DESIGN OF AN EXPERIMENTAL MULTIPLE INSTANTANEOUS RESPONSE FILE*

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SUMMARY

An experimental model of an electronic reference retrieval file in which all file entries are interrogated simultaneously has been designed and constructed. The experimental model is designed to store and search on a file of indexes to 5,000 documents. A document index consists of a decimal accession number and up to eight English word descriptors that are closely related to the contents of the document. The vocabulary required to describe the documents is held in a machine dictionary that has a design capacity of 3,000 words. In the model delivered to the sponsor, Rome Air Development Center, the storage capacity is only partially used. The specification for the delivered model calls for the storage of approximately 1,100 documents that were selected from the ASTIA (now DDC) Technical Abstract Bulletin and of the vocabulary needed to describe them (about 1,000 words). The document indexes and the dictionary words are stored in wiring patterns associated with arrays of linear ferrite magnetic cores.

A search question, consisting of one to eight descriptors in their natural English form, is entered by means of an electric typewriter. During entry of the search question, the dictionary magnetic store is interrogated by the alphabetic code of each search word. If a word is not contained in the dictionary, it is automatically rejected. After all words of the search question have been entered, the document magnetic store is interrogated by the search question in superimposed code form. The comparison between the search word and the document indexes is made for all documents simultaneously and the machine instantaneously determines if any documents in the file include the search question. If there are none, the machine indicates visually that there is no response. If there is at least one, the machine counts the number of responding documents and displays this number. Then it types out the indexes of all responding documents on the same typewriter that was used to ask the question.

INTRODUCTION

Memories that can be searched in parallel and from which stored information is retrieved on the basis of content have received considerable attention for application to retrieval file problems.1, 2, 3, 4 This paper describes the design of an experimental retrieval file based on the work reported by Goldberg and Green.3 Since the contents of the semipermanent magnetic memory used in the experimental file can be searched in parallel and multiple responses

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to the search question are permitted, the system is called MIRF—Multiple Instantaneous Response File.\(^5\)

LOGICAL ORGANIZATION OF THE MIRF SYSTEM

The logical organization of the experimental MIRF system is illustrated by Fig. 1. Information pertaining to the document indexes and to the descriptors used in the document indexes is contained in two major units called MIRF units. A MIRF unit is basically a magnetic memory in which information is permanently stored in the wiring associated with the magnetic cores. The Document MIRF is the principal element of the system. It contains for each stored document index the document accession number and the descriptors (in coded form) that describe that document, as well as a superimposed search code that is used in the searching process. The Dictionary MIRF has two functions. During the input phase of operation it translates the alphabetic code of the English word descriptor that is entered from the typewriter into the binary serial number assigned to that English word for use inside the machine. During the output phase, the Dictionary MIRF translates the binary serial number of a word that is obtained during a search into the alphabetically coded form of that word.

After the binary serial number of an input English word has been generated, this binary number is translated by a logical process in the Search Code Generator into a search code that is assigned to the particular English word. The search codes of successive words of a search question are superimposed by adding them together, bit by bit by an inclusive-OR operation. When the search question is complete, the superimposed search code of the question is compared with the superimposed code section of the Document MIRF. Each document index whose search field includes the superimposed code of the search question is said to respond to the question. Frequently more than one document will respond. By a logical process for resolving multiple responses,\(^6\) the accession number of a particular responding document is generated. Then the binary serial numbers of the English words contained in this document index are generated one at a time. By means of the Descriptor Selector, each serial number is transmitted to the Dictionary MIRF, where it is translated to the alphabetic code of the English word. This process is repeated for each responding document.

SYSTEM DESIGN

1. Magnetic Implementation of the MIRF Unit

The MIRF units of the experimental model use an interesting modification of the Dimond Ring\(^7\) translator in which the drive and sensing functions are interchanged. Information is stored in unique wiring patterns associated with an array of linear ferrite cores as il-
lustrated by Fig. 2. Each item of stored information (a document index in the Document MIRF or a descriptor in the Dictionary MIRF) is represented by a conductor that passes through or around each associated core in a unique pattern determined by the information it contains. In series with each conductor is a diode. The cathodes of many diodes are connected together to form the input to a detector amplifier. Notice that one core is required for each bit of information, but that each core can be associated with a particular bit of many item conductors.

Each core has an input winding that can be selected by means of a switch. All cores whose selector switch is closed will be energized when a drive pulse is applied. A voltage will be induced in each item conductor that threads an energized core, but no voltage will be induced in conductors that do not thread the core. A test can be made on the information stored in many cores by selecting a particular set of cores and energizing them. In order for an item to match the test information, its conductor must pass outside of every energized core. Then no voltage will be generated in the item wire and the input to the detector amplifier will be held near ground through the item diode. Voltages will be induced in the conductors of items that do not match the test; the polarity of these voltages is chosen to back-bias the associated diodes. If no item matches the test information, a voltage will be induced in every item conductor and every diode will be back-biased. The input to the detector will then assume a significantly negative voltage. Thus, the presence or absence of desired stored information can be determined by applying the drive currents to a particular set of cores.

Now consider in more detail how a bit of information of a search question is compared with information in a MIRF unit. Figure 3 illustrates how a test is made to determine whether or not the test bit is logically "included" in the stored information. This circuit is typical of those used in the superimposed section of the Document MIRF. One core is used to store the kth bit of many items. The kth bit of the search question is stored in a flip-flop whose one side is connected by way of an AND gate to a drive amplifier, which in turn is connected to the primary winding of the kth core. The conductor of an item whose kth bit is equal to one (Conductor 1) passes outside the kth core. On the other hand, the conductor of an item whose kth bit is equal to zero (Conductor 2) threads the core. If the flip-flop stores a one, the primary winding will be energized when the timing pulse is applied to the AND gate. A voltage will be induced in Conductor 2 (indicating a mismatch) but none will be induced in Conductor 1 (indicating a match). If the flip-flop stores a zero, the primary winding will not be energized because the timing pulse will be blocked at the AND gate. No voltage will be induced in either conductor, and a match will be indicated on both lines. Therefore, it can be seen that a stored one bit includes both a test one and a test zero, while a stored zero bit includes only a test zero.

The circuit for testing for identity between the test bit and the information stored in the MIRF is shown in Fig. 4. This circuit is typical of those used in the alphabetic descriptor portion of the Dictionary MIRF. The jth bit of many items is stored in a pair of cores jA and jB. The jth bit of the test question is stored in a flip-flop. In this case, both the one and zero sides of the flip-flop are connected to AND gates.
whose outputs control drive amplifiers that are connected to the primary windings of the cores \( j_A \) and \( j_B \). The conductor of an item whose \( j \)th bit is \( \text{one} \) (Conductor 1) bypasses core \( j_A \), while the conductor of an item whose \( j \)th bit is a \( \text{zero} \) threads core \( j_A \). The threading of core \( j_B \) by the two conductors is the reverse of the wiring of core \( j_A \). If the flip-flop stores a \( \text{one} \), the primary winding of core \( j_A \) will be energized when the timing pulse occurs. No voltage will be induced in Conductor 1 (a match indication) but a voltage will be induced in Conductor 2 (a mismatch indication). If the flip-flop stores a \( \text{zero} \), the primary winding of core \( j_B \) will be energized. In this case, a voltage will be induced in Conductor 1 but not in Conductor 2. Thus it can be seen that the bit stored in the MIRF must match the test bit identically for a match indication to be obtained.

2. Basic Operations Using the MIRF Units

Two types of operations involving the MIRF units are basic to the operation of this experimental model. One operation tests to see if certain information is contained in the MIRF. The other uses information that is contained in the MIRF to generate a number in a flip-flop register external to the MIRF unit. Examples of these basic operations are given in the following paragraphs.

a. Testing of Information Contained in the MIRF Unit

Dictionary MIRF—During the input of the English words to form a search question, the Dictionary MIRF is tested to see if the input word is contained in the vocabulary (that is, if it is a valid descriptor). This is done by gating the alphabetic descriptor register to the drive amplifiers associated with the alphabetic portion of the MIRF (50 bits long, two cores per bit). As a result, 50 drive amplifiers are energized and 50 primary windings in the MIRF carry current. If one of the stored words has a bit pattern in the alphabetic portion that matches identically the energized set of primaries, the match detector will indicate a match condition. If not, the match detector will indicate a mismatch condition. The output of the match detector is used to determine the next step in the logical sequence. It is important to note that the test is applied to the entire Dictionary MIRF simultaneously and that a match or mismatch signal for the entire MIRF is obtained in about 5 microseconds.

Document MIRF—After all words of the search question have been typed, the superposition of their search codes is held in the search code accumulator. At the beginning of the actual search operation, the flip-flops of the search code accumulator are gated to their associated drive amplifiers. A particular set of drive amplifiers is energized and current flows in a corresponding set of primary windings in the 80 bit superimposed code field of the Document MIRF. If the detailed bit pattern represented by the energized primaries is included in any of the superimposed fields of the stored document indexes, a match condition is indicated by the match detector. If not, a mismatch indication is given. The test is made on the entire contents of the document MIRF simultaneously and a YES/NO response is obtained in about 5 microseconds.

It should be pointed out that the criterion for a match is inclusion, not identity. A document index includes the search question if the following conditions of the superimposed search code portion of the index are satisfied. First, for every bit of the index search field that is a \( \text{one} \), the corresponding bit of the search question is either a \( \text{zero} \) or \( \text{one} \). Second, for every bit of the index search field that is a \( \text{zero} \) the corresponding bit of the search question is a \( \text{zero} \) (in other words a binary \( \text{one} \) includes both...
a one and a zero, but a binary zero does not include a binary one).

b. Generating Numbers by the MIRF Process—The generation of the serial number of an input descriptor illustrates this operation. Assume that an English word has been typed in and that the test for valid descriptor is true. Because a match is obtained when the alphabetic descriptor register is gated to the Dictionary MIRF, one item wire in the MIRF is effectively isolated: namely, the wire that is uniquely related to the input descriptor. The detailed wiring pattern of this wire in a group of cores outside the alphabetic code field contains the binary serial number of the input descriptor. By gating the alphabetic descriptor register to the MIRF and at the same time causing current to flow in the primary winding of a core that is in the serial number portion of the MIRF, the binary value associated with that core for the selected line can be determined. The presence of current in the additional winding tests for a binary one in that position. If the match detector indicates a match, the value is indeed one. However, if a mismatch is obtained, the value must be zero.

The sequence for generating the serial number is as follows: First the flip-flop register that will eventually hold the serial number is cleared to all ones. Then the alphabetic descriptor register is gated to its drive amplifiers and a drive amplifier associated with the parity bit of the serial number is energized. The output of the match detector is observed. If a match condition is observed, it is known that the parity bit is actually a one and the parity bit flip-flop in the serial number register is not changed. If a mismatch is observed, it is known that the parity bit is zero and the parity bit flip-flop in the serial number register is not to zero. The next step is to energize the drivers associated with the alphabetic descriptor register and a driver associated with the least significant bit of the serial number. Again the output of the match detector is observed and the flip-flop assigned to the least significant bit is either allowed to stay at one or is changed to a zero. This procedure continues for thirteen steps. At the end of this time, the 12-bit serial number and its parity bit will have been generated and stored in the serial number register.

CIRCUIT DESIGN

Three principal types of transistor circuits are used in the experimental model: transistors are used as switches to drive the primary windings of the MIRF cores; discriminator-amplifier circuits are used to accept the voltage generated on the secondary windings of the MIRF cores (this is the match detector circuit); and transistor logic circuits are used for the over-all control of the MIRF operations. All three types were designed at SRI.

1. MIRF Driver

The drive currents that are required by the ferrite cores in the Document and Dictionary MIRFs are furnished by circuits such as the one shown schematically in Fig. 5. Four MIRF driver circuits are mounted on one printed circuit plug-in board, as shown in Fig. 6. Each circuit is capable of supplying the required 2 amperes at low impedance. The power transistor that delivers the drive current (Type 2N1905) is driven by a push-pull emitter follower that provides 60 milliamperes of base drive current into 2N1905. The output power transistor has rise-and-fall time capabilities of less than 0.3 microsecond. The actual current in the load is nearly linear because of the inductive nature of the load and builds up to the 2 ampere amplitude at the end of approximately 10 microseconds. The overshoot voltage induced when the transistor is turned off is clamped by a silicon diode to -36 volts. The clamp prevents excessive voltage spikes from appearing across the output transistor while still allowing the load inductance to recover within 10 microseconds.

Two protective features of the MIRF driver circuit should be noted. One is a fuse, which is inserted in series with the load to protect against excessive load currents. Before the winding of the magnetic circuits internal to the MIRF assembly can be damaged by too much current from, say, an accidental short circuit, the fuse wire will open up. The second protective circuit includes a square-loop memory core that is threaded by the lead going to the transistor load. This core is normally biased off, but if the drive current exceeds a safe value the square-loop core will switch and induce a voltage in a sense lead. The voltage in
the sense lead is amplified and used to turn off the system clock. The purpose of this circuit is to protect the 2N1905 transistor against excessive heat dissipation from currents that are excessive but not large enough to burn out the fuse wire.

2. MIRF Discriminating Amplifier

The electrical output of the MIRF magnetic modules is generated by a very large diode gate including almost 300 diodes. Under the worst conditions a match signal from this array can reach a level as high as 0.4 volt. On the other hand, a mismatch signal from the same array may only generate a potential of 0.6 volt. It is necessary for the MIRF discriminating amplifier to differentiate between these two signals and generate a standard logic level output of —6 volts for a mismatch and 0 volts for a match. The circuit for the amplifier is shown in Fig. 7. In order to distinguish between very closely spaced match and mismatch signals, two thresholds are employed in the amplifier. The first threshold is provided by a 1N3605 silicon diode at the input to the amplifier. This diode does not pass signals unless they exceed approximately 0.5 volt. After passing the first threshold, the signal is amplified in a feedback amplifier with a gain of about 50. If the amplified signal then exceeds the second threshold of 3 volts, a mismatch signal is delivered at the output of the amplifier.

3. Logic Circuits

In the flip-flop register and over-all control circuits, resistor-transistor logic is used. Highly reliable circuits that operate in the 100-kc frequency range have been developed. The basic gate circuit is shown in Fig. 8. This circuit in typical use performs a simple majority operation. If one or more of its three inputs are at a negative potential, the output is held at ground potential. Since ground is defined as the one state in this system, and a —6 volt potential is defined as a zero state, the basic gate performs the “not and” or NAND operation.

All the passive components shown in Fig. 8, plus one resistor and two capacitors, are contained in one physical element supplied by Centralab, Inc. These components are screened on a passive substrate to a tolerance of 3% for the resistors (5% design tolerance) and...
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521

6.8K
6.8K
6.8K
51K
+12 v

Figure 8. RTL Circuit Designed for the MIRF System.

10% for the capacitors. The substrates are encapsulated with a Durez coating, and are ready for mounting to a printed circuit card via their projecting leads.

The gate circuit is a basic part of every logic circuit employed in the machine. By itself it performs the combinatorial function of logical conditions. Two gate circuits properly interconnected form a bistable, or flip-flop, circuit. Two gate circuits interconnected in a slightly different way form a monostable, or one-shot, circuit. The gate circuit is also used as a pre-amplifier for an emitter-follower circuit. The basic logic circuits, e.g., gates, one shots, flip-flops, etc., are mounted on plug-in logic boards. A typical logic board, with seven gate circuits mounted on a printed circuit board, is shown in Fig. 9.

MAGNETIC DESIGN

1. General Considerations

The magnetic design of a MIRF unit is centered in the individual magnetic core, which acts as a transformer with a multiturn primary winding and many single-turn secondary windings. When current flows in the primary winding, the magnetic core must be capable of producing a flux change of sufficient time duration and amplitude to generate the desired signal in secondary windings. The amplitude of the induced voltage is determined primarily by the characteristics of the diode associated with the secondary winding. The duration of the induced voltage is determined primarily by noise on the secondary winding and the consequent delay required before sampling of the output can be accomplished.

The cross-sectional area of the magnetic core is proportional to the product of the amplitude and duration of the voltage induced in the secondary windings (this is usually referred to as the volt-second area of the induced voltage pulse). This was kept reasonably small by using a high-quality germanium diode (the 1N500) which requires a back-biasing voltage of only 0.6 volt in order to perform properly in the diode circuit associated with the input to the discriminating amplifier. The circumferential length of the magnetic core is determined primarily by the number of secondary windings associated with the core and the mechanical design of the supports for these windings. In the MIRF units of the experimental equipment, the core has the capacity for 2,000 secondary windings. The core’s mean circumferential length is 7 inches; its cross section is a square, ¼ inch on a side.

Two other considerations influenced the selection of the magnetic cores used in the MIRF units. One is the requirement that the core be made in two pieces so that the array of cores

Figure 9. Component Assembly of Gate-Logic Board.
can be separated into two portions to facilitate initial wiring and changes in wiring. The other is the necessity of using commercially available parts. The number of cores needed in this experimental equipment is too small to justify the design and production of a core of special size or shape.

2. Details of the Dictionary and Document MIRF Units

The individual cores used are the same for both the Dictionary and Document MIRF. Each core is composed of two U-shaped ferrite structures (Allen Bradley part no. UC 892–141C), which have been specially modified at the factory to permit a maximum of 0.0005 inch air gap in each leg when two such structures are joined together to produce a MIRF core. To drive each core, a twenty-turn primary winding is provided. This consists of two ten-turn windings distributed in such a manner as to minimize the leakage flux and the resulting noise signal (see Fig. 10). The primary winding drives the core from an 18-volt voltage source through a transistor switch driver. The output voltage induced upon each secondary winding is an essentially rectangular voltage pulse having a droop of 0.1 volt in 10 microseconds, from 0.8 volt at the leading edge to 0.7 volt just prior to the trailing edge. The maximum primary current, 0.7 ampere, occurs at 10 microseconds after the beginning of the pulse. To accommodate the expanded capacity of the MIRF document file (5,000 documents) three primary windings will be driven in parallel, so that a maximum driver current of 2.1 amperes is required.

The performance requirement of the magnetic circuits is that consistent and easily separable match and mismatch signals be generated at the diode end of the item wires (see Fig. 2) when a set of primary windings is driven. The design objective was that a maximum match signal of 0.1 volt and a minimum mismatch signal of 0.6 volt should be realized within 1.5 microseconds after the application of the primary drive pulses, and that pulsing of the MIRF cores be repeated for many cycles at a 50-kc clock rate. To achieve these goals, noise due to ringing and leakage flux had to be minimized.

A MIRF unit contains many cores (the Document MIRF has 234 and the Dictionary MIRF has 140), each with a separate primary winding; further, each core is associated with more than a thousand single-turn secondary windings. The secondary windings pass through or around all cores in the unit and so form a long rope. The capacitance between wires in the rope, the inductance of these wires, and the inductance of the primary windings are intercoupled in a very complex manner. In the development of the MIRF units, substantial noise on the secondary (item) windings was experienced due to ringing currents in the primary windings. This noise was reduced to a negligible level by inserting a Type DI52 diode in series with each primary winding and shunting each primary by a 1000 ohm resistor. A low-amplitude noise signal of about 5 Mc, due to inductance and inter-item capacitance of the secondary windings, was also observed. Such noise could be reduced to a very low level by filtering at the input to the discriminating amplifier, but in the experimental system this was not necessary.

Noise due to leakage flux must be kept small in order to hold the maximum match signal at 0.1 volt. A secondary wire that represents a match item must pass outside all energized cores. Since in the worst case, 57 cores may be energized, the maximum permitted noise due to leakage flux at each core is less than 2 millivolts (this corresponds to a leakage flux of \( \frac{1}{4} \) of one per cent at each core). In the experi-

Figure 10. Details of Primary Windings.
mental model two methods are used to reduce leakage flux. One is distributing the primary winding on the cores to compensate for the magnetic potential drop by a corresponding rise in magnetic potential at the points where the drop occurs. As Fig. 10 shows, the winding has a linear spacing except at the points where the air gaps occur; there two turns are closely spaced. The second method uses cancellation of induced voltages to reduce the effect of leakage flux. The common end of many item wires, instead of being connected to ground, as shown in the simplified diagram of Fig. 2, is actually connected to a wire that lies in the item wire rope and passes outside of all cores. The voltage induced in the “cancellation lead” at any core by leakage flux is approximately equal to that induced in item wires and is opposite in polarity (relative to the input terminals of the discriminating amplifier).

MECHANICAL DESIGN

1. The MIRF Module

Implementing the wiring-patterns-on-cores method of storage illustrated by Fig. 2 presented a challenging mechanical design problem. It was necessary that the physical structure containing the magnetic cores and the associated wiring be made in two parts that could be easily separated. It was desirable to fabricate submodules of wiring patterns, so that the permanently stored information could be changed mechanically in relatively small blocks.

Separate MIRF modules are used to store the information concerning document indexes and dictionary words. In each, the cores are arranged in a rectangular pattern and are supported by long bobbins. These bobbins are firmly attached to a base structure and carry the primary windings for the cores. A MIRF module is a complete assembly of magnetic cores, primary windings for the cores, and submodules of secondary windings with their associated diodes. The construction of a module is illustrated by the exploded view of Fig. 11. The principal parts of the assembly are the base, or coil bobbin, assembly and the item wiring trays.

The coil bobbin assembly consists of a field of paper bobbins (two per magnetic core) that are cemented to a 1/8-inch-thick phenolic board. Each bobbin carries a ten-turn winding. The windings on pairs of bobbins are connected in series to form the primary winding for one of the magnetic cores. An item tray is a 1/16-inch thick phenolic board with a field of shallow bobbins that matches the field of coil bobbins. The bobbins on the item tray are slightly larger than the coil bobbins, permitting item trays to be stacked up on the coil bobbin assembly. One item tray can accommodate 286 item wires. The diodes that are connected in series with the secondary windings and form the input circuit to the discriminating amplifier are mounted on the edge of the item tray. A MIRF module is assembled by sliding up to seven item trays into position on the coil bobbin assembly. One set of U cores is then inserted into the set of coil bobbins and held in place by a plate with a silicone-rubber pad. The other set of U cores is then dropped into position on the opposite side of the bobbin coils. Finally, the top plate (also with a spongy pad) is dropped into position to hold the entire assembly intact. The two sets of U cores are held together under slight pressure from the silicone pads.

From the collection of the Computer History Museum (www.computerhistory.org)
A complete item tray is shown in Fig. 12. The item wires start in the upper left corner of the trays, where they are connected to a common bus bar. They pass from left to right in the first row of cores, then back and forth until they emerge in the lower left center part of the tray. The wires then run to assemblies of diodes, where each wire is connected to its own individual diode. The output side of the diodes (the cathodes) are connected together and wired to a small connector, which is seen in the lower left hand portion of the tray. Even though each tray contains detailed wiring for 286 items, only two wires run from the tray to the external discriminating amplifier. Figure 12 also shows a pair of primary coil bobbins with the two U cores inserted. A closeup of a MIRF module with the top plate removed is shown in Fig. 13. The tops of one set of U cores can be seen as well as four item trays. The connectors for the output of the item trays can be seen in the lower center part of the photograph. The discriminating amplifier circuits (one for each of the seven item trays that can be included in a module) are located on the circuit board that is mounted in front of the magnetic module.

2. Wiring of the Item Trays

The item trays in the Document and Dictionary MIRF units store more than one-third of a million bits of information. To ensure the greatest possible accuracy of the wired-in information, two steps were taken. First, the raw data for the documents were computer-processed to give a set of punched cards that contain the detailed wiring information. Second, a wiring scheme was devised, which presented the detailed wiring information to a wireman in a very simple form, and which included a means of checking the accuracy of the wiring as the wiring was actually done. In this scheme, the path that a wire was to take was delineated by a set of lights in an array of incandescent lamps.

An over-all view of the item-tray wiring equipment (wiring aid) is shown in Fig. 14. The empty wiring tray is placed on the wiring jig in front of the operator. A card is then
placed in the punched-card reader and a pattern of lights is set up in the wiring jig. Number 36 Nyleze wire is taken from a spool through a tensioning device to the top of a special wiring tool (shown in the hand of the operator). The wire from the bottom of the wiring tool is first soldered to the common bus shown in the upper left part of the wiring tray. The tool is then moved along the path specified by the pattern of lights, leaving the wire wound in the desired pattern around the item tray bobbins. Correct wiring at a bobbin is indicated by a light turned on to yellow brilliance. If a light is off, or is on at white brilliance after the wiring tool passes a bobbin position, a wiring error is indicated.

3. Alternative Method of Fabricating Item Trays

Alternative methods of preparing wired-in information that may be more easily automated than stringing of small wire have been investigated. One alternative is illustrated by Fig. 15, which shows an item conductor in the form of a metallic path etched on a thin, copper-coated Mylar sheet (half-ounce copper on 2-mil Mylar). It will be noted that the item conductor is connected to a bus at the top of the sheet and to another bus at the bottom. These copper areas are used for connecting the item conductor to the common bus at one and to a diode at the other. This sheet contains one item, but two item conductors could easily be placed on one sheet, one being associated with one leg of the magnetic core and the other with the other leg. The experimental model contains a submodule of 75 items on Mylar sheets.

DELIVERED EXPERIMENTAL EQUIPMENT

The experimental Multiple Instantaneous Response File System is an all-solid state equipment. Transistor drive circuits capable of supplying two amperes of current to magnetic circuits, special discriminating amplifiers capable of operating reliably with a poor signal-to-noise ratio input signal, and transistor logic circuits were designed for high reliability, low cost, and moderate speed. About 300 current drive transistors, 2500 logic transistors, 2500 printed gate circuits (a group of 6 resistors, 2 capacitors and their interconnecting wiring on a passive substrate) and 5,000 diodes are used in the system. Except for sequences involving the input-output typewriter, the system operates synchronously under the control of clock pulses derived from a 50-kc transistor multivibrator.
The experimental equipment shown in Figs. 16 through 18 was delivered to Rome Air Development Center in July, 1963. A front view of the equipment is shown in Fig. 16. The main equipment cabinet, the input-output typewriter, and the display and control unit can be seen. Figure 17 shows a rear view of the equipment cabinet with the doors removed. The right hand portion of the cabinet contains logic circuits for control of the system, arranged in modules of plug-in transistor logic boards. The Dictionary MIRF unit is contained in the center portion of the cabinet. Directly beneath the MIRF unit are modules of drive circuits which provide current to the MIRF. In the left hand portion of the cabinet are the Document MIRF and the transistor circuits for providing drive currents to it. It will be observed that space has been allowed for one additional MIRF unit in the center section and for two additional MIRF units in the left hand section. This is to provide for the expansion of the Dictionary MIRF to 3,000 words and expansion of the Document MIRF to 5,000 document indexes. A front view of the cabinets that house the MIRF units and their drivers is shown in Fig. 18. Here the Document MIRF unit has been pulled out to show it in its extended position. Below the MIRF units the wiring side of the transistor drive modules can be seen.

The format of the typewritten record of a search in the experimental model is shown in Fig. 19. The first two lines, “Stanford Research Institute Project 4110,” etc., are a manually typed heading for the subsequent search. The heading was typed while the typewriter was effectively disconnected from the rest of the equipment. The search question consists of three words: “coding,” “computers,” “digital.” This line was also typed manually. The rest of the printout is the machine's response to the search question. Seven documents responded. For each one, a four-digit accession number and the English words that describe the document are printed on a single line. The asterisk prefix on some words have been copied from the ASTIA abstract. It will be observed that the three search words appear in every respond-
ing set of indexes. It should be especially noted that the search words appear in different positions and different order in the different responding documents. This independence of order of the search words and the position of the corresponding descriptors in the document indexes is an important result of the superimposed coding of the search field.

CONCLUSIONS

From experience with the Experimental MIRF it is concluded that interrogation of the magnetic storage units and the over-all control of the system can be accomplished with reliable circuits of modest complexity. Storage of the document index information in wiring associated with arrays of cores that are physically separable appears feasible; arrays of cores can be separated, submodules of wired information can be changed, and the core arrays reassembled in a reasonably short time. More work on the mechanical design of the magnetic modules is needed, however, to permit easier and faster changing of the stored information. Based on the performance of the experimental model, which contained a file of more than 1,000 document indexes, it is concluded that with the present design a system building block should contain about 5,000 document indexes. It appears that as many as ten such building blocks could be combined in a system whose over-all control is little more complex than that for a single building block. Therefore it is concluded that files of the order of 50,000 indexes could be built with no major changes in the basic concepts or circuits used in the experimental model.

Easy communication between a human operator and the Experimental MIRF System has been demonstrated. The machine's response to a search question is essentially instantaneous in terms of human reaction time and the information content of the response is sufficient to allow the operator to start the document search with a general question and to use the information received to define a more specific question. In this way it is possible to home-in quickly on the documents of special interest. Several automatic features of the equipment have proved to be useful. One of these is the capability of accepting a synonym in the search question and automatically translating it into the synonymous descriptor contained in the machine's vocabulary. Another feature is the capability of automatically modifying the search question inserted by the human operator and initiating a new search. For example, if any of the input words have attached to them a "see-also" reference, that see-also reference will be substituted for the original word to form a new search question.

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