Memorandum M-2314

Saul Fine
July 23, 1953

ELECTRICAL ENGINEERING DEPARTMENT
MASTER'S THESIS PROPOSAL

TITLE: Readout-Noise Reduction in a Magnetic-Core Memory

STATEMENT OF THE PROBLEM

The problem for this thesis is the analysis of unwanted signals occuring during the readout of a magnetic-core memory plane and the evaluation of certain proposed sensing schemes for reducing these unwanted signals.

HISTORY OF THE PROBLEM

The storage of digital information in a three-dimensional magnetic-core memory was first proposed in 1949 by J. W. Forrester. The most serious problem at that time was the lack of a core material with a sufficiently rectangular hysteresis loop. During the past few years new core materials have been developed, and several magnetic-core memory planes have been constructed and successfully operated in the Digital Computer Laboratory at MIT.

The operation of a magnetic-core memory depends upon the remanent magnetism of the cores. The cores can be magnetized in either of two directions which can be arbitrarily called ONE or ZERO. Once magnetized, the core will store or retain this information and function as a memory cell.

In order to read the information from the core it is necessary to switch the core to its ZERO state. During the readout some difficulty may be experienced with discrimination of the signal obtained when the selected core holds a ONE from the signal obtained when the selected core holds a ZERO. Some ZEROES have been large enough in magnitude to be mistaken for a ONES when the constellation of stored information yields unwanted signals of certain polarities and magnitudes. This results in an operation error and reduces the overall accuracy of the computer.

The signal-to-noise ratio for a magnetic-core memory plane will be defined as the ratio of the voltage observed when a ONE is read out of the memory plane to the voltage observed when a ZERO is read out of the memory plane. This ratio, therefore, defines a ZERO as a noise. A maximum discrimination between ONE and ZERO is to be achieved.

A number of voltage components contribute to the signal in addition to that due to a flux change in the selected core. For purposes of this analysis these voltage components can be considered as unwanted signals or noise sources. These components include voltages due to inductive and capacitive coupling between the driving circuits and the sensing winding, voltages due to incomplete cancellation of signals from half-selected cores, and the variation in the voltages from cores due to both the differences in magnetic properties of the cores and the magnetic state the cores are in at readout time.

In small memory planes the effects of the above listed noise sources may be negligible, but in proposed large planes consisting of many cores their cumulative total on the sensing winding may be equal or greater in magnitude than a ONE and cause an error.

PROPOSED PROCEDURE

A. Introduction

Study will be made of the basic noises that accompany the readout signal in order to determine the origin of each. Attention will first be given to an investigation of the effect of memory plane geometry (and specifically of sensing-winding geometry) on the amount of noise resulting from air-flux and capacitive pickup and from half-selected cores.

Half-selected-core noise, the largest and most troublesome of the unwanted signals will be investigated on the basis of hysteresis curves. The effect of half-selected-core noise in determining a so-called "worst" pattern, that is a pattern which results in the smallest signal-to-noise ratio will be explained.

The effect of the variation in output voltage of individual cores in producing a form of noise and the effect of this noise in helping to determine a worst pattern will be considered. The method of reducing the variation in a core's output voltage to a small percentage deviation by testing and selecting only certain cores will be evolved.

B. An Investigation of the Readout Signal

1. Air-flux-pickup

An attempt will be made to determine what portion of the total readout noise is due to air-flux and capacitive pickup. This will be attempted both analytically and experimentally with the two basic sensing-winding geometries used at the MIT Digital Computer Laboratory.

Both types of sensing windings will be wound on a plane using magnetic cores. The same sensing-winding geometry will be wound on a dummy plane using non-magnetic cores, e.g., fiber washers. The dummy array will be driven by a memory-test setup. It will be possible to observe and record this noise with the aid of an oscilloscope. Any noise observed should be due primarily to air-flux and capacitive pickup.

The same procedure will be repeated using a magnetic-core memory plane. A comparison of results will make it possible to approximate the portion of readout noise due to air-flux and capacitive pickup. This method will be repeated with the other type of winding geometry; a correlation of experimental with analytic results will be attempted. The results may indicate a geometry that will reduce the noise to a minimum.

2. Half-selected-core noise

A method of reducing the effects of half-selected core noise by means of proper sensing-winding geometry will be explained. It can be shown that for certain patterns that a memory plane may hold, the effects of such noise will be reduced to a minimum through cancellation of half-selected core voltages. For other patterns, the half-selected-core outputs do not cancel but result in an unwanted signal. This results during the worst patterns that a memory plane may hold. Various schemes may be used to improve the signal-to-noise ratio when the array is holding a worst pattern. Three of the more promising schemes to be appraised are described in the following paragraphs.

a. Disturb all cores in the plane with a half-amplitude read-current pulse. This reduces the magnitude of the half-selected core's output. The name "Post-Write Disturb" has been given to this scheme.

b. Stagger the start of the read currents so that the current on one coordinate driving line reaches a steady-state value before the current is applied to the other coordinate line. This effectively reduces the noise at the strobing time. The amount of this reduction will be determined both analytically and experimentally.

c. Break up the sensing-winding of very large memory planes into a number of smaller windings. Such a step will reduce the noise in each individual winding to a small fraction of the noise present if one large winding were used. A method of mixing individual windings going to the sensing amplifier will be studied.

C. Methods of Improving the Sensing-Winding Output Signal

1. The frequency spectrum of a ONE output and a ZERO output will be analyzed. Design of pulse-shaping circuits with improved ONE to ZERO discrimination may be possible on the basis of this analysis.

2. An investigation will determine whether it is possible to use non-linear rather than linear amplification stages in the sensing amplifier. If it is possible, then the ZERO output (smaller in magnitude than the ONE output) will be amplified less. With some form of clipping, it may be possible to remove most of the ZERO and thus improve discrimination.

3. An attempt will be made to assess the value of a proposed differentiating scheme which makes use of the fact that the slope of a ONE at the time of strobing information is almost zero and the slope of a ZERO is large at this same time. The worth of a scheme using partial differentiation will also be weighed. Proposed voltages and flux-integrating schemes will be studied and evaluated for signal-to-noise ratio, readout time, and over-all cycle time.

4. A noise-reducing scheme using a symmetrical read-current pulse will be appraised. Assuming the slope at the start of the read-current is equal to the slope at its fall, then the $\frac{d\Phi}{dt}$ produced by half-selected cores will be equal in magnitude and opposite in polarity at the start and finish of the read pulse. The noise at the start of the read pulse is delayed by a delay line until it occurs at the same time as the noise at the close of the pulse. These two noise signals are then made to cancel in a difference amplifier. Air-flux pickup noise is also made to cancel through this scheme. The over-all noise at point of strobing information from the readout signal is reduced to a small magnitude.

The most promising technique determined in part b. and part c. of this proposal will be investigated experimentally.

EQUIPMENT NEEDS

Equipment for the evaluation and testing of proposed sensing schemes and all necessary measuring equipment is available at the MIT Digital Computer Laboratory. Use will be made of the standard laboratory pulse test equipment and laboratory facilities will be available for the construction of any special units that may be needed during the course of research.

ESTIMATED DIVISION OF TIME

1. Preparation of Proposal.............................. 50 hours
2. Further Study of Literature.......................... 25 hours
3. Experimental Work and Analysis.......................150 hours
4. Correlation of Results and Formulation of Deductions and Conclusions...........................100 hours
5. Preparation of Thesis Report......................... 75 hours
6. Total...400 hours

SIGNED: Saul Fine
Saul Fine

SF/rmb

DATE: July 23, 1953

SUPERVISION AGREEMENT

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

SIGNED: David R. Brown
David R. Brown
DDL Staff Member

BIBLIOGRAPHY

1. Forrester, J. W., "Digital Information Storage in Three Dimensions Using Magnetic Cores", MIT Digital Computer Laboratory Report R-187 (May 16, 1950).

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3. Olsen, K. H., "A Multi-Position Magnetic Switch and Its Incorporation into a Magnetic Memory", MIT Digital Computer Laboratory Report R-211 (June 6, 1952).

4. Widrowitz, B., "The 16 by 16 Metallic Array Model I", MIT Digital Computer Laboratory Report R-216 (September 25, 1952).