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A MULTIPLEX SYSTEM FOR USE WITH
LINEAR DISPLACEMENT TRANSDUCERS (U)

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A MULTIPLEX SYSTEM FOR USE WITH LINEAR DISPLACEMENT TRANSDUCERS (U)*

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Abstract

This paper describes a system which serially interrogates and digitally records the signals from a large number of linear displacement transducers. The 200-nanosecond interrogating pulses are amplitude modulated by the transducers and are mixed onto a single coaxial cable, reducing the number of downhole cables required. The signals from the transducers are then digitized and recorded on a magnetic disc along with timing information and a zero time reference signal.

Total recording time is 33 milliseconds and during this time 132,000 data points are stored on the disc. Time resolution of the system depends upon the number of channels to be recorded. Amplitude resolution is 1% of full scale.

Data may be read from the disc in two different formats. The data can be plotted vs. time on a digital strip chart recorder or the data can be punched on paper tape for input to the data reduction facility.

The system is located in an 8' x 40' van and has been successfully used on several events at the Nevada Test Site.

*Work performed under the auspices of the U.S. Atomic Energy Commission.

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Introduction

The system described here was designed to measure the impulse generated when a thin region of material is melted or vaporized due to instantaneous energy deposition. A sample, initially at rest is allowed to move linearly and its displacement is measured as a function of time. If we know the mass of the sample and its velocity, we then know its momentum and therefore the impulse it received.

The sample is attached to a transducer which acts as a variable coupling transformer with the coupling being proportional to displacement. The transducer is energized with a train of constant-amplitude pulses and delivers a train of pulses whose amplitudes are proportional to displacement as a function of time. A pre-recorded timing program is used to sequentially interrogate many transducers. A block diagram of the system is shown in Figure 1.

The amplitudes of the returning pulses are digitized and recorded in digital form on a 32-track magnetic disc. In order to make full use of the disc, four transducers are simultaneously interrogated by each interrogating pulse. Data returns to the recording trailer through four separate cables as four unique amplitude-modulated pulses. These pulses are digitized simultaneously and parallel recorded on the data disc as four 7-bit binary words.

The number of interrogating pulses in a frame is limited to 32, the number of tracks on the program disc. A maximum of 128 (32×4) transducers can be used with this system. The worst case sampling rate on any one transducer is one sample every 34 μ s. The 7-bit binary words limit displacement resolution to approximately 1% of full scale.

This paper will be divided into the following six parts: 1) System Timing, 2) Modulators and Modulator Drivers, 3) Downhole Components, 4) Encoding the Data, 5) Recording the Data, and 6) Recovering the Data from the Disc.

System Timing

The timing program that determines when and in what order the transducers are interrogated originates with the Timing Chassis. As shown in Figure 1, the Timing Chassis consists of a clock, a ring counter, and the timing one-shots with their associated delays. The size of the ring counter is $(N+2)$ where N is the number of modulators (interrogating pulse generators) in the system. Each modulator is associated with one output of the ring counter. The two extra counts create a "gap" in the timing program to separate frames of data. The adjustable delays are necessary to compensate for differences in round-trip cable length for various transducers and are adjusted so that data pulses

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returning from downhole arrive at equally spaced 1- μ s intervals. The clock rate (word rate) is 1 MHz and each transducer gets interrogated every (N+2) microseconds.

The timing chassis is built in a 40-connector rack-mounted card frame with all components mounted on 3" by 4" printed circuit cards. During system setup the system is operated directly from the Timing Chassis.

Once the timing program is established and all delays have been adjusted the timing program is recorded on the 32-track program disc. Each track contains the record of one timing one-shot and is used to time one modulator. The disc offers better reliability than the Timing Chassis and once the program is recorded no further timing adjustment is necessary.

Modulators and Modulator Drivers

In the Modulator Driver Chassis the timing program from the program disc is gated by a control signal from the Write Enable chassis to produce a 40-ms burst of timing pulses. After further conditioning the timing program is sent to the modulators which generate the 300-V, 200-ns-wide interrogating pulse to be sent downhole. The outputs of the modulators are electrically isolated from each other and from ground. The output amplitude of each modulator is adjustable to permit one to adjust the output of the transducers by adjusting their input. This assures that the maximum signal to each ADC does not exceed full scale.

Downhole Components

The downhole components, all of which are passive, include 1) cables, 2) splitters, 3) transducers, and 4) mixers. The entire system including instrumentation trailer, power source, and all downhole components is electrically isolated from earth ground.

Interrogating pulses are sent to the splitters over 50- Ω coaxial cables with one cable being required for each modulator-splitter connection. The splitters divide each 300-V interrogating pulse into four 75-V pulses that are used to interrogate four transducers simultaneously. All splitters for the system are at one location and their outputs are connected to the transducers by short runs of 50- Ω coaxial cable. The splitters are built on standard 3" by 4" printed circuit cards which are mounted in a prefabricated metal can.

The transducers amplitude modulate the input pulse with displacement data by varying the coupling between the primary and secondary of a transformer.^{1,2} The coupling is greatest when the sample is in its initial rest position and decreases as displacement increases. The transducer attenuates and broadens the input pulse giving a maximum output of about 20 V with a width of about 1 μ s. The mass of the sample is chosen to give velocities in the order of 100 to 1000 cm/s.

Time multiplexing of the interrogating pulses allows the outputs of a frame of

transducers to be mixed onto a single 50- Ω coaxial cable. Since four transducers are interrogated at a time four cables are necessary to send all the data back uphole. Four mixers are used to mix the four simultaneous frames of N data pulses onto the four cables. The mixers use diodes to isolate the transducers from each other. The mixers, like the splitters, are all at the same location and are connected to the transducers by short runs of 50- Ω coaxial cable. The mixers are built on standard 3" x 4" printed circuit cards which are mounted in a prefabricated metal can.

All data returns to the trailer on four 50- Ω coaxial cables, each carrying data from N transducers where N is the number of modulators used.

Encoding the Data

To assure that the data pulses are encoded at peak amplitude, the encoding must be synchronized to the interrogation. This synchronization is provided by the Encode Delay Chassis. The Encode Delay Chassis has one encode delay for each modulator. Each time a modulator sends a pulse downhole it also sends a 5-V pulse to the Encode Delay Chassis which after an adjustable delay generates an "encode" pulse. The delay is adjusted such that the encode command is generated at the peak of the four returning data pulses. The output of the Encode Delay Chassis is a train of encode pulses equally spaced at 1- μ s intervals with frames separated by a 2- μ s gap. In addition to being used for commanding the four ADC's, this pulse train is recorded on one track of the data disc. This gives a timing pulse on the disc each time new data appears from the ADC's. This timing track and a second track containing a single pulse at zero time are used to recover the data from the disc.

The ADC's, on command, quantize the data pulse into a 7-bit binary number. The outputs of the four ADC's are recorded one bit per track on 28 tracks of the data disc. This constitutes one sample of data from four different transducers.

Recording the Data

Twenty-eight tracks of data and two tracks of timing information are recorded on the data disc. To assure that only one revolution of data is recorded, the data and timing information are gated onto the disc by the "Write Enable" signal. The disc contains circuitry for performing the gating.

The "Write-Enable" signal is generated by the Write Enable Chassis, which also generates the 4- μ s-wide zero time signal to be recorded on the data disc. The Write Enable Chassis is the system's link to the outside world and requires -10 ms and $\emptyset$ time as inputs. Each of these triggers a 30-ms one-shot and the outputs of the two one-shots are sent through an OR gate to produce the "Write-Enable" signal. The Write-Enable signal is a 40-ms-wide pulse beginning at -10 ms and ending at +30 ms. Its use in gating the timing program has been discussed already. It also determines when and for how long data can be written on the data disc. Recording begins at -10 seconds and continues until +30 ms. The first 7 ms of pre-zero data is rewritten leaving 3 ms of pre-zero

data and 30 ms of post-zero data on the disc. The 3 ms of pre-zero data gives the output of the transducers in their rest position. After recording the data disc contains four sets of parallel data arranged in frames of N words separated by a 2- μ s gap.

Recovering Data From the Disc

The readout chassis uses the two timing tracks on the data disc to locate and read a new data point with each revolution of the disc up to some preset number of data points. A unique set of data is selected by selecting the modulator and ADC of the desired transducer on front panel switches. The readout chassis then employs three counters to locate successive data points. One counter counts revolutions of the disc by counting the zero time pulse; the second counter counts frames of data by detecting the "gap" in the timing track and is reset each revolution; and the third counter counts words within each frame and is reset each frame.

Figure 3 is a logic diagram of the readout. Selection of the ADC determines which seven tracks the readout looks at. Selection of the modulator determines which word in each frame is to be read. Since the revolution counter is being incremented, coincidence between it and the frame counter occurs one frame later in the data for each revolution. Once the frame is located the word counter is advanced until it agrees with the number of the selected modulator. As the revolution counter is incremented, the desired word is read from successive frames of data. The chassis is also capable of reading all channels of data automatically in a predetermined sequence.

The binary data can be punched in order on paper tape using a high speed punch or can be converted to BCD and printed on an electrostatic strip chart recorder. In the case of the strip chart the time scale is $(N+2)$ μ s per point. In the case of the paper tape, a point ID number precedes the data for each point. Figure 4 shows a strip chart record of typical data.

Summary

All active components are located in an 8' by 40' van. The two discs, the ADC's and the strip chart recorder are commercially available items; other system components were designed and built at LLL.

References

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Fig 1
SYSTEM BLOCK DIAG

SYSTEM TITING

Fig 2

Fig 3
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