The Heritage of the IBM System/360

Earlier Commercial Computers

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Outline and Rationale

The goal of this lecture is to describe the early history of computing machines manufactured by the International Business Machines Company.

I hold that many of the design choices seen in the IBM S/370 architecture reflect the use made of earlier computing machines, especially in 1930 – 1960.

Outline of this lecture:

1. Discussion of technologies and computer generations.
2. Early mechanical and electro–mechanical computers.
3. Early electronic computing machines.
4. The genesis of the IBM System/360: its immediate predecessors.
5. Design choices in the IBM System/360 and System/370.

The Classic Division by Generation

Here is the standard definition of computer generations.

Note that it ignores all work before 1945.

1. The first generation (1945 – 1958) is that of vacuum tubes.
2. The second generation (1958 – 1966) is that of discrete transistors.
3. The third generation (1966 – 1972) is that of small-scale and medium-scale integrated circuits.
4. The fourth generation (1972 – 1978) is that of large–scale and very–large–scale integrated circuits; called “LSI” and “VLSI”.
5. The term “fifth generation” has been widely used to describe a variety of devices. It still has no standard definition.

Early Computing Machines Were Mechanical

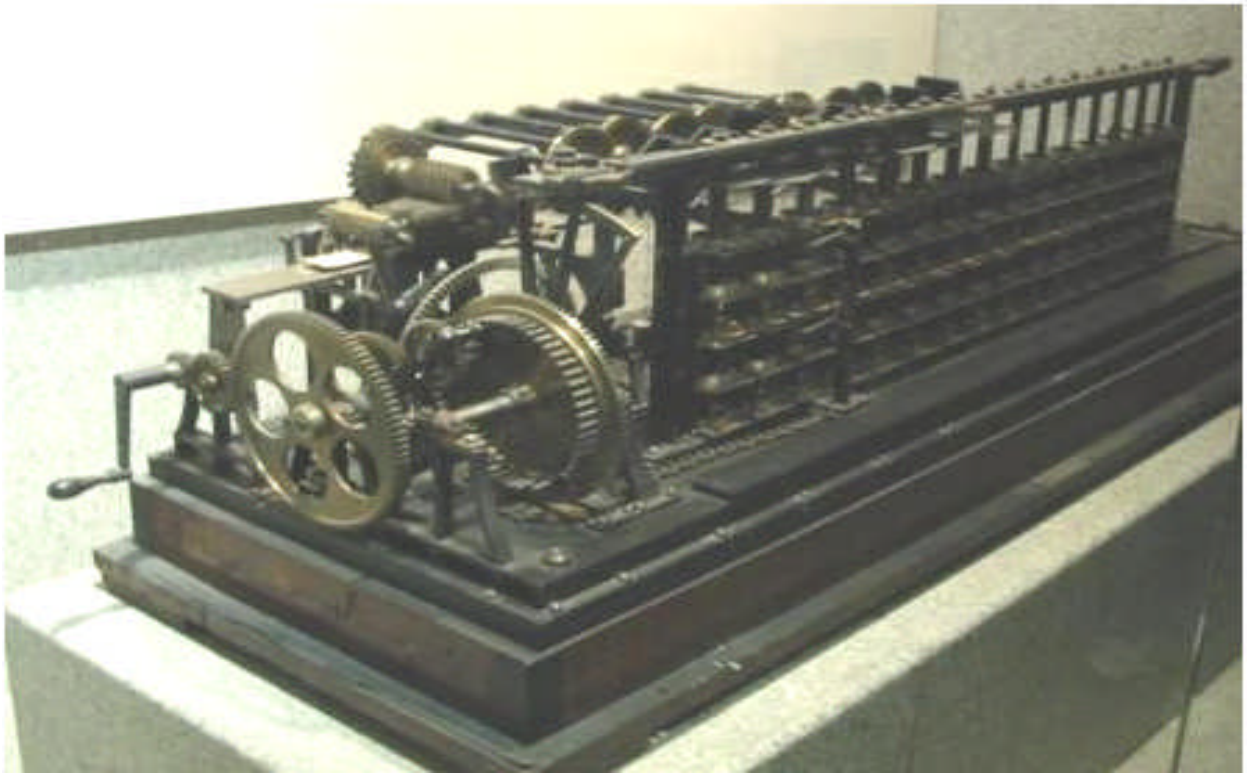
Here is an unexpected example: the Jacquard Loom. Though not a computer, it was powered by steam and controlled by punched cards.

A Reconstructed Jacquard Loom in the Deutches Museum in Munich

Scheutz’s Difference Engine

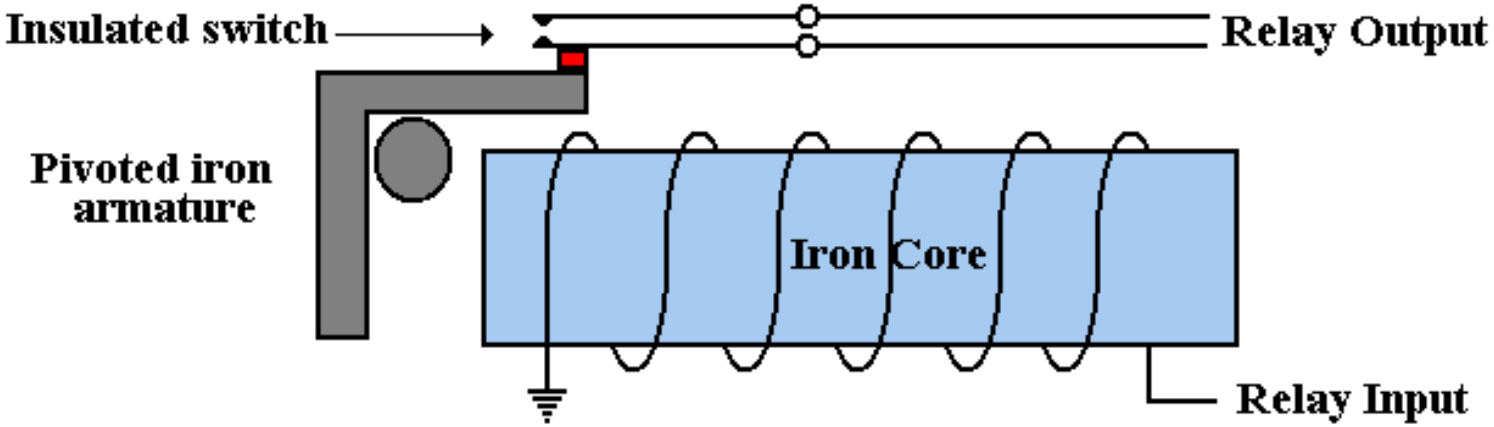
This is an example of a purely mechanical computing machine.

Note the gears and the hand crank.



Electro–Mechanical Computing Machines

Beginning in about 1900, the computing machines used electro–mechanical relays. Below is a diagram of such a relay.

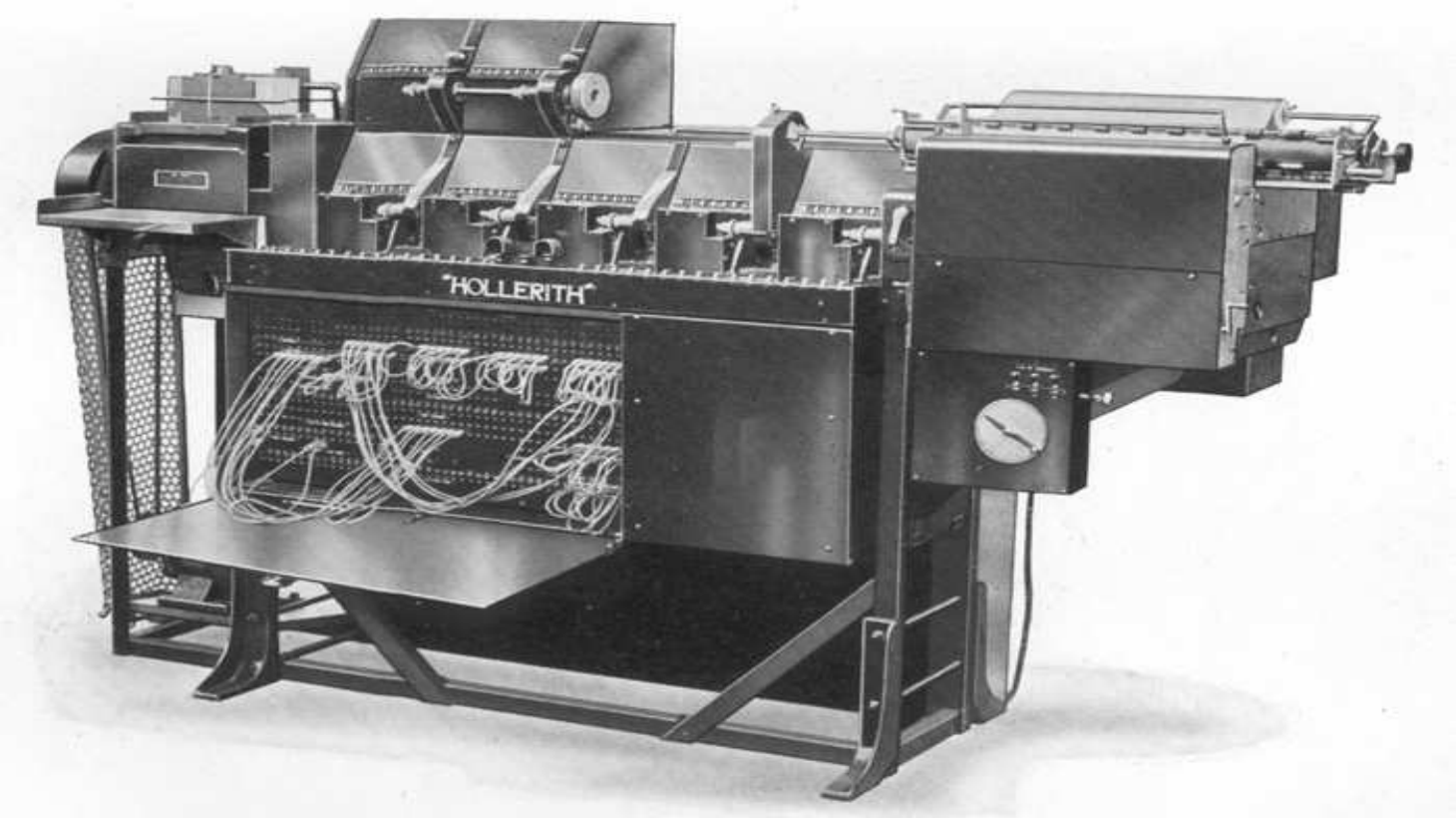


This is an electrically activated switch.

When the relay input is energized, the electromagnet is energized, and the pivoted armature is moved. This causes the switch to close.

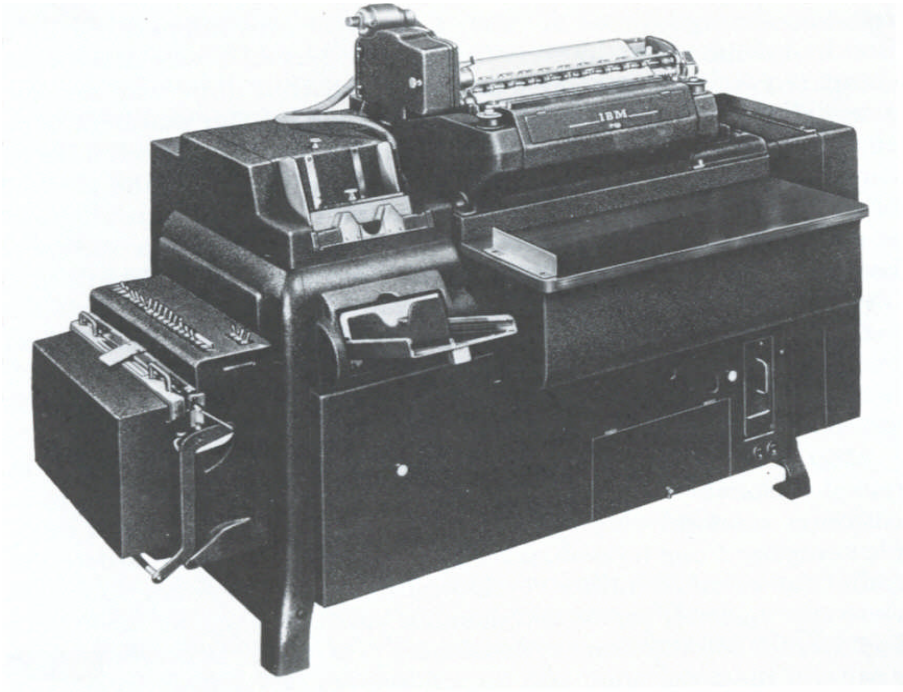
The Hollerith Type–III Tabulator

This electro–mechanical computing machine dates from 1932.



Note the plug–board with wires. These were used to program the machine.

The IBM 405: IBM's High–End Tabulator

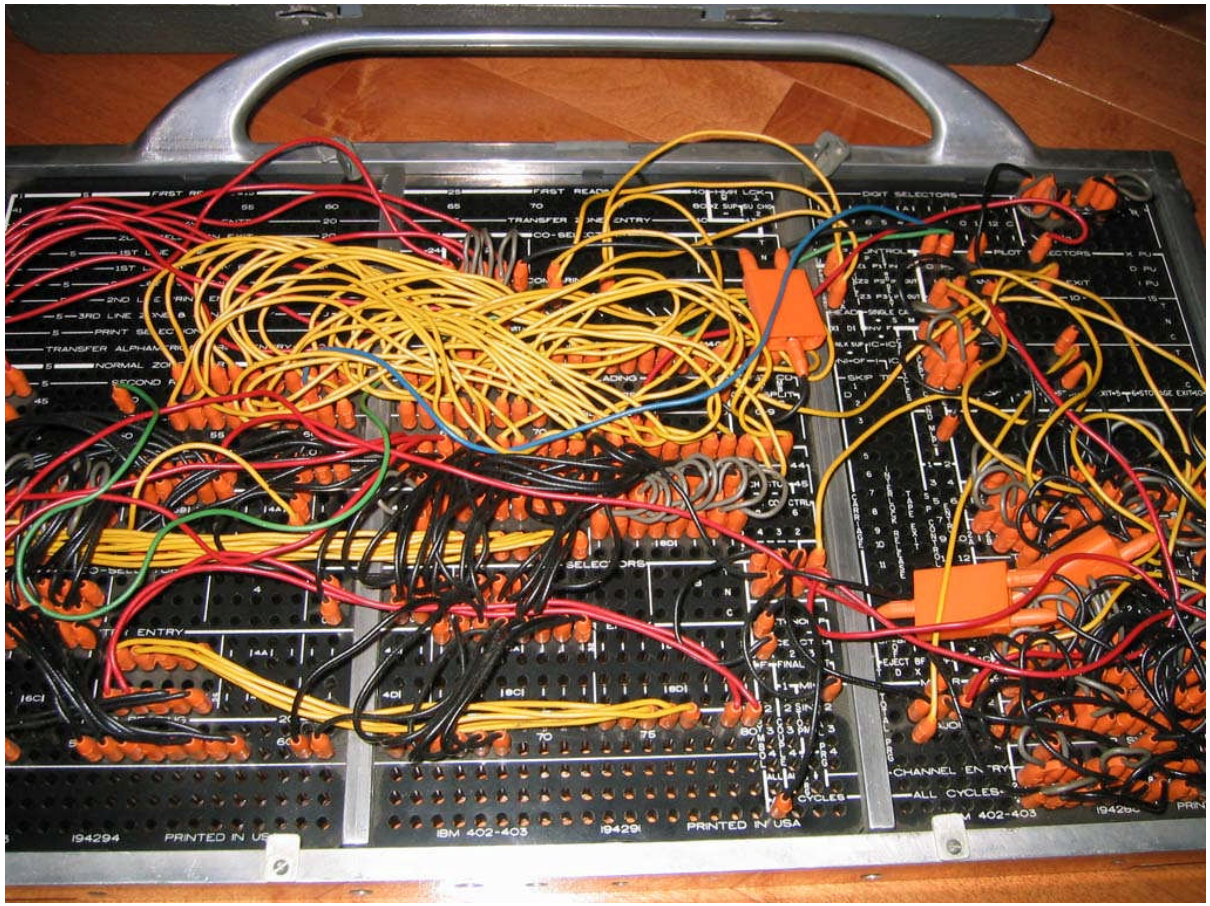


It was first one to be called an Accounting Machine.

It was programmed by a removable plug–board with over 1600 functionally significant "hubs", with access to up to 16 accumulators.

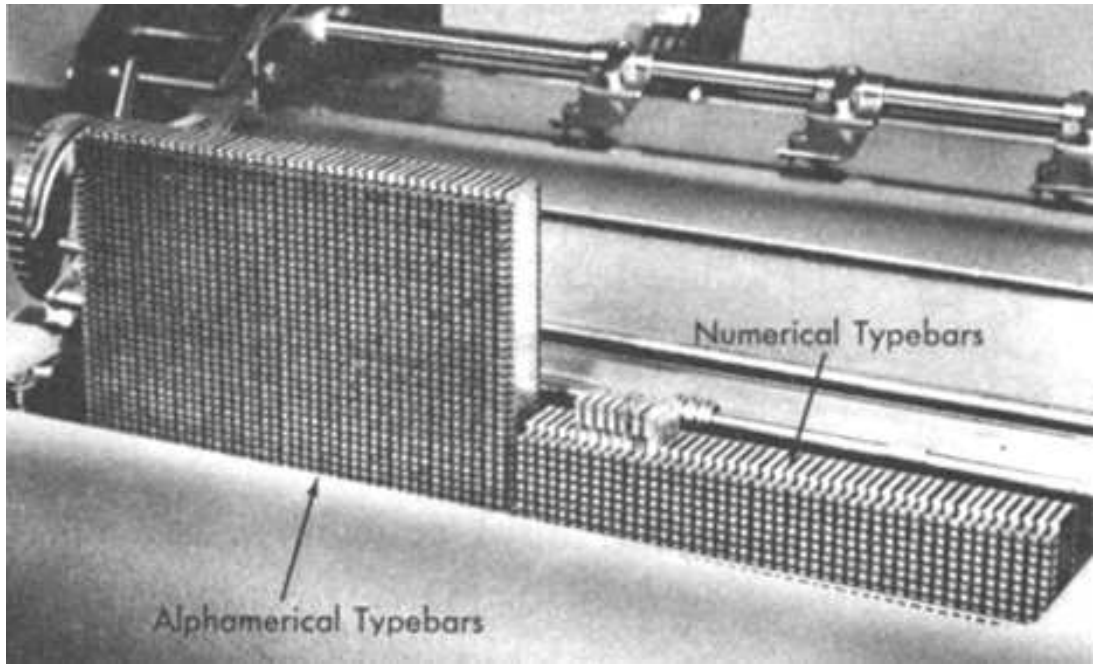
The machine could tabulate at a rate of 150 cards per minute, or tabulate and print at 80 cards per minute.

A More Modern Plug–Board



This is a plug–board from the IBM 405, manufactured about 1946.

The Printer for the IBM 402 (1950)



Note that the typebars on the right can print only numerical characters.

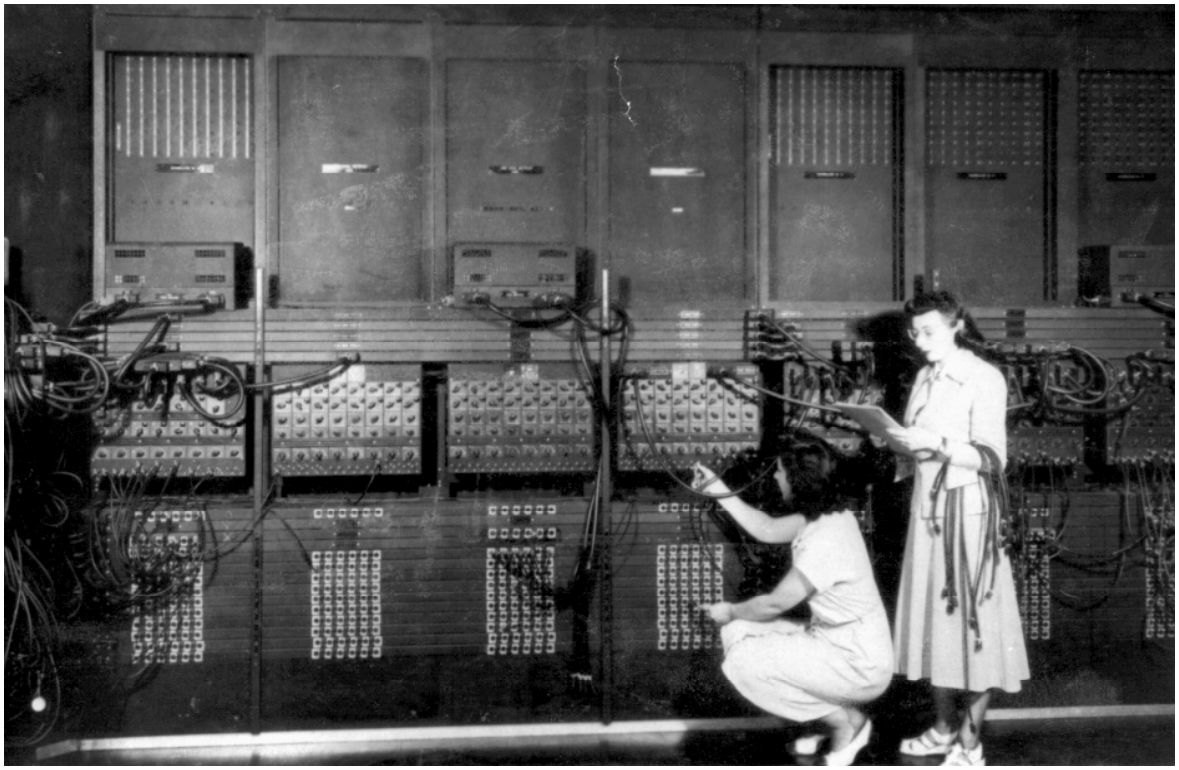
All–Electronic Computing Machine

These were built with vacuum tubes, which only became sufficiently reliable in the 1940's. Even then, it was common for the machine to run for only 4 hours.

Here are four vacuum tubes from my private collection.

The ENIAC (1945)

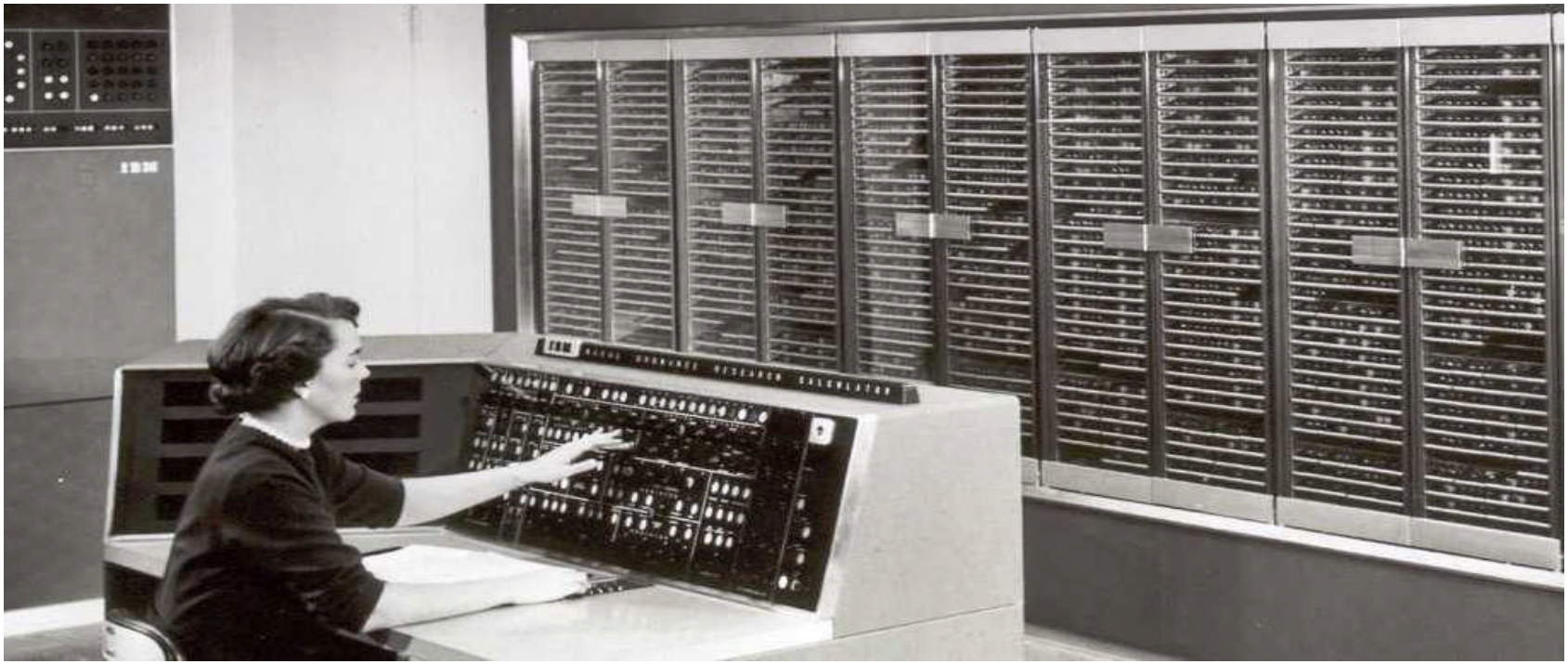
The ENIAC was possible only after the problem of vacuum tube reliability had been solved. There was also the problem of rodents eating the wiring.



Two women programming the ENIAC (Miss Gloria Ruth Gorden on the left and Mrs. Ester Gertson on the right)

The IBM NORC (1954)

Here is a picture of a typical large computer of the early 1950's.



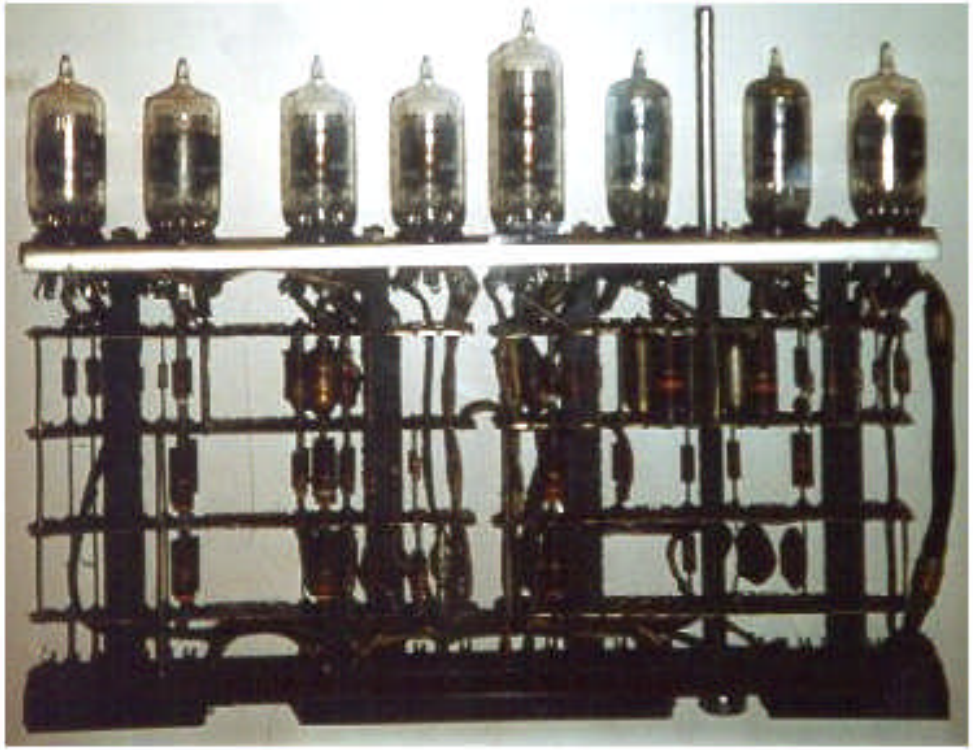
Note the trays of vacuum tubes in the background. These form the computer.

The IBM 650 (Circa 1955)

This computer used vacuum tube technology.

The IBM 650 – Power Supply, Main Unit, and Read-Punch Unit
Source: Columbia University [R41]

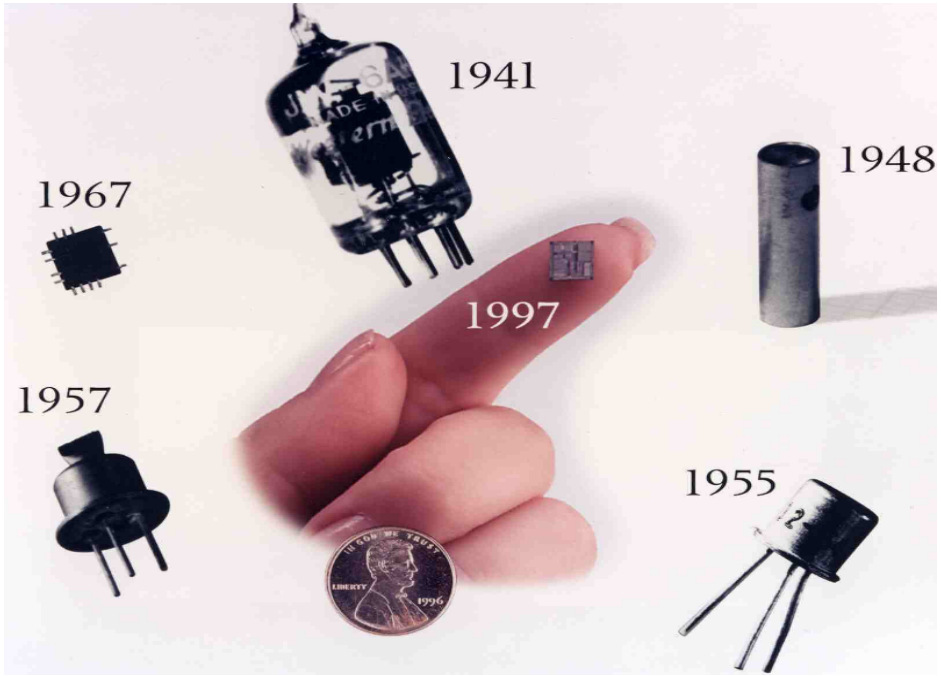
A Block of Vacuum Tubes from the IBM 701



The IBM 701, produced in 1952, used replaceable components to facilitate maintenance.

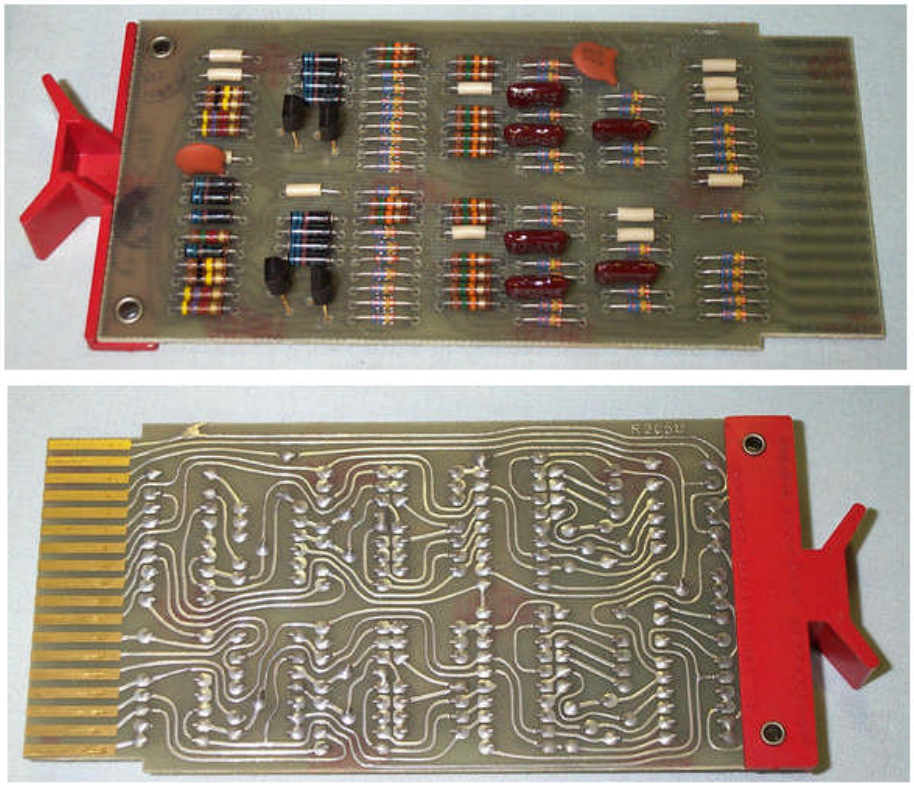
Smaller Components:
Transistors and Integrated Circuits

Here is a picture showing some smaller tubes, with transistors and an integrated circuit (presumably with a few thousand transistors).



Discrete Transistors

In the 1960’s, computers were fabricated from circuit boards populated with discrete transistors. Again, this allowed for module replacement.



These were manufactured by the Digital Equipment Corporation.
The “black hats” are the transistors.

Circuit Boards Plugged Into a Backplane

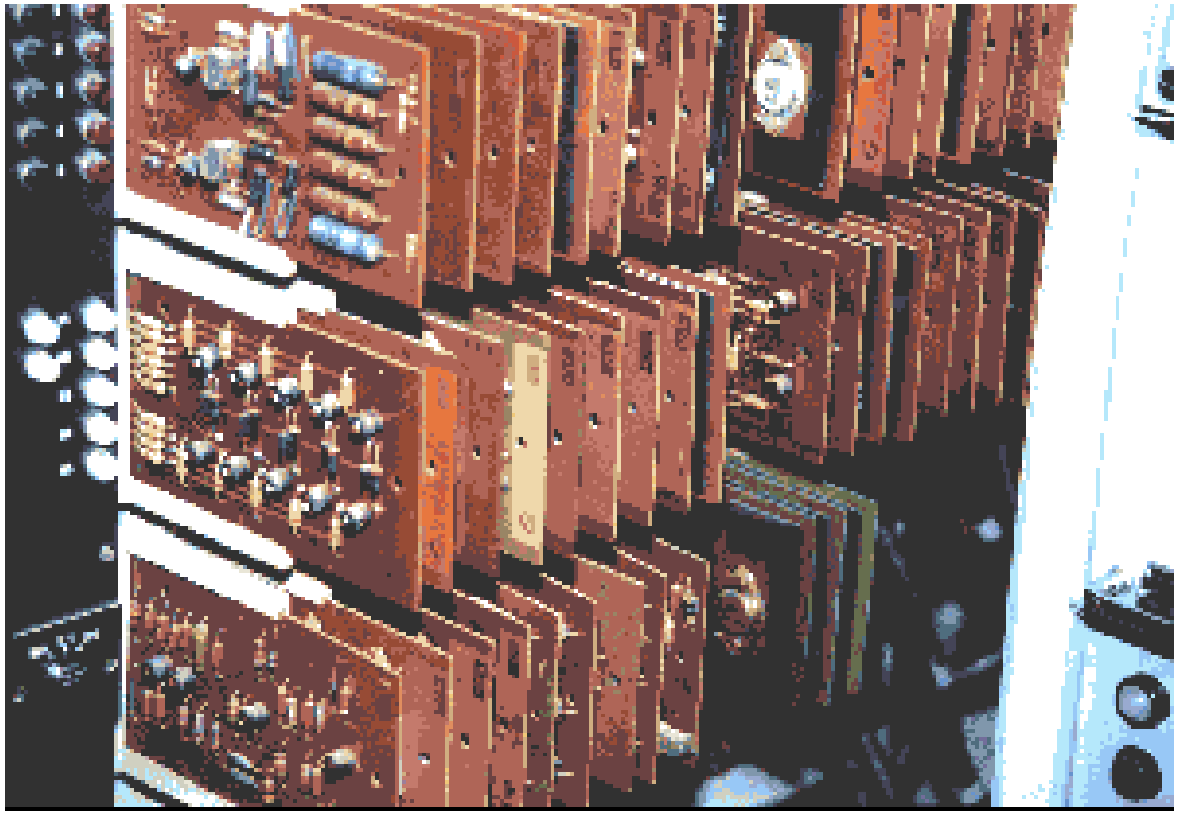
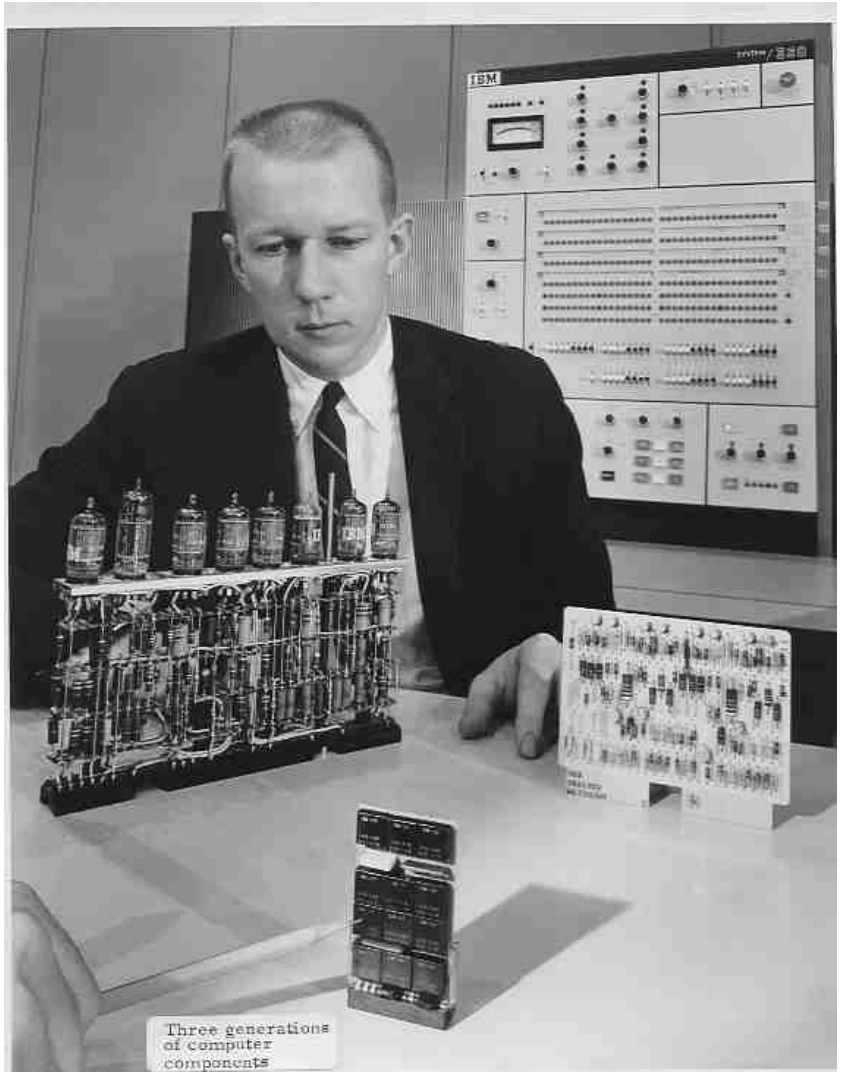


Figure: A Rack of Circuit Cards from the Z–23 Computer (1961)

An IBM Engineer with Three Generations of Components



The first generation tube component is one that we have already seen.

The second generation discrete transistor board is a bit out of focus. Presumably it has the same function.

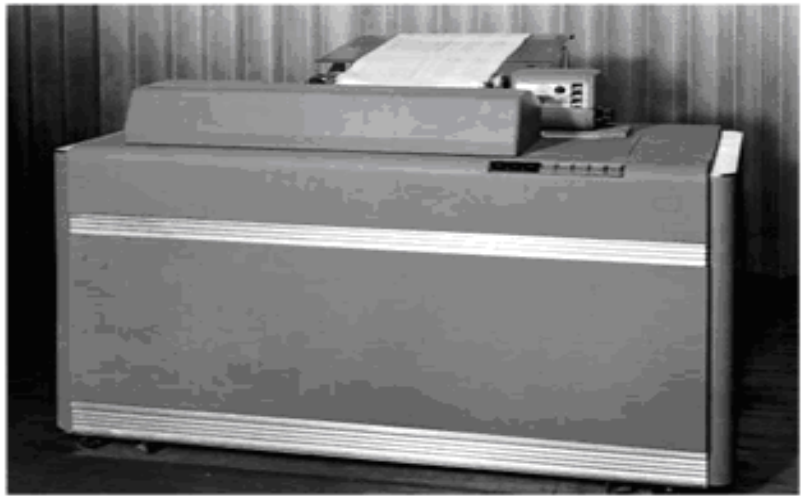
Note the pencil pointing to one of nine integrated circuits on the 3rd generation component. Presumably, it also has the same function as the first board.

Note also the coat and tie. This was the IBM corporate culture.

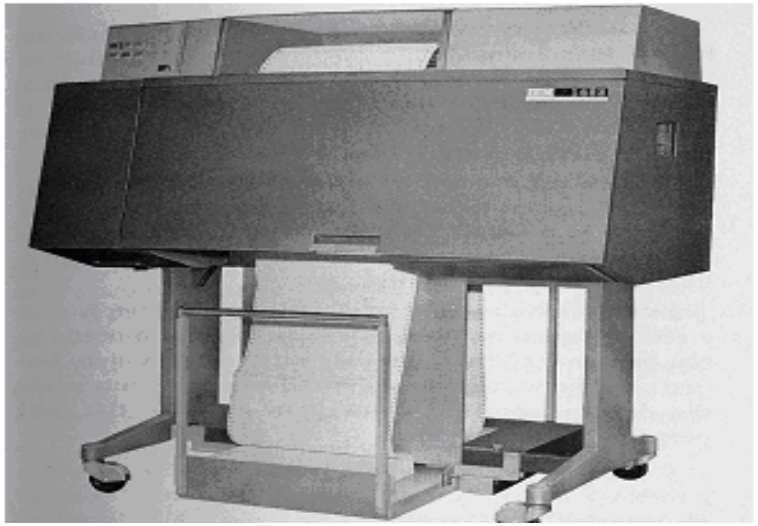
The IBM S/360 might be considered an early 3rd generation computer.

Some Line Printers

Line printers were used to print large volume outputs, typical of a data center. Here are two such printers, the IBM 716 and the IBM 1403.



IBM 716



IBM 1403

A Typical “IBM Shop” of the 1960’s

Seen here (at left) is an IBM 523 gang summary punch, which could process 100 cards a minute and (in the middle) an IBM 82 high-speed sorter, which could process 650 punched cards a minute.

Early IBM Product Lines

In 1960, IBM had four major “lines” of computers:

1) the IBM 650 line – a small, general purpose computer.

2) the IBM 701 line, for scientific computations.
   This had hardware for floating–point arithmetic, but not packed decimal.
   This includes the IBM 701, 704, 709, 7090, and 7094.

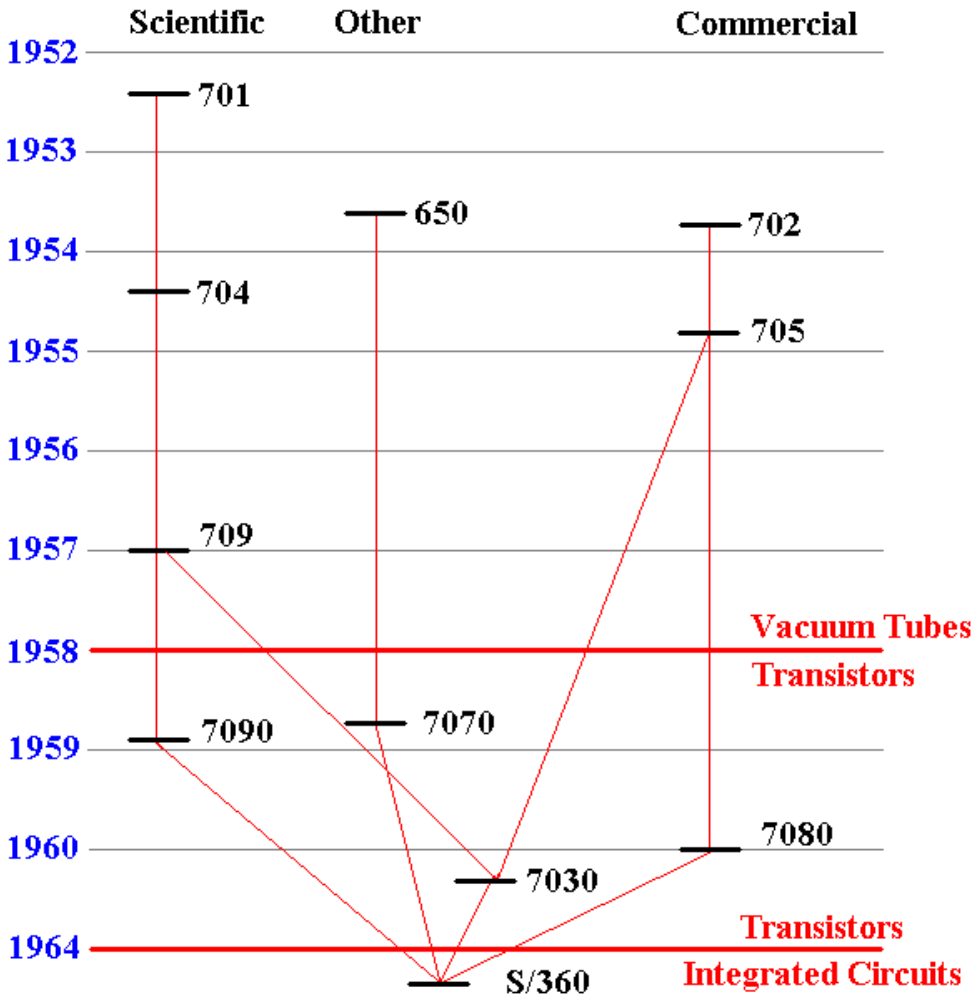
3) IBM 702 line, for commercial computations.
   This had hardware for packed decimal arithmetic, but not floating–point.
   This includes the IBM 702, 705, and 7080.

4) the IBM 7030 (Stretch).
   This was a research computer. It was not produced in volume.

The big issue is that none of these computer lines were compatible, either in the software sense or hardware sense.

Field technicians generally were trained for the 701 line or 702 line, but not both

The IBM S/360 “Family Tree”



This shows the chronological “descent” of the IBM S/360.

Some Design Goals for the System/360

Here are a number of goals for the system.

1. To replace a number of very successful, but incompatible, computer lines with a single computer family.
2. To provide “an expandable system that would serve every data processing need”. It was to excel at all “360 degrees of data processing”. [R11, p 11]
3. To provide a “strictly program compatible” family of processors, which would “ensure that the user’s expanding needs be easily accommodated by any model [in the System/360 family]”.

The System/360 was announced on April 7, 1964.

The first offerings included Models 30, 40, 50, 60, 62, and 70 [R49].

The first three began shipping in mid–1965, and the last three were replaced by the Model 65 (shipped in November 1965) and Model 75 (January 1966).

Strict Program Compatibility

IBM issued a precise definition for its goal that all models in the S/360 family be “strictly program compatible” [R10, page 19].

A family of computers is defined to be strictly program compatible if and only if a valid program that runs on one model will run on any model.

There are a few restrictions on this definition.

1. The program must be valid. “Invalid programs, i.e., those which violate the programming manual, are not constrained to yield the same results on all models”.
2. The program cannot require more primary memory storage or types of I/O devices not available on the target model.
3. The logic of the program cannot depend on the time it takes to execute. The smaller models are slower than the bigger models in the family.

> “Programs dependent on execution–time will operate compatibly if the dependence is explicit, and, for example, if completion of an I/O operation or the timer are tested”.

The Term “Architecture”

The introduction of the IBM System/360 produced the creation and definition of the term “**computer architecture**”.

According to IBM [R10]

> “The term ***architecture*** is used here to describe the attributes of a system as seen by the programmer,, i.e., the conceptual structure and functional behavior, as distinct from the organization of the data flow and controls, the logical design, and the physical implementation.”

The IBM engineers realized that “logical structure (as seen by the programmer) and physical structure (as seen by the engineer) are quite different. Thus, each may see registers, counters, etc., that to the other are not at all real entities.”

We shall see in another lecture that any specific logical structure may be supported by a number of physical implementations.

References

NOTE: The reference numbers in this set of slides are those from the original textbook. For that reason, they are out of order.

R_11 Mark D. Hill, Norman P. Jouppi, & Gurindar S. Sohi, Readings in Computer Architecture, Morgan Kaufmann Publishers, 2000, ISBN 1 – 55860 – 539 – 8.

R_10 G. M. Amdahl, G. A. Blaauw, & F. P. Brooks, Architecture of the IBM System/360, IBM Journal of Research and Development, April 1964. Reprinted in R_11.

R_12 D. W. Anderson, F. J. Sparacio, R. M. Tomasulo, The IBM System/360 Model 91: Machine Philosophy and Instruction–Handling, IBM Journal of Research and Development, January 1967. Reprinted in R_11.

R46 C. J. Bashe, W. Buchholz, et. al., The Architecture of IBM's Early Computers, IBM J. Research & Development, Vol. 25(5), pages 363 – 376, September 1981.

Web Sites of Interest

R_45 http://www–03.ibm.com/ibm/history/exhibits/

R_41 http://www.columbia.edu/acis/history/