JOURNAL OF THE EXPERIMENTAL ANALYSIS OF BEHAVIOR VOLUME 5, NUMBER 3 JULY, 1962

A RELAY SEQUENCING DEVICE FOR SCRAMBLING GRID SHOCK[1]

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One of the most convenient ways to administer electrical shock to a freely moving organism is through a grid floor. When doing so, however, the polarity of the grid bars must be changed continuously so that *S* cannot avoid shock by straddling bars of similar polarity.

Conventional grid-shock scramblers are usually motor-driven, and they have components which are expensive and subject to relatively rapid wear when driven at high speeds. The circuit in Fig. 1 describes a grid-shock scrambler which operates at high speed and yet is subject to little wear. Since the device consists of only four relays, the materials should cost less than $50. (For example, Union Switch and Signal Type UN334607, 6PDT relays cost $6.75 apiece.)[2] The above,

[1]This device was developed and tested as a part of a program of research supported by Grant M-2433 from the National Institute of Mental Health.

[2]These, as well as many other suitable kinds of relays, are available from the Universal Relay Corporation, 42 White Street, New York 13, N. Y.

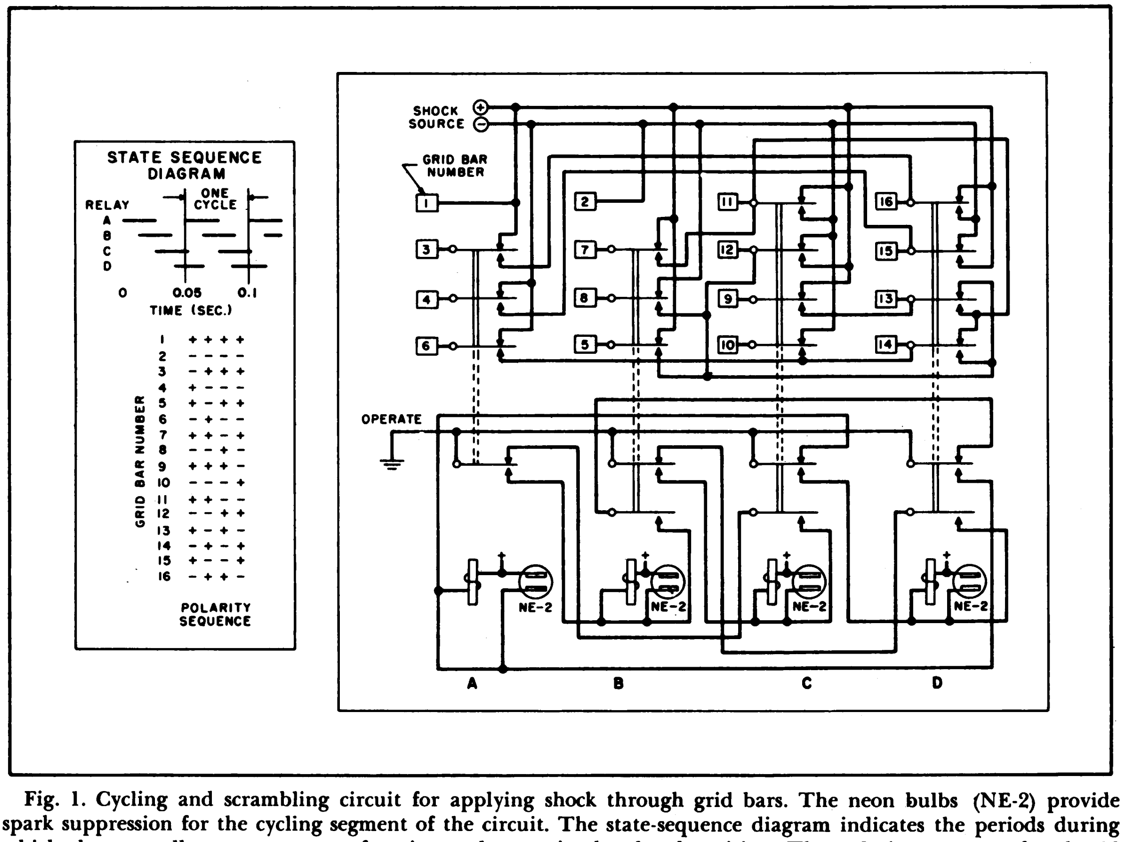

Fig. 1. Cycling and scrambling circuit for applying shock through grid bars. The neon bulbs (NE-2) provide spark suppression for the cycling segment of the circuit. The state-sequence diagram indicates the periods during which the normally open contacts of a given relay are in the closed position. The polarity sequence for the 16 grid bars is shown for one complete cycle.

as well as four other makes of relays, have been tested; and, regardless of manufacture, the device cycled more than 5 times per sec. Moreover, cycling always began less than 50 msec after the application of ground and terminated with the removal of ground. Because of the high rate and short latency of cycling, the scrambler need operate only when shock is actually being administered to the *S*; for this reason, its life expectancy is long.

To estimate the life span of the device, a unit, constructed with the relays described above, was allowed to run on a duty cycle of 10 sec on and 1 sec off, until a breakdown occurred. With these relays, the device cycled 20 times per sec; and when the unit was operating, the capacitance between the poles of the shock input was less than 0.002 mfd. No changes in these characteristics were observed during the initial 34 hr of its operation. Breakdown occurred in the 35 hr, because of the failure of one contact on one relay. It appears, therefore, that even when using relatively inexpensive relays, the device can deliver at least 0.1 million shocks of 1-sec duration each.

Two electrically independent segments are used in this circuit: a cycling segment, shown in the bottom half of Fig. 1; and a scrambling segment, shown in the top half of Fig. 1. Cycling of the relays is induced by applying ground at the point marked "operate." Current passes through the poles of Relay C to operate and hold Relay A. When A makes, current passes through its poles to operate Relay B. When B makes, it passes current to operate C and simultaneously locks. When Relay C makes, it breaks ground to A, operates D, and locks. When D makes, it breaks ground to B, operates A, and locks. When A makes, it breaks ground to C, operates B, and locks; and this cycle continues for as long as ground is applied.

A state-type sequence diagram for the circuit is at the left in Fig. 1. In this diagram, the solid bars indicate the periods during which the normally open contacts of a given relay are in the closed position. The duration of the cycle reflects the operating characteristics of the particular relays used, because the basic unit of the cycle is the lag between the moment a relay is energized and the moment the center pole connects with the normally open contact. For this reason, all four relays should be of similar manufacture and should contain the same number of contacts (whether or not all of the contacts are used).

The scrambling unit of the circuit is based upon the notion that certain sequences of polarity can be derived by combining segments of other sequences. Thus, for example, the sequence of polarity for grid bar No. 16 is determined solely by the action of Relay D. Grid bar No. 16 is negative when the normally open contacts on Relay D are closed, and it is positive when they are released. On the other hand, the polarity of grid bar No. 3 is determined by the states of both Relay A and Relay D; it is positive when Relay A is released, and it is the same as grid bar No. 16 when Relay A is in the make position. The state-type sequence diagram shows that during the illustrated cycle, Relay D is in the make position only during the first segment of the total period that Relay A is in the make position. Thus, for example, during the cycle marked off in the state-type sequence diagram, the sequence of polarity on grid bar No. 3 is $-+++$, even though no one relay in the circuit actually passes through this sequence. The sequence of polarities on all 16 grid bars is shown beneath the state-type sequence diagram. The sequences of polarity are such that no pair of grid bars has similar polarity throughout the entire cycle. The net effect is that if the *S* contacts any pair of the 16 grid bars, shock is delivered at least once per cycle and, hence, at least 20 times per sec.[3]

[3]Occasionally, it is desirable to use more than 16 grid bars in a given experimental chamber. When doing so, effective scrambling can still be maintained if each additional bar is wired in parallel to that bar which is 16 steps removed.