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Digital Computer Laboratory
Massachusetts Institute of Technology
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SUBJECT: GROUP 63 SEMINAR ON MAGNETISM, IX

To: Group 63 Staff

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The resultant domain configuration of a ferromagnetic material is that configuration which minimizes the energy due to all the factors discussed in the previous lecture.

In order to minimize the magnetic energy, there is a tendency for a closed flux form with no surface poles, as shown in Figure 11 (d) and (e). As shown in the figure, this form has neighboring domains with perpendicular magnetization directions. Since iron and nickel have mutually perpendicular directions of easy magnetization (Figure 10 (a) and (b)), it is quite easy for the domains to align themselves in this way. In the case of cobalt, however, we find a unique direction of easy magnetization, and all directions normal to this are hard magnetization directions. (Figure 10 (c)).

Domain closure, therefore, requires too high an anisotropy energy for complete flux closure in cobalt. This was demonstrated by L.H. Germer in 1942 when, by employing electron beam methods, he confirmed the existence of strong local magnetic fields of the order of 10000 oersteds at the hexagonal face of a cobalt crystal. This strong field shows that the flux circuit is not closed inside the material, as this would lead to weak fields at the crystal faces.

Very small magnetic particles (powders, thin films) display interesting magnetic characteristics. They are limited to being single domain particles by their size and the high exchange energies for domain walls. Domain motion is therefore non-existent in these particles, so in order to reverse their magnetization, the applied field must be high enough to rotate the domains. As domain rotation requires a strong field, magnetized particles display a high coercivity.

Strains

Domain motion may also be opposed by the application of a strain upon magnetic material. A strain within the elastic limit can either increase or decrease the initial permeability, depending upon the material used. Beyond the elastic limit, however, the permeability is always decreased.

Domain wall motion is also difficult for materials with high magnetoelastic energy. In this case, a change in the magnetization of a domain can cause a distortion of the structure, setting up a strain in the material.

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Applications of Hysteresis Curve

The primary purpose of this group is to provide a memory storage device for the Whirlwind II Computer. It must operate on a binary basis, reading either 1 or 0. The difference between the two possible readings must be distinct, and the system must be capable of maintaining either value indefinitely without danger of its deteriorating to the other value.

The other factor of prime importance is speed. A reversal of of magnetization must occur as quickly as possible. Magnetization by domain wall motion is the most suitable for this as it occurs rapidly; domain rotation has the disadvantage of requiring a higher field strength for reversal, and hence might cause a high switching time.

The theory of the magnetic memory may be found in the literature.* A brief introduction will be given here.

Magnetic materials are available which have an almost rectangular hysteresis loop. For our discussion an idealized loop will be used, and is given in Figure 13.

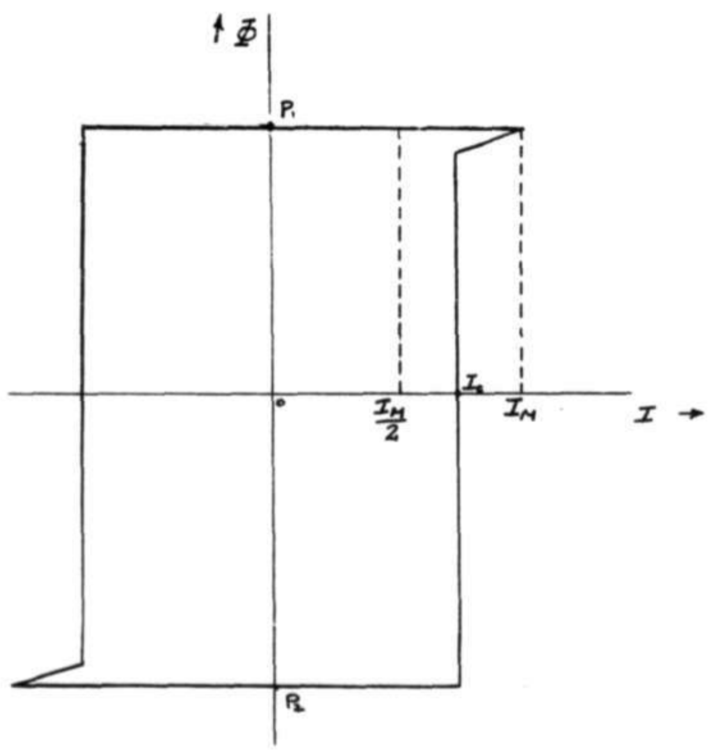

Figure 13

* Forrester, Jay W., "Digital Information Storage in Three Dimensions Using Magnetic Cores," Journal of Applied Physics, 22, January 1951, p.44.

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After a magnetizing current of I_m is applied, the material will be in the condition P_1 of Figure 13. Similarly, after the application of current $-I_m$, the material will be in the condition P_2. These two conditions correspond to the two binary digits 0 and 1 respectively. If the core is in either of these conditions, it will remain therein until the application of a current exceeding I_c.

If the core is originally at P_2 and a positive current I_m is applied, a large flux change will occur in a short time. $\frac{d\phi}{dt}$ represents an e.m.f. which may be determined by a detecting coil on the core. However, if the core is in state P_1 when $+I_m$ is applied, there will be a very small flux change.

Thus, going from zero current to $+I_m$, there is a large flux change if the core was storing a one, and a slight flux change if it was storing a zero. This is known as a read pulse. Conversely, application of $-I_m$ is known as a write one pulse. It should be noted that a read pulse destroys the memory; a method of rewriting has to be used with this type of storage.

To store a large number of digits in a system, a series of cores are arranged as in Figure 14.

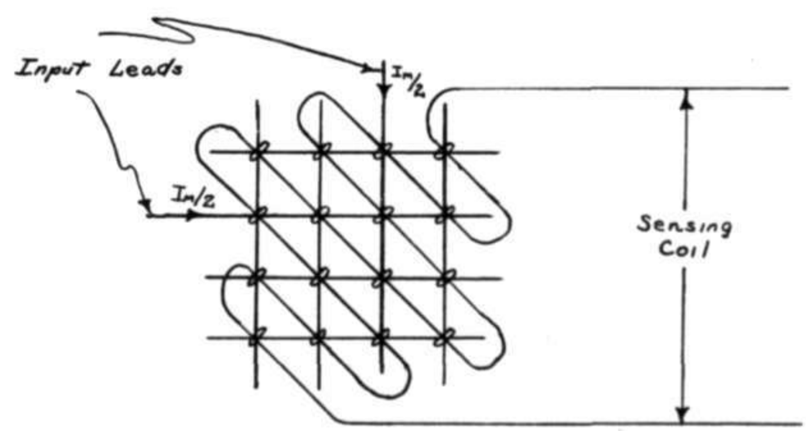

Figure 14

The total current through any core is the sum of two possible currents going through the core at angles 45° from the plane of the ring. If in the 4 x 4 array of Figure 14 a current $\frac{I_m}{2}$ is applied to the two leads shown, a current I_m will pass through only one core. A number of cores will have a current $\frac{I_m}{2}$ passing through them.

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If the hysteresis loop of the core material has a sufficiently high squareness ratio, a current $\frac{I_m}{2}$ passing through the cores will produce a negligible flux change. However, the application of I_m to one core may produce a large flux change, depending upon the initial direction of the core magnetization.

The sensing wire passes through all cores in series; the sensing is therefore done in two logical steps:

a) The machine records which two primary wires cause the currents $\frac{I_m}{2}$, hence which core experiences a current I_m.

b) The sensing wire tells whether there is a flux change in <u>any</u> core, but since step a) has already indicated the only core in which such a flux change could possibly occur, this core is effectively examined by means of the sensing coil.

Signed ______________________
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