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Memorandum M-1282

K. H. Olsen
September 21, 1951

ELECTRICAL ENGINEERING DEPARTMENT
MASTER'S THESIS PROPOSAL

1. TITLE: A MULTI-POSITION MAGNETIC SWITCH AND ITS INCORPORATION INTO A MAGNETIC MEMORY

2. BRIEF STATEMENT OF THE PROBLEM

Considerable research has been carried on with core materials suitable for a multi-dimensional magnetic memory. However, in its present development the memory is expensive because of the complex method of switching with a crystal matrix and driving with hard tubes. It is herein proposed that a magnetic switch will significantly simplify the memory unit. The switch may have many other uses such as selecting recording heads on a magnetic drum or a tape recorder. It might also be used in many places where relays are now used such as decoding "flexowriter" tape where it could drive the typewriter keys directly. Techniques developed might be used to build arithmetic tables, so that arithmetic operations with binary numbers could be carried out almost instantly.

3. BRIEF HISTORY OF THE PROBLEM

The practical application of a magnetic core as a "gating" device dates back to the use of a large saturable reactor as the antenna-keying switch on one of the early radio-transmitting alternators as developed by E. F. W. Alexanderson in the late 1900's.[1] Since then

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1. E. F. W. Alexanderson, "Transatlantic Radio Communication", Trans. A.I.E.E., Vol. 38, p. 1269, 1919.

saturable reactors have been used in many similar applications. Recently their use as high-speed low-power gates has been partially investigated by laboratories interested in their application to digital-computer circuits.[1,2]

The idea of storing digital information in a magnetic-core array of two or more dimensions was first proposed in 1949 by J. W. Forrester, Director of the Digital Computer Laboratory at M.I.T.[3] At that time the most serious problem was the lack of a core material with a sufficiently rectangular hysteresis loop that could be switched fast enough to be of use in a high-speed computer. Intensive research has been carried out and a master's thesis written on this subject by W. N. Papian.[4] Although considerable improvement is expected in the future, core materials are now available which can be incorporated into a memory. Of particular interest are the ceramic cores which can be switched in a fraction of a micro-second.

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1. Harvard University Computation Laboratory, Progress Report 5 (Summer of 1949), Investigations for Design of Digital Calculating Machinery.

2. James G. Miles, "Saturable Core Reactors as Digital Computer Elements". A Report of the Engineering Research Associates. Contract NObsr 42001, 17 June, 1949.

3. J. W. Forrester, "Digital Information in Three Dimensions Using Magnetic Cores," Project Whirlwind Report R-187, (May 16, 1951), M.I.T. Servomechanisms Laboratory.

4. W. N. Papian, "A Coincident-Current Magnetic Memory Unit," Project Whirlwind, Report R-192, (September 8, 1950), M.I.T. Servomechanisms Laboratory.

The problem to be considered in this thesis will be divided into two parts: the development of a suitable switch and the incorporation of the switch into a working memory.

Because the switch is an integral part of the memory and because the mode of operation of the memory with the switch will be different from that originally proposed, the second part of the problem will be a large part of the thesis. It is difficult to realize now what problems will be found when such a large number of interacting elements are tightly coupled together.

4. DESCRIPTION OF SWITCH

The magnetic switch is very much like the crystal matrix switch which is now in common use particularly in digital computers. One of 2^n output terminals can be selected by n inputs, each operating a flip-flop or a two-position switch. In the crystal matrix switch this selecting is done by arranging crystals from the flip-flop outputs to the switch terminals in a binary scheme so that all but one terminal is drawn negative (Fig. 1). The terminal not drawn negative is the one selected by the binary number set up in the flip-flops.

The equivalent magnetic switch (Fig. 2) has a core or a saturable transformer for each switch terminal. On each core there are n control windings connected to the flip-flops as the crystals were in the crystal switch. The output of one flip-flop is enough to saturate a core so with this connection all but one core will be saturated.

Each core also has an output winding and an input winding as in a transformer. All the input windings are driven in series but only the unsaturated core will pass a signal to the output winding. This signal can be a square wave as will be used in the memory or a sine wave for power switching.

5. DESCRIPTION OF MEMORY UNIT

The memory will be made up of an array of small cores or rings of a magnetic material which has a rectangular hysteresis loop. When the residual magnetization of a core is in one direction the core is said to be holding a ONE, and when in the other direction it is said to hold a ZERO. The contents of a core is "read out" by driving current through a winding on the core in such a way as to drive the core to the ZERO position. If the core is already in the ZERO position there will be very little change in flux, but if the core is in the ONE position there will be a large change in flux and a voltage will be induced in a sensing winding on the core. The information in a core is of course destroyed and it has to be "rewritten."

Each core in the array has one winding in series with a line from each of two or more co-ordinates (see Fig.3). In the original scheme, a selected core is switched from one position to another when a measured current is applied to each of the windings of that core so that the sum is enough to switch the core. Many other cores also have current in one winding, but this is not enough to switch them. This nessitates carefully regulated current sources and very rectangular hysteresis loops. However, when the array is driven from the magnetic switch, a considerably greater current can be used in each line because every non-selected core is kept from switching by the saturated switch core it sees on the other co-ordinate or co-ordinates. Eliminating the necessity of many critically adjusted current sources simplifies the problem significantly, and the increased current will speed up the switching.

6. PROPOSED PROCEDURE

A 16x16 memory array of ceramic cores using the magnetic switch will be built and the problems investigated. Study will be made of the reliability of the system and the deterioration of the information in a single core as information is read out of and written into neighboring cores. Provision will be made in the equipment to display the output of the cores as an array of spots on an oscilloscope.

Every time the core is cycled about the hysteresis loop an amount of energy equal to the area of the hysteresis loop is dissipated in the core. The frequency at which cores can be switched will be limited by the temperature rise in the core due to this and other losses. Apparatus will be built to switch several test cores for a long period of time to investigate this problem.

7. EQUIPMENT NEEDS

Equipment for the proposed system for testing the complete memory (Fig. 4) is under construction or readily available at the Digital Computer Laboratory.

Cores have been already ordered for the 16x16 array, and more are procurable as needed.

8. ESTIMATED DIVISION OF TIME

a.	Preparation of Proposal	40 hours
b.	Experimental Work and Analysis	240 hours
c.	Correlation of Results and Formulation of Deductions and Conclusions	40 hours
d.	Preparation of Thesis Report	80 hours
e.	TOTAL	400 hours

9. SIGNATURE AND DATE

Kenneth H. Olsen

Kenneth H. Olsen,
September 21, 1951

10. SUPERVISION AGREEMENT

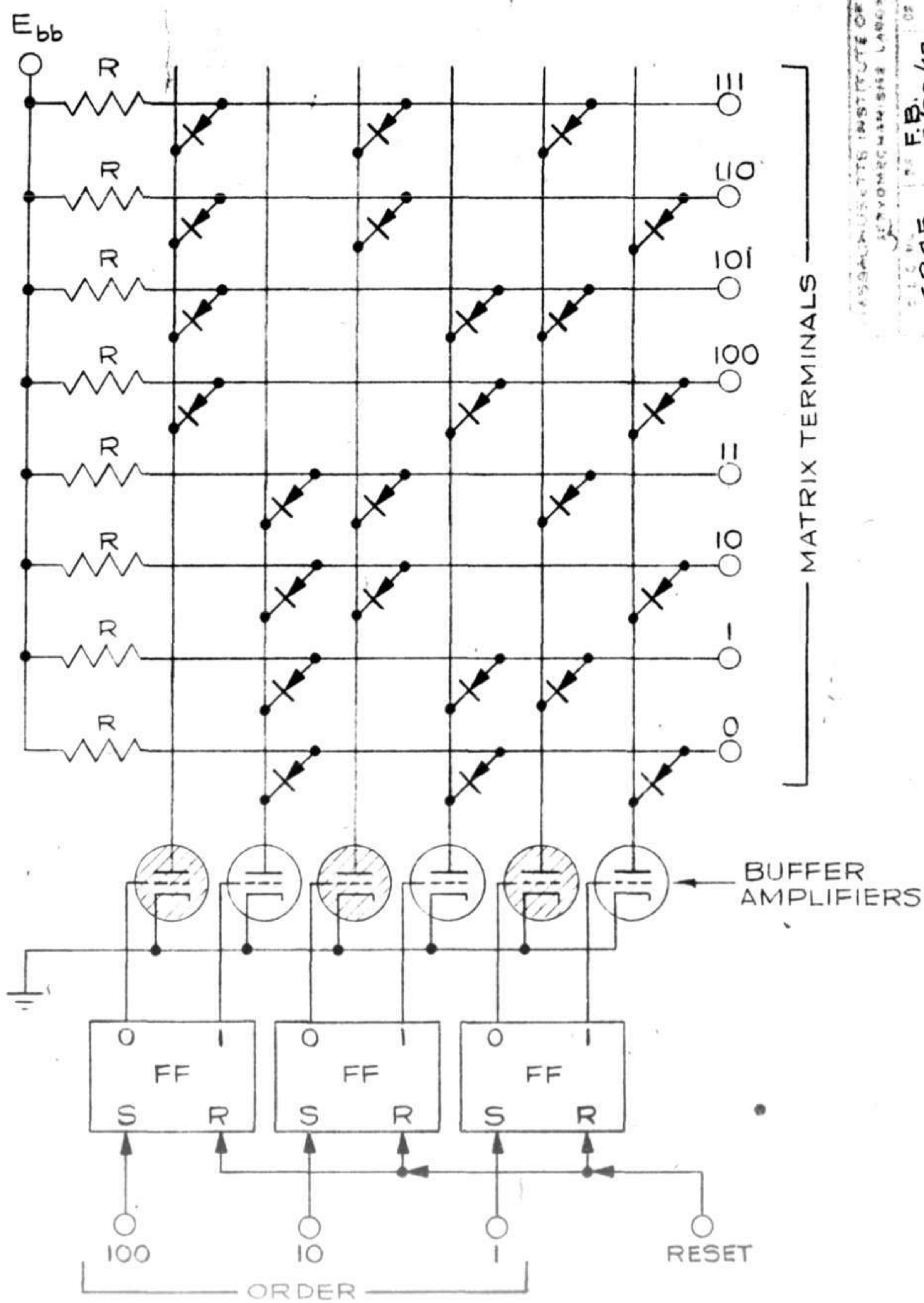
The problem described here seems adequate for a Master's research. The undersigned agrees to supervise the research and evaluate the thesis.

Robert R. Everett

KHO:kst

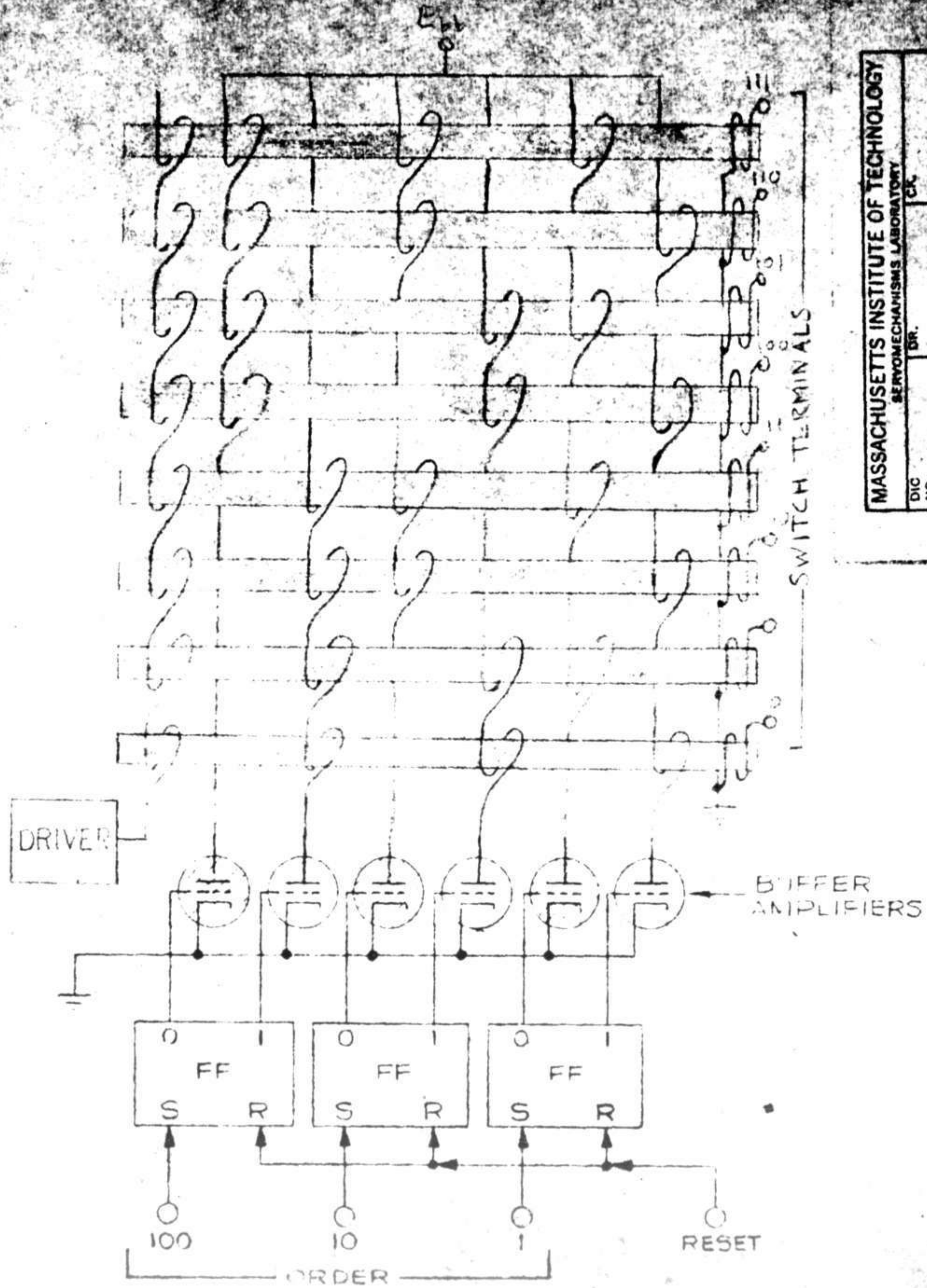
Drawings Attached:

A-30527	Figure 1
SA-50348	Figure 2
A-36656	Figure 3
SB-50349	Figure 4



CRYSTAL-MATRIX SWITCH REDRAWN

FIG. 1



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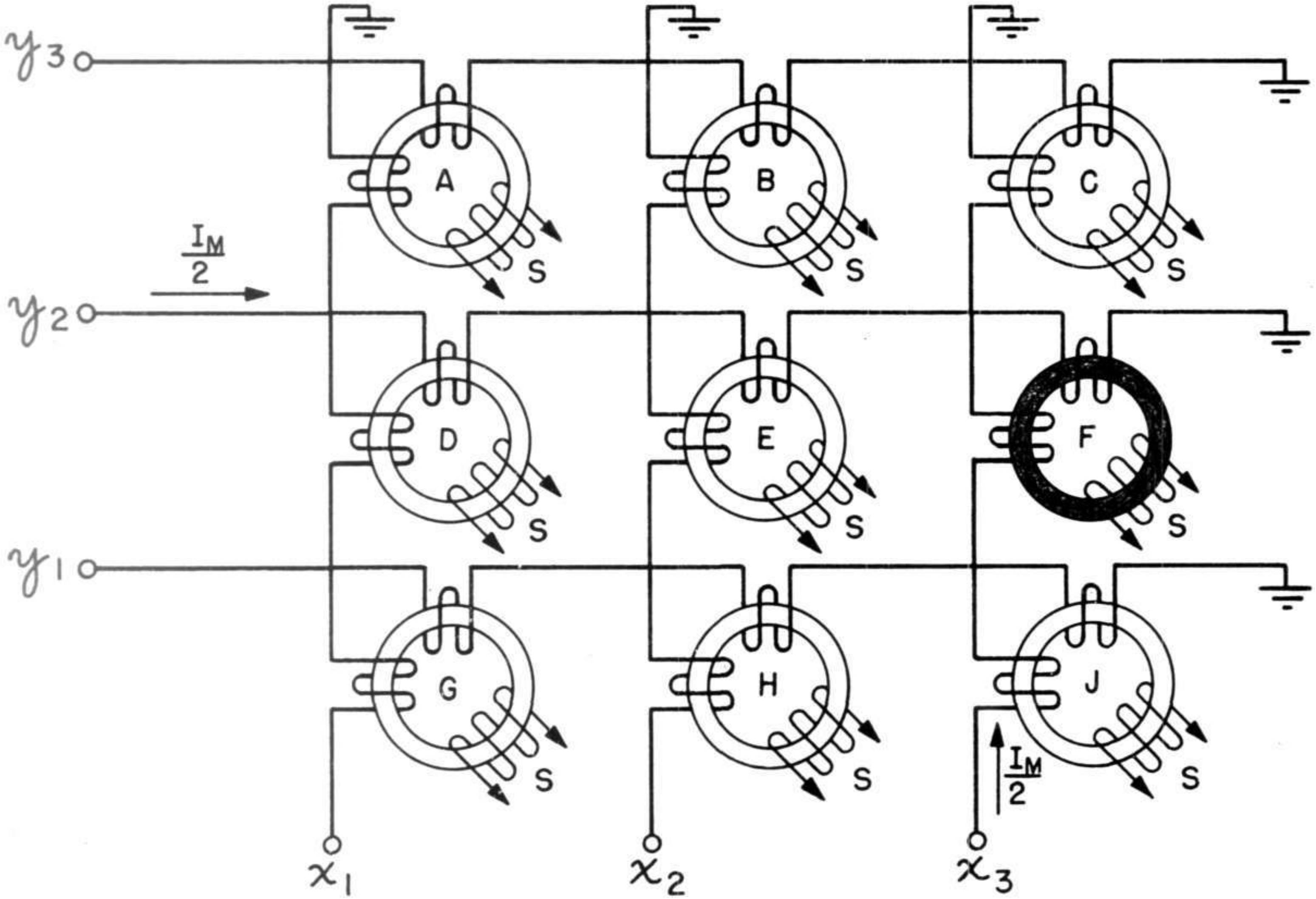
8-POSITION MAGNETIC SWITCH

FIG. 2

A-36656



A TWO-DIMENSIONAL ARRAY OF CORES

FIG. 3

SB-50349

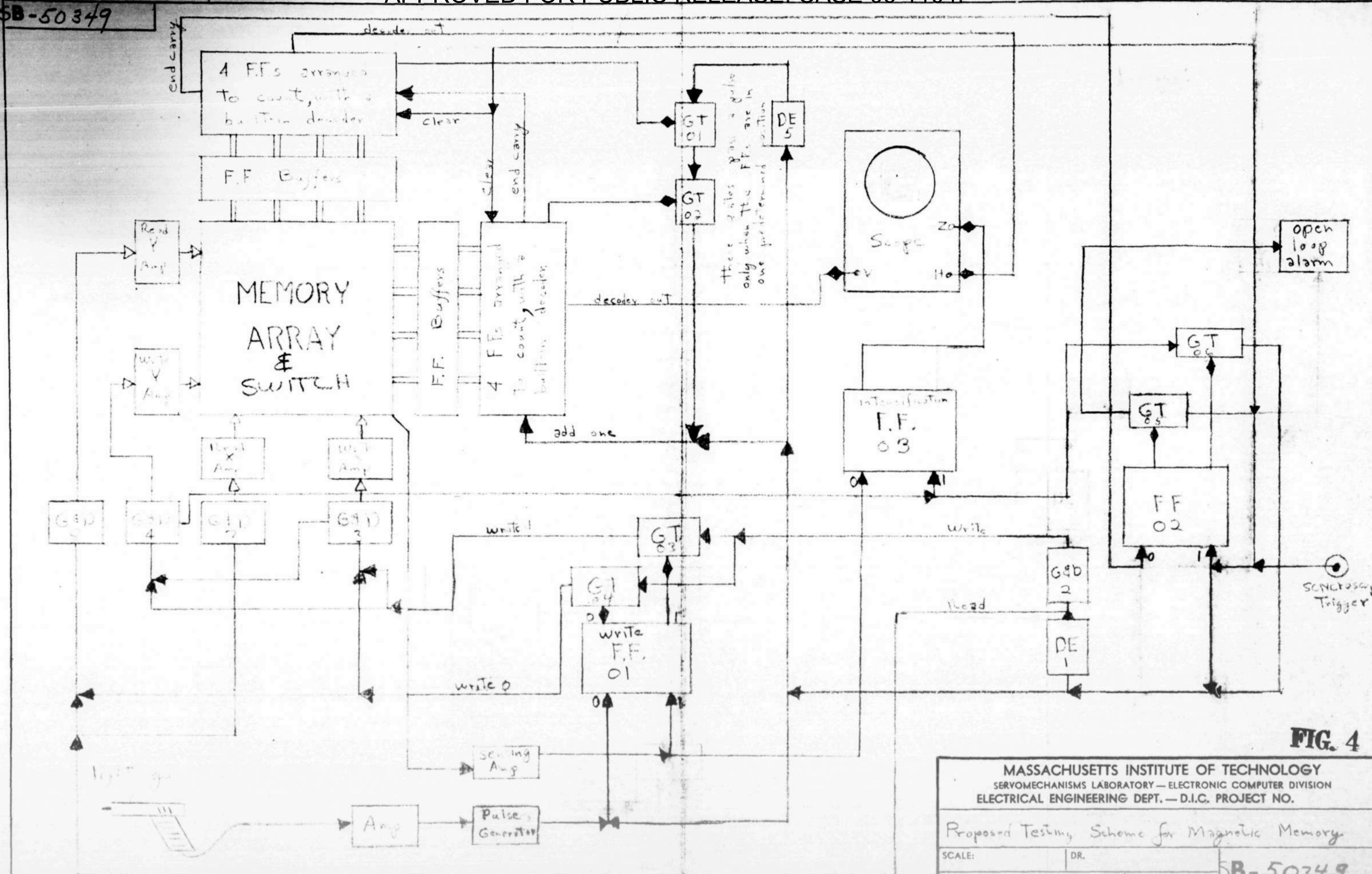


FIG. 4

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
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ELECTRICAL ENGINEERING DEPT. — D.I.C. PROJECT NO.

Proposed Testing Scheme for Magnetic Memory

SCALE:	DR.	
ENG. K. Olsen	CK.	APP.

SB-50349