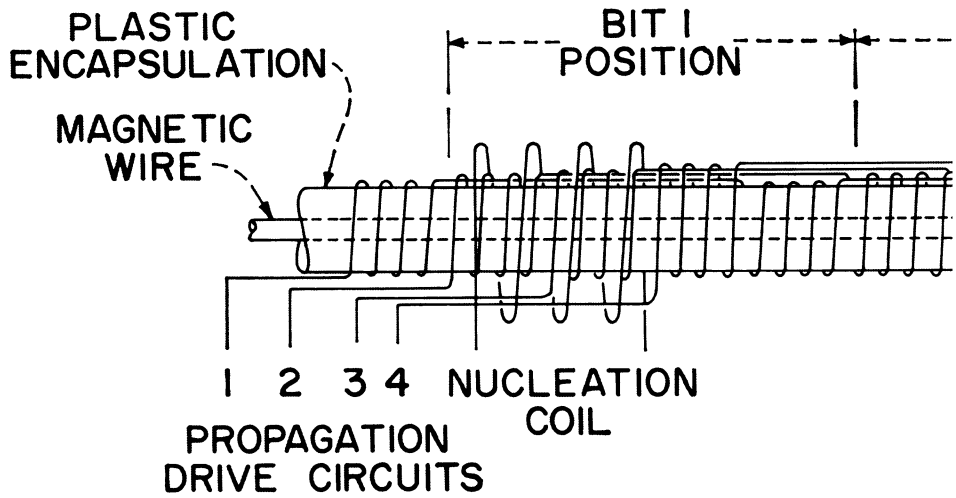


Scheme for producing domain wall devices, showing solenoids counterwound on

Domain Walls in Computers

By Manipulating the atoms-thick walls between magnetic domains engineers hope to develop a computer revolution.

by Ann Ewing

"Domain walls" sounds like a term from the Middle Ages, but in the 20th century, scientists working with magnetic fields use it to describe the boundary between one magnetic field and another having different polarization.

The technique involved in using the magnetic changes between domain walls in thin wires could very well bring about the same kind of revolution in electronic computers that occurred when it was found vacuum tubes could be replaced by transistors.

Within a magnetic domain, all the whirling electrons that give a material its magnetism are aligned in the same direction. The boundary, or wall, between the atoms in one domain and those with an opposite polarization in an adjacent domain is very sharp, only a few atoms thick.

In an engineering shop at Bell Telephone Laboratories, the scientists who developed a way to take advantage of domain walls have shown that mass production of thin wire domain wall devices for computer parts is possible. They can control the placing of domains, and move the domain walls at will.

The Bell scientists have demonstrated that many logic functions can be mechanized with domain wall devices, with performance levels high enough to be of practical value.

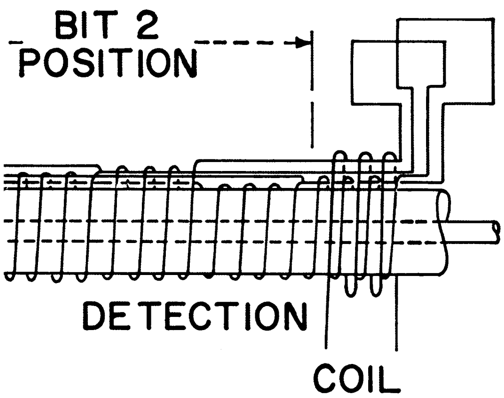
The most difficult problem still to be resolved before domain wall propagation devices can be widely used is the interconnection of logic cells in different directions. Until this problem is solved, Dr. Reg A. Kaenel of Bell believes they will be used mainly for special purposes within a computer, such as for a character recognizer or for local memory storage.

Dr. Kaenel is careful to emphasize that his work is still experimental, and that any actual applications are still some time in the future. But he is optimistic about the principle.

The foundation for today's generally accepted theory of ferromagnetism was laid by Dr. Pierre R. Weiss in 1907, who proposed that the elementary magnets (atoms) in a material tend to line up in the same direction under the influence of the magnetic field of the molecule. This theory accounted, in a general way, for spontaneous magnetization.

A ferromagnetic material, however, does not always exhibit permanent magnetization. Dr. Weiss therefore further assumed that ferromagnetic substances were subdivided into large numbers of blocks, or domains.

Within each domain, all the elementary magnets point in the same direction, even though the substance as a whole appears unmagnetized because the individual domains are randomly oriented.



Bell

a plastic tube containing permalloy wire.

of the Future

When an external magnetic field is applied, more and more of the domains line up parallel to it. The magnetizing force does not have to overcome the random thermal motions of the atom, but only the crystalline forces.

When most of the atoms and most of the domains are oriented along the field, the metal becomes a magnet with a total magnetic field.

In an experiment in 1915, Dr. Heinrich B. Barkhausen placed a piece of iron inside a magnetizing coil, then wrapped both with another coil connected to a pair of sensitive headphones. As the magnetizing current was increased slowly, Dr. Barkhausen heard "clicks" making a rustling sound, suggesting that magnetization was proceeding by steps.

The effect was believed due to current pulses induced in the coil as successive domains in the specimen lined up parallel to the external field, the first evidence for domains.

Direct evidence for the existence of domains is now obtained routinely by dusting the polished surface of a ferromagnetic crystal with a magnetic powder. When observed through a powerful microscope, the powder can be seen, or photographed, collected along well defined lines that form intricate geometrical patterns.

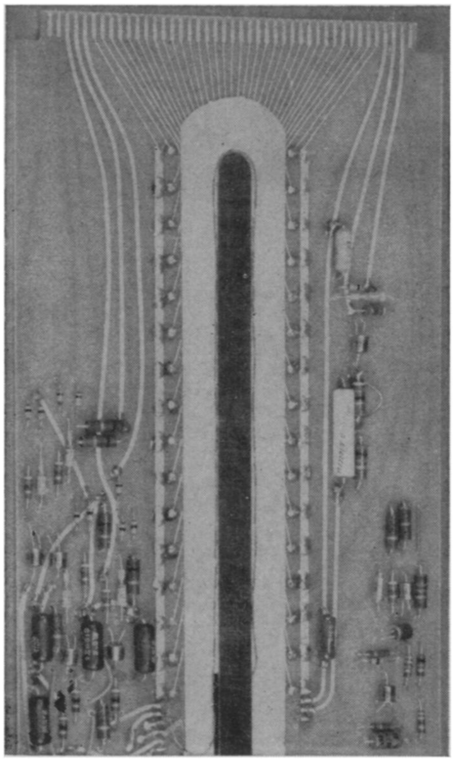
These lines are the domain boundaries; the particles are attached there because of the strong local fields.

Based on research by many investigators during the last 35 years, scientists at Bell Laboratories started looking into the practicality of domain wall devices for computer applications in 1965. They were spurred by the discovery in 1964 by Drs. D. H. Smith and E. M. Tolman, also of Bell, that domain walls could be propagated in permalloy wire under ordinary conditions.

Dr. Kaenel and his co-workers have found it possible to create, expand or contract domains in permalloy wire by an applied magnetic field. Domains magnetized in one direction, to the right for example, represent binary one; those magnetized to the left, which is also the direction of overall magnetization, represent binary zero.

Each bit is separated from its neighbors by a buffer zone, also magnetized is the overall direction. The applied magnetic field attracts the existing domain walls to regions where the field is zero, and it does so without creating additional walls.

Moving the magnetic field to the right causes the domain wall pattern to move along. As the domain walls pass a detection coil, the changes in magnetization at their boundaries induce electrical pules that are amplified and transmitted to other circuits.



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A 64-bit converter, 5 by 8 inches.

These changes constitute the "on-off" sequence essential to the operation of a digital computer.