ELECTRICAL ENGINEERING DEPARTMENT
MASTER'S THESIS PROPOSAL

1. **Title:** A COINCIDENT-CURRENT MAGNETIC MEMORY UNIT

2. **Brief Statement of the Problem**

It is proposed to investigate the problems involved in combining the binary-memory (residual magnetism) property of a "hard" ferromagnetic core with its coincidence (multiple-winding) possibilities, to form a small, high-speed, memory unit. Such units, assembled into two- or three-dimensional matrices, might be suitable for the memory system of an electronic digital computer such as Whirlwind I (M.I.T. Project 6345).

3. **History of the Problem up to the Present**

By the Fall of 1948 the Computation Laboratory of Harvard University had constructed magnetic-memory units utilizing the residual magnetism of small ferromagnetic cores having near-rectangular hysteresis loops. These they connected in cascade to produce a "Static Magnetic Delay Line",[1] along which binary information could be stored and shifted serially. In Report No. 4 of the same series, issued in the Spring of 1949, they reported attaining operating frequencies of the order of 33 kc per second; their latest reports, Nos. 5 and 6, indicate that this figure has not been increased. They have also experimented with and speculated about the coincidence possibilities of a saturable core for gating and other applications.

1. Harvard University Computation Laboratory, "Investigations for the Design of Digital Calculating Machinery", Progress Report No. 2, August 10, 1948 - November 10, 1948).

It was suggested by J. W. Forrester, Director of Project Whirlwind at M.I.T., that a two- or three-dimensional selection scheme of a digital nature might be ideally suited to a memory matrix made up of small multi-winding ferromagnetic cores. Such a system might have many advantages including permanence of storage, easy access, preservation of the digital nature of the computer during the selection process, interesting packaging potentialities, and very simple power-supply requirements.

A major section of the problem has to do with the characteristics of the cores to be used. The undersigned has just written a Graduate Seminar Paper for the Electrical Engineering Department of M.I.T. on the subject "Ferromagnetic Materials for Applications Requiring Rectangular Hysteresis Loops and Short Response Times", in which the binary-memory application is used as an illustration of the requirements on the core material.

4. Description of a Basic Unit[1]

A brief description of the basic mode of operation of the magnetic-memory unit to be investigated is in order preliminary to any indication of expected procedure. Figure 1 shows, schematically, a possible arrangement for a unit using two-current coincidence excitation. (Such a unit might be suitable for a two-dimensional matrix representing one digit in a memory system.) Windings A and B are excitation, or selection, coils; S is a pickup, or signal, coil. Assume that a hysteresis loop of the core is as shown in Figure 2. (The loop shown is less rectangular than is desirable in order to exaggerate certain

1. See attached drawing for figures 1 and 2.

aspects of the problem.) Assume that, at the start, the operating point is at the lower stable position $-B_r$.

The application of a magnetizing force of amplitude $H_m/2$ moves the operating point to x, resulting in a very small change in flux density B; return to H = 0 moves the operating point to $-B_n$, a point not far removed from $-B_r$.

The result for the application and removal of the full H_m is quite different; the operating point moves to y, and then to $+B_r$. The core has reversed its magnetization upon application of H_m; in the process there was a large change of flux density B, with a correspondingly large pulse induced in the signal coil.

If the currents i_A and i_B (in Figure 1) are made equal and of such an amplitude that they correspond to values of magnetizing force equal to $H_m/2$ each, and sum to H_m together, then the magnetization of the core can be changed from $-B_r$ to $+B_r$ only by the coincidence of i_A and i_B. The development of a relatively large signal pulse would also, therefore, depend on such coincidence. Reversing the current directions reverses the procedure. (There are problems having to do with "reading-in", erasure of information, and some other items which come to mind relevant to using this type of unit efficiently in a memory system; these problems will be ignored at first.)

It is immediately apparent that forms of noise and instability result from the minor hysteresis loops travelled when magnetizing forces less than H_m are applied and removed. (One such is indicated between $-B_r$, x, and $-B_n$.) These and other factors make a very high degree of rectangularity and a relatively high coercivity desirable in the core material.

Up to now, quasi-static operation has been assumed. Obviously, the frequency with which operations may occur will be limited by losses, eddy-current shielding, and other factors.

5. Proposed Procedure

Calculations already made indicate that freedom from eddy-current shielding is very important, as is the degree of rectangularity of the core material. So far, the latter quality is only obtainable in metallic (low resistivity) materials. Testing will start, therefore, with wound tape cores of Deltamax[1] and similar alloys. (Magnetic ferrites may be considered later.) It should be possible, by observing the dependency of the response on frequency, core geometry, tape geometry and composition, to obtain experimental verification of the identity of limiting factors.

Equipment will be set up to measure and display the flux density (or its rate of change) of a core as a function of the amplitude and form of an applied magnetizing force. Cores will be tested with a view to identifying limiting factors and to selecting promising candidates for further study. A basic memory unit will be set up and measurements taken to determine the following:

a. The minimum magnetizing force needed to reverse magnetization completely enough to allow stable cyclic operation.

1. The Arnold Engineering Co., "Technical Information on Deltamax" (April 1, 1949), Chicago, Illinois.

b. The maximum permissible magnetizing force, just insufficient to start reversal, which may be repeatedly applied and which will not significantly reduce the response of the core to a full reversing force later.

c. The output signal (noise) resulting from b.

d. The changes in a and b as functions of frequency or speed; or, the response time as a function of the variables in a and b.

Should time allow, an attempt will be made to build a small (2 by 2) memory matrix with associated circuitry, and determine its operating characteristics.

6. Equipment Needs

All necessary test and measurement equipment is available at Project 6345.

A number of test cores are already available at the Project and more will be procurable as needed. Correspondence with possible sources is in progress and will continue.

7. Estimated Division of Time

a.	Preparation of the proposal	55 hours
b.	Further study of the literature	25 hours
c.	Experimental work and analysis	200 hours
d.	Correlation of results, and formulation of deductions and conclusions	40 hours
e.	Preparation of thesis report	80 hours
f.	Total	400 hours

8. Signature and Date

William N. Papian

William N. Papian, January 24, 1950

9. Supervision Agreement

The problem described here seems adequate for a Master's research. The undersigned agrees to supervise the research and evaulate the thesis.

Jay W Forrester

J. W. Forrester

WNP:set

Attached drawing: A-35238

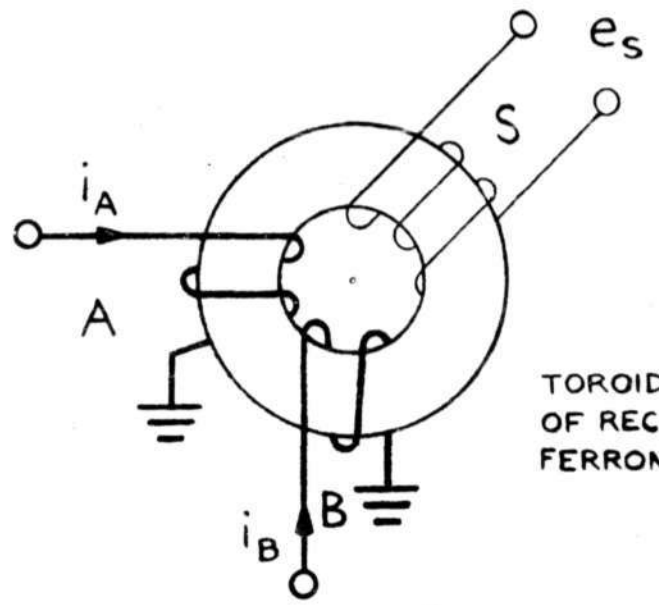

FIGURE I. A TWO-CURRENT-COINCIDENCE MEMORY UNIT

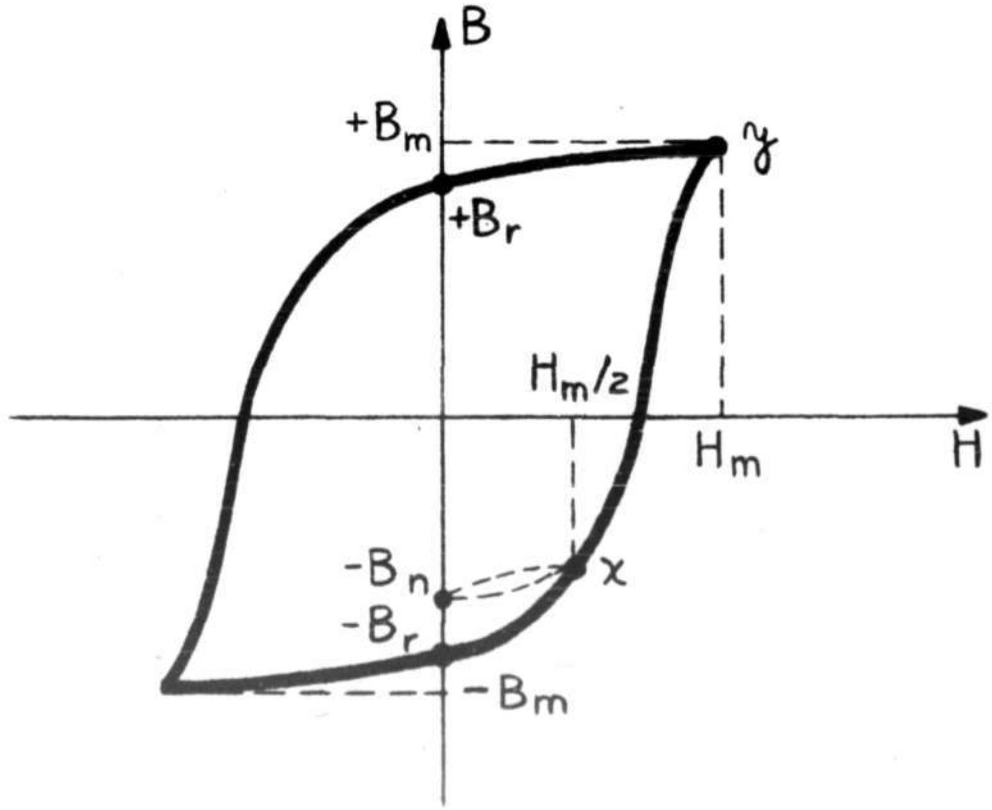

FIGURE 2. PATHS OF OPERATION OF A MAGNETIC-MEMORY UNIT

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