IBM-604

Manufacturer	IBM
Identification,ID	IBM-604 Electronic Calculating Punch
Date of first manufacture	1948
Number produced	5600
Estimated price or cost	-
location in museum	-
donor	Robert Garner

Contents of this page:

Photo

- **IBM-604**
- Photo Photo by International Business Machines Corporation
- An advertisement for the IBM-604. Donated by Robert Garner.

Placard

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Architecture

Link to **IBM-604** - by Ron Mak

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from Bernard Palicki, February 2006

Dear Sir,

At age 75, am probably just one of a very few still alive who was employed by IBM as a 'Customer Engineer' (CE), in the IBM Data Processing Division, one who performed service on the IBM 604 Calculating Punch.

Hired into IBM on 1/15/53, after an honorable discharge from the US Air Force(AF) in Dec 1952.

Previous experience in the US Air Force was accepted as qualification for that employment. Previously served in the US Air Force as a Technical Instructor of 'Electronics Fundamentals' [2nd Phase - from AC & DC Circuit Analysis, through motors, generators, power supplies and filter ckts, vacuum tubes, amplifiers, oscillators and transient ckts],

Spent 12 days of training on the 604 in a Detroit, MI Branch Ofc. I worked out of the IBM Branch Ofc in Toledo, OH. Was sent for this training because I was being assigned to the accounting machine department of the 'Electric Auto-Lite Co. headquarters, in Toledo. OH, as 'resident' IBM CE for Auto-Lite.

Auto-Lite, at its peak, manufactured all the products required for all auto ignition systems for all Chrysler autos - Chrysler, Dodge, Desoto and Plymouth.
That office, for my assignment at Auto-Lite, processesd all accounts payable and receivable, plus payroll for some 7000 plus factory employees on a weekly basis.

Have a few vivid recollections you might want to have:

1. The IBM 604 contained some 2,000 vacuum tubes.
2. A total of 455 pentagrid converters (vacuum tubes) were required for the 'column shift register' , required for both multiplication and division. The 1st and 4th grids of these tubes were used to control the ON-OFF condition of these tubes.
3. The Counter was 12 digit positions. The 13th position was used to designate polarity of the number in the counters as + or -.
4. Five vacuum tubes were required for each of the 12 digit positions of the counter. Four tubes were required for each of the 'counter digit-position' numbers displayed, using 1, 2, 4 or 8 (the binary code - also known as the 'byte') for display of a number. The fifth tube was required to allow for binary code display of a number using four-tubes.

   The 'cut-off condition' of counter tubes was the number contained and displayed in the counter. A neon bulb was connected in parallel with each of the binary code tubes. of the counter When a counter tube was in a cut-off condition, in the OFF position, the neon bulb was lit.

5. Positive numbers were displayed as complements of 9; e.g., a positive 1 was displayed as 8, a positive 2 was displayed as 7, a positive 3 was displayed as 6, etc.

   All addition of positive numbers was done by additions of numbers as 'complements of nine'.
   All subtractions of numbers was done by addition of true numbers.
   Negative numbers were displayed as true figures.
   The 13th position of the counter indicated polarity (+ or -) of the number displayed by the counter.
   Other:
6. The IBM 604 employed what is known as 'parallel processing'; that is, all 12 positions of the counter were were transferred simultaneously to a storage unit, and/or vice-versa. The IBM 604 was the first commercially available electronic computer on the market.
7. The IBM 650 Magnetic Drum Calculator, successor to the IBM 604, was the first commercially available execution of 'serial processing' of number/numeric data, and was the forerunner of the personal computer. Also received training and service experience with the IBM 650 Magnetic Drum Calculator.

Would be pleased to hear from you with acknowledgement that you received this info and whether or not it any of it merits inclusion at your websight.

Very truly yours,

Bernard Palicki

Special features

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Historical Notes

Contents

Points of electromechanical interest,

- The IBM 601 Multiplying Punch, introduced in 1933, could multiply an 8 digit number by an 8 digit number, using special relays, in 6 seconds.
- The electromechanical ASCC (Harvard Machine, by IBM and Howard Aiken) demonstrated in 1943, was about twice as fast.

From the book **"IBM's Early Computers"** MIT PRESS, by Bashe, Johnson, Palmer, Pugh
pages 59 - 68

- electronic multiplier and the IBM 603
- IBM 604 Electronic Calculating Punch
- phase out of 603, increase clock to 50 KHz
- delivered in fall 1948
- standardized pluggable circuits
- improved manufacturability and repairability
- 3-dimentional saved space, volume
- minature tubes
- use of tubes as linear devices well established
- digital computers used tubes in an ON-OFF mode
- intermittent failures
- design a tube that would not fail
- new 6J6 tube
- gold plated grids
- IBM prototype tube manufacture
- other manufacturers became more responsive
- More than 5600 604s manufactured over 10 years
- 604 helped in success of Card-Programmed Electronic Calculator

2.4 The Type 604, an Electronic Workhorse

{ 5 paragraphs not included }

[Ralph] Palmer believed in involving his laboratory in experimental work on all devices and technologies that showed real promise for the electronic approach to calculation. As a result, this small nucleus of an electronics group began to experiment with a variety of techniques for electronic switching, counting, and storage. The group's first major assignment was one that would occupy most of its attention for several years and constitute an intensive experience in electronic product development. It had become evident months before announcement of the ***603 Electronic Multiplier*** *in September that a device able to calculate at electronic speeds was used to little advantage in a product of such limited function. All the machine was required to do was multiply one number from a card by another and present a result to be punched in the same card; it was capable of neither division nor cross-footing. Clearly, the electronic box in such a configuration ought to be able to do a great deal more than it was doing in the time available-the "card cycle" that corresponded to a*

feeding rate of one hundred cards per minute.

Reporting on the laboratory's September 1946 activities, McPherson said, "Mr. Palmer is redesigning the machine to include ***crossfooting and dividing*** *on a larger-capacity basis to replace the present machine within eight months after production begins. The result of this effort was the* ***IBM 604 Electronic Calculating Punch****, a machine on which considerable expectations for the future of the business were pinned and in which a corresponding amount of planning talent was invested. Assigned to the project from IBM world headquarters was Stephen W. Dunwell, who had returned from military service to IBM's Future Demands department in mid-1946. Dunwell had taken part in highly secret projects of the Army Signal Corps. Recalling those projects years later, he said, "I think they are forever classified." He also said of his and Palmer's closely related wartime work, "I feel sure that [Palmer] felt the same dismay and astonishment when he walked in and saw some of the things that had been done .... They often involved vast numbers of vacuum tubes . . . vast numbers of relays." Clearly, it had been a sobering experience to become suddenly immersed in secret data processing developments involving electronics, a technology to which IBM had not yet made a commitment. Partly, no doubt, because of their shared but never-to-be disclosed wartime experience, Palmer and Dunwell made a strong engineering and planning team. Dunwell contributed a great deal to the understanding of the new calculator's requirements and to evaluation of alternative solutions.*

Plans for the new machine progressed so rapidly that the ***decision was made to accept orders for no more than one hundred 603 multipliers****. The 603 had provided a set of basic circuit designs, which, with some improvements,* ***could be used in the 604****. The "clock" or basic timing signal frequency was increased from 35,000 to* ***50,000*** *cycles per second, so that more operations could be squeezed into a card-feeding cycle. And although additional versions of the flip-flop and the switching circuits were required in the more complex new machine, these were basically the circuits invented in 1941 and 1942 for the Endicott model cross-footer and multiplier and used in both the 603 and the SSEC.*

When the ***604 was first delivered in fall 1948****, no other calculator of comparable size or cost could match its capability. It could execute at least twenty, and optionally as many as forty (soon increased to* ***sixty), plugboard- controlled program steps each time a card was read*** *by the accompanying reader-punch and could suppress specified steps under control of input data or results of calculations. Division was included in its set of arithmetic operations, and the 604 was only the second product IBM offered with that capability. (The first was the 602, an electromechanical calculating punch introduced about two years earlier.) The 604 could hold thirty-two digits in "general" and "factor" storage units consisting of flip-flops,* *and was able to perform any sequence of arithmetic and data-moving operations that did not exceed program-step capacity or the time allocated within a card cycle." The 604 was not, however, a computer in the sense that word has acquired. It lacked the essential characteristic of a stored program; its program was bound to the reader-punch, operating within the time provided by that unit rather than directing input-output along with internal operations. In short, it was a punched-card calculator in the EAM tradition, with impressive new capabilities derived from the speed and flexibility of electronics.*

*In the 604, IBM had to face for the first time a number of problems whose solutions would be important to the computer industry as a whole: the **problems of manufacturing, testing, maintaining, and repairing an electronic machine to be produced by the thousands** and installed wherever punched-card machines were used for calculating. Ralph Palmer had wisely exerted great pressure on his engineers to hold the number of circuit types to the minimum that would permit an efficient system design. It is usually desirable to maintain **"standard circuit" control** (i.e., avoid the unnecessary proliferation of circuit types) in an electronic system in order to ensure predictable operation and minimize the time required for testing and servicing. And Palmer had hit on an idea that greatly increased the benefits to be gained from this element of design control: he theorized that if every vacuum tube and its closely associated resistors and capacitors were packaged separately in a **"pluggable unit," each such circuit could be tested before insertion into the machine**, and the manufacturing-test process could be greatly simplified.*

*The **604 pluggable circuit unit** was a fundamental contribution to the art of digital electronic equipment design, not only because it **improved manufacturing efficiency** but also because it increased the ." For customer engineers who had been trained and provided with tools to maintain electromechanical accounting machines, it was important to minimize the new requirements suddenly imposed by the arrival of the 604, with its all-electronic calculating unit that contained more than 1400 vacuum tubes. **It became a common servicing technique to "swap" pluggable units** as a simple and effective means of locating defective components. If the trouble moved to a new location along with the pluggable unit, then that unit was likely to be defective. If the trouble remained-for example, in a particular order of a counterwhen pluggable units were switched between columns, then something in the back-panel wiring or elsewhere in the machine was suspected of being faulty.*

*A noteworthy feature of the pluggable-unit mode of construction is that, for the first time, electronic machines were built to **occupy space efficiently in three dimensions instead of two** (figure 2.8). Such familiar products as television sets continued for fifteen years or more to be designed so that the vacuum tubes and other* *components were spread out over the two-dimensional surface of a metal chassis, occupying no more of the third dimension than was required by the height of a vacuum tube.* ***The 604 pluggable unit greatly increased the packing density of electronic equipment****; the idea was adopted, with appropriate evolutionary changes, for all subsequent calculators and computers developed by the company.*

The 604 used so-called ***"miniature" vacuum tubes****, which were* ***much smaller than the standard radio tubes*** *of the 603 and the SSEC. Because they had the advantage of compactness, which was especially important in mobile equipment, miniature tubes had undergone great development and rapid improvement during World War II. Both vacuum tubes and the so-called "passive" class of components-mainly resistors and capacitors, which did not amplify signals-required a great deal of further improvement in order to make the 604 a practical, successful product. The history of these improvements is extensive, but a few examples suffice to show the relationship between the newly emerging field of digital electronics and the well-established "radio electronics" industry of the late 1940s.*

Consider the vacuum triode, the three-element electron tube invented by Lee de Forest in 1906. From the day of its first application through years of improvement in design, materials, and fabrication, its main purpose had been to amplify-that is, turn weak signals into strong ones. To preserve the "shape" of the signal-maintain the proportionality of output to input signal as a function of time-it was necessary to operate the tube in a moderately conductive mode: neither cut off nor fully conducting. It could then be used as a ***linear amplifier, in which a small negative signal on its control grid decreased anode (or plate) current by an amount equal*** *to the increase that a positive signal of the same magnitude would produce. Many types of tubes were* ***designed, tested, and improved over the years with this operating mode as an important consideration****.*

In the case of vacuum tube flip-flops and switching circuits, on the other hand, the tubes had to be driven ***beyond their linear response range****-driven, that is, by signals so large as to force the tubes into either the fully conducting or the cutoff condition-in order to produce unmistakable* ***output voltages representing either 0 or 1****. Early digital circuit designers and tube manufacturers alike were* ***surprised to find that tubes often exhibited a degradation*** *in their ability to conduct current after being held in a cutoff condition for long periods of time with their cathodes heated as for normal conduction. This problem, which was alluded to in the description of the SSEC operation, was known as "****cathode interface resistance****. Its solution required careful analysis and improvement in cathode material, and it provides an example of setbacks engineers encountered in their attempts to turn radio tubes into computing elements. It was neither the first nor the most urgent problem that* *arose during the 604 project; indeed, until certain less subtle effects had been discovered and corrected, the one involving interface resistance went unnoticed.*

Some of the earliest problems-and some that demanded the ***most urgent attention****-revealed themselves through* ***intermittent failures****. A component in which an undesired open or short circuit occurs occasionally, for* ***perhaps a fraction of a millionth of a second each time****, might easily pass the tests required for use in radio or television circuits. The human eye, ear, and brain are insensitive to interruptions of such short duration. In a digital circuit, however, a single such mishap could cause a miscount of voltage pulses somewhere and an erroneous result. Again, the vacuum tube, a complex component to make, provides a good example. For years tubes had been manufactured under conditions of cleanliness and quality control adequate for radio or television components but quite unacceptable for the production of digital devices. As the quantities of vacuum tubes used in digital circuits increased, tube manufacturers came to recognize the need to revise their production methods, installing "clean rooms" for assembly and establishing a clean room mentality among employees.*

Miniature tubes had been chosen in order to minimize size, power consumption, and heat dissipation in the 604, which was to be used in an ordinary office environment. But the new tubes introduced some problems of their own. For example, the spacing between cathode and grid of one of the miniature types-the 6J6 twin triode-was so small that ***particles of conducting dust*** *or other loose material too small to be visible could bridge it, causing intermittent operation or outright failure. It became obvious to Palmer that the available tubes were neither satisfactory for digital calculator use nor likely to be improved by the manufacturers for a market as small as that for calculators. After a number of 6J6 tube failures, Palmer asked Haddad to explore the problem. Haddad built an elaborate tester in which the* ***vacuum tubes were rotated on a wheel and turned on their own axes in such a way as to test them in every possible spatial orientation, while being tapped regularly*** *by metal studs on rubber mountings outside the circumference of the wheel. The tubes were connected to test circuits during this grueling process, and as Haddad recalled many years later, "every single tube we put on that machine failed." Palmer asked him to* ***design a tube that would not fail****.*

Tube design was a specialty not included among the academic experiences of the typical electrical engineer, even one trained in electronic circuits. Haddad recalls that he went out and bought a copy of a new book on the design and construction of vacuum tubes and with the help of that textbook designed a ***6J6 replacement****. A good deal of the solution lay in reshaping the grid and plate structures and providing separate cathodes for the two triodes in each tube. (The 6J6 used a single cathode shared by both triodes.)*

The ***new tube was sufficiently better than the old one that General Electric was eventually persuaded to build it****.*

A comparable story can be told about the pentagrid switch tube, a miniature tube known as the 6BE6 used in the 604 in place of the pentode switch of the 603. The 6BE6 had been designed for mixing radio-frequency signals in a superheterodyne receiver. As the tube was used in the 604, secondary emission from certain of the grids, due apparently to their ***contamination during manufacture****, caused loss of control of the voltage on those grids.* ***Gold plating the offending grids was found to be the solution****, and RCA finally agreed to manufacture the corrected tube. While these and other tubes were being analyzed and eventually replaced by improved types, Haddad, Phelps, and several other IBM engineers spent many days each month at the factories of the tube manufacturers.*

Considering the critical importance of tube quality to the reliable operation of digital circuits, it would seem that ***IBM might have decided to manufacture its own vacuum tubes****, just as it had manufactured most of the components of its electromechanical machines. Indeed, at an early stage in production of the 604,* ***Palmer set up a tubemaking laboratory in a building known as the "pickle factory,"*** *located on the east bank of the Hudson River just below the Poughkeepsie IBM factory. (This building was one of those on a parcel of land purchased by IBM in 1941 from the R. U. Delapenha Company, food packers.) In view of the difficulty of obtaining usable tubes from manufacturers of radio tubes, Palmer thought it important at least to demonstrate that they could be produced, given* ***proper attention to design details and proper care in manufacture****.*

IBM management was not inclined, however, to go into full-scale production of tubes*. The electronics industry was already well populated with manufacturers of radio tubes. RCA, Sylvania, CBS Hytron, General Electric, and Tungsol-to name only a few-each produced many millions of tubes every year. It was questionable that IBM had anything to offer in the manufacture of vacuum tubes that would make such a venture profitable. But the facility for turning out even small quantities of tubes permitted laboratory representatives to approach the regular tube manufacturers with convincing samples, rather than mere designs on paper, of the higher-quality tubes IBM was asking for. Directly or indirectly, the tube laboratory seems to have had the desired effect. One manager of that facility recalled that, when* ***"word leaked out that we were doing something mystical in vacuum tubes," several of the large tube manufacturers became much more responsive."*** *As it turned out, other benefits were derived from the tube laboratory. At about the time it had* ***served its original purpose in ensuring a supply of good triodes and switch tubes****, it was found to be a valuable facility in which to experiment with special counting and storage tubes, and in particular to improve the cathode-ray tube for use as a largecapacity storage device (discussed in chapter 4).*

The 604 (figure 2.9) was manufactured in quantities of over a thousand per year in some years, and more than 5600 were built over a ten-year period. *There is no question that its development and success in the marketplace enhanced the ability of IBM engineers to cope with the demands of the dawning age of computers. It introduced a remarkably useful pluggable circuit package, along with a set of standard circuits whose simplicity and versatility would help to promote design standardization in later projects, and broke the ice for acceptance by the marketing and service departments of widely distributed electronic calculating machines. Finally, by encouraging manufacturers to develop computer-grade tubes, the 604 program made a significant contribution to computer development in IBM and elsewhere.*

2.5 The Card-Programmed Electronic Calculator

The 604 was to play a part, too, in a system that helped IBM and its customers significantly in the transition from calculating machines to computers. The background of ideas that culminated in the machine's use in such a system may be traced back to at least two years before the introduction of the 604.

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and from a discussion of "**cathode interface resistance**" from http://www.geofex.com/Article_Folders/mandt.htm

"CATHODE INTERFACE RESISTANCE
In many vacuum tubes there develops with use a cathode interface layer between the base metal of the cathode and the active emitting surface of the cathode ... The interface compound is a semiconductor compound formed as a result of the chemical interaction between the oxide-emitting material and the base metal or with some reducing constituent of the base metal. The resistance of the interface layer may lie in the range from several ohms to several hundred ohms and may therefore have an appreciable influence on tube operation. ...

Interface resistance is present to some extent in all tubes with oxide coated cathodes but is usually particularly pronounced in tubes whose cathode base material contains a ***large amount of silicon****.*

From Lloyd Hubbard Here is an anecdote on a computer that I haven't found on any WEB pages:

In or around 1948, Rex Rice, Bill Woodbury and Greg Tobin of Northrop Aircraft had wired together an IBM tabulator and multiplying punch for use in some engineering computation. They subsequently convinced IBM to produce the Card Programmed Calculator in 1950. The CPC has been well documented in computer history.

But later, at Northrop's urging, a subsequent plugboard programmed "ELECTRONIC CPC" was built in Poughkeepsie by IBM's Truman Wheelock and delivered to Northrop in 1953. It emulated the old CPC but used vacuum tubes, not transistors. (Wheelock distained solid-state devices as unreliable--he even used vacuum tube diodes.) Since the CPC used relays and mechanical counters, the new machine was much faster. It was appropriately named the "WOODEN WHEEL" (WOODbury, TobEN and WHEELock).

At the time, IBM engineering was very interested in microprogramming as a means of extending a single instruction set across computers of different speeds and capacities. I had just been transferred to a new "Product Planning" group in Poughkeepsie, but was given a temporary assignment to Northrop to learn the Wooden Wheel's approach to microprogramming via a plugboard. A big internal battle ensued at IBM on the relative virtues of wired vs. software implemented microprogramming. For good and valid reasons, the software approach won and that was the starting point of the design for System/360 architecture.

The Wooden Wheel was eventually returned to IBM and in 1959, donated to the Engineering College at UCLA.

Lloyd Hubbard

This Artifact

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Interesting Web Sites

- University of Amsterdam Museum, 604
- Ballistic Research Lab, 1961 Report
- IBM Archhives
- a user's viewpoint
- Dr. Dobb's Journal article

Other information

- **IBM 604 Principles of Operation** - all 72 pages
- **IBM 604 Operation Manual** - 1st 13 pages

If you have comments or suggestions, Send e-mail to Ed Thelen

Go to Antique Computer home page
Go to Visual Storage page
Go to top

Updated December 24, 2002