NOTES

Electronic windows: A follow-up note

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We have previously described an electronic window circuit used to define target zones in motor coordination research (Pettijohn, 1975). In these experiments, a monkey moves its arm or head into a target zone whose width is electronically determined; the position of arm or head is described by a voltage. This circuit uses voltage comparators to define the window edges. The edge detector circuit is shown in Figure 1. $+V_E$ are the voltages which define the edges; window width is $2V_E$.

On occasions in which the monkey's head or arm enters a window very slowly or dwells near an edge, we have noticed that a comparator will sometimes exhibit erratic behavior, resulting in false triggering or oscillations. In these cases, the voltage that measures arm or head position is slowly varying near the comparator's threshold voltage (V_E). All comparators have some uncertainty in recognizing when $V_{IN} = V_E$; in the 301A, this may be several millivolts.

A comparator is basically a very high gain differential amplifier. When the input voltage dwells near the threshold voltage level, the comparator will act like a very high gain linear amplifier, and may be unstable (Note 1; Note 2). If the comparator is a 301- or 741-type amplifier with 30 pF internal or external compensation, the slow output transition ($\sim 10 \mu s$) in conjunction with the slowly moving input can cause the output to latch at an intermediate voltage level.

These problems can be eliminated by the circuit of Figure 2. A small amount of positive feedback, set by the 10 M Ω and 10 k Ω resistors to the positive or noninverting input, creates a small amount of hysteresis in the comparator switching point voltage, removing the threshold uncertainty and eliminating the instability. For these component values, the two switching points differ by about 5 mV. This difference in switching points causes a negligible angular error in our setup (less than $\frac{1}{2}$ deg).

Intermediate voltage latchup is eliminated by increasing output switching speed. If the compensation pins (Pins 1 and 8 on the 301) are left open, the positive feedback will drive the amplifier into the high or low state at maximum speed, near 150 nsec. If this

Figure 1. Basic window edge detector.

Figure 2. 301A comparator connection for slowly varying inputs.

Figure 3. 311 comparator connection for slowly varying inputs and TTL compatibility.

method of increasing speed is not possible, a 311 comparator is suggested. Although it is more expensive than standard 301 or 741 operational amplifiers, it can be operated from logic power supplies, it is relatively fast (200 nsec), has a low threshold uncertainty (400 μV), and is easily interfaced to logic. Figure 3 shows a 311 connected for TTL compatibility, with 5 mV of hysteresis to compensate for slowly varying input signals.

REFERENCE NOTES

1. Linear and Interface Circuits Applications. Texas Instruments, Inc., Dallas, Texas, 1974, Chapter 3.
2. Precision IC Comparator Runs from 5V Logic Supply. National Semiconductor Applications Note AN-41, October, 1970.

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An inexpensive solid state unit for free-operant avoidance training

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Sidman (1953) described the use of an avoidance training technique in which subjects could delay an aversive stimulus for a prescribed interval by producing an appropriate response. This procedure has been successfully employed in many conditioning studies, including those involving human subjects (Ader & Tatum, 1961). A valuable synopsis is provided in Sidman (1966).

There are many instruments available on the market which have provision for a Sidman, or free-operant, avoidance schedule. However, the limited requirements of a particular study, or economic considerations might warrant the construction of this simple unit in which standard integrated circuit logic modules are used as the control elements to provide a versatile means of programming an avoidance schedule. A small audio-warning device is suggested as the aversive stimulus.

The circuit diagram is given in Figure 1, and a parts list in Table 1.¹ The actual integrated circuit modules used by the author are indicated, but any other compatible packages will suffice. The device was programmed for independent shock-shock and response-

Figure 1. Low-cost circuit for programming a variable free-operant avoidance schedule.

Table 1

List of Components for Free-Operant Avoidance Training Unit

A.W.D.	RS 24-V audio-warning device
C1	1000- μ F 16-V electrolytic capacitor
C2	150- μ F 25-V electrolytic capacitor
C3	.01- μ F ceramic capacitor
C4	50- μ F 25-V electrolytic capacitor
C5, C6	.1- μ F ceramic capacitors
D1, D2	IN4148 diodes
IC1	Texas SN74122N retriggerable monostable
IC2	RS Timer A (NE555) integrated circuit timer
IC3	Texas SN74121N monostable
R1, R2, R3, R7	33 K Ω preset resistors (miniature open-track)
R4, R5, R6	100 K Ω preset resistors
R8, R10, R11	2.2 K Ω 5% resistors
R9	1 K Ω 5% resistor
R12, R13, R14	4.7 K Ω 5% resistors
RL1	RS 6-V 70- Ω 2-pole relay
SW1, SW2	1-pole 12-way midget wafer switches
T1	BC109 transistor

shock intervals of 5 sec, 10 sec, and 20 sec. Shock-shock intervals are selected by SW2: each is set by adjusting the appropriate trimming potentiometer R4, R5, or R6 while measuring output pulse duration at Pin 3 of IC2 on an oscilloscope or digital timer. Similarly, response-shock intervals are selected by SW1 and are set by adjusting trimming potentiometers R1-R3, measuring the pulse duration at Pin 8 of IC1. The range can be easily extended by adding more trimming potentiometers to SW1 and SW2, and, if necessary, increasing the Timing Capacitors C1 and C2. Potentiometer R7 varies the shock duration from approximately 250 msec to 1,500 msec. If required, an additional potentiometer can be included in the output and calibrated for various stimulus intensities.

The +5-V power supply should be well stabilized and smoothed. Many suitable logic supply cards are now marketed. However, a 4.5-V to 6-V cell will also drive the unit provided that a check is kept on the voltage under load. The +30-V supply can be obtained directly from a transformer and full-wave rectifier, no smoothing is necessary.

Logic modules of this type can be falsely triggered by interference spikes as they operate with very fast pulse edges. The circuit should therefore be reasonably compact and mounted inside a metal case which is connected to the earth line. The loads to the response input might also need to be screened. Capacitors C5 and C6 have been included to guard against transients on the power-supply line.

The two-pole relay RL1 can be used to gate a variety of aversive stimuli and, in addition, to switch a reinforcement marker pulse for an event or cumulative recorder. The author found that a very simple and inexpensive audio-warning device marketed by RS Components Ltd.² provides a convenient and effective aversive stimulus. This device produces a penetrating and unpleasant 2,600-Hz modulated tone. When