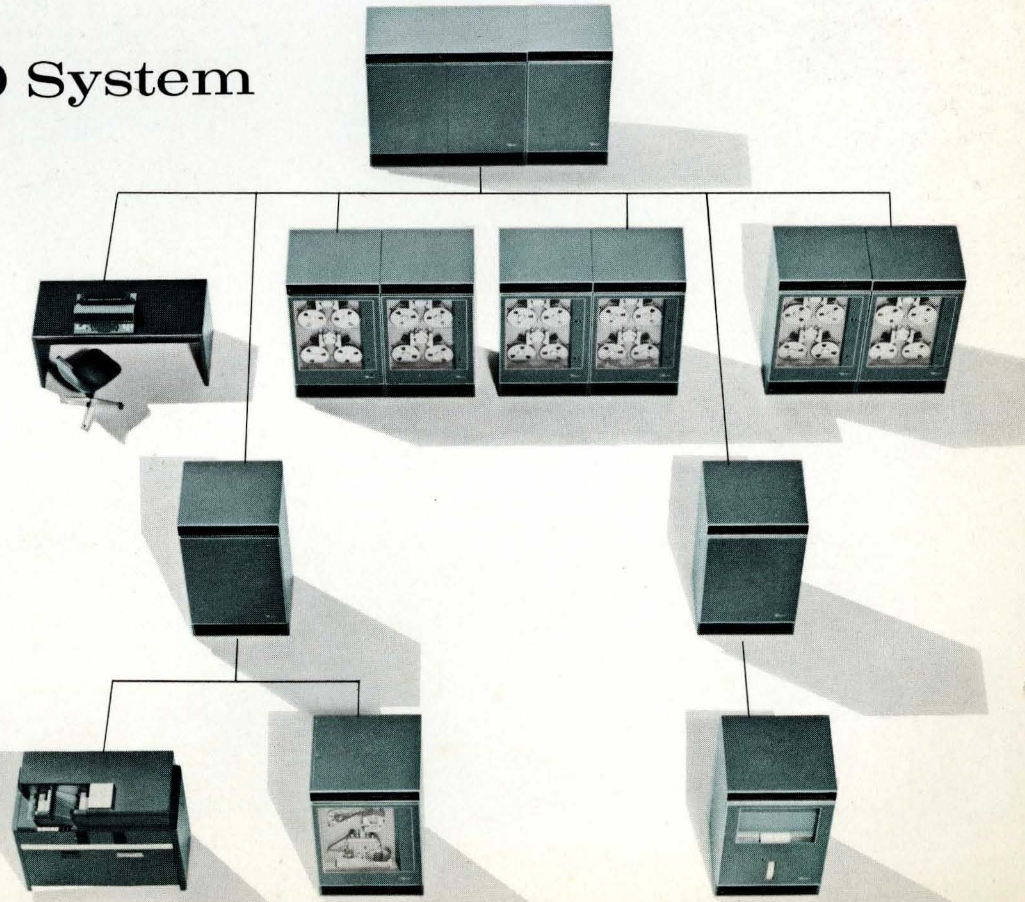
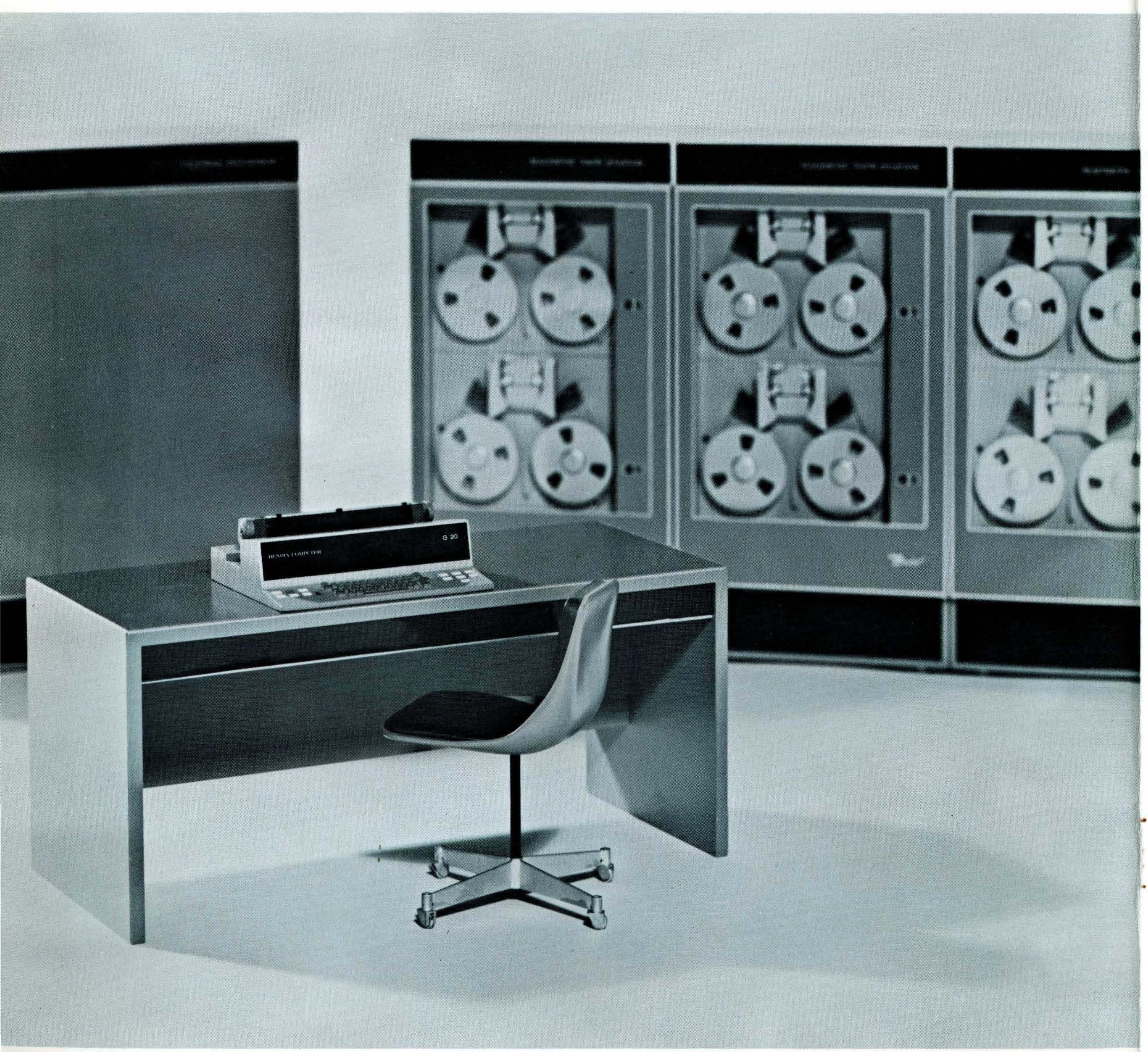
A TECHNICAL INTRODUCTION

The Bendix G-20 System



FOR HIGH-SPEED COMPUTING


BENDIX COMPUTER
G 20

A Technical Introduction

THE BENDIX G-20 COMPUTING SYSTEM

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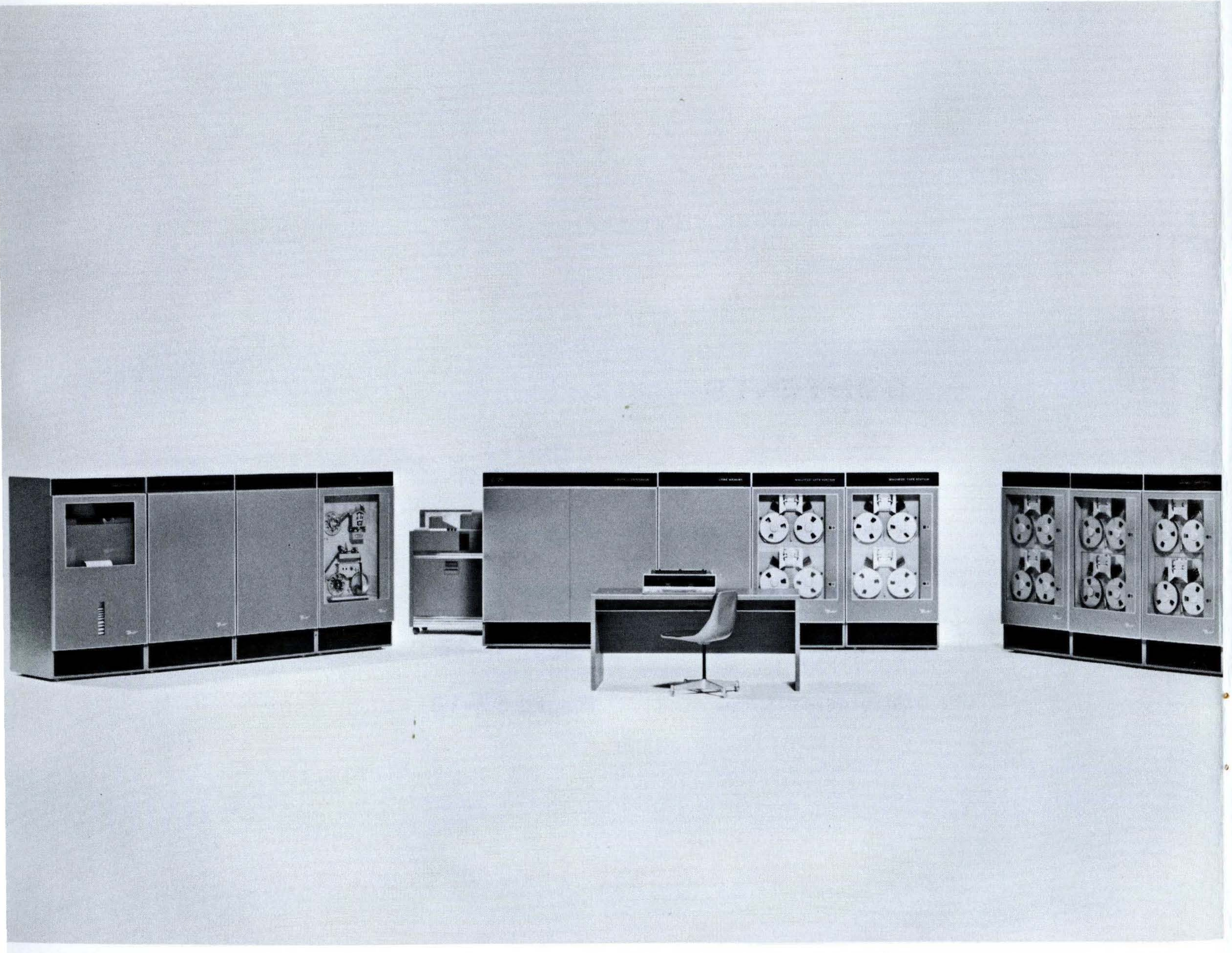
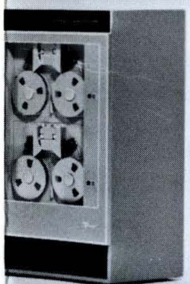




The G-20 System

The Bendix G-20, general purpose, automatic data processing system represents a new achievement in computing machinery design. **Completely modular,** the system can be expanded in size, or the nature of its operation changed, when desired. **Of high processing speed,** the system couples a fast central processor with terminal equipment that can operate concurrently with, and independently of, the central processor. **Functionally efficient,** the system may include low cost control buffers which free the central processor from routine data-handling operations. **Versatile in application,** the system may also include card and printer couplers, control consoles, magnetic tape units, punched card equipment, paper tape equipment, and high speed printers.

A wide variety of systems with widely different characteristics can be assembled from these common elements. Information can pass from one element to another without passing through the central processor enroute. The units can be connected together in such a manner that desired elements operate simultaneously.

For example:

> A scientific computing system can be assembled from a central processor, control console, magnetic tape units, a card and printer coupler, a high speed printer and punched card equipment.
>
> An independent system for tabulation of information held on magnetic tape, can be assembled by connecting together a magnetic tape unit, a high speed printer and a control buffer.
>
> A business data processing system with input/output units operating concurrently can be put together by combining a central processor, control console, card equipment, magnetic tape units, control buffer and a data communicator.

The user can change the nature of his system at will, since elements of the same type are interchangeable. The change from one system to another can be made under program control if desired.

Programs for the new Bendix system are written in an easy to use language. The programming language may be algebraic or symbolic. Input and output data may be expressed decimally in either fixed point or in floating point form.

THE G-20 COMPUTER

The G-20 computer is the central processor of the Bendix data processing system. The processor is built of solid state components, and includes a random access, expandable, magnetic core memory. Its internal computing speed is very high since the bits of a word are handled simultaneously during information transfer to and from the memory, and during all arithmetic operations.

Memory

The internal memory of the G-20 consists of from one to eight magnetic core modules of 4096 words each. Two memory modules can be located in the G-20 cabinet. Additional modules are held in adjacent matching cabinets. Each cabinet holds either one or two modules. Each word in the eight modules is directly addressable.

Arithmetic Operation

Numerical information may be read prior to computation, and tabulated after computation, with the decimal point in any specified digit position. For example:

$$\begin{array}{r} 1{,}234{,}567{,}898.76 \\ +\ \underline{666{,}666{,}000.00} \\ 1{,}901{,}233{,}898.76 \end{array}$$

Or numbers may be read and tabulated in floating decimal point form. For example:

$$\begin{array}{r} 123{,}456{,}789{,}876 \times 10^{2} \\ +\ \underline{666{,}666 \times 10^{3}} \\ 190{,}123{,}389{,}876 \times 10 \end{array}$$

The arithmetic circuitry provides precision greater than a word length for both numbers operated on and results of the operation. A full length number (12 decimal digits) can be stored in the memory in two sequential word locations. Or if less precision is required, the number may be stored in the memory in a single word location. Either double precision or single precision computation can be automatically performed.

The accuracies and speeds of computation are listed on page 18.

Command Structure

When the algebraic or symbolic program is entered into the computer, it is automatically transformed into a stored program in the internal language of the computer. Some technical reasons why a transformation can be made completely and efficiently are listed below.

The effective length of an internal command is variable; it may consist of any number of words. The basic machine command specifies a single operand. Either the value of the operand, or its address may be written in the command. The operand may be specified in the command directly by a single address, or indirectly by combining the contents of any number of addresses written in the command. The latter feature provides very flexible index register operation in which any address in the memory and any number of addresses may be used for indexing.

Information Flow

CONNECTION OF UNITS

All types of elements in the Bendix Data Processing system attach to common communication lines. A compact but powerful punched card computing system is shown in Figure 1. A magnetic tape unit (MT-10) can search for a specified block of information independently of any other operations on the line. Operation of the card reader or the tape punch can be concurrent with internal computation. By adding from one to seven MM-10 auxiliary memory modules of 4096 words each, the internal memory may be expanded. The communication system may be expanded by adding elements to the communication line and by additional communication lines.

Different types of system elements, including a central processor and auxiliary memory, and the manner in which they tie to a communication line, are illustrated in Figure 2. A line can be any desired length up to about 1500 feet and can handle information at whatever rates the units attached to it operate. As many as 38 direct connections may be made to a single communication line. Up to 32 units can be connected to the four data communication lines of the data communicator (DC-11). The units can be spaced along a communication line in any manner desired.

Without passing through the central processor, information can be sent from one element on a communication line to another via the data communicator (DC-11) or control buffer (CB-11) since these units also control data flow. The DC-11 or CB-11 can be used to instruct any input device to send information to any output device attached to their lines.

In Figure 3, information from magnetic tape via the DC-11 may be tabulated by the printer while the central processor is performing internal computation or communicating with the control console. (CC-10).

Multiple pairs of input/output elements can communicate concurrently. Input/output elements communicate with each other under control of the central processor, DC-11, or CB-11. The addition of control buffers or the data communicator to the system permits additional pairs of input/output elements to communicate with each other at the same time.

A COMPACT PUNCHED CARD DATA PROCESSING SYSTEM

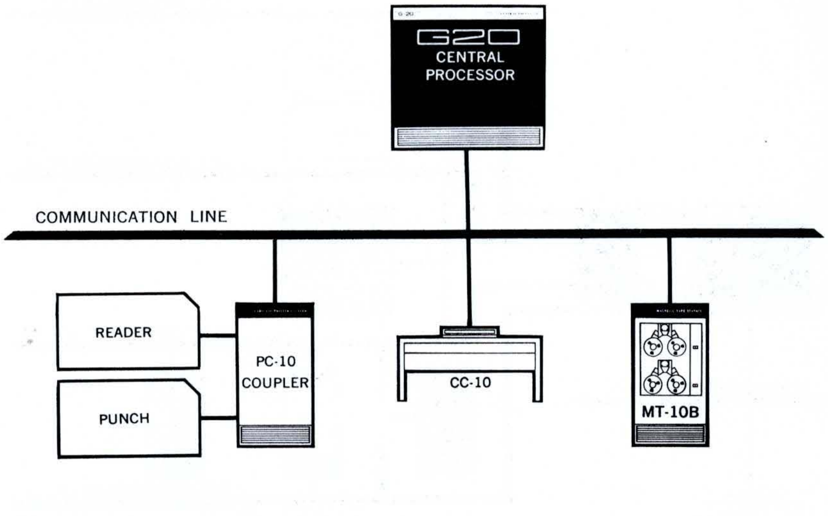


FIGURE 1

DIFFERENT TYPES OF UNITS THAT ATTACH TO A COMMUNICATION LINE

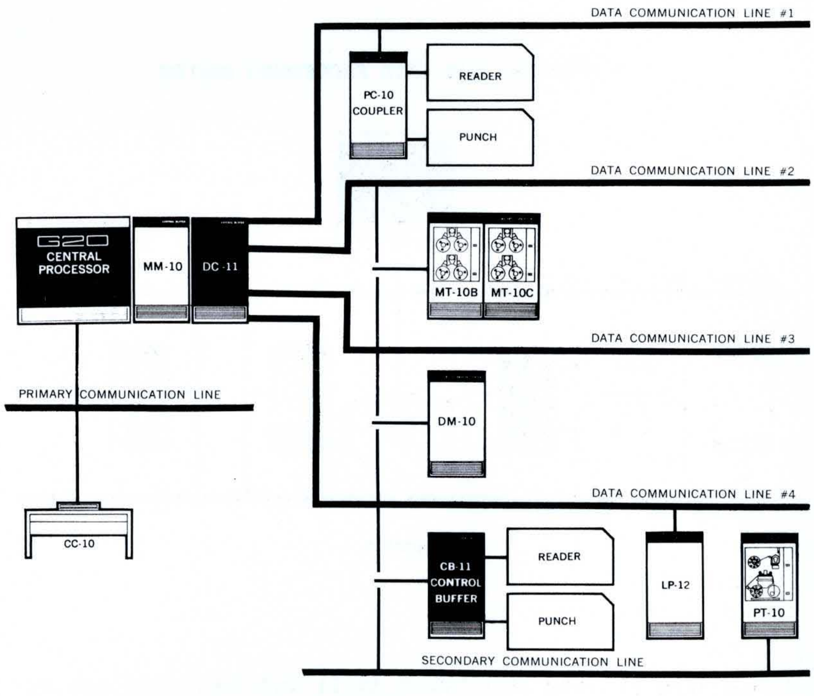


FIGURE 2

The figures that follow are examples of feasible systems or sub-systems.

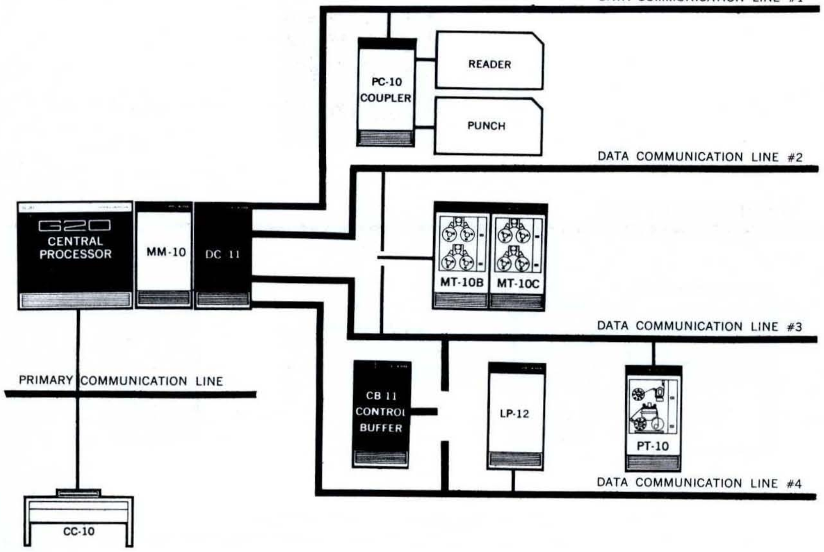


FIGURE 3

A MAGNETIC TAPE DATA PROCESSING SYSTEM

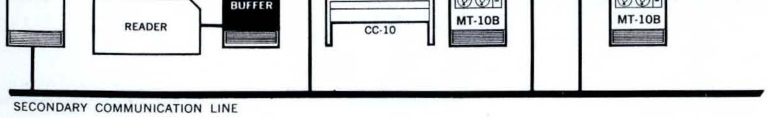


FIGURE 4

THE G-20 CENTRAL PROCESSOR, DC-11 AND CB-11 CAN ACT AS CENTERS FOR COMMUNICATION BETWEEN OTHER UNITS.

A single communication line handles a number of messages at the same time by programmed multiplexing of the messages. Additional communication lines can be added as necessary via the DC-11 and CB-11. Two communication lines can be attached to a control buffer; up to four communication lines can be attached to the data communicator.

In Figure 3, low speed elements are attached to a card coupler (PC-10) and the high speed line printer (LP-12) is attached directly to a communication line. By using a DC-11 in a G-20 communication system, reading of cards, computing and line printing can occur simultaneously.

Magnetic tape units can be switched from one communication line to another under program control. Using the switching feature possessed by both magnetic tape units and control buffers, a control buffer can control a card punching operation on one communication line while the central processor is communicating with magnetic tape units on another communication line.

In the system shown in Figure 4, the central processor can receive information from the magnetic tape system on the left, while the control buffer is modifying and transmitting information to the other tape system. Then, under program control, each magnetic tape system can switch to its other line and the central processor can communicate with the tape system on the right while the control buffer is communicating with the magnetic tape unit on the left.

In Figure 5, the disc memory unit (DM-10) provides random access of information for the controlling devices in the system. For example, the central processor can initiate a record search operation in the DM-10; during this operation the central processor may direct the read-in of information from magnetic tape. Upon a signal from the DM-10 that the record has been found, the central processor can instruct the DM-10 to either read or write the record. After the information from the magnetic tape unit has been read in, the MT-10 unit can be switched to a secondary line, controlled by a CB-11. The CB-11 could instruct the tape unit to transfer information via the CB-11 to the line printer. Or, information may be read from the card reader and sent via the CB-11 to the magnetic tape unit.

Either an on-line or an off-line data processing system can be made from the same elements. The user can establish whichever type of system suits his needs and can change from one type to the other when he desires. An off-line data processing system is illustrated in Figure 6. Magnetic tape is prepared off-line under the control of a control buffer. The prepared information can then be sent to another location to be processed by a master G-20 system of the kind shown in Figure 3. The results can be tabulated from tape by an off-line system of the last type shown in Figure 6 which may be located next to, or far from, the master computing system. The same elements can be connected in a system in which input/output can be effectively off-line, or on-line, the selection being made under program control.

A RANDOM ACCESS DATA PROCESSING SYSTEM

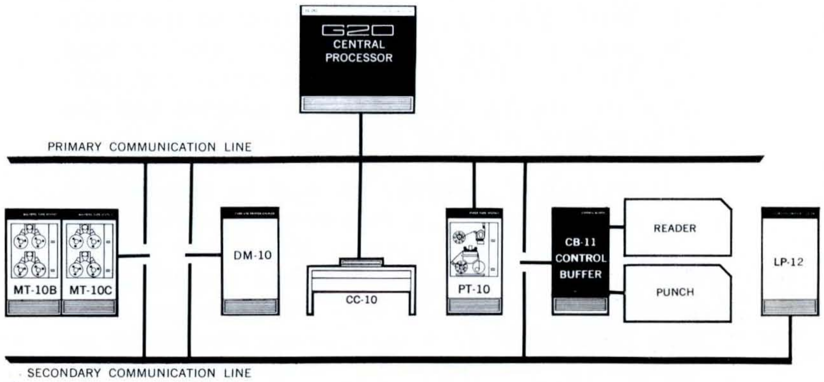
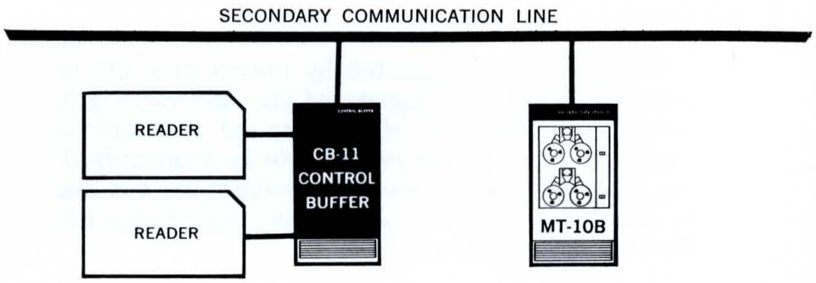
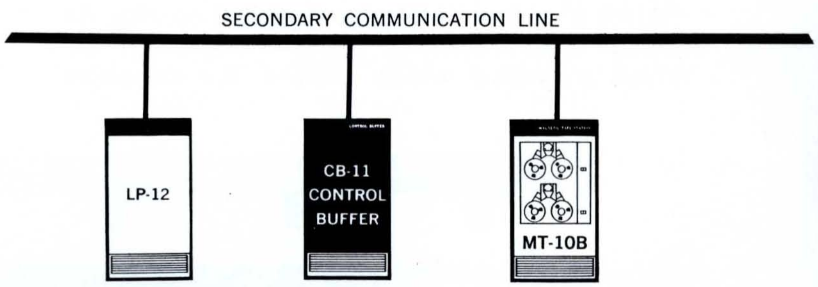


FIGURE 5

AN OFF-LINE DATA-PROCESSING SYSTEM



PREPARATION



PRESENTATION

FIGURE 6

INPUT/OUTPUT

Elements attached to a communication line are addressed via the unit which controls transmission of information along the line. The controlling unit may be the central processor, the data communicator, or a control buffer.

To initiate a central processor input or output operation, the programmer specifies the operation to be performed, the number of the unit on the communication line, and the portion of the internal memory which is to be either filled or read out. The portion of the internal memory is indicated by stating the beginning address and the total number of word positions involved.

Input/output information may be transmitted via up to four DC-11 data communication lines with complete independence. The DC-11 permits simultaneous reading, writing and computing by providing for time sharing of the external memory. When data flow outbalances computing requirements, this capability is especially valuable. All four DC-11 data communication lines may communicate at the same time with one memory module to which the central processor also has access. Each of the DC-11 lines is independent in its operation. When input or output is started, it is completed independently of the central processor.

The DC-11 is instructed by means of a list in memory. This list consists of the addresses and lengths of segments of data to be transmitted or received, or of instructions to be transmitted. By interspersing command segments, the list can be used as a stored input/output program for the data communication line.

Input/output information, and also instructions, may be sent from the central processor and stored in a control buffer. The control buffer can then operate independently of the computer by obeying its own stored program.

When a control buffer has finished obeying its internal instructions, it sends a signal to the central processor which notifies the computer that it is ready for additional instructions or for another assignment. Such a signal is called an "interrupt"; it has the ability to interrupt computation and causes a transfer of control to a separate program. A command can be written at the end of the separate program to transfer control back to the main program.

Interrupts in the data communicator are used chiefly to inform the central processor that the data communication line has completed its tasks. Interrupts are also used to indicate completion of operations that can be set up by the data line and can continue without further use of the line (for example, magnetic tape slewing or control buffer operations).

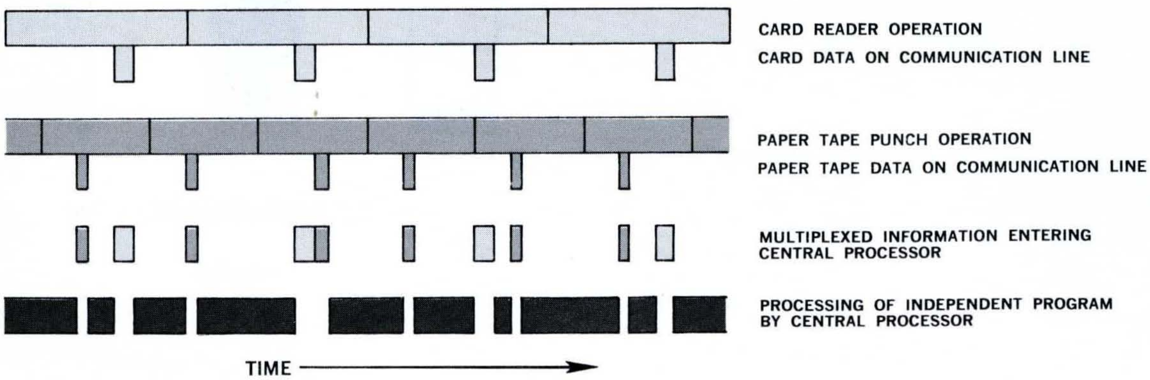
An "interrupt" signal can be generated by a piece of terminal equipment as well as by a control buffer or the data communicator.

Multiple Concurrent Operations on One Communication Line

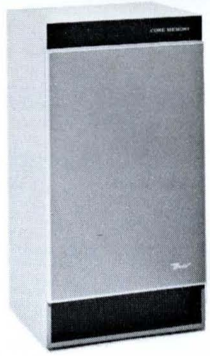
Since each communication line in a system is independently controlled, communications on one line can occur at the same time as communications on other lines.

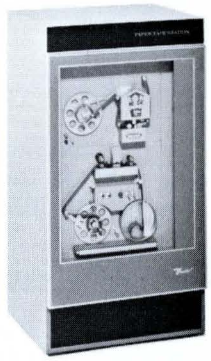
Moreover, depending on input/output speeds and the application involved, more than one input/output operation can be multiplexed on the same line.

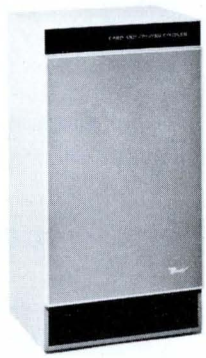
The chart below (drawn out of scale for the sake of clarity) indicates how it is done. The time during which information characters occupy the communication line is a small fraction of the time required for a complete card reading or tape punching operation. When both the card reader and paper tape punch are operating continuously, the data from the card reader can be carried on the communication line without interfering with the data being sent to the tape punch. Meanwhile, the central processor can be working with a completely independent program; the processing of the independent program pauses for the small intervals of time necessary to receive and store information from the card reader and to send information to the tape punch.

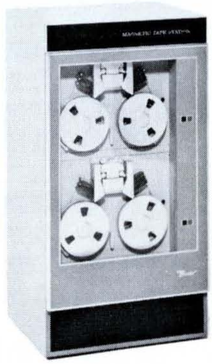


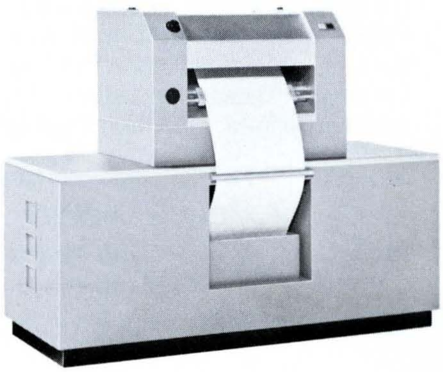
Accessories











CC-10 Control Console

The operator can initiate, monitor, and control execution of programs from the control console.

The console includes a full-keyboard typewriter for entering input information and printing output information. All characters on the keyboard, both upper case and lower case, alphabetic, numeric, and algebraic, can be entered or typed out. Instructions to the computer can be entered via the keyboard. Type-out is at the rate of approximately 8 characters per second.

The console also includes a set of indicator lights to provide information concerning the status of the program being processed.

MM-10 Auxiliary Memory Module

An additional core memory module is similar in size and characteristics to the G-20 internal memory. From one to seven additional memory modules may be attached to the central processor. The modules extend the directly addressable memory to 32,768 words in increments of 4096 each. In programming, auxiliary memory is indistinguishable from the internal 4096 words.

MT-10 A-B-C Magnetic Tape Modules

A tape control unit couples one to four tape transports to either of two communication lines. One of the four attached transports may be receiving or transmitting information at any given time. All tape transports may be independently searching for specific blocks of information on tape, in either the forward or reverse direction, at any given time.

A tape control unit can switch from one communication line to a second line under control of a program in the central processor or a control buffer.

A tape control unit is mounted in the same cabinet as one of the tape transports it is controlling. A single cabinet may be equipped with either a control unit and one tape transport, a control unit with two tape transports, or with two tape transports alone. The three different configurations are identified as follows:

Module MT-10A	One control unit and one transport.
Module MT-10B	One control unit and two transports.
Module MT-10C	Two transports.

The MT-10C must be attached to a tape module which contains a control unit.

Ten channels are recorded on tape: eight information channels, one parity checking channel and one block indicating channel. One reel of tape can hold about 45 million alphanumeric and 90 million numeric characters of information.

Information may be recorded in blocks of arbitrary length. Tape can be erased and updated in blocks. Information written on tape is checked for validity by special reading heads immediately after recording.

The tape unit specifications are:

Packing Density	1100 frames per inch
Read-Write Speed	120,000 eight-bit characters per second
Search Speed	240,000 eight-bit characters per second
Re-wind Speed	240,000 eight-bit characters per second (220 inches per second)
Tape Length	3,600 feet
Tape Width	1 inch

When magnetic tape is used for temporarily storing information from the central processor, an eight-bit character may be equivalent to two decimal digits. When a character indicates two decimal digits, the read-write speed is 240,000 digits per second, and the search speed is 480,000 digits per second.

PC-10 Printer and Card Coupler

The Printer and Card Coupler, the PC-10, can couple a G-20 Communication Line to conventional card machines. The card machines may be a card reader and a card punch or tabulator. The maximum configuration is a card reader with verification (2 read stations) and a card punch with verification (1 punch station and 1 read station). The card punch may be replaced by a tabulator. The appropriate adaptor is required for each station attached.

PT-10 Paper Tape Station

The PT-10 Paper Tape Station consists of a photo-electric paper tape reader and a tape punch. The reader reads tape of eight or fewer channels bidirectionally at the rate of 500 characters per second; it can be stopped on a single character. The punch punches tape of eight or fewer channels at the rate of 110 characters per second.

DC-11 Data Communicator

The DC-11 Data Communicator connects the full complement of G-20 input/output equipment to G-20 memory modules through data communication lines (up to four). The DC-11 permits simultaneous reading, writing and computing with complete input/output independence. Additional system flexibility is provided by the "scatter-read," "gather-write" capability of the Data Communicator. System speed via the DC-11 is up to 480,000 characters per second for magnetic tape input/output.

All four DC-11 channels may communicate simultaneously with one memory module to which the central processor also has access. Each of the four DC-11 communication channels is independent in its operation. Once initiated, input/output is carried to completion independently of the central processor. When a DC-11 communication channel and the central processor require access to the same memory module at the same time, the central processor waits only the few microseconds required to retrieve or store a word of data.

The DC-11 permits the G-20 to perform high-speed sorting, file maintenance, and matrix manipulation. Automatic segmentation and memory allocation of input data and automatic grouping of output data may be accomplished; any number of segments of any length or any set of auxiliary memory locations may be involved.

The DC-11, and individual input/output equipment, can be added at any time without system modification.

CB-11 Control Buffer

The CB-11 Control Buffer is an independent, information processor which can, operating under control of its own stored program, do editing and sorting operations outside of the central processor. By use of a control buffer, information may be sent from one element to another, and may be modified during transit, if desired, without passing through the central processor.

The CB-11 can couple a G-20 Communication Line to conventional card machines. The card machines may be a card reader and a card punch or tabulator. The maximum configuration is a card reader with verification (2 read stations) and a card punch with verification (1 punch station and 1 read station). The card punch may be replaced by a tabulator. The appropriate adaptor is required for each station attached.

The CB-11 contains 4096 9-bit characters (8 bits of information, 1 parity bit) of magnetic core storage and facilities to control the flow of information along either of two communication lines. The CB-11 can switch from control of one line to control of the other by a programmed command. Since the CB-11 can receive information from one line, and can send information to the other, the unit permits an input device on one communication line to send information to an output device on a separate communication line.

Information is transmitted between the control buffer and the central processor at a rate of 167,000 eight-bit characters per second. The use of control buffers as intermediaries between the computer and input/output devices permit a number of input/output operations to be handled concurrently.

LP-12 Line Printer

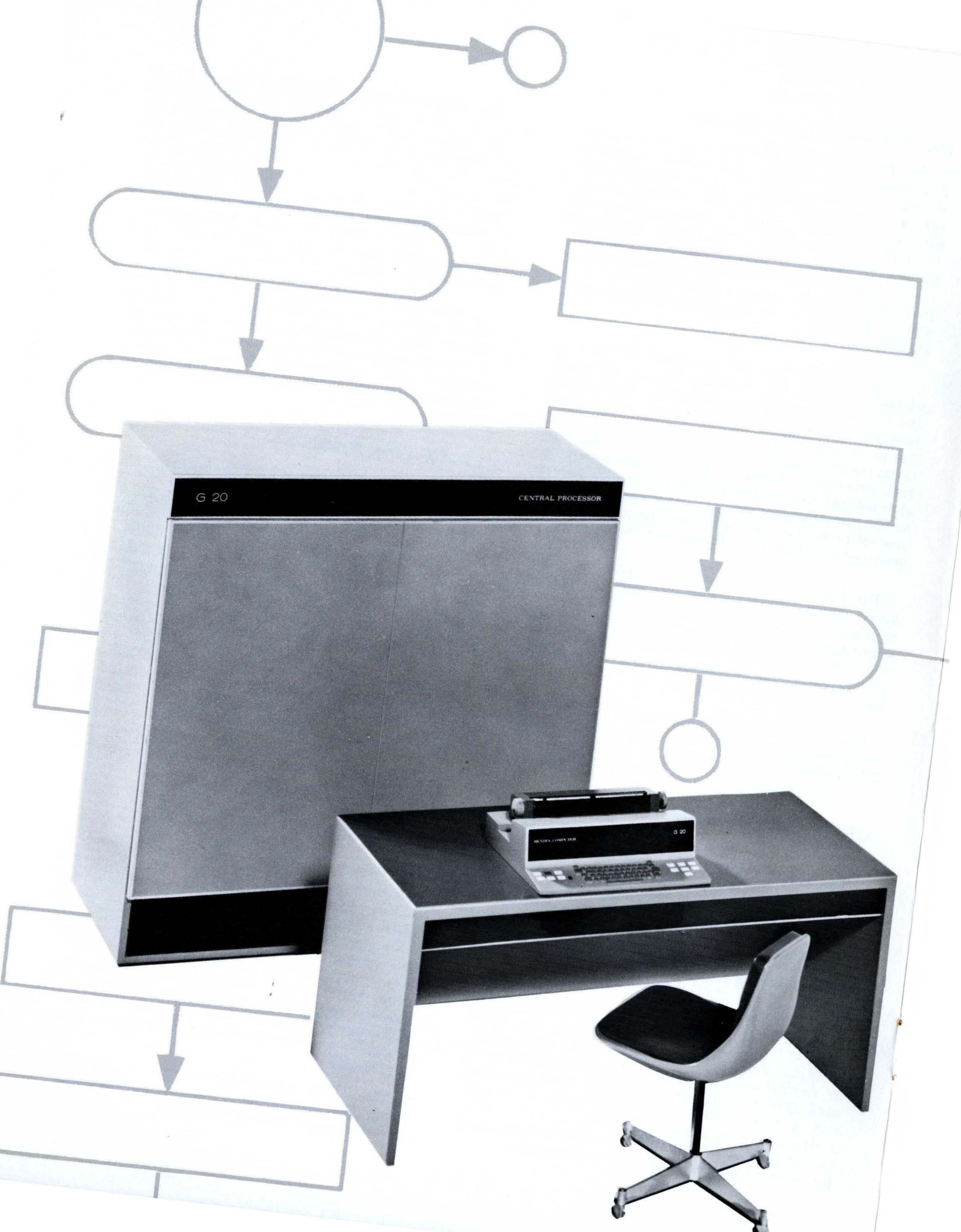
The LP-12 Line Printer is a fully buffered, solid state printer. Since the LP-12 connects directly to a communication line, it has direct communication with the central processor and other controlling units. The LP-12 prints up to 63 different characters, 120 characters per line, at a spacing of 6 lines per inch vertically and 10 characters per inch horizontally. The drum speed is 1000 RPM. It prints and advances paper independently at rates up to 800 lines per minute, single-spaced, for a 63-character alphabet and up to 1000 lines per minute, single-spaced, for a 47-character alphabet. Numeric characters only can be printed at 1000 lines per minute with multiple spacing of paper.

Information is transferred to the LP-12's buffer at a rate up to 67,000 characters per second. The print format is under program control.

DM-10 Disc Memory

The DM-10 Disc Memory unit provides on-line, random access of information from bulk storage modules; these modules may contain in excess of either 10 million or 20 million 8-bit characters (plus parity bit). A parallel-recording technique used by the DM-10 allows all bits of a character to be simultaneously read or recorded. Maximum access time to any record is 170 milliseconds. Average access time for random locations is 90 milliseconds. Transfer rate between the central processor and disc memory is 140,000 characters per second.

The DM-10 is available with either 5 or 9 discs. Each disc is 39 inches in diameter. The rotation speed is approximately 900 RPM.


G 20
CENTRAL PROCESSOR
G 20

Programming

PROGRAMMING SYSTEMS

Input statements for the Bendix G-20 system may be written in algebraic, symbolic, or business language form. Under control of a programming system that has been entered into the central processor from magnetic tape, punched cards, or paper tape, the computer converts the input statements into a machine language program. Converted programs need not be processed immediately but may be stored on magnetic tape or on other media and called into the central processor for computation when desired.

The machine language program into which the input statements have been converted is in a relocatable form. That is, when the program is requested by the central processor it will be automatically entered into any portion of the internal memory that is large enough to receive it. Consequently, the program can be automatically made part of another program and may be included in a permanent library.

Algebraic Programming System

Technical problems may be programmed in a standard algebraic form. The algebraic programming system converts the input statements into a relocatable machine language program.

The algebraic language used for coding is similar to conventional mathematical expression except that certain conventions have been adopted to permit use of a typewriter or line printer. The system is based on ALGOL, the international algebraic language.

Symbolic Programming System

Programs may be written in which alphabetic characters specify both the operation to be performed and the memory location containing the operand.

For example, a memory location which contains the salary of a man named Johnson may be designated JOHNSON in commands; and the ninth memory location following the one containing Johnson's salary could then be addressed in commands as JOHNSON + 9. The block of information pertaining to Johnson, which may cover any number of word positions, can be entered into any available portion of the memory for computation. To add Johnson's salary to a previously calculated sum the programmer would write "ADD JOHNSON".

It may be desired to repeat the computations concerning Johnson for a large number of employees. A single program may be written in generalized form for one employee which, by use of G-20 indexing facilities, will consecutively process the block of information concerning each employee. In this case, the locations in the program previously designated JOHNSON and JOHNSON + 9 might perhaps be called instead SALARY and SALARY +9.

Generalized Business Routines

Generalized programs simplify often used commercial procedures such as sorting, report preparation, and file maintenance. The programmer supplies to the generalized program specific data for the particular problem. In order to prepare a sorting program, for example, the programmer supplies information as to the number and size of the data blocks to be sorted, the fields on which the sort is to take place, and their order of priority. The generalized sorting routine then prepares the remainder of the program.

To use a generalized report preparation program the programmer specifies the data to be extracted from the file block, the arithmetic operations to be performed, if any, and the manner in which the results are to be printed. Two or more reports can be prepared simultaneously, if two printers and a control buffer or data communicator are available. Also, a control buffer can be used to prepare a report off-line.

File maintenance will ordinarily consist of sorting the group of file changes into the same order as the main file and then merging the correction tape with the old tape to produce an up-dated tape. Here, again, the programmer need only supply data pertinent to the particular run and the generalized file maintenance program will take care of the details.

The business programs are based on COBOL, the Common Business-Oriented Language.

BASIC COMMANDS

The G-20 programming systems have been built from basic G-20 commands; each basic command corresponds to a single internal machine command. When basic commands are used in programming, complete control is provided over the detailed internal operations performed by the computer.

A basic command specifies an operation code and an operand. The operation code is expressed mnemonically and the operand as a decimal number or symbol. Numeric operations are performed on the contents of an accumulator. The accumulator can hold either double precision or single precision information.

Numerous "test" commands provide conditional transfers of control. If the test specified by such a command is satisfied, the next command executed is the one in normal sequence. If the test is not satisfied, the next command in sequence is skipped.

A partial list of commands is tabulated below. In their descriptions the terms "Acc" and "X" are used. "Acc" represents the initial contents of the accumulator before execution of the command. "X" represents a value specified by the command. The term "X" in the description means that X is an operand indicated in the command either directly or by its memory location. The term "Address X" in the description means that X is itself a memory location rather than an operand.

NUMERIC COMMANDS

Arithmetic Commands

CODE	COMMAND
CLA	CLEAR AND ADD Copy X into Accumulator

CODE	COMMAND
CLS	CLEAR AND SUBTRACT Put – X into Accumulator
ADD	ADD Put X + (Acc) into Accumulator
SUB	SUBTRACT Put (Acc) – X into Accumulator
SUN	SUBTRACT AND NEGATE Put X – (Acc) into Accumulator
ADN	ADD AND NEGATE Put –X–(Acc) into Accumulator
ADA	ADD AND TAKE ABSOLUTE VALUE Put X + (Acc) into Accumulator
SUA	SUBTRACT AND TAKE ABSOLUTE VALUE Put (Acc) – X into Accumulator
MPY	MULTIPLY Put (Acc) x X into Accumulator
DIV	DIVIDE Put (Acc)/X into Accumulator
RDV	REVERSE DIVIDE Put X/(Acc) into Accumulator

The operands and results of arithmetic operations may be expressed as floating point double precision, floating point single precision, or fixed point single precision numbers.

STORE COMMANDS

The contents of the accumulator may be stored in either single precision, or double precision form. When the stored value is read from the memory, it will be read in whichever form it was stored. Consequently, a series of commands may use both single precision numbers and double precision numbers.

Three "store" commands are listed below:

CODE	COMMAND
STS	STORE SINGLE PRECISION Store (Acc) at Address X
STD	STORE DOUBLE PRECISION Store (Acc) at Addresses X and X + 1
STI	STORE INTEGER Store Integer Portion of (Acc) at Address X

The "Store Integer" command differs from the other two commands in that only the integer portion of the number in the accumulator is stored. For example, if the Accumulator contains the number "528.17", and the command "Store Integer" is executed, the value "528" will be stored in the memory.

Numeric Test Commands
(Conditional Transfers of Control)

CODE	COMMAND
FOM	IF OPERAND MINUS Is X less than zero?
FOP	IF OPERAND PLUS Is X greater than zero?
FLO	IF LESS THAN OPERAND Is (Acc) less than X?
FGO	IF GREATER THAN OPERAND Is (Acc) greater than X?
FUO	IF UNEQUAL TO OPERAND Is (Acc) unequal to X?
FSM	IF SUM MINUS Is X + (Acc) less than zero?
FSP	IF SUM PLUS Is X + (Acc) greater than zero?
FSN	IF SUM NON-ZERO Is X + (Acc) unequal to zero?

NON-NUMERIC COMMANDS

Non-numeric or "logical" commands handle a word of information as a code made up of ones and zeros rather than as a numeric quantity. These commands facilitate sorting and other operations on alphanumeric characters; each alphanumeric character is represented by a specific code made up of ones and zeros.

In the commands below, X is interpreted as a 32-position series made up of ones and zeros.

In a "unite" operation, indicated $\vee$, two such series are combined in this manner:

101101	value in Accumulator
011001	value X
111101	Result in Accumulator

A "one" appears in the result in each position that a "one" appears in either operand.

In an "extract" operation, indicated $\wedge$, two such series are combined in this manner:

101101	value in Accumulator
011001	value X
001001	Result in Accumulator

A "one" appears in the result in each position that a "one" appears in both operands.

The complement of X, indicated $\overline{X}$, is a value in which ones and zeros have been reversed. For example the complement of 001001 would be 110110.

Manipulations

In the group of commands listed below, the least significant 32 positions of the accumulator participate. The other positions are cleared to zero.

CODE	COMMAND
CAL	CLEAR AND ADD LOGIC WORD Copy X into Accumulator
CCL	CLEAR AND ADD COMPLEMENT OF LOGIC WORD Put $\overline{X}$ into Accumulator
ADL	ADD LOGIC WORD Put X + (Acc) into Accumulator
SUL	SUBTRACT LOGIC WORD Put (Acc) – X into Accumulator
EXL	EXTRACT WITH LOGIC WORD Put X $\wedge$ (Acc) into Accumulator
ECL	EXTRACT WITH COMPLEMENT OF LOGIC WORD Put $\overline{X}$ $\wedge$ (Acc) into Accumulator
UNL	UNITE WITH LOGIC WORD Put X $\vee$ (Acc) into Accumulator
UCL	UNITE WITH COMPLEMENT OF LOGIC WORD Put $\overline{X}$ $\vee$ (Acc) into Accumulator

Non-numeric Store and Test Commands

In the commands below, the least significant 32 positions of the accumulator participate; the remaining positions are unaffected.

CODE	COMMAND
STL	STORE LOGIC WORD Store (Acc) at address X
IOZ	IF OPERAND ZERO Is X identical with zero?
ICZ	IF COMPLEMENT OF OPERAND ZERO Is $\overline{X}$ identical with zero?
IUO	IF LOGIC WORD UNEQUAL TO OPERAND Is (Acc) – X non-zero?
ISN	IF SUM NON-ZERO Is X + (Acc) non-zero?
IEZ	IF EXTRACTION ZERO Is X $\wedge$ (Acc) identical with zero?
IEC	IF EXTRACTION WITH COMPLEMENT EQUAL TO ZERO Is $\overline{X}$ $\wedge$ (Acc) identical with zero?
IUZ	IF UNION ZERO Is X $\vee$ (Acc) identical with zero?
IUC	IF UNION WITH COMPLEMENT ZERO Is $\overline{X}$ $\vee$ (Acc) identical with zero?

UNCONDITIONAL TRANSFERS OF CONTROL

CODE	COMMAND
TRA	TRANSFER Execute commands from consecutive memory locations beginning with Address X.
TRE	TRANSFER AND ENABLE INTERRUPT Execute commands from consecutive memory locations beginning with Address X. "Interrupt" signals may interrupt computation.
SKP	SKIP Execute commands from consecutive memory locations beginning with an address which is X greater than the location of this command.
TRM	TRANSFER AND MARK Store location of this command at Address X and execute commands from consecutive memory locations beginning with Address X + 1.

INDEXING COMMANDS

As is described under "Command Structure", any memory location, and any number of memory locations, can be used in a command to modify the address to which it refers. However, special commands facilitate use of memory locations 1 through 63 as address modifiers. These commands do not affect the accumulator in any way. Locations 1 to 63 can be considered to be index registers if desired; in the descriptions below, "I" refers to a memory location between 1 and 63.

CODE	COMMAND
LXP	LOAD INDEX PLUS Copy X into I
LXM	LOAD INDEX MINUS Put – X into I
ADX	ADD TO INDEX Add X to I
SUX	SUBTRACT FROM INDEX Subtract X from I
XPT	LOAD INDEX PLUS AND TEST Copy X into I; does X differ from zero?
XMT	LOAD INDEX MINUS AND TEST Put – X into I; does X differ from zero?
AXT	ADD TO INDEX AND TEST Put X into I; does result differ from zero?
SXT	SUBTRACT FROM INDEX AND TEST Subtract X from I; does result differ from zero?

REPEAT COMMANDS

Operations can be executed repetitively on operands in successive memory locations by being written in the form of a "Repeat" command. A Repeat command simplifies the coding of such problems as summation, numerical integration, and the examination of a block of data for specific information.

Operations which can be executed repetitively correspond to the following single operand commands:

All Arithmetic Commands except Multiply, Divide, and Reverse Divide

All Numeric Test Commands

All Non-numeric Manipulation Commands

All Non-numeric Test Commands

A Repeat command is coded in the manner described under "Command Structure". A beginning address and a limiting number are specified in the command. The command is executed repetitively on consecutive operands beginning with that at the first address. Any one of three conditions terminates the repetition: The processing of an operand which has a flag, a transfer of control which may occur because a test command is being repeated, or the processing of a number of operands equal to the limiting number specified.

ADDRESSABLE REGISTERS

The Central Processor includes three addressable registers for internal control and input/output control. One, the "Interrupt Request" register, indicates whether interrupt signals have been received and from where they have been sent. Specific positions in the register correspond to specific sources for the request signal. The programmer specifies in a second register those sources which he desires to be able to interrupt internal computation. The third register indicates the current status of the communication line.

In the command descriptions below (Reg) represents the contents of the specified register before execution of the command.

CODE	COMMAND
LDR	LOAD REGISTER Copy X into Specified Register
EXR	EXTRACT TO REGISTER Put (Reg) $\wedge$ X into Specified Register
ERO	EXTRACT REGISTER TO OPERAND ASSEMBLY REGISTER Put (Reg) $\wedge$ X into Operand Assembly Register
ERA	EXTRACT REGISTER TO ACCUMULATOR Put (Reg) $\wedge$ X into Accumulator

DETECTION OF CODING ERRORS

The processing of a command which contains a non-existent address, an illegal address, a non-existent operation code, or which results in an arithmetic overflow, will be indicated in the "Interrupt Request" register. The central processor may then perform any operation desired by the programmer as a result of the error.

STRUCTURE OF COMMANDS IN BASIC PROGRAMMING SYSTEM

The G-20 computer uses a single-operand command structure. A basic command specifies an operation code and an operand.

The operand can be specified by its address in the magnetic core memory. Arithmetic commands operate on the contents of an Accumulator Register.

For example:

MPY 1600 means multiply the value in the accumulator by the contents of Memory Location 1600.

An address can be written in a command which, instead of containing the operand, contains the address of the operand. Such an address is identified by parentheses.

For example, if Memory Location 1600 contains the value 235:

MPY (1600) means multiply the value in the accumulator by the contents of Memory Location 235.

A command has unlimited indexing facilities. That is, the address of the operand can be modified by the contents of any number of other memory locations. Each location which holds a value that modifies the address of the operand is put in parentheses. If a single memory location from 1 to 63 is used to modify an address, the entire command will fit in a single word position.

For example:

MPY 1600+(37) means multiply the value in the accumulator by the contents of an address determined by adding to 1600 the integer in Memory Location 37. This command will occupy one word position in the memory.

MPY 1600+(37)−(2985) means multiply the value in the accumulator by the contents of an address determined by adding to 1600 the value in Memory Location 37 and subtracting the value in Memory Location 2985.

When an operand is an integer less than 32,768, its value can be written directly in the command instead of being indicated by an address. An arrow specifies that the term, or terms, which follow represent the value of the operand rather than its address.

For example:

MPY ← 1600 means multiply the value in the accumulator by 1600.

MPY ← (1600) means multiply the value in the accumulator by the number held in Location 1600. If Location 1600 contains the number 235, the value in the accumulator would be multiplied by 235.

MPY ← (1600)+460 means multiply the value in the accumulator by a number determined by adding the contents of Location 1600 to the number 460. If Location 1600 contains the number 235, the value in the accumulator would be multiplied by the number 695.

Any command can include a "flag". A flag can interrupt the normal consecutive sequence in which commands are executed. After execution of a flagged command, control is transferred to a special memory location which can contain any instruction desired by the programmer. A flag is indicated by a digit from 1 to 3 written before the operation code. The three different flag numbers permit three different types of action to be predicated on the presence of a flag.

For example:

2 MPY 1600 means that after the command MPY 1600 is executed the next command will be taken from a special memory location indicated by the figure "2".

In "Repeat" commands two numbers are designated; one is the address of the first operand and the other is the number of consecutive operands for which the command is to be executed. An "R" written in front of the operation code specifies that the command is to be executed repetitively.

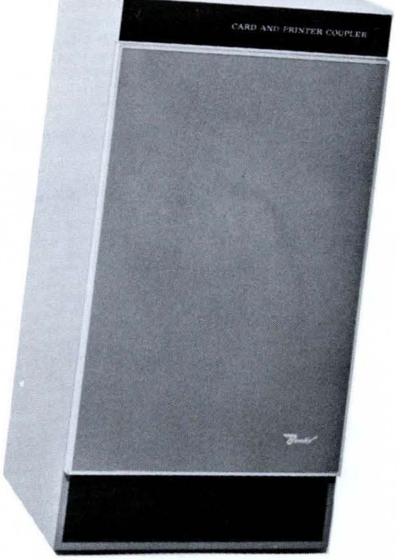
For example:

RADD 1600,250 means make a summation in the accumulator of the 250 consecutive operands which begin at Memory Location 1600. If all the operands are single precision numbers, the contents of Memory Locations 1600 to 1849 will be added to the accumulator.

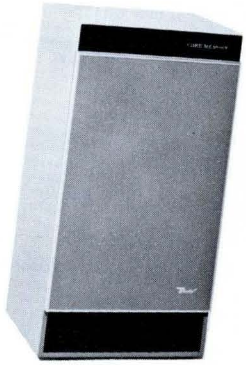
RADD 1600+(37),250 means perform the summation of 250 operands beginning at a location determined by adding to 1600 the contents of Memory Location 37.

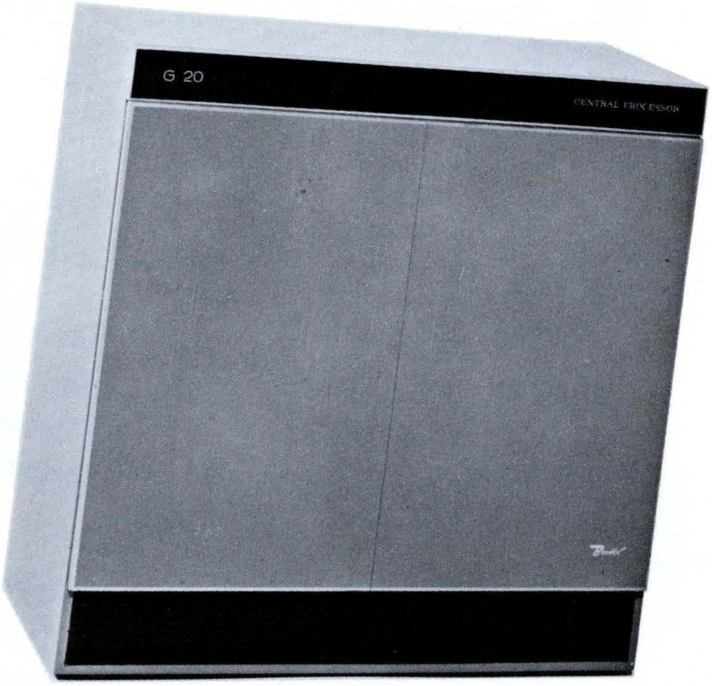
Relative Addressing

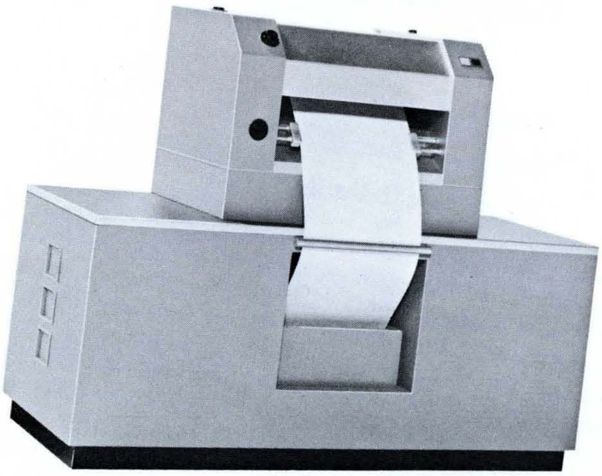
Both the Algebraic and Symbolic Programming systems for the G-20 create programs which are made up of basic G-20 commands but which have relative addressing in place of absolute addressing for command and data locations. The computer itself assigns the absolute locations in the memory space available when the program is to be executed.

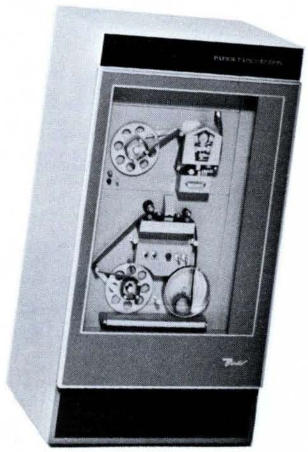


Specifications









Input/Output Notation

Numeric, Alphabetic, and/or Algebraic notation can be used.

Numeric information is expressed in decimal form with fixed or floating decimal point.

Precision of Input/Output Data

Single Precision	
Fixed Point:	8 decimal digits and sign
Floating Point:	6 decimal digits and sign, for mantissa
	2 decimal digits and sign, for exponent
Double Precision	
Floating Point:	12 decimal digits and sign, for mantissa
	2 decimal digits and sign, for exponent

Floating point numeric range is from 10^{-56} to 10^{+56}. In fixed point data representation, the programmer may select any fixed position for location of decimal point.

Memory

Magnetic core memory is in modules of 4096 words each. One to eight modules may be used. Each machine word is 33 bits long including a parity bit. Four alphanumeric characters, or a single precision number, occupy one word. A double precision number occupies two words. A basic machine command occupies one or more words.

Access to a word in the memory requires 3 microseconds. The word may then be used for computation. An additional 3 microseconds elapses before the memory is again available.

Average Command Execution Times

The average execution times given, when added to the time required to read a command and obtain the operand to be used, represent the complete operation times for the listed commands.

Arithmetic Commands

(The times below are listed in microseconds.)

	single precision		double precision	
	fixed point	floating point	fixed point	floating point
Add	0	2	0	2
Subtract	0	2	0	2
Multiply	24	33	42	42
Divide	64	68	54	54
Store				
Store sum or difference	8	8	15	15
Store product or quotient	16	16	15	15

Other Commands

Clear and Add	0
Any Numeric Test	6
Any Logic Operation	0
Any Logic Test	4
Transfer to Specified Address	0
Transfer and Enable Interrupts	0
Skip	2
Transfer and Mark	8
Load Index	7
Increment Index	14
Increment Index and Test	14

The average additional time required internally to read an unindexed command, obtain an operand from memory and restore the memory, is 12 microseconds for single precision and 18 microseconds for double precision; a portion of this time is used for the execution of most commands. The fixed point Add and Subtract commands, the Clear and Add command, the two transfer commands and all non-numeric operations can be completely executed during the memory restore operation.

Internal Characteristics

Single-operand command structure permits an operand to be expressed by any number of addresses.

Numbers are processed in parallel, binary, floating point form during internal computation.

Input/output circuitry is asynchronous and can handle information at rates up to 200,000 eight-bit characters per second.

Internal Checking

Every word stored in memory is accompanied by a parity bit; a validity check is made on all information read internally from the memory.

Each input/output character is accompanied by a parity bit. A validity check is made on information received by the central processor.

Information written on magnetic tape is checked for validity immediately after recording. The checking is done by separate "read" heads.

Punched cards may be verified via re-reading at a second "read" station on the equipment.

By means of a repeat command, the contents of a block of information entering the computer can be added together during input; the result can then be compared to a previously calculated check sum in order to provide a check which will detect any type of error.

Internal Timing

Timing is synchronous, at a pulse repetition rate of 1.0 megacycle per second.

Electrical Specifications

The Central Processor contains about 5,500 transistors and 32,000 germanium diodes. Each module of memory contains about 135,000 cores.

The equipment uses 117 volt, single phase, 50 or 60 cycle power.

EQUIPMENT		POWER	DIMENSIONS (inches)			WEIGHT (lbs)
			width	depth	height	
G-20 Central Processor		3.5 kva (4096 words) 4.0 kva (8192 words)	64	28.5	64	2500
MM-10 Auxiliary Memory Module		1.5 kva (4096 words) 2.0 kva (8192 words)	34	28.5	64	800
CC-10 Control Console		0.6 kva	64	28.5	30	550
MT-10 Magnetic Tape Module	A	2.1 kva	34	28.5	64	1000
	B	3.8 kva	34	28.5	64	1300
	C	3.4 kva	34	28.5	64	1300
PC-10 Printer and Card Coupler		1.5 kva	34	28.5	64	900
LP-12 Line Printer		2.5 kva	72	28.5	30	1000
CB-11 Control Buffer		2.0 kva	34	28.5	64	1200
PT-10 Paper Tape Station		1.0 kva	34	28.5	64	1000

Specifications subject to change without notice

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