# A "Word Spotter"

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*A description, with elementary footnotes, of a device that will automatically record the presence of preselected words in teletypewriter text.*

## INTRODUCTION

A completely transistorized special-purpose computer has been developed by RADE-2 which will recognize ordered sequences of teletype characters. The input to the device can be from punched paper tape, or magnetic tape, in parallel form. With a serial-to-parallel converter, sequential data from a magnetic-tape recorder can be used[1]. The theoretical maximum input speed is 50,000 words per minute for twelve-character words.

The computer incorporates a memory unit (or vocabulary) which is an unusual arrangement of pulse transformer cores where, by simply laying a single wire in a specified maze pattern, a word is inserted. It is contemplated however that printed-circuit cabling techniques will be used to form words for insertion in the vocabulary of the spotting equipment.

The entire equipment, with power supplies, is expected to take up approximately one-fourth of a conventional rack (or bay).

## METHOD OF OPERATION

The logic behind the operation of this equipment can be more easily explained by referring to Fig. 1, which is a block diagram of one stage of the "Word Spotter" (or XR2-34). The longest word to be "spotted" will determine the number of stages needed. The XR2-34 consists essentially of two memories coupled by a gating arrangement in a "Coincidence Detection" system originally proposed by Lincoln Laboratories.

One memory of the XR2-34 is transient, changing at a rate dependent on the speed of the tape-reading equipment feeding five parallel shift registers. On receipt of a synchronizing (feed hole or sync) pulse, all information stored in the shift registers is simultaneously advanced one stage. During the interval between synchronizing pulses, while the memory is static, complementary voltage levels from each of the five bi-stable

[1] These foot-notes are appended solely for the benefit of those who, like the editor, cannot follow the original text unaided. Others are urged to avoid them. [Editor]
If the tape is in parallel form it has five tracks recording simultaneously the five bits that make up a teletype character and a sixth recording a "sync pulse" which says in substance to the circuitry, "There is a signal here, record it." If it is not in parallel form, but records the five bits one after another, a serial-to-parallel converter stores the bits until all five are ready and sends them out over five circuits simultaneously.

multivibrators (flip-flops)[2] associated with each stage are applied to ten diode-resistor "and" gates. These gates are then "interrogated" by a mono-stable multivibrator (one-shot).[3]

Five gates (determined by the states of the five flip-flops associated with each character) will be open. An open gate will permit the "interrogation" pulse from the one-shot to trigger its associated pulse transformer core drive transistor. Interrogation is then performed on the "and" gates of the remaining characters, one at a time, until all characters have been interrogated. Each character has its own one-shot. As soon as all characters have been interrogated, an additional interrogation is performed on "and" gates associated with unsaturating flip-flops. These flip-flops have been following the character-by-character interrogation of the stored "vocabulary". In the case illustrated in Fig. 1, the letter R is the stored vocabulary. If coincidence has been detected in all characters by an unsaturating flip-flop, then its associated "and" gates are open and an "output" pulse is permitted to pass. The circuitries of the flip-flops, one-shots, "and" gates, and pulse transformer core drivers are conventional configurations and will not be dealt with in this report.

The second memory (or "vocabulary") of the XR2-34 which was mentioned in the previous paragraph is permanent, although it can be readily altered manually as the occasion arises. It consists of a one-turn secondary, threaded in a logical arrangement through the pulse transformer cores, which are shown as doughnut shapes in the block diagram of Fig. 1. These cores are Manganese Zinc Ferrite U-Cores fitted together to form a doughnut-shaped toroidal core. The letter R was chosen to illustrate the manner in which a word is inserted in the "vocabulary". The teletype code for R is "space-mark-space-mark-space". The reader will note that the letter R has been threaded through the cores which are pulsed in the complementary coding "mark-space-mark-space-mark". We are, therefore, looking for the absence of pulses in all cores through which our one-turn secondary has been threaded. It is, of course, obvious

[2] A flip-flop is a device which can record either of two states, e.g. "mark" or "space" and records the one last signalled to it, the previous one being lost. In a shift register, however, the previous state is not lost but is passed on to the next flip-flop in the series. Thus with five parallel shift registers the five bits constituting a signal move from row to row until they finally fall off the other end. The number of rows governs the length of word that can be held in this transient memory. One of those electric signs in which words pass across the face of the sign from right to left furnishes a simple analogy.

[3] An "and" gate is a device which allows a pulse to pass if its elements are all in the same predetermined one of two possible states; i.e., if there are two elements, AA allows a pulse to pass, but AB, BA and BB do not. An "or" gate allows a pulse to pass if any element is in the predetermined state; i.e., for two elements, AA, AB or BA will pass the pulse, but BB will not.
Here, each of the five flip-flops in each row has it's own two "and" gates and sends an A to an element of one and a B to an element of the other. Which gets which depends on whether the flip-flop is recording "mark" or "space". An A is then sent to the other element of each gate by a "one-shot" (a kind of pulse-gun, firing uniform ammunition when triggered, and reloading itself for the next shot). Thus one of the two gates now has two A's and allows a pulse to pass, while the other hasn't and doesn't.

why this is done. The digital task of detecting no-pulse among pulses can be done more reliably than the analog task of detecting a certain discrete voltage among other discrete voltages.[4] Fig. 2 illustrates waveforms obtained from the six-character feasibility model of the XR2-34. As reference to Fig.1 will show, we need thread our one turn secondary through only five of the ten cores in each stage in order to recognize a letter. Inasmuch as the feasibility model has a maximum word length capacity of six characters, we need only wind our one turn secondary through thirty cores in order to recognize a six character word. Fig. 2 illustrates the condition of coincidence on thirty cores. Ideally, this figure should be a straight line, but the reader will note that there are six transient pulses approximately 10 $\mu$seconds apart and of amplitude approximately 0.6 volts. These undesirable transients are caused by inter-wiring "pickup" of the interrogation pulses, and will be referred to as noise. Fig. 2b illustrates the condition of coincidence on all but one core. This is the limiting condition in the operation of the XR2-34. We must be able to detect the difference between the "signal" pulse from one core and the noise pulses. The scale in the region of the signal pulse has been expanded ten times in the right-hand photograph of Fig. 2b. It can now be seen that the signal-to-noise figure of the equipment is approximately 2:1.[5] Fig. 2c illustrates the fact that non-coincidence on more than one core will result in addition of the signal pulses, and consequent increase of amplitude. Here, as in Fig. 2b, the scale in the region of the signal pulse has been expanded ten times in size in the right-hand photograph. To obtain Fig. 2d, our one turn secondary was wound through only one core in each character. As can be seen, the transient pickup on only one core is very small.

Manganese Zinc Ferrite was chosen for use in the XR2-34 in preference to the other core materials available on the open market. Ferrite has the advantages of (1) higher permeability, (2) lower losses at high frequency, (3) ease of manufacture in unusual shapes, (4) more uniform electrical and mechanical properties, and (5) lower cost.

[4] When a pulse is sent along a "primary" wire threaded through a core, a "secondary" wire threaded through the same core also receives a pulse by induction. This secondary wire is threaded through the cores whose primaries will *not* be pulsed if the character is the one we wish to recognize R in the case indicated), so that "no pulse in the secondary" means "this is R".

Each row has its own set of ten gates and ten cores. To put SEA in the permanent memory a single wire is threaded through the five cores that will not be driven by an A in row 1, then through the five that will not be driven by an E in row 2, and similarly for an S in row 3. The event that no pulse passes along that wire happens if and only if the word SEA has just entered the temporary register. Other words have other wires.

[5] Even when the cores through which the secondary is threaded are not driven it "picks up" unwelcome noise from pulses on other wires. These are shown in the photographs. The right-hand photographs of 2c and 2d, in which the horizontal scale has been multiplied by 10, also show signal pulses from one and two cores respectively. The least favorable case, which is always the one meant by "signal-to-noise ratio", is the one shown in 2b, with only one core contributing to the signal. It can be seen that the signal pulse has about twice the amplitude of the noise pulses.

Disadvantages of Ferrite are (1) its low Q, and (2) low Curie temperature.[6]

Inasmuch as the cores are key components, it may be well to discuss in more detail their advantages and disadvantages. Our primary objective is to obtain a maximum output pulse amplitude with minimal input drive. The input drive pulse is influenced by the following factors in Lenz's equation:

$$e_{in} = L \frac{di}{dt} .$$

To increase $e_{in}$ without increasing $i$ or decreasing $t$, we need a large $L$. Since $L$ is directly proportional to permeability ($\mu$), it would be advantageous to have a core with a high $\mu$. In Table 1, values are given for various properties, including toroidal permeability ($\mu_o$) and losses, of the Manganese Zinc Ferrite cores used in the XR2-34 versus various iron cores. Above about 100 KC, the residual losses do not follow the simple relation given by Legg. (see Table 1, and item 2 in the Bibliography.) Fig. 3 shows the relationship of $\frac{R}{\mu f L}$ and frequency over the range of 2KC to 1 megacycle. This figure is shown because the cores of the XR2-34 are being used at a 500 KC rate, as appears from the waveforms of Fig. 2.

The Curie temperature of ferrite cores is much lower than is found in iron cores. In those used in the XR2-34 it is 170° C. Inasmuch as the maximum ambient temperature permissible with the transistors used in this equipment is 85° C, the low Curie temperature is of no concern to us.

For those readers who are interested, the Q of the ferrite cores can easily be found by using the relationship:

$$Q = \frac{2\Pi}{\mu\left(\frac{R}{\mu f L}\right)}$$

$\mu$ is the permeability, which is approximately 1000 (between 25°C and 150° C). The value of $\frac{R}{\mu f L}$ can be obtained directly from Fig. 3. In our application, the Q of the cores ($\approx 17$) is of little concern.

The cost of the Ferrite cores is very small. A U-core costs approximately thirty cents.

## FEASIBILITY MODEL XR2-34

A feasibility model of the XR2-34 has been constructed and successfully tested in the RADE-201 laboratory. Fig. 4 shows front and rear photographs of the breadboards. This equipment can recognize 600 to 800 six-character words. Ten arbitrarily chosen words, ranging in length from

[6] For obvious reasons no attempt will be made to annotate the mathematical physics in the paragraphs that follow. The lay reader may be interested to know that Q is the ratio (per cycle) of energy stored to energy lost, so that low Q means much loss of energy. The Curie point of a core material is the temperature above which its ferro-magnetic properties disappear. When the material is cooled these properties are regained at a point only slightly below that at which they were lost.

three to six characters, were threaded through the cores for testing purposes. Although they were combined by means of a simple diode "or" gate to obtain a single output, individual outputs may be obtained, if desired, to facilitate various logical functions.[7] This equipment contains 181 2N414 transistors. The total power consumption is 3 watts.

**FUTURE PLANS FOR THE XR2–34**

An engineering model of the XR2-34 is now under construction and scheduled for completion by 1 February 1960. A sketch of it is shown in Fig. 5. This unit will be capable of recognizing ordered sequences of up to twelve teletype characters. Construction will be single-chassis, with hinged side-panels, and self-contained power supplies. This will eliminate messy inter-chassis cabling. The cores will be Ferrite *U*-cores with spring loaded bars on top, so that the tops can be lifted for insertion or removal of words in the vocabulary. The words may be inserted in the form of printed-circuit wiring on large sheets of plastic which have been prepunched to fit down over the legs of the U-cores. The unit will require approximately 20 inches of front-panel height in a standard rack (or bay). Approximately 160 printed-circuit cards will be used, with a power requirement of 6 watts. It is estimated that the engineering model will cost slightly less than $10,000.

Presently under development is a system which will incorporate the XR2-34, a Potter *Model 907* perforated tape reader, and a high-speed paper tape punch. This system will perform the function of searching through perforated paper tape for desired portions, and then re-perforating the portions selected.

BIBLIOGRAPHY


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3. Gelbard, E., "Magnetic Properties of Ferrite Materials", *Tele-Tech*, Vol. 11, No. 5, May 1952, pp. 50-52, 82, 84.
4. Owens, C. D., "A Survey of the Properties and Applications of Ferrites Below Microwave Frequencies", *Proc. of the IRE*, October 1956, pp. 1234-1249.


[7] If all that we want to know is how many of a certain set of words have passed through the machine, we connect their wires with the elements of an "or" gate. All the wires are pulsed when none of the words is in the register. If one of the words *is* in place that wire alone is not pulsed. This second situation is an "or" situation for a "no-pulse" gate and the gate lets a pulse through, which can be used to operate a counter.

**Table 1**

Comparison of loss coefficients for various magnetic core materials.

| | $\mu_o$ | $ax10^6$ | $cx10^6$ | $ex10^9$ |
|---|---|---|---|---|
| Powdered Iron A | 35 | 49 | 109 | 88 |
| Powdered Iron B | 26 | 81 | 139 | 31 |
| Powdered 81-Permalloy | 75 | 5.5 | 37 | 51 |
| Powdered 2-81-MO-Permalloy | 125 | 1.6 | 30 | 19 |
| Mn Zn Ferrite used in XR2-34 | 900 | 1.8 | 30 | 1.7 |

NOTE: *a*, *c*, and *e* are the coefficients of V. E. Legg's equation:

$$\frac{R}{\mu f L} = aB_M + c + ef$$

where $R$ is the equivalent loss resistance of the core and $\mu_o$ its permeability; $f$ is the frequency; $L$ is the inductance of a coil wound upon a closed core; and $B_M$ is the maximum flux density at which the results are obtained. When this equation can be used, the coefficients $a$, $c$, and $e$ characterize the magnetic core material. The coefficient $a$ is characteristic of the hysteresis losses; $c$ is characteristic of the residual losses; and $e$ is characteristic of the eddy current losses as well as the dimensions of the dimensions of the specimen.

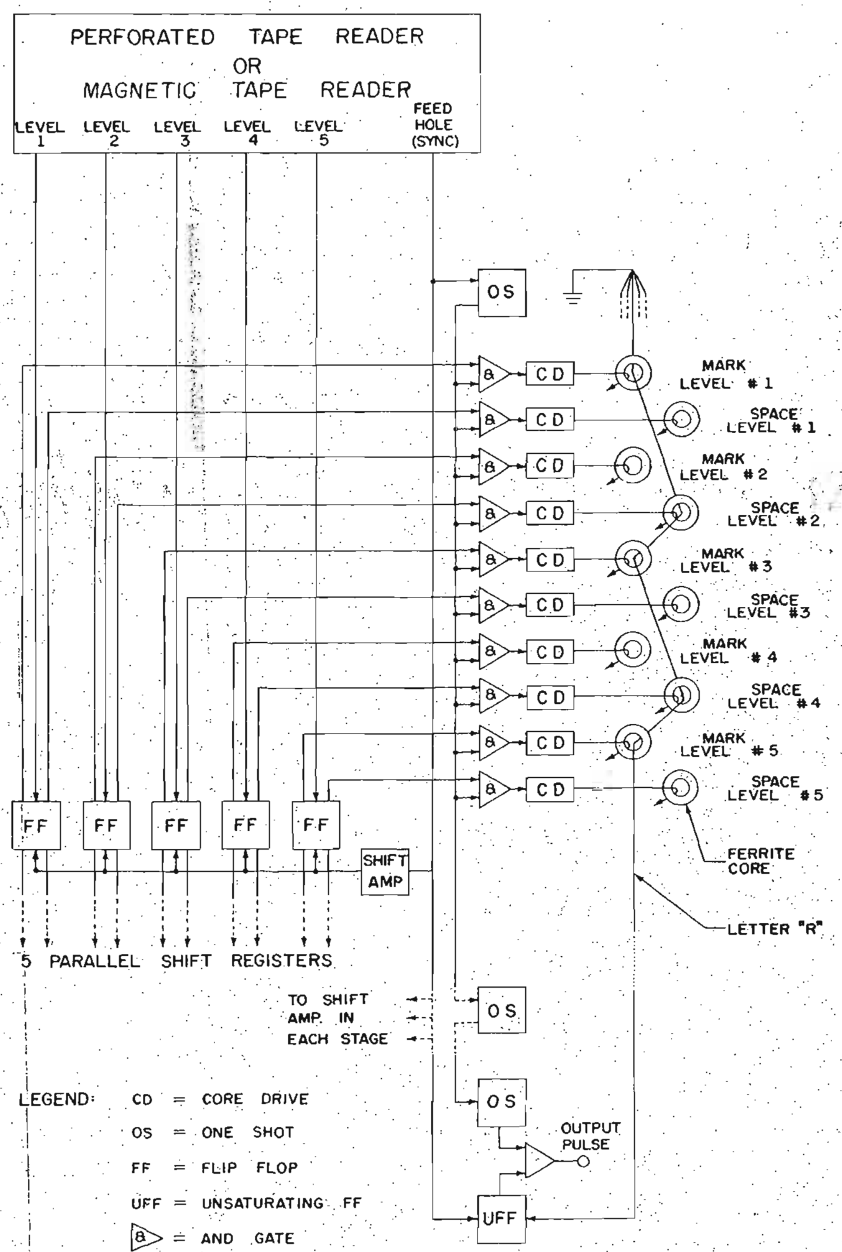
PERFORATED TAPE READER
OR
MAGNETIC TAPE READER
LEVEL 1
LEVEL 2
LEVEL 3
LEVEL 4
LEVEL 5
FEED HOLE (SYNC)
OS
MARK LEVEL #1
SPACE LEVEL #1
MARK LEVEL #2
SPACE LEVEL #2
MARK LEVEL #3
SPACE LEVEL #3
MARK LEVEL #4
SPACE LEVEL #4
MARK LEVEL #5
SPACE LEVEL #5
CD
FF
SHIFT AMP
FERRITE CORE
LETTER "R"
5 PARALLEL SHIFT REGISTERS
TO SHIFT AMP. IN EACH STAGE
OUTPUT PULSE
UFF
LEGEND: CD = CORE DRIVE
OS = ONE SHOT
FF = FLIP FLOP
UFF = UNSATURATING FF
a = AND GATE

Fig. 1

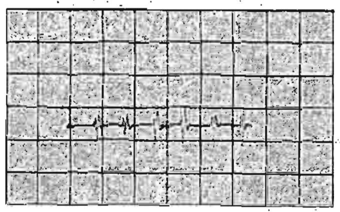

Fig. 2a

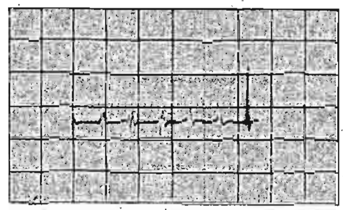

Fig. 2b

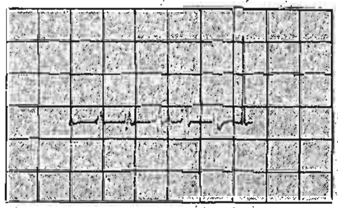

Fig. 2c

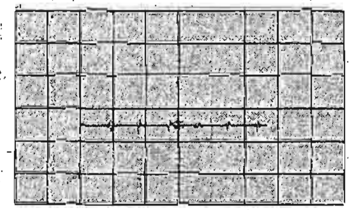

Fig. 2d

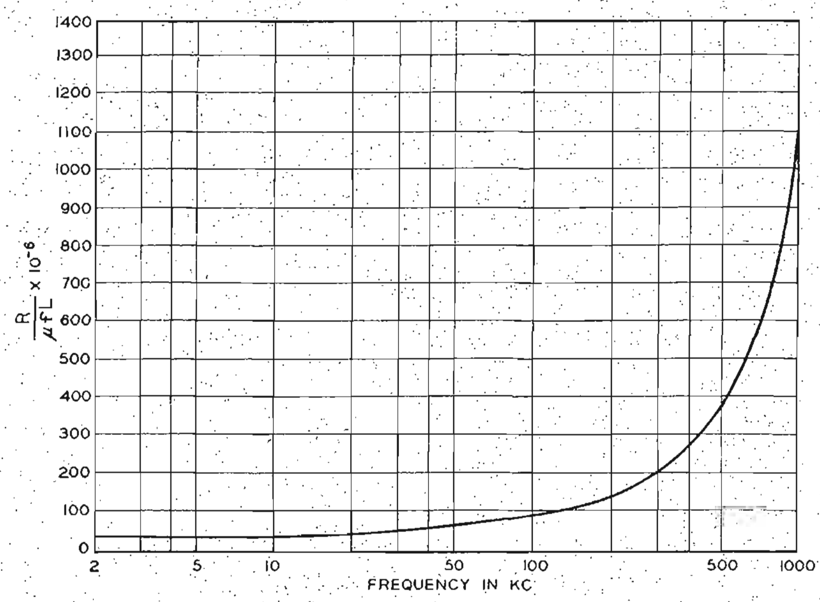


Fig. 3 $\frac{R}{\mu f L}$ vs. Frequency for Ferroxcube 3

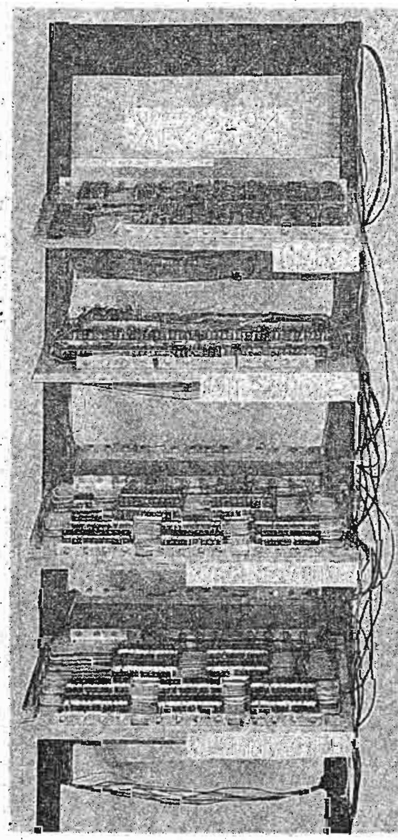

Fig. 4a

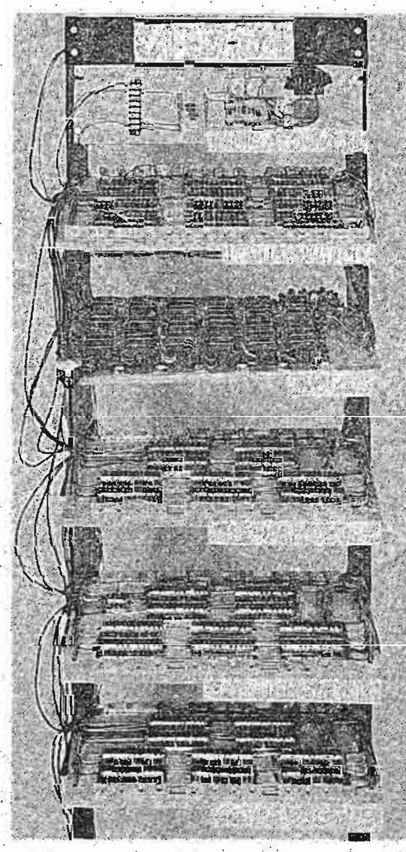

Fig. 4b

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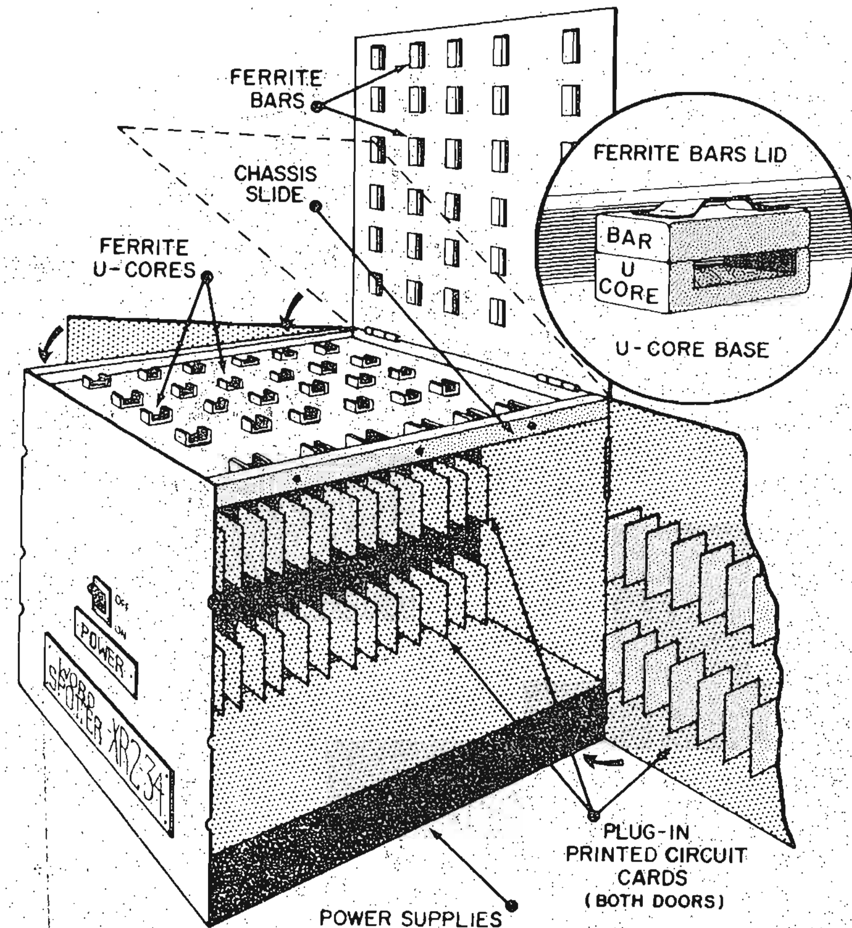


SKETCH OF ENGINEERING MODEL OF XR2-34

**Fig. 5**