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Abstract

A system is described that can decrease the number of scalers required in a magnetostrictive spark-chamber readout system by a factor of four. Information from magnetostrictive sensors is impressed upon six magnetostrictive delay lines and digitized in sequence by six sets of scalers. In addition, an oscilloscope display is produced which correlates the delayed time-domain information with its digitized form.

I. Introduction

The large number of scalers required to digitize the information from a few magnetostrictive spark chambers can be substantially decreased if a suitable multiplexing scheme can be realized. One such method involves the serial storage of data on magnetostrictive delay lines prior to digitizing. The spark-position information contained in the relative positions of magnetostrictive pulses on the delay lines can be sequentially digitized by one or more sets of clocked scalers, then transferred to a buffer store or computer memory for further processing. There is no reason why the magnetostrictive sensors in the spark chambers could not be fitted with regenerating drivers and serviced by a single set of scalers. However, various considerations led to the construction of the system described in this paper, consisting of six magnetostrictive delay lines wound on helical supports and serviced by six sets of two 12-bit scalers.

The basic delay line is shown in Fig. 1. Each line has four input taps so that each set of scalers can be used four times in a single event. The use of these four-tap delay lines expands the system capacity from six to 24 sensors per event.

II. The System

Figure 2 is a block diagram of the basic system. Magnetostrictive pulses are fed from the sensors located in the spark chambers to the delay-line pulse regenerators. The signals are impressed upon the delay lines and propagate down the magnetostrictive wire at about 5000 m/sec. At the end of the delay lines, the signals are received and amplified, and the peaks are detected by zero-crossing discriminators.

The detected pulses then control the gating of a 20-MHz clock signal such that numbers are entered into each of the 12 scalers in proportion to the time difference between successive magnetostrictive pulses. Because the first pulse in each group, which opens the clock gate, is a fiducial pulse marking the edge of the spark chamber, the numbers appearing in the scalers are proportional to the spark position in the chamber.

The numbers stored in the scalers are then read out into a core memory. An adequate dead time must be provided in the delay lines so that the scaler information can be transferred to the core before the next group of magnetostrictive pulses arrives at the discriminators. The following groups of information are digitized and stored in the same manner as the first.

While the digitizing is taking place, the discriminated magnetostrictive pulses from the last delay line in the regenerating chain are fed to the display device. This device displays a pattern of horizontal lines whose spacing is proportional to the time difference between magnetostrictive pulses. When the contents of the core memory is transferred onto tape, the most significant 6 bits of each 12-bit word are read from tape into the display device. Thus the digitized information is displayed as a series of vertical lines whose position should agree with that of the previously displayed horizontal lines. This information is displayed on a storage oscilloscope so that a pattern of crosses results if the system is operating properly.

This system was first used during the fall of 1966 in an experiment which required the readout of 26 magnetostrictive sensors. The chambers were in three groups: Group A with ten sensors, Group B with ten sensors, and Group C with eight sensors. Each event required the readout of eighteen sensors of either C and A or C and B, depending on the type of event detected. Gating signals from the fast logic selected either the sensors of Group A or those of Group B by activating logic in the delay-line system. Figure 3 shows the logic in the delay-line system and the timing of the magnetostrictive pulses as they come off the delay line.

The introduction of "marker" pulses into all the pulse regenerators was necessary when attempts to "gate out" spark-chamber noise were unsuccessful. The marker-pulse line is activated at the time the spark chambers are pulsed. Noise from the sparking chambers may or may not cause the pulse regenerators to fire at this time, but the marker-pulse method guarantees that all regenerators fire. Then, even if multiple firing of the regenerators occurs, the marker pulse can be used as a signal to the digitizing and display*

*This work was done under the auspices of the U. S. Atomic Energy Commission.
electronics to ignore itself and any noise-induced pulses that may follow for a period of several microseconds. A generator with a fast-inhibit gate could, of course, be used, but ours was not designed this way and therefore depended on the marker-pulse technique for reliable operation.

No degradation of accuracy results from the use of delay lines, since the system of fiducial marks preserves position-information accuracy even if absolute time separation changes, due to different propagation velocities in different wires.

The biggest problem resulting from the use of long magnetostrictive delay lines in this application is the degradation of double-pulse resolution. This is discussed in the next section.

III. The Delay Lines

The delay lines for this system were built at the Laboratory, using many of the same techniques used in fabricating the magnetostrictive sensors for spark chambers.

Figure 4 shows a delay line mounted on its holder. The holder is made of 4.5-in.-diam aluminum conduit, machined in a helical fashion to provide a support groove for the wire. The holder is coated with Teflon to minimize friction, and fitted with drive coils, pickup coil, and preamplifier. The wire used was 0.45 mm Vacoflux "50" hard-annealed iron-cobalt-vanadium alloy, the same as used in spark-chamber sensors. This wire, which exhibits a characteristic magnetostrictive pulse with 400-nsec base width when impulse-excited in the longitudinal mode, was used with the hope of preserving double-pulse resolution of 400 to 500 nsec. The 400-nsec resolution was obtained from the first delay-line tap, but had degraded to ≈ 600 nsec from the third tap, and 800 nsec from the fifth tap. In this respect, commercially available delay lines employing the torsional mode perform better. They exhibit a characteristic pulse with ≈ 500-nsec base width, which is not significantly broadened on lines as long as 8 to 10 msec. Experiments show that the wire we used would exhibit less dispersion when mounted on a holder with fewer points of contact, but base widths of less than 500 nsec do not seem feasible with long lines of this type.

Figure 5 shows the pulse regenerator. Two separate channels are mounted on each board and can be used independently or in the logic pattern of Fig. 3, depending on the position of the jumpers. Each channel consists of a zero-crossing discriminator driving a variable-width one-shot which activates the send coil on the delay line. At point (1), the signal enters and is fed to a differentiating amplifier. The differentiated signal appears at point (2). The positive-going portion of this signal switches the tunnel diode at point (3) into the low-voltage state, thereby enabling it to switch back to the high-voltage state, when the signal at point (2) crosses the baseline. A differentiated version of the trailing edge of the tunnel diode signal is fed through point (4) to the 80%-duty-cycle one-shot with pulse width variable from 150 to 350 nsec. The driver transistor, Q10, turns on in this interval, and sends current through the 20-turn "send" coil with a rise time of about 50 nsec at 1.5 A peak. The gating is accomplished by Q11 and diodes CR6 and CR10.

IV. The Display

The display system uses the serial presentation of data from the delay lines and the tape transport, along with the memory capability of a storage oscilloscope, to produce a display such as that shown in Fig. 6. Each horizontal row represents an individual sensor, with first fiducials referenced to the left-hand edge of the screen. A pattern of crosses, corresponding to sparks and second fiducials, appears on the screen. The second-fiducial marks are partially obscured by grease-pencil markings on the surface of the screen, which are used to distinguish the second fiducials from the sparks.

The arrival of each group of pulses, corresponding to a sensor, triggers a linear sweep which provides horizontal displacement. Intensification takes place every time a pulse appears. At the end of the sweep period, a binary counter which governs the vertical displacement is incremented, thereby producing a raster of one sweep per sensor. When the information is read back from the tape, the same vertical displacement occurs, but in a different sequence. The horizontal displacement is controlled by the numbers from the tape, and intensification is produced once per word of stored data. When the display of a single event is complete, the system is disabled until the operator presses a button that erases the storage scope and enables the control logic. This event-by-event display has proved very useful in detecting system malfunctions and, with some practice on the part of the operator, can be used to monitor spark-chamber performance.

V. Conclusion

This system represents one way of handling information from magnetostrictive spark chambers which is attractive when a digital computer is not available to make displays and an intermediate core storage is available as a buffer to the tape transport.

When this system was used for the second time, in the summer of 1967, with a PDP-5 computer, the computer core was used as the buffer store. The display system was also used in order to free the computer memory for a histogram-producing program.

Commercial delay lines, although usually sold for data-storage applications, are quite adequate for this multiplexing service. Commercial lines are available for less than four cents per microsecond, and therefore represent a possible economic advantage over multiple scalers.
The advent of mass integrated-circuit memory systems for digitizing large numbers of sparks promises economic advantage over present scaler systems, and offers the advantage of simultaneous digitization of information from many sensors. Such a system does not need the multiplexing capability of delay lines, but could well use a recirculating data-storage line for oscilloscope display.

Reference

Fig. 1. Basic delay line.
Fig. 2. System block diagram.
Fig. 3. Delay-line system logic.
Fig. 4a. Internal view of delay-line holder.
Fig. 4b. External view of delay-line holder.
Fig. 5. Magnetostrictive-regenerator schematic.
Fig. 6. Storage-oscilloscope display.
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