COMPUTER TECHNOLOGY

Audio tape storage of experimental data: An application to tachistoscopic research with children

ROBERT LENTZ *and* MARSHALL M. HAITH, *DEPARTMENT OF SOCIAL RELATIONS, HARVARD UNIVERSITY, Cambridge, Massachusetts 02138*

An inexpensive portable system is described for storing digital data on audio tape for later computer processing. The technique involves the use of integrated circuits and an ordinary stereo tape recorder. Each datum is converted to a binary-coded voltage level that, through a sampling device, controls the phase of a square-wave signal. Depending on whether the bit being coded is "0" or "1," the signal recorded on one tape track is either in phase or 180 deg out of phase with a reference signal recorded on the other track. Later, the recorded tape may be played back into a computer for data analysis. An application of this technique for tachistoscopic research is described.

The present-day computer has been of great service to the behavioral scientist, not only as a super calculator, but also as a device that can accept and store on-line information from experiments that yield large quantities of complex data. This latter function has greatly reduced the time, clerical error, and tedium that are involved in manual recording of experimental observations. However, a direct computer link may not always be accessible to the investigator. For example, the developmental psychologist, who may carry out his research in an elementary school or in a mobile trailer, seldom has access to on-line computer facilities. Thus, the data generated by his Ss must be stored in some form that can be made acceptable to the computer. When paper-and-pencil recording in such situations has been impractical, investigators have used paper-tape punches (Kagan & Lewis, 1965) or I.B.M. card punches (Haith, 1966) to produce stored records of the experimental data. Unfortunately, these devices are relatively noisy and expensive in addition to sharing all of the maintenance and interface problems of electromechanical apparatus. More exotic recording instruments, such as digital magnetic discs or digital tape recorders, have eliminated some of these problems but are quite expensive.

This paper will describe a technique for storing experimental data on an ordinary audio tape recorder, resulting in a quiet, inexpensive, and portable system. At the E's convenience, the audio tape can be played back into a computer for automatic data analysis. Although this technique has virtually unlimited applications, our system was originally designed to record several pieces of stimulus and response information on each trial of a tachistoscopic (T-scope) recognition study with children, carried out at an elementary school. The system components to be described are (1) a T-scope with associated circuitry, (2) adaptations to the T-scope, (3) a data multiplexer unit, (4) a stereo tape recorder, and (5) decoding apparatus.

T-scope with Associated Circuitry

A Gerbrands three-field mirror T-scope is used. The lamps in each stimulus field are switched on by one of three timers. adjustable from 10 to 1000 msec in 10-msec steps. Three additional timers control two interstimulus durations and the time between stimulus offset and the presentation of response alternatives. A rear-illuminated response unit displays 10 response alternatives on touch-sensitive panels.

The data-blocks of interest on each trial are: (1), a code number by which the S can be identified; (2), (3), and (4), the stimulus cards for the three fields; (5), (6), and (7), the exposure durations of Fields 1, 2, and 3; (8), (9), and (10), the two interstimulus intervals and the interval between stimulus presentation and response-alternative presentation; (11) . . . (20), the particular responses made by S (maximum of 10); and (21) . . . (30), the latency of each response. A description of how these data are recorded follows.

Adaptations to the T-scope

At the beginning of a session, 10 toggle switches are set to identify the S. These switches each control a voltage output. Each stimulus card is numerically coded at the top ½-in. margin, which is divided into 10 "data slots" separated by ¼ in. These slots are marked black or white in a pattern that uniquely represents the card. When a card is in a stimulus field, ready to be displayed, the slots are illuminated and the reflected light from each slot is detected by a temperature stabilized photocell; a bright white field results in a photocell 4-V (logical "1") output, and a black field results in a photocell 0-V (logical "0") output.

The timing duration of all six timers is adjustable through rotary switches. An extra wafer on each switch (two per timer) was wired, through a diode matrix, to give a unique binary-coded voltage output (eight outputs for each timer) for each time setting.

The response unit contains circuitry to give a binary-coded voltage output (four outputs) corresponding to the panel touched. The latency of response is measured by a 2-Hz electronic clock that starts counting at the onset of the first stimulus field. When a response panel is touched, the binary-coded clock reading is transferred to a storage register.

Data Multiplexing Unit

The multiplexing unit is the heart of the recording system. The principle employed is that of representing each binary digit (datum), 0 or 1, by recording two square-wave signals that are either in phase or 180 deg out of phase. Exactly one cycle of the square-wave signals is used to represent one binary digit. The interfacing circuitry discussed in the preceding section provided 4-10 data outputs from each interfacing unit, in the form of electrical "0s" and "1s" (see Fig. 1a). Disregarding the response information for the moment, the 10 separate units—toggle switches (1), stimulus fields (3), and timers (6)—constitute 10 10-bit binary words, or a string of 100 binary digits.

Each data line (i.e., each of the 100 binary data sources) was wired to Input A of a two-input "and" gate (data gate). The output terminals from the 100 data gates were wired to an "or" gate. The "or"-gate output will be referred to as the "gate-output line." When the S begins a trial by pressing a button, each of the data gates, in turn, is "interrogated" by a stepper (data-gate stepper) that is advanced by a 150-Hz clock (reference generator).

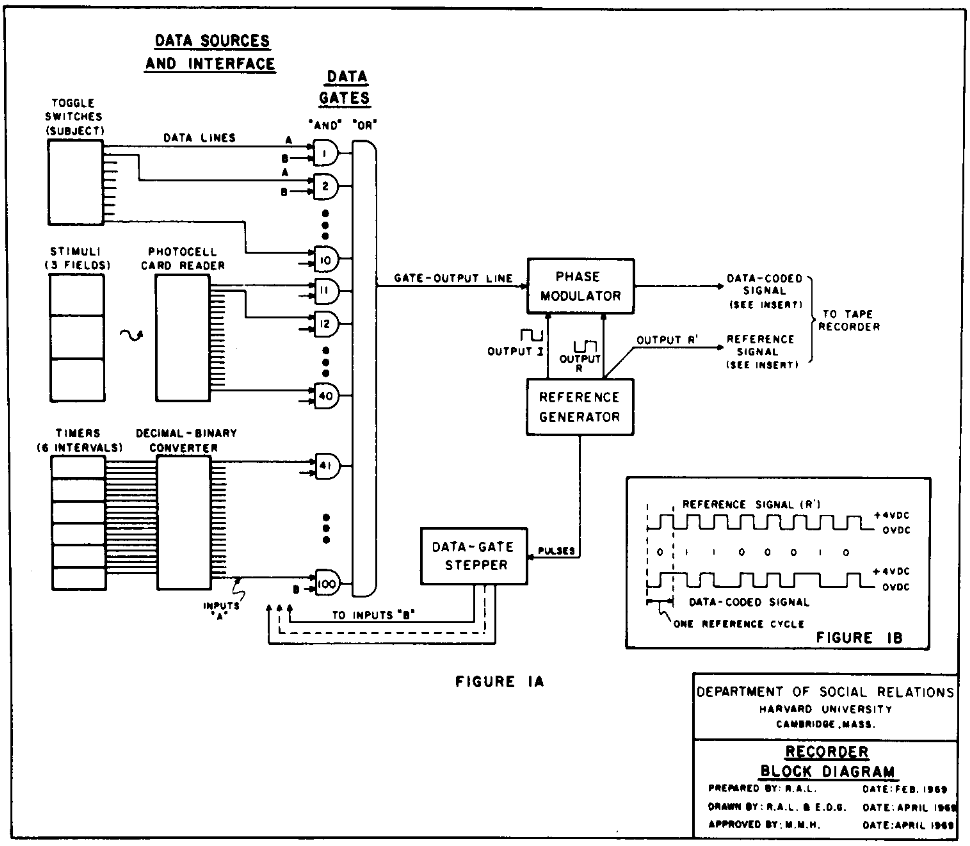

Fig. 1. (a) Block diagram showing functional units described in text, and (b) reference signal and typical data-coded signal to be recorded on tape.

The stepper sequentially applies a "0" to each "and" gate at Input B for one cycle of this 150-Hz reference generator. If the data line at Input A of a data gate is "1" when the stepper signal is applied to Input B, the gate-output line becomes "0"; if the data line is "0," the gate-output line becomes "1." (When the B input is "1," the output is always "0.") A complete step cycle through all 100 data gates requires 660 msec and produces a string of "0s" and "1s" at the gate-output line, which, in turn, feeds a phase modulator.[2]

The phase modulator is circuitry that controls outputs from the 150-Hz reference generator. This reference generator has three outputs, R, R′, and I. Outputs R and R′ are the same square-wave signal and Output I is an electrical inversion of this square-wave signal. Output R′ is used as a reference signal that is recorded on one track of the stereo tape recorder. Outputs R and I are connected, through control gates in the phase modulator, to the other track of the tape recorder. By means of the control gates, a "0" at the gate-output line "enables" (switches in) Output R and "inhibits" (switches out) Output I. A "1" at the gate-output line enables Output I and inhibits Output R. Thus, for each clock cycle, during which time one bit of information is transferred, either the R′ and R signals (in phase) are recorded on the two audio tracks or the R′ and I signals (180 deg out of phase) are recorded. Figure 1b illustrates the binary number 01100010 coded electronically in this manner.

In sum, the stepper samples each data gate in turn, thereby producing a string of 0-V and 4-V signals that represent the actual data. This string is fed to the phase-control circuitry of the square-wave reference generator. The gated output of the phase modulator is either in phase or 180 deg out of phase with the reference signal (R′) depending on whether the bit being coded is 0 V or 4 V.

After the 10 10-bit words are coded, the multiplexer stands by in a "response mode." The response information is recorded as follows. The 4 binary outputs from the response unit circuitry and the 10 outputs from the latency storage register are connected to Input A of 14 additional data gates. When a response is made, the touch sensor circuitry is temporarily locked in and the latency-clock contents are transferred to the storage register. The data-gate stepper then sequentially applies a "0" signal to Input B of these 14 data gates, thereby converting the information in these gates into a data-signal code in 92 msec. This cycle is repeated until the last response is given (up to 10) at which time the E presses a button which resets the multiplexing circuitry.

A logic diagram that specifies the integrated circuits used is shown in Fig. 2.

Stereo Tape Recorder

The tape recorder runs continuously throughout our experiments, but circuitry could be added to stop it between trials. The reference signal (R′) from the multiplexer is recorded on Track 1, and the "coded" data signal is recorded on Track 2. These signals are routed to the tape recorder input jacks through wave-shaping networks. Since R′ is only recorded during data transmission, individual data words can later be easily separated one from the other.

Decoding Apparatus

The particular decoding apparatus used will depend on the facilities available to the investigator. In our application, the output from Channels 1 and 2 of the stereo tape recorder are connected to Schmitt triggers that restore the original square waves. (Some waveform distortion occurs during magnetic

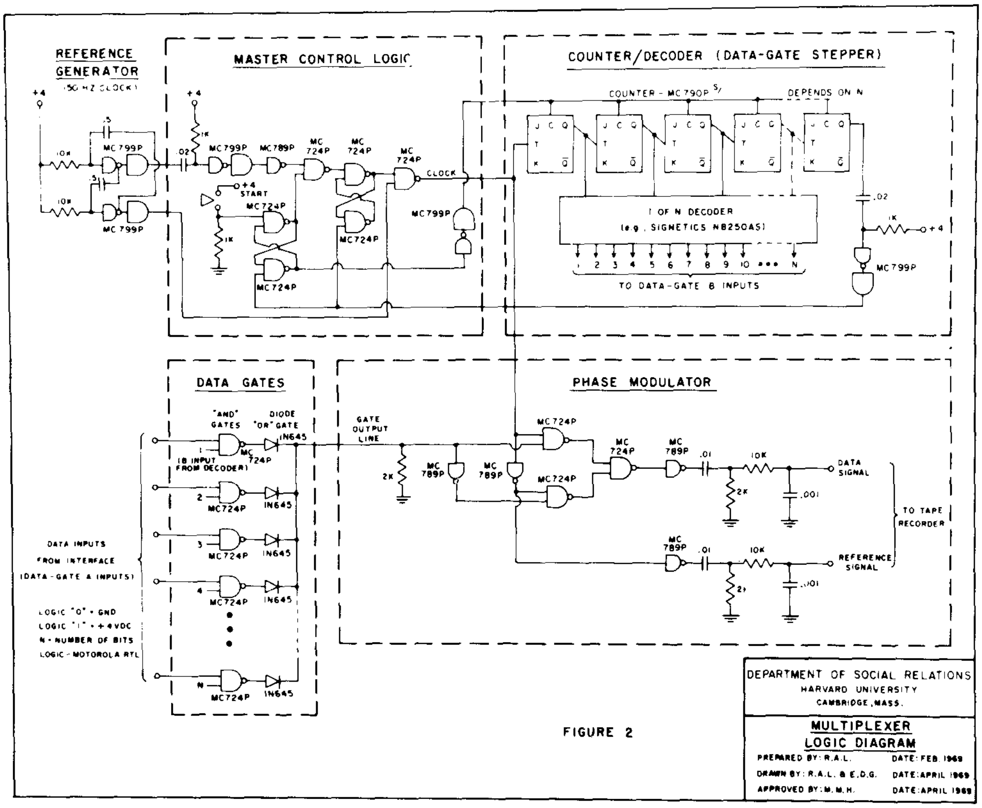

Fig. 2. Multiplexer logic diagram.

recording.) The reconstituted square-wave signals are then fed into a PDP-9 (Digital Equipment Corp.) computer that compares the voltage levels of the reference channel and the data channel for each clock cycle (i.e., at 1.5 msec after the beginning of each cycle). If the voltage levels of both signals are 4 V, the computer registers and stores a zero for that bit. If the voltage of the reference signal is 4 V but that of the coded data signal is 0 V, the computer registers a one. Further processing of the data, now in the computer, is done with additional programs.

If a computer is not available, the decoding function can be provided in the following way. Square-wave data from Schmitt triggers may be fed directly into a shift register. (A shift register converts serial data to parallel data.) Through some additional circuitry, the contents of the shift register can then be punched into a paper tape or I.B.M. cards.

The data-multiplexing and tape-recorder combination may, of course, be used in any application that requires the storage of binary data. Inasmuch as the basic components for the data-multiplexing system are relatively inexpensive (approximately $80.00 for 100 bits), the system described here compares quite favorably with more traditional methods for storing information.

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NOTES

1. The development of the technique described here was supported by NICHD Grant HD 02680 to Marshall M. Haith.

2. Operation has been reliably demonstrated up to 1,000 bits/sec.