TECHNICAL NOTE

A MULTIFUNCTION PULSEFORMING CIRCUIT¹

In the programming of operant equipment, it is often convenient to produce a pulse upon the onset or "make" of a voltage so as either to stretch the duration of a voltage impression sufficiently to operate relays, counters, *etc.*, or to shorten the duration of the voltage to prevent lever-holding responses, *etc.* On other occasions, it is convenient to produce a pulse on the offset or "break" of a voltage impression. For example, when tape timers are used to commence trials, short-latency responses sometimes occur within the relatively long pulse period of the tape timer causing a misfiring of the circuit; or, in shuttle avoidance conditioning using an onset pulse produced by the crossing response to terminate trials results in the brief occurrence of the CS and UCS on the "safe" side. Both of these circuit defects can be adequately corrected by an offset pulse-former.

Another form of pulseforming circuitry is the multi-vibrator, which originates a stream of pulses upon signal. Such devices are useful for timing response latency in conjunction with a printout counter (Verhave, 1958), with a stepping device to provide precise CS-UCS relationships with overlap and cotermination, or to produce intermittent shock to optimize avoidance performance in rats (D'Amato, Keller, and DiCara, 1964) or in fish (Bitterman, 1965).

Although not strictly a programming device, another related unit is the contact switch. Such circuits are useful in recording the number of tongue licks to a water delivery mechanism, or as a photocell relay to record the amount of time spent in a segment of an alley, *etc.*

There are a number of circuits available that will perform each of these functions, although none is versatile enough to perform all of them. Additionally, many of the published circuits have distinct disadvantages. Most onset pulseformers require two relays, some circuits will shorten but will not stretch pulses, and other circuits require a switch closure rather than the impression of a voltage to operate, and hence are not ideally compatible with existing operant equipment. The present circuit will operate in any of the aforementioned modes, uses few components likely to break down, operates with a voltage impression, or release, of a few microseconds to infinite duration, and costs about \$10 for the components.

The basic pulseforming circuitry includes the pulse trigger circuit, C_2 and R_2 , the silicon control rectifier, SCR, the relay, K, and the timing capacitor, C_1 . C_1

charges through the normally closed contacts of the relay and surge current limiter, R_1 , when the circuit is at rest. When a positive signal is applied to capacitor C_2 , the gate of the SCR is made positive with respect to its cathode and the SCR conducts. Whenever the gate of an SCR is made momentarily positive, the SCR conducts and continues to conduct until it is removed from the circuit, such as by shorting the anode and cathode. The gate pulse duration is determined by the charging time of C_2 and is on the order of a few microseconds with the component values given. Operating contact closures of any duration longer than the C_2 charge time will result in a positive trigger pulse to the gate of the SCR. Resistor R_2 is used to discharge C_2 upon completion of the trigger pulse. When the SCR conducts, C_1 is discharged, operating the relay for a time determined by the RC time constant of the circuit and the relay holding voltage (approximately 0.05 sec with the values given). Output duration can be altered

Fig. 1. All resistors $\frac{1}{2}$ w, 10% except $R_1 = 2$ w, 10%. Exact value of R_2 depends on exact value of other resistors and may require alteration after circuit is constructed.

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by altering the value of C_1 without affecting the values of other components in the circuit and is relatively stable given a particular relay. The second set of relay contacts short the SCR, effectively removing it from the circuit until it receives another gate signal.

When the unit is in the "make" (or contact) mode, the transistor functions to amplify the input and to change input polarity, thus preserving the conventional ground-to-operate input polarity. Application of ground to the "make" terminal results in conduction through the transistor to trigger capacitor, C_2 . Resistors R_5 and R_6 as well as capacitor C_3 act to suppress transient voltages that might otherwise cause false operations. C_3 absorbs the energy of the transient while R_5 and R_6 hold a positive base bias, which must be reversed before the circuit can operate. We found that transients sufficient to cause false operations in two commercially available pulseformers were neutralized by the safeguards in the present circuit.

In the "break" mode, the "make" terminal is shorted to ground causing the transistor to conduct continuously. In addition, the "break" terminal is grounded shunting the collector current to ground. When the "break" contact is momentarily separated from ground, the collector current flows through the trigger circuit, activating the SCR.

In the multivibrator mode, the "multi" terminals are shorted and the circuit is activated by completing the "make" to ground connection. Resistor R_4 is then shunted by R_3 lowering the total resistance path to the SCR gate, providing a constant gate signal. The gate signal combined with the intermittent shorting of the SCR, upon activation of K, results in the steady oscillation of the relay. To increase the versatility, we have run leads from both sides of the timing capacitor, C_1 , to external terminals so that another capacitor can be paralleled, changing the time constant. A 10 μf external capacitor changes the pulse rate to 10/sec and a 350 μf capacitor to 1/sec.

In the contact switch application, the unit is utilized in the same manner as the "make" circuit. In the usual application as a drinkometer, the grid bars are grounded and the drinking tube is connected to the "make" terminal. The unit will operate with up to

one million ohms contact resistance and will produce one pulse for each contact up to the limit imposed by the duration of the pulse. It has not been necessary to reduce the sensitivity of the device, although there are some applications in which it would be desirable to include a potentiometer between the make contact and the rest of the circuit for this purpose. In some other application, if contact duration is to be recorded, the "multi" terminals are shorted and this results in a number of pulses proportional to contact duration.

Instead of different contacts for separate functions, it may be more convenient to bring out the contacts to a three-position switch and preserve just the input and output terminals. In our application in a patch-board setup, it is more desirable to reduce the number of switches to be set between experiments.

Two units have operated for approximately 10 hr daily for about three months and neither has thus far required any attention. The second unit was constructed directly from the values in the circuit diagram and required no adjustments in terms of specific values of resistances and capacitances, although the value of R_2 may require alteration depending on the exact value of other resistors in the circuit.

REFERENCES

- Bitterman, M. E. The CS-US interval in classical and avoidance conditioning. In W. F. Prokasy (Ed.), *Classical conditioning*. New York: Appleton-Century-Crofts, 1965. Pp. 1-19.
- D'Amato, M. R., Keller, D., and DiCara, L. Facilitation of discriminated avoidance learning by discontinuous shock. *Journal of Comparative and Physiological Psychology*, 1964, 58, 344-349.
- Verhave, T. A simple way to record latencies. *Journal of the Experimental Analysis of Behavior*, 1958, 1, 66.

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