INSTRUMENTATION & TECHNIQUES

A circuit to permit an electronic drinkometer to operate during footshock*

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A circuit to permit an electronic drinkometer to operate during footshock is described. The circuit employs a diode matrix that allows all grid bars to be connected at one point to form one electrode of the drinkometer; it is isolated at another point so as not to shortcircuit the impressed footshock.

A common form of an electronic contact relay circuit is one in which the S completes a path between two electrodes in the grid circuit of an electron tube, thus either "shorting out" the existing grid bias or allowing a bias to be applied. This action typically results in the flow of a subthreshold current through the S and in a change in the cathode-plate resistance of the tube. The plate circuit normally contains a relay which opens or closes, depending upon the amount of current flow in the plate circuit. Thus, momentary contacts of the S between the electrodes in the grid circuit result in corresponding changes in state of the relay.

This type of a circuit has been usefully applied to record the drinking behavior of rats. The rat is usually placed in a chamber with a grid floor that serves as one electrode of the circuit; the drinking tube serves as the other. For best results, all of the grid bars are connected together such that contact between any one grid or combination of grids and the drinking tube serves to operate this "drinkometer" circuit. The use of such a circuit would normally preclude concurrent application of electric footshock since the grid bar arrangement would tend to short out the applied voltage. Thus special arrangements must be made in order to insure effective footshock and to allow for sensitive operation of the drinkometer circuit.

The circuit shown in Fig. 1 was used successfully to record the drinking behavior of rats during administration

of a relatively weak footshock employed as a conditioned stimulus.¹ A diode matrix allows all grid bars to be connected together to form an electrode of the drinkometer, while keeping them isolated so as not to short the voltage impressed across the grids during footshock. This is accomplished by attaching the cathode side of a diode to each of the grid bars and connecting the anodes of all diodes to the positive side of the drinkometer. This arrangement provides a high resistance path to the flow of electrons through the diode matrix from one bar to another and effectively isolates each bar on the cathode side of the matrix. A low resistance path is provided between each of the grid bars and the positive

side of the drinkometer. The rat completes a path between the positive and negative sides of the drinkometer by resting on any or all grid bars and touching the drinking tube. The drinkometer represented in Fig. 1 is a Lehigh Valley Electronics Model 1520 contact relay.

The footshock is generated with a matched-impedance shock circuit (Campbell & Teghtsoonian, 1958). The output of a variable transformer is full-wave rectified and fed through a 150 K-ohm resistor (R1) to a scrambling device. Each of the output lines of the scrambler is attached to a grid bar on the cathode side of the diode matrix and, hence, the bars of opposite polarity in the grid constantly change their respective positions. The variable resistor (R2) is added to the circuit in series with the rat in order to partially compensate for an increase in the current flowing through the rat into the drinkometer which may be provided by the addition of footshock. The size of R2 is subject only to the restriction that

Fig. 1. A circuit to allow an electronic drinkometer to operate during footshock. Details are provided in the text.

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Fig. 2. A simplified version of the circuit presented in Fig. 1 in which the rat is represented as two resistors. R1 is the portion of the rat between the grid and the drinking tube and R2 is the portion of the rat across the two bars of opposite polarity in the grid floor.

the total resistance across the electrodes of the drinkometer should not exceed 10 megohms, according to the manufacturer's specifications.

A simplified version of this circuit is presented in Fig. 2. For convenience, only the two grid bars of opposite footshock polarity (across which the rat stands) and the drinkometer are considered. The animal is assumed to consist of two resistors: R2, which corresponds to the portion of the body across the grid bars, and R1, the portion of the body from the grids through the tongue to the drinking tube. The footshock voltage is represented by a battery across the two bars, and the diode (D1) (not

represented in Fig. 1) is part of the actual drinkometer circuit provided by the manufacturer. In addition to providing current flow through R2, the battery is in a series-aiding arrangement with respect to the drinkometer voltage, R1, D1, and D3. This implies that the presence of the battery (i.e., footshock) will contribute to the current flowing into the drinkometer and hence through R1 (i.e., the rat's tongue). The input impedance of the drinkometer is approximately 15 megohms, however, and since under normal circumstances this is substantially greater than R2, the majority of the additional current provided by the battery will be diverted through R2 rather than through the drinkometer. Thus the battery voltage needed to appreciably enhance the current flow through R1 is higher than would be needed to produce a footshock adequate to disrupt drinking behavior altogether. If the battery polarity were reversed, then no current would be added through the drinkometer and R1, since the negative pole of the battery and the junction of R1 and R2 would then be at the same potential and D3 would be reversed biased. Successive reversals of battery polarity, as would occur with scrambled footshock, will have no greater effect on current flow through R1 than the case depicted in Fig. 2.

The polarity of the drinkometer with respect to the diode matrix is important in the operation of this circuit. If the polarity is opposite that in Fig. 2, then current will not flow

from the negative to the positive sides of the drinkometer, due to the opposition provided by the diode matrix, irrespective of battery polarity.

Alternating current may be used as the source of the footshock since the diode matrix will serve to half-wave rectify the current flowing through the drinkometer and R1 from the footshock voltage. Such half-wave rectification allows the average current flow through R1, provided by the footshock, to be less than full-wave rectified footshock.

Contact relay circuits other than the Lehigh Valley Model 1520 may be used in conjunction with the present circuit, but care should be taken, especially in the case of devices employing transistors, to insure that any additional voltage drop across components of the circuit provided by the footshock voltage does not exceed recommended ratings.

REFERENCE

- CAMPBELL, B. A. & TEGHTSOONIAN, R. Electrical and behavioral effects of different types of shock stimuli on the rat. *Journal of Comparative & Physiological Psychology*, 1958, 51, 185-192.

NOTES

1. All diodes represented in Fig. 1 are Mallory Type M2.5 A rated at 1,000 V (peak inverse voltage) and 2.5 A (forward current). Under normal circumstances, however, successful operation of this circuit may be achieved employing diodes with substantially lower ratings. R1 is a 150 K-ohm .5-W carbon resistor and R2 is a 5-megohm Ohmite potentiometer, No. CMU5052 rated at 2 W.