A RELIABLE SILENT ELECTRONIC SHOCK SCRAMBLER[1]

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This scrambler (Fig. 1) is simple, silent, not subject to mechanical wear, and reasonable in price (about $50 for a 10-stage scrambler without power supplies). Construction time is about 8 hr. The first one has logged over 1500 hr without failure. The scrambler uses stable radioactive-additive neon bulbs (Signalite Inc., Neptune, N.J., @ 50¢), in a ring-counter configuration (any number of stages may be used). Each pulse from a driver stage advances the "count," or active lamp, by one step in the ring-counter chain. This lamp illuminates its associated photoconductive resistor (Opto-Electronics, 660 National Avenue, Mountain View, Calif., @ $3.10 in lots of 10, or $1.95 in lots of 100), which has a dark resistance greater than 5.0 M and a light resistance of about 5 K with short rise and fall times. These resistance values are, respectively, more than 10 times and less than one-tenth the value of the 100 K shock current limiting resistors. The physical layout should be such that λ_1 is illuminated by only N_1, λ_2 by only N_2, *etc.*

The principle of operation of the ring-counter is as follows. When power is turned on, the light with the lowest firing voltage will come on. Current flows in the 100 K resistor, dropping the voltage at the base of this resistor below minimum firing voltage for the other bulbs.

The current in the 47 K resistor associated with the ignited light causes further voltage drop. The associated coupling capacitor charges so that its right-hand plate is more positive than its left-hand plate, because there is essentially no voltage drop in the 47 K resistor at the right-hand plate as its neon bulb is not conducting.

Now, deliver a negative pulse, either from the driver circuit shown or from some other source (momentarily short point A to ground). This will turn out the light that was on. The next light to the right will come on when the negative pulse is over because it is the only lamp that has an extra positive charge on the coupling capacitor. The diodes prevent discharge of the capacitor during the negative pulse, directing the charge to the proper place.

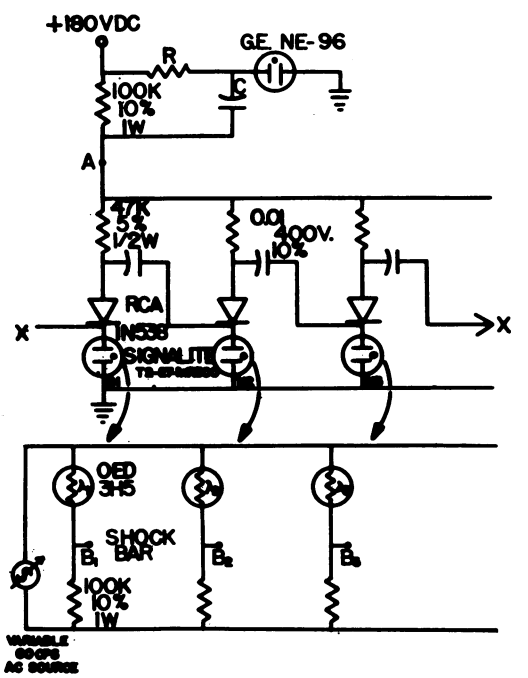

Fig. 1. Silent scrambler. Top portion of diagram is neon bulb oscillator-driver circuit. Middle portion is ring counter. Bottom portion is shock bar driver circuit which provides single outputs, one for each bar to be electrified (and one for the walls of maze if they are to be "hot"). The shock source should not exceed the 300v maximum rating of the photoconductors.

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The driver circuit is a standard neon relaxation oscillator using the entire ring-counter circuit as a composite discharge resistor. When capacitor C charges to the firing voltage of the NE-96, the NE-96 fires, driving point A in a negative direction. The RC of the driver circuit controls the rate of firing.[2]

RC Rate. With an R of 1.0 Meg, C of 0.15 mfd, the time per step was 275 msec. With values of 500 K and 0.15 mfd, the time was 160 msec; 330 K and 0.15 mfd, 110 msec; 330 K and 0.033 mfd, 35 msec; 330 K and 0.01 mfd, 12 msec.

Rise-Fall Time. The rise time of the 60 cycle ac shock output voltage is one to two cycles. The fall time is about one-tenth cycle. Therefore, the minimum time per step should be two cycles (33 msec). With an R of 330 K, C should be .033 mfd or greater.

Occasional T2-27-1WR500 bulbs do not function properly. It is a good idea to get a few extras. It is also a good idea to select out of a set of 15 or 20 the 10 bulbs with best matched firing voltages (smallest range). Use a variable-voltage dc supply, a 150 K 1 w series resistor, and a VTVM to make this test.

For input voltages up to 135 v RMS ac, with test loads of 100 K and 220 K, shock current at a given input voltage was constant within 10%. The shock current was about 1 ma peak-to-peak for 135 v RMS ac input. This level is the largest tried, and is adequate for effective use. (The maximum RMS input voltage for the photocells is *300.*)

The mean output voltage between any pair of output terminals was within 10% of the grand mean over all pairs. The voltage between any pair was within the same tolerance (a) with other outputs shorted to either member of the pair, and (b) with other outputs connected via a 100 K resistor to either member of the pair. In other words, bar-to-bar shorts and leakages do not have much effect.

For best results, adjacent scrambler elements should be wired to maximally separated bars. Table 1 shows appropriate connections for a 10-unit scrambler.

Table 1

Scrambler Output Terminal	*Bars to be Connected*
1	1, 11, 21, —
2	4, 14, 24, —
3	7, 17, 27, —
4	10, 20, 30, —
5	3, 13, 23, —
6	6, 16, 26, —
7	9, 19, 29, —
8	2, 12, 22, —
9	5, 15, 25, —
10	8, 18, 28, —

In this manner there will be maximum space between components with resistance lower than dark-state at the same time. A similar arrangement should be made if a different number of scrambler elements is used.

In other applications which require silent commutating or stepping, light-sensitive resistors can be used in series with relays, as inputs to logic circuits, transistor audio oscillators, stimulus light drivers, *etc.* The ring-counter circuit may be driven by any periodic or aperiodic event which has been converted to a large negative pulse, at rates as high as 60 per sec or more.

[2]If the NE-96 cannot be left exposed to some ambient light and instability occurs, it can be lit with a NE-2 in series with a 220 K 1 w resistor from the 115v ac line.