INSTRUMENTATION & TECHNIQUES

A simple and inexpensive computer-compatible shock circuit

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A circuit for computer control of shock stimulation that uses an optically isolated triac is described.

Low-current ac or dc shock is often used in escape or avoidance learning paradigms or as a discriminative stimulus to which a subject must respond. Shock apparatus are often expensive and are not always easily interfaced with computer or transistor-transistor logic (TTL) circuitry. This paper describes a simple, low-cost (less than \$10), optically isolated circuit capable of controlling low-current, high-voltage shock with TTL-interfaced computer output.

In this circuit, shown in Figure 1, the presentation of shock to the subject is controlled by an integrated circuit, U1, which is in series with the subject. U1 is an optically isolated triac driver of the MOC3000 family, for example, MOC 3020, and can be regulated by a 7406 inverter-driver receiving logic signals from any computer system operating at 5 V dc. For example, any 6502-based microcontroller system, such as any of the Apple II series, KIM, SYM, and the Commodore PET, can be interfaced directly with this circuit. The light source of U1 is an infrared-emitting diode (IRED) with the anode (Pin 1) connected to 5 V dc and the cathode (Pin 2) connected to the output driver of the 7406. A controller logic-high signal to the 7406 activates the IRED. The IRED opens the trigger gate of the triac and allows ac (or dc) current to flow through the triac. The triac remains open until the ac cycle returns to zero voltage and then stops conducting unless the trigger gate is still activated by the IRED. Thus, the logic signal must remain high to keep the triac gate open until shock to the subject is to be terminated. However, as long as the IRED is activated, ac currents ranging from less than 0.01 mA up to 50 mA can be maintained indefinitely through the triac (Pins 4 and 6). R2 is a current-limiting resistor that can be selected to function as either fixed or matched impedance (Campbell & Masterson, 1969), depending upon the needs of the experimenter. R3 is a variable resistor with which the experimenter can adjust the level of shock to the subject, if that is desired.

The additional circuitry seen in Figure 1 is required to prevent transient spiking from reaching the subject. When

the IRED is in an "off" state, the triac tends to leak voltage spikes as the ac voltage at the terminals crosses zero. These spikes are brief enough that they do not register on panel or volt-ohm meters, but they can be seen with an oscilloscope and can be detected by the subject. To overcome this problem, two circuits parallel to the one containing U1 and the subject are used. The first involves U2, another MOC3000 device of the same design as U1, that is activated to the "on" state by a controller signal to another 7406 when the U1 circuit containing the subject is turned off. This circuit functions essentially as a bypass or a short circuit around the subject. If the number of computer output ports is limited, a pulse from a single port to a TTL flip-flop (e.g., 7476) set to toggle can be used to change the states of U1 and U2. The two outputs of the flip-flop are always opposite states, and if one output is connected to the 7406 driver for U1 and the other output signals the 7406 driver for U2, then one optically isolated triac is always on when the other is off. The second parallel circuit consists of an RC snubber circuit. If R4 is approximately 47Ω and C1 equals $0.047\mu\text{F}$, no alteration of the ac voltage cycle can be seen on an oscilloscope. However, the values of R4 and particularly C1 must be kept small, since larger values will begin to have undesirable effects on dv/dt of the ac cycle.

Multiple U1 circuits to the same or different subjects can be operated simultaneously and independently without interactive effects, thus making even scrambled shock (Seiden, Thieme, & Anderson, 1964) computer controllable. For example, scrambled shock can be controlled by attaching two U1 devices, one connected to each side of the shock source, to the same grid bar. When shock stimulation is desired, U2 is turned off and the two U1 devices are initially set up in opposite states; that is, one triac is in the "on" state, and the other is in the "off" state. The states of both U1 devices are then alternated simultaneously at the desired rate. Since one of the two U1 devices is always in the "on" state, the grid bar is always connected to one side or the other of the shock source when the subject is in contact with it. If the number of computer output ports is limited, then TTL support equipment can be used to increase the number of U1 devices driven.

In a typical application of this circuit in our laboratory,

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Figure 1. Computer-controllable shock circuit.

several hundred rats have been trained with a shock-avoidance paradigm and equipment previously described (Delay, 1982). Current levels employed in training have ranged between 0.3–1.0 mA (RMS) with a 350-V ac fixed impedance source. Oscilloscope monitoring of over 100 training sessions has not shown any circuit malfunctions.

Several of the MOC3000 family (MOC3009–MOC3021 or their equivalents) can be used as U1 and U2 in this circuit. The specific component will depend upon the ac voltage and/or the IRED trigger current desired. MOC3009, 3010, and 3011 devices are rated up to a maximum of 250 V ac, and MOC3020 and 3021 are rated at 400 V ac. The minimum IRED trigger current required to latch the triac output open, which can be set with the appropriate resistance value for R1, is typically 15 mA for MOC3009 and 3020, 8 mA for the MOC3010 and 3021, and 5 mA for the MOC3011. However, the IREDs of all of these devices have maximum ratings of 50 mA and appear to function more efficiently with current values between 30 and 50 mA. All of these devices also come in standard 6-pin DIP form and have identical pin configurations. We have also found that optically coupled

SCRs such as the H11Cx series can easily handle dc shock and, when placed in opposite direction to each other, perform, with ac, in a manner similar to that in which the triacs described above perform. This arrangement, however, requires more circuitry, and these devices are usually slightly more expensive than the optocoupled triac.

As a final note, this circuit also has a few advantages over a circuit using a TTL-controlled relay driver and relay to control shock stimulation. While maintaining the ability to control either ac or dc shock, it does not require the current levels often needed to drive and operate both a relay driver and a relay coil. With many systems, it can use the same 5-V dc power supply as that supplying the computer; that is, it does not need another external power source to operate a 12- or 24-V dc relay in use in many laboratories. Furthermore, this circuit does not generate the troublesome voltage transients often associated with the expansion and collapse of inductive fields produced by the coil of a relay as it is opened and closed. This then eliminates the necessity of dealing with transient signals in noise-susceptible lines and peripheral sensing equipment.

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