TECHNICAL NOTE

STIMULATION TRIGGERED AUTOMATICALLY BY ELECTROPHYSIOLOGICAL EVENTS*

In studying functional interplay between different parts of the brain, it is becoming increasingly important to evaluate the effects of stimulation upon one locus in terms of activity prevailing elsewhere in the system. For experimental purposes it is often convenient to make this latter activity a fixed variable, that is to say, stimulation will be delivered to one structure only during a particular pattern of activity in a second. The authors employed this approach in recent experiments where peripheral (photic and acoustic) or central (intracranial) stimulation was made contingent upon the appearance of certain features of the EEG, EMG or electro-oculogram.

A device was developed to detect these features electronically and trigger the stimulator automatically. With such an interface between recorder and stimulator the experimenter is relieved of an exacting vigilance task and stimulation is delivered with repeatable precision. The advantages of this procedure have already been demonstrated by McDonald who was able to stabilize the appearance of cortical evoked potentials in the cat by

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FIG. 1. The five modes of operation. Upper tracings, Approximately 3 sec burst of 20 Hz high amplitude input signal. Lower tracings, The output of trigger pulses.
arranging for stimulation to occur only during period of low background activity in the brainstem (McDonald, 1964). Similarly, Jouvet used an automatic system to deliver nociceptive stimuli to waken cats upon the disappearance of muscular activity in the neck corresponding to the onset of the Rhomboencephalic Sleep Phase (Jouvet, 1963).

The device employed by the present authors enables a number of different aspects of the recorded signal to trigger the stimulator. It provides a choice of five triggering modes each dependent upon the onset or disappearance of activity defined in terms of its amplitude. Figure 1 illustrates the different operations of which the instrument is capable. The tracings are photographic records from a CRO showing the output of trigger pulses (lower tracings) associated with trains of high amplitude phasic potentials. Mode A. A trigger pulse is emitted each time the input exceeds a certain amplitude. The trigger level is variable so that potentials of different amplitude may be discriminated.

Mode B. A single pulse is obtained at the beginning of a wave train. No further pulse will be emitted until the signal has fallen below the trigger threshold for at least 300 msec.

Mode C. A single pulse marks the end of a period of high amplitude activity and the return of the recorded signal toward quiescence. The device requires 300 msec to recognize that the train has ceased and the output occurs with this latency.

Mode D. Slow recurrent trigger pulses are obtained during periods of quiescence. The frequency of the output pulses is variable between 6 and 240 pulses/min. Quiescence is defined as activity whose amplitude does not exceed the selected trigger level. Trigger pulses resume with fixed latency after the signal returns to the quiescent level. This latency is approximately 300 msec plus 1.5 times the period of the selected trigger frequency.

Mode E. Recurrent trigger pulses are obtained during high amplitude activity. They begin with a latency of 1.5 times the period of the selected trigger frequency and may continue until 300 msec after the end of the wave train. These functions are obtained from the circuit of Fig. 2 by appropriate interconnection of the various stages, effected by the selector switches in the lower part of the diagram. The device receives its input from an amplifier whose output impedance is less than 10 kΩ; the authors found it convenient to tap the next to last stage of an electroencephalograph (Offner Preamplifier Type 481, Offner Dynograph Amplifier Type 482, Offner Electronics, Chicago, Illinois). The device generates 12 V positive pulses of 1 msec duration suitable for triggering peripheral as well as intracranial stimulators (Model PS2 Photostimulator, Grass Instruments, Quincy, Mass.; Model 7150 Series Constant Current Stimulator, Nuclear-Chicago, Des Plaines, Illinois).

Circuit operation

The input signal is fed first to an amplitude detector. This is a Schmitt Trigger whose threshold is reliably variable over the range 2–30 V. The voltage at the collector of Q2 rises 12 V when the input exceeds the selected level. For operation in Mode A, the output from this stage is fed via the final diode network directly to the stimulator. The diode network serves to remove the negative component of the capacity coupled output.

For operation in other modes the output from the Schmitt Trigger is connected via SW1 to the 'group detector,' a modified monostable multivibrator. Upon receiving a positive pulse from the Schmitt Trigger, the output of the Group Detector falls from approximately +14 V almost to ground for a period of 300 msec before reverting to its original state. However, if it receives a further pulse from the amplitude detector during the 300 msec it will begin timing this period afresh before resetting. For operation in Mode C the signal from this stage is fed to the output network of the device where it appears as a single pulse 300 msec after the end of a train. The period of the multivibrator sets a lower limit on the frequency of phasic potentials to be detected as groups. The frequency response may be extended by increasing the value of the 2 μF timing condenser but at the cost of increased latency in reporting the end of a train.

For operation in Mode B, the signal from the group detector is inverted by the phase changer before being fed to the output; the device then delivers a single positive pulse at the beginning of each wave train.

A unijunction transistor oscillator whose frequency is variable from 6 to 240 c/min provides the recurrent trigger pulses for Modes D and E. The oscillator can be blocked by applying a positive potential to the base of Q8. Thus when the group detector is coupled to the oscillator, the latter is free to cycle only during high

**Fig. 2.** Circuit diagram of the device.