TTL IC serves as touch keyboard.

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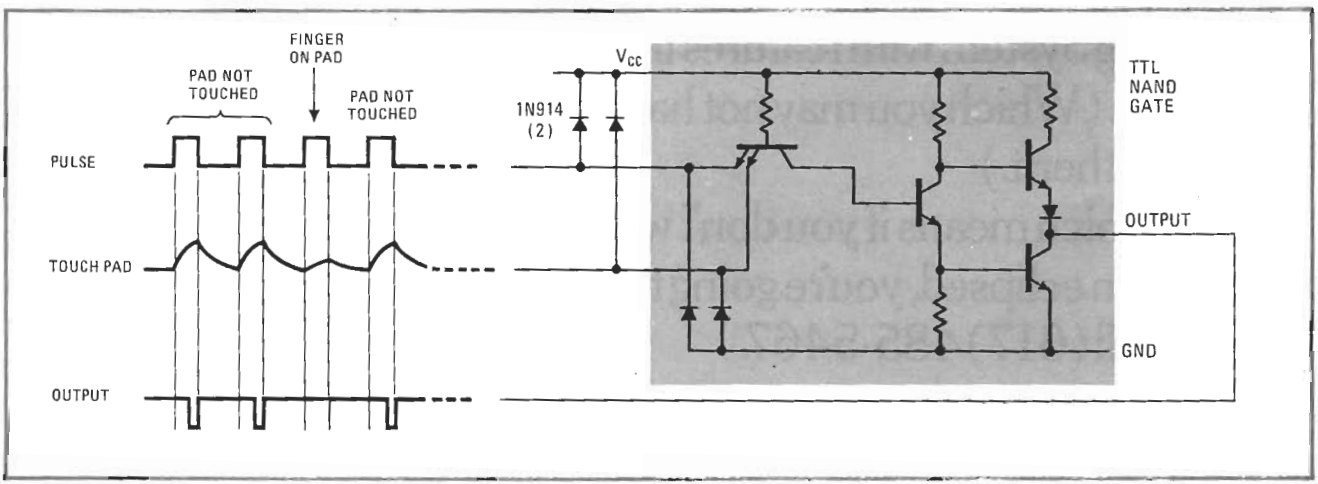
The terminals of a $2 multiplexer IC can be used as a contactless keyboard to produce binary-coded output. The IC is mounted on a printed-circuit board, and its terminals are connected to finger-tip-size touch pads. During scanning of the 16 multiplexer inputs, which are actually NAND-gate terminals, a number is generated at the output only when the corresponding pad is touched by an operator's finger.

The transistor-transistor-logic NAND gate in Fig. 1 illustrates the operating principle of this keyboard. If one input of the gate is pulsed high while the other input terminal is allowed to float, the stray capacitance of the floating terminal (typically 3 picofarads) is charged by a current of about 1 milliampere. This makes the floating terminal also go high, and the two high inputs result in



1. **Touch control.** Operator's finger on terminal of TTL NAND gate makes output stay high when other input is pulsed. Output is generated by addition of capacitance from finger—no switches or leads are required. Using this technique, 16-terminal IC can be contactless touch-control keyboard for BCD output. External diodes protect against positive voltage spikes, and internal diodes protect against negative spikes.

a low output. If the operator touches a 30-pF finger to the floating terminal, however, that terminal charges more slowly; it does not have time to reach the threshold voltage (unless the pulse is very long), and therefore the output stays high.

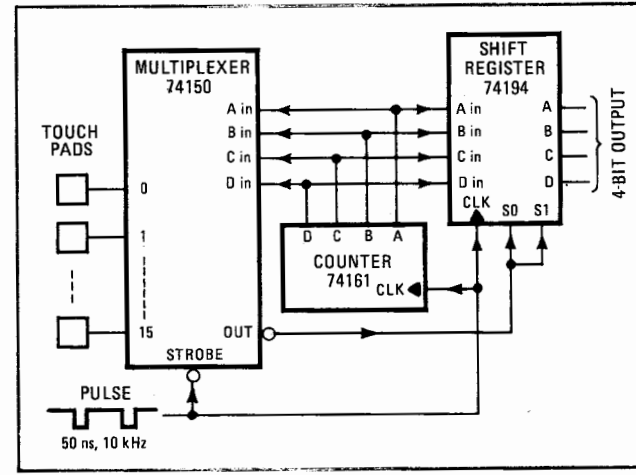
The complete circuitry for the capacitive touch keyboard is shown in Fig. 2. The pulse that strobes the multiplexer also clocks the scanning counter, which delivers A,B,C, and D inputs to both the multiplexer and the parallel-load shift register. During 16 successive clock pulses, the counter scans the 16 possible 4-bit combinations at ABCD, and, at the 4-bit word corresponding to the pad that is touched, the multiplexer produces an output pulse to the shift register. This pulse (into S1 and S0) loads 4-bit word ABCD into the shift register on the trailing edge of the clock pulse.

The shift register can be loaded only if the multiplexer output has been high during the last 20 ns of the clock pulse. This requires that the duration of the clock pulse be more than 20 ns (to let untouched terminals charge up to threshold voltage), but not long enough to let the touched pad charge. A pulse duration of 50 ns has been used successfully.

If the input current to a pad were unusually low, the pulse might have to be longer. Manufacturers of TTL specify only a maximum value for input current, but in fact, the spread in values is less than two to one from one device to another, and is even less between terminals on the same chip. To minimize the effect of this spread without having to adjust each circuit, fixed capacitance of the touch pads should be kept low.

The clock frequency is not critical. It merely must be low enough to allow 10-nanoampere inter-emitter leakage to discharge the touch pads between scans. A clock frequency of 10 kilohertz has operated satisfactorily.

The wise designer will add diodes to clamp the pads to V_{CC} because rubber shoes on nylon carpets can produce some horrifying voltages—as high as 10 kV for a man, and 20 kV for a woman—that can easily destroy the emitter junction of a gate. These diodes, included in Fig. 1, protect against positive voltage spikes. The internal ground-clamping diodes provide protection against negative spikes. □



2. **Keyboard.** Complete circuit for contactless touch-control keyboard uses multiplexer, counter, and parallel-load shift register. Pulse that strobes multiplexer also clocks scanning counter into shift register on its trailing edge. Output from register is 4-bit word.