Rod Memory Array Production Design

DONALD L. BEHRENDT, ASSOCIATE MEMBER, IEEE

Abstract—Applications of thin magnetic films in random-access memories of digital computing systems have received considerable attention recently because of their potential speed advantages. The necessity for using hundreds of thousands, or even millions of these elements in a single computer dictates that careful attention be given to cost. This paper describes the production design package for a thin-film, 20 000-word rod memory array that offers nanosecond switching and reasonable fabricating cost. Rod fabrication and solenoid plane fabrication are discussed in Sections II and III. Solenoid plane assembly, rod insertion, electrical connections, and final assembly are described in Sections IV through VII, respectively.

Additional Key Words for Information Retrieval—automatic coaxial winding, electrodeposition of cylindrical magnetic films, semiautomatic winding machines.

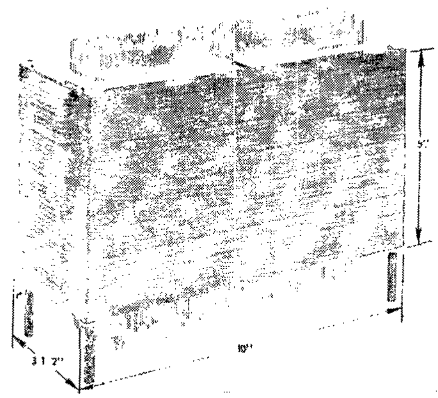

Fig. 1. Rod memory module.

I. General

THE ROD consists of a cylindrical film of magnetic material, electrodeposited on a conductive substrate.[1]–[3] The substrate can be silvered-glass cane or, as presently used, a beryllium-copper wire. Composed of 97 percent iron and 3 percent nickel, the magnetic material is approximately 4000 angstroms in thickness. The cylindrical structure of the rod facilitates the use of multiple-turn windings, which minimize the usual problems associated with thin magnetic films. Also, the cylindrical shape allows for tight coupling between windings and magnetic material. Thus, large switching fields can be provided with reasonable currents and small inductances. Because the rod is adapted to three-dimensional winding fabrication, windings can be organized to minimize crosstalk problems in high-density memories.

A 20 000-word rod memory is composed of eight modular units. A typical module, shown in Fig. 1, is composed of 40 solenoid planes and 1056 rod elements. Each solenoid plane contains 16 rows of 66 serially connected solenoids, spaced on 1/8-inch centers in each of the three-dimensional planes.

The module organization described provides a packing density of 512 bits per cubic inch, excluding the solenoid frames. Each word in the memory is 13 bits long, including the parity bit; thus, each row or line consists of five words and a spare bit. Spare bits are provided by using only 14 of the 16 rows of each plane or module. When required, these spare rows can be used with additional circuitry as a small auxiliary or scratch-pad memory.

II. Rod Fabrication

An important advantage of the rod is the continuous automatic fabrication and test procedures which are employed. Two automatic processing phases are employed in the manufacture of the rod. The first phase consists of plating and testing. In the second phase, a ribbon helix winding is applied, the rods are tested magnetically, and the rod is cut into the required lengths.

A. Plating

The rod plating process[4] is performed in a closely spaced series of small, rectangular tanks as shown in Fig. 2. The beryllium-copper substrate material is stored on a large-diameter reel at the beginning of the plating line. Two contacting rollers, one of rubber and one of copper, draw the wire from the reel and guide it through carefully aligned, small holes in the ends of each tank. Because leakage through the small holes occurs at a negligibly small rate, only occasional readjustment of the solution levels is necessary. The copper feed roller also provides electrical contact with the wire for the subsequent electrolytic processes.

The first and second tanks contain a hot alkaline cleaner. In the second tank, electrolytic cleaning is also employed by using the wire as a cathode, so that hydrogen gas is vigorously evolved.

After passing through tanks of running water, the wire is passed through an acid solution which removes oxide and slightly etches the surface. The wire is again washed and plated with an approximate 97 percent iron and 3 percent nickel alloy from a carefully regulated iron-chloride nickel-chloride (modified Fischer–Langbein[5]) plating solution.

B. Testing

After the final washing, the plated wire is passed through a magnetic test fixture, which provides a record on a strip chart recorder of the total magnetic flux and

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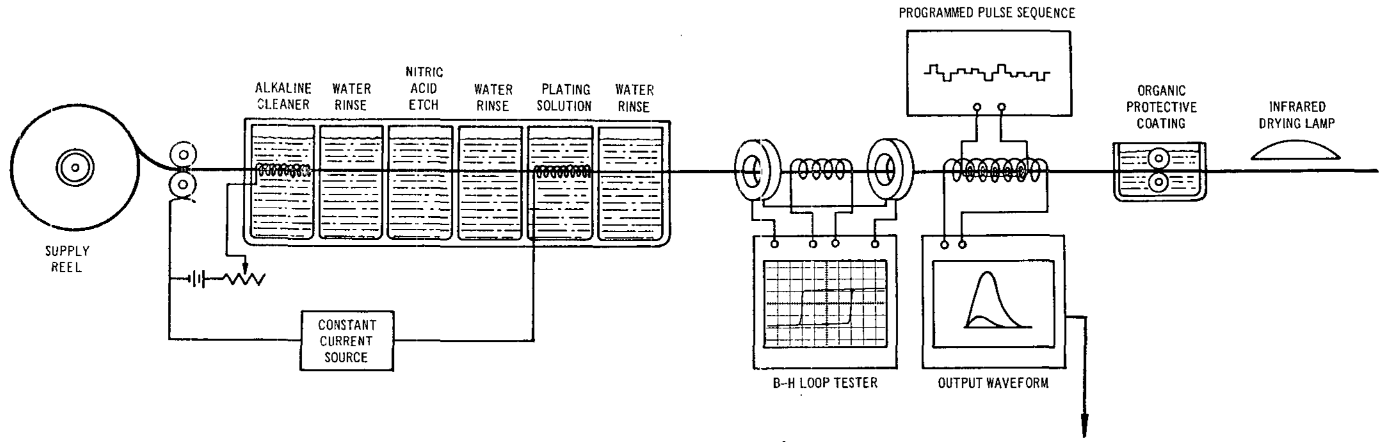
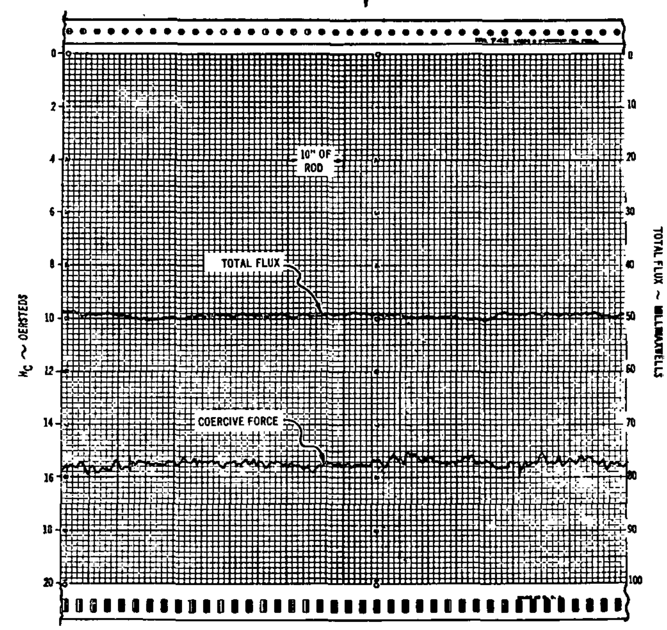
The author was with the Electronics Division, National Cash Register Company, Hawthorne, Calif. 90250. He is presently with Spectrol Electronics Corporation, City of Industry, Calif. 91745.





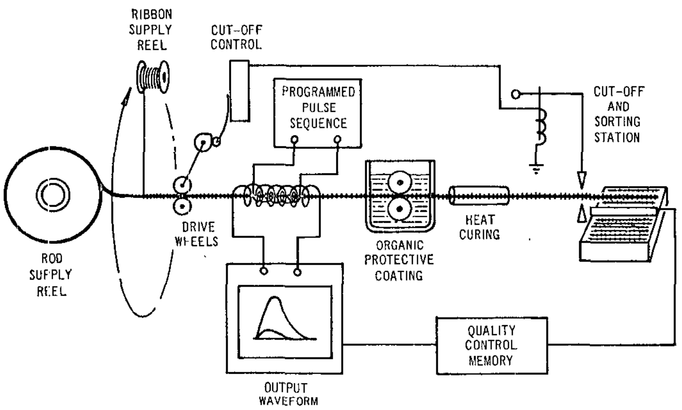


Fig. 3. Automatic coaxial winding line.

Fig. 2. Continuous rod plating process line.

the coercive force measured at 40 kilocycles. A chart recording of a typical section of the rod tested is shown in Fig. 2. The output of the test fixture is also displayed as a hysteresis loop (see Fig. 2) on a cathode-ray oscilloscope. The rod then passes through a machine that applies a corrosion-inhibiting coating. The coating is dried in a series of ovens and the plated rod is rewound on a reel, identical to the supply reel.

C. *Automatic Coaxial Winding*

After plating and testing, the wire is placed on the continuous winding machine (see Fig. 3) for the second phase of rod fabrication. As the plated wire is drawn through the winding head by the drive wheels, a uniform helix of flat copper ribbon wire is applied. The wound rod then passes through a magnetic test fixture. The output of this fixture controls quality selection at the mechanical cutoff and sorting station. Between the testing station and the cutoff sorting station, the wound rod passes through a machine that applies a protective plastic coating. The coating is dried in a continuous oven before the rod reaches the cutoff station.

III. Solenoid Plane Fabrication

The solenoid plane[6] consists of a narrow plastic frame with rows of small, serially connected solenoids encapsulated inside this frame. The tolerance problem in producing the solenoid planes is complex in that it is desirable to avoid any mechanical strain on the rods after assembly. There are 1056 solenoids in each plane and 40 planes are stacked together for insertion of rod elements. Each rod element passes through 40 solenoids and each solenoid is in a different plane.

A. *Automatic Winding*

The solenoid planes are wound on an NCR automatic multiple coil winding machine (see Fig. 4). This machine consists of a gear-driven motion table and an indexing carriage. Wire supply bobbins are mounted in a separate drive system above the motion table. The individual wires are passed through guides to the needle-tube bar, suspended over the motion table and carriage. A solenoid plane frame is fastened to a stripper plate by means of machine screws. The stripper plate and frame are placed

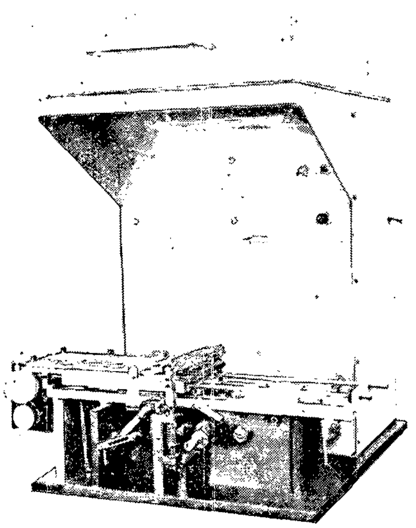


Fig. 4. Automatic coil winding machine.

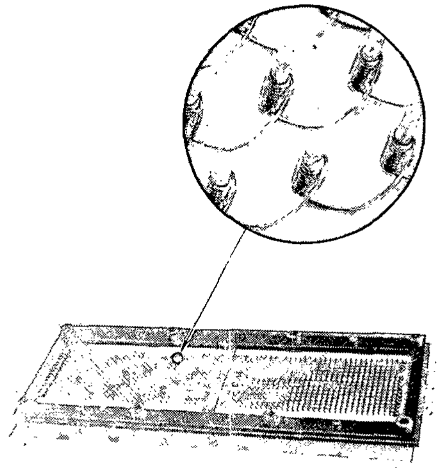


Fig. 5. Solenoid plane windings.

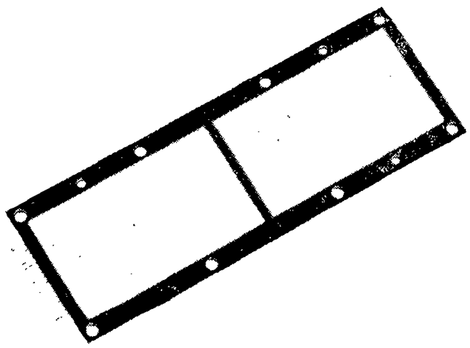


Fig. 6. Encapsulated solenoid plane.

on the winding pin jig and secured by additional machine screws. The needle bar is raised manually to clear the frame, and the assembly is positioned on the carriage.

After installing the assembly, the operator places the winding machine in operation. Sixteen solenoids are wound simultaneously by feeding the wire through the small fixed needle tubes, and by rotating a row of pins on the winding jig around the needle tubes. When the machine has made the required number of turns, the motion table pauses; the carriage indexes to the next row and the machine repeats the operation. The entire plane of 1056 solenoids is wound in approximately 1½ minutes. The machine is automatically stopped when the plane is completed. The operator raises the needle tube bar manually and removes the winding jig assembly. The machine operator is now ready to start a new plane, using another jig. Fig. 5 shows a completed plane prior to encapsulation.

B. Termination

The first and last coils of each string of solenoids are wound around the specially formed terminal pins molded into the frame. The combination of molded terminals and machine termination of the wire provides considerable man-hour savings in the fabrication of memory planes.

C. Encapsulation

On completion of coil winding and termination, the solenoid plane is ready for encapsulation with Eccofoam PT. Eccofoam PT is one of a series of pack-in-place foams, consisting of very small, hollow glass spheres covered with a heat-activated epoxy resin. A spatula is used to pack the foam material into the open cavity of the completed frame. A hydraulic press is used to tamp the packed material to eliminate voids. An ejector tool is used to separate the winding pin jig from the stripper plate and encapsulated plane. After separation, the winding pin jig is ready for use in another assembly and winding cycle.

D. Curing and Finishing

The encapsulated plane, still attached to the stripper plate, is placed in the oven to cure. Upon completion of the cure cycle, the plane is removed from the oven and a very thin coat of epoxy or acrylic resin is sprayed on the surface for sealing. When this film is dry, the plane is removed from the stripper plate and the reverse side is also sealed. After both sides have been sealed, the plane is ready for inspection and assembly. A completed solenoid plane is shown in Fig. 6.

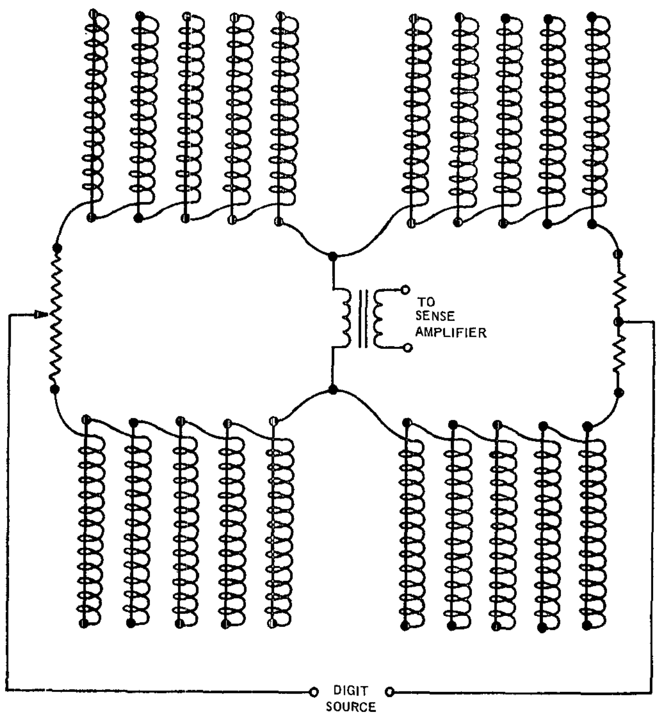


Fig. 7. Digit-sense plane.

E. Jig System

The jig system was designed around the encapsulation technique. The number of stripper plates is large in comparison to the number of winding pin jigs. The winding pin jigs are in constant use while some stripper plates are in the oven. In this manner, the maximum utilization of the expensive portion of the jig system is obtained. Interchangeability is achieved through use of a hardened steel master template for the fabrication of all parts.

IV. Solenoid Plane Assembly

A group of 40 planes are stacked together and alignment pins are inserted in the proper places. The stack is clamped lightly with threaded studs through the frames, and then placed on an inspection light fixture to check alignment and clearance of all holes. After inspection, the upper interconnection plate is assembled to the stack of solenoid planes.

V. Rod Insertion

Rod elements are inserted individually from the bottom of the solenoid plane stack. Because of the relatively uniform winding on the rod and the continuous magnetic film, precise longitudinal positioning tolerances of the rods within the solenoids are not necessary. When all the rods are in place, the lower protective cover is fastened to the stack.

VI. Electrical Connections

To minimize inductive coupling between digit planes, the helical solenoid digit-sense winding segment is dip-soldered to the Be-Cu substrate on one end, thus forming a return path for the current through the substrate.

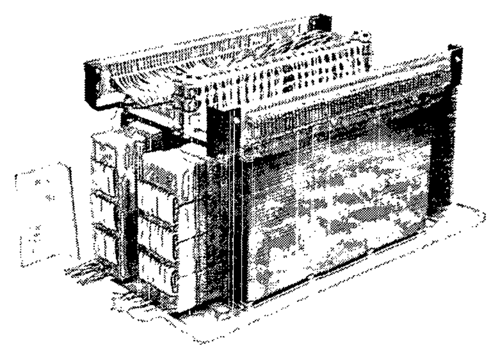


Fig. 8. 5000-word memory block.

Windings are stripped back from the remaining end of the rod and the substrate is trimmed to proper length. The end of the substrate is tinned, using a special flux and a fine-pointed soldering iron. The ribbon from the adjacent rod in the digit plane is wrapped around the tinned end of the substrate and soldered to the substrate. This process is repeated until all digit planes are completed. Fig. 7 is a schematic of a digit-sense plane.

VII. Final Assembly

Two 40-plane stacks are interconnected to form a 5000-word memory block. Fig. 8 shows two stacks mounted on a common bracket, with read–write isolation diodes attached. The sense transformers and bias resistor boards are mounted on top. The assembly is completed and ready for installation into a frame with card cages for driving circuitry.

VIII. Conclusions

An ideal memory element not only should be of small size, but also should possess the following characteristics:

1) Compatibility with other system components.
2) Easy fabrication with appropriate process control and economy through a continuous fabricating and testing procedure.
3) Semiautomated operation in assembly.
4) Insensitivity to environment.
5) High-speed operation.

The rod cylindrical thin-film approach meets these requirements. A continuous electrodeposition and testing technique for fabrication of rod elements, in combination with semiautomatic winding machines, can result in an economically produced memory array. The rod and solenoid planes are fabricated from inexpensive materials and are stable with respect to environmental conditions. Packing densities and propagation delay times for the rod cylindrical film approach to memory design are sufficient for the design of an efficient, high-speed memory of relatively large capacity.

The ultimate speed of the cylindrical film rod approach to high-speed memories has not been determined. However, investigations have indicated that it is possible to achieve units with a packing density of 4000 bits per cubic inch, with slight modifications to present machinery and processes.

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Donald L. Behrendt (A '61) was born in Toledo, Ohio, on April 22, 1926. He received the A.A. degree in engineering from Compton College in Compton, Calif., in 1948. He has attended the University of Southern California, Los Angeles, and is presently attending California State College at Long Beach, Calif.

From 1951 to 1957 he worked on missile guidance equipment at Autonetics Division of North American Aviation, Anaheim, Calif. From 1957 to 1961 he worked on military computer equipment at the Ground Systems Group of Hughes Aircraft Company. He then worked at the Electronics Division of National Cash Register Company, Hawthorne, Calif., on the 315 RMC computer system, and was Group Leader of the Microelectronic Circuit, Device and Packaging Research Group. He is presently Supervisor of Cermet Development Laboratory of Spectrol Electronics Corporation, City of Industry, Calif.

Mr. Behrendt is a member of the Association for Computing Machinery, the American Ceramic Society, and the International Society for Hybrid Microelectronics.