A VARIABLE PROBABILITY COINCIDENCE PULSE GATE

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This paper describes a device used as a decision element to control the probability of some event. Commonly, the pulse produced by this element is used to set a reinforcement device such as a feeder to reinforce the next response of an animal. The purpose of this device is to make it impossible to predict which individual responses will be reinforced while guaranteeing that the reinforcement will be given for a predictable average number of times during the experiment.

PRINCIPLE OF OPERATION

Two gas tubes are used in a free-running multivibrator circuit with variable symmetry control of a square wave, while maintaining a constant period of each complete cycle. Figure 1 is a simplified diagram to illustrate this principle. Tubes V_1 and V_2 are type 2D21 thyratrons. The plates of both tubes are supplied with a +150 volts D.C. through plate-load resistors R_1 and R_2 .

The circuit is completed through a common ground. The control grid of each tube is biased with an independent B-supply to minimize interaction with the plate supply. The multivibrator is cross-coupled with Condensers C_1 and C_2 . These condensers and the fractions R_a and R_b to each grid control the time of conduction of each tube. When control R_3 is set at its midpoint so that R_a is equal to R_b , then the period of the square wave is approximately 20 milliseconds and is symmetrical. As the resistance is decreased with respect to V_1 (R_a decreased), the conducting time of V_2 is increased while that of V_1 is decreased. Since both V_1 and V_2 have equal plate-to-grid coupling condensers, the period of the square wave developed across the plate resistors R_1 and R_2 remains constant; but the conducting time of V_1 decreases while that of V_2 increases. This is illustrated in Fig. 2.

The switching action is free-running and oscillates at 50 cycles per second. If a plate relay is substituted for

Fig. 1. Basic multivibrator with symmetry adjustment control, R_3 .

Fig. 2. Output pulse symmetry for three settings of R_3 .

R_2 and the normally open contact of this relay is placed in series with an external keying device, the probability of a keyed pulse coinciding with the relay-contact closure will be proportional to the ON-time of V_2 . When coincidence occurs, the keyed pulse is gated on to the stimulator.

THE PRACTICAL CIRCUIT

In the practical circuit of the variable probability coincidence pulse gate, shown in Fig. 3, a plate circuit relay, Ry_2 , is substituted for the plate resistor of V_2 . Because the multivibrator must be free-running in the absence of an incoming key pulse, this relay would have to pull in once for each transfer of the circuit. To eliminate this relay chatter, a three-pole, single-throw START relay, Ry_1 , is used to substitute a resistor R_2 in the plate of V_2 at all times except when an incoming pulse is present. The START relay also is used to make the grid bias more negative at 0% and 100% probability settings so that the gate is never open at 0% and always

Fig. 3. The circuit of the completed VPCP gate.

open at the 100% setting. This, of course, stops the multivibrator from functioning at the extreme settings of probability. The free-running characteristic of the multivibrator is also interrupted by use of a commutating condenser, C_1 , at any time an incoming key pulse is received. This is done to prevent the anticoincident pulse of longer duration than 20 times the per cent setting from transferring to V_2 and feeding out through the coincident output-pulse relay, Ry_2 . A two-pole, 11-position switch is substituted for R_3 of Fig. 1, and is wired as shown in the practical circuit. This switch permits greater reset accuracy than can be obtained with a potentiometer and also allows the timing resistors R_3 through R_{12} to be chosen to compensate for the shunting effect of the commutating condenser, C_1 , across the timing condensers C_2 and C_3 . Section Sw_{1a} selects the proper timing resistors to get the desired ratio of conducting to nonconducting asymmetry required for the gate. Section Sw_{1b} renders V_2 always conducting for a probability setting of 100% and never conducting for a 0% setting by applying the negative

Fig. 4. Performance of the VPCP gate.

bias supply directly to the grid of V_1 or V_2 in either of the extreme probability settings.

The performance of the variable probability coincidence pulse gate is illustrated in Fig. 4. Without end-resistor compensation, it can be seen that a cross-over exists in the 50% probability region. With appropriate end-resistance compensation, the number of coincident pulses more closely follows the straight line. It must be realized that for any given setting of probability, the number of coincident pulses possible may be anywhere from all to none of the input pulses when the number of pulses is small. However, it is most probable that if a large number of incoming pulses is observed, the percentage of pulses passing through the gate will approximate the probability setting.

This gate has been in use in the animal behavior laboratory of The Lilly Research Laboratories for the last 4 years. It has been reliable and free of breakdown except for infrequent tube- and relay-contact failures.

COMPONENT PART LIST

- R_1, R_2 : 10,000 OHM, 1 watt composition resistor
- R_3, R_4, R_{11}, R_{12} : 50,000 OHM, 0.5 watt, 5% composition resistor
- $R_5, R_6, R_7, R_8, R_9, R_{10}$: 100,000 OHM, 0.5 watt, 5% composition resistor
- R_{13} : 33,000 OHM, 0.5 watt composition resistor
- R_{14}, R_{16} : 100 OHM, 1 watt composition resistor
- R_{15}, R_{17} : 100,000 OHM, 1 watt composition resistor
- C_1 : 0.1 mfd, 600 volt paper condenser
- C_2, C_3 : 0.02 mfd, 600 volt paper condenser
- C_4, C_5, C_6 : 40 mfd, 450 volt electrolytic condenser
- SR_1, SR_2 : 130 volt, 60 ma. selenium rectifier
- T : 117 volt A.C. to 6.3 volt A.C., 1.2-ampere transformer
- Ry_1 : 24 volt D.C. coil, DPDT relay
- Ry_2 : 10,000 OHM plate relay with SPDT contacts
- V_1, V_2 : 2D21 thyratron
- Pb : N.O. SPST push button
- Sw_{1a}, Sw_{1b} : single pole, 11-position wafer switch

Received June 10, 1960