TECHNICAL NOTE

PIEZOELECTRIC PECKING KEY¹

This device is an improvement over the conventional switch-action pigeon key in certain applications, and is also suitable for sensing other transient contacts. The key described utilizes a piezoelectric crystal (phonograph cartridge) instead of the typical switch-action sensing. This type of sensing is inherently more reliable than that obtained with electro-mechanical switches, and the following advantages are also obtained: (1) The key can be made relatively large while still requiring a minimal excursion for activation; (2) it requires no mechanical adjustment—the sensitivity is adjusted by a potentiometer; (3) the key is directly compatible with solid-state control systems (*i.e.*, the circuit described here is TTL-DTL compatible but a circuit could readily be designed for other types of logic); and, (4) it produces a bounce-free output.

As Figure 1 shows, the key is mounted in a rectangular hole in a 0.5 in. (1.27 cm) plywood wall. Covering the plywood on the side of the animal chamber is a metal plate with a 2 by 2 in. (5 by 5 cm) hole horizontally centered over the hole in the plywood. Surrounding the hole in the metal is a strip of 0.5 in. (1.27 cm by 0.95 cm) plastic foam tape. Behind the foam is the key, which is a piece of 0.32-cm transparent Plexiglas. There is another layer of plastic foam behind the key. The assembly is held in place by metal plates mounted over the top and bottom of the hole in the plywood. Friction prevents the key from slipping. This arrangement serves to isolate the key from the chamber wall.

A Minibox (Bud Manufacturing Co.) covering the top of the key is fastened to the outside of the chamber wall. A machine screw threaded into the key enters the Minibox through a clearance hole. The phonograph cartridge is mounted only to this screw. (A Sonotone clip-type "9TA" series ceramic phonograph cartridge provided the piezoelectric crystal but other ceramic phonograph cartridges would presumably do as well.) Since the crystal itself is rigidly attached to the cartridge housing, an impulse on the key is transmitted to the crystal. (Impulses arising elsewhere in the apparatus are attenuated before reaching the crystal because of the key isolation.) The inertia of the crystal and stylus assembly causes the impulse to produce a deformation of the crystal, generating an electrical potential in the piezoelectric crystal. Leads from the crystal go to a circuit board mounted in the rear of

Fig. 1. Section through key showing its suspension and the location of the other components.

the Minibox. A remotely mounted sensitivity control completes the system.

Figure 2 is a schematic diagram of the supporting circuitry. The first section of the circuit is an operational amplifier (Fairchild 709C) wired as a voltage comparator. The ac signal from the crystal pickup is compared with a dc reference level established at the wiper of the sensitivity control. When the input signal is positive with respect to the reference level, the comparator output is at its positive limit; when the input goes negative with respect to the reference, the comparator output switches to its negative limit, *i.e.*, the

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C_1	10 PF	R_4	680 Ω
C_2	5 PF	R_5	500 Ω LINEAR POT
C_3	47 MFD 6V	R_6	330 Ω
C_4, C_5	1 MFD 35 V	R_7	360 Ω
R_1	1 MEG	R_8	300 Ω
R_2, R_3	82 K	D_1	10D2

Fig. 2. Schematic diagram.

setting on the potentiometer determines the sensitivity of the circuit. The resistors R_4 and R_6 determine the operating range of the sensitivity control. As described, the sensitivity can be adjusted between just under 0 V (maximum sensitivity) and +3 V. Referencing one side of the control to ground would eliminate the need for R_6 and only slightly decrease the maximum sensitivity. This change would also simplify adjusting the sensitivity, since the maximum attainable sensitivity is then produced at one end of the potentiometer.

Two NAND gates (Texas Instruments SN7400) are used as a one-shot to eliminate multiple pulses produced by vibrations from a single key peck. The width of the one-shot pulse can be increased by increasing the value of C_3 . (Appreciably increasing the value of R_8 would prevent the one-shot from operating.) With the specified values for C_3 and R_8 , the pulse width is 10 msec. Two other gates are utilized as inverters to buffer the output. Both the normal and the inverted outputs are available.

The materials for the key cost about \$20.

This key is responsive to impulse rather than force [Force (F) = ma . Impulse = $\int F dt = mv_2 - mv_1$, where mv = momentum, t = time, m = mass, v = velocity and a = acceleration. (Sears and Zemansky, 1970)]. Consequently, the sensitivity must be expressed in impulse units. Assuming the key is originally at rest ($mv_1 = 0$) and pecks produce inelastic collisions (bounce free), the impulse generated in the key is equal to the momentum of the peck. (If pecks generate a constant amount of

bounce the impulses generated are still proportional to the magnitude of the peck.) It should be noted that although conventional pigeon keys are responsive to both force and impulse, a pigeon's peck generates an impulse. Therefore, the sensitivity of conventional keys are more appropriately expressed in impulse units.

In calibrating the key, impulses were generated by producing inelastic collisions between a pendulum with known momentum and the stationary key. The sensitivity of the key was assessed by using the ascending method of limits. A weight was hung on a thread to form a pendulum. The momentum of a pendulum is given by the formula, Momentum = $m \times 2gh$, in which h is the height from which the pendulum is released and g is the gravitational constant (980 cm/sec²) (Sears and Zemansky, 1970). Coupling to produce the inelastic collision was obtained by applying non-hardening putty to both the pendulum and the key. Large changes in momentum were produced by varying the weight on the pendulum and smaller changes in momentum were produced by varying the height from which the pendulum was released. The length of the pendulum was approximately 9 in. (23 cm) for all measurements. The sensitivity of the piezoelectric key was measured in the center and at the top and bottom. The sensitivity of a standard key, Lehigh Valley Electronics, Model 1348, was obtained for comparison purposes. On this key, measurements were made on the center of the paddle. The data obtained with the pendulum are presented in Table 1.

Table 1
Calibration Data

Measurement	Mass (g)	Approximate Pendulum Release Height (cm)	Impulse Required ($\text{g} \times \text{cm/sec}$)	
			Center of Key	Top and Bottom of Key
Maximum Sensitivity	0.3	0.11	$4.4 \pm 5\%$	$+7\%$
Maximum Usable Sensitivity	1.5	0.17	$28.0 \pm 15\%$	$+25\%$
Standard Key ¹	24.0	0.14	$390.0 \pm 20\%$	—

¹Lehigh Valley Model 1348, requiring a static force of 16 g.

Some of the variability indicated in Table 1 can be attributed to measurement error, rather than key variability. Without more sophisticated instrumentation, precise measurements cannot be obtained. The maximum sensitivity of the piezoelectric key can not be used for experimentation because the key is not well enough isolated from the rest of the apparatus; at maximum sensitivity a tap anywhere on the apparatus activates the key. The greatest sensitivity that can be used without danger of such artifact is the sensitivity used. This sensitivity is still about 10 times greater than that obtained with the conventional key.

Three keys of the type described have been used with complete satisfaction for several months. In these applications, rapid rates of responding were not generated, approximately 100 responses per 30-min ses-

sion being the maximum. Under these conditions the key had sufficient travel so that the birds' peaks incurred no damage. We have no reason to expect that at higher rates the key would be less satisfactory in either its effects on the birds or its response characteristics.

REFERENCE

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Fred Altman¹ and
Larry D. Hull
University of Kentucky

¹Present address: NIMH Clinical Research Center, Lexington, Kentucky 40507.