An event-coder for evoked potential studies

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A device is described which has 10 input and 2 output lines. Grounding an input causes a pulse with a specific amplitude, polarity, and duration to appear on one of the output lines. Pulse parameters can be set by front-panel controls. Thus, 10 distinct events can be coded by associating a unique pulse with each event. These pulses can be recorded on one (or two) channels of a magnetic tape recorder for subsequent processing. The use of this coder in the study of event-related potentials is described.

The extraction of event-related potentials from the EEG using signal-averaging techniques requires that the time of occurrence of the events be known. (For a review of average-evoked-potential studies, see Donchin & Lindsley, 1969; Mackay, 1969.) Event-synchronous markers, usually voltage pulses, are commonly used to trigger the digitizing process that acquires the event-related EEG segment. When data are recorded on analog magnetic tape, the event-marking triggers must also be recorded. Experimental designs often call for a number of different events during a trial; encodement of the various trigger pulses can be a serious problem. Tape decks are limited to a fixed number of channels (7 or 14 in the common IRIG configuration), and it is prudent to use a minimum number of channels to record the event-marker pulses. A solution is to associate with each of the events a unique trigger pulse. The averaging instrument, or some intermediate device, must then discriminate among the various pulses, selecting only the ones desired in each phase of analysis.

This report describes a pulse-coding system used successfully for 2 years in an average-evoked-potential data-acquisition and analysis system. We shall describe the circuitry that generates the pulses and the IBM 1800 computer-implemented logic used to decode the pulses for specific event-locked signal averaging.

GENERAL DESCRIPTION

The event coder (Iconix 6086) can be used to code 10 different events and to record their occurrence on one or two tracks of magnetic tape. Event coding is achieved by associating with each event a unique pulse defined by pulse duration, amplitude, and polarity. The event coder is comprised of 10 one-shots and two summing amplifiers, with front-panel control of all pulse parameters (see Fig. 1). Grounding the input (Point A or its back-panel equivalent) triggers the one-shot for a duration determined by Dial B. The one-shot output (−12 V "off," 0 V "on") is always available at Point C. The output of each one-shot can simultaneously be applied to either or neither of two summing circuits, selected by Toggle Switch D. Toggle Switch E determines if the pulse would appear at the output of the summing circuit as a positive or negative pulse, and Dial F determines the amplitude of this positive or negative pulse. Front- and rear-panel outputs are provided for each of the summing circuits. Any combination of the 10 one-shot pulses can be encoded in the summing-circuit outputs. Thus, if stimulus-generating mechanisms can provide ground signals synchronous with the occurrence of critical events, marker pulses with unique amplitude, duration, and polarity can be assigned to each event.

ELECTRONICS

A block diagram of the event-coder circuitry is shown in Fig. 2. Front- and rear-panel inputs to each one-shot channel are isolated by an OR circuit. When either input undergoes a −12 V to 0 V change, the one-shot is triggered. The output of the one-shot then changes from 0 V to −12 V for a duration determined by an RC network. Capacitor C and Variable Resistor R, controlled by Dial B, determine the duration. For each value of the capacitor, the duration can be changed over a 20-to-1 range by Dial B (e.g., in the present version, with C = 2.0 microfarads, the duration can be changed from 20 to 400 msec).

The output of the one-shot is inverted by two independent inverters, I_1 and I_2. The output of Inverter I_1 is routed to Output Jack C on the front panel (and to a corresponding back-panel connector). Output C is thus at −12 V when the one-shot is at "rest" and at 0 V when the one-shot is "on." A neon lamp indicates when the one-shot is "on." The output of Inverter I_2 is level-shifted (i.e., the −12 V to 0 V change is converted to a 0 V to +12 V change) and routed to Toggle Switch E. The one-shot output is directly routed to the other side of Toggle Switch E. Toggle Switch E thus routes to the summing amplifier either the output of the inverter (I_2) (when the user needs a negative pulse) or the output of the

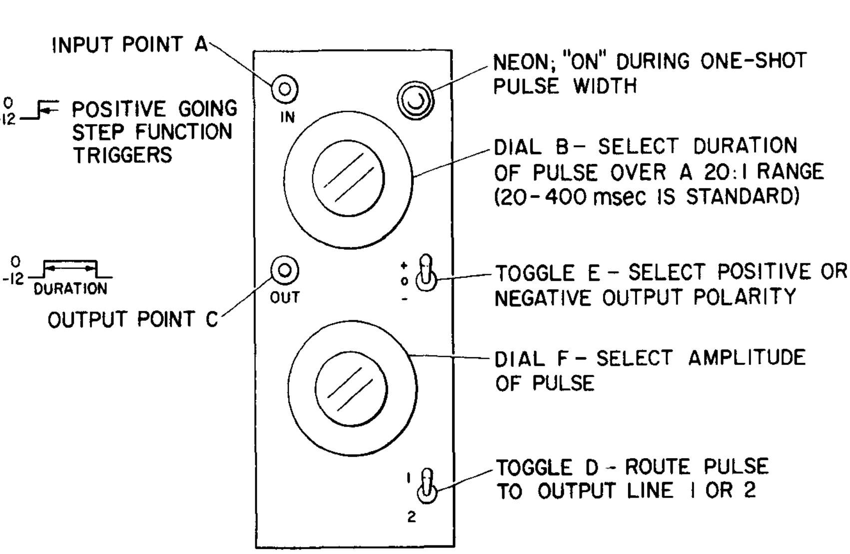

Fig. 1. Front panel of 1 of the 10 one-shots used in the event coder.

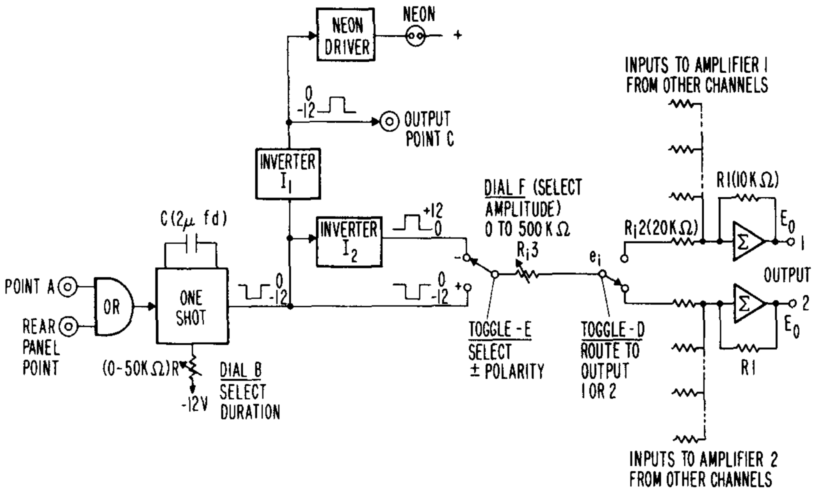

Fig. 2. Block diagram of 1 of the 10 subunits, i.e., channels, of the event coder. The flow of the signal from the input of 1 of the 10 one-shots to the output of the summing amplifiers is indicated. Identical subunits are connected to the other 9 pairs of inputs to the summing amplifiers.

one-shot (when the user needs a positive pulse).

As summing amplifiers, we used operational amplifiers (Analog Devices No. 111). For an operational amplifier wired as shown in Fig. 2, the output voltage (E_0 at Pin 1) is $E_0 = -\Sigma A_i e_i$, where the e_i are the voltages at the input points and A_i is $R1/(R_i2 + R_i3)$. As R1 and R_i2 are fixed, the gain is determined by R_i3, which is controlled by Dial F, on each of the channels. When R_i3 is set to 0 ohm, the gain of Channel i is $R1/R_i2$, and the channel gives its maximal contribution to E_0. When R_i3 is set to its maximum value, the gain of Channel i is $R1/(R_i2 + \max R_i3)$, and Channel i provides its minimal output. For example, with the values indicated in Fig. 2 (R1 = 10 K ohm; R_i2 = 20 K ohm; and R_i3 varying from 0 to 500 K ohm), the gain at each channel ranged from 10/20 to 10/520, so that an output range of 26 to 1 is obtained, and the maximum contribution of each channel to the output was 4 V. (A bias control, not indicated in Fig. 2, cancels amplifier zero offsets.)

Toggle D allows each one-shot to be routed to one or neither of the two summing amplifiers. The very low impedance at the circuit nodes, where the one-shot output is connected to the summing amplifier, effectively isolates the channels. Both summers have push-pull emitter followers at their outputs that are included in their feedback loops. In this way, summing accuracy is preserved, and a capability for driving long coaxial lines is added.

APPLICATION

This device has been used in a study in which monkeys are presented with tone and light stimuli and in which they had to press and release keys in a prescribed manner to obtain food pellets. Event-related potentials associated with all stimuli and with both key presses and key releases were needed for the data processing. One pulse coded each of the four critical events—the tone, the light, key presses, and key releases. Stimuli were associated with positive pulses, responses with negative pulses, and an amplitude difference of 1 V was maintained between the two pulses in each polarity. These pulses were encoded by one summing circuit and recorded on one channel of the magnetic tape. The remaining one-shot channels were routed to the other output of the coder and were used to trigger various on-line monitoring devices.

Care must be exercised in selecting the durations and amplitudes of the various pulses, as the operational amplifiers indeed *sum* the voltages appearing at their inputs. If the output of several one-shots overlap in time, the resulting output may produce a misleading waveform. For example, assume Channel 1 is set to produce a 300-msec + 1-V pulse and Channel 2 is set to produce a −1-V pulse for 100 msec; then, if Channel 2 is triggered 100 msec after Channel 1, the summed output will be two 100-msec positive pulses separated by a 100-msec interval. Of course, by judicious selection of pulse duration and amplitude, the E can assure that any combination of events will be associated with a unique pulse configuration. The computer can then be programmed to decode such combinations.

DATA PROCESSING

The event markers generated by this device were used for logging the animals' behavior (recording successes, failures, reaction times, etc.) and for obtaining event-related signal averages. Because these events occur in an unpredictable sequence at unpredictable times, a pulse-discrimination procedure was necessary to decode the pulses for data analysis.

Two methods were used to achieve pulse discrimination. A hardware pulse discriminator was developed at NASA-Ames. This was a device with one input and eight outputs. Front-panel controls could determine, for each of the eight inputs, which pulse amplitude *at the input* would provide a pulse on a particular *output*. These outputs were connected to the IBM 1800 "process interrupt-voltage" terminals, a 16-bit register. A specified voltage change on any of the 16 terminals provides a processor "interrupt," the register is then decoded, and the specific terminal requesting "service" is determined. An interrupt is essentially a forced-program branch that literally interrupts any lower-priority activity in the computer, transferring control to a specified location in memory. A routine designed to respond to the "interrupting" event resides in core at the location to which control is passed. It is the essence of an interrupt system that, after the interrupting event is properly responded to, control returns to the interrupted activity, and the computer proceeds with its previous business.

This procedure was used to log the animal's behavior. The routine responded to the interrupt, determined which of the 16 bits in the interrupting register was turned on, and thus determined which event had occurred. The computer program's logic provided for various contingencies in the experiment, determined reaction time, success, failures on the task, and the specific kind of failure that occurred. This hardware approach to the pulse discrimination proved unsatisfactory, largely because of system inflexibility and limited pulse-amplitude discrimination capability. We have, therefore, chosen to replace the hardware pulse discriminator with a computer subroutine (IBM 1800). However, for investigators using a special-purpose averaging device, such a choice is not available. The "CAT," for example, has a rigid set of requirements for its trigger and allows no pulse-discrimination flexibility and thus requires a device of the type just described. Other averagers (e.g., Hewlett-Packard and FabriTek 1070) provide more flexible trigger functions.

The IBM 1800 analog/digital converter can be provided with a "comparator"; two "limit" values are set (by the program) for a given analog input channel so that when the analog voltage exceeds the upper limit, or is less than the lower limit, an "interrupt" is generated. This out-of-limits interrupt functions in the same manner that was described above, except that the digitizing activity proceeds in spite of the interrupt, and no data are lost while the interrupt is being "serviced."

The logic we used is as follows. When the trigger subroutine is called by the averaging program, the computer initiates digitization of a specified analog channel at 50 microsec per sample (minimum possible interval). The comparator for that channel is turned on, and its limits are set at ±300 mV. Sampling and storage of the current-sample value continues until an out-of-limits condition occurs. The computer can proceed with other activities while this sampling process goes on. A process interrupt occurs when an out-of-limits value is encountered. The program then tests to determine if the sample value occurring 100 msec after the interrupt falls within limits specified for an acceptable trigger. The 100-microsec wait is instituted to allow for the slow rise time of pulses recorded at 1-7/8 in./sec. If the value falls within specified limits, the trigger routine is excited, and the averaging routine is begun. A refinement includes testing for the lapse of a specified time interval from the onset of the program. If this interval has lapsed before a desired trigger is found, the search is terminated.

The event-coder, program-decoder system has proven to be reliable and convenient. Analog tape channel usage has been optimized for data acquisition. Complex event-marking conditions are easily dealt with and conveniently monitored on a single display channel during the experiment and subsequent data playback.

REFERENCES

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NOTE

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