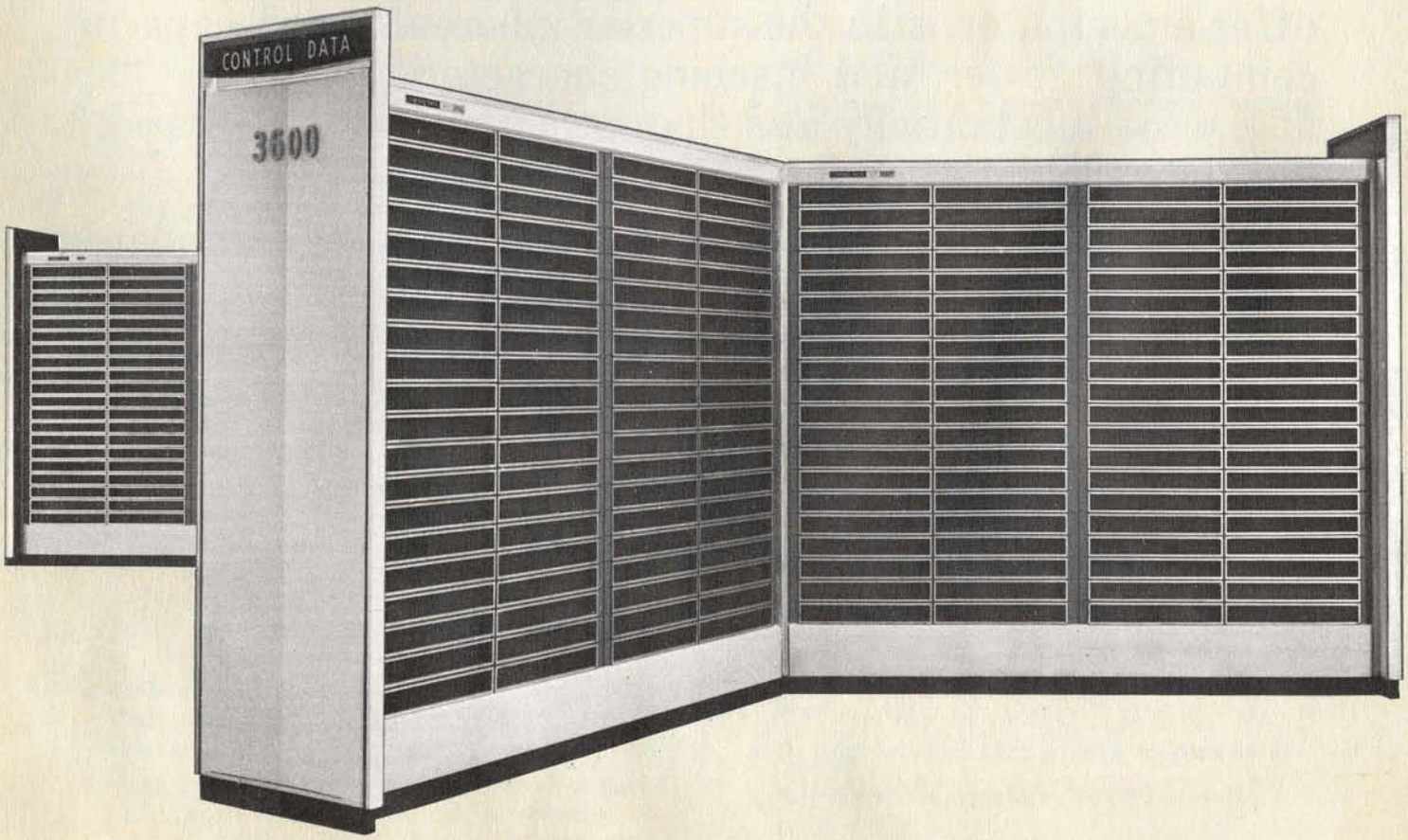
3600

CONTROL DATA 3600 COMPUTER SYSTEM



INTRODUCTION

The Control Data 3600 is the latest addition to the line of advanced large-scale computers offered by Control Data Corporation. Again, Control Data is the first in the industry to offer a computer with the superior inherent speed, capacity, computing power, and machine characteristics of the 3600 at a price substantially less than other computers approaching the capabilities of the 3600 Computer.

The basic 3600 Computer is large by any industry standards. However, its modular design enables the user easily to add functional modules tailored to satisfy specific increased computing and data processing requirements as they arise.

3600 COMPUTER CHARACTERISTICS

Exceptionally suited for handling large-volume data processing and for solving large-scale scientific problems at very high speeds, the Control Data 3600 has the following machine characteristics:

- 48-bit word length plus 3 bits for parity checking.
- Storage Module of 32,768 48-bit words – expansible in 32,768-word modules up to 262,144 48-bit words:
  1.5 microseconds – memory cycle time
  .7 microseconds – access time
- Communication Module with 4 bi-directional data channels – expansible up to 8 bi-directional data channels. (Up to 8 control and/or peripheral devices can be attached to each bi-directional data channel.)
- Up to 3 additional Communication Modules may be added, with from 1 to 8 bi-directional data channels each.
- Execution times, including access:
  4 microseconds – Floating Point Add
  1-6 microseconds – Floating Point Multiply
  1-13 microseconds – Floating Point Divide
  2-25 microseconds – Double Precision Floating Point Multiply
- Code compatible with the Control Data 1604 Computer except for three 1604 I/O instructions.
- Byte-scan operation in which: 1) data of variable length within a word can be operated on by one operation or 2) high-speed scanning can be performed on computer storage in byte-size pieces.
- Special computing functions easily added to system via special channel in the Compute Module, e.g., trigonometric and exponential functions, etc.
- Double precision floating point commands – with mantissa of 84 bits plus sign.
- Results of all arithmetic operations normalized or un-normalized, rounded or unrounded . . . at programmer's option.
- Inter-register instructions.
- Two-way search instructions.
- Data transmission control performed by high-speed registers located in Communication Module – permitting I/O activity to proceed *independent and asynchronous* of main computer program.
- Universal bit-sensing instructions.
- Shifting time constant – regardless of number of positions shifted.
- Sophisticated interrupt capability.
- Auto-load button for selectable peripheral equipment.
- Direct typewriter entry into Arithmetic Register.
- Parity check on all I/O data transmission.
- Registers for memory lockout – under program control.
- Various special, high-speed circuits operating at 4 nanoseconds.

BASIC 3600 COMPUTER

Characteristic of the 3600 is the high degree of modularity achieved in this large-scale computer. Smooth expansion of the basic system is effected by the addition of functional modules. These can be added without the necessity of installing specialized interconnecting black boxes.

The basic 3600 Computer consists of three functional modules, as follows:

1) High-Speed **3602 Communication Module** – equipped with 4 bi-directional 3606 Data Channels.
2) High-Speed **3603 Storage Module** – with 32,768 48-bit words, each with an additional 3 parity bits.
3) High-Speed **3604 Compute Module.**

Also included with the basic computer is the 3601 Console. The console contains an electric typewriter which, when used as an input device, has direct access to the accumulator. Used as an output device, its data is buffered through the Communication Module. Also included with the basic 3600 Computer is a 250 card per minute reader which has direct access to the accumulator. Figure 1 shows a diagram of the basic 3600 Computer.

3604 COMPUTE MODULE

Functioning as the heart of the 3600 Computer, the 3604 Compute Module performs all the computing and logical operations. In addition, it contains the control for *initiating* I/O operations. Having direct access to the core storage module(s), the 3604 operates in the parallel binary mode.

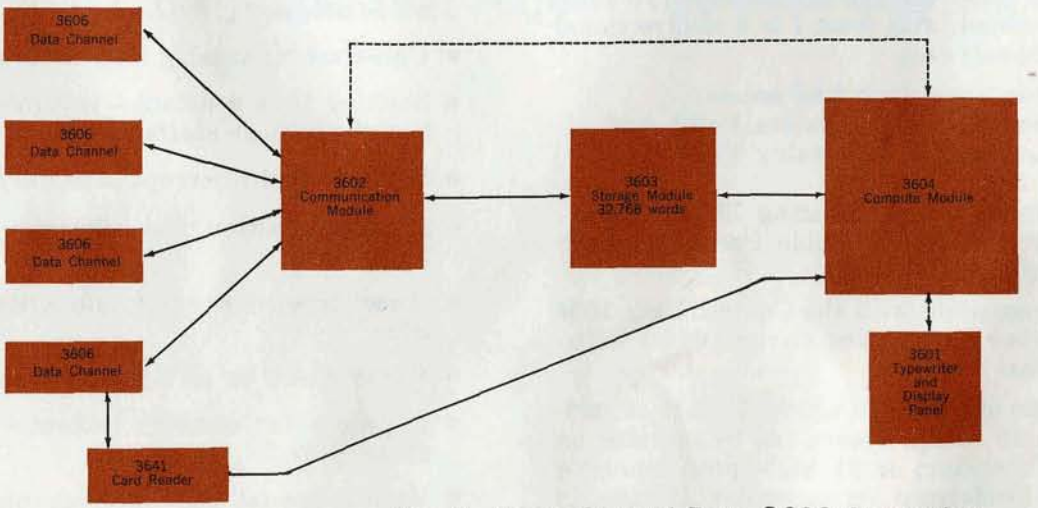


Fig. 1. Basic Control Data 3600 Computer.

Fixed point operations are performed modulus 2^{48}-1. Floating point operations are performed in either single or double precision. Single precision coefficient is 36 bits plus sign, double precision is 84 bits plus sign. A 10-bit plus sign exponent is used in both single and double precision operations.

The 3604 instruction repertoire consists of both half-word and full-word instructions. A sub-set of half-word instructions is identical to the Control Data 1604 Computer instruction repertoire, except for three I/O instructions in the 1604.

Several new categories of instructions have been included in the 3600 instruction repertoire, as follows:

- Commands which facilitate manipulating portions of a data word. For example, bytes of 48 bits or less may be transmitted to any portion of a register or storage word in a single operation. Provision is made for indexing through bytes in a word (horizontally) and through a list of such words (vertically) in the same operation.
- Double precision floating point commands include add, subtract, multiply, divide, fetch, and store. A 10-bit plus sign exponent is used with an 84-bit plus sign fraction.
- Two-address transmissive and repeated transmissive instructions are included with provision for any size address increment to be used in the repeated operations–independent of the number of words in the list.
- A special instruction for list processing, as well as several new indexing operations.
- A universal bit-sensing instruction which permits any bit in any register to be tested and branched upon. In addition, the bit sensed may then be complemented, set, cleared, or left unchanged.
- A powerful, extremely fast interrupt facility is provided, as well as instructions for processing interrupts.
- Indexing instructions which may, under program option, be performed in either one's or two's complement arithmetic.
- Six sense switches are included on the console and can be program sensed. These are in addition to three selective jump and three selective stop switches.
- A 48-bit sense-light register is included. Each position in the register may be set or cleared under program or manual control. Provision is made for sensing the status of each position and branching upon the condition of its complement.
- Two *bounds registers* of 18 bits each, used for memory lockout. Information is not written outside of the region of the core storage specified by the addresses contained within the *bounds registers.*

The 3604 Compute Module employs special circuitry to speed up the basic arithmetic processes. Thus, the basic cycle time of the adder network is 250 nanoseconds. The shift time is a constant 250 nanoseconds regardless of the number of places shifted. These times do not include storage references. Typical average execution times including storage reference are listed in the following table:

Instructions	Fixed Point	Single Precision Floating Point	Double Precision Floating Point
Multiply	1-6	1-6	2-26
Divide	1-14	1-14	2-26
Fetch/Store	1.5-2.2	1.5-2.2	3
Add/Subtract	1.5-2.2	4	5

Table 1. Typical Average Execution Times* (in microseconds)

*Average time of multiply and divide instructions is the same as the maximum time; the lower figure of the range permits abortion of the sequence for zero values of one or both operands.

3603 STORAGE MODULE

The 3603 Storage Module provides high-speed, random access magnetic core storage of 32,768 48-bit words. A storage word may be two 24-bit instructions, a single 48-bit instruction, a 48-bit data word, or half of a 96-bit data word. Three parity bits are generated for each storage word; thus, a storage word is 51 bits in length.

The parity bits are generated each time a word is read from or written into storage. One of the three parity bits is assigned to each of the 15-bit addresses; the third parity bit is assigned to the remainder of the word.

Each 3603 contains two independent storage banks of 16,384 words. Within each such bank, storage addresses are consecutive, permitting the 3603 storage module to be treated as two independent storage units.

The storage cycle time of each 16,384 word sub-module is 1.5 microseconds, and is totally independent of other sub-modules.

3602 COMMUNICATION MODULE

Input-output operations are initiated by the compute module and controlled by the 3602 Communication Module. The basic 3602 contains a storage access control section, an arithmetic and control section, and four bi-directional data channels. Up to 8 bi-directional I/O data channels can be attached to this 3602. (From one to eight data channels may be attached to additional 3602's, at the user's option.)

Input-output operations may occur independently and asynchronously with operations in the compute module. Input or output data is transmitted to or from storage directly, and *does not pass through the compute module.*

The arithmetic and control portion of the 3602 supervises all I/O functions once operating conditions have been initiated. The compute module directs the selection of a specific external equipment and the channel in which I/O activity is to take place, as follows: A 48-bit control word is read from storage and entered into a 48-bit control register. The control word specifies a starting address, i.e., the storage address from which the first output word will be read . . . or where the first input word will be stored – along with a 15-bit word count. Once these initial operating conditions have been generated, the channel control supervises all I/O activity.

Each data channel is bi-directional, i.e., it may be used for both input and output communication. Each 48-bit data word is transmitted in 12-bit bytes and is assembled/disassembled in a 48-bit assembly/disassembly register. Assembly/disassembly time is less than one storage cycle, thus permitting the storage module to be used at its maximum rate and allowing full utilization of a parity bit for each 12-bit byte transmitted.

Peripheral equipment in the 3600 System operates on 12-bit data, as disassembled from the 48-bit data word. The use of 12 rather than 48 bits as the peripheral equipment common language results in reduced cabling and hardware while maintaining maximum data transfer rates. For special applications, other data channels may be attached to the 3602 Communication Module.

Upon completion of the assembly/disassembly of the 48-bit word, it is transmitted to the appropriate storage module via the access control section. The parity bits accompanying the output transmission are checked by the external equipment; parity bits accompanying input transmissions are checked by the 3602.

3600 COMPUTER EXPANSIBILITY

The basic 3600 Computer can be smoothly expanded to include up to eight 3603 Storage Modules, each with a capacity of 32,768 48-bit words, with each word having 3 additional parity bits. The fully expanded 3600 Computer is shown in Fig. 2.

If a 3600 employs more than one storage module, its compute module references each storage module in either one of two ways, or a combination thereof, as follows:

1) One type of instruction where the full 18-bit address is specified and/or
2) By means of two 3-bit bank address registers:
   a) an operand bank register
   b) a program address bank register

These two registers are *directly addressable* by the main computer program and can be changed at will.

All 24-bit instructions implicitly refer to these two registers; all other instructions explicitly contain an operand bank address together with one bit . . . indicating whether the implicit operand register address or the explicit instruction operand address is to be used in the instruction.

The stored program may thus be located in one storage module, while the operands, i.e., data, constants, etc., may be located in a different storage module – thus, significantly increasing the speed of the 3600 Computer.

Any of the four possible 3602 Communication Modules can *directly reference* any of the eight possible storage modules . . . once I/O operations have been initiated by the 3604 Compute Module.

For example, the 3604 Compute Module may use storage module #3 for operands and storage module #2 for stored programs. At the same time, communication module #1 may be transmitting data to storage module #5. Concurrently and asynchronously, communication module #2 may be transmitting data to storage module #4. And while communication module #3 is transmitting data to storage module #6, communication module #4 can be transmitting data to storage module #7.

Thus, six storage modules may be operating simultaneously and asynchronously at peak rates.

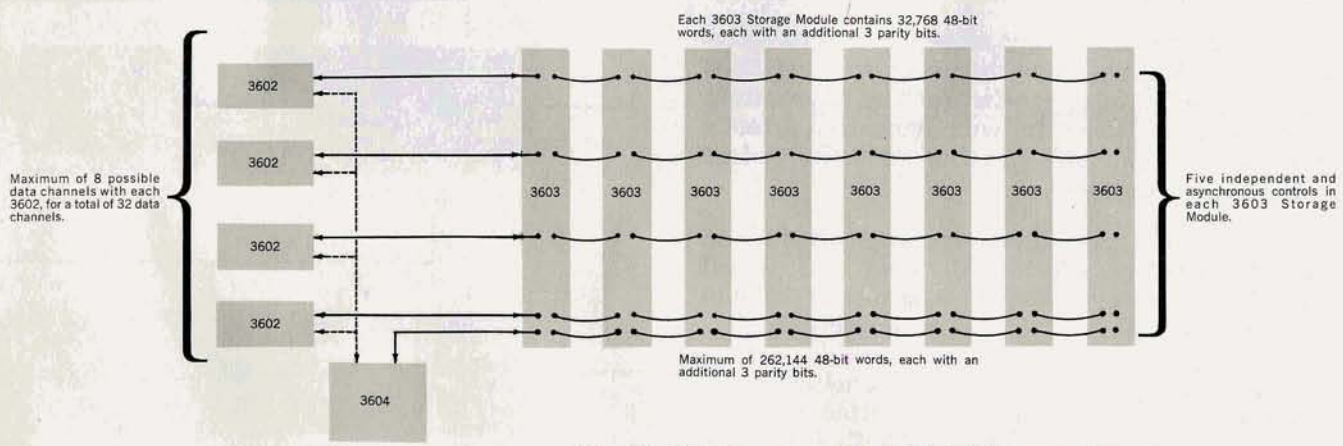


Fig. 2. A fully expanded 3600 Computer.

MULTIPLE 3600 COMPUTER SYSTEM

The 3600 is designed to permit multiple computer installations without need for special adaptors. All interconnecting of various modules between systems is via standard cables, and requires no special treatment. Two typical types of multiple computer installations are described to illustrate the flexibility of the 3600 System. Many other systems are possible.

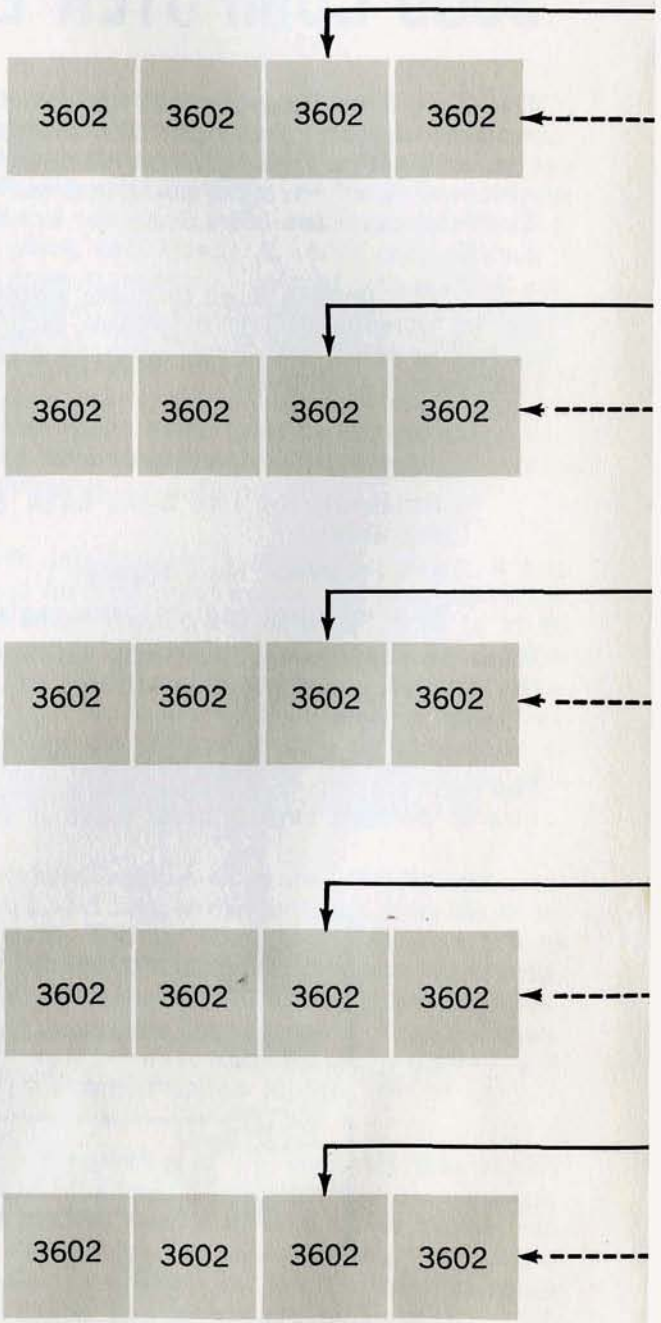
In one mode, the compute module of each 3600 Computer can address eight storage modules. In a common system, the compute modules of each 3600 would address a fixed number of storage modules which the remaining compute modules could not address. In other words, the eight addressable storage modules are considered an integral part of each 3600 Computer in the common system.

However, each compute module in the common system can address a common pool of storage modules. The total number of storage modules in this common pool, and the number of modules connected to a given 3600 Computer, cannot exceed eight. Five such 3600 Computers can address this common pool of storage modules independently and asynchronously.

In the second operating mode, each 3602 Communication Module may contain up to eight 3606 bi-directional data channels. Each of these eight channels has provision for communication directly with identical channels in other 3600 Computers in the common system.

These 12-bit data channels exchange control and computer-identity information. They also permit one 3600 Computer to interrupt any other 3600 in the common system . . . under program option.

Should they occur, machine malfunctions, e.g., a parity error, are instantly transmitted via these 12-bit channels to any other 3600 Computer in the common system.



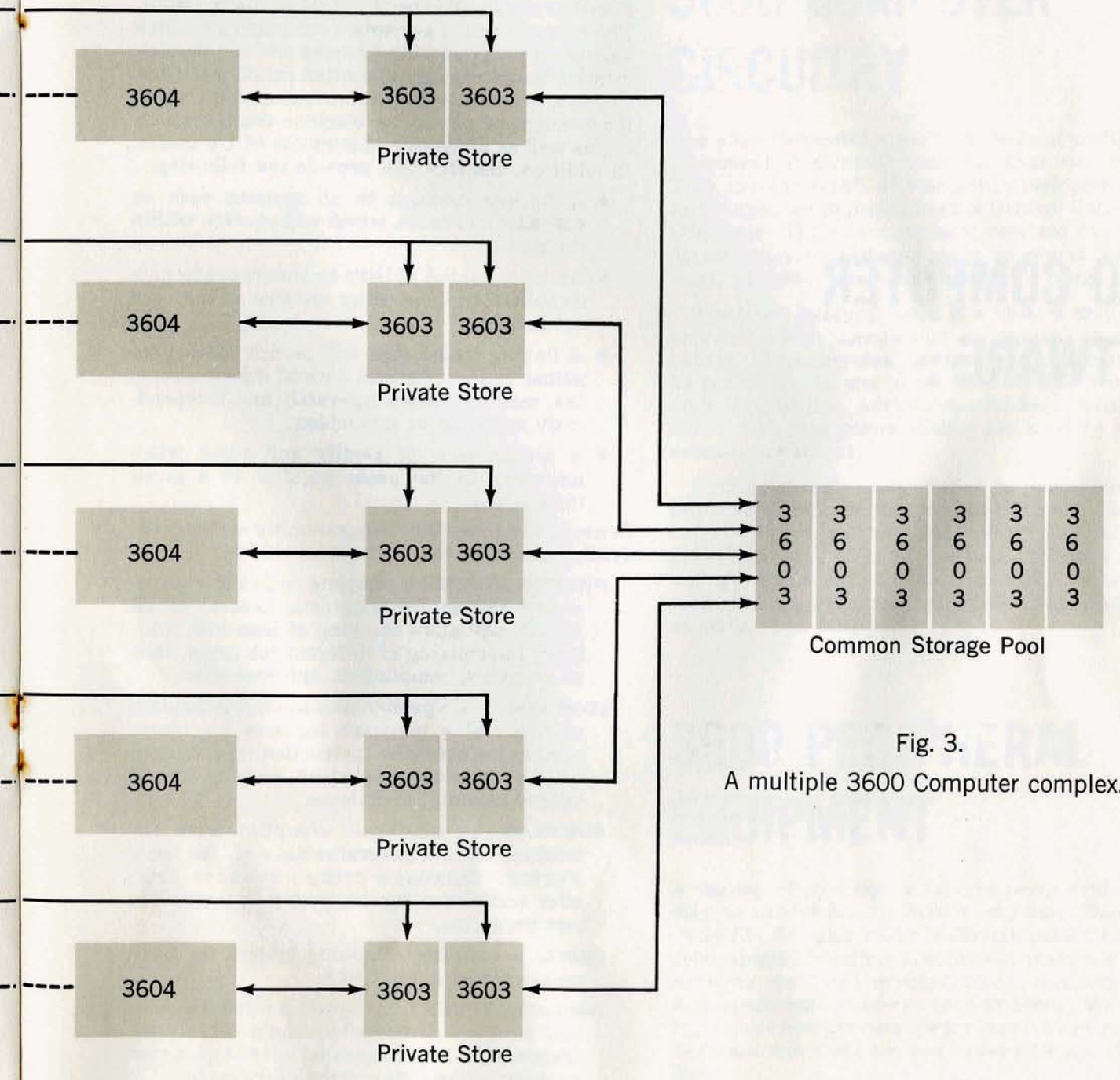


Fig. 3.
A multiple 3600 Computer complex.

3600 COMPUTER SOFTWARE

The 3600 Computer software system will be oriented around a Master Control System (MCS). The MCS will act as a common communication link among all programming systems and I/O devices, interrupt, and memory allocation functions. Thus, the MCS will allow programming systems to be independent of particular machine configurations . . . as well as of types and numbers of I/O media. In addition, the MCS will provide the following:

- A library common to all systems such as FORTRAN and COBOL which will operate within the MCS.
- An open-ended ability to incorporate new compilers and operating systems as they are developed.
- A linking loader that will permit joining together in one program several sub-programs that may have been separately and independently compiled or assembled.
- A system easy to modify and adapt when necessary to the needs peculiar to a given installation.

Some of the important programming systems operating under control of the MCS will be:

MONITOR SYSTEM: a complete operations supervisory system for automatic control of all jobs. It will allow stacking of jobs with arbitrary intermixing of different job types, such as assembly, compilation, and execution.

COMPASS: a comprehensive assembly system with versatile language features for representing the extensive instruction repertoire in a simple symbolic notation, employing advanced assembly techniques.

FORTRAN: an algebraic compiler with extensions to, and generalizations of, the basic Fortran language using advanced compiler techniques for producing optimum object programs.

COBOL: a complete compiling system for business-oriented applications.

1604 COMPATIBILITY PACKAGE: a software package which will execute interpretively all trapped I/O instructions of a 1604 program running in the 1604 compatibility mode.

3600 COMPUTER CIRCUITRY

The 3600 Computer circuits have been under development at Control Data for over two years. They are the result of extensive development efforts expended in producing the Control Data 3600 Computer. These circuits have received the benefits of many refinements made in evaluating the most reliable commercially available components.

The basic building block is a bi-level amplifier-inverter which operates at an equivalent phase rate of 16 megacycles. Several levels of logic can be performed in one phase time of 62.5 nanoseconds. In addition, various special high-speed circuits employing tunnel diodes are used (4 nanoseconds per stage).

Printed-circuit cards similar to those found in the 1604 Computer are used in the 3600. The dimensions have been changed slightly, and the component packing density has been increased. The voltage levels are -5.5 volts and -1.5 volts. All cards are pluggable and have eyelet test points for attaching oscilloscopes.

3600 PERIPHERAL EQUIPMENT

A variety of optional on/off-line peripheral items may be used with the 3600 Computer. These include 12-, 24-, and 48-bit bi-directional data channels; special function generators; magnetic tape handlers and tape synchronizers; medium- and high-speed card readers; card punches; low- and high-speed line printers; paper tape I/O equipment; keyboard entry devices and typewriters; and disc files.

CONTROL DATA SALES OFFICES

ALBUQUERQUE, N. M., 937 San Mateo N.E., Phone 265-7941

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SAN FRANCISCO, CALIF., 885 North San Antonio Road, Los Altos, Phone 941-0904

WASHINGTON 16, D. C., 4429 Wisconsin Avenue N. W., Phone EM 2-2604

CONTROL DATA
CORPORATION

8100 34TH AVENUE SOUTH, MINNEAPOLIS 20, MINNESOTA

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Litho in U.S.A.