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Inexpensive solid-state peck key for the operant conditioning of small birds

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Inexpensive piezo ceramic disks make ideal keypeck switches for use in the operant conditioning of passerine birds. The advantage of solid-state keys over conventional microswitches is that their sensitivity may be adjusted to detect extremely gentle pecks. The advantage of this piezoelectric system over optical detection is the lack of problems due to misalignment and contamination. Instructions are provided for constructing both the peck key and the accompanying interface circuitry.

Visual choice methodology has received a recent boost from the use of infrared optoelectronics that can report the position of a choice made by an animal (or human) subject pointing to a stimulus displayed on a video screen (Blough, 1986; Pisacreta & Rilling, 1987). In comparison with comparative visual methodology, the needs and methods used in animal psychoacoustics are simpler. Operant research on avian auditory perception requires the subject to make one of two choices, either by hopping to the correct perch (e.g., Shy, McGregor, & Krebs, 1986) or by poking the correct button (e.g., Park, Okanoya, & Dooling, 1985).

I have employed a variety of mechanical and optical methods of detecting the response and movement of small birds in the laboratory. For detecting perch hops, an infrared emitter-detector pair is preferable to a microswitch because it eliminates the need for perch movement, which many birds dislike. The optics do need to be shielded from random bird droppings. A problem with microswitches used in keypecking (Park et al., 1985) is that the switch lever must travel a certain distance and direction to activate the switch. Small birds have difficulty depressing the switch far enough when they peck; thus many pecks go undetected (K. Okanoya, personal communication, January 1986; personal observation). Optical "peck" detection systems have several advantages over microswitches. Peck force is of no concern with optical systems that detect beam interruption and not actual contact.

Although infrared detection systems are ideal for many applications, there are certain advantages of piezo ceramic transducers as peck detectors. Alignment of invisible beams and interference from ambient light sources pose no problem with a piezo contact system. Subjects that work for messy rewards, such as diced insects or fruit, will eventually manage to get some opaque goo on the optics and bring their automated experimental session to a halt. (Blough, 1986, mentioned the importance of wiping the optics clean between sessions.) Piezo ceramic peck detectors are impervious to such abuse. For psychoacoustic work, an LED can be attached to the edge of the transducer for a pecking target. For systems in which visual images are presented, the key can be a small square of transparent plastic that lies in front of the stimulus. In all but visual CRT presentations, piezo ceramic transducers can be concealed behind the presentation panel out of the way. Piezo contact keys, unlike optical detectors, still require physical contact with the key and thus can measure contact force if interfaced with an analog/digital (A/D) converter instead of a single voltage comparator. In this latter mode, I have used a piezo ceramic transducer disk attached to a hummingbird's perch to monitor sleep-wake cycles. The transducer is sensitive enough to allow discrimination between the small muscle movements, breathing rates, and heart rates of resting and sleeping hummingbirds.

Piezo ceramic transducer disks have been developed commercially for use as flat speakers and low-current electronic beepers. They also have been used in physiological measurement of blood pressure and for detection of physical shock waves. Piezo ceramic transducers appear as 2-4 cm diameter brass disks with white, ceramic, piezoelectric material fused to one side. A wire lead is soldered to the brass disk and another to the piezo ceramic. The useful properties of piezo ceramic disks are that when a voltage is applied, they deform, and when they are deformed by an external force, they produce a voltage. The first property facilitates their use as thin high-frequency speakers. To observe the second property, one has only to attach an oscilloscope to the leads. Every vibration is detected and turned into a voltage spike visible on the screen. With digital conditioning, the piezo

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ceramic disk has functioned as a reliable and sensitive solid-state peck key for the operant conditioning of small passerine birds such as swallows (*Hirundo* sp) and sparrows (*Melospiza melodia* and *Zonotrichia* sp), as well as larger species.

The simple hybrid A/D circuit that is described here combines with the piezo ceramic transducer to make a solid-state switch that can be adjusted to detect even the feeblest peck. Some instructions are provided for the construction of a solid-state peck key. Figure 1 is the schematic diagram of the conditioning circuit that is equivalent to the circuit described by Clauson, Izatt, and Shimp (1985) for use with infrared optical detectors.

The piezo ceramic disk can be mounted by soldering a brass washer so that it partially overlaps the edge of the brass disk. Since the piezo ceramic may crack if overheated, both contact areas must be "wet" with solder before soldering. High soldering temperatures (900° F) should be used to heat the material quickly. The disk should be allowed to cool between applications of the soldering iron. Low-temperature solder is useful for this purpose, but fumes should not be inhaled since they contain high levels of cadmium. Once the parts are soldered, the joint may be reinforced with 5-min epoxy.

One lead is soldered to the brass disk (−lead) and a second to the piezo ceramic close to the edge (+lead), observing the precautions against overheating. A fine (e.g., 30 g), multistranded, insulated wire is best, and using different colored wires (red/black) is good practice. A dot of 5-min epoxy at the solder contacts provides reinforcement. All solder and glue should be kept to a minimum or the transducer will be damped. Likewise, sensitivity will be severely reduced if the mounted disk is bent or under pressure.

A Fresnel-lensed light-emitting diode (LED) makes an ideal peck object because it can be turned on as a signal and the lense grooves keep the bird's beak from glancing off the key, thus directing force in a consistent direction. The LED may be glued with epoxy to a second washer mounted across the disk from the first (Figure 1). The LEDs should be mounted so that their leads stick out the same side as the wires from the piezo ceramic disk. In this orientation, a peck to the LED will generate a positive voltage at the +lead relative to the −lead. The key may be mounted behind a sheet of opaque acrylic with a 1/4-in. diameter hole drilled so that only the LED is exposed to the bird. Additional washers may be used to provide some travel space between the disk and the acrylic shield.

The signal conditioning circuit (Figure 1) should be mounted as close as possible to the piezo ceramic disk; otherwise it will be very prone to electrical interference. The supply voltage (V_{cc} in Figure 1) should be ripple free anywhere between 3 and 18 V (5–12 V is best). If the key is to be interfaced with other equipment or the TTL family of integrated circuits (SN74xx or SN74LSxx), a regulated 5-V supply should be used. All semiconductors listed here are manufactured by Motorola, but equivalent numbered parts from any of a dozen manufacturers can be substituted.

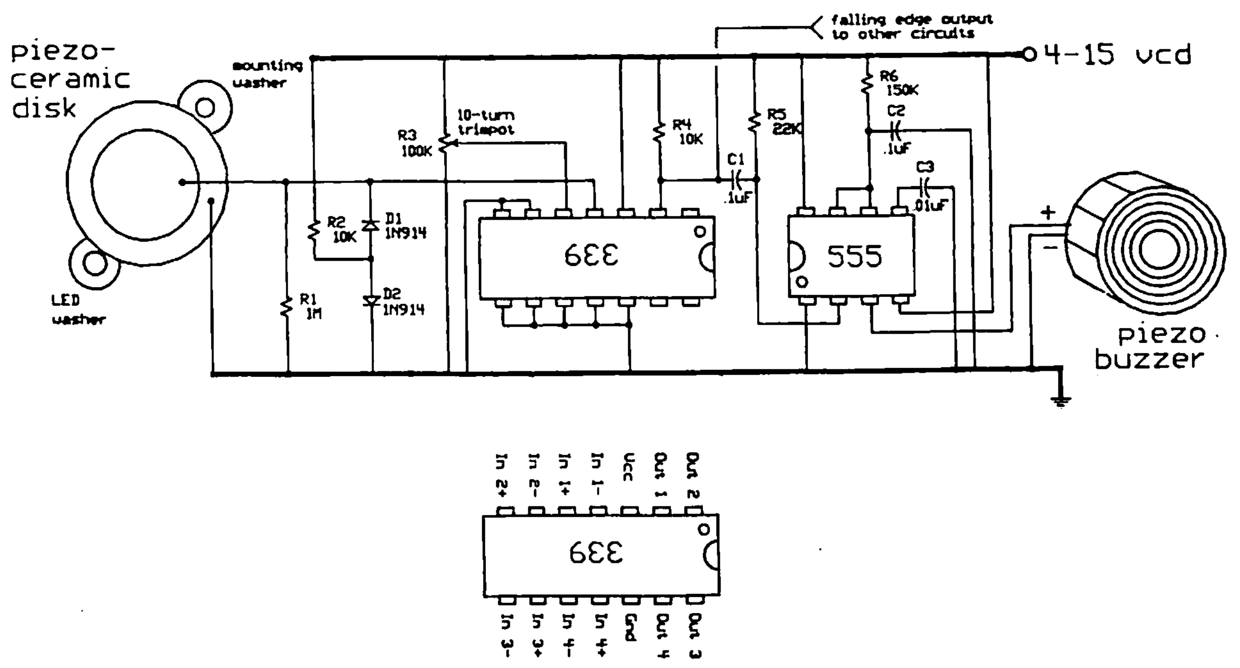

Figure 1. Piezo ceramic peck key and circuit diagram. Note the reverse orientation of the 339 quad comparator chip. A pin diagram for the 339 is shown at the bottom of the figure to facilitate running more than one peck key from the same chip.

The high-impedance signal from the piezo ceramic disk first passes a medium-impedance voltage clamp of signal diodes that grounds any signal below 0 V. The signal then runs to the −input #1 of an LM339 quad voltage comparator in the linear family of integrated circuits. The normal output of the comparator in this application should be high (V_{cc} with a 10-kΩ pull-up resistor attached to the open collector output. When the voltage at the −input (from the +piezo ceramic disk lead) exceeds the voltage at the +input, the output changes states, going low (to 0 V). A 100-kΩ 10-turn trimpot across the supply and ground leads acts as an adjustable voltage divider to provide a reference voltage for the +input. The low-going output pulse may be interfaced to other circuitry, such as an SN74LS05 inverting buffer connected to an SN74LS74 clock-edged flip-flop and then routed to a computer through a higher current device (e.g., a cable driver). For further information on interfacing transducer circuits, see Horowitz and Hill (1980, chaps. 8, 9, and 12).

The remaining portion of the circuit is optional, providing auditory feedback in lieu of the click from a microswitch. It is an LM555 linear integrated circuit, configured as a one-shot timer. The output from pin 3 drives a piezo buzzer unit ($3 at Radio Shack). These beepers contain a piezo ceramic disk and an oscillating drive circuit. A piece of sticky tape over the sound hole in the beeper attenuates the tone to a reasonable level. A series resistor would do as well. To lengthen the tone pulse, the value of the charging resistor (R6 in Figure 1) should be increased. The value of this resistor should be reduced to shorten the pulse.

Four peck keys may all be run from the same LM339 quad comparator (a pin diagram of the LM339 is included on the bottom of Figure 1 for this purpose). The same LM555 timer beeper circuit may also be used for several inputs if a reverse-biased signal diode is inserted between the 10-kΩ pullup resistor on the output of each comparator on the LM339 and the .1-μF blocking capacitor on the input of the LM555 timer. For further information on interfacing transducer circuits, see Horowitz and Hill (1980, chaps. 8, 9, and 12).

Piezo ceramic devices can sometimes be obtained from Jerryco, Inc., 601 Linden Place, Evanston, IL 60202, or through the manufacturer, Panasonic Company, Electronic Components Division, P.O. Box 1503, Secaucus, NJ 07094. Piezo ceramic disks can also be removed from buzzers or can occasionally be acquired from electric guitar shops where they are installed as electric pickups. Piezo ceramic disks generally cost $1 to $2 each. Disks about 2.7 cm in diameter give a good combination of sensitivity, drive, and resistance to abuse (they can withstand the repeated jabbing of a starling). Some disks have an isolated strip of piezo ceramic for use in feedback circuits. If the only piezo ceramic disks readily available have this feature, the strip may be ignored.

REFERENCES

Blough, D. S. (1986). Odd-item search by pigeons: Method, instrumentation, and uses. *Behavior Research Methods, Instruments, & Computers*, 18, 413-419.

Clauson, H. D., Izatt, E. J., & Shimp, C. P. (1985). An infrared system for the detection of a pigeon's pecks at alphanumeric characters on a TV screen: The dependency of letter detection on the predictability of one letter by another. *Journal of the Experimental Analysis of Behavior*, 43, 257-264.

Horowitz, P., & Hill, W. (1980). *The art of electronics*. New York: Cambridge University Press.

Park, T. J., Okanoya, K., & Dooling, R. (1985). Operant conditioning of small birds for acoustic discrimination. *Journal of Ethology* (Japan), 3, 5-9.

Pisacreta, R., & Rilling, M. (1987). Infrared touch technology as a response detector in animal research. *Behavior Research Methods, Instruments, & Computers*, 19, 389-396.

Shy, E., McGregor, P. K., & Krebs J. R. (1986). Discrimination of song types by great tits. *Behavioural Proceedings*, 13, 1-12.

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