TECHNICAL NOTE

RECORDING A PULSE SERIES ON ANALOG TAPE FOR FAST INPUT INTO THE DIGITAL COMPUTER

Much of the data generated by psychological and physiological experiments in general and behavioral experiments in particular are in the form of a time series of events. Such data, for example subject responses and single neuron unit activity, are frequently recorded on analog magnetic tape during the experiment and processed later off-line by digital computer. This processing usually occurs at rates comparable to the original data rates.

When the time series of events is presented to the computer from magnetic tape at the original rates, the bulk of the computer processing time is spent waiting for each event. This "idling" time, dedicated to the measurement of the inter-impulse intervals by counting the number of passes of the program through a timing loop (Krekule, Skvaril, Bures, and Vlach, 1968; Jokinen and Leinonen, 1969) or by counting the number of computer clock pulses (Wyss, 1970) can be reduced considerably by reducing the time scale of the data during the input process.

Simply reading the magnetic tape into the computer at a speed many times greater than the recording speed will not result in the precise recovery of the recorded time intervals because these intervals will depend upon tape speed stability, which is reduced at high speeds. However, this dependence upon tape-transport speed stability for the precise recovery of inter-event intervals is eliminated by simultaneously recording, (on the same track as the experiment-generated pulse series) a series of equally spaced, clock generated, timing pulses. This independence will be ensured even when the fast-rewind mode of the tape transport is used during the reading of the data into the computer. Owing to the higher speed of the tape, the shape of the reproduced pulses may be distorted, so that pulse shape restoration circuitry is required. This method of recording and reproducing time pulse series is described below.

The advantage of the proposed method is in its simplicity. Actually, only the clock-generated timing pulses are recorded on tape. When an experiment-generated event occurs during the recording process, the clock pulse next in time, ordinarily of positive polarity, is reversed in polarity and recorded as a negative-going clock pulse. This is so even when an event occurs simultaneously with a positive-going clock pulse (see Figure 1). The interval between events, therefore, is evaluated during playback by having the positive-going pulses counted in the computer's accumulator. At each negative-going clock pulse, the content of the accumulator is transferred to the computer's memory,

Fig. 1. Diagram of input and reproduced pulses: (a) clock, (b) responses (analyzed pulses); (c) reproduced pulses.

Fig. 2. Flow chart diagram of the LINC computer input subroutine for reproduced pulses. Subroutine could be finished manually using the sense switch (SNS 0). (Buffer registers on the SXL n inputs are reset by OPR n pulses.)

Fig. 3. Functional block scheme of the recording unit. Bistables F 1, F 2 represent units B 11; monostables M₁ (output pulse duration: t'), M₂ (t') = units T 11 and shapers S₁, S₂ = units K 11 of the Regimat ZPA logic system in which the state "1" ("0") is represented by the ± 10 (0) V level. Pin numbers are encircled. AND gates are composed from Ge diodes OA 5 (Tesla) and R = 10 K Ω , Si transistors Tesla are used in shaping circuit: T₁ = KF 507, T₂ = KF 517.

the accumulator is cleared and the process repeats (see Figure 2).

The maximum error in each interval evaluated in the above manner is equal to the interval between one clock pulse pair. The upper limit on frequency of the reproduced clock pulses is determined by the computer's data-input transfer rate, the frequency response of the tape recorder and the clock-pulse shaping circuit. For the tape recorder and computer used, Tesla B 47 (Czechoslovakia), LINC D.E.C. (U.S.A.), this frequency is approximately 20 kHz. The lower limit on recorded clock pulse frequency is determined by the precision to which inter-event intervals must be measured and the probability of the occurrence of more than one event in any inter-clock pulse interval. The latter probability may be negligible. The upper and lower limits determine the maximal achievable reduction of the time scale.

The recording circuitry (Figure 3) transforms clock pulses into the recorded pulses of triangular form (fast rising, slow falling edges) and of correct polarity as a function of the occurrence of events in the original time series. Each event pulse after being shaped by S₁ (saturated amplifier) sets the bistable flip-flop F 1 to the state "1" by its falling edge. The output of F 1 sets the bistable flip-flop F 2 to the state "1" if the intervening AND gate (diodes) is not inhibited by a clock pulse (i.e., output of the monostable flip-flop M 1). The leading edge of the "1" signal of F 2 in turn resets F 1 to state "0". F 1 serves as a buffer register that stores an event pulse occurring during the generation of recorded pulses. F 2 is reset to "0" by means of the falling edge of each clock pulse (M 1). Shortened clock pulses (output of the monostable flip-flop M 2) are fed into the shaping circuitry (T₁, T₂) through AND gates that are controlled by outputs of F 2. If F 2 is in the "0" state (timing pulses) the positive part (T₁) of the

shaping circuit is triggered, if F 2 is in the "1" state the negative part (T₂) is triggered.

The reproduce circuitry (Figure 4) simply distinguishes between positive and negative recorded pulses, thereby distinguishing events from timing pulses. The recorder channel is first amplified, then negative pulses are inverted by T 3 and pulses are separated into two arms, positive (timing pulses) and negative (event pulses). Both arms are identical. In each arm, the positive (inverted negative) pulse is shaped by each saturated S₄ amplifier S₄(S₅), which then operates the monostable flip-flop M 4 (M 3) if the intervening AND (diodes) gate is not inhibited by the "1" output of the flip-flop in the opposite arm. These diodes could be omitted if there are not spurious pulses from the distorted trailing edges of recorded triangular pulses (when the maximal speed is applied to the tape transport). Output of M 3, resp. M 4 operates the buffer register on the SXL lines of the LINC computer.

The described system was tested using an AM tape recorder Tesla B 47 (15 $\frac{1}{16}$; 17 $\frac{1}{8}$; 3 $\frac{3}{4}$ IPS) and the LINC laboratory computer. Recording and reproducing circuitry was built using standard blocks of the Regimat ZPA (Czechoslovakia) logic set. Time scale reduction of 100:1 has been achieved, by using clock frequency of 100 Hz (10 msec inter-clock pulse interval) and tape speed 3 $\frac{3}{4}$ IPS for recording.

Although this approach could be applied to the recording of two and more independent pulse series, the advantage of the above proposal, i.e., the utilization of the same channel for the timing and event pulses is lost, because each pulse series should be recorded on a separate channel.

If one block of an experiment pulse series does not fill the whole tape, the zones of empty tape should be used for separation of different blocks of data. These zones, being easily recognizable by acoustical signal,

Fig. 4. Functional block scheme of the reproducing unit. Monostables M_3 , M_4 represent units T 11; shapers S_3 , S_4 = units K 11 of the Regimat ZPA logic system. T_3 = KF 507. Channel amplifier ($A = 1000$) is Tesla AZZ 941.

give an opportunity to the operator to switch on and off the input program and the tape recorder. This procedure could be automated using another SXL of the LINC computer, controlled by the output of a Schmitt trigger fed by the RC circuit that integrates both clock and inverted event pulses.

REFERENCES

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