single feature module. Up to 32 inputs points of either low-speed or medium-speed analog input can be selected. The specifications on these features are the same as described above. Two analog output digital-to-analog converters (DAC) are available in this module. The output voltage range is 0 to 10.24 V with 10-bit resolution. Each DAC is separately isolated from system ground at the digital DAC interface to provide freedom from ground loops, noise and interconnection problems.

The digital input feature provided in the Multifunction Module provides the capability of sensing binary signals connected to the system. Both voltage levels and switch closure signals can be detected. The basic circuit is a voltage threshold detector which provides a binary "1" output signal for input signals in the range of $+2$ to $+48$ V. A binary "0" results for an input between -48 and $+0.8$ V. The circuit is isolated from system ground so that negative input signals can be accommodated by interchanging the input leads. In addition, the isolation minimizes installation and application problems due to ground loops and similar noise problems. In conjunction with a $+48$ V internal power supply, the same feature is used for sensing the open or closed state of a switch contact. An optional filter provides a detection time constant of approximately 4 msec, and the user may easily construct other filters by adding resistors and capacitors on the termination card. Without a filter, the feature is capable of operating at system rates up to 500 kHz. Up to 128 digital input signals may be accommodated in the Multifunction Module. Of these, up to 32 points may function as priority interrupt inputs.

Three digital output features provide for up to 64 digital output signals in each Multifunction Module. The Low Power Digital Output feature is intended for interfacing System/7 to devices requiring logic voltage level inputs. This feature, capable of switching at the system logic speed, provides a binary "1" output signal of between 2.4 and 6 V and a binary "0" signal between 0 and 0.6 V. The Medium Power Digital Output provides a greater power capability for applications requiring the switching of up to 0.45 A at voltages up to 48 V. Switching speeds of up to 100 kHz are possible. At a reduced switching load of 0.1 A, the system switching speed may be increased to 500 kHz. Although the solid-state switch utilized in this feature switches only voltages of a single polarity, the feature is isolated from system ground so that both positive and negative polarity loads may be switched by interchanging the connections to the system. The Contact Digital Output feature provides mercury-wetted relay contacts as outputs. These relays can switch loads of up to 3 A and 125 Vac with a maximum limitation of 100 VA. Relay contact protection is provided by user-mounted resistor and capacitor circuits on the termination card.

The 2790 Control feature[8,9] in the Multifunction Module provides the control for the IBM 2791/93 Area Stations, IBM 2795/96 Data Entry Units, IBM 1035 Badge Readers, IBM 1053 printers, and customer-provided digital devices. The functions provided by the control are similar to those provided by the IBM 2715 Transmission Control Unit or the 1800/2790 Adapter available on the IBM 1800. The primary difference is in the number of devices and functions which can be accommodated. The IBM 2791 and 2793 Area Stations provide operators with the capability of transmitting data to, or receiving data from, System/7. Data represented on cards or badges, or entered by use of numeric keyboards or by customer-provided digital devices are transmitted to the Processor Module. Operator guidance is also provided through the Area Station by means of illuminated panel decals that are customized for the particular application. The selection of these guidance indicators is provided under the control of the 2790 Control support program. Data from the Processor Module can be made available in a hard-copy printed form via the IBM 1053 printer, which is an available option on the Area Station. The IBM 2795/6 Data Entry Units are small input devices for entering digital information into the system from cards or badges and from switch settings. The Data Entry Units are connected to the Area Stations by a two-wire communication line and require no separate power other than that provided through the communication line.

System configurations

The modular structure of System/7 and the many features which are provided result in many possible system configurations. These can be categorized, however, as either stand-alone, directly connected multisystem or as teleprocessing-connected multisystems. Within each category, the System/7 may be as small as a single two-module system or as large as a system consisting of two interconnected 6-position module enclosures having space for a Processor Module and 11 input/output modules.

The stand-alone configurations are shown in Fig. 4. The two-module system can be expanded only by replacing the enclosure. A three-module system may also be expanded to six modules by adding a bolt-on expansion enclosure. Further expansion is provided by adding either a three- or a six-module enclosure extension which may be located up to 200 feet from the enclosure containing the Processor Module.

In the direct-connected category, any of the stand-alone configurations can be coupled to an IBM 1130 host processor through the optional host attachment feature. Independent supervisor functions exist in each processor and the communication between them is via the 1130 Storage Access Channel (SAC) to and from System/7 storage. This provides storage-to-storage transfers of data and program loads initiated by the host processor.

Instead of the 1130 attachment feature, any of the configurations illustrated in Fig. 4 can be provided with the Asynchronous Communication Control. This provides for a teleprocessing interconnected system in which data can be transferred between the System/7 and the attached processor. The adapter is designed such that the System/7 appears in the same way that an IBM 2740 Model 1 Communication Terminal would appear to the host processor.

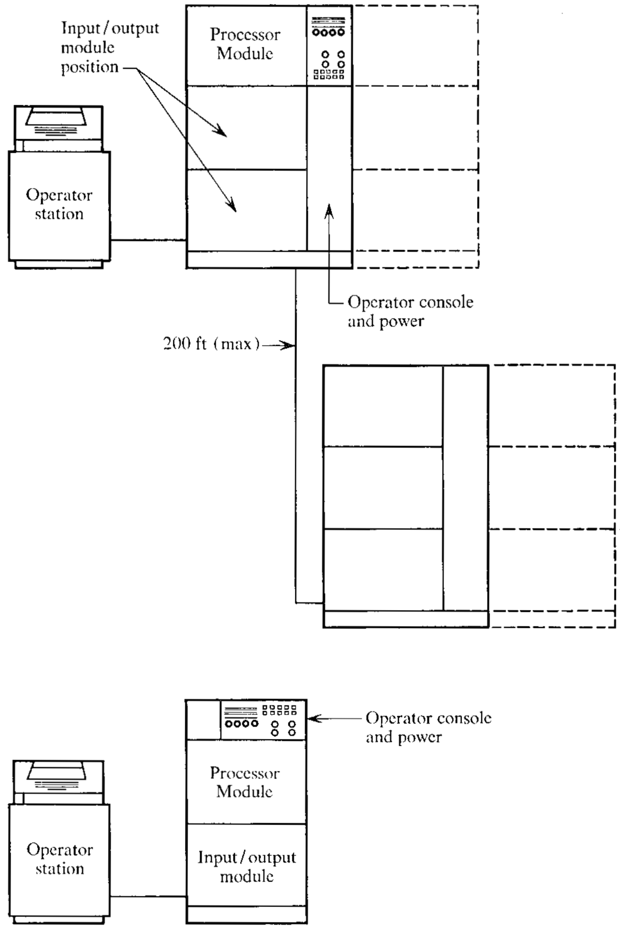

Figure 4 IBM System/7 stand-alone configurations.

Software support

System/7 is program supported in each of the three system configuration categories. The basic software support for the system is called the Modular System Programs (MSP/7) system. It is a collection of macro routines which can be combined into a MSP/7 storage load for execution on the System/7. The programming system is highly modular to allow the user to select only those facilities required for his application. The minimum nucleus consists of an interrupt controller, recovery system and the operator station driver. MSP/7 supports all configurations of System/7 with storage sizes from 2K to 16K words.

The programming modules available in the library include modules for System Support, Direct Sensor Based I/O Support, Basic Sensor-Based Data Access, Telecommunication Support and 2790 Control support. The system support modules provide system functions normally associated with an executive or supervisor. These include modules for master interrupt control, task scheduling error recovery, operator station communications, storage load, and dumps and patches.

The macros included in the Direct Sensor Based I/O Support include READ and WRITE commands for transfers of data between the input/output modules and storage and timer control routines. The Basic Sensor-Based Data Access macros enable the user to perform the input and output operations for the various analog and digital devices included in System/7.

The Telecommunications Support provides the necessary functions for systems interconnected using the Asynchronous Communications Control. The programming system supports System/7 in such a way that to the host processor it appears identical to an IBM 2740 Model 1. Programming support on the IBM System/360 and IBM System/370, therefore, is included under BTAM, QTAM and TCAM.

The macros provided in support of the 2790 Control give the system functions necessary to interpret the user's transaction control list, control the 2790 hardware, and specify the loop configuration and tables.

Program preparation is accomplished either on the System/7 or on a connected or independent processor. A single-pass one-for-one assembler is provided for use on a System/7 that has a minimum of 4K words of storage. The macro assemblers presently available on the IBM 1130, 1800, System/360 and System/370 can also be used for program preparation in conjunction with the IBM-supplied System/7 macros. The output from the macro assemblers is provided as a System/7 storage load which can be transferred to the System/7 via teleprocessing, the direct connection between an IBM 1130 and a System/7, or paper tape through the Operator Station.

Programming support is also provided for configurations in which System/7 is interconnected with the IBM 1130 or IBM 1800 to form a distributed system. These programming support packages are called the 1130 and 1800 Distributed Systems Programs (DSP) and provide subroutines which can be called from programs written in 1130/1800 assembler or in 1130/1800 FORTRAN language. The 1130 and 1800 DSP subroutines control the exchange of data between an 1130 or 1800 and System/7. Subroutines are provided for general control, request control, transmission control and interface control. In addition, utility programs are provided for general support of the interconnected system.

System/7 application example

System/7 is well suited to the task of automating the production of complex electronic equipment. In this section, one particular example of its use is discussed. Specifically, the use of an interconnected System/7 that can be used for the testing of the input/output modules is considered. Although this is only a small portion of a total plant automation system, it illustrates the role of the System/7 in a typical plant automation application in the computer industry.

• *Test philosophy*

In the extensive testing and quality assurance procedures incorporated into the manufacturing process, tests typically are performed at the electronic component, card, subassembly, final assembly and system level. Extensive use of simulators and special test equipment is involved, along with data collection and analysis under the control of an integrated computer automation system which, in turn, is integrated into a corporate information system.

The test philosophy is basically one of testing equipment at each level of assembly using a series of logically progressive tests. Thus, for example, components are subjected to tests at incoming inspection, after cards have been partially assembled, at the completed card level. and finally in subassembly and total system tests. The tests are designed so that errors are detected and corrected at the lowest possible level of assembly. This minimizes the rework of cards and assemblies and simplifies the testing of more complex subassemblies and systems. At the higher levels of testing, the procedures consist of logical progressions of function and performance testing. The initial tests are simple and primarily verify that basic functions or subfunctions are properly performed by the unit under test. After these simpler functions have been verified, more complex functions are tested. By the time an assembly is ready for incorporation in the system it has been subjected to hundreds of tests.

• *Test facilities*

Testing facilities are provided for each level of testing. Incoming inspection tests, primarily concerned with the testing of precision analog components used in the analog subsystems, involve high-precision measurements of voltages and currents in an environmentally controlled area and the calculation of pertinent parameters. At higher levels of assembly, input signals and sequences are simulated under computer control to verify proper operation. These tests may be purely digital in nature, as in the case of testing portions of the Processor Module, or they may involve precision analog testing when they are concerned with subsystems such as the ADC in the input/output modules. As a result of these diverse requirements, a number of different types of testing facilities are required.

The test stations at the various assembly levels are located throughout the manufacturing plant and are organized on a production line basis. System/7 can be used in all of the diverse test situations in the incoming inspection area, at points along the manufacturing line, and at final assembly and test facilities.

The various test stations are interconnected with a System/360, Model 40, providing over-all test coordination and centralization of information. In addition to providing computational power when required, the centralized computing facility gives shared services and collects summary production and management data as input to the integrated corporate information system.

- *Test objectives*

The objectives for particular tests vary with the application. In general, however, the design of the system provides a comprehensive test procedure to satisfy the needs of the many different applications found in the manufacture of complex electronic equipment. Included in the system features are detection and isolation of errors or malfunctions to a replaceable portion of the system, a range of options selectable by the technician, and automatic data collection and housekeeping chores.

- *Multifunction Module testing*

The testing method for the Multifunction Module is indicative of the testing automation provided in the manufacturing process at the higher levels of assembly.

The equipment provided in a typical test station for testing the Multifunction Module is illustrated in Fig. 5, showing the relationship between the individual test stations and the integrated system hierarchy. The test station consists of a two-module System/7 with an IBM 2791 Area Station connected to the 2790 Control, the operator station, and special digitally controlled test equipment. The System/7 is connected to the central System 360/40 via a teleprocessing link. The System/7 contains a Multifunction Module equipped with a moderate number of digital and analog inputs and outputs. The digital input and outputs are connected to the input/output module being tested and to the special test equipment. A small number of analog inputs are connected to the module being tested for measuring key voltage parameters.

The IBM 2791 Area Station is used primarily as an input device to identify the particular module being tested and the test technician who is performing the tests. The operator station, in addition to providing facilities for initial program loading (IPL), provides technician guidance instructions and hard-copy records of individual test results. The special test equipment provides facilities unique to the testing procedure which cannot be directly provided or simulated using System/7. The primary facilities in the case of the Multifunction Module are precision voltage sources and measuring equipment used in testing the analog input features.

- *Test procedure*

When the Multifunction Module is installed in the test fixture, the operator inserts a coded card into the IBM 2791 Area Station to identify the module and its particular complement of features. In addition, he inserts a badge which identifies him as the technician in charge of testing. After recording these data, the central 360/40 automatically transmits the appropriate test programs to the System/7 via the telecommunication link. System/7 executes the test programs, providing automatic sequencing of signals to the input/output module under test, instructions to the test technician, and recording of data for verification of test results and for later statistical analysis by the central processor. After the series of tests is completed, the operator verifies the test results from the printed output on the operator station and indicates that he is ready for the next sequence of tests. The 360/40 then provides a new test program load for the System/7 and

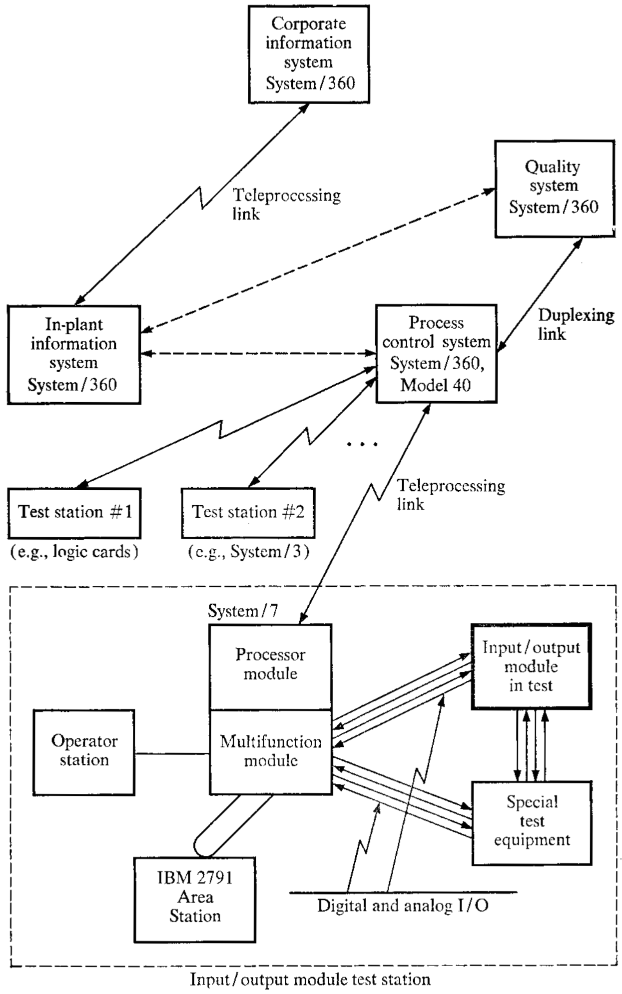

Figure 5 Example test station configuration and integrated information system.

the test procedure continues. In this way, comprehensive testing is accomplished in a sequence of relatively simple tests whose cumulative effect is a thorough analysis of the module performance.

If the module fails to pass any of the individual tests in the various sequences, the operator is notified via a message on the operator station. At this point the normal test sequence is interrupted with the test programs providing diagnostic information as to the probable cause of error. If the diagnostic routines fail to pinpoint the exact source of trouble, the technician can request special test options. Examples of such options include single-cycle operation of the various features or repetitive operation to provide stable waveforms for observations utilizing oscilloscopes and other test equipment.

Once the source of the malfunction has been identified and the repairs effected, the operator can either continue the sequence of tests or return to any previous point in the test sequence. After successful completion of each sequence of tests, a summary test report is printed out as a permanent record. The test software is designed such that a valid test execution is required and verified before the module under test is released from the test station. Pertinent data are extracted from the test report by the process control programming system in the 360/40 for historical and statistical records.

- *Test programming system*

The software testing package written to support this testing application is designed to satisfy the wide range of requirements inherent in the manufacture of System/7.

The basic philosophy guiding the development of the software was that the test routines were tools for use by the test engineer and technician. As such, the housekeeping and secondary functions are implemented in the test supervisor and need not concern the diagnostic programmer responsible for the design of the test routines and sequences.

The software system provides for the detection of errors, the isolation of the error to a replaceable unit whenever possible, the selection of diagnostic conditions by the test technician, simulation of I/O devices and interfaces to reduce the requirement for robots and special test equipment, and provisions for maintaining test integrity. In addition to these primary functions, the system includes facilities for data collection and report generation, communication with other programming systems such as the management information system, and communication with background programs which provide functions such as extensive evaluation and statistical calculations.

The programming of the actual test routines is accomplished with the macro assembler in the test software system to create program loads for transmission to the System/7 in the test station. Each test consists of a series of marco statements followed by data constants. This program construction greatly simplifies the programming task for the test engineer and, in addition, allows modification of particular test routines without disruption to other portions of the system. As an example, more than 20 separate routines are provided for testing the analog input function in the input/output modules. These routines include functions such as logic analysis, accuracy calculations, point selection, selection of input voltage, calculation of the mean value of a sample of readings, and scanning sequence. By combining these routines, the test engineer can build comprehensive tests and test sequences to provide complete testing of the function. The test software interface to the test technician, however, remains constant and noncomplex.

Conclusion

This paper has described the recently announced System/7 and emphasized some of its features that are important in the implementation of a plant automation system. An example test application involving the testing of the Multifunction Module was briefly considered to illustrate a typical subtask from the manufacturing environment.

Of particular importance in the example application and in applications for process control, laboratory automation, and data acquisition is the modular structure of System/7, which provides flexibility and expandability. The physical, functional, and programming modularity provide a means for creating a large number of system configurations optimized for the particular application. The computing power and time responsiveness provided by the System/7 allows exceptional conditions to be handled within the system itself. Teleprocessing and direct connection to a host processor gives access to any required degree of additional computing power and extensive I/O resources of the centralized host processor. In smaller applications, the stand-alone System/7 provides an independent system capable of future expansion and integration into a hierarchical system structure with a minimum disruption of either system.

Acknowledgments

The development of System/7 and the test system described in this paper involved the creative contributions of many individuals in planning, development, and manufacturing departments. The authors, in reporting their work, wish to acknowledge their contributions to the system and to this paper.

References

1. J. E. Stuehler, "An Integrated Manufacturing Process Control System: Implementation in IBM Manufacturing," *IBM J. Res. Development* **14**, 605 (1970, this issue).
2. F. W. Thoburn, "A Transmission Control Unit for

High-speed Computer-to-computer Communication," *IBM J. Res. Develop.* **14,** 614 (1970, this issue).
3. J. R. Calva, "PCOS: A Process Control Extension to OS/360," *IBM J. Res. Develop.* **14,** 620 (1970, this issue).
4. Fischer, Cox and Holdinsky, "Computer-aided Testing and Fabrication of Magnetic Tape Heads," *IBM J. Res. Develop.* **14,** 633 (1970, this issue).
5. M. R. Radio, et al, "Precision Automatic Measuring of *X-Y* Coordinates," *IBM J. Res. Develop.* **14,** 641 (1970, this issue).
6. See Laboratory Automation Issue, *IBM J. Res. Develop.* **14,** 2–138 (1969).
7. C. Kinberg and B. W. Landeck, "Integrated Manufacturing Systems: Architectural Considerations," *IBM J. Res. Develop.* **14,** 589 (1970, this issue).
8. "IBM 2790 System Summary" Form A27-3016, IBM Corporation, Raleigh, North Carolina, 1969.
9. R. M. Duncan, *Telecommunications* **4,** 2, 32 (1970).

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