The Selectron -- A Tube for Selective Electrostatic Storage

We are engaged at the RCA Laboratories in the development of a storage tube for the inner memory of electronic digital computers. This work is a part of our collaboration with the Institute for Advanced Study in the development of a universal electronic computer. The present note describes briefly the principle of operation of the tube, which is still in its experimental stage. It is a summary of a paper presented at the "Symposium of Large Scale Calculating Machinery" at Harvard University on January 8, 1947; see *MTAC,* v.2, p. 22~238.

The necessity of an inner memory in electronic digital computers has been realized by all designers. The high computing speed possible with electronic devices becomes useful only when sufficient intermediary results can be memorized rapidly to allow the automatic handling of long sequences of accurate computations which would be impractically lengthy by any other slower means. An ideal inner memory organ for a digital computer should be able to register in as short a writing time as possible any selected one of as many as possible on-off signals and be able to deliver unequivocally the result of this registration after an arbitrarily long or short storing time with the smallest possible delay following the reading call.

The selectron is a vacuum tube designed in an attempt to meet these ideal requirements. In it, the signals are represented by electrostatic charges forcefully stored on small areas of an insulating surface. The tube comprises an electron source which bombards the entire storing surface. The insulator can be a circular cylinder coaxial with a standard thermionic cathode. Between the cathode and the storing surface there are two orthogonal sets of spaced parallel metallic bars, which form a checkerboard of windows creating the corresponding small storing elements on the insulating surface. In the cylindrical structure one set is formed by rings and the other by straight bars spaced angularly around the cylinder. These bars are insulated from each other, making it possible to apply positive or negative potentials to them and thereby to stop the flow of electrons through all windows except a desired one. Between the selecting structure and the insulating surface is the collector, a gridlike unipotential electrode. The insulating surface is backed by a metal plate called the capacity plate. The operation of the tube consists of assigning selectively an element of surface for each incoming signal, storing the signal-information on that element, and subsequently detecting the stored information identified by its previously assigned location. The selecting and storing mechanisms will now be described separately.

Consider one of the sets of selecting parallel bars. Electrons will pass between two adjacent bars when they are both at the same positive potential with respect to the cathode. On the other hand, if both bars are substantially negative, the electrons will be blocked by a negative potential barrier in front or in the gate formed by wires. When one bar is positive and the adjacent one negative, electrons will also be stopped, provided the geometry of the bars and voltage levels are properly chosen. It is clear, therefore, that if another set of parallel bars is placed at right angles behind the first, electrons will pass through a window limited by two pairs of bars only if all four bars are positive. For a large checkerboard of windows, the number of control voltages and consequently the number of leads to be sealed through the vacuum envelope would be very large if each bar had to be controlled separately. However, this is not necessary, because the fact that a coincidence of both limiting bars is necessary for the opening of a gate makes it possible to connect internally the bars of any one set in groups and control only the potential of a relatively small number of groups. Single positive wires surrounded by negative ones do not open any gates and, therefore, can be connected to the wires of the selected open gate. There are many connection systems solving the combinatorial problem of how to group the elements of each row such that each group contains one element neighboring with an element of each of the other groups, once and once only. As an example, in a system used in some experimental tubes, there are 64 selecting bars in each direction, connected in 16 groups of 4 each. These groups are divided into two families identified by 1, 2, 3, 4, 5, 6, 7, 8 and 1', 2', 3', 4', 5', 6', 7', 8'. The enumeration of the bars according to the group to which they belong is as follows: 1, 1', 2, 2', 3, 1', 4, 2', 5, 1', 6, 2', 7, 1', 8, 2'; 1, 3', 2, 4', 3, 3', 4, 4', 5, 3', 6, 4', 7, 3', 8, 4'; 1, 5', 2, 6', 3, 5', 4, 6', 5, 5', 6, 6', 7, 5', 8, 6'; 1, 7', 2, 8', 3, 7', 4, 8', 5, 7', 6, 8', 7, 7', 8, 8', from which it is apparent that each non-primed group has an element neighboring with an element of every primed group once and once only. In this example, 16 + 16 = 32 sealed leads control 64 X 64 = 4096 elements. More efficient combinatorial systems are possible, particularly with several successive sets of bars in each direction. Anyhow, the number of necessary seals in the indicated system for which N leads control $(1/4\ N)^4$ elements is relatively so small that it presents no technological limitation even for many elements (e.g., 128 seals can control 1,048,576 elements).

The storage mechanism is based on the fact that an insulating surface exposed to electron bombardment will assume naturally one or the other of two stable equilibrium potentials for which the net electron current will be zero, the cathode potential for which electrons cannot reach the surface for lack of energy or the potential of the collector for which the primary and resulting secondary electron currents are exactly equal. These equilibria are stable because any potential deviation, as could occur from imperfect insulation, for example, results in stabilizing' electron currents of a direction proper to bring the surface back to equilibrium. The potential of the collector, the electrode determining the potential gradient at the target surface, may be several hundred volts. It must be sufficiently high for the intrinsic secondary emission ratio to be greater than one. When all the surface of the insulator is bombarded, some elements of surface can be stably maintained at the high collector potential, while others are simultaneously maintained at the low cathode potential. This is an ideal condition for the quiescent state of the memory tube in its stand-by condition. It can be obtained by the simple expedient of making positive all the selecting bars and thereby opening all the windows. The pattern of the equilibrium potentials is "written" into the tube, one element at a time, by closing momentarily all windows except a chosen one and overpowering the electron current locking mechanism remaining on the corresponding element by a displacement current resulting from a voltage pulse applied to the backing capacity plate. The polarity of the pulse is made to depend on the on-off signal assigned to that element and determines to which of the two stable potentials the element will be driven. The "reading," also one element at a time, is obtained by closing momentarily all windows except the one identified by its previously assigned location in the tube and detecting at which of the two potentials the element finds itself. This detection can be by means of a displacement current or with special targets, by a direct electronic current. Another method, convenient for monitoring in any case, consists of coating the insulator with a cathode-luminescent material and making the backing capacity plate semitransparent. Clearly, light will be produced by electron impact for the high but not the low equilibrium potential. This signal can easily be detected and amplified by a multiplier photo-tube viewing the whole storing surface. It is apparent that this method of storage provides for an indefinite storing time, for writing without previous erasing, and repeatable readings.

The tentative engineering characteristics of the selectron tube which we are engaged in developing are: Size from 3 to 4 inches in diameter, 4 to 6 inches long, 50 lead stem, capacity of several thousand elements; and writing and reading times of about 30 microseconds. A greater storage capacity can be compounded by using a number of tubes. It is convenient to use as many selectrons as there are basic binary places in the computer, or in nonbinary machines as many as on-off signal channels, and to connect the selecting control leads in parallel and operate all writing and reading channels simultaneously.

JAN A. RAJCHMAN

RCA Laboratories