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Form A26-5709-0

IBM Systems Reference Library

IBM 1710 Control System

This manual contains the basic programming and operating information required to control industrial processes with the IBM 1710 Control System. Information concerning industrial processing and instrumentation is presented in the technical language used in these fields.

This manual makes the following publications obsolete:

IBM *1710 Control System Reference Manual* (A26-5601-0)
IBM *Technical Newsletter* N26-0021
IBM *Technical Newsletter* N26-0036
IBM *1710 Additional Special Features and Attached Units* (A26-5660-1)
IBM *Technical Newsletter* N26-0041

Copies of this and other IBM publications can be obtained through IBM Branch Offices. Comments concerning the contents of this publication may be addressed to: IBM, Product Publications Department, San Jose, California

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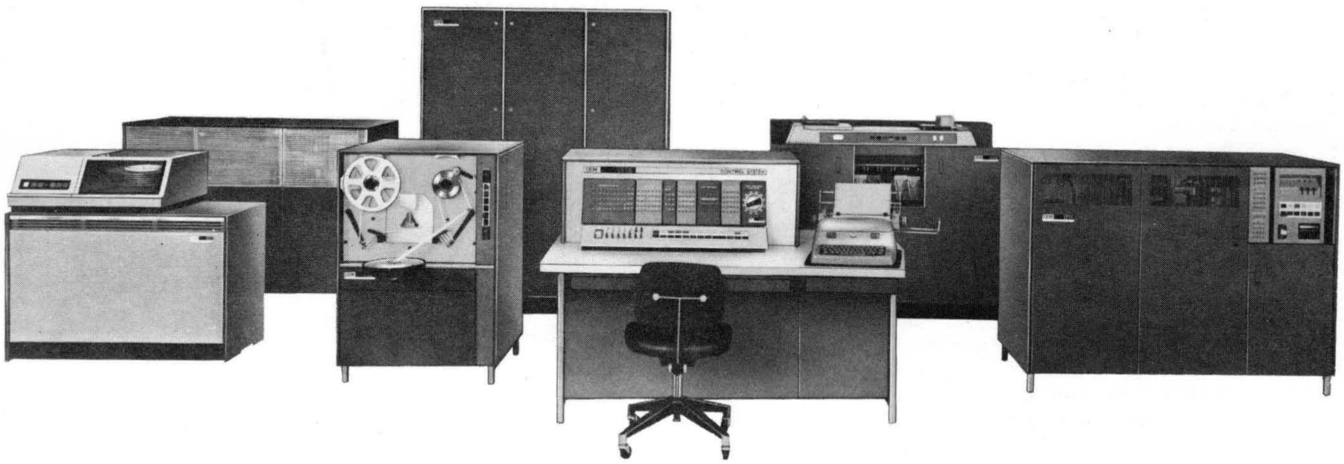
Preface

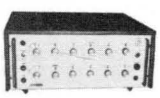
Publications for the 1710 Control System have been adapted to the new IBM Systems Reference Library format. This publication contains the most current machine reference information for the 1710, and represents a major revision of information contained in the publication IBM *1710 Reference Manual* (Form A26-5601).

Machine reference information for the 1710 Control System is contained in the following publications:

IBM *1620 Central Processing Unit (Model 1)*	A26-5706
IBM *1620 Input/Output*	A26-5707
IBM *1620 Special Features*	A26-5708
IBM *1710 Control System* (This publication)	A26-5709
IBM *1311 Disk Storage Drive*	A26-5650

The IBM *1710 Reference Manual* (Form A26-5601) is made obsolete by the publications listed above.

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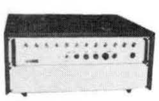
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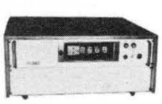
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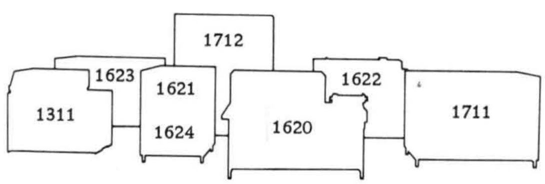

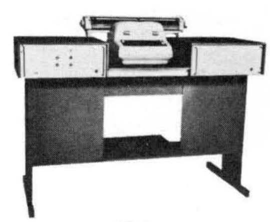
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IBM 1710 Control System

The IBM 1710 Control System is specially designed for controlling processes in such industries as petroleum refining, chemical processing, electric utility, natural gas transmission, and steel production. It is an on-line control system that meets the requirements demanded by industrial processing management by offering versatility of operation, reliability, and ease of expansion through modular construction of the System.

Reliability is achieved through the use of solid-state circuitry and a high-speed, self-checking, digital computer – the IBM 1620. Flexibility is achieved with the availability of announced special features and additional units, which offer any degree of control from data logging and analysis to complete closed-loop control. The customer may start with the minimum 1710 System required to satisfy initial control and analysis needs, and selectively add or substitute features and units as control requirements change. Each control operation can be financially proven before a move toward more complex control is made. The initial investment is protected because changes in control requirements do not necessitate removal of the installed 1710 System.

Applications

The IBM 1710 is capable of accepting electrical signals, both analog and binary, from such devices as thermocouples, pressure and temperature transducers, flow meters, analytical instruments, and contacts. It provides electrical on/off and analog control signals for the customer's controlling devices. Typical applications exist in the area of industrial processing and manufacturing quality control.

Industrial Processing

Industrial processing applications are as wide and varied as are the degrees of control that individual processes may require. All control is based on the collection of process data, and the more complex the control, the greater the need for rapid collection of data. Some of the degrees of control that a 1710 Control System may exercise follow in order of complexity:

Data Logging and Conversion. Process data is sent to the 1710 System, converted into digital information, and logged for process operator and management review.

Data Collection and Analysis. Process data is collected by the computer for mathematical analysis. Current performance figures are compared with those obtained in the past, and the results are printed for process operator and management evaluation.

Data Evaluation and Operator Guidance. Process data is collected, analyzed, and evaluated with respect to previously stored guidance charts. Control instructions are then typed out for the process and control room operator, and messages and log sheets are provided for management review.

Process Study. The computer rapidly collects the process data that is necessary for the development of a model of the process. The model is developed by using a combination of empirical techniques and observing past methods of running the process. When a more complete and more precise description of the process is required, a model is constructed by using such mathematical techniques as correlation analysis and regression analysis. The process control program is then tested on the mathematical model prior to its use on the process. Extensive operator guide information is obtained. In addition, the model represents considerable progress toward closed-loop control.

Process Optimization. An extensive computer control program, based on the model of the process, directs the 1710 System. Process data is continuously collected and analyzed for computation of optimum operating instructions. These instructions are given to the process operator via the computer console typewriter.

Closed-Loop Control. Closed-loop control is the ultimate in industrial process control. Process conditions obtainable through instrumentation are continuously monitored by the computer. The instrument readings are analyzed rapidly and simultaneously, and the computations initiate controlling signals, which are sent to the devices that control the process.

In addition, input and output units located in the process area enable the computer to send messages directly to the process operator. These messages guide the operator in adjusting the status of *instruments located at the point of control.* Data messages based upon visual observation of the process and point-of-control instrumentation are sent back to the computer by the process operator. These messages are evaluated by the computer to provide additional process control directly through controlling instrumentation and to provide continued process operator guidance.

Communication between the control room operator and the process is maintained through the Central Processing Unit (CPU). The console typewriter provides log sheets and messages that aid management in evaluating process performance. The speed and reliability of the 1710 System enable the operation of industrial processes at a higher level of performance than heretofore realized.

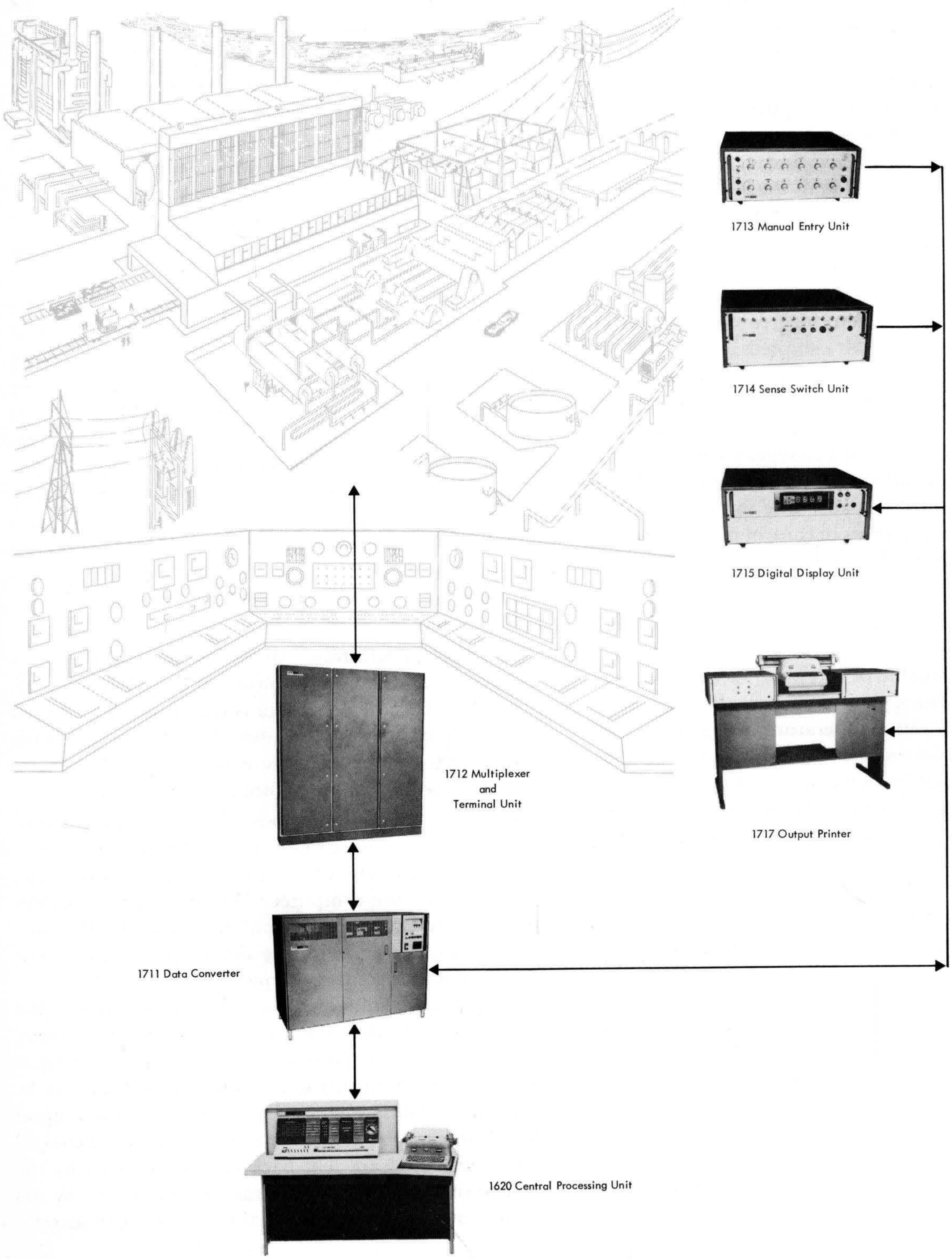


Figure 1. Data Flow — 1710 Control System

1710 Control System Units

The IBM 1710 Control System is comprised of the IBM 1620 Central Processing Unit, the IBM 1711 Data Converter, and the IBM 1712 Multiplexer and Terminal Unit, Model 1. In addition, all 1620 and 1710 special features and additional units are available. Appendix B is a chart of the features and units that can be utilized in the 1710 Control System. A system configuration showing all special features and additional units and their prerequisites is contained in the publication IBM *1710 System Configuration* (Form G26-5693). All system components and special features are modularly constructed and use solid-state (transistorized) circuitry. SMS (Standard Modular System) cards (Figure 2) are used throughout the 1710 System. These printed circuit cards are pluggable. Each card contains all the electronic components and printed wiring for a particular function or functions. The use of SMS cards not only makes the system more flexible and reliable, but, in addition, increases its reliability and availability because of reduced maintenance requirements.

Abbreviations and acronoyms used in this publication that are peculiar to the 1710 Control System are listed and defined in Appendix E.

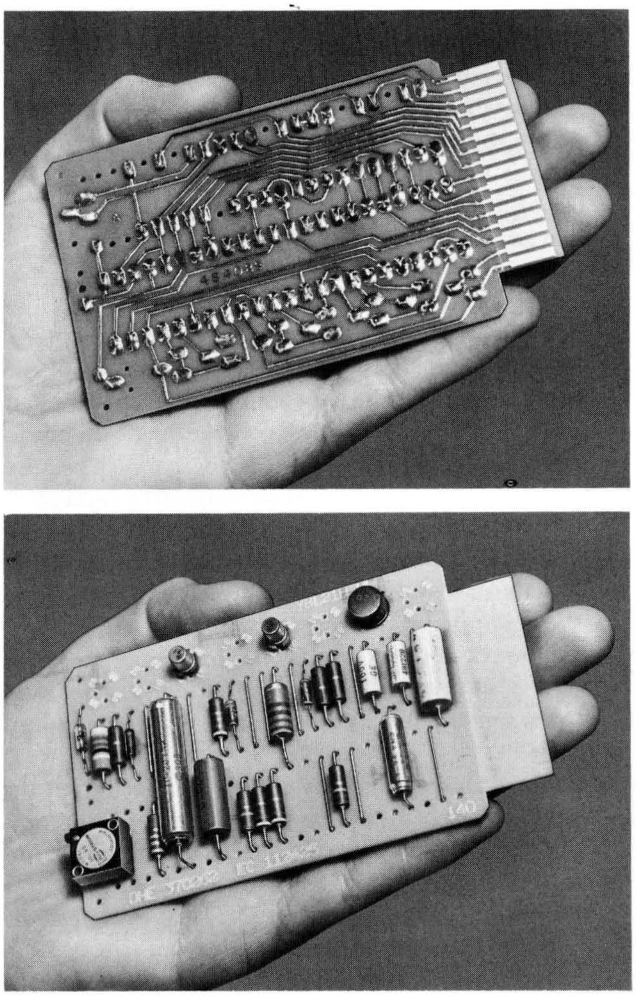


Figure 2. IBM SMS Card

1710 Publications and Programming Systems

Systems Reference Library

The continuing demands of business and industry have necessitated the design and manufacture of an increasing number and variety of versatile computer systems. The programmers and operators of these systems are challenged, as never before, to learn and implement effective man-to-computer communications. The recognition of this challenge and the desire to effect the highest communication level between all concerned — manufacturer, system engineer, user, and computer — has resulted in the establishment of the IBM Systems Reference Library.

A Systems Reference Library is provided for each computer system. Each reference library includes literature applicable to the installation and operation of its

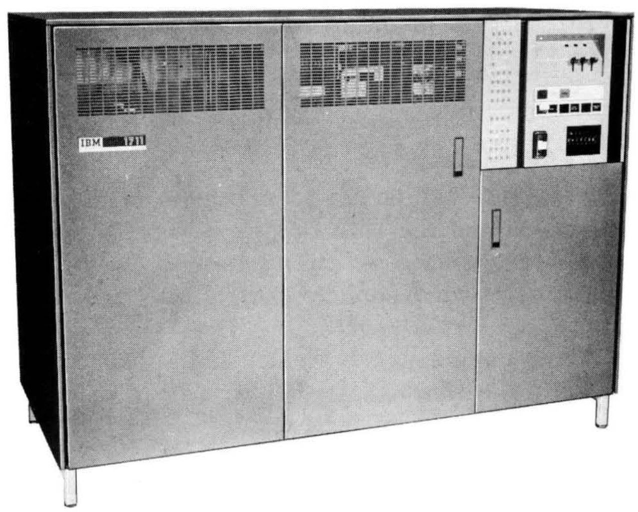


Figure 3. IBM 1711 Data Converter

respective system. The Systems Reference Library is organized in three main categories:

1. Systems Information — Condensed: introductory and summary publications for machine units and programming systems and a bibliography of all library literature is included in this category.
2. Machine Systems: includes a detailed publication for each unit and feature of the system and its physical installation (CPU, I/O, Special Features, Physical Planning, etc.).
3. Programming Systems: includes general and detailed publications for each programming system (SPS, Utility Programs, Processors, etc.).

1710 Bibliography (Form A26-5695)

Reference literature applicable to the installation and operation of the IBM 1710 Control System is indexed in this bibliography. The bibliography is published in three parts: In Part 1, the publications are listed under major subject headings; this listing can serve as a table of contents for the 1710 Systems Reference Library.

Part 2 is a cross-index of publications by machine type number to help the user find publications for which the title is not known.

Part 3 contains the abstracts of all publications in form number sequence. The abstract of a publication enables the user to determine whether the publication is applicable to his needs.

All 1710 publications listed in this bibliography can be obtained by form number from the local IBM Sales Representative.

1710 Systems Summary

This publication briefly describes system concepts, system units, and special features. Of particular importance to the programmer is the section of this manual that describes the programs and programming systems for the 1710 Control System.

1711 Data Converter

Figure 1 illustrated the relationship between an industrial process and the 1710 Control System. The 1711 may be programmed to control processes as follows (the numbers correspond to the circled numbers in Figure 4):

1. Analog Input signals are sent to the 1710 System via the 1712 MTU. The 1712 is used as the interconnecting device between the process and the 1710.
2. The Interrupt feature enables the control system to give prompt attention to critical signals caused by such occurrences as the liquid level of a tank approaching an overflow condition. The interrupt causes the computer to suspend routine operation, to notify the process operator of the condition, and/or to initiate corrective action. With the installation of special features, corrective action can turn on a motor in the process area which will close a valve and stop liquid flow to the tank.

   Interrupts are assigned to high-priority conditions in the process that are not expected to occur in normal processing, or if they are expected to occur, their occurrence cannot be scheduled. Without the ability to interrupt its program *at any time,* the computer would repeatedly scan these signals, even though the signals occur infrequently or not at all.

   An internal interrupt, Multiplex Complete, is available when the Input/Output Interrupt feature is installed. The Multiplex Complete interrupt is turned on by completion of process input/output functions such as the end of conversion of an analog input signal. The Multiplex Complete interrupt is used to direct the computer program to a program subroutine that will cause appropriate program action such as reading the contents of the ADC register into core storage.
3. Analog Output sends computer-controlled signal pulses to the customer's controlling devices in the process area. Contact Operate is used to turn on or off the customer's process devices (motors, alarms, etc.).
4. Up to 20 Process Branch Indicators are available for program interrogation of conditions in the process area. Each Process Branch Indicator reflects the on/off condition of a contact in the process area — if the contact is closed, its associated indicator is on. When the contact opens, the indicator is turned off. Thus, as the contacts in the process open and close, their respective indicators in core storage are turned off and on.

   Process Branch Indicators can be assigned to signals in the process that are not as critical as those requiring the Interrupt feature, yet must be frequently interrogated by the computer program. These indicators can be *individually* scheduled for interrogation by the program at timed intervals.
5. Process Operator Units can be connected to the 1710 Control System so that input information can be originated by the process operator, or output data can be made available at vital points throughout the process area. These units can be connected to or disconnected from the system without disturbing other Process Operator Units on the system, and without affecting the operation of the 1620 CPU.

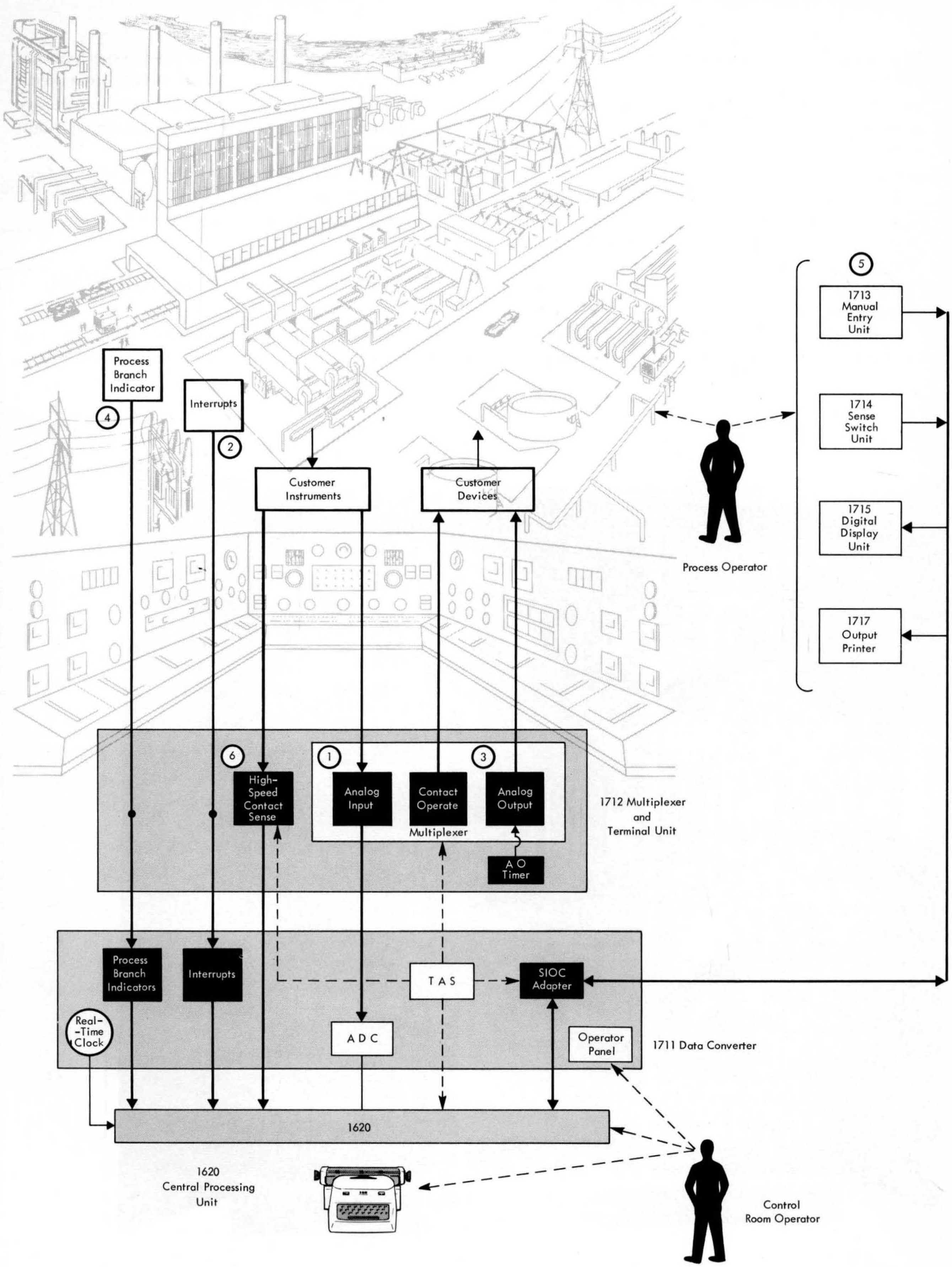


Figure 4. Data Flow Diagram of 1710 Control System

6. The High-Speed Contact Sense feature enables the 1710 System to sense the on/off condition of up to 400 contacts in the process. The contacts are scanned and the status of the contacts is placed in 1620 core storage at rates of up to 100,000 points per second.

   This feature is used to terminate the majority of on/off signals in the process that are neither critical nor must be interrogated individually. These signals may occur frequently or infrequently, but they are scanned by the computer as a routine operation.

   Unlike Process Branch Indicators that can be continually turned on and off inside the computer by the opening and closing of their respective contact points in the process, the status of contact sense points are recorded in the computer's core storage as being either off or on at the particular point in time at which they are scanned.

   A particular advantage of the High-Speed Contact Sense feature is that it can be used with any industrial contacts and any industrial wiring.

1712 Multiplexer and Terminal Unit (MTU), Model 1

The 1712-1 MTU (Figure 5) provides interconnecting terminals for process and control system connections.

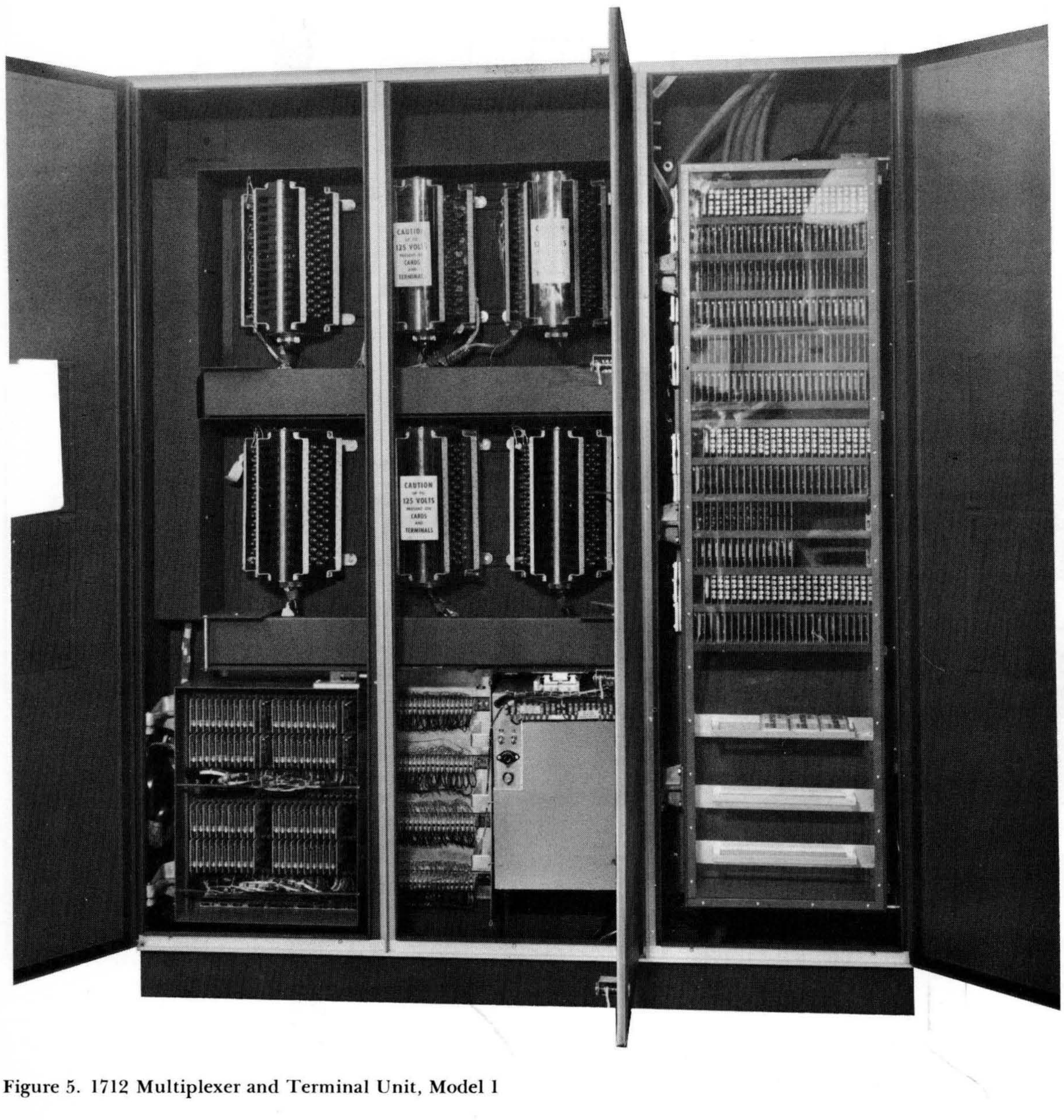


Figure 5. 1712 Multiplexer and Terminal Unit, Model 1

It contains space for six terminal blocks (50 points per block) and associated SMS cards. A terminal strip may be installed for 12 Process Interrupts and 20 Process Branch Indicators. In addition, a terminal block may be installed for terminating as many as 400 contact sense points. In keeping with 1710 System philosophy, all terminal blocks and terminations are available as special features. In addition, the 1712-1 is available with one, two, or three SMS card panels, i.e., it is capable of terminating a total of 150 or 300 process input/outputs and 400 contact sense points.

The design and construction of the 1712-1 offers the following advantages: (1) multiplexing and terminating in the same unit minimize coupling problems between the process and the control system, and (2) system expansion in the 1712 simply involves the connection of terminal wires and the addition of SMS cards.

Process Input/Output Special Features

Analog Input. Low-level voltage and current signals from process thermocouples and instruments are sent to the ADC in the 1711.

High-Speed Contact Sense. Process conditions are sensed by the on/off status of contacts in the process area.

Process Branch Indicators. 1710 indicators are turned on and off by associated contacts in the process area. The 1710 program interrogates the indicators to determine the appropriate program instructions to follow.

Interrupt. Process disturbances that require corrective action interrupt the routine operation of the 1710.

Analog Output. Controlling signals are sent from the 1710 to the customer's set-point positioners.

Contact Operate. Contacts are momentarily closed to switch process control devices on and off.

1711 Data Converter Features

The 1711 Data Converter contains an Analog-to-Digital Converter (ADC), a Real-Time Clock (RTC), a Terminal Address Selector (TAS), and an Operator's Panel.

Analog-to-Digital Converter (ADC)

The ADC enables the 1710 to accept analog voltages or currents from customer instruments and transducers. Fifty milliseconds are required for each analog signal conversion (a maximum of 20 conversions per second).

Analog Input functions, available in increments of two, include SMS cards for matching (transforming incoming current signals to an acceptable voltage level) and filtering (reducing the effect of spurious signals). Analog Input functions cannot be terminated on terminal blocks containing Contact Operate and Analog Output functions.

Standard SMS cards are available for terminating the following signals which may be of either polarity:

0 to 50 millivolts
0 to 5 milliamperes
0 to 20 milliamperes
0 to 50 milliamperes

Signal polarity is determined as a part of the function of signal conversion.

SMS cards for signals outside of the ranges listed are available by special order.

Analog Input

The program selects each analog signal individually via TAS (Terminal Address Selector) and the multiplexing relays. As shown in Figure 6, an analog signal passes through a multiplexing relay contact and into the ADC (Analog-to-Digital Converter). The converted signal, which will be in the digital range of 0000 to

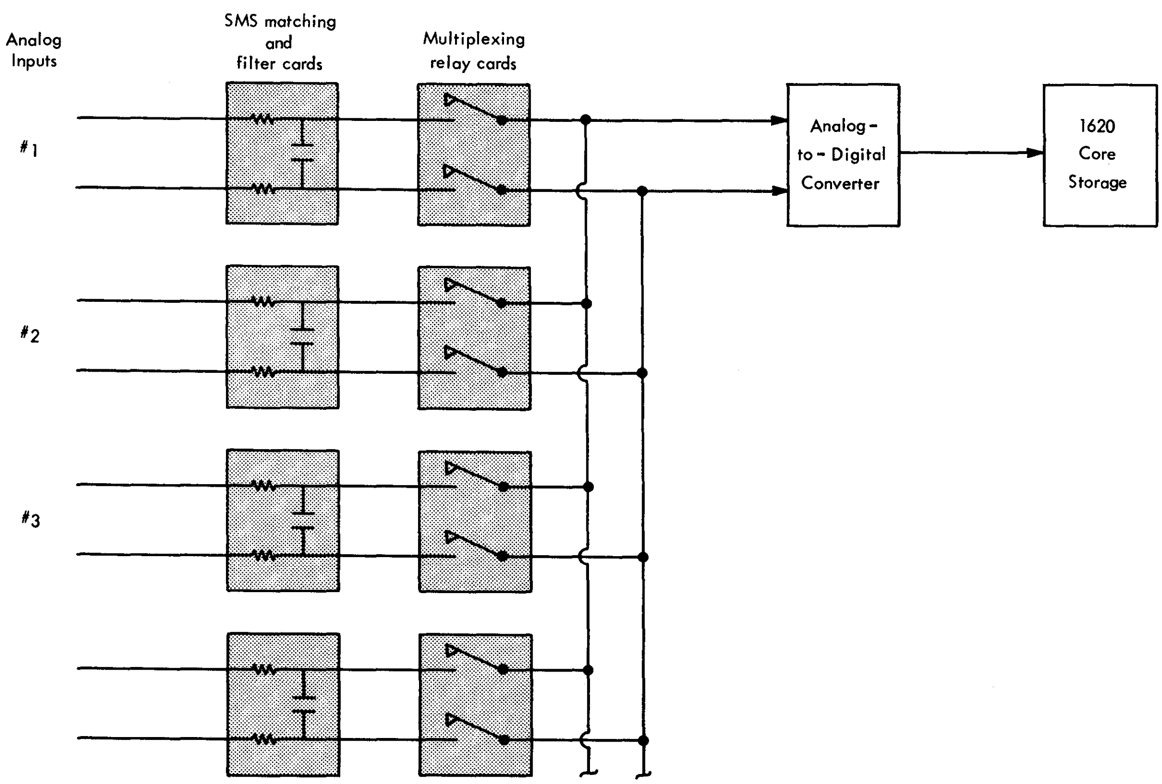


Figure 6. Analog Input Data Flow

9999, remains in the ADC register until the program causes it to be transferred to core storage. An ADC conversion scale is shown in Figure 7. Pertinent programming details follow.

If a negative analog voltage is read into the ADC, a flag is placed over the units digit of the ADC register and the Negative light on the 1711 Operator's Panel is turned on. This flag bit is transferred to core storage with the units digit when the transfer from the ADC register to core storage occurs.

If the analog signal exceeds the range of its matching card, four flag bits rather than the contents of the ADC register are placed in core storage. The ADC register and associated 1711 Operator Panel lights will contain an 8-2 or 8-2-1 bit configuration in the high-order position and 000-999 in the other three positions depending on the value of the overload signal.

When the four digits from the ADC register are transferred to core storage, the high-order digit is flagged. The replaced data including flag bits is lost.

Once the converted data is in core storage, the program transforms the digital value into a meaningful measurement of the variable (temperature, flow rate, pressure, etc.).

Two Program Select instructions: **Select Address** and **Select ADC Register** are available for reading analog signals into the ADC for conversion. **Select Address** and **Select ADC Register** are provided with Random Addressing of TAS, a special feature. The **Select Address** instruction merely reads the selected signal into the ADC for conversion, whereas the **Select ADC Register** transfers the contents of the ADC register into core storage first, and then reads the newly selected analog signal for conversion.

ADC INPUT				DIGITAL OUTPUT
0-50 Millivolt	1-5 Milliamp	4-20 Milliamp	10-50 Milliamp	
+50 and over	5 and over	20 and over	50 and over	$\bar{0}\bar{0}\bar{0}\bar{0}$
+49.995	4.995	19.995	49.995	$\bar{9}999$
+40	4	16	40	$\bar{8}000$
+30	3	12	30	$\bar{6}000$
+20	2	8	20	$\bar{4}000$
+10	1	4	10	$\bar{2}000$
0	—	—	—	$\bar{0}000$
-10	-1	-4	-10	$\bar{2}00\bar{0}$
-20	-2	-8	-20	$\bar{4}00\bar{0}$
-30	-3	-12	-30	$\bar{6}00\bar{0}$
-40	-4	-16	-40	$\bar{8}00\bar{0}$
-49.995	-4.995	19.995	-49.995	$\bar{9}99\bar{9}$
-50 and under	-5 and under	20 and under	50 and under	$\bar{0}\bar{0}\bar{0}\bar{0}$

Figure 7. ADC Conversion Scale

The Multiplexer Busy indicator (29) is on during the 50 millisecond conversion cycle. This indicator may be interrogated to determine when conversion is completed. The computer proceeds with succeeding instructions during conversion unless an instruction that uses the multiplexer is initiated (Analog Input, Analog Output, or Contact Operate instructions). In this case, both the instruction and the computer are delayed until after conversion is completed and Multiplexer Busy is turned off.

The Multiplex Complete indicator (40) is turned on at the end of conversion. Multiplex Complete initiates an interrupt which can cause reading of the ADC register, selection of the next Analog Input address, etc.

It is often desirable to take successive readings of an input variable in order to assure that no error occurred in the measuring of the variable or in the analog-to-digital conversion of the measurement. By taking three separate readings, the output of all three readings may be compared against a predetermined range. If all three readings lie within a specified range, the first reading, or perhaps an average of the three readings, may be used with more certainty as the value of the input variable. When this is done, a time delay of 600 ms should be programmed between successive readings of the same point to ensure maximum accuracy.

Real-Time Clock (RTC)

The RTC designed for use in logging applications is an electronically powered 24-hour mechanical device which keeps time (to the nearest minute) in hours, tenths of hours, and hundredths of hours. The contents of the RTC, 00.00 through 23.99, are displayed on the 1711 Operator's Panel, and may be read into core storage by use of the **Select Real-Time Clock** instruction. The low-order position clock wheel advances once each minute, as follows: 0-2-3-5-7-8-0.

The RTC may be programmed so that the logging time is printed along with log data. To prevent the possibility of erroneous readings, readout of the RTC is blocked during the time the clock wheels advance (approximately 320 milliseconds).

Three levers are provided on the 1711 Operator's Panel to set the clock. The levers travel up and down as their respective clock wheels advance. The hundredths of hours (rightmost) lever must be positioned by the clock to its upward limit of travel before it can be used to set its clock wheel.

Terminal Address Selector (TAS)

TAS is program-controlled to select individual process signals. Consisting of a 300-point scanning counter and matrix and a three-digit register, TAS selects Analog Input, Analog Output, and Contact Operate addresses from 000 to 299; High-Speed Contact Sense address from 00 to 19; and Process Operator Units addresses from 00 to 99. TAS contents are displayed on the 1711 Operator's Panel. The **Select TAS** instruction may be used to store the contents of TAS. For the purposes of programming and timing considerations, it is important to note (see Figure 6) that Analog Input, Analog Output, and Contact Operate addresses are routed through the Multiplexer, and that the Process Operator Units addresses and the High-Speed Contact Sense addresses are *not* routed through the Multiplexer. The significance of this fact is mentioned in appropriate parts of the manual.

1711 Operator's Panel

The 1711 Operator's Panel (Figure 8) contains switches, keys, lights, and indicators that are pertinent to operating the 1711. The Operator's Panel is described in detail under 1711 OPERATING KEYS AND LIGHTS.

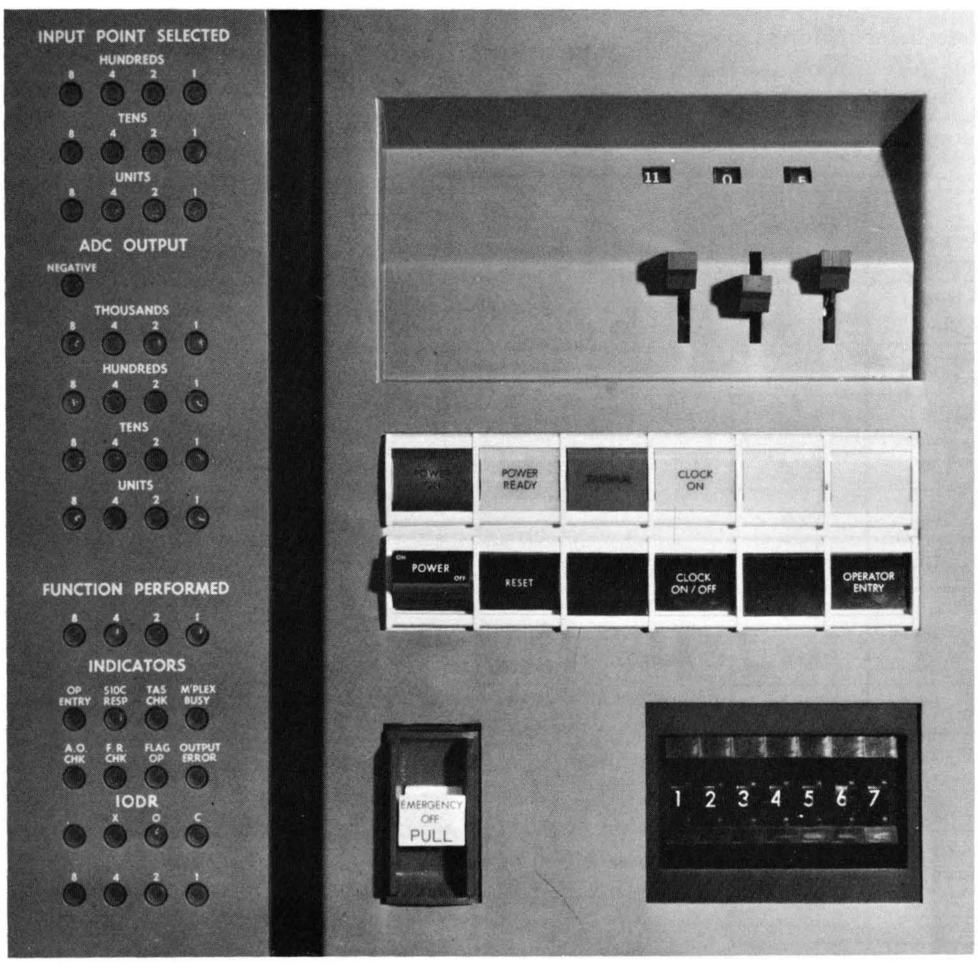


Figure 8. 1711 Operator's Panel

1710 Special Features and Additional Units

Flexibility, a major advantage that permits the 1710 Control System to meet individual customer requirements, is achieved through the installation of announced special features and additional units. A minimum 1710 Control System may be installed for existing needs, and the installed system may be altered as control requirements change to provide new functions and increased capabilities. This section describes the 1710 special features and additional units. The publication IBM *1710 System Configuration* (Form G26-5693) shows all special features and additional units and their prerequisites.

Four types of terminal blocks are available for installation in the 1712 Multiplexer and Terminal Unit: Standard Terminal Block, Thermocouple Terminal Block, Interrupt/Process Branch Indicator Terminals, and Contact Sense Terminal Blocks.

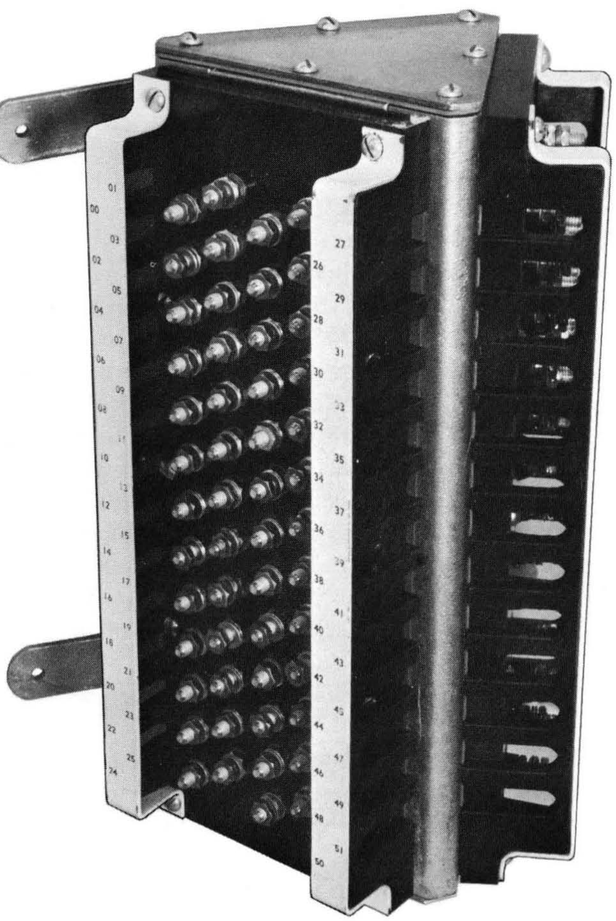


Figure 9. Terminal Block

Standard Terminal Block

The standard terminal block (Figure 9) may be used to connect Analog Input, Contact Operate, and Analog Output functions. The following rules must be observed, however:

Contact Operate and Analog Output functions may be connected on the same block. In order to minimize undesirable stray voltage effects, Analog Input functions must be located on a block containing only Analog Input functions.

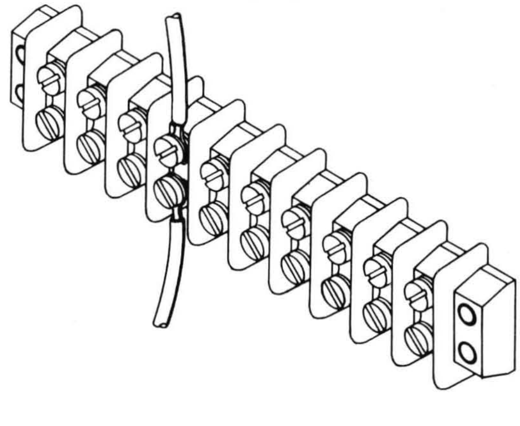
Analog Output functions require two addresses for each analog output channel. In addition, two addresses must be assigned for control of the slew and trim operations.

Fifty terminal addresses or 100 terminals are provided for customer connections on each block.

Analog Input terminations other than thermocouple terminations can be made on a thermocouple terminal block. Analog Output and Contact Operate terminations can only be made on a standard terminal block.

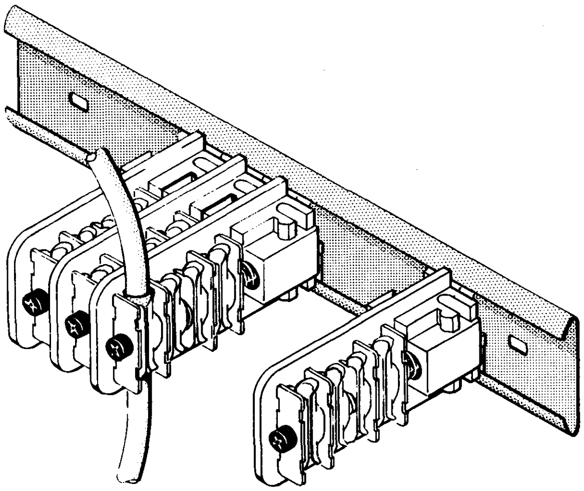
Interrupt/Process Branch Indicator Terminals

This terminal block is used to terminate the 12 External (process) Interrupts, and the 20 Process Branch Indicators.



Contact Sense Terminal Block

This terminal block is used to terminate high-speed contact sense terminal points. Each block provides for termination of 50 contact sense connections.



Thermocouple Terminal Block

The thermocouple block is a standard terminal block that has been modified for thermocouple terminations. A thermocouple is a temperature-measuring device. It provides an analog voltage which is developed by the difference between the ambient temperatures of the thermocouple measuring junction and the thermocouple block reference junction. A resistance bulb thermometer (RBT) and its associated circuit components are mounted on the block to measure the reference temperature. The RBT circuit also provides a reference voltage signal (V_R). The 1710 uses the thermocouple, RBT, and V_R signals to compute the measured temperature.

Analog Input terminations other than thermocouple terminations may be made on a thermocouple block. Analog Output and Contact Operate terminations can only be made on a standard terminal block.

Fifty terminal addresses or 100 terminals are provided for customer connections on each block. The RBT and V_R must be assigned to the first two (lowest-numbered) addresses on the thermocouple block.

Measuring Thermocouple Temperatures with the 1710

The 1710 Control System is connected to each process thermocouple via the 1712 MTU. The thermocouple measuring junction is located in the process area where temperature sensing is desired, and the reference junction is located on the 1712 terminal block. The reference junction wires are extended to a matching card in the 1712. The 1710 compensates for reference temperature fluctuations by means of an RBT, located on each thermocouple terminating block for reference-temperature sensing, and through calculations performed as part of the program.

Resistance Bulb Thermometer (RBT)

Essentially, an RBT is a wire-wound resistor whose electrical resistance varies with temperature. The resistor is electrically connected to a Wheatstone bridge (balanced circuit). A temperature variation causes a change in resistance and a consequent unbalance of the bridge circuit. The RBT circuit provides two signals for 1710 program evaluation: the voltage produced by the RBT, and an RBT reference voltage. Thus, not only are thermocouple signals compensated for by reference temperature fluctuations, but the reference temperature signal itself is read by the computer to permit compensation for any RBT supply voltage variations that may occur.

Thermocouple Programming and Conversion

The conversion of a thermocouple signal to a meaningful and accurate temperature value is performed as part of the computer program. The signals from the thermocouple and the RBT circuit, plus related thermocouple and RBT data, provide the means for mathematical analysis and conversion. Thermocouple data is available from commercial sources for each thermocouple type, i.e., tables and curves which express the temperature-to-millivolt relationship. Data for the RBT supplied with the thermocouple terminal block is provided below. Three points should be stressed about the conversion procedure which follows: (1) It is recognized that there are other means, such as curve fitting, to convert thermocouple signals, (2) The procedure below is valid only where the RBT supplied with the thermocouple terminal block is used, and (3) This procedure pertains to the signal conversion of only one thermocouple type, i.e., constants A, B, C, and D (see below) must be computed and stored for each thermocouple type:

1. Study the thermocouple temperature-to-millivolt curve and determine the number of segments or divisions that must be made to obtain the desired degree of accuracy. For example, a $-100°$ to $+500°$ temperature range may be divided into four segments as follows: $-100°$ to $+50°$, $50°$ to $200°$, $200°$ to $350°$, and $350°$ to $500°$.

This segmentation is required because thermocouple millivolt output is not a straight line relationship with respect to measured temperature — particularly at the upper end of the thermocouple temperature range. Smaller segments, of course, provide a more linear or straight line approximation.

2. Take the upper and lower millivolt values from each segment, and use the relationship, 1 millivolt equals a DRO (digital readout) value of 200, to obtain equivalent DRO values. The DRO value for a given thermocouple signal is the same as the digital value obtained in the ADC register for that same thermocouple signal. For example, a 15-millivolt value is equal to a DRO value of 3,000 (15×200) and, where the ADC range is ± 50 millivolts, a 15-millivolt thermocouple signal is converted to 3,000 by the ADC. Since all thermocouple signals are converted to digital values, the use of DRO values rather than millivolt values facilitates the computation of actual temperatures.
3. For each segment, use the formula

   $$\text{temperature} = A\ (\text{DRO}) + B$$

   twice to solve for A and B, the two unknowns, i.e., solve once for the upper temperature and DRO values and once for the lower temperature and DRO values. Actually, A is the slope of the segment and B is the intersection of the segment, if extended on the y-axis.
4. Store A and B for each segment.
5. Use the same formula (step 3) to solve for A and B in the temperature area of 25° C, which is the normal temperature region for the RBT (approximate room temperature). Use these A and B values in the following formulas

   $$C = \frac{1}{A} \qquad D = -\frac{B}{A}$$

   These two formulas express the thermocouple block RBT relationship to the thermocouple signal; C and D are used for the linear conversion from temperature to DRO of the computed RBT temperature (step 8).
6. Store C and D. You now have stored: (1) a pair of constants, A and B, for each segment of the curve, and (2) constants C and D for the base temperature of the RBT.
7. Read both signals of the RBT circuit and use their ADC values in the formula

   $$RBT_t = 28.82\ \left(\frac{RBT}{RBT_r}\right) + 5.0$$

   to solve for the RBT temperature (RBT_t). RBT and RBT_r are the ADC values obtained by reading the RBT signal and the RBT reference signal (the first two addresses on the thermocouple block). The values, 28.82 and 5 (expressed in degrees Centigrade), are constants for the RBT supplied with the thermocouple block. These values must be converted to degrees Fahrenheit if the thermocouple tables and curves are expressed as such ($F = 9/5\,(C) + 32$).
8. Use the formula

   $$CRBT = C\,(RBT_t) + D$$

   to obtain a corrected DRO value for the RBT (CRBT). C and D were obtained in step 5; RBT_t was obtained in step 7.
9. Read the thermocouple signal, and use its ADC value in the formula

   $$ATC = TC + CRBT$$

   to obtain an adjusted DRO value (ATC).
10. Use the formula

    $$TC_t = A\,(ATC) + B$$

    to compute the actual thermocouple temperature (TC_t). A and B are selected according to the DRO value of ATC, i.e., whatever segment the value of ATC falls into, the A and B values are used from that segment.

Example of Thermocouple Conversion

Example: An iron-constantan (type J) thermocouple is installed in a temperature region of 800° C. The A and B values for the segment that includes 800°C are: $A = .07803$, $B = 89.554$. The A and B values for the segment that includes 25°C are: $A = .0961$, $B = .385$.

From step 5: $C = 10.4$ and $D = -4.0$

Assume the RBT temperature (RBT_t) is 25°C; then from step 8:

$CRBT = 256.0$

Assume the ADC or DRO value of the thermocouple is 9236; then from step 9:

$ATC = 9492$

and from step 10:

$TC_t = 830.2°C$

High-Speed Contact Sense

High-Speed Contact Sense, available as a special feature, gives the 1710 the ability to determine the status of on/off conditions in the process area. It is especially suited for control system applications that require very fast sensing of process contacts and for reading the many types of contacts used in industrial processing. Contact sense points are available in increments of five, with a maximum of 400 on any one system.

Description

Contact sense points are terminated in blocks of 50 points each. One terminal *address* is assigned for a group of 20 terminal *points*. A total of 20 terminal addresses is available if all 400 contact sense points are installed. For the purposes of programming, the terminal block can be thought of as consisting of two parts with 200 terminal points (10 terminal addresses) on each part. When a program instruction specifies any one of the 10 terminal addresses on either part, the 20 terminal points at that address and *all of the terminal points for the remaining higher-numbered terminal addresses for that part* are scanned and read into core storage. For example, in the following chart of terminal addresses it can be seen that an instruction specifying terminal address 03 causes the program to scan and read into core storage terminal points 60 through 199.

Terminal Addresses	Points Scanned
00	000-199
01	020-199
02	040-199
03	060-199
04	080-199
05	100-199
06	120-199
07	140-199
08	160-199
09	180-199

Terminal Addresses	Points Scanned
10	200-399
11	220-399
12	240-399
13	260-399
14	280-399
15	300-399
16	320-399
17	340-399
18	360-399
19	380-399

As another example, terminal address 10 would cause the program to scan and read into core storage terminal points 200 through 399; thus, up to 200 terminal points can be read with one instruction.

Contact points are scanned and read into core storage at the rate of 100,000 points per second. When fewer than 200 points are scanned, the rate is less than 100,000 points per second.

Table 1 contains examples of actual scanning rates.

The program instruction associated with the High-Speed Contact Sense special feature is **Select Contact Block.**

Table 1. Examples of High-Speed Contact Sense Scanning Rates

Number of Points Scanned	Number of Computer Instructions	Time in Microseconds	Scanning Rate in Points per Second
20	1	335	59,000
100	1	1,035	96,000
200	1	1,910	105,000
400	2	3,820	105,000

Contact Operate

The Contact Operate feature enables the 1710 to control on/off conditions in the process area. Motor start-ups, annunciators, horns, alarms — any device which can be controlled by a momentary contact closure may be programmed.

Contact Operate functions are available in increments of two. They may be terminated on the same terminal block with Analog Output functions, but not with Analog Input. The special feature, Random Addressing of TAS, is required. Contact Operate utilizes mercury-wetted relay switches for its operation.

Application

A simplified Contact Operate circuit is shown in Figure 10 to point out the following:

1. Customer power is used to operate a customer's device (an alarm in this case) — the Contact Operate function merely completes the circuit. The contact capacity is 100 volt-amperes with a 2-ampere, 120-volt AC or 24-volt DC maximum. Note that the contact lines are fused within the 1712.
2. The customer's relay is energized when the Contact Operate instruction is executed. The relay contact R-1 closes and the alarm is activated.
3. The customer relay circuit may or may not be self-latching. The relay shown is latched, that is, held energized by its R-2 points. An unlatching method such as a push button may be provided by the customer.
4. Adequate arc suppression must be provided by the customer for contact protection. For additional information, refer to IBM *1710 Control System Installation Manual — Physical Planning* (Form C26-5605).

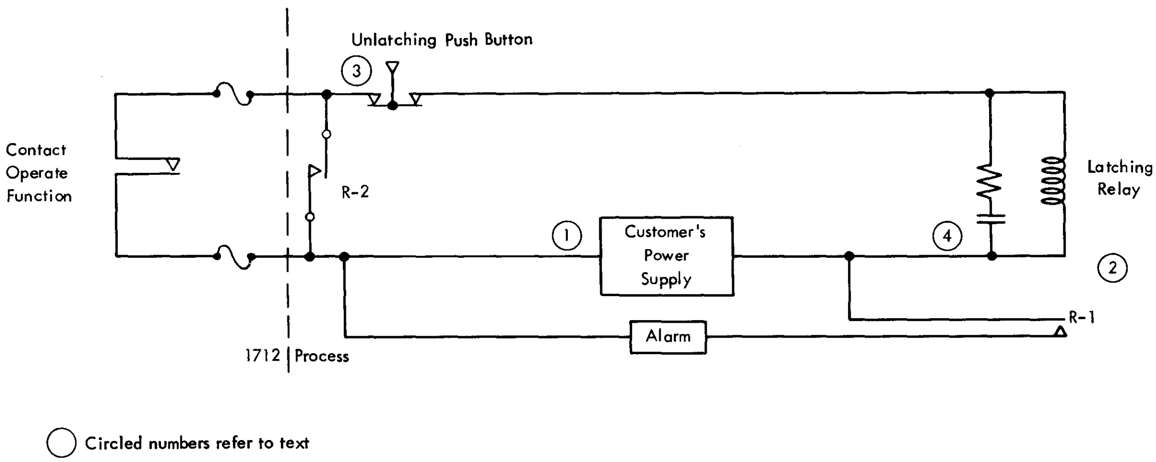


Figure 10. Contact Operate Logic

Contact Operate Programming

The Contact Operate instruction **Select Address and Contact Operate** initiates a contact closure of 50 ms. The Multiplexer Busy indicator is on during this time. If the multiplexer is busy when the **Select Address and Contact Operate** instruction is initiated, the instruction is delayed until the Multiplexer Busy indicator goes off. The computer is disconnected 160 μsec after initiating the instruction. If the computer is disconnected before an instruction using the multiplexer is initiated and before completion of the 50 ms interval, the instruction is delayed for the remainder of the 50 ms. If the Input/Output Interrupts special feature is installed, a Multiplex Complete Interrupt signal occurs after the 50-ms interval.

Analog Output

The Analog Output feature enables process engineers to "close the loop" with the IBM 1710 Control System. Process instrumentation provides data to the computer which, after programmed analysis of the collected data, returns controlling signals to the process via the Analog Output and Contact Operate features (Figure 11). All

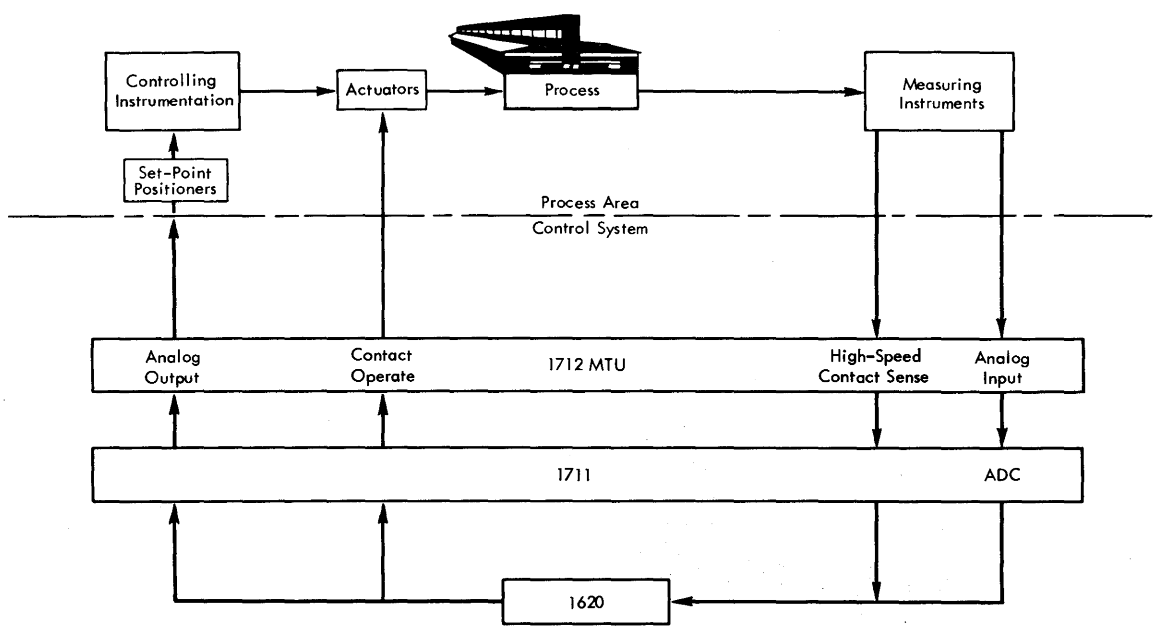


Figure 11. On-Line, Closed-Loop Control

process instrumentation, both measuring and controlling, is provided by the customer, as are the set-point positioners, to alter the set-point adjustments on controlling instrumentation. The controllers regulate the actuators (valve motors and valves, dampers, relays, solenoids, etc.) that implement process control.

The Analog Output feature has been designed so that the customer has maximum control over his output functions.

Controlling Instrumentation

A home furnace thermostat is a controlling instrument. Depending on feelings of coolness or warmth, the householder adjusts the thermostat (set-point) up or down. The difference between the room temperature and the temperature specified by the set-point causes a signal that controls the fuel supplied to the furnace. The resulting change in BTU output from the furnace corrects the room temperature to the temperature specified by the set-point.

Industrial controlling instruments are generally more complex, but contain essentially the same elements:

A device for measuring the value of variable.
An adjustable set-point.
A control mechanism for maintaining the measured variable at the value specified by the set-point.

In addition to these basic elements, a controlling instrument may or may not have associated with it an indicator and/or a recorder. An indicator provides a continuous visual indication of the measured variable, e.g., the thermometer mounted on the home thermostat. A recorder provides a continuous record of the measured variable. Controlling instruments are generally named according to the scope of their functions — recording, indicating, and controlling. For example, an instrument consisting of all three units is referred to as an Indicator/Recorder Controller; an instrument consisting of a recorder and a controller is referred to as a Recorder-Controller, etc.

A basic automatic control loop for regulating fluid flow is shown in Figure 12. The variable is measured and transmitted to the Flow Recorder-Controller by Flow Transmitter I. The *controller,* which may or may not be mounted inside the instrument, acts as an analog computer in that it determines the difference between the measured variable and the set-point value. This difference, if present, results in a corrective signal to the actuator or controlling valve, V. Thus, the fluid flow is maintained at the value specified by the position of the set-point. When the process requires a change in flow rate, the process operator repositions the set-point up or down.

Most process instrumentation set-points are adjusted by the operator. Some control problems, however, require that the set-point of an instrument be automatically adjusted by the controller of another instrument. This form of control is designated as Cascade or Multiple-Loop control. Cascade control may be employed to regulate the supply of fuel to a steel-mill furnace. The fuel, coke oven gas, is obtained as a byproduct of another operation and as a result its pressure in the fuel line varies considerably. The demand for furnace heat also varies and Cascade control is employed to compensate for both variables (Figure 13). Fluctuations in furnace temperature are sensed by the thermocouple (T/C). The temperature Indicator/Recorder, T,

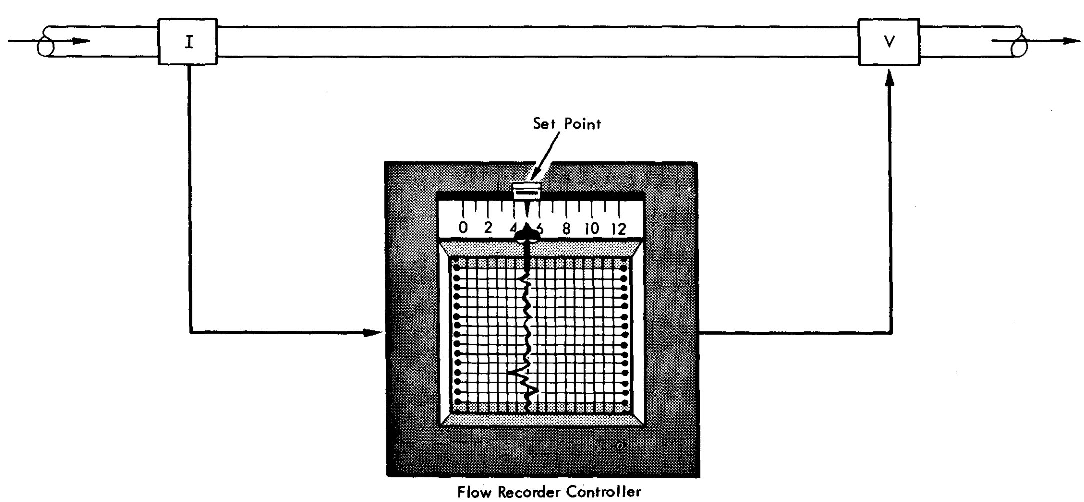


Figure 12. Automatic Control Loop

uses the T/C signal to determine the furnace temperature. Differences between the furnace temperature and the set-point value of T (note that the set-point is adjusted by the operator) cause appropriate adjustments of the set-point on the fuel Flowmeter Controller, P. Fluctuations in fuel pressure cause flow rate changes which are sensed by Flow Transmitter I. Differences between the fuel flow rate and the Cascade-controlled set-point on P cause appropriate adjustments of the actuator V.

Set-Point Positioners

Set-Point Positioners (SPP's) are controlled by the 1710, and they, in turn, control the controlling instruments as shown in Figure 11. An SPP is required for each controlling instrument, and like T in Figure 13, each SPP provides a signal to control the set-point and therefore permit computer control of its associated controlling instruments. The principal advantage of 1710 control is its ability to control many controlling instruments simultaneously. Process conditions are rapidly monitored and simultaneously analyzed and, based on this analysis, SPP's are individually selected and simultaneously adjusted for optimum process control.

A set-point positioner has an *up* motor and a *down* motor for up scale- and down-scale adjustments of its set-point. The up and down motors are individually operated, as determined by computer analysis of process conditions. The up or down adjustment of a set-point causes a corresponding adjustment of its associated controlling-instrument set-point.

Closed-Loop Computer Control

Some Indicator/Recorder Controllers used with closed-loop computer control contain a three-position switch. These positions are labeled Cascade (or Computer), Automatic, and Manual. Others do not include the Cascade position.

Manual

With the instrument switch on Manual, the Indicator/Recorder Controller is removed from closed-loop control of the process variable. The valve position is completely under control of the process operator. If any change in the valve position is necessary, the controlling signal to V is supplied through the manual adjustment knob (Figure 14). Thus, a means of operator control is available irrespective of instrument or computer malfunction. Switching from Automatic to Manual or Manual to Automatic usually requires some adjustment or matching by the process operator to avoid bumps.

Automatic

With the instrument switch on Automatic, the automatic control loop shown in Figure 12 is in effect. Set-point adjustment is under control of the process operator rather than the SPP (Figure 14).

On automatic Indicator/Recorder Controllers not equipped with a three-position switch, i.e., without a Cascade (or Computer) position, the SPP signal goes directly to the set-point adjustment control. On some

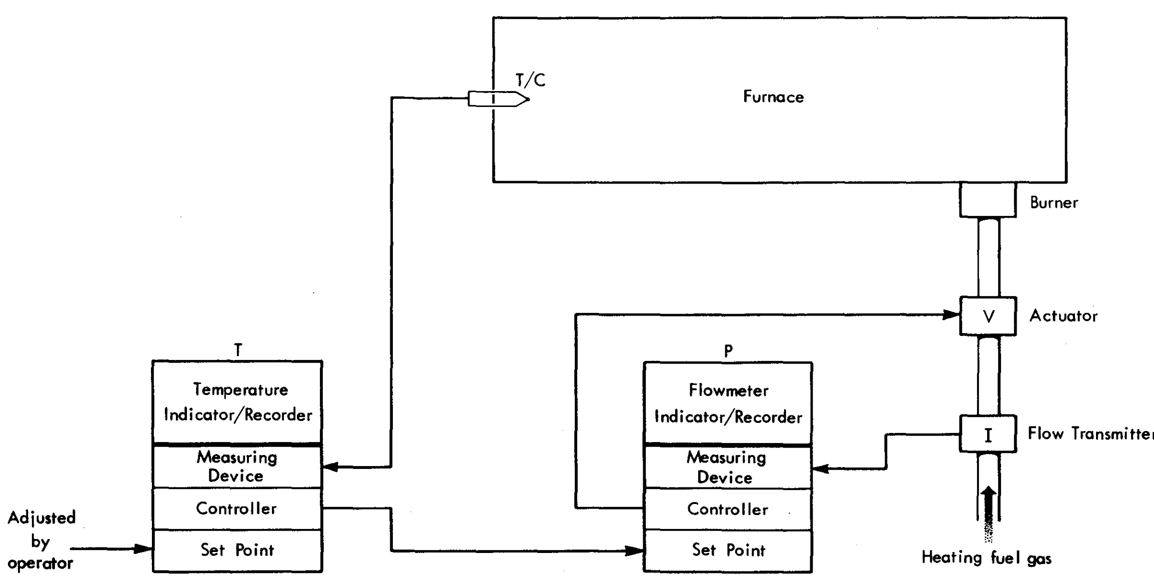


Figure 13. Cascade Control

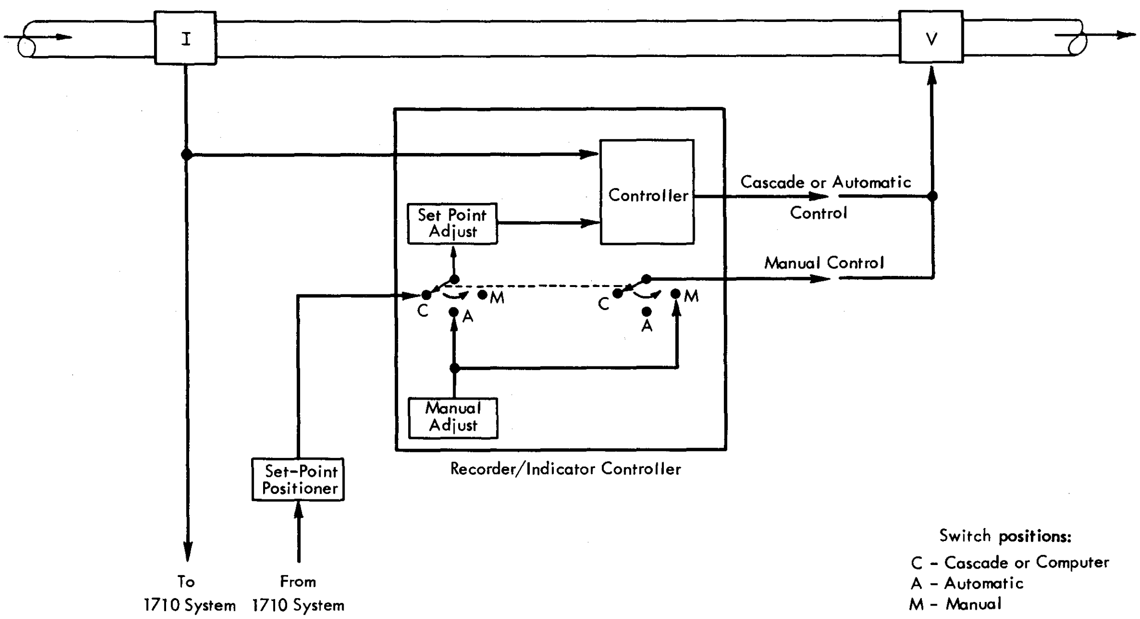


Figure 14. Controlling Logic

control loops an isolation switch or valve, which in effect duplicates the function of the Cascade switch described above, must be installed. Each individual situation must be investigated to determine whether such additional switching or valving is required, depending on the manufacturer of the instrument and the particular arrangement of the installation.

Cascade (or Computer)

Some Indicator/Recorder Controllers are designed to operate as Cascade Controllers. With the instrument switch on Cascade, the set-point is automatically adjusted with signals supplied from outside of the controller according to computer analysis of process conditions. As shown in Figure 14, the signal from the Flow Transmitter I is sent to both the controller and the 1710. If the signal is pneumatic, the customer must provide a transducer to convert the signal to the required electrical range of the 1710. Based on program analysis of process data, including the signal from I, the 1710 sends controlling signals to the SPP. The SPP, in turn, provides a signal through the Cascade switch position to adjust the set-point (the broken line between the two switches signifies that both operate from the same manual switch – they are not connected electrically). The SPP must provide the same type of signal, electrical or pneumatic, as I. The controller, differentiating between the new set-point position and the signal from I, sends a signal to V which alters the fluid flow.

Analog Output Logic

There are two TAS (Terminal Address Selector) addresses for each SPP, an up address and a down address, and, in addition, one TAS address for selection of the slew signal and one TAS address for selection of the trim signal. Only one slew address and one trim address are required, regardless of the number of SPP's. However, the slew and trim addresses should be consecutive and so numbered that they can be assigned to the same matching card.

An Analog Output logic diagram is shown in Figure 15. The circled numbers refer to the numbers in text that follow.

1. The program determines from the collected data which SPP's require slewing and what the direction of each is, up or down. The multiplexing relay is latched for each up and down address selected.
2. The slew address is selected, and the 1710 voltage supply causes energization of the slew relay.
3. With the slew relay picked and the 2.5-second slew cam contact closed, a circuit is completed from the customer's voltage supply (upper right, Figure 15), down and up through the slew cam contact, through the slew relay contact, through the previously selected up-and-down multiplexing relay contacts, through the SPP up-and-down motors, and back to the customer's voltage supply. The selected SPP's are slewed for 2.5 seconds. The computer is free for other calculations during this time. A reset pulse unlatches all previously latched

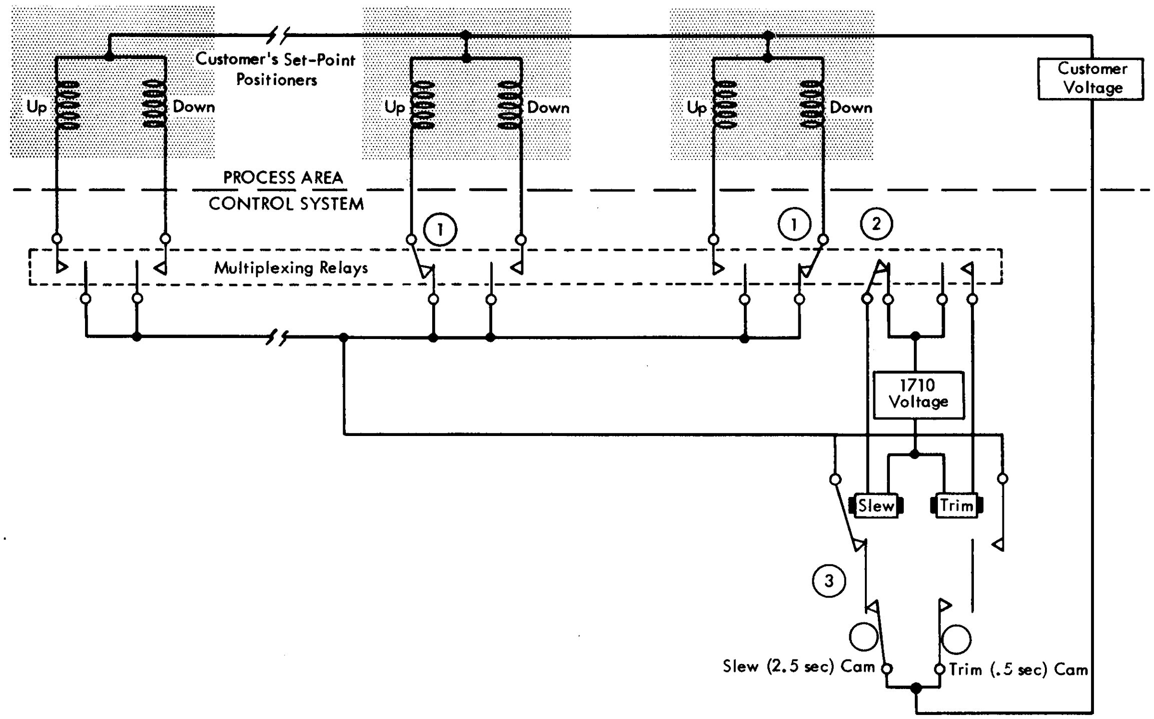


Figure 15. Analog Output Logic

Analog Output multiplexing relays and the Analog Output Check circuit tests to be sure all multiplexing relays are unlatched (Figure 16). Program re-selection of SPP's which require additional slewing or trimming begins. This description (steps 1 through 3) continues until all slewing and/or trimming operations are completed.

Analog Output Timer

The Analog Output Timer is located in the 1712 MTU, and consists of a continuously running motor, circuit breakers, control relays, and associated circuitry. The timer provides the following electrical pulses:

Setup. At the beginning of each Analog Output cycle, .7 seconds are allowed for the program selection of SPP addresses.

Slew. A pulse duration of 2.5 seconds is provided for driving the SPP motors.

Trim. A pulse duration of .5 seconds is provided for driving the SPP motors. SPP motors may be either slewed or trimmed in any one Analog Output cycle, but not both. Note the nominal 5-1 ratio between slew and trim. A slew operation moves the SPP set-point five times as far as a trim operation.

Reset. Following a slew or trim operation, a reset pulse is provided to drop out the Analog Output multiplexing relays. These relays, previously selected during setup time, are latch-type relays, i.e., once selected, they stay latched until reset.

Analog Output Check. Following a reset pulse, the Analog Output Check pulse tests to be sure that all Analog Output multiplexing relays are unlatched. A latched relay would cause the Analog Output Check indicator (23) to be turned on.

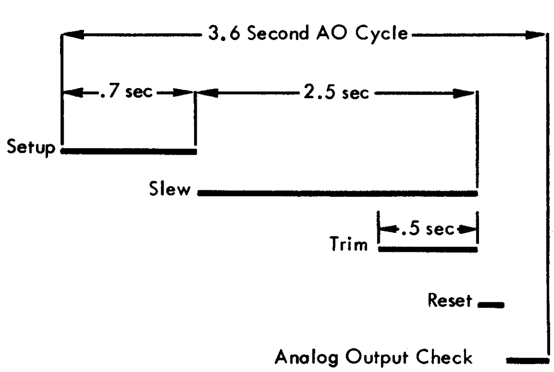


Figure 16. Analog Output Timings

Analog Output Programming

The IBM Analog Output program provides for three essential functions: (1) each SPP position is determined before adjustment, (2) SPP adjustments are synchronized by adjustment rate variation, and (3) SPP's are automatically adjusted (slewed and/or trimmed). The **Select Analog Output and Signal** instruction provides for SPP selection and operation.

SPP Set-Point Determination

Increased Analog Output accuracy is obtained when the precise setting of each SPP is known before adjustment. Several methods may be used to keep track of SPP settings: The computer can start with the original setting and progressively add and subtract each up and down adjustment, or it can read a feedback signal from either the SPP or the controlling instrument (an Analog Input address is necessary for each feedback signal). This latter method offers greater accuracy.

However, where the control loop is such that it is known that the offset between set-point and the process variable will be negligible, it is sufficient just to read the valve of the process variable and assume its position is equal to the set-point of that control loop.

SPP Adjustment Synchronization

A stored table is used to facilitate programmed synchronization of SPP adjustments. The table includes the *desired setting,* the *actual setting,* the *% of slew,* the *% of trim,* the *feedback setting,* and the *rate change.* The rate change is the frequency with which an SPP is to be adjusted. For example, a rate change of four initiates a slew or trim every fourth 3.6-second Analog Output cycle. The fastest rate change is determined by the customer by proper selection of his SPP. Slower rates of change can then be accomplished by the rate change program in the 1710.

Programmed Set-Point Positioner Adjustment

The desired SPP setting, determined by computer calculations, is compared with the actual setting. If the difference between the desired and actual settings necessitates one or more slew operations, a "Slew indicator" is turned on. The Slew indicator is strictly a program indicator (digit or no-digit in core storage); it is used as a slew or no-slew guide. Calculations remove the digit when the desired SPP setting is either achieved or so close to being achieved that another slew would be too much. The trim operations and a "Trim indicator" are programmed in a similar manner.

Analog Output Setup Indicator (28). A Setup indicator, which is turned on and off with the setup circuit breaker in the Analog Output timer (see Figure 16), is provided for program interrogation; up or down or trim operations should not be initiated unless this indicator is on. The ON condition of this indicator is the only means that the program has of determining that a full 2.5 seconds is available before the Analog Output multiplexing relays are reset. For example, if an up or down address is selected during slew or trim time, the selected SPP will be operated less than a full slew or trim cycle. Execution of a slew or trim instruction also turns off the Setup indicator.

Reset Conditioning. The program is not actually limited to .7 seconds of setup time. The reset pulse is conditioned so that it occurs only if a slew or trim has been initiated. Thus, additional 3.6-second Analog Output cycles may be used for setup time. The SPP is not operated until the slew or trim instruction is executed.

Analog Output Check Indicator. The Analog Output Check indicator (23) is turned on if an Analog Output multiplexing relay fails to unlatch when the reset pulse occurs. The program interrogates this indicator at the end of every Analog Output operation. If the Basic Interrupt special feature is installed, an interrupt is initiated when this indicator is turned on.

Analog Output Fail-Safe Features

Programming Protection. The Analog Output program and the Analog Output Check indicator prevent erroneous slewing or trimming of SPP's if an Analog Output multiplexing relay fails to unlatch. The program initiates an "open the loop" action.

The ratio between the duration of slew and trim pulses has been established to avoid process upsets by sudden undesirable set-point changes.

Set-point positioners are designed so the operator can observe what the computer is doing to the set-points, and, therefore, can easily take over control of a set-point positioner with a minimum of delay.

If there is a power failure, the set-point positioner stays at, or very close to, its last position and cannot advance farther than the slew or trim adjustment in operation at the time of the failure.

The internal data checking features of the 1710 Control System are programmed to log and bypass intermittent errors. When internal checking reveals that effective control system operation is impossible, a "return to manual operation" is initiated (see ANY CHECK in the Interrupt section).

SPP Adjustment Limiting. Most SPP's are provided with mechanical stops which prevent adjustments beyond the limits specified by the stops themselves. For example, an SPP with a range of 0-100 cannot be slewed and/or trimmed beyond the 60-80 range if the stops are manually positioned at 60 and 80. Thus, neither SPP nor 1710 malfunctions can cause SPP settings to exceed safe operating limits.

Power Failure Protection. If a power failure occurs, the SPP's are inoperative, except upon manual intervention. Thus, instrumentation set-points cannot be falsely altered as a result of power failures.

Interrupt

The Interrupt feature gives the 1710 the ability to recognize conditions demanding immediate attention. The disturbance (interrupting condition) causes the computer to suspend routine operation. In an open-loop system, the control room operator is notified of the disturbance by the console typewriter. A closed-loop system can actually initiate corrective action as well as notify the control room operator or the process operator.

Interrupt Modes of Operation

The 1710 normally operates in the *interruptible mode,* that is, it interrupts the main program when an interrupt condition occurs. However, once the interrupt is recognized, the 1710 is in the *noninterruptible mode* until the interrupt subroutine has been completed. In other words, an interrupt cannot interrupt another interrupt *until the appropriate action required by the first interrupt has been completed.* Interrupts are serviced in the program in a sequence that corresponds to the priority established for them by the process engineer. Four interrupt instructions, **Branch Out** (of noninterruptible mode), **Branch Out** (of noninterruptible mode) **and Load, Mask,** and **Unmask,** are provided with this feature for interrupt control. The **Branch Out** and **Branch Out and Load** instructions are used to end an interrupt subroutine and to place the 1710 in the interruptible mode. The **Mask** instruction is used to mask all interrupts, i.e., it places the 1710 in the noninterruptible mode, delaying all interrupts until the interruptible mode is restored. The **Unmask** instruction is used to restore the interruptible mode when the noninterruptible mode exists as a result of a **Mask** instruction.

Figure 17 shows the relationship between the four interrupt instructions and the two interrupt modes. Starting at the top (progress in time is shown from top to bottom) interrupt 1 causes the 1710 program to branch to interrupt subroutine 1 and to enter the noninterruptible mode. A **Branch Out** or **Branch Out and Load** instruction returns the 1710 to the main program and the interruptible mode. A **Mask** instruction places the 1710 in the noninterruptible mode, also causing interrupt 2 to be delayed (not lost) until the **Unmask** instruction is executed. The 1710 then enters the interruptible mode long enough to recognize interrupt 2; this causes an immediate return to the noninterruptible mode and the interrupt 2 subroutine. With the 1710 in the noninterruptible mode, as a result of interrupt 2, the *Unmask has no effect,* and the **Branch Out** or **Branch Out and Load** returns the 1710 to the main program and the interruptible mode. Interrupt 3 causes the 1710 to branch to interrupt subroutine 3 and to enter the noninterruptible mode. Execution of the **Mask** instruction during interrupt subroutine 3 keeps the 1710 in the noninterruptible mode even after the **Branch Out** or **Branch Out and Load** has returned the computer to the main program. Any interrupts occurring *after* the **Mask** instruction are delayed, not only until a **Branch Out** or **Branch Out and Load** instruction is executed but until an **Unmask** restores the computer to the interruptible mode.

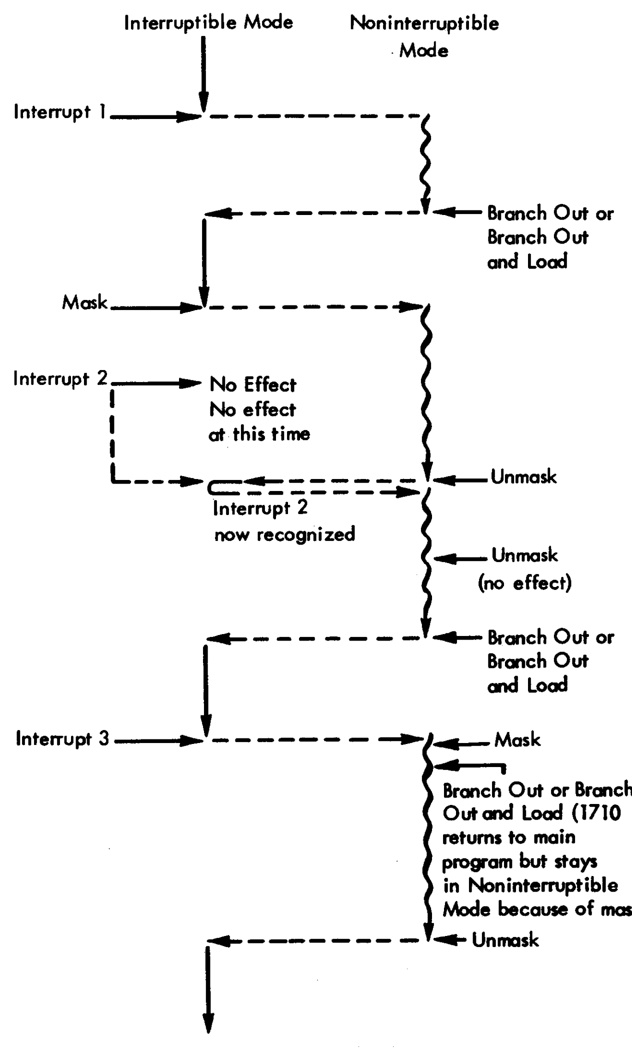


Figure 17. Interrupt Modes

External and Internal Interrupts

External interrupts are interrupts that occur as the result of conditions in the process. These interrupts cause the 1710 to give almost immediate attention to a situation or occurrence in the process whenever required.

Internal interrupts originate within the 1710 Control System and facilitate the concurrent handling of many programs.

External Interrupts

A maximum of twelve external (process) interrupts are available with the External Interrupt feature. An indicator is provided for each interrupt. Once an interrupt indicator is turned on by its related interrupt, it remains on until it is interrogated by the program. The External Interrupt indicators are assigned indicator codes 48 through 59.

Internal Interrupts

Nine internal interrupts are available in groups of three, as follows:

Basic Interrupt Feature	
Operator Entry	(18)
Any Check	(19)
CE (Customer Engineer) Interrupt	(27)
Input/Output Interrupts Feature	
Multiplex Complete	(40)
Seek Complete	(42)
Any SIOC (Serial Input/Output Channel)	(45)
Timed Interrupts Feature	
Analog Output Setup	(41)
One Hour	(44)
One Minute	(43)

An indicator is provided for each interrupt listed above, and is identified by the number in parentheses. An interrupt condition turns on its associated indicator, which remains on until program recognition occurs.

Operator Entry Interrupt (Indicator 18). The Operator Entry interrupt provides for the entry of data previously set in the seven Manual Entry switches on the 1711 Operator's Panel. When the process operator positions the Manual Entry switches and presses the Operator Entry key, the Operator Entry indicator turns on and the computer branches to the program subroutine that causes the contents of the Manual Entry switches to be read into core storage.

This *indicator* is a basic feature of the system; its *interrupt* function is available as part of the Basic Interrupt feature.

Any Check Interrupt (Indicator 19). The Any Check indicator (19) is turned on by any of nine error conditions shown here:

Read Check	Indicator 06
Write Check	Indicator 07
MAR Check	Indicator 08
MBR-E Check	Indicator 16
MBR-O Check	Indicator 17
TAS Check	Indicator 21*
Function Register Check	Indicator 22*
Analog Output Check	Indicator 23*
Any Disk Check	Indicator 39*

*These indicators are available only if their associated special features are installed on the system.

When one of these errors occurs, the Any Check interrupt is initiated and the computer can branch to the Interrupt Identification routine (Figure 18). (Thus, all of the indicators shown above initiate an interrupt, *through* the Any Check interrupt.) This routine identifies the interrupt and initiates a branch to the Any Check Interrupt subroutine or Error Analysis subroutine. The programming philosophy of this subroutine is to keep the process in operation, regardless of errors, if at all practical. Thus, as shown in the logic diagram (Figure 18), each error check is tested individually with a **Branch Indicator** instruction, and, if that indicator is on, a one is added to the count of that individual error. The count of each type of error can be reviewed by the IBM Customer Engineer during diagnostic testing and analysis. Note that the TAS error is handled differently if the error occurs during an Analog I/O operation – here, the analog instruction will repeat until it is executed correctly or until three consecutive errors occur. When three consecutive TAS errors occur on an analog input or output operation, it is assumed that the control system is unreliable, and system operation is discontinued.

The Any Check indicator is a basic feature of the system, its *interrupt* function is available as part of the Basic Interrupt feature.

CE (Customer Engineer) Interrupt (Indicator 27). The CE Interrupt provides the IBM Customer Engineer with a rapid method of transferring the 1710 from normal program operation of the process to 1710 diagnostic programming. For example, the CE can initiate a routine maintenance check of the 1710 Control System by simply depressing the CE Interrupt – the computer automatically branches to the diagnostic subroutine program.

Multiplex Complete Interrupt (Indicator 40). The Multiplex Complete interrupt provides an interrupt after completion of contact operate, analog input, and analog output operations. In addition, it provides an interrupt 3.75 milliseconds after initiation of an Analog Output instruction (see BRANCH INSTRUCTION).

The Multiplex Complete indicator is turned on when the Multiplexer Busy indicator (29) turns off. Programming steps and core storage are saved when the Multiplexer Complete interrupt is installed because the main program need not test the Multiplexer Busy indicator. Multiplex Complete is turned off by program testing or by the execution of a new instruction using the multiplexer.

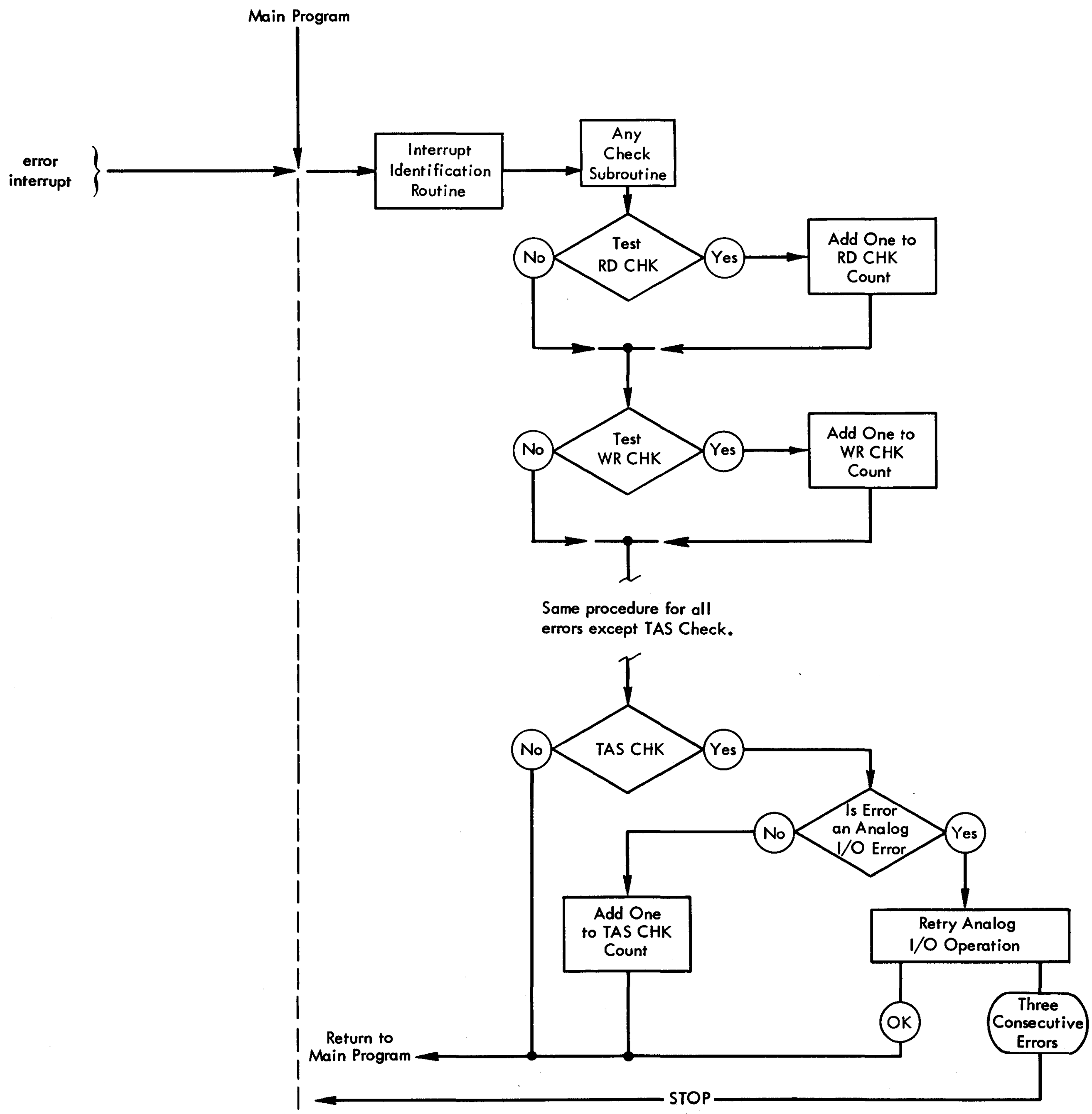


Figure 18. Error Analysis Subroutine Logic

Seek Complete Interrupt (Indicator 42). This interrupt is available when the 1311 Disk Storage Drive is attached to a 1710 Control System. This signal interrupts the main program when a seek operation is completed. It is reset by program interrogation.

Any SIOC (Serial Input/Output Channel—Indicator 45). This signal causes interruption of the main program upon receipt of a signal that a Process Operator Unit is ready to transmit or receive data. A complete description of the SIOC Interrupt feature is contained in 1710 PROCESS OPERATOR UNITS. This indicator is reset by program interrogation.

Analog Output Setup (Indicator 41). This signal interrupts the main program at the beginning of the setup portion of the analog output cycle, which occurs automatically every 3.6 seconds. This signal makes certain that the program has the full setup time for selecting the analog output points to be operated and for executing the slew or trim instruction. The indicator is reset by program interrogation.

The regularity of the signal makes it a timing device that can be used for other program functions for which a 3.6-second cycle is satisfactory.

One Minute (Indicator 43). This signal causes interruption of the main program once each minute of real-time when the minutes drum of the clock advances. The indicator is reset by program interrogation. This interrupt may be used to cause desired actions every minute or multiple of a minute. The One Minute interrupt precedes the One Hour interrupt by approximately 300 milliseconds.

One Hour (Indicator 44). This signal causes interruption of the program once each hour of real-time. The interrupt is initiated when the hours drum of the clock advances. The indicator is reset by program interrogation.

Interrupt Operation

Assuming the interrupts are not masked, an interrupt causes the computer to branch to an interrupt identification routine. The interrupt identification routine executes a series of **Branch Indicator** or **Branch No Indicator** instructions to determine which interrupt indicator or possibly indicators are on. The sequence in which the interrupt indicators are interrogated establishes a degree of interrupt priority; that is, the first one tested and found on is the first one serviced. The first indicator found to be on causes a branch to its interrupt subroutine. An interrupt subroutine must be established in the program for each interrupt indicator. The interrupt condition is taken care of by its interrupt subroutine, and the computer then returns to the main program. *If another interrupt is waiting, the computer immediately returns from the main program to the interrupt identification routine without executing any instructions in the main program.*

The above description of interrupt operation provides an over-all picture. The details necessary for programming the Interrupt feature are as follows:

The instruction being executed when the interrupt occurs is completed, and then the status of the arithmetic indicators is stored within machine circuitry for use when the computer returns to the main program.

The arithmetic indicators are reset off for use in the interrupt subroutine.

The Instruction Register, IR-1, which contains the address of the next sequential instruction in the main program, is saved.

The Instruction Register, IR-3, is substituted for IR-1. IR-3 contains the address of the interrupt identification routines (the address must be initially placed in IR-3 when the program is loaded). When an interrupt occurs, the computer branches to the address specified by IR-3, which is the location of the interrupt identification routine. IR-3 is then used in place of IR-1 for instruction addressing until the computer returns to the main program.

These operations are performed automatically by the computer — program instructions are not required.

If the interrupt indicators are in an ON condition when interrogated by **Branch Indicator** or **Branch No Indicator** instructions in the identification routine, they are turned off. This is true even though the interrupt contact that turned on its indicator remains closed (ON condition). The indicator cannot be turned on again until the contact is opened and closed again. An external interrupt may not be recognized until 8 milliseconds after contact closure. There is also a 35-millisecond circuit delay before an opening contact can be recognized. Thus, a contact that opens and closes within 35 milliseconds may never be recognized as ever having opened.

Following completion of the interrupt subroutine, and assuming that no interrupt is waiting, the following actions ensue:

The address of the interrupt identification routine is restored in IR-3 for use when the next interrupt occurs.

The saved status of the arithmetic indicators is restored.

IR-1 is placed back in normal use, and the computer returns to the main program.

Random Addressing of TAS

All process input/output functions except interrupts and Process Branch indicators require the Random Addressing of TAS feature. Three instructions are provided with Random Addressing: **Select Address**, **Select TAS**, and **Select ADC Register. Select Address** and **Select TAS** instructions provide for resetting TAS, and storing its contents, respectively. The **Select ADC Register** instruction permits the random selection of analog inputs.

TAS parity-checking circuits are installed with the Random Addressing feature, and a TAS Check indicator (21) is turned on if a TAS parity error occurs and if an invalid address above 399 is specified. No function utilizing TAS can be performed while the TAS Check indicator is on. The indicator remains on until interrogated by a **Branch Indicator** or **Branch No Indicator** instruction. If the Basic Interrupt feature is installed, the ON condition of the TAS Check indicator causes an Any Check interrupt.

Process Branch Indicators

Twenty Process Branch Indicators (PBI's) are available for program determination of conditions in the process area. Each PBI has a contact in the process area. When the contact closes, an associated indicator is turned on. When the contact opens, the indicator is turned off. The PBI is not latched on or off — it merely follows the closed and open status of its contact. (Due to filtering, a PBI is turned on approximately 8 milliseconds after its contact closes; it is turned off approximately 35 milliseconds after its contact opens.) PBI's, which are available in increments of two, have indicator codes 70 through 89 instead of terminal addresses, and like interrupts, are terminated in the 1712 on a terminal strip instead of a terminal block. They are interrogated individually by **Branch Indicator** or **Branch No Indicator** instructions. The instruction shown below is used to interrogate PBI, number five. In this example, if indicator 74 is on, a branch to 01200 will occur; if off, the next sequential instruction will be executed.

4	6	0	1	2	0	0		7	4		

Manual Entry

A Manual Entry feature consisting of seven cylindrical-wheel-type Manual Entry switches (Figure 19) is available for installation on the 1711 Operator's Panel. Each switch has ten positions (0-9), which the operator may set to any value, 0000000 to 9999999. The **Select Manual Entry Switches** instruction is provided to read the seven digits from the switches into core storage at any time during the program. The Operator Entry key on the 1711 Operator's Panel can be used by the control room operator to initiate reading of the contents of the switches into core storage at any predetermined time.

A branch instruction in the program can be used to test Operator Entry indicator (18) to determine if the operator pressed the Operator Entry key. If the key was pressed, the indicator is on and the program can then branch to a subroutine that reads the contents of the switches into core storage by using the **Select Manual Entry Switches** instruction.

If the Basic Interrupt special feature is installed, pressing the Operator Entry key will cause an interrupt and turn on the Operator Entry indicator (18). The interrupt branches the program to the interrupt identification routine which, in turn, by testing the Operator Entry indicator, directs the program to a subroutine that reads the contents of the switches into core storage by using the **Select Manual Entry Switches** instruction.

1710 Process Operator Units

The range and flexibility of the IBM 1710 Control System are extended by the 1710 Process Operator Units.

As shown in Figure 20, the Serial Input/Output Channel special feature makes possible the connection of local or remote units to the 1710 System so that input information can be originated by the process operator and output data can be made available at vital points throughout the process area.

Located at the point of control, the Process Operator Units provide two-way communication with the 1710 System. The IBM 1713 Manual Entry Unit permits the operator to forward data to the computer as the occasion warrants. The IBM 1714 Sense Switch Unit provides the operator with alternative process computations or requests for information to meet conditions as they arise. The IBM 1715 Digital Display Unit provides a visual indication of the data sent from the computer. The IBM 1717 Output Printer with the IBM 1716 Output Printer Control and Power Units provides data logs, periodic reports, and other printed information at points in the process where they are needed for implementing control of the process.

The special feature Serial Input/Output Channel (SIOC) is a prerequisite for the installation of any of the 1710 Process Operator Units. The input and output functions of these units are associated directly with the Serial Input/Output Channel, and for this reason, the term SIOC is used to identify some of the indicators, lights, and functions used in operating and programming the 1710 Process Operator Units.

Functional descriptions of the Process Operator Units are contained in the following paragraphs. More detailed information regarding their operation, pro-

Figure 19. Manual Entry Switches, 1711 Operator's Panel

gramming information, and a typical programming example are contained under PROGRAMMING PROCESS OPERATOR UNITS and under 1710 INSTRUCTIONS.

General Description

Input Operations

The sequence of operations to transfer a character from an input unit to core storage is:

1. A **Select Input Channel** instruction sends the address of the input unit to TAS, thereby connecting the unit to the Serial Input/Output Channel. The computer and TAS are released for other programming after 160 μsec.
2. The **Select Input Channel** instruction also causes the character in the input unit to be placed into an Input/Output Data Register (IODR).
3. After the transfer of the character from the input unit to IODR is completed, a Data Ready interrupt occurs. This interrupt is used to branch the program to a read instruction that causes the contents of IODR to be read into core storage.

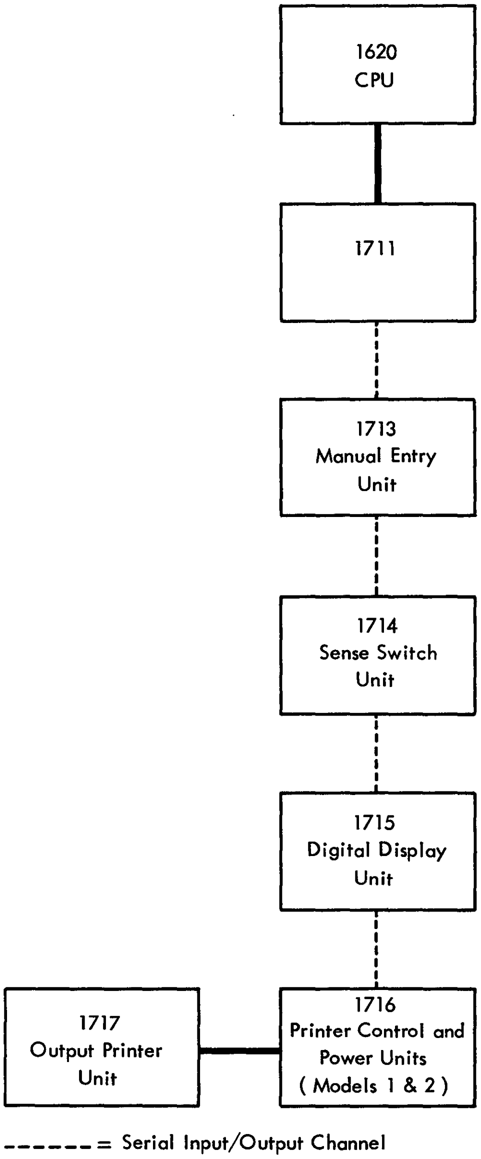


Figure 20. Serial Input/Output Channel for the 1710 Process Operator Units

4. When the input unit is ready to transfer another character to IODR, a Unit Response interrupt is initiated, and a Unit Response indicator is turned on by the unit. (A separate Unit Response indicator is provided for each Process Operator Unit attached to the system.) The interrupt and the indicator are used to branch the program back to the **Select Input Channel** instruction to begin the cycle again in order to read the next character into core storage.
5. Transmission of data from the last character position of the unit removes the unit from Unit Response status.

Output Operations

The sequence of operations to transfer a character from core storage to an output unit is:

1. A write instruction sends the address of the input unit to TAS, thereby connecting the unit to the Serial Input/Output Channel. The character in core storage is placed in the Input/Output Data Register (IODR) and then immediately transferred to the output unit.
2. After the character has been placed in IODR, the 1620 and TAS are released for other programming.
3. When the output unit is ready to accept another character from IODR, a Unit Response interrupt is initiated and a Unit Response indicator is turned on. This places the unit in "response status." The interrupt and indicator are used to branch the program back to a write instruction to begin the cycle again in order to write the next character to the output unit.
5. An operation using the Digital Display Unit is terminated when the last character position is addressed by the write instruction. An operation using the Output Printer is terminated when an end-of-message character is sent to the printer.

IBM 1713 Manual Entry Unit

Manual entry of data into the 1710 System is accomplished by setting the data to be transmitted in ten rotary data switches and two rotary mode switches and then pressing and releasing the Execute button (Figure 21). When the Execute button is released, a Unit Response indicator turns on to initiate an interrupt. This signals the program that the data is ready to be read into core storage (via IODR). The program may then read the data from each one of the twelve switches. The unit remains in response status until the last data switch is read. (The last data switch is also known as the End-of-Message switch.) The unit may also be put into response status if the program addresses Mode switch 1. Addressing Mode switch 1 initiates the same action as that produced when the process operator presses the Execute button.

When the Execute button is pressed or when Mode switch 1 is addressed, the Execute light turns on and remains on until the End-of-Message switch has been read by the program.

Since data switches are individually addressable, each may be read in any order as determined by the program. A total of thirteen SIOC addresses is assigned to each Manual Entry Unit: one for the Enter light and twelve for the rotary switches.

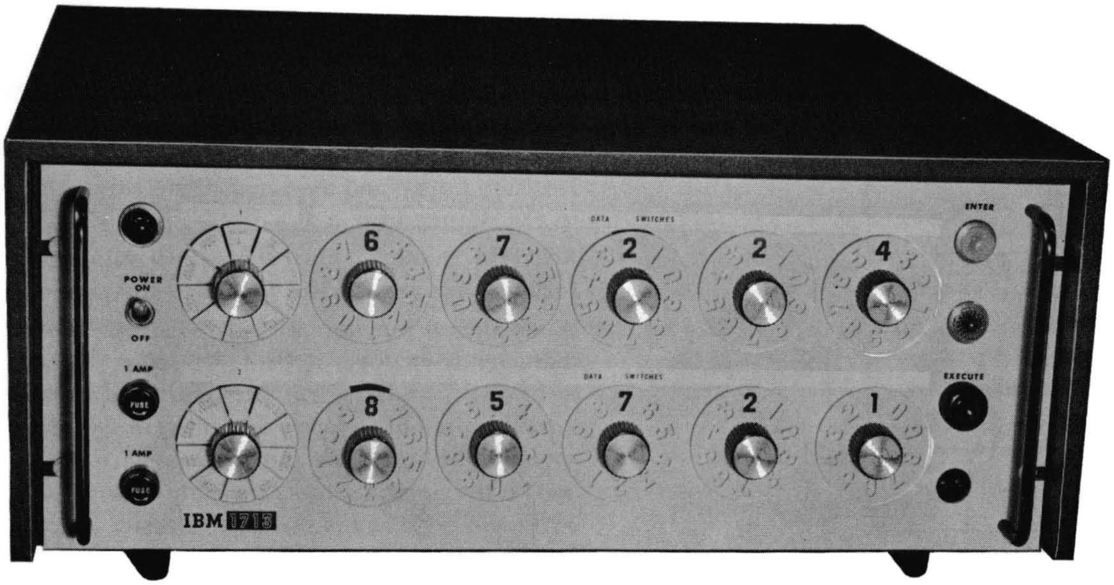


Figure 21. IBM 1713 Manual Entry Unit

Mode Switches. The two rotary switches at the left of the two rows of five data switches are designated Mode switches 1 and 2, respectively. Each switch has ten digit positions (0-9). These positions are labeled by the user to identify for the process operator the nature of the information to be entered through the data switches. The program can identify the nature of information entered through the data switches by an analysis of the digits entered by the mode switches.

End-of-Message. In addition to its function as a data switch, the switch at the right end of the bottom row of switches also serves as an end-of-message indication. Transmission of data from this switch removes the unit from response status and turns off the Execute and Enter lights. To initiate the next interrupt, the Execute button can be pressed or Mode switch 1 can be addressed by the program.

Enter Light. This light is used to signal the process operator when the program requests input data. The Enter light can be turned on by addressing it with a **Select Input Channel** instruction if the program is to immediately start reading the data already in the switches, or the Enter light can be turned on by addressing it with a **Write Numeric Output Channel** instruction if the operator is to enter data before the read operation begins. The Enter light is turned off when the unit is removed from response status. If the **Select Input Channel** instruction is used to turn on the Enter light, the Data Ready indicator will be turned on and the Data Ready interrupt initiated. The **Write Numerical Output Channel** instruction does not turn on the Data Ready indicator or initiate the Data Ready interrupt. Therefore, in programs where it is desired that the operator enter the data and then initiate the interrupt, the latter instruction will be used.

Power On/Off Switch and Light. This switch is used to control electrical power to the Manual Entry Unit. The light serves as a visual indicator that power is on.

IBM 1714 Sense Switch Unit

The Sense Switch Unit (Figure 22) allows the process operator to provide data to the program through twelve toggle switches. The program can sense the ON or OFF condition of each switch upon command. Switches are addressed in groups of three (Figure 23). Therefore, four consecutive addresses are required for the twelve switches, one for each group. Since each group of switches is individually addressable, each may be read in any order as directed by the program. Program analysis of a character (numerical digit) to be read will reveal the switch settings of the individual switches of a group.

In each group of three switches, the first one stores a 4 bit if it is on; the second, a 2 bit; and the third, a 1 bit. If a switch is off, no bit is stored. Therefore, at each three-switch address, a character is transmitted to denote the corresponding combination of switches ON as shown in Table 2.

Figure 22. IBM 1714 Sense Switch Unit

The three switches on the right are considered the last group. Each time the Sense Switch Unit is read, the last group must be read in order to terminate the interrupt status of the unit.

In addition to the sense switches, the following elements are on the Sense Switch Unit.

Execute Button. Depression and release of this button initiates an interrupt if the SIOC Not Busy is ON; if it is OFF, this button initiates an interrupt as soon as SIOC Not Busy is turned on. The interrupt turns on the related Unit Response indicator, which signals the program that the switches are ready to be read. The unit may also be placed in response status by a program instruction addressing the first (leftmost) group of three switches.

Execute Light. This light turns on when the Execute button is pressed and released or when the first switch group is addressed by the program. It remains on until the "last group" of switches has been read. *Switch settings must not be changed while this light is on.*

Power On/Off Switch and Light. This switch is used to control electrical power to the unit. The light serves as a visual indication that power is on.

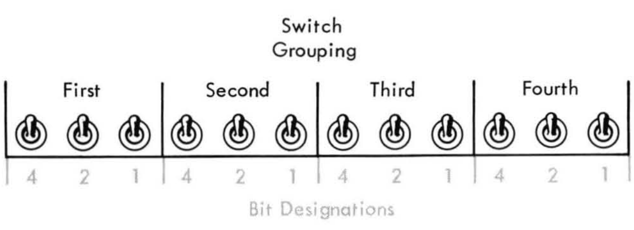


Figure 23. Twelve Sense Switches

IBM 1715 Digital Display Unit

The Digital Display Unit (Figure 24) provides the process operator with four digits of data and an associated sign. Each digit position is addressable and reflects the digit in the core storage location of the P address of a **Write Numerical Output Channel** instruction. The unit requires one address for each of the four digits displayed.

The digits and sign of the display unit can be read by the process operator at a distance of up to 20 feet in normal industrial lighting.

Table 2. Designations of Sense Switches ON

Bits Stored	Character	Switch(es) On
1	1	3
2	2	2
2, 1	3	2 and 3
4	4	1
4, 1	5	1 and 3
4, 2	6	1 and 2
4, 2, 1	7	1, 2, and 3

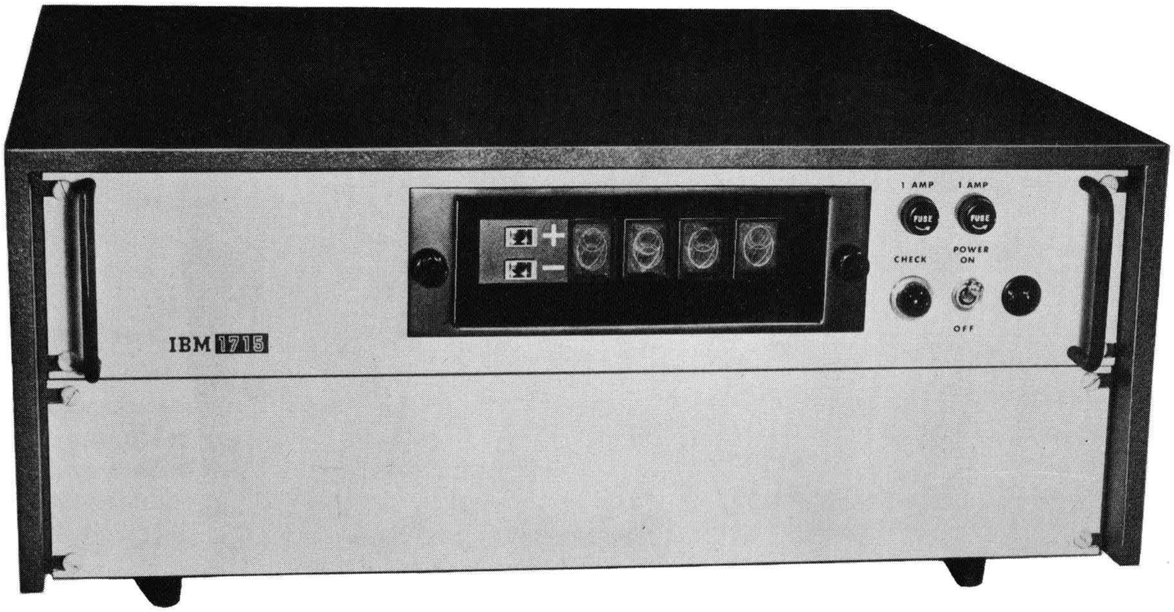


Figure 24. IBM 1715 Digital Display Unit

The Plus and Minus lights reflect the absence or presence of a flag over the digit transmitted to the units position. *All four digits must be addressed whenever the 1715 is operated,* starting with the thousands position and proceeding *in sequence* to the units position. Addressing the thousands position places the unit in unit response status; addressing the units position removes the unit from response status. The four digits are not *displayed* until the units position is addressed and they remain displayed until the unit is reset by entering another digit in the thousands position by the program. Digits sent to the unit must not contain a flag bit, with the exception of the digit sent to the units position which uses the flag bit to represent the sign.

Check Light. Each digit sent to the display unit is checked for parity. A parity error in any one digit turns the Check light on, resets the four display positions to blank, and turns on the SIOC Output Error indicator.

Power On/Off Switch. This switch is used to control electrical power to the unit. When power is on, either the Plus or Minus light is on.

Display Lights. The display lights may be easily replaced from the front panel.

IBM 1717 Output Printer

The IBM 1717 Output Printer is available for connection to the IBM 1710 Control System through the 1716 Output Printer Control and Power Units and the Serial Input/Output Channel. It fills the need for output information from the 1710 Control System to remote locations in the process where it is most vitally needed, or to other locations such as the superintendent's office.

Description

The IBM 1717 Output Printer is a modified model B IBM electric typewriter. The standard machine has a 12-inch carriage, medium platen, and red and black ribbon shift. The standard type is Manifold No. 10, which prints ten characters to the inch. The standard character set includes A-Z, 0-9, and the special characters

$$* \quad + \quad - \quad = \quad , \quad . \quad / \quad \triangle$$

All alphabetic characters print as capitals and all printing is done in the lower-case position, so that carriage shifting is not required.

The power and control circuits for the Output Printer are contained in the IBM 1716 Output Printer Control and Power Units, which are mounted in two standard relay rack drawers for installation in appropriate locations in the process. Protective housings are available for the control and power units when relay rack mounting is not feasible. Fuses and lights on the front of the power unit can be easily replaced without removing the cover. The printer is connected to the control unit by an 8-foot cable which permits the printer to be placed on a convenient table or desk. Output Printers and control units can be disconnected for off-line servicing from the Serial Input/Output Channel without affecting the operation of other units on the channel.

When it is desired to have the entire Output Printer unit together as a compact device, the 1717 Output Printer and the control units can be supplied in one unit complete with table and protective housings. Figure 25 shows the printer and the control units on an accessory table.

The table is also available with a protective cover that fits over the printer.

Selective and special features for the output printer are listed in Table 3.

Operation

Data and control codes (Table 4) are sent to the output printer by a **Write Numerical Output Channel** or **Write Alphameric Output Channel** instruction. The printer accepts, stores, and prints the character transmitted. When the operation is complete, the printer emits a signal that turns on the Unit Response indicator associated with it and initiates an interrupt. This informs the 1620 Central Processing Unit that the unit is ready to accept the next character.

The Output Printer prints in both the numerical and alphameric modes at up to ten characters per second. The actual rate is established by the manner in which the 1620 program is written. All alphabetic, numerical, and special characters are printed in the alphameric mode; all digits and special characters (period, comma, hyphen, and space) are printed in the numerical mode. Negative digits 0 and 1 through 9 are printed as – (hyphen) and J through R in the numerical mode.

Printer Control

The controlling of the functions of the printer is accomplished by control codes sent to the printer by the write instruction. These codes are listed in Table 4. Each control code is composed of a leading record mark character and a control character. Flag bits are not allowed with control codes.

When the character transferred to IODR (Input/Output Data Register) is a record mark, the record mark is not transmitted to the output unit; instead, the Output Record Mark indicator and Alert indicator are turned

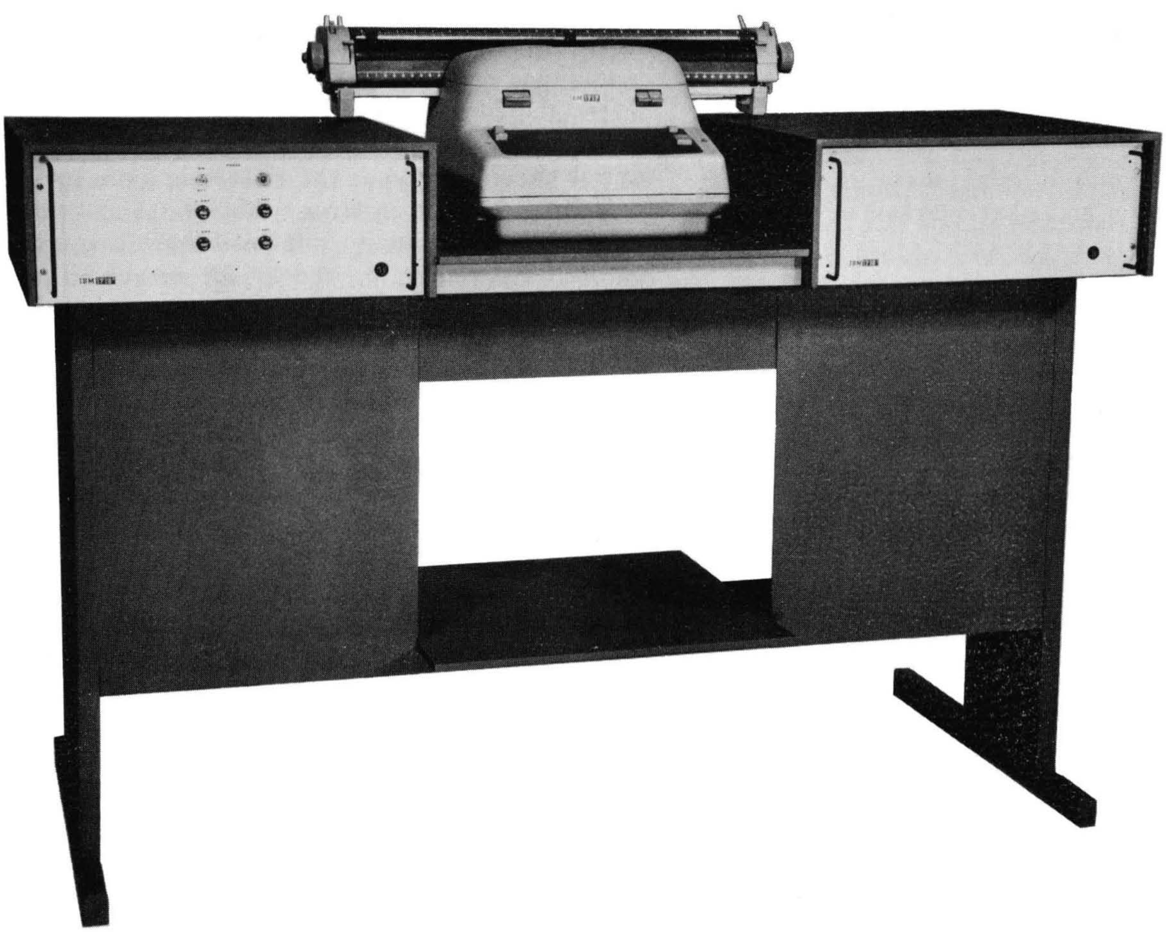


Figure 25. IBM 1717 Output Printer with 1716 Control Units

Table 3. Output Printer, Basic, Selective, and Special Features

Feature	Basis	Description
Carriage	Selective	16 inch, 10 char. per inch
	Selective	16 inch, 12 char. per inch
	Basic	12 inch, 10 char. per inch
	Selective	12 inch, 12 char. per inch
	Special	20 inch, 10 char. per inch
	Special	20 inch, 12 char. per inch
	Special	24 inch, 10 char. per inch
	Special	24 inch, 12 char. per inch
	Special	Automatic carriage
Platen	Basic	Medium
	Selective	Hard
	Selective	Soft
	Special	Pin feed
Type style	Basic	Manifold No. 10
	Selective	Manifold No. 12
	Selective	Pica Gothic
Vertical spacing	Basic	6 lines per inch
	Selective	8 lines per inch
Other	Basic	Red/black ribbon shift

Note: Selective features may be selected instead of comparable basic features. Special features are available at extra cost.

on and IODR is conditioned to treat the next character sent to it as a control character. The program should provide for testing the Output Record Mark indicator. If it is on, the proper control character can be immediately sent to IODR by another write instruction.

Mode Shift Indicator. Control character 2 is not transmitted to the output unit; instead, it causes the Mode Shift indicator and Alert indicator to be turned on. The program must provide for testing the Mode Shift indicator. If it is on, the next write command must be in the mode (numerical or alphameric) that is the opposite mode of the previous write instruction. Writing continues in this mode until another mode shift control character is sensed or until transmission is completed.

End-of-Message Indicator. A record mark transferred to IODR as a control character causes the End-of-Message and Alert indicators to be turned on. The program must provide for testing the End-of-Message indicator. If it is on, the proper end-of-message routine is initiated. The EOM control character also removes the unit from response status so that it cannot initiate another interrupt signal.

Table 4. Output Printer Control Codes

Control Code *		Function
Alphameric	Numerical	
0‡71	‡1	Type numerical period
0‡72	‡2	Change mode
0‡73	‡3	Type numerical comma
0‡74	‡4	Shift printer ribbon to black
0‡75	‡5	Shiftprinter ribbon to red (Alert)
0‡76	‡6	Tabulate printer carriage
0‡77	‡7	Space printer carriage one position
0‡78	‡8	Return printer carriage and advance one line
0‡79	‡9	Advance printing form to next form feed stop
0‡0‡	‡‡	End of message

* Note that a control code is always a leading record mark followed by a character to designate the function.

Error Indication

When a character with incorrect parity is received, it is not printed or acted upon, but the error condition is stored. When the next character – with the exception of the leading record mark of a control code or control character 2 – is received, it is ignored, and the SIOC Output Error indicator is turned on, an error interrupt is initiated, and the Unit Response indicator is turned on. When the SIOC Output Error indicator is tested, the error condition is reset and the Output Printer can be addressed again. A second attempt can now be made to send the erroneous character to the printer. If the second transmission results in an error, the printer control circuitry removes the error condition, causes the printer to print an error symbol (△), and then signals that the printer is ready for the next character. An *invalid* character received by the output printer causes the printer to space once, an interrupt to be initiated, and a unit response indicator to be turned on. If a color shift code is transmitted and the printer is already operating in that particular color mode, the printer spaces once.

Serial Input/Output Channel

The Serial Input/Output Channel (SIOC) available as a special feature provides a single connection to the 1710 for one to twenty input and output units. Because some units require more than one address, 100 addresses (00-99) are available.

Address Assignment

Up to twenty Process Operator Units, in any combination, can be attached to the 1711. However, the total number of addresses cannot exceed 100. The addresses (00-99) are assigned by the user.

Process Operator Units	Number of Addresses Required
1713 Manual Entry Unit (7 maximum)	13
1714 Sense Switch Unit (20 maximum)	4
1715 Digital Display Unit (20 maximum)	4
1717 Output Printer (20 maximum)	1

The following rules should be observed when making the address assignments:

1. Unit response codes for all units must be consecutive, beginning with 00 and ending with 19, if all twenty units are involved.
2. All addresses assigned to all units must be consecutive, subject only to the provision of the next rule.
3. The addresses assigned to any one unit must be consecutive and must not go beyond the numbers possible with *one* tens digit (e.g., 10-19, 20-29, etc.), except for the 1713 where addresses assigned must not exceed *two* tens digits.

   This rule applies if there is a conflict with instructions in rule 2. For example, if the last address used for any unit was 48 and the next addresses to be assigned were the 13 necessary for a Manual Entry Unit, 49 through 61 could not be assigned to the Manual Entry Unit because *three* tens digits are involved. Instead, 49 would not be used, and addresses 50 through 62 would be assigned. If enough devices are connected so that all of the 100 available addresses are used, the sequence of units in the addressing scheme may have to be carefully arranged to prevent the group of addresses for a Manual Entry Unit from beginning with an address containing an 8 or 9 units digit.

SIOC Characteristics

Transmission to and from the control system is serial by character. Operational speed of the attached units depends on the capability of each unit and upon the arrangement of the 1620 Data Processing Unit program. The maximum transmission *rate* is 80 characters per second, 12.5 milliseconds (ms) per character.

Although characters are transferred serially to and from each unit, the relatively fast internal speed of the computer as compared to the speeds of the individual input/output units, and the design of the Serial Input/Output Channel permits the operation of the units to be overlapped. From the standpoint of the programmer, the program is "looping" through a series of input and output operations, but from the standpoint of the process operator, data can be displayed, read, and printed almost simultaneously.

The SIOC cable is a single, multi-wire cable with a connection for each input or output unit, as required. Cable design permits an individual unit to be connected or disconnected without disturbing the operation of remaining units on the cable. The cable can be continuous with junctions for attached units or branching cables for units in remote locations. The maximum accumulated length of cable is 2,500 feet.

The Basic Interrupt, Input/Output Interrupts, and Random Addressing special features are prerequisites for the installation of the Serial Input/Output Channel.

Input/Output Data Register

The Input/Output Data Register (IODR), a part of the SIOC feature, is a single-character register that acts as buffer storage for input data from an attached unit and for output data from 1620 core storage. IODR is a 7-bit register with the following bit configuration:

X O C 8 4 2 1

The proper encoding and decoding of input/output data is accomplished by the 1620 as each character is transmitted between core storage and IODR. The bits for each character are transmitted in parallel between IODR and the SIOC unit and between IODR and core storage. Appendix D is a chart of IODR character codes.

Output Operations

The selection of the output unit (1715 Digital Display Units or 1717 Output Printer) and the transmittal of data are accomplished by the **Write Numerical Output Channel** (WNOC-88) or **Write Alphameric Output Channel** (WAOC-89) instruction with a Q_7 digit of 5, which identifies it as an SIOC operation. Only one instruction is needed to completely transfer one character from core storage to an output unit. The address of the output unit is contained in Q_{10} and Q_{11}. The P part of the instruction is the core storage address of the character transmitted. If alphameric data is being transferred, the P address must be an odd number, as in normal output operation.

Upon execution of the output instruction, the 2-digit code in Q_{10} - Q_{11} is sent to the Terminal Address Selector (TAS) which selects the proper unit. The character at the P address in core storage is encoded and stored in IODR. At this point, the 1620 and TAS are released for other programmed operations; SIOC remains busy for 12.5 ms. Figure 26 illustrates the timing for an operation using the Output Printer. The "printer action time" represents the *mechanical* operations of the printer, which can range from merely printing one character to tabulating across the entire width of a 24-inch carriage. After the 12.5-ms interval that the SIOC is busy, the SIOC Not Busy indicator is turned on, thereby allowing another input or output operation to take place during the "printer action time."

If SIOC is addressed by an instruction while it is still busy from a previous operation, the 1620 is interlocked until the 12.5-ms SIOC operation is complete before proceeding with the instruction.

When the output unit has completed the indicated operation with the character transmitted from IODR, a signal is generated to turn on the Unit Response indicator and to initiate an interrupt, which indicates to the computer that the unit is in response status and is ready for the next operation.

Input Operation

Transfer of data from an input unit to 1620 core storage is accomplished by two instructions. The first instruction, **Select Input Channel** (SLIC-86), moves the character to the IODR; and the second instruction, **Read Numerical Input Channel** (RNIC-$8\bar{6}$) or **Read Alphameric Input Channel** (RAIC-$8\bar{7}$), moves the character from the IODR to core storage. The SLIC-86 instruction must be followed by a RNIC-86 or RAIC-87 instruction, with no interceding SIOC instructions, in order to prevent loss of the character transferred to the IODR by the SLIC instruction.

SELECT INPUT CHANNEL

This instruction selects an address of an input unit and causes the addressee to place its contents into the IODR. This instruction requires an operation code of 86 with the Q_{10} and Q_{11} digits specifying an address of an input unit. The Q_7 position requires a digit of 5. The P address is not used.

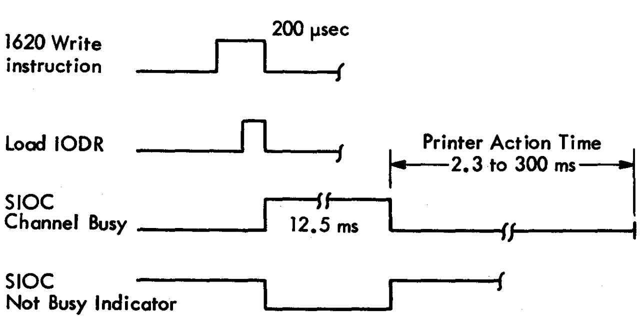


Figure 26. Output Printer Timing

READ NUMERICAL INPUT CHANNEL OR
READ ALPHAMERIC INPUT CHANNEL

These two instructions operate similarly except that one specifies numerical data and the other specifies alphameric data. Either instruction will cause the contents of IODR to be read into core storage. The Q_7 position requires a digit 5. The core storage location where the input character will be stored is the P address. Note that the **Read Numerical** instruction contains a flag over the Op code to distinguish it from the **Select Input Channel** instruction.

The squence of operations to transfer an alphameric or numerical character from an input unit to core storage is as follows:

1. The select instruction sends the input address to TAS, which connects the addressed unit to SIOC. The computer and TAS are released for other programming after 160 μsec.
2. Data from the selected input unit is transferred to IODR. This transfer requires 10 ms.
3. At the end of 12.5 ms, the Data Ready interrupt occurs and a read instruction transfers the data from IODR to core storage.
4. When the input unit is ready to transfer another character to IODR, it initiates a Unit Response interrupt and turns on the Unit Response indicator, which remains on until the next select instruction is given to begin the cycle again.

Transmission of data from the last character position of the unit removes the input unit from response status.

Execution Times

The time required to transfer a character from core storage to an output unit or from an input unit to core storage depends upon the unit involved. Precise instruction times are provided elsewhere in the manual. The times provided here are described from the standpoint of the operation of these units by the process operator.

In operations using the Manual Entry and Sense Switch input units, the speed of operation would be limited only by the speed of the process operator in entering data into the units. The data transfer time is less than the time it takes the process operator to remove his finger from the Execute button.

In operations using the Digital Display Unit, four data characters and a sign can be transferred to the unit in less than a second; that is, in less time than it would take the process operator to read the data or to read the data and transcribe it on a log sheet.

The speed of the output printer is ten characters per second, which means that the printing of a line of output data would normally appear as a continuous operation. Any time required to tabulate across the carriage or to return the carriage can be overlapped with other input or output operations.

As mentioned earlier, because of the design of the SIOC channel and the fast internal speed of the 1620, the operation of many Process Operator Units could be virtually simultaneous.

Interrupt Operation

The interrupt feature *associated with the Process Operation Units* allows the 1710 Control System to make efficient use of various Process Operator Units and to eliminate any waiting by the 1620 and TAS for an input or output cycle to be completed. The Any SIOC interrupt is connected to indicator 45 and can be tested with a **Branch Indicator** or **Branch No Indicator** instruction.

The Any SIOC Interrupt indicator is turned on by the SIOC Output Error indicator, the Data Ready indicator or any of the Unit Response indicators *when the* SIOC *becomes not busy.* All SIOC interrupts of the *mainline program* are initiated *only* by the Any SIOC interrupt.

When in response status (that is, waiting and ready to transmit or accept a character) each Process Operator Unit automatically initiates an interrupt (if SIOC is not busy) to signal the 1620 CPU that it is ready to send or accept additional data. The manner in which each unit is placed in response status was described in the section concerning that particular unit. Response status is removed by the transmission of the last character of a field or an end-of-message code.

The Unit Response indicator of the originating unit also turns on. The Unit Response indicator is identified by a 60 in Q_8 - Q_9 and the unit response code for the particular unit in Q_{10} - Q_{11}. The program can establish an interrupt priority for input/output units by the sequence in which the Unit Response indicators are tested in the program.

In some programs, the user may desire to inhibit SIOC interrupts in certain portions of the program. To inhibit SIOC interrupts, that is, to selectively mask, the program should test the Any SIOC indicator with a **Branch Indicator** or **Branch No Indicator** instruction and then omit any read or write instructions (SLIC, RNIC, RAIC, WNOC, WAOC) following the test. No more SIOC interrupts will occur until the program executes an SIOC read or write instruction (this could be a pseudo instruction), thus freeing the SIOC interrupt to operate again.

Data Ready interrupts must be serviced prior to Unit Response interrupts, since the data to be read is occupying IODR.

All SIOC interrupt signals are monitored by the SIOC to ensure that it is free to handle the transmission. When the SIOC channel is available, the SIOC Not Busy indicator is turned *on* and any interrupt signals from the units are allowed to interrupt the program.

SIOC interrupts that occur during an SIOC busy condition must wait until SIOC is *not* busy before interrupting the computer.

The functions of all SIOC Branch indicators are shown in Table 5.

Table 5. SIOC Branch Indicators

Code Q8-Q11	Indicator	Turned on by	Turned off by
45xx	Any SIOC	6043, 6044, and 6070 through 6089 providing SIOC Not Busy (6046) is on	Program test
6040	Output Record Mark	Record mark transmitted to IODR by write instruction	Program test
6041	End of Message	Control code Record Mark transmitted to IODR by write instruction	Program test
6042	Mode Shift	Control code 2 sent to IODR by write instruction	Program test
6043	SIOC Output Error *	Parity error detected by output unit	Program test
6044	Data Ready *	Character sent to IODR from input unit by read instruction	Program test
6045	Alert	SIOC indicator 6040, 6041, 6042, 6043, or 6044	Indicators off
6046	SIOC Not Busy	SIOC free to accept instruction or interrupt	SIOC busy
6070 to 6089	Unit Response*	SIOC unit ready to transmit or receive data. (Q_{10}-Q_{11} identifies individual unit: 70, No. 00; 71, No. 01; ... 89, No. 19.)	Not ready

* Interrupts

Because of the asynchronous operation of the Process Operator Units, the SIOC Not Busy indicator (6046) must be off before the other SIOC indicators can be tested by the program. The SIOC Not Busy indicator will always be off when an SIOC interrupt occurs.

SIOC Error Indications and Procedures

Data from SIOC input units is given the normal parity and invalid character check upon transfer from IODR to core storage. An invalid character will turn on the Read Check, MBR-E, and MBR-O indicators if the resulting character has incorrect parity.

Output data transmission and proper operation of the unit are checked by each output unit. An invalid output character with correct parity does not cause an error condition. An invalid output character with correct parity will cause the output printer to space one position.

Programming Process Operator Units

Programming is based upon a system which uses the interrupt feature to branch to a control program for the purpose of testing the SIOC indicators and then reading or writing data to the appropriate unit. After servicing the interrupt, by transmitting a single character to or from an input/output unit, the control program returns to the mainline program. In this manner, SIOC operations are overlapped with other processing operations, thus allowing more time in the mainline program.

A typical programming example is shown in the block diagram, Figure 27. This figure illustrates the programming and associated testing of SIOC indicators required to operate two 1717 Output Printers, one 1713 Manual Entry Unit, or 1714 Sense Switch Unit, and one 1715 Digital Display Unit attached to the 1710 Control System.

Note that each section of the program is designed to handle addressing of units, addressing of data, initializing unit response, etc., in a prescribed manner. The manner in which this program treats these items follows.

Unit Addresses

With the exception of the printers, each unit has consecutive unit addresses. For example, the 1715 Digital Display Unit may have addresses 21 through 24.

Unit Response Indicators

Unit Response indicator numbers 6070 through 6074 are assigned to the two Output Printers, the Manual Entry Unit, the Sense Switch Unit, and the Digital Display Unit, in that order. These indicators are tested by the program to determine which units require servicing.

Initializing Unit Response Mode

An output unit is placed in the Unit Response mode when a write instruction in the initializer step in the mainline program transmits the first character of a message to it. Subsequent write instructions are executed in the SIOC control program until the unit is removed from the Unit Response mode. The operator places an input unit in Unit Response mode by depressing the Execute button.

Input Data

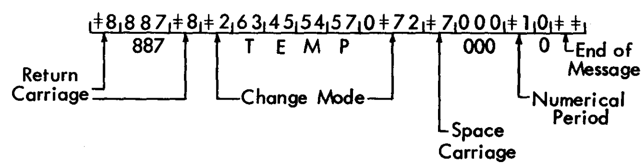
The twelve digits read from the Manual Entry Unit should be read into twelve consecutive positions of core storage each time the unit is placed in the Unit Response mode. Likewise, the four digits read from the Sense Switch Unit should be read into four consecutive positions of core storage each time the unit is placed in the Unit Response mode.

Output Data

1. Output Printer - A message to be typed may consist of mixed-mode data, i.e., 2-position alphameric characters can be mixed with 1-position numerical characters providing they are separated by *Change Mode Control Codes.* The characters which make up a message should be in adjacent core storage positions although alphameric characters must have odd-numbered addresses. The typed output message

   887
   TEMP 000. 0

   could take the following form in core storage.



   NOTE: The 1710 SPS-II language provides a special statement, DMES - Define MESsage that aids the programmer in constructing messages such as that given above.

2. Digital Display Unit - The four digits to be sent to the Digital Display Unit must occupy four adjacent positions of core storage.

Block Diagram

Most steps in the block diagram are self-explanatory. The following explanations are included for those blocks that may require additional information:

To *"Adjust Write Instruction (Modify Character Address)"*:

1. Add a constant 2 to the P part of the *write* instruction if in alphameric mode (O_1 of *write* instruction equal 9).
2. Add a constant 1 to the P part of the *write* instruction if in numerical mode (O_1 of write instruction equals 8).

To *"Adjust Write Instruction (Modify Operation Code)"*:

1. Change O_1 of the *write* instruction from 8 to 9 if it is 8; or from 9 to 8 if it is 9.

To *"Check Character Address"*:

1. Perform a check to determine that the character address in the P part of the *write* instruction is odd when O_1 of the *write* instruction contains a 9. This check is optional.

To *"Restore Character Address and Mode for next Message"*:

1. Reset position O_1 and the P part of *write* instruction to that of the leftmost character position of the next message.

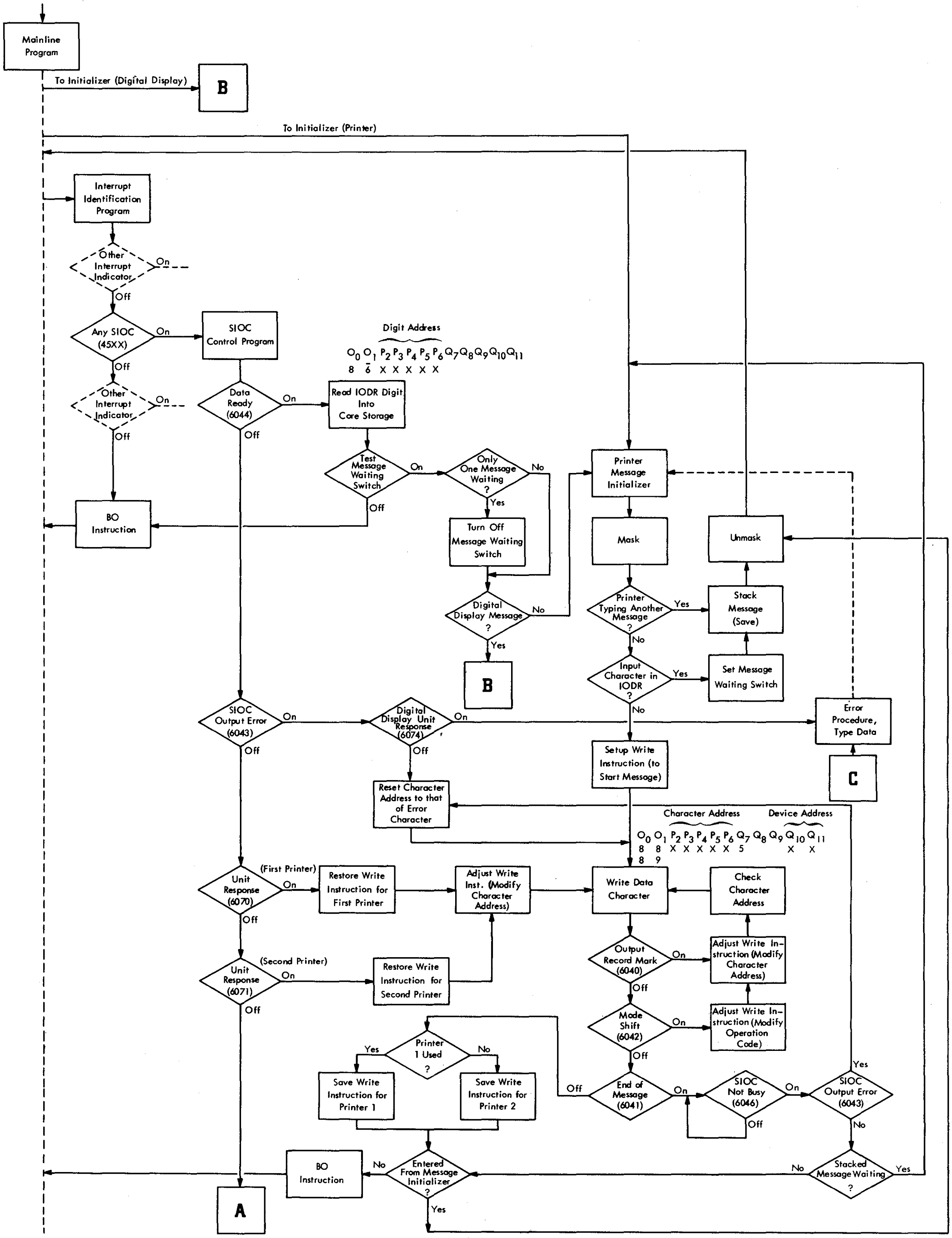


Figure 27a. Block Diagram for SIOC Program, Part 1

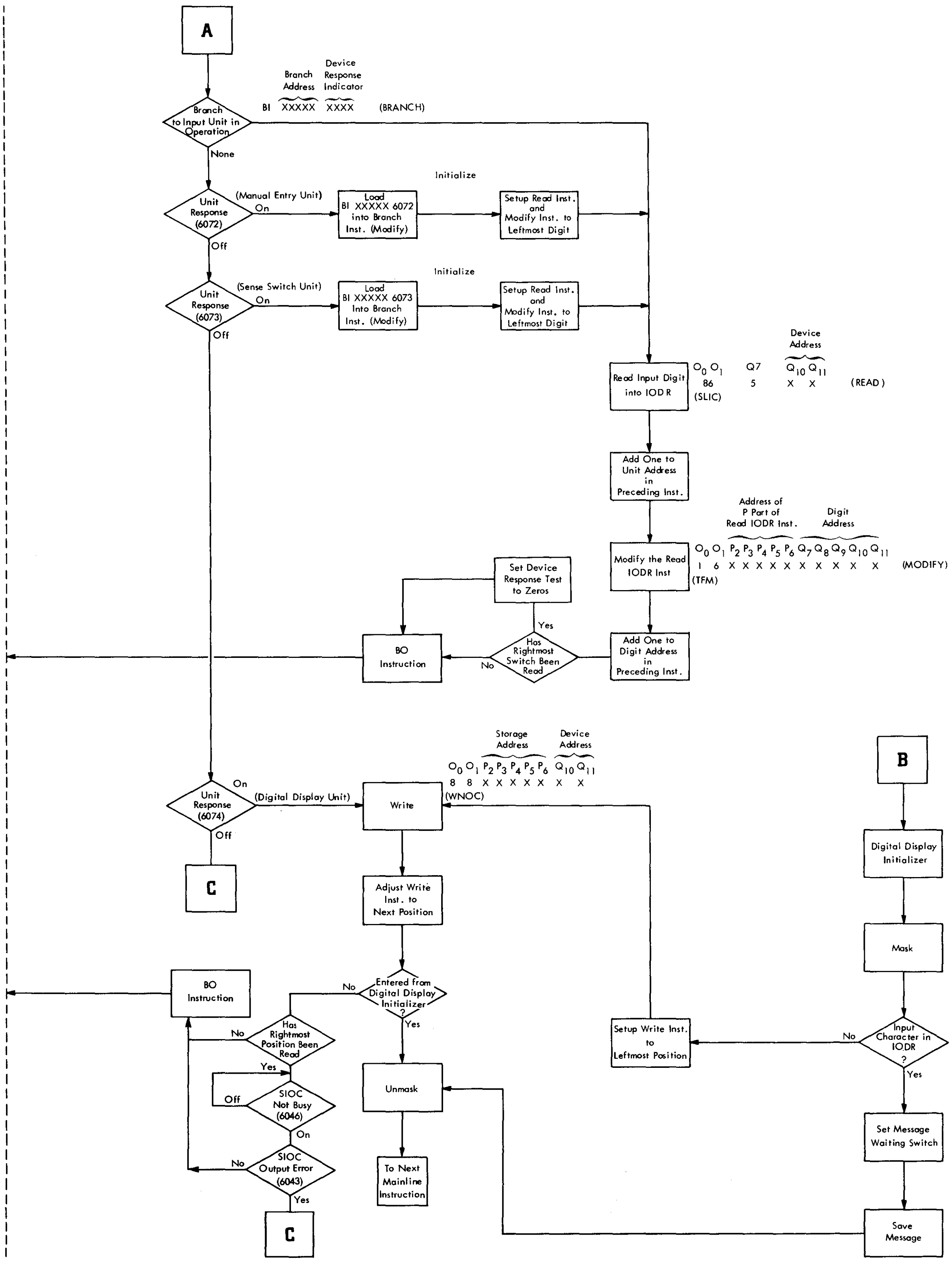


Figure 27b. Block Diagram for SIOC Program, Part 2

1710 Instructions

Instructions for the 1710 Control System described here, have been arranged in groups according to functional similarities. These consist of instruction for:

- Selecting input signals and contacts
- Operating contact points and set-point positioners
- Interrupt routine instructions
- Reading the contents of TAS and RTC into core storage.
- Input/Output operations with the Process Operator Units
- Branch Indicator instructions

Figure 28 is a summary of the instructions described in this manual, and shows the function of and associated special features for each instruction.

Appendix A contains a summary listing of the instructions in the 1710 Control System including all basic and special feature instructions for the 1620. This listing, in alphabetic sequence by instruction name, contains the operation code, any operation code modifiers, instruction times, and a Symbolic Programming System (SPS) mnemonic. The Symbolic Programming System for the 1710 Control System is described in the publication IBM *1620/1710 Symbolic Programming System* (Form C26-5600).

Selecting Input Signals and Contacts

- Select Address
- Select ADC Register
- Select Contact Block
- Select Manual Entry Switches

Select Address

SA or 84 with Q_7 of 1

Description. This instruction, provided with the Random Addressing of TAS special feature, causes the analog signal specified by the Q_9 - Q_{11} digits of the instruction to be read into the ADC for conversion.

Execution Time. The computer is released after 160 μsec. Conversion time requires 50 ms.

Select ADC Register

SLAR or 86 with Q_7 of 2

Description. This instruction is provided with the Random Addressing of TAS special feature and has two functions (the numbers correspond to the circled numbers in Figure 29):

1. The four digits in the ADC register which represent the previously selected analog input signal are transferred to the P address and to successively higher-number core storage locations. The high-order digit is automatically flagged. If the transferred digits represent a negative analog voltage, the low-order digit is also flagged. Core storage data that is replaced, including flag bits, is lost. If the previously converted signal exceeded the analog input range specified by the matching SMS card in the 1712, four flag bits (negative zeros) would be transferred to core storage.
2. Following transfer of the contents of the ADC register to core storage, the Q_9 - Q_{11} digits of the instruction are transferred to TAS and the analog input signal specified by this address is converted to a four-digit value (0000-9999) by the ADC. The Multiplexer Busy indicator (29) is on during the 50 ms conversion time. If the Multiplex Complete Interrupt indicator (40) is installed, an interrupt will occur after conversion. TAS is busy for 12.5 ms during this instruction, and any following instruction using TAS is delayed until the 12.5 ms delay time is complete.

Execution Time. The computer is free for operations that do not require the Multiplexer or TAS after 240 μsec (time required to transfer the ADC register contents to core storage). TAS operations require 12.5 milliseconds; ADC operations require 50 milliseconds.

Select Contact Block

SLCB or 86 with Q_7 of 7

Description. This instruction is used to program the special feature, High-Speed Contact Sense. Contact sense points are terminated on contact sense terminal blocks in the 1712. One terminal *address* is assigned for

Instruction Name	Associated Special Features	Function	Machine Codes			SPS Mnemonic
			OP	Q_7	Q_9-Q_{11}	
Select Address	Random Addressing	Select terminal address and begin conversion of signal at the addressed point	84	1	000-299	SA
Select ADC Register	Random Addressing	Transfer contents of ADC register to core storage. Set TAS register to the Q_9-Q_{11} address and begin conversion of new signal.	86	2	000-299	SLAR
Select Contact Block	High-Speed Contact Sense	The status of the terminal points specified by the address in Q_9-Q_{11} are transferred to core storage.	86	7	00-19	SLCB
Select Manual Entry Switches	Manual Entry	Transfer contents of manual entry switches to core storage.	86	8	Not used	SLME
Select Address and Contact Operate	Contact Operate	Select terminal address and close the contact at the addressed point	84	2	000-299	SACO
Select Analog Output and Signal	Analog Output	Select terminal address and provide set-point positioning signal.	84	3	000-299	SAOS
Mask	Basic Interrupt	Places program in noninterruptible mode - interrupts are detained until execution of an Unmask instruction	46	–	Q_8-Q_9=00 Q_{11}=1	MK
Unmask	Basic Interrupt	Removes program from noninterruptible mode, if the noninterruptible mode exists as the result of a Mask	46	–	Q_8-Q_9=00 Q_{11}=0	UMK
Branch Out	Basic Interrupt	Returns 1710 program from subroutine back to main program at same location where original branch occurred.	47	–	Q_8-Q_9=00 Q_{11}=0	BO
Branch Out and Load	Basic Interrupt	Returns 1711 program from subroutine back to main program, but to the instruction specified by the P address.	47	–	Q_8-Q_9=00 Q_{11}=1	BOLD
Select TAS	Random Addressing	Transfer address of terminal point in TAS register to core storage.	86	1	Not used	SLTA
Select Real-Time Clock	None	Transfer contents of Real-Time clock to core storage	86	4	Not used	SLTC
Select Input Channel	Serial Input/Output Channel	Selects address of an input unit and causes contents of the unit to be placed in IODR.	86	5	00-99	SLIC
Read Numerical Input Channel	Serial Input/Output Channel	Transfers numerical character in IODR to core storage location specified by P address.	$8\bar{6}$	5	Not used	RNIC
Read Alphabetic Input Channel	Serial Input/Output Channel	Transfers alphabetic character in IODR to core storage location specified by P address.	$8\bar{7}$	5	Not used	RAIC
Write Numerical Output Channel	Serial Input/Output Channel	Transfers numerical character from core storage location specified by P address to output unit specified in Q_9-Q_{11}.	88	5	00-99	WNOC
Write Alphabetic Output Channel	Serial Input/Output Channel	Transfer alphabetic character from core storage location specified by P address to output unit specified in Q_9-Q_{11}.	89	5	00-99	WAOC
Branch Indicator	None	Indicator specified by Q_8-Q_9 is interrogated. If indicator is on program branches to P address.	46	–	–	BI

Figure 28. Instruction Summary

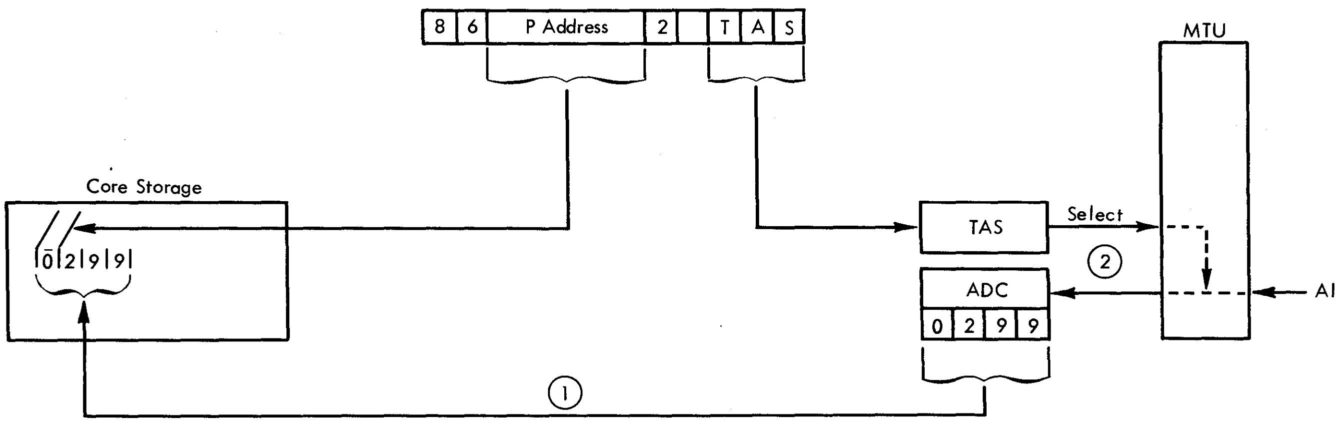


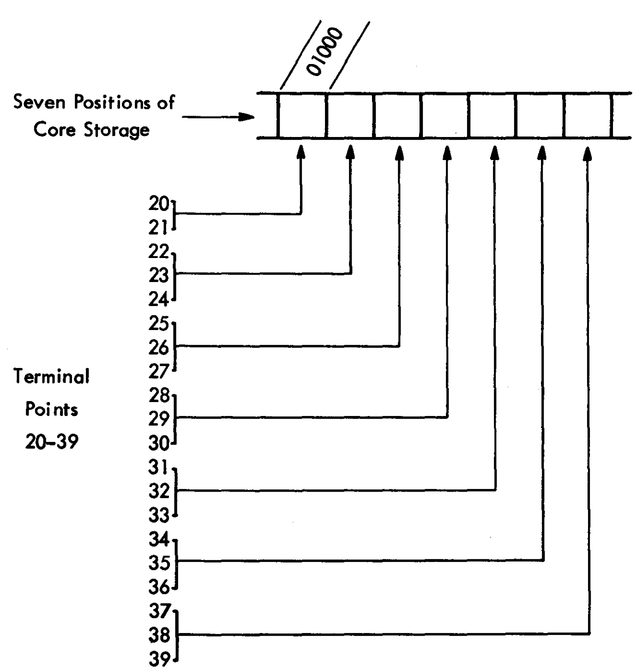
Figure 29. Select ADC Register Instruction Data Flow

a group of 20 terminal *points*. A total of 20 terminal addresses is available if all 400 contact sense points are installed. For the purposes of programming, the terminal block can be thought of as consisting of two parts or halves with 200 terminal points (10 terminal addresses) on each half. Positions Q_{10} and Q_{11} of the instruction must specify one of the 20 terminal addresses. When the instruction is executed, the 20 terminal points at the terminal address specified in Q_{10} and Q_{11}, *and all of the terminal points for the remaining higher-numbered terminal addresses* (in that "half" of the terminal block) are scanned and read into core storage. The following chart lists the twenty terminal addresses and the corresponding points that are scanned. Note, for example, that a terminal address of 03 in Q_{10} and Q_{11} causes the program to scan and read into core storage terminal points 60 through 199.

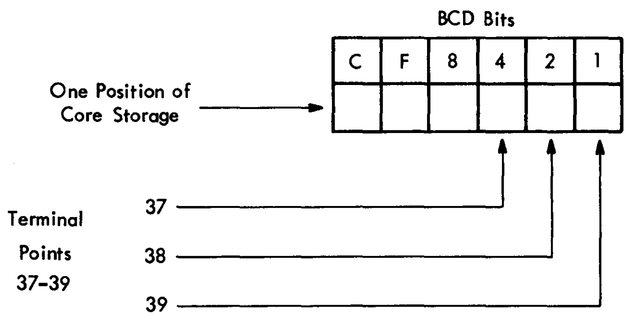
Terminal Address	Points Scanned	Terminal Address	Points Scanned
00	000-199	10	200-399
01	020-199	11	220-399
02	040-199	12	240-399
03	060-199	13	260-399
04	080-199	14	280-399
05	100-199	15	300-399
06	120-199	16	320-399
07	140-199	17	340-399
08	160-199	18	360-399
09	180-199	19	380-399

For another example, the terminal address 10 causes 200 terminal points to be scanned and read into core storage. The *contact points that must be scanned most frequently* should be installed so that they *are assigned to the highest-numbered* terminal addresses on either "half" of the contact sense terminal block.

As the contacts are scanned, the status of each one is entered in core storage beginning at the location specified by the P address of the instruction. The status of the 20 contacts of each terminal address group is stored in seven positions of core storage. (Flags bits already existing in the seven core storage positions are removed.) The status of the first two points is recorded in the first of the seven position; the status of the remaining 18 points is stored in the second through seventh positions as shown in the following diagram.



To accomplish this saving in scanning time and core storage capacity, individual bits of the 6-bit binary-coded-decimal (BCD) configuration in each core storage location are used to record the status of the terminal point contacts. In the first location, the first contact is assigned to the 2 bit and the second contact to the 1 bit. In the second through seventh positions, the first of the three contacts is assigned the 4 bit, the second contact is represented by the 2 bit, and the third contact by the 1 bit, as shown in the following diagram.



The corresponding bit is stored if a contact is closed; the bit position is blank if the contact is open. For example, if the first and third contacts are closed, the core storage position assigned to the group of three contacts contains a 4 bit and a 1 bit. Table 6 illustrates this by showing the bit configuration for all possible combinations of the three contacts when open and closed. The column on the right contains the corresponding numerical designation of the combination of bits stored according to the standard BCD notation for 6-bit data storage. A closed or open contact may be recognized as such by the program 2 to 5 ms after it opens or closes.

Table 7 shows the distribution of the 20 points of a group over the seven core storage positions designated by the P address. The figures in the table are the numerical representations of the bits stored as a result of the related contacts being closed. Note that the location P_1 records the status of *two* terminal point contacts, while each of the remaining six locations reflects the conditions of *three* terminal point contacts. As an example, if it is desired to test for contact 14 being open and contacts 15 and 16 being closed, a 3 is compared with the data in P_6, because terminal point contacts 15 and 16 are the second and third contacts in that location.

By selecting the proper number to compare with the data in a given core storage location, the status of each contact can be determined. In addition, where program logic and process operation dictate, any combination of two or three contacts in the same location can be tested with one instruction. For example, an emergency condition may be indicated if one of three blowers in a hazardous area is not operating. This can be deter-

Table 6. Bit Configuration of Closed Contacts

Terminal Contacts 37 - 39			BCD Bits of One Storage Position						Character Core Storage
37	38	39	C	F	8	4	2	1	
C*						X			4
	C						X		2
		C						X	1
C	C		C			X	X		6
C		C	C			X		X	5
	C	C	C				X	X	3
C	C	C				X	X	X	7
(none closed)			C						0

* Contact Closed

Table 7. Digits for Identifying Open and Closed Contacts for one Terminal Address of 20 Terminal Contacts

Status of Terminal Points			Core Storage Positions						
1st	2nd	3rd	P_1	P_2	P_3	P_4	P_5	P_6	P_7
C*			2	4	4	4	4	4	4
	C		1	2	2	2	2	2	2
		C		1	1	1	1	1	1
C	C		3	6	6	6	6	6	6
C		C		5	5	5	5	5	5
	C	C		3	3	3	3	3	3
C	C	C		7	7	7	7	7	7
			$n_0 n_1$	$n_2 n_3 n_4$	$n_5 n_6 n_7$	$n_8 n_9 n_{10}$	$n_{11} n_{12} n_{13}$	$n_{14} n_{15} n_{16}$	$n_{17} n_{18} n_{19}$
			Terminal Point Numbers Included in each Core Storage Position						

* Contact Closed

mined in one operation by comparing a seven with the data in the assigned core storage position.

After the first 20 terminal point contacts have been scanned and entered in core storage, the terminal address in TAS is advanced by one and the next 20 terminal point contacts are scanned and entered into succeedingly higher-numbered core storage positions. This operation is continued until all addresses on one "half" of the terminal block have been addressed, and the status of their terminal points read into core storage. The entire operation is performed by only one instruction. The second group begins with the P address + 7, and so on. The highest-numbered core storage position required for an instruction that scans the maximum of 200 contacts is P + 69 (70 positions). The exact range of addresses in core storage for any instruction is

$$P \text{ through } P + 7 \ (10 - Q_{11}) - 1$$

where Q_{11} is the digit in that position of the instruction.

PROGRAM INSTRUCTION TIME

The elapsed time required for this instruction varies according to the number of 20-point groups scanned. It should be noted that the *scanning* time for each terminal address is the same whether the entire 20 points are connected or not. The formula for computing the total time, in microseconds, for each program instruction is as follows:

$$T = 160 + 175 \ (10 - Q_{11})$$
Q_{11} = digit in that position of instruction

A group of points must not be addressed more often than once every 1.5 milliseconds.

Select Manual Entry Switches

SLME 86 or Q_7 of 8

Description. This instruction is used to program the Manual Entry special feature. The seven digits in the 1711 Manual Entry switches are read into the P address and into successively higher-numbered core storage locations. The high-order digit is flagged. Core storage data that is replaced, including flag bits, is lost.

The **Select Manual Entry Switches** instruction may be executed while the Multiplexer Busy indicator is on. The Q_8 - Q_{11} digits of the instruction are not used.

Execution Time. T = 300

Operating Contact Points and Set-Point Positioners

Select Address and Contact Operate
Select Analog Output and Signal

Select Address and Contact Operate

SACO or 84 with Q_7 of 2

Description. This instruction is used to program the special feature, Contact Operate. The contact in the 1712 whose terminal address is specified by the Q_9 - Q_{11} positions of the instruction is closed for 50 ms. The closed contact completes a circuit to a customer device (motor, light, alarm, etc.). The customer supplies the voltage required to power the circuit.

Execution Time. The computer is released after 160 μsec. The Multiplexer Busy indicator and the selected multiplexing relay are activated for 50 ms.

Select Analog Output and Signal

SAOS or 84 with Q_7 of 3

Description. This instruction is used to program the special feature, Analog Output, as follows:

1. A **Select Analog Output and Signal** instruction that specifies the up or down address of each SPP (set-point positioner) to be adjusted is executed.
2. After selection of SPP addresses, another **Select Analog Output and Signal** instruction specifying the slew or trim address is executed.

All **Select Analog Output and Signal** instructions, including those for SPP selection and slew or trim selection, must be executed while the Analog Output Setup indicator (28) is *on* to ensure complete slew or trim adjustments.

Execution Time. 160 μsec are required to execute this instruction. The computer is free to execute other instructions after this time. The Multiplexer Busy indicator is on for 3.75 ms, the time required to pick an Analog Output latching relay. A complete Analog Output cycle, which includes a selection of channels (.7 second) and slewing (2.5 seconds) or trimming (.5 second), requires 3.6 seconds. At least two **Select Analog Output and Signal** instructions are required during the .7-second setup time – one or more instructions for Analog Output channel selection and one for slew or trim selection.

Interrupt Routine Instructions

Mask
Unmask
Branch Out
Branch Out and Load

These four instructions are used to control the computer program when process or internal (1710) interrupts occur. They enable the program to branch to special routines in order to satisfy the interrupt condition, and then return to the main program.

Mask

MK or 46 with Q_8-Q_9 of 00 and Q_{11} of 1

Description. This instruction, provided with the Basic Interrupt special feature, is used to "mask" all interrupts. Masked interrupts are not lost; they are merely detained until the execution of an **Unmask** instruction. If the 1710 is in an interrupt subroutine when the "unmask" occurs, the interrupts are further detained until a **Branch Out** or **Branch Out and Load** instruction is executed.

The Mask indicator (26) is turned on and off by the **Mask** and **Unmask** instructions, respectively.

The P address, Q_7 and Q_{10} positions of the instruction, are not used.

Execution Time. T = 160.

Unmask

UMK or 46 with Q_8-Q_9 of 00 and Q_{11} of 0

Description. This instruction, provided with the Basic Interrupt special feature, is used to "unmask" all interrupts. It also places the 1710 in the interruptible mode if the noninterruptible mode exists as a result of a **Mask** instruction. The **Unmask** instruction operates the same as a **No Operation** instruction when executed without a preceding **Mask** instruction.

The Mask indicator (26), turned on by the execution of a **Mask** instruction, is turned off by the **Unmask** instruction.

The P address, Q_7 and Q_{10} positions of the instruction, are not used.

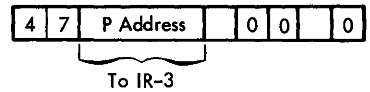
Execution Time. T = 160.

Branch Out

BO or 47

Description. This instruction, provided with the Basic Interrupt special feature, is normally used in the interrupt subroutine to return the 1710 to the main program. The effect of this instruction is to branch the program out of the noninterruptible mode. Execution of this instruction within an interrupt subroutine causes the following:

1. The P address of the instruction is stored in IR-3. This operation is necessary to restore IR-3 for use when the *next* interrupt occurs. Therefore the P address of this instruction is normally the address of the interrupt identification routine.
2. The arithmetic indicators are restored to their saved status, i.e, their on/off condition before the interrupting condition was recognized.
3. The interruptible mode of operation is restored if a **Mask** instruction is not in effect.
4. IR-1 is placed back in normal use (that is, it is used to obtain the address of the next instruction to be executed), and the computer returns to the main program at the address that was saved in IR-1.



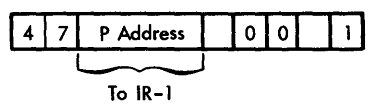
In addition to the Op code and the P address, zeros must be placed in Q_8, Q_9, and Q_{11}; Q_7 and Q_{10} are not used.

Execution Time. T = 200.

Branch Out and Load

BOLD-47

Description. This instruction, provided with the Basic Interrupt special feature, operates in the same manner as the **Branch Out** instruction, except that the P address is placed in *IR-1* and the address in IR-3 is not disturbed. Thus, the instruction is used to return the computer to the mainline program, but it *does not restore IR-3 to the address of the interrupt identification routine.* The computer does not branch to the address saved when the interrupt occurred, but, instead, the computer returns to the mainline program at some other address. The address originally saved in IR-1 when the interrupt occurred is lost. The address in IR-3 is not affected, and *if* it is the address of the interrupt identification routine it can be used by the next interrupt.



In addition to the Op code and P address, zeros must be placed in Q_8 and Q_9 and a one must be placed in Q_{11}; Q_7 and Q_{10} are not used.

Execution Time. T = 200.

Reading the Contents of TAS and RTC into Core Storage

Select TAS

Select Real-Time Clock

Select TAS

SLTA or 86 with Q_7 of 1

Description. This instruction, provided with the Random Addressing special feature, is used to transfer the three digits in the TAS register (000-299) to the P address and to successively higher-numbered core storage locations. The high-order digit is automatically flagged in core storage. Data and flag bits in core storage that have been replaced are lost. The contents of the TAS register are not altered. The Q_8 - Q_{11} digits of the instruction are not used.

Execution Time. T = 240.

Select Real-Time Clock

SLTC or 86 with Q_7 of 4

Description. This instruction, a basic feature of the system, is used to transfer the contents of the RTC to core storage. Storage begins at the P address and continues through three successively higher-numbered locations. The high-order digit is flagged. Core storage data that is replaced, including flag bits, is lost.

This instruction may be executed while the multiplexer is busy. The Q_8 - Q_{11} digits of the instruction are not used.

Execution Time. T = 240.

If the clock is advancing when the Select Real-Time Clock instruction is executed, the computer may be interlocked for up to 320 ms.

Input/Output Operations with the 1710 Process Operator Units

Select Input Channel
Read Numerical Input Channel
Read Alphabetic Input Channel
Write Numerical Output Channel
Write Alphabetic Output Channel

Select Input Channel

SLIC or 86 with Q_7 of 5

Description. This instruction, provided with the Serial Input/Output Channel special feature, is used to select the address of an input unit via TAS, which places the character from the input unit into the Input/Output Data Register (IODR). This instruction must be followed by an SIOC read instruction in order to transfer the character from IODR to core storage.

The P address is not used. The Q_7 position must contain a 5. The Q_{10} and Q_{11} positions of the instruction are used to specify the input unit to be selected.

Execution Time. T = 160.

Read Numerical Input Channel

RNIC or $8\bar{6}$ with Q_7 of 5

Description. This instruction, provided with the Serial Input/Output Channel special feature, is used to transfer a character from IODR to core storage in *the numerical mode.*

The P address specifies the core storage address where the character is to be placed. The Q_7 position must contain a 5.

Execution Time. T = 190.

Read Alphameric Input Channel

RAIC or $8\bar{7}$ with Q_7 of 5

Description. This instruction operates the same as the **Read Numerical Input Channel** instruction, except that data is placed in core storage in the alphameric mode.

The P address must be an odd-numbered address.

Execution Time. T = 240.

Write Numerical Output Channel

WNOC or 88 with Q_7 of 5

Description. This instruction, provided with the Serial Input/Output Channel special feature, is used to select an output unit via TAS, and then to transfer a character from core storage into IODR and then out of IODR to an output unit. The character is read out of core storage *in the numerical mode.*

The P address is the core storage address of the character to be transmitted. The Q_7 position must contain 5. The output unit to be selected is specified by the Q_{10} and Q_{11} positions of the instruction.

Execution Time. T = 200.

Write Alphameric Output Channel

WAOC or 89 with Q_7 of 5

Description. This instruction operates the same as the Write Numerical Output Channel instruction except that the character is read out of core storage in the alphameric mode. The P address must be an odd-numbered address.

Execution Time. T = 200.

Branch Instructions

Branch Indicator

BI-46

This is a standard 1620 CPU instruction. It is described here to show both the 1620 and 1710 indicators that can be tested.

Description. The indicator specified by Q_8 and Q_9 of the instruction is interrogated and a branch to the P address occurs if the indicator is on. Indicators are always in one of two conditions, on or off. The status of each indicator is dependent on process and/or control system conditions at the time of interrogation. The Q_7, Q_{10}, and Q_{11} positions of the instruction are not used.

Execution Time. If the branch occurs (indicator on), T = 200. If the branch does not occur, T = 160.

NOTE: If the 1710 indicators – 18, 19, 21-23, 27-29, 40-45, and 48-59 – are tested, the execution times for this instruction are changed to 290 if the branch occurs, and to 150 if the branch does not occur.

Information concerning 1620 and 1710 indicators is given in Table 8 and further explained, as follows.

Program Switches (01-04). The status of these four indicators is determined by the on/off conditions of their respective Program switches on the 1620 Console.

Read and Write Check (06 and 07). The Rd/Wr Check indicators are turned on when erroneous data is transferred to or from an I/O device. Indicator 19 is on when these indicators are on.

MAR Check (08). When a parity error or invalid address occurs in MAR and the Parity Check switch on the 1620 console is set to PROGRAM, the MAR Check indicator is turned on. Indicator 19 is on when this indicator is on.

Last Card (09). This indicator is turned on whenever the data from the last card is correctly transferred from 1622 input buffer storage to core storage.

Arithmetic (11, 12, 13, and 14). The arithmetic indicators – 11, 12, and 14 – are explained under ARITH-

Table 8. 1710 Indicators

Machine	Code	Name	Light	Turned on by	Turned off by	Turns on Indicator	Initiates Interrupt	Special Feature Prerequisite
1620	01-04	1620 Program Switches 1-4	No	Operator (Program Switch on)	Operator (Program Switch off)			**
	06	Read Check	Yes	I/O input error	BI, BNI or 1620 Reset key	19	x	**
	07	Write Check	Yes	I/O output error	BI, BNI or 1620 Reset key	19	x	**
	08	MAR Check*	Yes	Parity error or invalid address in MAR	BI, BNI or 1620 Reset key	19	x	**
	09	Last Card (1622 Card Read)	Yes	Last card data transfer to Core Storage	BI, BNI or 1620 Reset key			**
	11	High-Positive (H/P)	Yes	Arithmetic result positive and greater than zero	Reset key	13		**
	12	Equal-Zero (E/Z)	Yes	Arithmetic result of zero	Reset key	13		**
	13	H/P or E/Z	No	Indicator 11 or 12	Indicators 11 and 12 Off			**
	14	Overflow Check	Yes	Arithmetic check	BI, BNI or 1620 Reset key			**
	15	Exponent Check	Yes	Exponent Overflow or Underflow	BI, BNI or 1620 Reset key			Automatic Floating Point
	16	MBR-E Check	Yes	Parity error in MBR-E	BI, BNI or 1620 Reset key	19	x	**
	17	MBR-O Check	Yes	Parity error in MBR-O	BI, BNI or 1620 Reset key	19	x	**
	26	Mask	Yes	Mask instruction	Unmask Instruction			Basic Interrupt
1711	*18	Operator Entry	Yes	Operator Entry key depression	BI, BNI, 1711 or 1620 Reset keys		x	Basic Interrupt
	*19	Any Check (1710)	No	Indicator 06, 07, 08, 16, 17, 21, 22, 23 or 39 on	Indicators 06, 07, 18, 16, 17, 21, 22, 23, 36, 37 and 38 off		x	Basic Interrupt
	21	TAS Check	Yes	Parity error or invalid Address in TAS	BI, BNI, 1711 or 1620 Reset keys	19	x	Random Addressing
	22	Function Register Check	Yes	Invalid Q_7 digit	BI, BNI, 1711 or 1620 Reset keys	19	x	**
	23	Analog Output Check	Yes	Multiplexing relay failing to unlatch	BI, BNI, 1711 or 1620 Reset keys	19	x	Analog Output
	27	CE Interrupt	No	CE Switch On (CE Panel behind 1711 Covers)	BI or BNI		x	Basic Interrupt
	28	Analog Output Setup	No	Start of Analog Output cycle	Slew or Trim instructions, or end of setup time (.7 seconds)			Analog Output
	29	Multiplexer Busy	Yes	Instruction Using 1712 Multiplexer	Multiplex Complete or 1711 or 1620 Reset Keys			**
	40	Multiplex Complete	No	Completion of Multiplexing (Initiates Interrupt)	BI, BNI or Power-On Reset		x	Input/Output Interrupt
	41	Analog Output Setup Interrupt	No	Start of Analog Output cycle	BI, BNI or Power-On Reset		x	Timed Interrupt
	43	One Minute Interrupt	No	Advance of RTC hundreds-of-hour wheel	BI, BNI or Power-On Reset		x	Timed Interrupt
	44	One Hour Interrupt	No	Advance of RTC hour wheel	BI, BNI or Power-On Reset		x	Timed Interrupt
	48-59	External Interrupts	No	Process disturbances	BI or BNI		x	External Interrupt
	70-89	Process Branch	No	Process conditions (closed contact)	Process Conditions (open contact)			Process Branch Indicator
	45	Any SIOC Interrupt	No	A SIOC Not Busy (6046) and any one of three conditions: 1. A unit Response (6070-6089) 2. SIOC Output Error (6043) 3. Data Ready (6044)	BI, BNI, EOM (End-of-Record Mark) or Power-On Reset		x	Input/Output Interrupt
	6040	Output Record Mark	No	Record Mark in IODR (I/O Data Register)	BI, BNI or 1710 Reset ‡	6045		SIOC
	6041	EOM (End of Message)	No	‡ control code in IODR during write operation	BI, BNI or 1710 Reset ‡	6045		SIOC
	6042	Mode Shift	No	2 control code in IODR during write operation	BI, BNI or 1710 Reset ‡	6045		SIOC
	6043	SIOC Output Error	No	Error detected by output unit	BI, BNI or Power-On Reset	6045, 45	x	SIOC
	6044	Data Ready	No	Character waiting in IODR following a SLIC Instruction	BI, BNI or Power-On Reset	6045, 45	x	SIOC
	6045	Alert	No	Indicator 6040, 6041, 6042, 6043, or 6044 on	Indicators 6040, 6042, 6043, and 6044 off			SIOC
	6046	SIOC Not Busy	No	SIOC available for instruction or interrupt	SIOC Busy			SIOC
	6070 through 6089	Unit Response	No	SIOC I/O unit ready to transmit or receive data	Unit not ready or EOM	45	x	SIOC
1311	36	Address Check	Yes	No sector address in Disk Storage to match address in OR-1	BI, BNI or 1620 Reset	39	x	1311 Disk Storage Drive
	37	WLR/RBC	Yes	Wrong Length Record or Read Back Check	BI, BNI or 1620 Reset	39	x	1311 Disk Storage Drive
	38	Cylinder Overflow	Yes	Operation through last sector of cylinder without sector count decrementation to 000	BI, BNI or 1620 Reset	39	x	1311 Disk Storage Drive
	39	Any Disk Check	No	Indicator 36, 37 or 38 on	Indicators 36, 37 and 38 off	19	x	1311 Disk Storage Drive
	42	Seek Complete	No	End of seek operation	BI, BNI or Power-On Reset		x	Input/Output Interrupt

* Standard feature of the system. The interrupt function of this indicator is available only with the Basic Interrupt special feature

** Included on Basic 1710 System.

‡ 1711 Reset is caused by pressing 1711 Reset on by a Power-on reset

METIC INSTRUCTIONS in the publication IBM *1620 Central Processing Unit* (Form A26-5706). The single indicator, High/Positive or Equal/Zero (13), provides the means for interrogating both the High/Positive (11) and Equal/Zero (12) indicators with one BI or BNI instruction, no indicators are turned off by this instruction. The H/P or E/Z indicator is turned off only when both the H/P (11) and E/Z (12) indicators are off.

Exponent Check (15). (1620 Special Feature). This indicator is turned on by an exponent underflow or overflow.

MBR-E and MBR-O (16 and 17). All data entering and leaving core storage does so via the MBR registers. Their associated indicators (16 and 17) are turned on if a parity error occurs. Indicator 19 is on when these indicators are on.

Operator Entry (18). This indicator is used with the Manual Entry and Interrupt features for the manual entry of data from the 1711 Operator's Panel. It is turned on when the operator presses the Operator Entry key. If the Basic Interrupt feature is installed, an interrupt has been initiated when this indicator is on.

Any Check (19). This indicator provides the means for interrogating nine error conditions – 06, 07, 08, 16, 17, 21, 22, 23, and 39 – with a single **Branch Indicator** or **Branch No Indicator** instruction, no indicators are turned off by the instruction. Indicator 19 is turned off only when all of the nine error conditions are off. When this indicator is on, an interrupt has been initiated, if the Basic Interrupt feature is installed.

TAS Check (21). This indicator, provided with the Random Addressing of TAS special feature is turned on either by a parity error or an invalid terminal address in TAS. If a 3 digit is erroneously inserted in the hundreds position of TAS, no TAS Check will occur. Indicator 19 is on when this indicator is on.

Function Register Check (22). The Function Register decodes all the Q_7 modifier digits. An invalid digit or parity error in the Function Register turns on indicator 22. Indicator 19 is on when the indicator is on.

Analog Output Check (23). This indicator, provided with the Analog Output special feature, is turned on if an Analog Output multiplexing relay fails to unlatch. This provides one of the fail-safe features of the 1710 Control System. Indicator 19 is on when the indicator is on.

Mask (26). This indicator is turned on by a Mask instruction and turned off by an Unmask instruction. It can be tested to determine if the system is in the interruptible mode (unmasked) or the noninterruptible mode (masked). This indicator is also turned on when power is turned on or when the 1620 Reset key is pressed.

Customer Engineer Interrupt (27). This indicator provides the IBM Customer Engineer with a method of transferring the 1710 from normal program operation of the process to 1710 diagnostic programming. This indicator is turned on by the CE Interrupt switch on the Customer Engineer control panel. It is turned off by program interrogation.

Analog Output Setup (28). This indicator is turned on during the .7-second setup period in the analog output cycle. It is turned off at the end of the setup period or turned off by the execution of a slew or trim instruction.

Multiplexer Busy (29). This indicator is turned on by instructions that use the multiplexer – Analog Input, Analog Output and Contact Operate. If an instruction which uses the multiplexer is initiated when Multiplexer Busy is on, the computer waits until Multiplexer Busy is turned off. Figures 30, 31, and 32 show some relative timings for Multiplexer Busy, Multiplex Complete, and process input/output functions.

Disk Storage Indicators (36-39, 42). These indicators are used in conjunction with the 1311 Disk Storage Drive.

36 Address Check
37 Wrong-Length Record/Read-Back Check
38 Cylinder Overflow
39 Any Disk Check
42 Seek Complete

These indicators are described in detail in the publication IBM *1311 Disk Storage Drive* (Form A26-5650).

Multiplex Complete (40). This indicator is turned on when the Multiplexer Busy indicator (29) is turned off. Multiplex Complete is turned off by interrogation or by the execution of a new instruction using the multiplexer.

Analog Output Setup (41). This indicator is on during the setup portion of the analog output cycle. It is turned off by program interrogation or by execution of a slew or trim operation.

One Minute (43). This indicator is turned on once each minute of real-time. It is turned off by program interrogation.

One Hour (44). This indicator is turned on once each hour of real-time. It is turned off by program interrogation.

Any SIOC (45). This indicator is used with the Serial Input/Output Channel for the 1710 Process Operator Units. This indicator is turned on when any of the following indicators are turned on:

SIOC Output Error	6043
Data Ready	6044
Unit Response	6070

It is turned off by program interrogation.

External Interrupt (48-59). These twelve indicators are available for immediate detection of process disturbances. These are turned on by a contact closure in the process. They are turned off by program interrogation.

Output Record Mark (6040) This indicator is turned on when a leading record mark (first character of a control code) is transmitted from core storage to IODR. It is turned off by program interrogation.

End of Message (6041). This indicator is turned on when a control code record mark is transmitted from core storage to IODR. It is turned off by program interrogation.

Mode Shift (6042). This indicator is turned on when a control code 2 is transmitted from core storage to IODR. It is turned off by program interrogation.

SIOC Output Error (6043). This indicator is turned on and an interrupt is initiated when a parity error is detected by a Process Operator output unit. It is turned off by program interrogation.

Data Ready (6044). This indicator is turned on and an interrupt is initiated when a character has been sent to IODR from a Process Operator input unit. It is turned off by program interrogation.

Alert (6045). This indicator is turned on when any of the following indicators have been turned on:

Output Record Mark	6040
End of Message	6041
Mode Shift	6042
SIOC Output Error	6043
Data Ready	6044

It is turned off only when all of the indicators listed above are off.

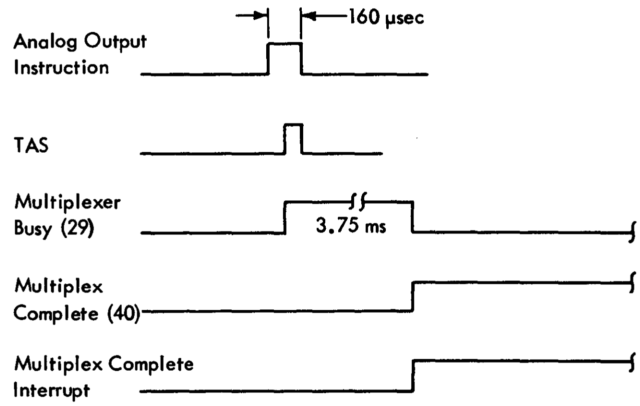


Figure 31. Analog Output Interrupt Timing

SIOC Not Busy (6046). This indicator is turned on when the SIOC channel is free to accept an instruction or an interrupt. It is turned off when the SIOC channel is busy.

Unit Response (6070-6089). This indicator is turned on and an interrupt is initiated when any Process Operator Unit is ready to transmit or receive data. It is turned off when all Process Operator Units attached to the system are in a not ready condition.

Process Branch (70-89). Twenty PBI's (Process Branch Indicators) are available for program sensing of conditions in the process area. These indicators are turned on and off by the closing and opening, respectively, of their contacts in the process.

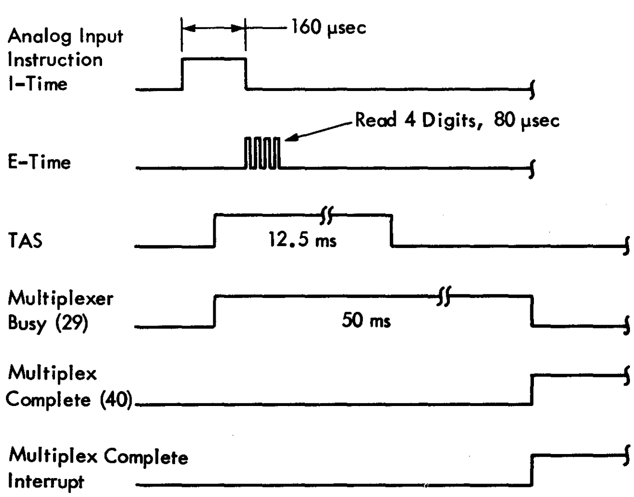


Figure 30. Analog Input Interrupt Timing

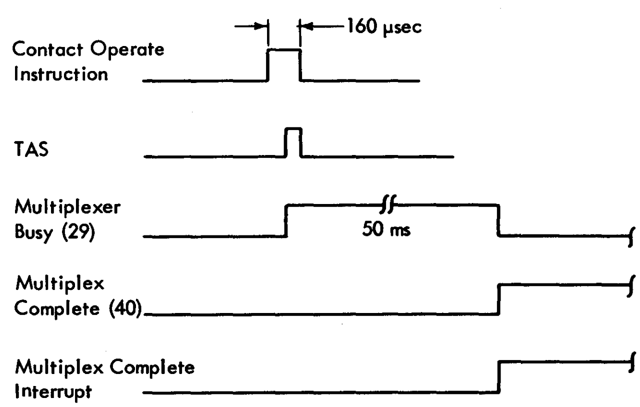


Figure 32. Contact Operate Interrupt Timing

1711 Operator's Panel

The 1711 Operator's Panel (Figure 33) contains switches, keys, lights, and indicators that are pertinent to the operating condition of the 1711.

1711 Keys, Lights, and Switches

The operating switches, keys, and lights are shown in Figure 34. There are two horizontal rows: switches and keys are in the bottom row and lights are in the top row. The switches and lights which complement each other are explained together as follows:

Power On/Off Switch and Power On Light. When the Power On/Off switch is manually positioned ON, DC power is applied to the 1711 (assuming 1620 power is on). The 1711, in turn, supplies DC power to the 1712. The Power On light turns on as evidence that DC power is applied. When the Power switch is positioned OFF, DC power is removed and the light turns off.

The performance of the Analog-to-Digital Converter (ADC) is reduced slightly during the first 15 minutes of 1711 operation.

Power Ready Light. This light turns on when both the 1620 and 1711 Power switches are on.

Excessive temperatures in either the 1711 or 1620 will cause the Power Ready light to turn off.

Thermal Light. If the internal temperature of the 1711 exceeds the range specified for reliable operation, 1711 DC power is lost and the Thermal light turns on. The Power Ready light turns off at the same time. The 1711 can be operated under this condition, but ADC

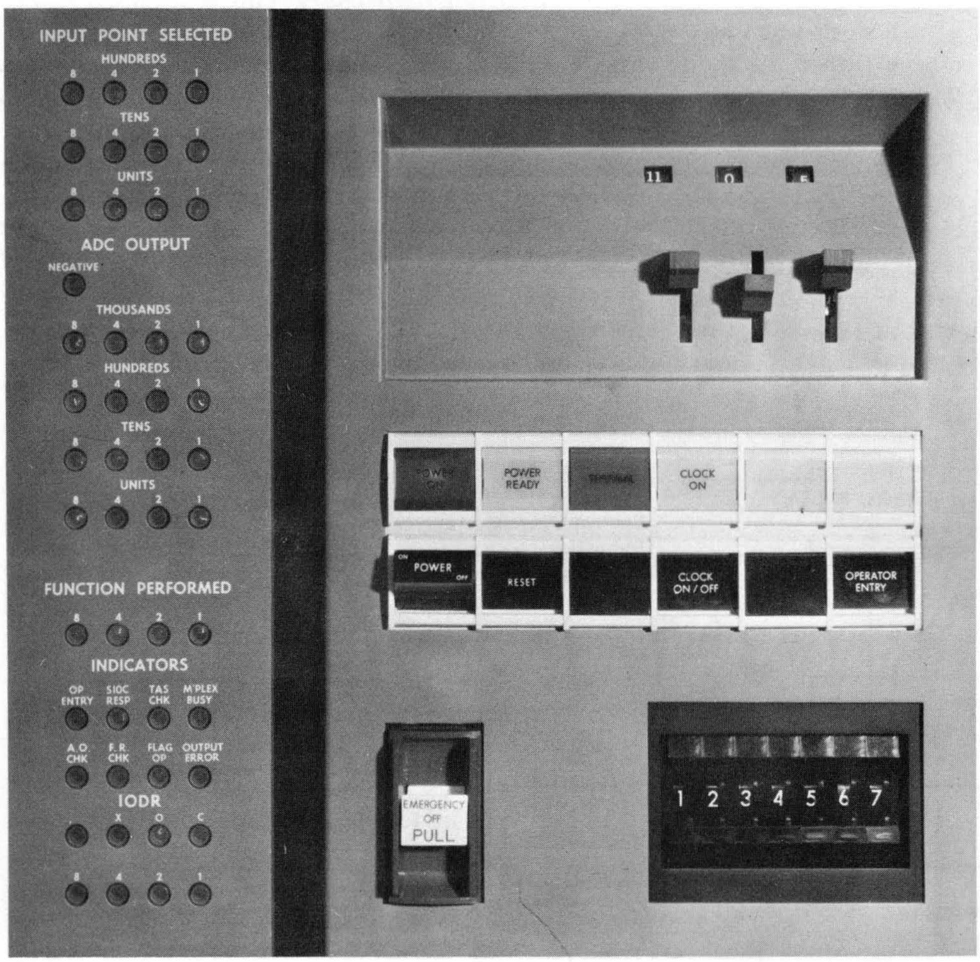


Figure 33. 1711 Operator's Panel

accuracy may be impaired. When the internal temperature drops within the specified range, the Thermal light may be turned off by depression of the Reset key. The Power On/Off switch must then be *positioned off and then on again* to restore DC power to the 1711.

Clock On/Off Key and Clock On Light. Pressing the Clock On/Off key causes the Real-Time Clock to start or stop, depending on its status when the switch is pressed. For example, if the clock is operating and a clock reset is required, the operator:

1. Presses the Clock On/Off key, which turns off the Clock On light and stops the clock.
2. Manually resets the clock by means of the three clock-reset levers on the 1711 Operator's Panel.
3. Presses the Clock On/Off key, and this time the clock is re-started and the Clock On light turns on.

Reset Key. The Reset key has these functions:

1. Pressing the Reset key turns the Thermal light off. The light can be turned off when the internal temperature of the 1711 is within the range required for reliable operation.
2. Pressing the Reset key resets the TAS register, Function Register, IODR, and the following 1711 indicators: Operator Entry (18), TAS Check (21), Function Register Check (22), Analog Output Check (23), and Multiplexer Busy (29), and SIOC indicators 45, 6040-6044.

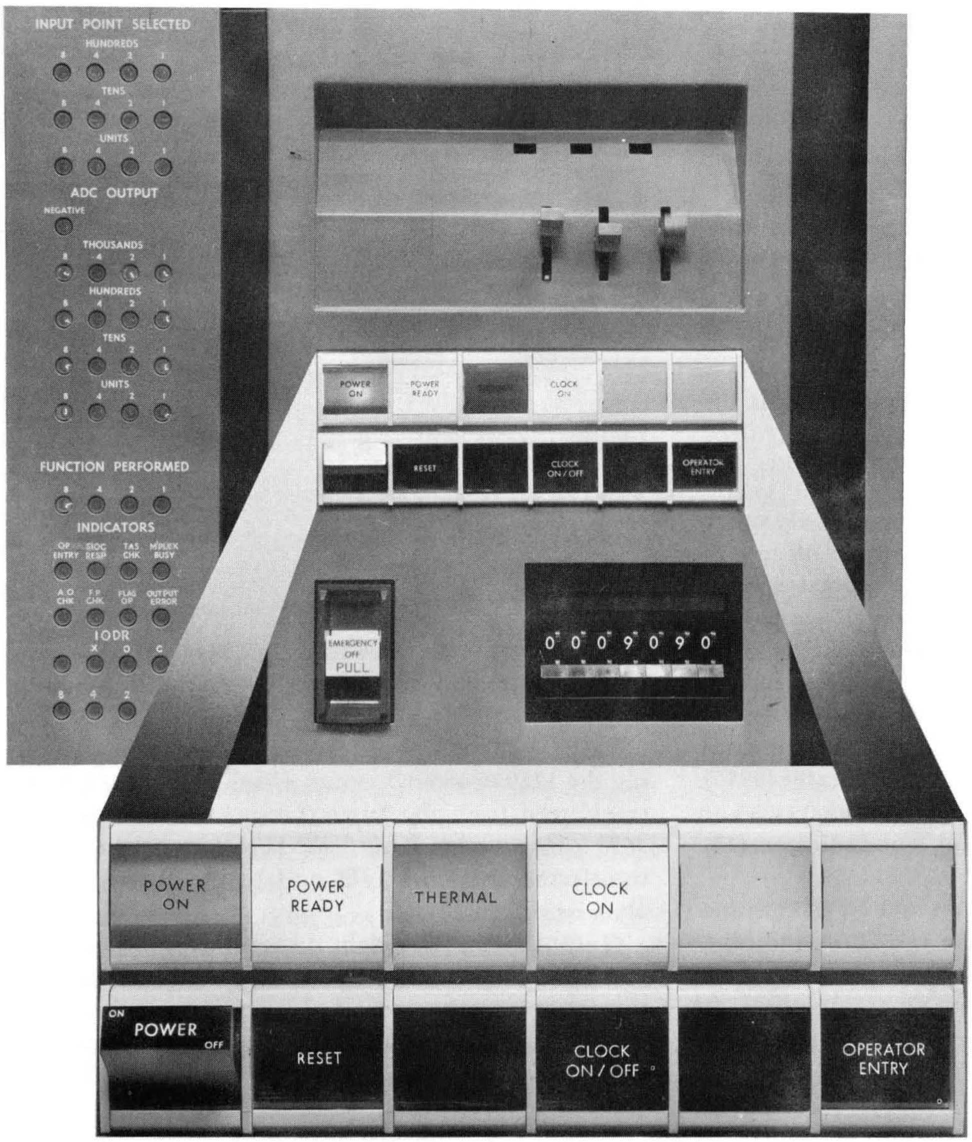


Figure 34. 1711 Operating Switches, Keys, and Lights

NOTE: Pressing the 1620 Reset key produces the same effect as pressing the 1711 Reset key.

Operator Entry Key. Pressing the Operator Entry key turns on the Operator Entry indicator (18). The indicator may be interrogated by Branch Indicator instructions to determine if an operator entry from the 1711 is required. If the indicator is on, the program branches to a subroutine which reads the Manual Entry switches (special feature). If the Interrupt feature is installed, pressing the Operator Entry key also initiates an interrupt which causes a branch to an interrupt identification subroutine.

Emergency Power Off Switch. Pulling the Emergency Power Off switch drops DC power and turns off the blower motors in the 1711 — this may cause damage to electronic components. Once the switch is pulled a Customer Engineer must be called to reset it so that the Power On/Off switch may be used to restore DC power to the 1711.

Register Indicators

The indicators on the 1711 Operator's Panel are shown in Figure 35.

Input Point Selected. The BCD value of the terminal address in TAS is displayed as shown in Figure 35.

ADC Output. The BCD value of the converted signal in the ADC register is displayed. The Negative light indicates the conversion of a negative analog voltage.

Function Performed. The Q_7 modifier digit is displayed in BCD form.

Program Indicators

Operator Entry. This light turns on and off in conjunction with the on/off status of the Operator Entry indicator (18).

SIOC RESP (Response). This light turns on when any one of the 1710 Process Operator Units is in a response status, indicating readiness to transmit or receive data. It will also be turned on by the SIOC Output Error indicator (6043) or by the Data Ready indicator (6044). When the SIOC is not busy, the same signal that turns on the light will also turn on the Any SIOC indicator (45) to request an interrupt.

TAS Check. This light turns on and off in conjunction with the on/off status of the TAS Check indicator (21).

M'PLEX (Multiplexer) Busy. This light turns on and off in conjuction with the on/off status of the Multiplexer Busy indicator (29).

AO (Analog Output) Check. This light turns on and off in conjunction with the on/off status of the Analog Output Check indicator (23).

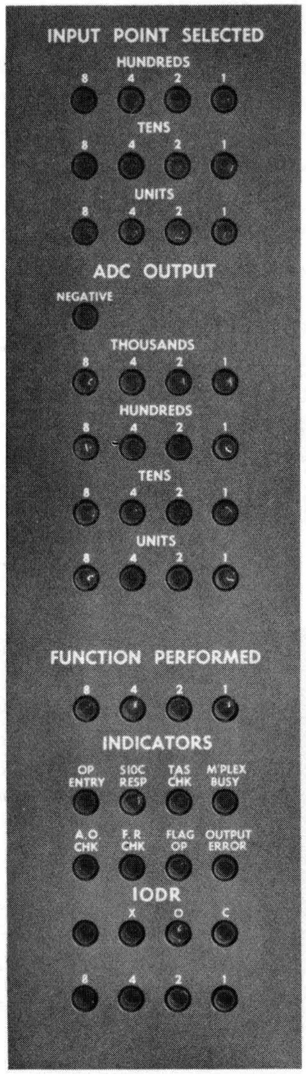


Figure 35. 1711 Register and Indicator Lights

FR (Function Register) Check. This light turns on if there is an invalid digit or parity error in the Function Register.

Flag Op. This light is on during operations involving the 1710 Process Operator Units when data is being transferred from the Input/Output Data Register to *1620 core storage.* This light is *not* on when data is transferred from the I/O unit to the Input/Output Data Register.

Output Error. This light turns on with the SIOC Output Error indicator (6043) to indicate that a transmission error (parity error) has been detected by a 1710 Process Operator output unit. The indicator and light are turned off by programmed interrogation of the indicator or by pressing the 1711 Reset key.

IODR. This 7-bit BCD display shows the contents of the single-digit Input/Output Data Register.

Figure 36 is a block diagram of the IBM 1710 Control System. The diagram shows all 1710 Special Features and the resulting data flow paths. The Function Register in the 1711 decodes the Q_7 modifier digit. The selected device sends data to core storage or controls the process as follows:

Input Data

Data from the input selected by the Function Register (TAS, RTC, ADC, SIOC, High-Speed Contact Sense, or Manual Entry switches) is sent to core storage. Although the contents of TAS can be read into core storage, its principal function is to select terminal addresses as specified by computer instructions.

Process Control Output

Controlling signals are not sent to the process directly from core storage. The Analog Output feature provides timed pulses to the set-point positioners in the process area when programmed to do so. The Contact Operate feature closes a TAS-selected multiplexing relay contact in the 1712. The selected contact completes the circuit to the customer's device in the process area.

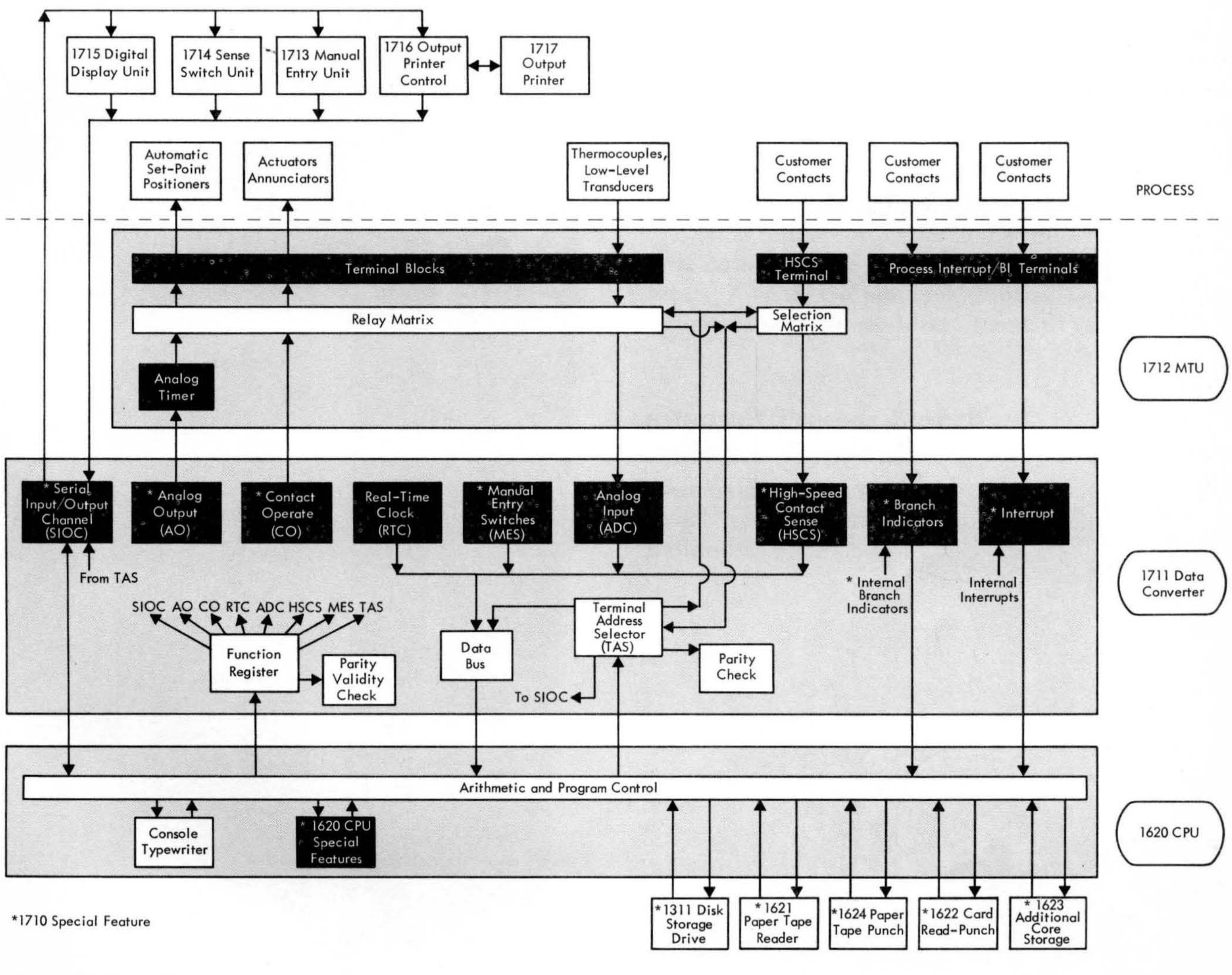


Figure 36. Data Flow, 1710 System

Interrupt and Process Branch Indicators

The Interrupt and Process Branch Indicators are not assigned terminal addresses, nor are they connected to the process via a standard or thermocouple terminal block connection. They connect through smaller terminal strips. An external (process) or internal (1710) occurrence turns on its associated indicator (Interrupt or Process Branch). The indicator must be interrogated by a Branch Indicator or Branch No Indicator instruction before any action can result.

Parity Checking

The contents of TAS and the Function Register are parity-checked for invalid characters and parity errors. A parity error or invalid character in TAS will turn on the TAS Check indicator (21), but with one exception: the terminal addresses 300-399 will not cause a TAS Check. A parity error or illegal character in the Function Register will turn on the Function Register Check indicator (22).

Whenever either of these two indicators is turned on, the program instruction is blocked so that an erroneous operation will not occur.

Appendix A

Instruction Summary

Instruction	Operation Code	Operation Code Modifier	SPS Mnemonic	Instruction Time 1620 Model 1	Notes
Add	21		A	160+80Dp Basic Time 80 Dp recomp time	If signs initially unlike and numerical value of Q data is greater than P data.
Add (I)	11		AM	Same as Add	
Branch	49		B	200	
Branch and Transmit	27		BT	200+40DQ	
Branch and Transmit (I)	17		BTM	Same as above	
*Branch and Transmit Floating	07		BTFL	240+40L	
Branch Back	42		BB	200	
Branch Indicator	46		BI	160 No Branch 200 Branch	Add 90 ms to times when testing indicators 18-19, 21-23, 27-29, 40-45, 48-59.
Branch No Flag	44		BNF	200 No Branch 240 Branch	
Branch No Indicator	47		BNI	160 No Branch 200 Branch	
*Branch No Group Mark	55		BNG	200 No Branch 240 Branch	
Branch No Record Mark	45		BNR	200 No Branch 240 Branch	
Branch on Digit	43		BD	200 No Branch 240 Branch	
**Branch Out	47	$Q_{11}=0$	BO	200	Q_8-Q_9 Must be 00
**Branch Out and Load	47	$Q_{11}=1$	BOLD	200	Q_8-Q_9 Must be 00
*Check Disk	36	 $Q_{11}=1$ $Q_{11}=3$ $Q_{11}=5$ $Q_{11}=7$	 CDGN CDN CTGN CTN	320+20,000+2,000S, average time (S=Number of Sectors)	Q_8-Q_9 Must be 07 Check one sector - with WLRC Check one sector - no WLRC Check full track - with WLRC Check full Track - no WLRC
Clear Flag	33		CF	200	
Compare	24		C	200+80 DZ-Unlike signs 160+80 DP-Like signs	DZ = Number of positions compared until a digit other than zero is detected in either field.
Compare (I)	14		CM	Same as above	
Control	34		K	Depends on control function and speed of I/O Unit	
*Divide	29		D	160+520DVQT+740QT	Avg Quotient = 4.5 Digits
*Divide (I)	19		DM	Same as above	Same as above
Dump Numeric	35		DN	Depends on speed of I/O unit and number of characters involved.	
*Floating Add	01		FADD	400+100L Basic Time 800L Recomp. Time	If signs initially unlike and numerical value of Q data is greater than P data.
*Floating Divide	09		FDIV	$880+940L+520L^2$	Avg Quotient = 4.5 Digits
*Floating Multiply	03		FMUL	$1120+80L+168L^2$	L_Z = Number of zero digits in multiplier.
*Floating Shift Left	05		FSL	200+40L+40L'	L' = Number of digits mantissa is increased by shift left.
*Floating Shift Right	08		FSR	200+40L	

Appendix A (cont.)

Instruction Summary

Instruction	Operation Code	Operation Code Modifier	SPS Mnemonic	Instruction Time 1620 Model 1	Notes
*Floating Subtract	02		FSUB	400+100L Basic Time 80L Recomp. Time	If signs initially alike and numerical value of Q data is greater than P data.
Halt	48		H	160	
*Load Dividend	28		LD	$400+40D_N$	D_N = Number of digits, including high-order zeros in the dividend.
*Load Dividend (I)	18		LDM	Same as above	
1 **Mask	46	$Q_{11}=1$	MK	160	Q_8-Q_9 Must be 00
*Move Flag	71		MF	240	
Multiply	23		M	560+40DQ+168DPDQ	
Multiply (I)	13		MM	Same as above	
No Operation	41		NOP	160	
Read Alphameric	37		RA	Card I/O 3.4 ms all other: see Notes	Time for other units depends upon speed of unit and number of characters involved.
**Read Alphameric Input Channel	$8\bar{7}$	$Q_7 = 5$	RAIC	240	
*Read Disk	36	 $Q_{11} = 0$ $Q_{11} = 2$ $Q_{11} = 4$ $Q_{11} = 6$	 RDGN RDN RTGN RTN	320+20,000+2,000S Average Time S = Number of Sectors	Q_8-Q_9 Must be 07 Read one sector - with WSLRC Read one sector - no WLRC Read Full Track - with WLRC Read Full Track - no WLRC
Read Numerical	36		RN	Card I/O: 3.4 ms All other: See notes	Time for other units depends upon speed of unit and number of characters involved.
**Read Numerical Input Channel	$8\bar{6}$	$Q_7 = 5$	RNIC	190	
*Seek	34	$Q_{11} = 1$	SK	320	Instruction execution time only. Seek operation requires max. 400 ms, average 250 ms.
**Select ADC Register	86	$Q_7 = 2$	SLAR	240 to Read 50,000 to convert	Computer released 12.5 ms after time to read.
Select Address	84	$Q_7 = 1$	SA	160 to Select 50,000 to convert	Computer released after time to select.
**Select Address, Contact Operate	84	$Q_7 = 2$	SACO	160 to Select 50,000 to close contact	Same as above
**Select Analog Output and Signal	84	$Q_7 = 3$	SAOS	160 to Select 3,750 to close circuit	Same as above
**Select Contact Block	86	$Q_7 = 7$	SLCB	$160+175\ (10-Q_{11})$	Same as above
1 **Select Input Channel	86	$Q_7 = 5$	SLIC	160	
**Select Manual Entry	86	$Q_7 = 8$	SLME	300	
Select Real-Time Clock	86	$Q_7 = 4$	SLTC	240	
**Select TAS	86	$Q_7 = 1$	SLTA	240	
Set Flag	32		SF	200	
Subtract	22		S	160+80DP Basic Time 80 DP Recomp. Time	If signs initially alike and numerical value of Q data greater than P data.
Subtract (I)	12		SM	Same as above	Same as above
*Transfer Numerical Fill	73		TNF	160+40DP	
*Transfer Numerical Strip	72		TNS	160+40DP	

Instruction Summary

Instruction	Operation Code	Operation Code Modifier	SPS Mnemonic	Instruction Time 1620 Model 1	Notes
Transmit Digit	25		TD	200	
Transmit Digit (I)	15		TDM	200	
Transmit Field	26		TF	160+40DQ	
Transmit Field (I)	16		TFM	Same as above	
*Transmit Floating	06		TFL	240+40L	
Transmit Record	31		TR	160+40DQ	
1 **Unmask	46	$Q_{11} = 0$	UMK	160	Q_8-Q_9 Must be 00
Write Alphameric	39		WA	Card I/O: 3.4 ms All other: See notes	Time for other units depends upon speed of unit and number of characters involved.
**Write Alphameric Output Channel	89	$Q_7 = 5$	WAOC	200	
*Write Disk	38	 $Q_{11} = 0$ $Q_{11} = 2$ $Q_{11} = 4$ $Q_{11} = 6$	 WDGN WDN WTGN WTN	320+20,000+2,000S Average Time (S = Number of Sectors)	Q_8-Q_9 Must be 07 Write one sector - with WLRC Write one sector - no WLRC Write full track - with WLRC Write full track - no WLRC
Write Numerical	38		WN	Card I/O: 3.4 ms All other: See notes	Time for other units depends upon speed of unit and number of characters involved.
**Write Numerical Output Channel	88	$Q_7 = 5$	WNOC	200	

Symbols and Definitions

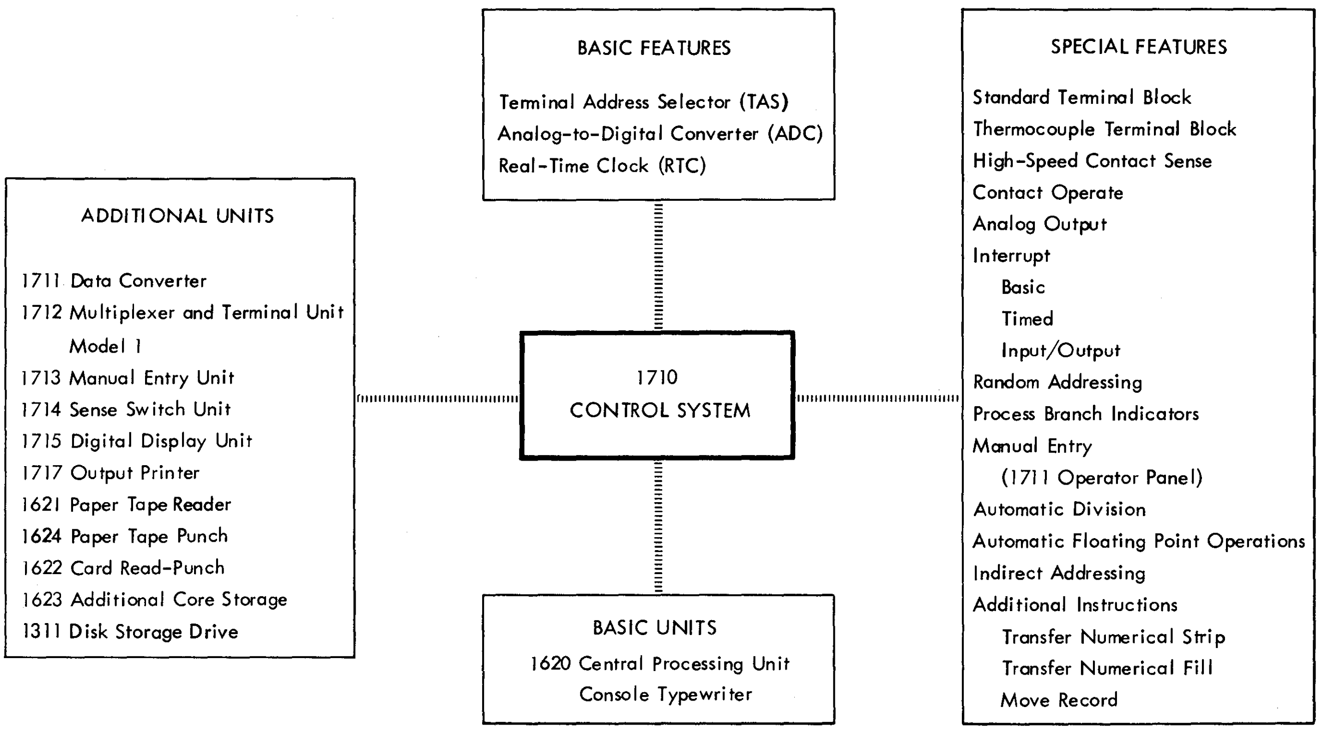
DP = Number of digits, including high-order zeros, in the field at P
DQ = Number of digits, including high-order zeros, of Q.
QT = Number of digits, including high-order zeros, in the quotient.
DV = Number of digits, including high-order zeros, in the divisor.
L = Number of digits in mantissa.

(I) =Immediate
ms =Milliseconds
WLRC =Wrong Length Record Check
* =1620 Special Feature
** =1710 Special Feature

1. Even though the P address is not used, it will be interpreted as an indirect address if a flag exists in the units position of the P address and if the special feature Indirect Addressing is installed on the system. If the P address is used to store miscellaneous program data, this data should not contain a flag bit in the units position.

Appendix B

Summary of 1710 Features and Units



Appendix C

Significance of P and Q Addresses

OP Code	Instruction	P Address	Q Address
01	Floating Add*	Location of units position of Exponent of Augend and Result.	Location of units position of Exponent of Addend.
02	Floating Subract*	Location of units position of Exponent of Minuend and Result.	Location of units position of Exponent of Subtrahend.
03	Floating Multiply*	Location of Units position of Exponent of Multiplicand and Product.	Location of units position of Exponent of Multiplier.
05	Floating Shift Left*	Location of high-order position of resulting field.	Location of units position of field shifted.
06	Transmit Floating*	Location of units position of Exponent of resulting field.	Location of units position of Exponent of field transmitted.
07	Branch and Transmit Floating*	P—1: location of units position of field to which Q field.is transmitted. P: location of next instruction executed.	Location of units position of Exponent of field transmitted.
08	Floating Shift Right*	Location of units position of field shifted.	Location of units position of resulting field.
09	Floating Divide*	Location of units position of Exponent of Dividend and Quotient.	Location of units position of Exponent of Divisor.
11	Add (I)	Location of units position of Augend and Result.	Q_{11} is units position of Addend.
21	Add	Same as Code 11.	Location of units position of Addend.
12	Subtract (I)	Location of units position of Minuend and Result.	Q_{11} is units position of Subtrahend.
22	Subtract	Same as Code 12.	Location of units position of Subtrahend.
13	Multiply (I)	Location of units position of Multiplicand.	Q_{11} is units position of Multiplier.
23	Multiply	Same as Code 13.	Location of units position of Multiplier.
14	Compare (I)	Location of units position of field compared with Q field.	Q_{11} is units position of field compared with P field.
24	Compare	Same as Code 14.	Location of units position of field compared with P field.
15	Transmit Digit (I)	Location to which digit is transmitted.	Q_{11} is digit transmitted.
25	Transmit Digit	Same as Code 15.	Location of digit transmitted.
16	Transmit Field (I)	Location to which units position of field is transmitted.	Q_{11} is units position of field transmitted.
26	Transmit Field	Same as Code 16.	Location of units position of field transmitted.
17	Branch and Transmit (I)	Same as Code 07.	Q_{11} is units position of field transmitted.
27	Branch and Transmit	Same as Code 07.	Same as Code 26.

* Special Feature - 1620
** Special Feature - 1710
(I) Immediate

Appendix C (cont.)

Significance of P and Q Addresses

OP Code	Instruction	P Address	Q Address
18	Load Dividend (I)*	Location in Product Area to which units position of Dividend is transmitted.	Q_{11} is units position of Dividend.
28	Load Dividend*	Same as Code 18.	Location of units position of Dividend.
19	Divide (I)*	Location in Product Area of units position of Divisor for first subtraction.	Q_{11} is units position of Divisor.
29	Divide*	Same as Code 19.	Location of units position of Divisor.
31	Transmit Record	Location to which high-order position of record is transmitted.	Location of high-order position of record transmitted.
32	Set Flag	Location at which flag is set.	Not used.
33	Clear Flag	Location at which flag is cleared.	Not used.
34	Seek*	Location of Disk Control Field	Q_8 and Q_9 specify disk storage (07) Q_{11} specifies disk storage function performed.
34	Control	Not used.	Q_8 and Q_9 specify I/O device. Q_{11} specifies control function performed.
35	Dump Numerically	Location of first character written.	Q_8 and Q_9 specify output device.
36	Read Numerically	Location where first character is stored or address of Disk Control Field.	Q_8 and Q_9 specify disk storage or input device. Q_{11} specifies function performed.
37	Read Alphamerically	P—1: location where zone digit of first character is stored. P: location where numerical digit of first character is stored.	Q_8 and Q_9 specify input device.
38	Write Numerically	Location of first character written or address of Disk Control Field.	Q_8 and Q_9 specify output device or disk storage. Q_{11} specifies function performed.
39	Write Alphamerically	P—1: location of zone digit of first character written. P: location of numerical digit of first character written.	Same as Code 35.
41	No OP	Not used.	Not used.
42	Branch Back	Not used.	Not used.
43	Branch on Digit	Branch: location of next instruction executed. No Branch: not used.	Location tested for digit other than zero.
44	Branch No Flag	Same as Code 43.	Location tested for flag bit.
45	Branch No Record Mark	Same as Code 43.	Location tested for Record Mark character.
46	Branch On Indicator	Same as Code 43.	Q_8 and Q_9 specify program switch or indicator tested.

* Special Feature - 1620
** Special Feature - 1710
(I) Immediate

Appendix C (cont.)

Significance of P and Q Addresses

OP Code	Instruction	P Address	Q Address
46	Mask**	Not used.	$Q_8Q_9=00$ $Q_{11}=1$
46	Unmask**	Not used	Q_8 Q_9 = 00 Q_{11} = 0
47	Branch Out**	Address to be placed in IR-3	$Q_8Q_9=00$ $Q_{11}=0$
47	Branch Out and Load**	Address to be placed in IR-1	$Q_8Q_9=00$ $Q_{11}=1$
47	Branch No Indicator	Same as Code 43.	Same as Code 46.
48	Halt	Not used.	Not used.
49	Branch	Location of next instruction executed.	Not used.
55	Branch No Group Mark*	Not used.	Location tested for Group Mark.
71	Move Flag*	Location to which flag is moved.	Location of flag to be moved.
72	Transfer Numerical Strip*	Location of units position of alphameric field.	Location of units position of numerical field.
73	Transfer Numerical Fill*	Same as Code 72.	Same as Code 72.
84	Select Address	Not used.	$Q_7=1$; Q_9-Q_{11} specify analog input address.
84	Select Address and Contact Operate**	Not used.	$Q_7=2$; Q_9-Q_{11} specify the process contact to be closed.
84	Select Analog Output and Signal **	Not used.	$Q_7=3$; Q_9-Q_{11} specify the analog output channel.
86	Select TAS**	Location where high-order position of TAS is transferred.	$Q_7=1$; Q_8-Q_{11} are not used.
86	Select ADC Register**	Location where high-order position of ADC register is transferred.	$Q_7=2$; Q_9-Q_{11} specify analog input address.
86	Select Contact Block**	Location where status of the first and second contacts scanned are stored.	$Q_7=7$; Q_{10}-Q_{11} specify terminal address where scanning begins. Q_8-Q_9 not used.
86	Select Real-Time Clock	Location where high-order digit of RTC is transferred.	$Q_7=4$; Q_8-Q_{11} not used.
86	Select Manual Entry Switches	Location where high-order digit of Manual Entry Switches is transferred.	$Q_7=8$; Q_8-Q_{11} not used.
86	Select Input Channel**	Not Used.	$Q_7=5$, Q_{10}-Q_{11} address of input unit.
$8\bar{6}$	Read Numerical Input Channel**	Core storage location where first input character will be stored.	$Q_7=5$, Q_{10}-Q_{11} address of input unit or device. Q_8-Q_9 not used.
$8\bar{7}$	Read Alphameric Input Channel**	Core storage location where first input character will be stored.	$Q_7=5$; Q_{10}-Q_{11} address of input unit or device. Q_8-Q_9 not used.
88	Write Numerical Output Channel**	Core storage address of the character transmitted.	$Q_7=5$; Q_{10}-Q_{11} address of unit or device. Q_8-Q_9 not used.
89	Write Alphameric Output Channel**	Core storage address of the character transmitted.	$Q_7=5$, Q_{10}-Q_{11} address of unit or device. Q_8-Q_9 not used.

* Special Feature - 1620
** Special Feature - 1710
(I) Immediate

Appendix D

IODR Character Code Chart

Character		IODR Code (7-Bit BCD)						
Valid Characters	0		0					
	1							1
	2						2	
	3			C			2	1
	4					4		
	5			C		4		1
	6			C		4	2	
	7					4	2	1
	8				8			
	9			C	8			1
	A	X	0					1
	B	X	0				2	
	C	X	0	C			2	1
	D	X	0			4		
	E	X	0	C		4		1
	F	X	0	C		4	2	
	G	X	0			4	2	1
	H	X	0		8			
	I	X	0	C	8			1
	J	X		C				1
	K	X		C			2	
	L	X					2	1
	M	X		C		4		
	N	X				4		1
	O	X				4	2	
	P	X		C		4	2	1
	Q	X		C	8			
	R	X			8			1
	S		0	C			2	
	T		0				2	1
	U		0	C		4		
	V		0			4		1
	W		0			4	2	
	X		0	C		4	2	1
	Y		0	C	8			
	Z		0		8			1
	+	X	0	C				
	.	X	0		8		2	1
	-	X						
	=				8		2	1
	*	X			8	4		
	/		0	C				1
	,		0	C	8		2	1
	Δ	X		C	8		2	1
	‡			C	8	4		
	Space			C				
Control Characters (Preceded by ‡)	Type Numerical Period (1)	X	0		8		2	1
	Change Mode (2)	X			8		2	
	Type Numerical Comma (3)		0	C	8		2	1
	Shift to Black (4)				8	4	2	
	Shift to Red (5)			C	8	4	2	1
	Tabulate (6)	X		C	8	4	2	
	Space (7)		0		8	4	2	1
	Return Carriage (8)	X	0		8	4	2	
	Advance Form (9)	X	0	C	8	4	2	1
	End of Message (‡)	X	0	C	8	4	2	1

The Following Invalid Characters Cause Printer To Space						
		C				
		C	8	4		
			8	4		1
X	0	C	8		2	
X	0	C	8	4		
X	0		8	4		1
X			8		2	
X		C	8	4		1
X			8	4	2	1
	0		8		2	
	0		8	4		
	0	C	8	4		1
	0	C	8	4	2	

Appendix E

Abbreviations and Acronyms

ADC	Analog-to-Digital Converter
AI	Analog Input
AO	Analog Output
CO	Contact Operate
DRO	Digit Read Out (value)
IODR	Input/Output Data Register
MES	Manual Entry Switches
MTU	Multiplexer and Terminal Unit
PBI	Process Branch Indicator
RBT	Resistance Bulb Thermometer
RTC	Real-Time Clock
SMS	Standard Modular System
SPP	Set-Point Positioner
SIOC	Serial Input/Output Channel
TAS	Terminal Address Selector
V_R	Reference Voltage Signal

Table Areas in Core Storage

Address	Area
00000-00099	Console Area
00080-00099	Product Area
00100-00299	Multiply Table
00300-00399	Add Table

Bit Configuration of Decimal Digits

Digit	Bit Configuration					
	C	F	8	4	2	1
0	X					
1						X
2					X	
3	X				X	X
4				X		
5	X			X		X
6	X			X	X	
7				X	X	X
8			X			
9	X		X			X

1620 Storage Register Functions

IR-1	Contains address of next instruction if machine is stopped with Stop key or Halt instruction. Saves return address when interrupt is serviced.
IR-2	Saves return address when BT and BTM instructions are executed.
IR-3	Contains interrupt address — used in place of IR-1 during interrupt program operation
OR-1	Contains Q address after I cycle of an instruction. In disk storage operations, used to store and control disk sector address.
OR-2	Contains P address after I cycle of an instruction. In disk storage operations, contains core storage address where data from disk storage is written to or read from.
OR-3	Retains address of low-order multiplier digit during multiplication.
OR-4	Used to store and control the exponent address E_q during automatic floating-point operations.
OR-5	Used to store and control the exponent address E_p during automatic floating-point operations.
PR-1	Saves return address when a Save key operation occurs. Decremented for each new multiplier digit during multiply.
PR-2	Decremented for each new multiplicand digit during multiply.
PR-3	Used to add partial product to each multiply cycle result. In disk storage operations, used to store and control number of sectors in operation.
MAR	Addresses core storage.
MBR	Receives digits entering or leaving core storage.
MDR	Receives addressed digit entering or leaving core storage.
Digit	Stores partial product during multiplication.
OP	Contains Op code of instruction just executed if machine is stopped with Stop key or Halt instruction.
CR-1	Used to store the algebraic difference between E_p and E_q for determination of decimal alignment during automatic floating-point operations. CR-1 is also used during floating-point operations to count high-order zeros when normalizing— the contents of CR-1 are subtracted from E_p.
Multiplier/Quotient	Contains multiplier and quotient digits during multiply and automatic divide operations.
Digit and Branch	Decodes Q_8 and Q_9 digits of BI, BNI, and I/O instructions. Stores partial product digits during multiply instructions. Stores digits affecting MARS during all I cycles.
IODR	Stores character transferred during SIOC operations

Appendix F

Multiply and Add Tables

Multiply Table

High-Order Positions of Address	Units Position of Address 0	1	2	3	4	5	6	7	8	9
0010	0	0	0	0	0	0	0	0	0	0
0011	0	0	1	0	2	0	3	0	4	0
0012	0	0	2	0	4	0	6	0	8	0
0013	0	0	3	0	6	0	9	0	2	1
0014	0	0	4	0	8	0	2	1	6	1
0015	0	0	5	0	0	1	5	1	0	2
0016	0	0	6	0	2	1	8	1	4	2
0017	0	0	7	0	4	1	1	2	8	2
0018	0	0	8	0	6	1	4	2	2	3
0019	0	0	9	0	8	1	7	2	6	3
0020	0	0	0	0	0	0	0	0	0	0
0021	5	0	6	0	7	0	8	0	9	0
0022	0	1	2	1	4	1	6	1	8	1
0023	5	1	8	1	1	2	4	2	7	2
0024	0	2	4	2	8	2	2	3	6	3
0025	5	2	0	3	5	3	0	4	5	4
0026	0	3	6	3	2	4	8	4	4	5
0027	5	3	2	4	9	4	6	5	3	6
0028	0	4	8	4	6	5	4	6	2	7
0029	5	4	4	5	3	6	2	7	1	8

Add Table

High-Order Positions of Address	Units Position of Address 0	1	2	3	4	5	6	7	8	9
0030	0	1	2	3	4	5	6	7	8	9
0031	1	2	3	4	5	6	7	8	9	$\bar{0}$
0032	2	3	4	5	6	7	8	9	$\bar{0}$	$\bar{1}$
0033	3	4	5	6	7	8	9	$\bar{0}$	$\bar{1}$	$\bar{2}$
0034	4	5	6	7	8	9	$\bar{0}$	$\bar{1}$	$\bar{2}$	$\bar{3}$
0035	5	6	7	8	9	$\bar{0}$	$\bar{1}$	$\bar{2}$	$\bar{3}$	$\bar{4}$
0036	6	7	8	9	$\bar{0}$	$\bar{1}$	$\bar{2}$	$\bar{3}$	$\bar{4}$	$\bar{5}$
0037	7	8	9	$\bar{0}$	$\bar{1}$	$\bar{2}$	$\bar{3}$	$\bar{4}$	$\bar{5}$	$\bar{6}$
0038	8	9	$\bar{0}$	$\bar{1}$	$\bar{2}$	$\bar{3}$	$\bar{4}$	$\bar{5}$	$\bar{6}$	$\bar{7}$
0039	9	$\bar{0}$	$\bar{1}$	$\bar{2}$	$\bar{3}$	$\bar{4}$	$\bar{5}$	$\bar{6}$	$\bar{7}$	$\bar{8}$

Appendix G

Character Code Chart

Mode	Character	Input Typewriter	Input Tape	Input Card	Core Storage Alpha	Core Storage Num	Output Typewriter	Output Tape	Output Card
ALPHAMERIC MODE	(Blank)	(Space)	C	(Blank)	C	C	(Space)	C	(Blank)
	. (Period)	.	X0821	12,3,8	C	3	.	X0821	12,3,8
	)	)	X0C84	12,4,8	C	4	)	X0C84	12,4,8
	+	+	X0C	12	1	C	+	X0C	12
	$	$	XC821	11,3,8	1	3	$	XC821	11,3,8
	*	*	X84	11,8,4	1	4	*	X84	11,4,8
	- (Hyphen)	-	X	11	2	C	-	X	11
	/	/	0C1	0,1	2	1	/	0C1	0,1
	, (Comma)	,	0C821	0,3,8	2	3	,	0C821	0,3,8
	(	(	084	0,4,8	2	4	(	084	0,4,8
	=	=	821	3,8	3	3	=	821	3,8
	@	@	C84	4,8	3	4	@	C84	4,8
	A-I	A-I	X0, 1-9	12, 1-9	4	1-9	A-I	X0, 1-9	12, 1-9
	0 (—)	(None)	(None)	11,0	5	C	- (Hyphen)	X	11,0
	J-R	J-R	X, 1-9	11, 1-9	5	1-9	J-R	X, 1-9	11, 1-9
	1-9 (—)	J-R	X, 1-9	11, 1-9	5	1-9	J-R	X, 1-9	11, 1-9
	S-Z	S-Z	0, 2-9	0, 2-9	6	2-9	S-Z	0, 2-9	0, 2-9
	0 (+)	0	0	0 or 12,0	7	C	0	0	0
	1-9 (+)	1-9	1-9	1-9	7	1-9	1-9	1-9	1-9
	ǂ	ǂ	082	0,2,8	C	C82	(Stop)	EOL	0,2,8
NUMERICAL MODE	(Blank)	(Space)	C	(Blank)		C	0	0	0
	0 (+)	0	0	0		C	0	0	0
	0 (-)	$\bar{0}$	X, X0C	11,0		F	0	X	11,0
	1-9 (+)	1-9	1-9	1-9		1-9	1-9	1-9	1-9
	1-9 (-)	$\bar{1}$-$\bar{9}$	X, 1-9	11, 1-9		F, 1-9	1-9	X, 1-9	11, 1-9
	ǂ	ǂ	082	0,2,8		C82	(Stop, WN) ‡ (DN)	EOL(WN) 082 (DN)	0,2,8
	ǂ̅	ǂ̅	X82	11,8,2		F82	ǂ̅	X82	11,8,2
	⧻	⧻	C8421	0,7,8		*C8421	⧻	C8421	0,7,8
	⧻̅	⧻̅	CX08421	12,7,8		F8421	⧻̅	CX08421	12,7,8
	Num Blank †	@	C84	4,8		C84	@	C84	(Blank)

† For Card Format Use Only
* Recorded as 0, 8, 4, 2, 1 in disk storage

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