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BRIEF COMMUNICATION

Application of a Computer-Controlled Infrared Beam Device to Behavioral Research

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WADA, H., T. HOSOKAWA AND K. SAITO. *Application of a computer-controlled infrared beam device to behavioral research.* PHARMACOL BIOCHEM BEHAV 24(6) 1789–1792, 1986.—An experimental control system was designed to evaluate the effects of toxic substances. This system consisted of a personal computer (Apple II), shuttle boxes, and their controller. The shuttle box (33×20×53 cm) was divided into two compartments of equal size with a hurdle (8 cm). An infrared beam device was set up 8 cm from each side of the hurdle and 5 cm above the floor to detect the occupied compartment. Signals from detectors were put into the Apple II through a peripheral interface adapter unit. Since the control program was written in assembly language, which could operate at high speed, it was possible to conduct experiments using four shuttle boxes simultaneously. During the execution of the experiments, the timer unit generated pulses 100 times/sec. Every pulse was counted and used to measure a response latency at intervals of 10 msec. The application of a computer-controlled infrared beam device made it possible to detect the location and operant responses of a subject mechanically from moment to moment and to construct an extremely flexible experimental control system.

Infrared beam device   Personal computer   Shuttle box

SKINNER boxes and shuttle boxes have been used in experimental psychology and behavioral pharmacology because of their utility in the analysis of behavior and drug screening. In recent years, environmental pollution caused by industrial wastes and toxic substances has become an extremely serious world-wide problem. However, toxicological research on these substances is progressing only slowly and it is absolutely necessary to develop new test batteries for the detection and evaluation of their toxicity, and for predicting the toxicity of various substances.

Behavioral toxicology has assumed a role of increasing importance in the evaluation of toxic substances. Experimental techniques for analysis of behavior based on operant learning are being used to establish methods which can be adapted to the special demands of evaluation of the after-effects of toxic substances on the central nervous system (CNS) [1]. However, ready-made experimental apparatuses are very expensive. Logic circuits and a minicomputer have been used for automatic control of these apparatuses, but logic circuits are lacking in flexibility and maintaining a minicomputer presents economic difficulties.

Recently, highly efficient, low-cost personal computers have come into wide use and have been introduced to control experiments, replacing logic circuits and minicomputers. The authors have been able to design an infrared beam device controlled by a personal computer which could be applied to behavioral research. This infrared beam device made it possible to detect the location and operant responses of a subject automatically and mechanically without direct human observation.

The experimental control system consisted of an Apple II personal computer, its peripheral devices (disk drives, a display and a printer), four shuttle boxes (shock avoidance apparatuses) and a peripheral interface adapter (PIA) unit which connected the Apple II with the shuttle boxes (Fig. 1). Communication between the Apple II and the shuttle boxes was performed through the PIA unit and the buffer unit. The circuits of the PIA unit included two PIA MC6821 ICs (Fig.

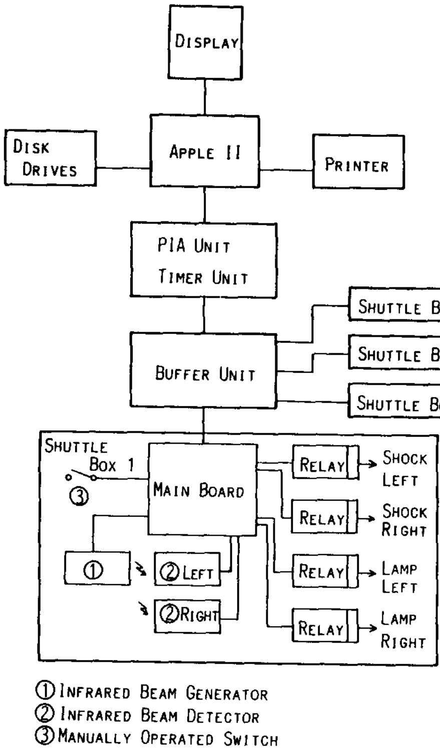

FIG. 1. Outline of the experimental control system.

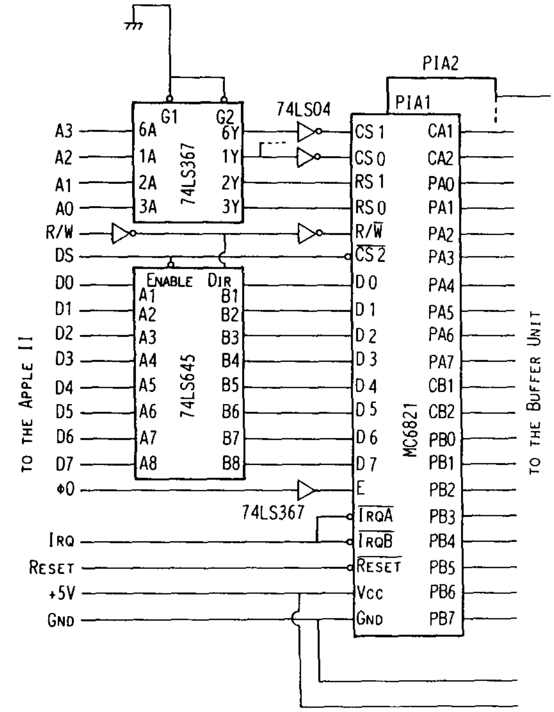

FIG. 2. Circuit diagram of the PIA unit.

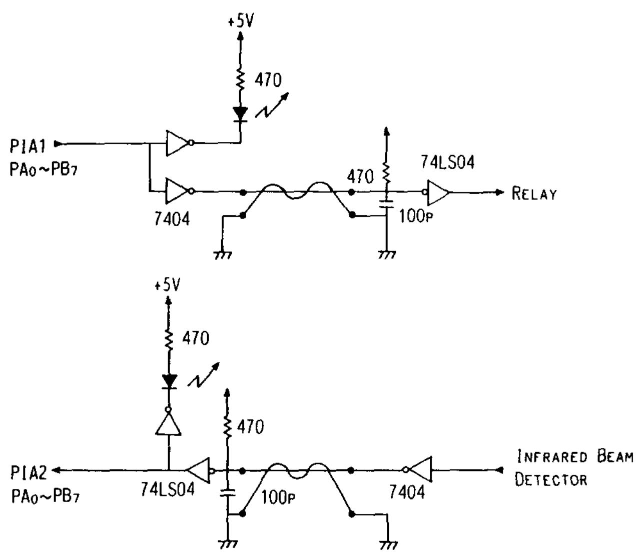

FIG. 3. Circuit diagram of the buffer unit. The upper circuit was used for output from the Apple II, and the lower circuit was used for input to the Apple II. Each circuit consisted of sixteen lines.

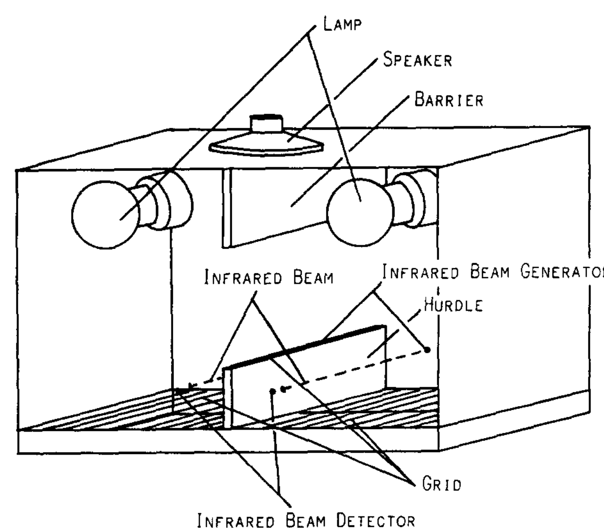

FIG. 4. The shuttle box.

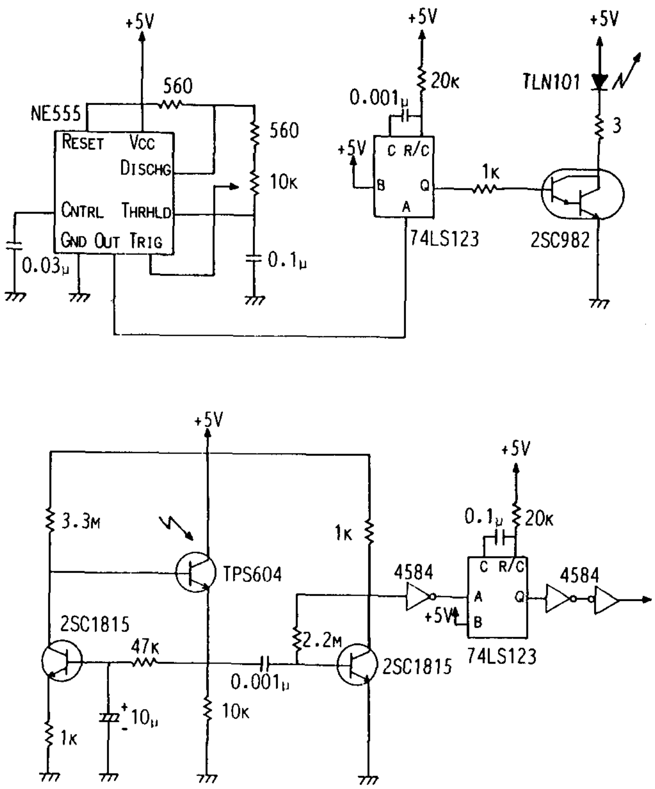

FIG. 5. Circuit diagram of the infrared beam generator (upper) and detector (lower).

2) and an MSM5592 timer IC from Oki Electric Co. The timer IC could provide periodical pulses for an interrupt request (IRQ) line going to the 6502 microprocessor. Each IRQ was added to the computer memory and the number of memories was counted to measure a response latency (RL) of subjects. The use of a dip switch allowed the pulse frequency to be flexible in the range between 1 Hz and 100 kHz. Since the dip switch was set at 100 Hz in the present device, an IRQ occurred every 10 msec. The PIA unit and timer unit were plugged into peripheral input/output (I/O) slot No. 4 of the Apple II. With the Apple II it is easy to add external interface circuitry. The signals between the Apple II and each shuttle box were transmitted through four twist-pair cables consisting of twenty conductors. The buffer unit (Fig. 3) was set for clear communication. This circuit could provide explicit signals, even if the distance was 5 m. Sixteen light emitting diodes (LEDs) were set on the buffer unit and indicated the activity taking place in the connector cables. It enabled the experimenters to monitor the I/O signals.

These cables connected to the main board on the shuttle boxes. The shuttle box consisted of gray acrylic plastics except for the front panel, and the dimensions were 33 cm height, 20 cm width, and 53 cm length (Fig. 4). The front panel was made of clear acrylic plastics to enable the experimenter to observe the subject at all times. This shuttle box was divided into two compartments of equal size with a barrier extending 10 cm from the ceiling and with a hurdle 8 cm high on the floor. Both partitions were made of gray acrylic plastics. The floor consisted of 5 mm diameter stainless steel grids spaced 2 cm apart, through which scrambled electrical shock was applied. Furthermore, three grids of 3 mm diameter were mounted on the hurdle to prevent a subject from staying on the hurdle during the onset of electrical shock. A 20 W lamp was located in the ceiling of each compartment and served as a warning stimulus. A speaker 8 cm in diameter was placed outside and above the center of the ceiling and white noise was presented through it as a masking noise.

An infrared beam generator and detector was mounted 8 cm from each side of the hurdle and 5 cm above the grid floor. The infrared beam generator provided a high power beam with pulse-drive circuits, in order to get a clear signal from the infrared LED in the distance (Fig. 5). Higher frequency pulses were made by an NE555 and a 74LS123, and the 74LS123 encoded this signal. These signals were put into the Apple II from moment to moment. The Apple II could detect the location and operant responses of a subject by an interruption of the infrared beam. Once the interruption occurred, that signal was available until the next interruption occurred, because the computer memory registered it. Accordingly, the Apple II presented a warning stimulus and electrical shock to the compartment occupied by the subject and measured RLs at intervals of 10 msec from the onset of the warning stimulus to the interruption of the infrared beam in the other compartment.

Since the experimental control program was written in 6502 assembly language, it enabled extremely high speed execution. No problem was caused when four subjects responded at the same time. Inter-trial interval, warning-shock interval, maximum shock duration, and the number of training trials were experimental variables on the control program. The experimenter could specify them by changing program parameters and design various experimental conditions.

A manually operated switch was used for indicating the beginning of an experimental session to the Apple II.

A shuttle box, unlike a one-way avoidance apparatus, can be automated easily, and a computer-controlled infrared beam device can detect the location and operant responses of a subject mechanically without human effort. Furthermore, the shock avoidance behavior in a shuttle box is easier for subjects (rats and mice) to learn than the pole-jump avoidance and Sidman avoidance [2,3]. Almost all subjects can acquire shock avoidance behavior in the shuttle box after 5–10 days training and show a highly efficient avoidance and a stable performance with little individual difference (mean±S.D. = 92.5±12.7%; n=167). Therefore the shuttle box shock avoidance behavior provides us with precise indices useful in research of behavior, drug screening, and evaluation of toxicity.

The application of a computer-controlled infrared beam device makes it possible to detect the location and operant responses of a subject mechanically from moment to moment and to design an experimental control system with simple circuits, and also allows the construction of a purposive and flexible experiment, since the experimenter can set up various conditions by changing experimental variables. Adding the PIA unit, it is possible to equip various experimental apparatuses (e.g., shuttle box, maze, and open field) with more infrared beam devices. Consequently, the specific movement and location of a subject could be detected.

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