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MAGNETIC MATRIX ACQUISITION UNIT FOR THE NEVADA AUTOMATED DIAGNOSTICS SYSTEM

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ABSTRACT

The Magnetic Matrix Recorder promises to be a device which can, with minimum protection, operate and survive in the hostile environment in which many transducers function. It is designed to convert to digital form and store wideband transient information. Stored data from a group of recorders can be read out serially, resulting in an appreciable reduction in cable plant costs.

The Magnetic Matrix approach, using uniaxal anisotropic magnetic thin films, combines fast analog-to-digital conversion and magnetic storage in one step. The system is potentially inexpensive (suitable for expendable use) and rugged.

An experimental magnetic matrix recorder has proven systems feasibility and determined performance limitations. Fieldable units are being built using solid-state strobe and readout circuitry. Research and development for an all-magnetic, passive, front-end unit is being conducted.

INTRODUCTION

Lawrence Livermore Laboratory is currently developing the Nevada Automated Diagnostic System (NADS), which is a centralized digital-data acquisition, transmission, and analysis system. It is designed to expedite

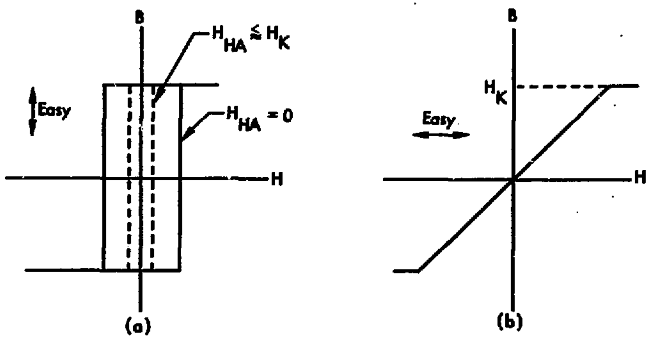
*Work performed under the auspices of the United States Atomic Energy Commission.

he diagnosis of underground nuclear tests and their effects. To satisy he system requirement for a forward-area, high-speed acquisition unit o convert transient transducer analog signals into NADS-compatible ligital information, we have undertaken the development of a Magnetic Matrix Recorder. This article covers basic recorder theory, describes he first recorder, and describes our proposed future effort. This program s a combined effort of Lawrence Livermore Laboratory, EG&G, Inc., he Defense Systems Division of Univac, and Purdue Research Foundation.

PRINCIPLES OF OPERATION

The Magnetic Matrix Recorder combines analog-to-digital conversion and emporary buffer storage into one step. Because storage is magnetic, it s nonvolatile and may be read out any time after recording is complete. The present recorder has a minimum sample time interval of 0.5 nsec, a maximum number of 20 amplitude levels, and 64 time samples.

Operation of the Magnetic Matrix Recorder is based on the properties of easy-axis, hard-axis magnetization of a uniaxial anisotropic magnetic thin film (Fig. 1). *A preferred direction (or easy axis) of magnetization can be*



ig. 1. (a) Easy-axis B-H hysteresis loop. Loop narrows toward zero H as coincident hard-axis drive approaches saturation. Very little easy-axis field is then required to switch easy-axis magnetization. (b) Hard-axis B-H hysteresis loop. Shows zero magnetization with zero H, i.e., all magnetization is rotated into the easy axis.

fixed in a film by applying a steady magnetic field in that direction during deposition of the film. Thereafter, electron spins (magnetic dipoles) will return or relax to this axis upon removal of any abritrary field to which they may have been subjected. This phenomenon exists because, during deposition, the basic structure of the film becomes fixed by its bonds to the substrate. The electron spins do not retain any polarity preference as to which direction they should relax along the easy axis even though they must have been oriented in one specific direction during deposition.

If the thin film is saturated in the hard-axis direction with a strong transverse field (the strobe pulse in the MMR), the magnetization will lie along the hard axis. When that field is removed, the magnetization falls back to lie along the easy-axis (see Fig. 2). Which way it turns depends on the direction of the applied easy-axis steering field (i.e., the signal field). This guilded fall-back effect can be used to record whether or not the signal field is positive or negative. If a bias field is applied, this effect can be used to record whether or not the signal field was greater or less than the known applied bias. If a row of n films has applied N different bias fields, then the films can record the magnitude of the unknown easy axis signal to one part in n at the time the hard-axis field is turned off (Fig. 3).

Dynamic range and resolution are limited by things such as skew, angular dispersion, and coercivity (see Fig. 1). Readout is accomplished by pulsing a strobe line and observing the pulse which is induced on the signal line as the element magnetization rotates from the easy to the hard axis (Fig. 4). Readout pulse polarity depends on the direction of easy-axis magnetization but is independent of strobe polarity.

In practice, the basic Magnetic Matrix Recorder (Fig. 3) consists of a circuit matrix of insulated conductors crossing at right angles. One set of conductors carrys the signal plus bias, and the other set the sequential strobe pulses. The uniaxial anisotropic magnetic film is deposited at the intersections of the conductors, with the easy axis in the direction of the signal field lines. The recorded information and memory lies in the direction of magnetization of these small patches of magnetic film.

PRESENT STATE OF DEVELOPMENT

Univac has made a systems study and built an experimental recorder to investigate systems feasibility and to determine general performance limitations of the MMR recording principle. The recorder built by Univac samples and stores the transient signal in a magnetic thin film matrix where the word dimension corresponds to the time scale and the digit dimension to the amplitude scale. The digit lines are incrementally back

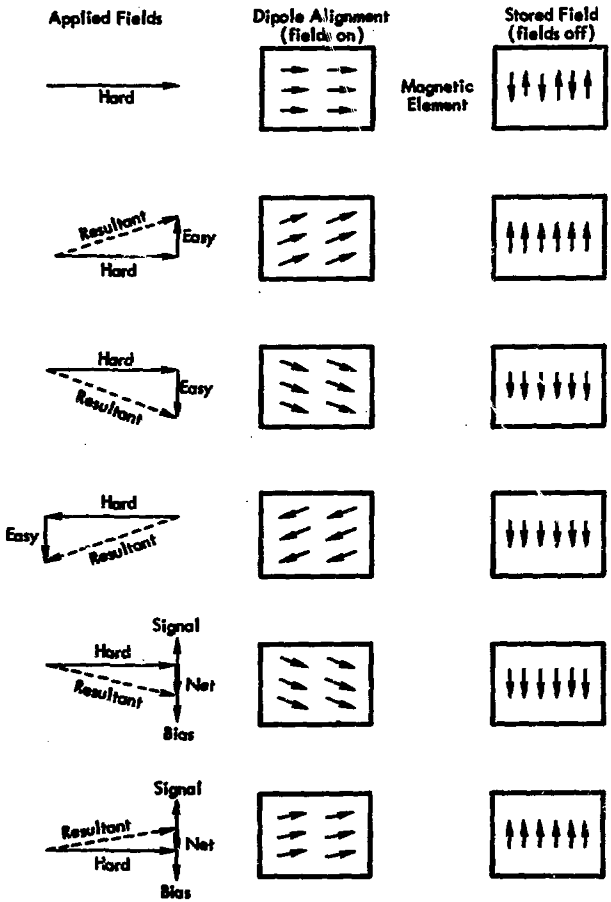


Fig. 2. **Behavior of magnetic elements with different conditions of hard, easy, signal, and bias fields applied.**

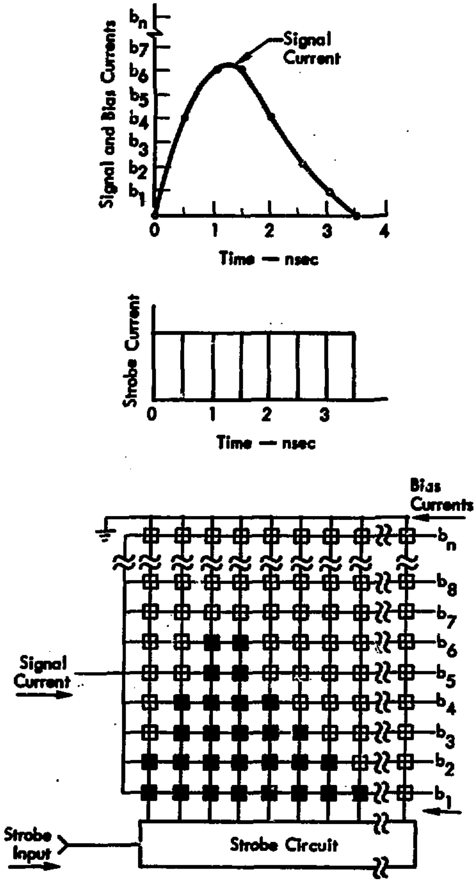


Fig. 3. Simplified diagram of the MMR with strobe, signal, and bias currents applied and the resulting pattern of recording in the matrix. Dark elements represent those bits that have been switched by the signal.

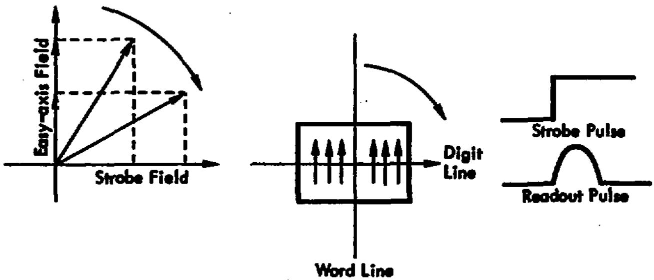


Fig. 4. As the easy-axis stored field is forced by the strobe pulse to rotate toward the hard axis, the magnetic component in the easy-axis direction decreases and a signal is induced in the digit line.

biased so that the bias difference between digit lines is equal to the quantization levels desired. The input signal to be recorded is applied equally to all digit lines.

At the start of a recording sequence, the word current (strobe pulse) is removed from the first word line. The bits of this word with a net digit current (signal-bias) greater than the film steering threshold will be written in the "1" state while all others will be written in the "0" state. The word currents in the successive word lines are removed in sequence. The actual recording occurs during the fall time of the word pulse as the guided fluxes relax to the easy axis. The amplitude of the input signal is then defined by the point along the digit lines where the stored bits change from "0" to "1". Readout can be made any time after recording is complete by sequentially pulsing the word lines and observing the signals that appear on the digit lines.

The MMR uses a "Mated Film"* array very similar to that used in the Univac 1230 memory. The "Mated Film" system (Fig. 5) is a process which encloses the digit line in single-domain ferromagnetic patches. This creates a closed flux structure which is self-shielding (less crosstalk and outside field effects) and is very closely coupled to the digit line.

The Magnetic Matrix Recorder is capable of sampling, digitizing, and storing 1 nsec risetime signals. The samples are taken at 0.5 nsec increments over a

*Trademark, Sperry Rand Corp.

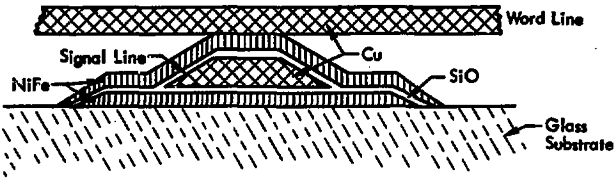


Fig. 5. Cross-section of "Mated Film" elements.

16 nsec interval. The input signal is quantized at each time sample into 16 threshold levels which limits the accuracy to ±3.1%. Because the individual bit thresholds can be calibrated to 1%, a system yielding greatly improved accuracies can be postulated. However, the first recorder as delivered from Univac to EG&G initially exhibited a worst-case measured accuracy of ±10%.

PROPOSED DEVELOPMENTS

As a Phase II effort, design and assembly of Magnetic Matrix Recorders using Matrix cards purchased from Univac is under way at EG&G San Ramon. These recorders will be evaluated on NTS events to gain knowledge of their performance in field operations. They are not completely radiation hard since solid state circuitry is used in conjunction with the Matrix cards.

To facilitate radiation hardness, the underground portion of the recorder should contain only passive magnetic circuitry. To pursue this goal, Phase II also has Purdue Research Foundation under contract to LLL to investigate the possibility of applying thin-magnetic-film technology to the addressing and strobe requirements of the MMR. Concurrently, Univac (also under contract to LLL) is developing an all-magnetic-thin-film readout amplifier system. It is intended that this amplifier system will be deposited on the substrate with the Magnetic Matrix. Achieving these goals will allow demonstration of an all-magnetic passive recorder and will complete Phase II of the Magnetic Matrix Recorder development program. Phase III is to be the development of a prototype fieldable recorder.

BENEFITS

'he MMR will combine the advantages of thin-film technology into a highly eliable, nonvolatile, high-speed recorder that can operate in high radiation evels. (The "Mated Film" elements have tolerated radiation levels as high s 10^8 rad/sec without adverse effects.) Being environmentally hard, the ecorders can be placed near the sensors where, acting as fast analog-to- igital storage units, they will change nanosecond analog information into nillisecond readout digital data that can be transmitted without distortion ver low cost, low bandwidth cables. Information can be read out in a ew milliseconds where closeness to an event makes destruction probable, r, where survival time permits, information from many recorders can e read out serially over one cable. MMR's should cost much less than scilloscopes and cameras, and could be expended with each shot if necessary. ecause they will be small in size, radiation hard, and require little power, rge savings can be realized in alcove construction, and electrical power equirements. Their digital signal output will be compatible with NADS nultiplexing, communications, recording, and data processing.

'he MMR installation and maintenance requirements should be small as the nderground portion will consist entirely of passive magnetic circuits whose trobe and readout interrogation pulses are received from remote units.

SUMMARY

'he MMR approach combines analog-to-digital conversion and buffer storage n one simple step. The system is potentially inexpensive and rugged. The evelopment of magnetic thin film strobe and read amplifiers for the MMR vill make the unit all magnetic and passive. Because it is passive, maintenance hould be negligible and being small (less than 50 cm^3 per recording channel) lcove requirements will be minimal. Because the information can be tored for a considerable length of time, many recorders can be read out erially over a single cable. Additionally, the storage is permanent, llowing post-event recovery as a backup procedure.

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