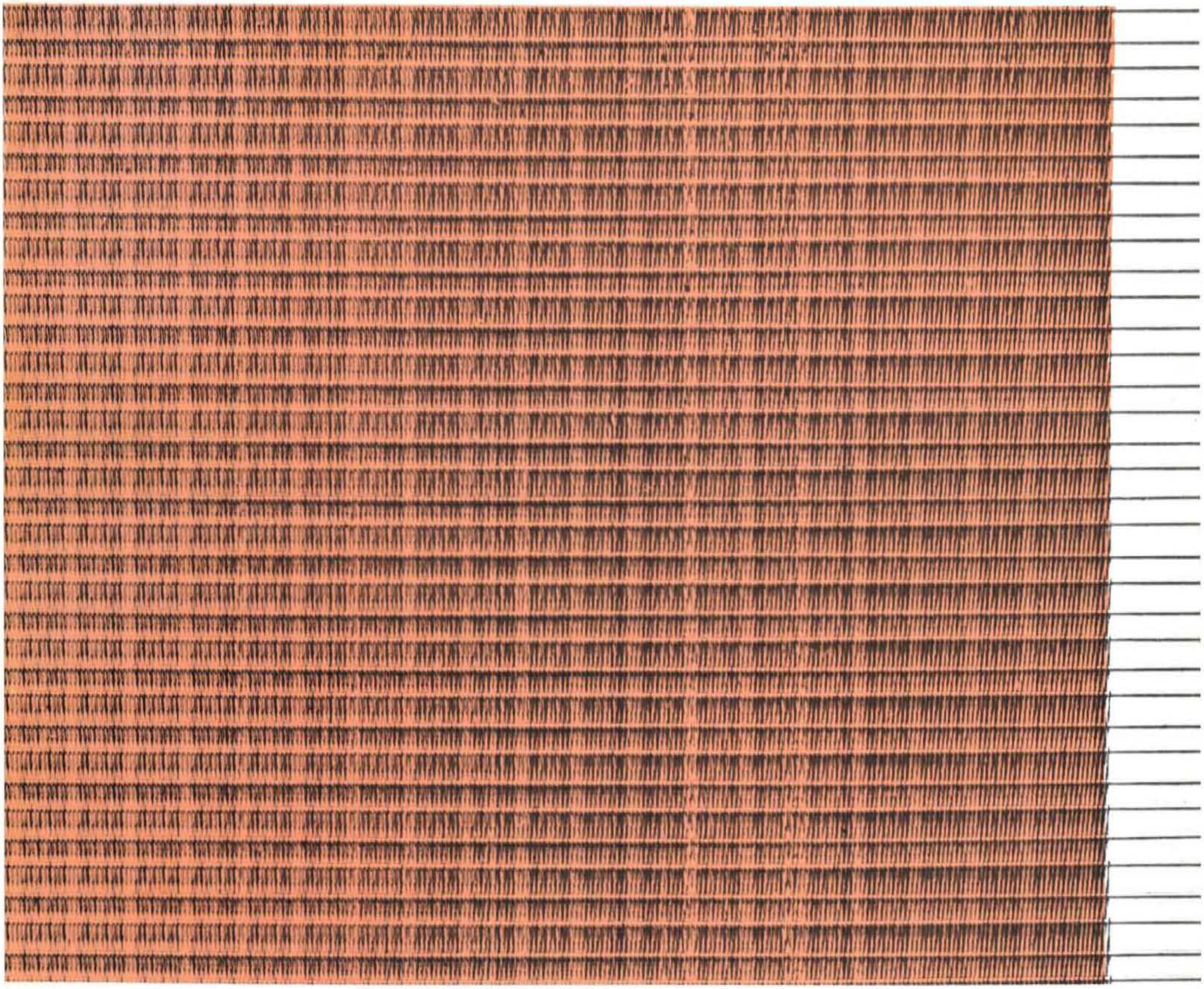
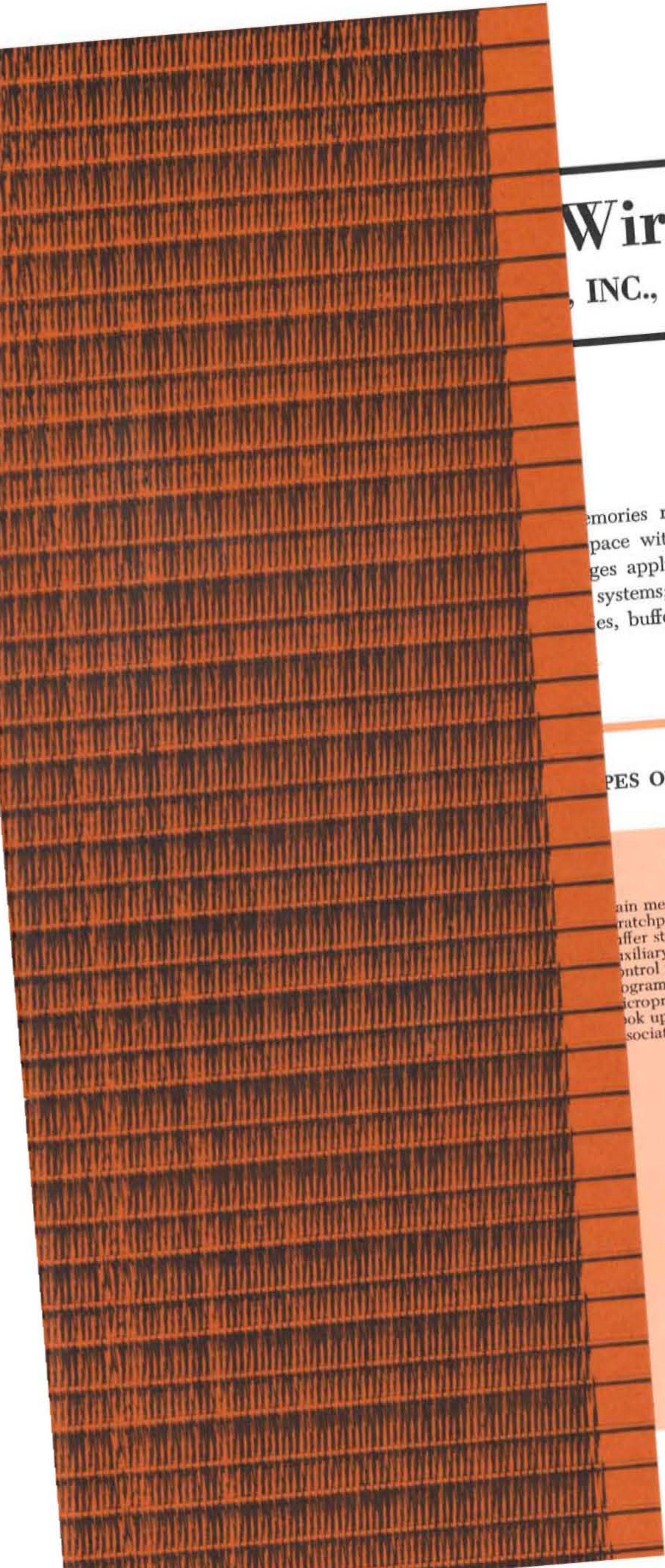
Woven Plated Wire Memories

GENERAL PRECISION, INC., LIBRASCOPE GROUP





Wire Memories

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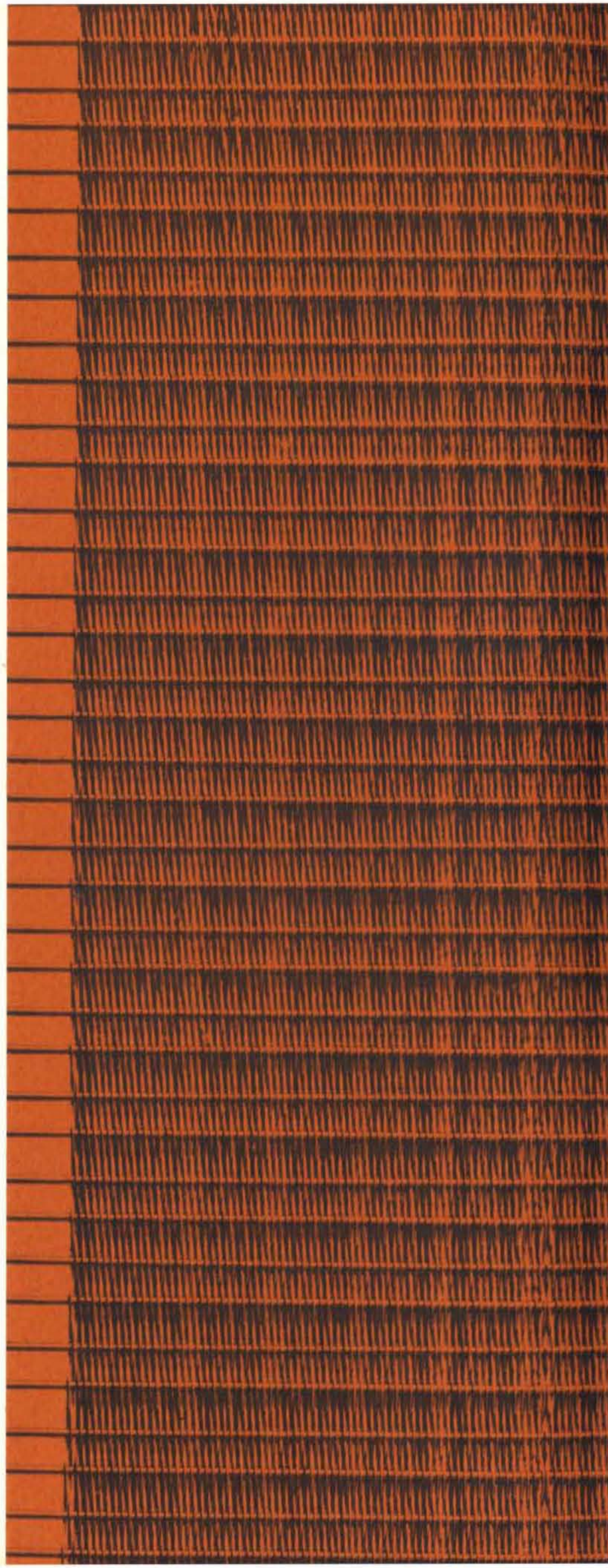
APPLICATIONS

- Airborne.
- Spaceborne.
- Shipboard.
- Ground-based.
- Mobile.
- Fieldable.
- Military.
- Industrial.
- Commercial.
- Scientific.



Woven Plated Wire Memories

GENERAL PRECISION, INC., LIBRASCOPE GROUP

Librascope's Woven Plated Wire Memories represent a breakthrough in memory-system technology, keeping pace with the requirements of new-generation computers. Their advantages apply equally to large and small computers; to military and commercial systems; and to use as main memories, scratchpad memories, control memories, buffer memories, or supplemental memories.

ADVANTAGES

- Ultra high speed operation:
  100 nanosecond, NDRO, full cycle.
  250 nanosecond, DRO, full cycle.
- Nondestructive readout (NDRO) or destructive readout (DRO) operation.
- Low power consumption.
- Low cost resulting from automatic machine fabrication, and from inherent characteristics of the memory.
- High bit density.
- Small size.
- Light weight.
- Inherently high environmental resistance.
- Temperature range −54 to +125°C.
- High reliability.
- No self-heating of memory elements.
- Automatic woven fabrication on programmable machines.
- Four functional organizations available:
  Linear select.
  Coincident select.
  Read-only, electrically alterable.
  Read-only, permanently woven.

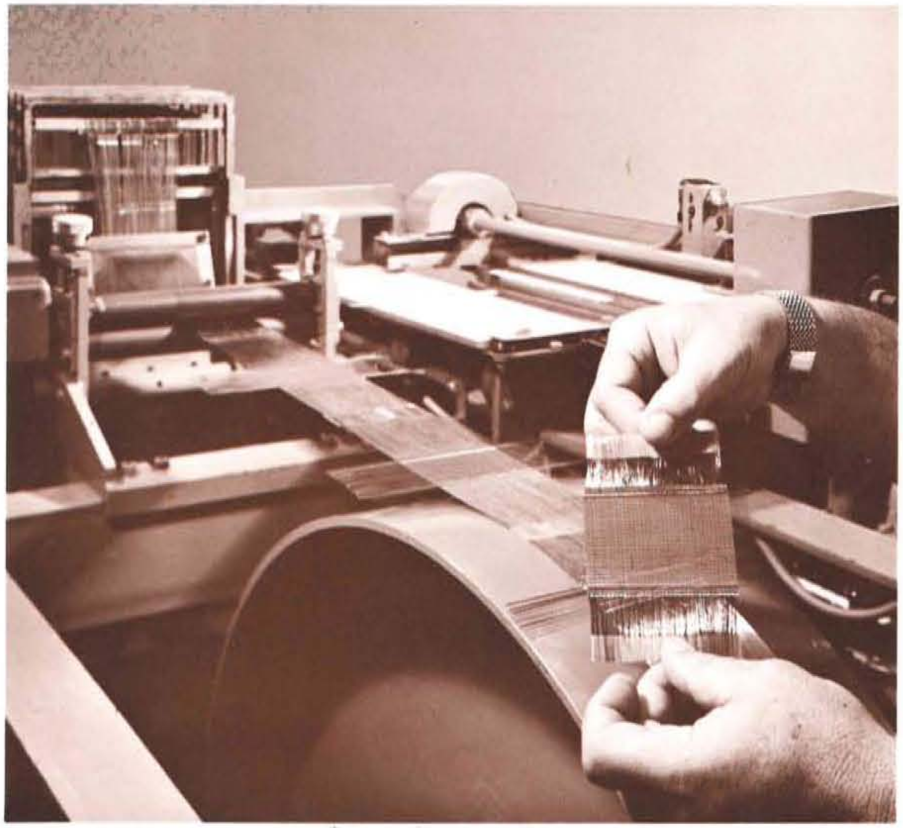
TYPES OF MEMORIES

- Main memory.
- Scratchpad memory.
- Buffer storage.
- Auxiliary memory.
- Control memory.
- Program and instruction memory.
- Microprogram memory.
- Look up table memory.
- Associative memory.

APPLICATIONS

- Airborne.
- Spaceborne.
- Shipboard.
- Ground-based.
- Mobile.
- Fieldable.
- Military.
- Industrial.
- Commercial.
- Scientific.

General Description



Woven plated wire memory matrix automatically fabricated at Librascope.

Basic element of a Librascope Woven Plated Wire Memory is the memory matrix, a cloth-like array woven of fine copper wires. The wires are woven on a large automatic loom, designed especially for this purpose; an economical and reliable method of construction that eliminates hand assembly.

The Librascope Woven Plated Wire Memory's storage medium is magnetic film on plated wires. These wires are intersected with insulated wires, which are interconnected to form word coils. A bit of information is stored at each intersection of a word coil with a plated wire, its binary value represented by the direction of its magnetic vector.

By varying the number and size of wires running in either direction, the matrices can be woven with specific electronic and physical characteristics. Thus a matrix can be matched to the requirements of the particular application.

To produce a memory of the required size, matrices can be stacked one upon another. Individual matrices can be woven to accommodate any number of bits per word. The number of words in each matrix is fixed by the configuration of the loom.

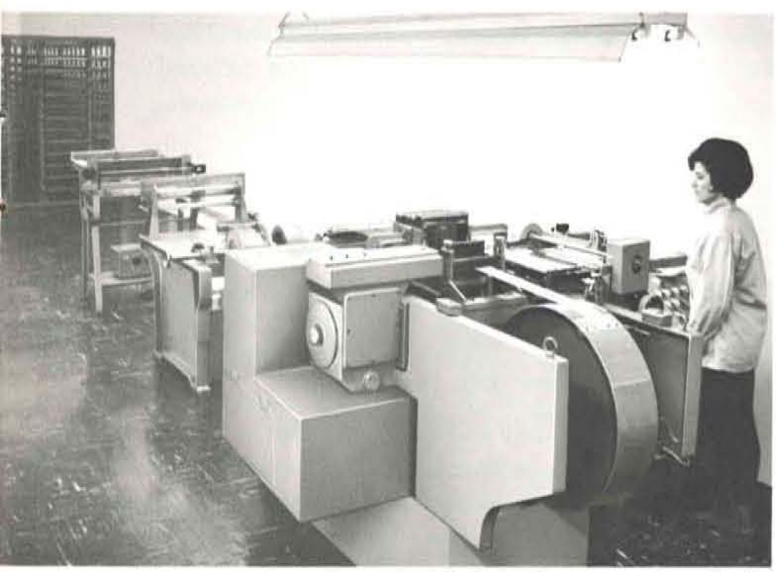
Principles of Construction

Plating. Conductive wires are coated with a thin-film magnetic material in a multibath, continuous-flow plating operation. During this operation, the wire is cleaned, polished, plated, tested, and cut into lengths suitable for the automatic weaving operation that follows.

The plating process permits continuous sampling of the properties of the wire during plating. This allows on-line detection and compensation, resulting in controlled optimum magnetic properties and high-yield levels.

Weaving. The programmable, automatic loom on which the memory matrices are woven was developed especially for this purpose.

In the weaving process, the desired number of strands of insulated wires are held parallel to each other in the loom. (Soft, very small diameter copper wire is used so that high bit densities are readily attained.) Alternate strands are raised, and a magnetically plated wire is inserted by the automatic loom at right angles to the insulated wires. Then the insulated wires reverse position, and another magnetically plated wire is inserted. This automatic process continues until the programmed number of wires has been woven into a memory matrix.



Loom, installed at Librascope, automatically weaves memory matrices like cloth.

The process permits replacement of plated wires after weaving, without having to cut or restring completed memory elements. This contributes materially to manufacturing economy and to high quality.

Memory arrays intended for operation at high levels of shock or vibration are potted in semiflexible material, to minimize stress and abrasion on the memory element.

Stacking. Large-capacity memories can be produced by stacking the appropriate number of individual matrices, with required interconnections. Excellent transmission properties of digit lines allow interconnection of many matrices with small delay and attenuation of propagated signals.

High Reliability: A Result of the Fabrication Process. The high reliability of Librascope's Woven Plated Wire Memories is due to characteristics inherent in the memories themselves, as well as to the fabrication process. Plating is a carefully controlled procedure. Weaving is an automatic process that eliminates many hand-assembly operations. Fabrication techniques are well known, fully proved, and themselves highly reliable. Extreme care is taken throughout fabrication, and rigid quality-control procedures are followed.

Historically, reliability has been constrained more by the electronics than by the memory itself. Therefore, considerable significance attaches to the fact that *woven* plated wire memories possess several inherent characteristics that permit the use of less complex and more reliable electronics. These characteristics are (1) their low power requirements, (2) word current pulses for reading and writing are of the same polarity, and (3) short interconnections can be used because the electronics can be mounted close to the memory.

Applicable military specifications include Mil-E-5400; Mil-E-8189; Mil-E-16400; Mil-E-4158; Mil-Q-9858. NASA requirements currently being met include NPC 200-3; NPC 200-4; NPC 250-1; resistance to sterilization at 145°C and by chemical means; resistance to shock, vibration, and acceleration; resistance to electromagnetic interference.

Principles of Operation

The Memory Element. In its simplest form, the Librascope Woven Plated Wire Memory is a small-diameter conductive wire plated with magnetic material that has controlled magnetic qualities. During fabrication the direction of magnetization is constrained to lie circumferentially, in the absence of an applied magnetic field, making this the "easy" axis of magnetization. A magnetization vector H_s (Figure 1) represents a binary digit by resting in either of the "easy" directions, which are 180° apart. The magnetic coating is sufficiently thin so that flux reversal within the memory element takes place by coherent domain rotation. This switching mode is much faster than the wall-motion mode of conventional ferrite cores, and is less sensitive to temperature variation.

The memory element features a closed magnetic path around the circumferential (easy) axis. Since self-demagnetization fields are not present, the coating can be thicker than planar magnetic films, thus generating greater output voltages. Coupling of the coating to the copper substrate also is improved, further increasing output voltage and decreasing digit drive requirements. The closed magnetic path also decreases susceptibility of external magnetic fields.

As diagrammed in Figure 2, the magnetically plated wires form the digit/sense lines, while the insulated wires are interconnected to form the word coils of the woven array. A memory element is formed at each looped position along the plated wire. Although the magnetic coating is continuous, only those sections in close proximity to the word coils contribute to memory operation. Thus a single plated wire is divided into many memory elements; suitable spacing of the word coils avoids interaction between elements.

A particular advantage of the weaving technique is the ability to produce multiturn coils of rather complex structure. Two such patterns, with their resultant magnetic fields, are shown in Figure 3.

To produce these "shaped" drive fields economically, an automatic device is used. Preselected word lines are interconnected to make word coils, or left unconnected to provide spacing between word coils. Thus bit interaction along the magnetically plated digit/sense lines is avoided, so that repetitive reading, writing, or rewriting with the same polarity will not cause spreading of magnetization.

The use of multiturn coils also permits the use of lower word-drive currents in writing and reading. The weaving process results in close coupling between word and digit wires, and thus in yet lower word currents.

Reading Information from the Memory Element. To interrogate the memory element, the word line is pulsed with current I_w (Figure 1). The induced magnetic field rotates the plated wire's magnetization vector from its quiescent position in the easy (circumferential) axis H_s, toward the hard (axial) axis H_t. This in turn induces a voltage in the conductive substrate wire, which now serves as the sense line. Its polarity depends on the direction of the magnetization vector in its quiescent state. On removal of the word current, the vector returns to its original quiescent state, again inducing a voltage of opposite polarity in the digit/sense line.

Since the readout process is inherently nondestructive, no rewriting or "restore" function is required, and ultra-high speed operation is possible. Full cycle time for nondestructive (NDRO) operation is on the order of 100 nanoseconds, and 250 nanoseconds

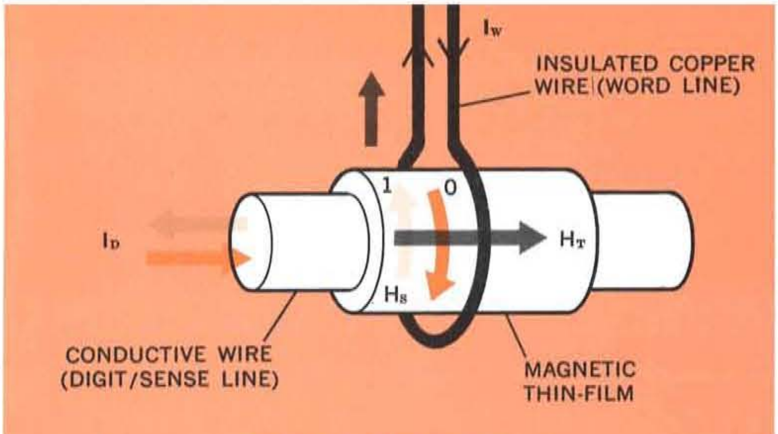


FIGURE 1. BINARY DIGIT

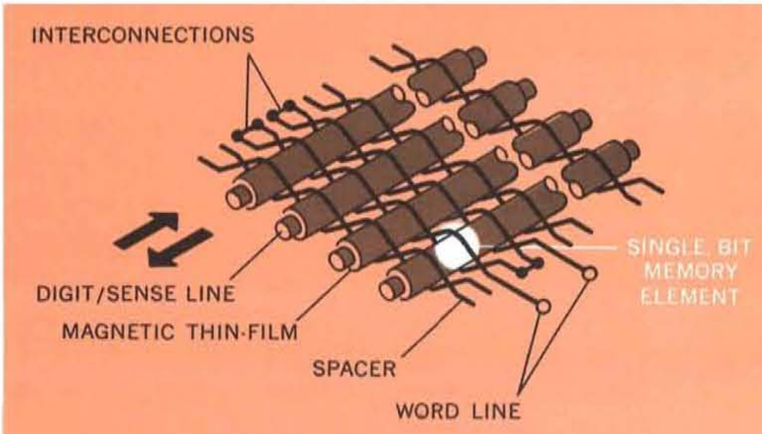


FIGURE 2. BASIC MEMORY MATRIX

for destructive readout (DRO) and restore operation.

In NDRO operation, information may be reused repeatedly, without fear that it has been altered by bit dropping, power-supply degradation, or signal interruptions caused by computer malfunction. Stored information may be altered by the write process described below.

Writing Information into the Memory Element. To write information into the memory element, a relatively large word field is applied by passing word current I_W (Figure 1) through the insulated wire word lines, thus rotating the magnetization vector H_s from the easy axis into the hard axis H_t of the magnetic film. On termination of the word current, a digit field applied by passing a relatively small digit current I_D (Figure 1) through the magnetically plated digit lines, steers the magnetization vector to the "1" or "0" direction along the easy axis of the magnetic film.

Output of the word line may be sensed on the leading edge of the word-drive current pulse, which rotates the magnetization vector into the hard axis, enabling the digit/sense line to sense the information stored in the memory element. New information is written, or the original information restored, by passing positive or negative current through the digit/sense line on the lagging edge of the word-drive current. Since reading and writing are accomplished by the same word-drive current pulse, very fast cycle times are possible. Word-addressing circuitry is also simplified relative to core memories which require oppositely directed pulses for reading and for writing.

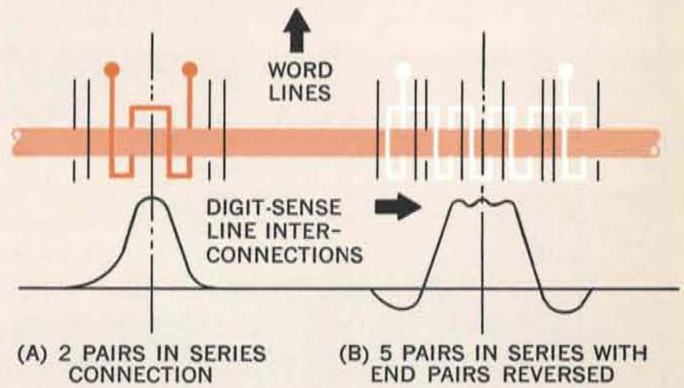
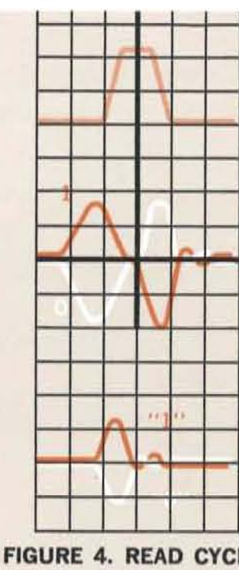


FIGURE 3. "SHAPED" DRIVE FIELDS

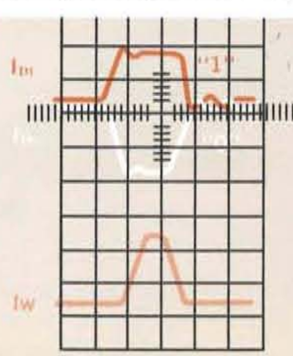


WORD DRIVE CURRENT
Vertical Scale = 100 ma/div
Horizontal Scale = 50nsec/div

BI POLAR SENSE OUTPUT
Vertical Scale = 5mv/div
Horizontal Scale = 50nsec/div

SENSE CURRENT
Vertical Scale = 5mv/div
Horizontal Scale = 50nsec/div

FIGURE 4. READ CYCLE, NDRO



DIGIT CURRENT
Vertical Scale = 5ma/div(NDRO)
Vertical Scale = 50ma/div(DRO)
Horizontal Scale = 50nsec/div

WORD-DRIVE CURRENT
Vertical Scale = 100ma/div(NDRO)
Vertical Scale = 200ma/div(DRO)
Horizontal Scale = 50nsec/div

FIGURE 5. WRITE CYCLE, DRO OR NDRO

Functional and

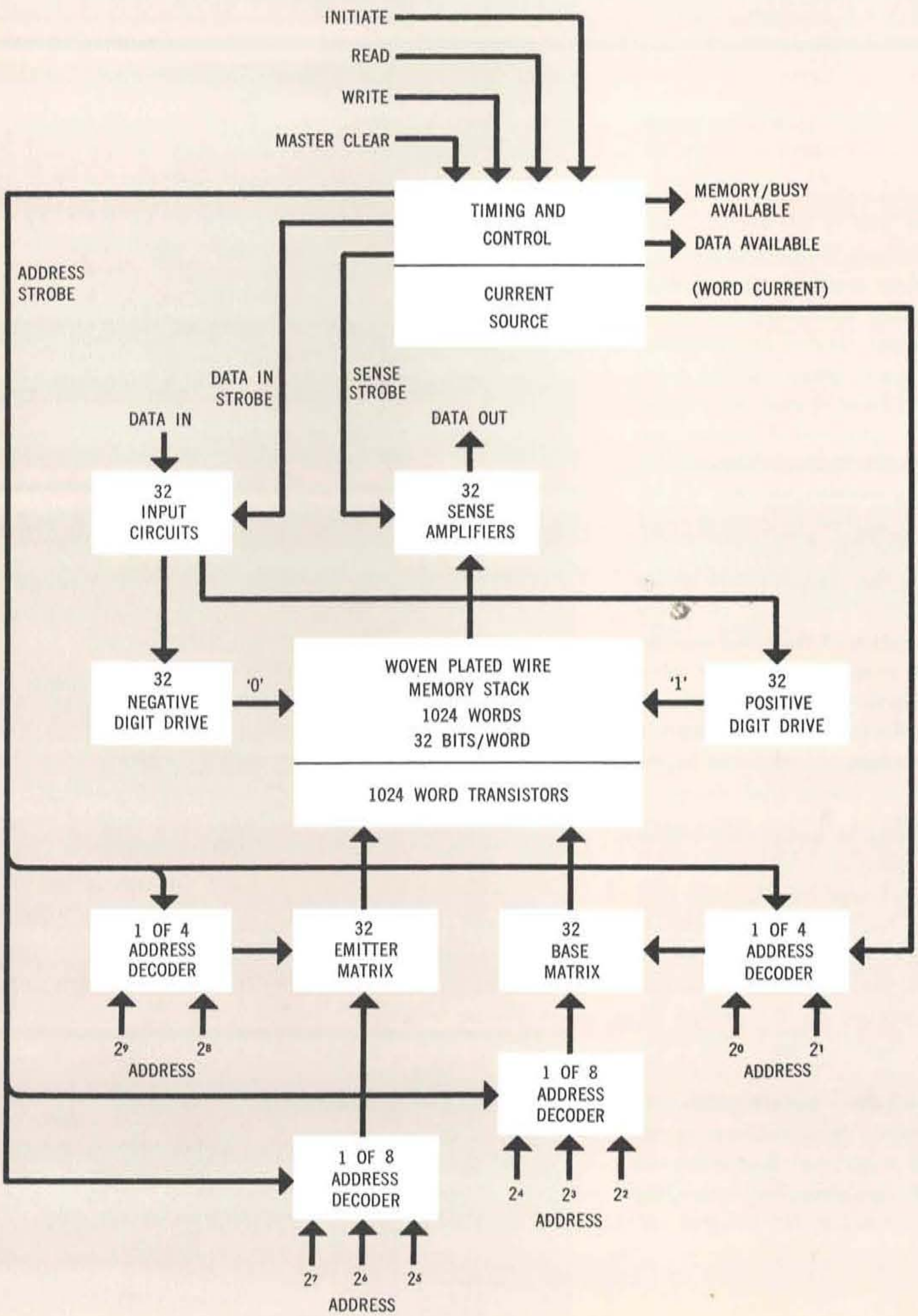


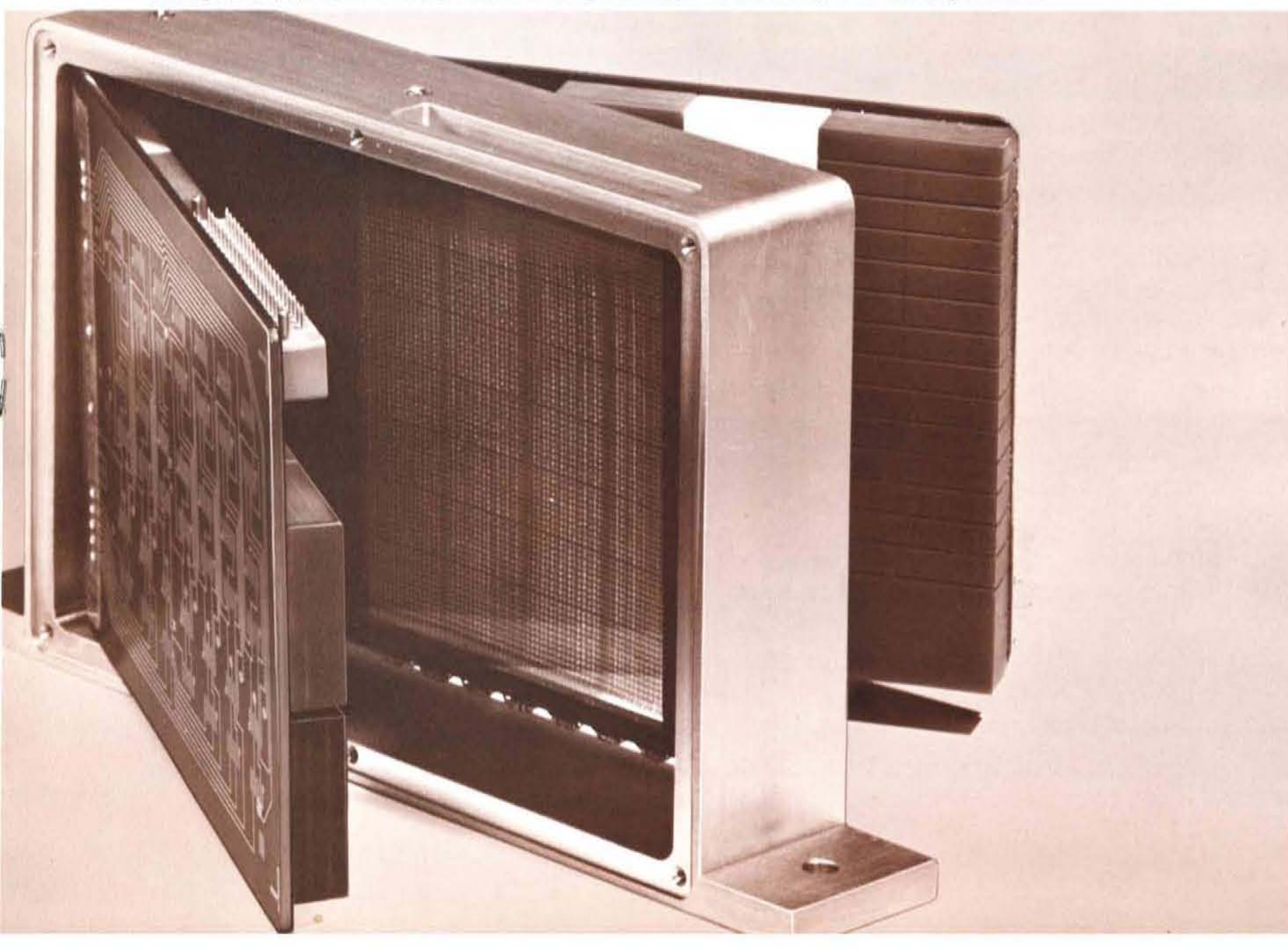
FIGURE 6. FUNCTIONAL BLOCK DIAGRAM OF TYPICAL LINEAR-SELECT MEMORY SYSTEM

Organizational Configurations

Librascope's Woven Plated Wire Memories are available in four basic functional and organizational configurations:

1. **Linear-select organization, either NDRO or DRO operation.** For use where low power consumption is required, and for high-speed memories of long word length and small-to-medium word capacity.
2. **Coincident-select organization, NDRO operation only.** For memories of shorter word length and medium-to-large word capacity, either high or low speed.
3. **Electrically alterable read-only memories, NDRO operation only, either linear select or coincident select.** "Write" electronics are in a separable module, available for use with any numbers of memories.
4. **Permanently woven read-only memories, NDRO operation only, usually coincident select.** For use where the stored information never changes, as in a look-up table or fixed-program memory.

Package size of aerospace memory module utilizing Librascope Woven Plated Wire Memory elements.



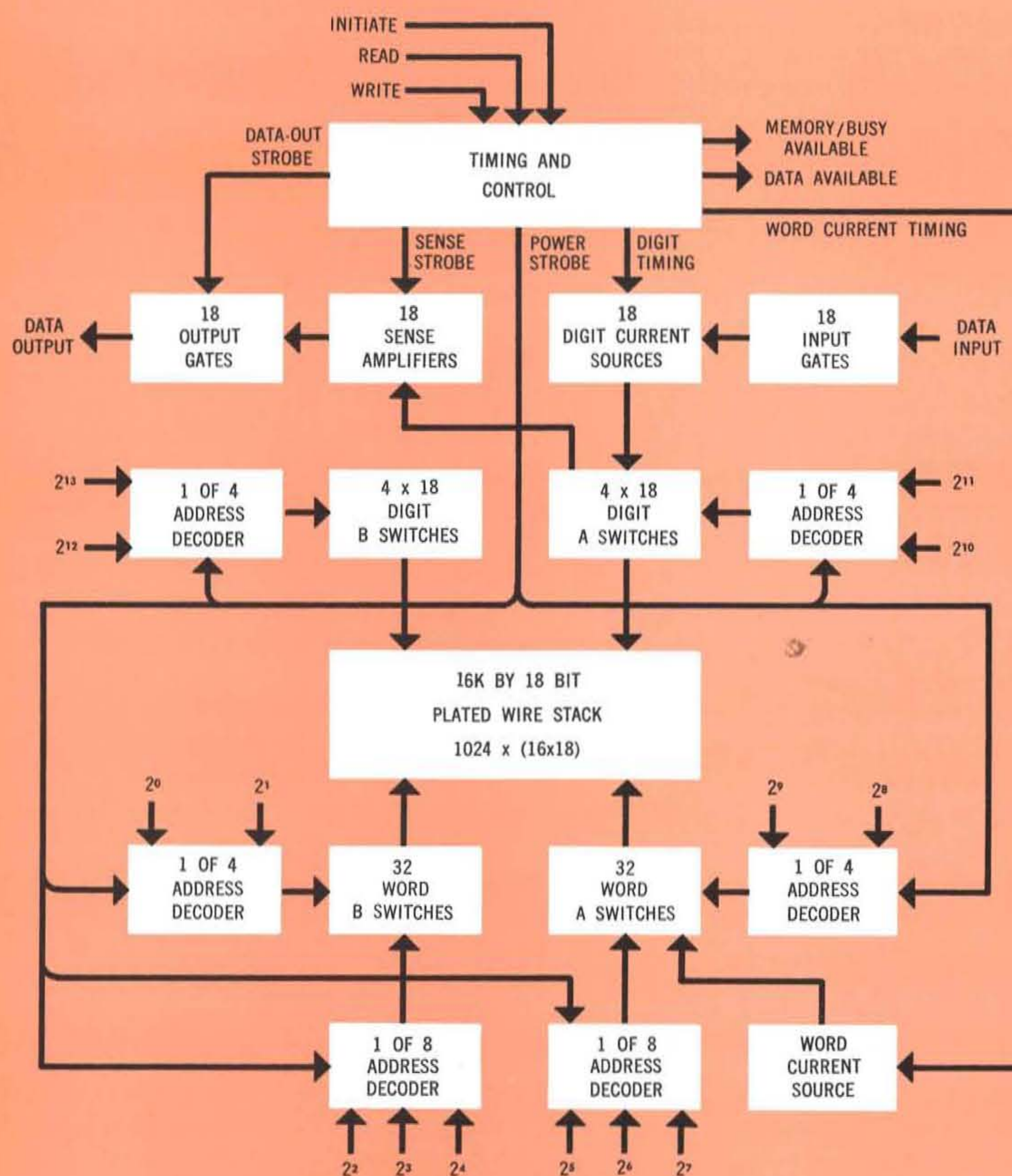


FIGURE 7. BLOCK DIAGRAM OF A TYPICAL COINCIDENT-SELECT MEMORY SYSTEM

Organizational Configurations

Power Considerations. High-speed operation means quick-response data transfers. This characteristic plus low drive current requirements result in very low power consumption. Thus woven plated wire memories are especially suited to spaceborne systems.

It is also possible to design a system so that power-consuming elements are de-energized between bit transfers, reducing power requirements still further. Combined with low-power-consuming integrated circuitry, these systems offer the ultimate in practical low-power memories. Little or no power is consumed between operations or on standby.

1. **Linear-Select Organization.** Linear-select organization can be used either in NDRO or in DRO operation. The memory matrix is woven so that the number of magnetically plated wires (digit/sense lines) is equal to the number of bits per word, and the number of insulated wire coils (word lines) is equal to the number of words in the system. A functional block diagram of a typical linear-select system is shown in Figure 6.

   On receiving the "read" command and the "initiate" command, the memory system strobes the address registers and decodes to select the addressed word coil. The word-drive current is pulsed through the selected word coil; the stored information is sensed and amplified in parallel through all digit/sense lines. In NDRO operation, the stored information is retained and may be reused repeatedly. In DRO operation, the information must be restored (or new information written) by energizing positive or negative digit drivers. Information is written into bits at the intersection of word and digit currents. No preliminary-operation clear is needed.

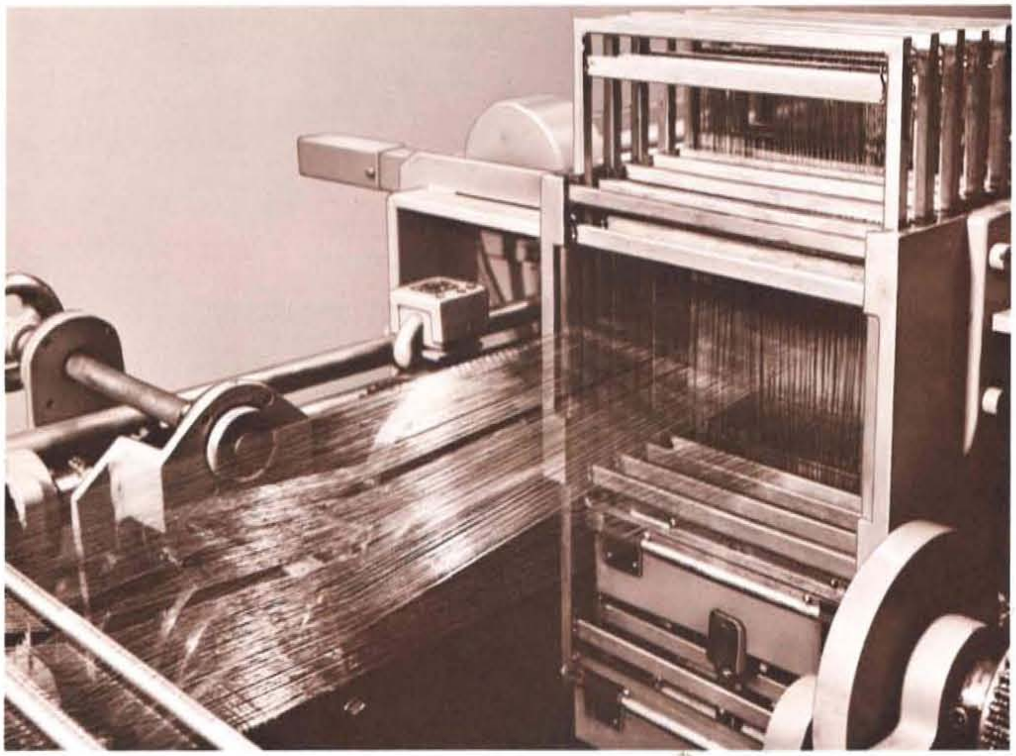
   Linear-select systems find best application as high-speed memories of long word length and small-to-medium word capacity.

2. **Coincident-Select Organization.** Coincident-select organization can be used only in NDRO operation. The memory matrix is woven so that the number of digit/sense lines is approximately equal to the number of word lines. This "square" array is the most efficient and economical, from the standpoint of electronic circuitry and matrix interconnections.

   A functional block diagram of a typical coincident-select system is shown in Figure 7. This memory consists of 16,384 words of 18 bits each, but is organized as 1,024 word lines and 288 bit lines. On receiving the "initiate" command, ten address bits are strobed and decoded, to select one of the 1,024 word lines. The four remaining address bits are strobed and decoded to select one of the 16 groups of 18 digit lines; the selected group is gated to the sense amplifiers and to the digit drivers.

   To perform the "read" operation, a word-drive current is pulsed through the selected word coil. The output is sensed on the selected 18 digit/sense lines. This bipolar output is amplified and converted to logical levels. The stored information is not disturbed by the word-drive current.

Functional and



In weaving operation, heddles separate insulated wires to allow insertion of magnetically plated wires.

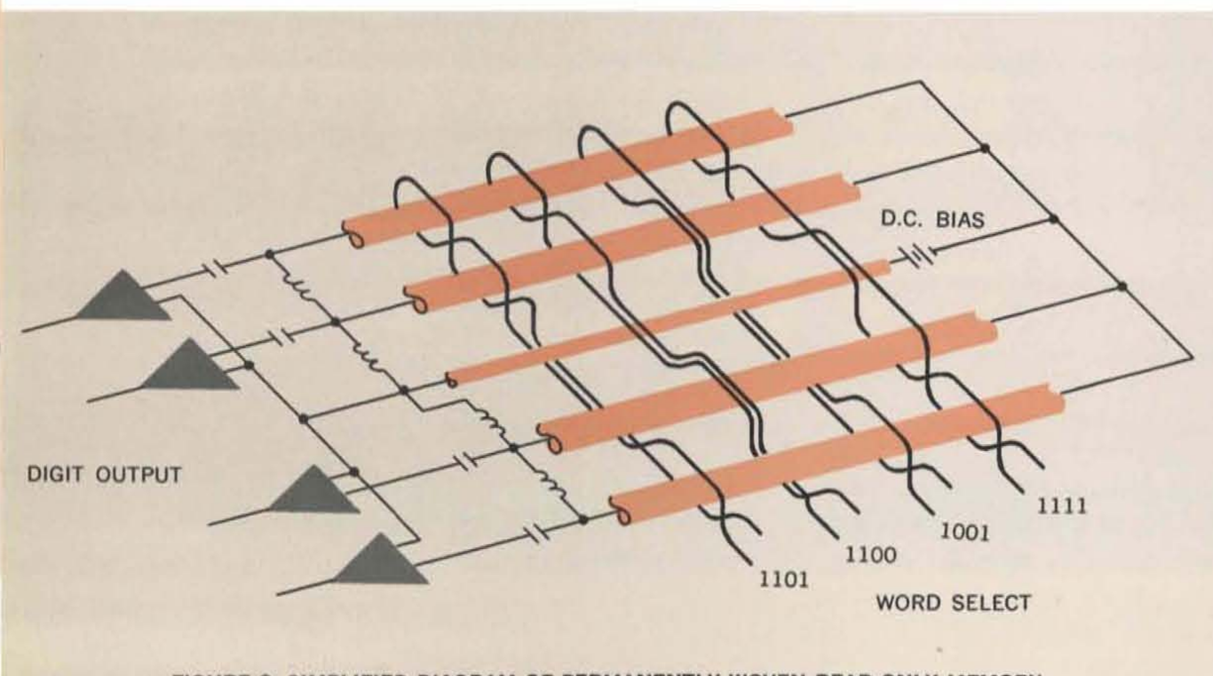


FIGURE 8. SIMPLIFIED DIAGRAM OF PERMANENTLY WOVEN READ-ONLY MEMORY

Organizational Configurations

To perform the "write" operation, the input data is strobed with the address. Positive or negative digit current sources are energized according to the "1" or "0" level of the input. Digit current is pulsed through the selected group of digit lines and word current is pulsed through the selected word coil. Input data is stored at the intersections of word and digit currents. Memory elements that do not receive digit current and word current simultaneously are not disturbed.

Coincident-select systems find best application as memories of shorter word length and medium-to-large word capacity. This is specifically true in a true *bit-serial* system, which may be interpreted as a parallel system with 1-bit word length.

In certain instances where a low-speed system can be used, the high-speed switching ability inherent in woven plated wire memories allows the transfer of information in a bit serial manner within the memory — but the information appears as parallel to the computer interface within a specified time frame. This results in a lower power requirement and lower component count, thereby decreasing total system cost and increasing reliability.

3. **Read-Only Memories—Electrically Alterable.** Electrically alterable read-only memories are identical to standard NDRO woven plated wire memories, either linear select or coincident select, except that they do not include integral "write" electronics. A single write electronics module can serve any number of read-only modules, being connected only during the write operation.

4. **Read-Only Memories — Permanently Woven.** Permanently woven read-only memories provide NDRO data storage that cannot be altered, and so are unsurpassed for repetitive data uses such as look-up tables, fixed programs, and indeed any repository of reference data. Their construction utilizes one of the basic characteristics of the weaving process: the ability to produce special patterns automatically, by lifting only specified insulated (word line) wires as the magnetically plated (digit/sense line) wires are inserted. Thus a digit line either is looped to form a magnetic coupling, or bypassed to eliminate an output: when the selected word coil is pulsed, "1" or "0" is generated, respectively.

A typical permanently woven read-only memory is illustrated in Figure 8. A small DC bias current is passed through all digit lines continuously, to assure that the easy axis magnetization vector is reset to its quiescent state. Since data storage is permanently woven into the array, no bit interaction is possible.

Thus the need for spacer wire and complex word coils is avoided. Consequently, ultra high bit densities are achieved, as is ultra high data storage reliability: data cannot be altered or lost by any computer malfunction. Operation is maintained over an extremely wide temperature range.

For maximum reliability and economy, permanently woven read-only memories usually are coincident select, with the memory element matrix as nearly square as possible.

Headquarters building of General Precision Equipment Corp. and General Precision, Inc., Tarrytown, N. Y.

Headquarters building of Librascope Group of General Precision, Inc., Glendale, Calif.

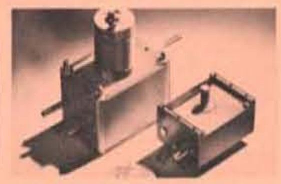
Strong Corporate Background

Librascope Group of General Precision, Inc., is a long-time leader in the design and production of computer components and peripheral equipment. Its line of disc memories is the largest in the computer industry and its encoder production volume is the largest in the industry. Librascope also produces weapon-control systems for anti-submarine-warfare weapons, digital systems, and precision optical systems. Librascope is a group of General Precision, Inc., a subsidiary of General Precision Equipment Corporation. Librascope's present capabilities and future growth are greatly enhanced thereby. GPE is a leading electronics company, one of the top 300 U. S. firms, with over 20,000 employees in 40 major plant locations in the United States and abroad. Annual sales of the corporation's subsidiaries total more than $300 million.

Other Components Division Products

DISC MEMORIES

ENCODERS



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General Precision/Librascope engineers are available to discuss your computer memory requirements, and to assist in the application of woven wire memory planes to your systems. Librascope's long experience and broad capabilities in the design and production of computers, computer memories, and data processing systems afford a reservoir of knowledge that is at your service.

GENERAL PRECISION, INC./LIBRASCOPE GROUP

BUSINESS REPLY CARD

NEW! WOVEN PLATED WIRE MEMORY SYSTEMS

Computer & Memory Engineers:

Compare the operational characteristics of Librascope Woven Plated Wire Memory systems and stacks with those of your present and future memory system requirements. If these characteristics anticipate the demands of your next-generation memory systems, answer the following questions for more detailed information:

1. Which categories best describe your memory utilization area?

☐ Commercial ☐ Space vehicle and missile systems
☐ Military ground systems ☐ Military airborne systems
☐ Other ____________

2. Do you use magnetic memories for—

☐ Scratch Pad ☐ Main ☐ Auxiliary
☐ Buffer ☐ Control ☐ Program
☐ Other ____________

3. Which operational characteristics are the most important consideration for your system design?

☐ Nondestructive readout ☐ Extra high speed
☐ Low-power consumption ☐ Small volume and low weight
☐ High-environmental tolerance ☐ No memory element heating

Why? ____________

4. Memory System Requirements

A. Capacity: ______words of ______bits/word
B. Access: ______ nanoseconds
C. Cycle: ______nanosec(NDRO)
______nanosec(DRO)
D. Speed: Time between successive "reads" or "reads" & "writes" equals ______ nanoseconds.
E. Temperature: −______°C to +______°C
F. Shock: ____________
G. Vibration: ____________
H. Addressing: ☐ Random
☐ Sequential
☐ Other ____________

5. Please briefly describe your application:

____
____
____

Program: ____________

6. May a Librascope applications engineer be of assistance to you?

☐ Yes ☐ Comments____________

Name ____________
Position ____________
Company ____________
Address ____________
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l Precision, Inc. Creative design and production artwork by Librascope's

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Strong C

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Librascope's long experience and broad capabilities

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