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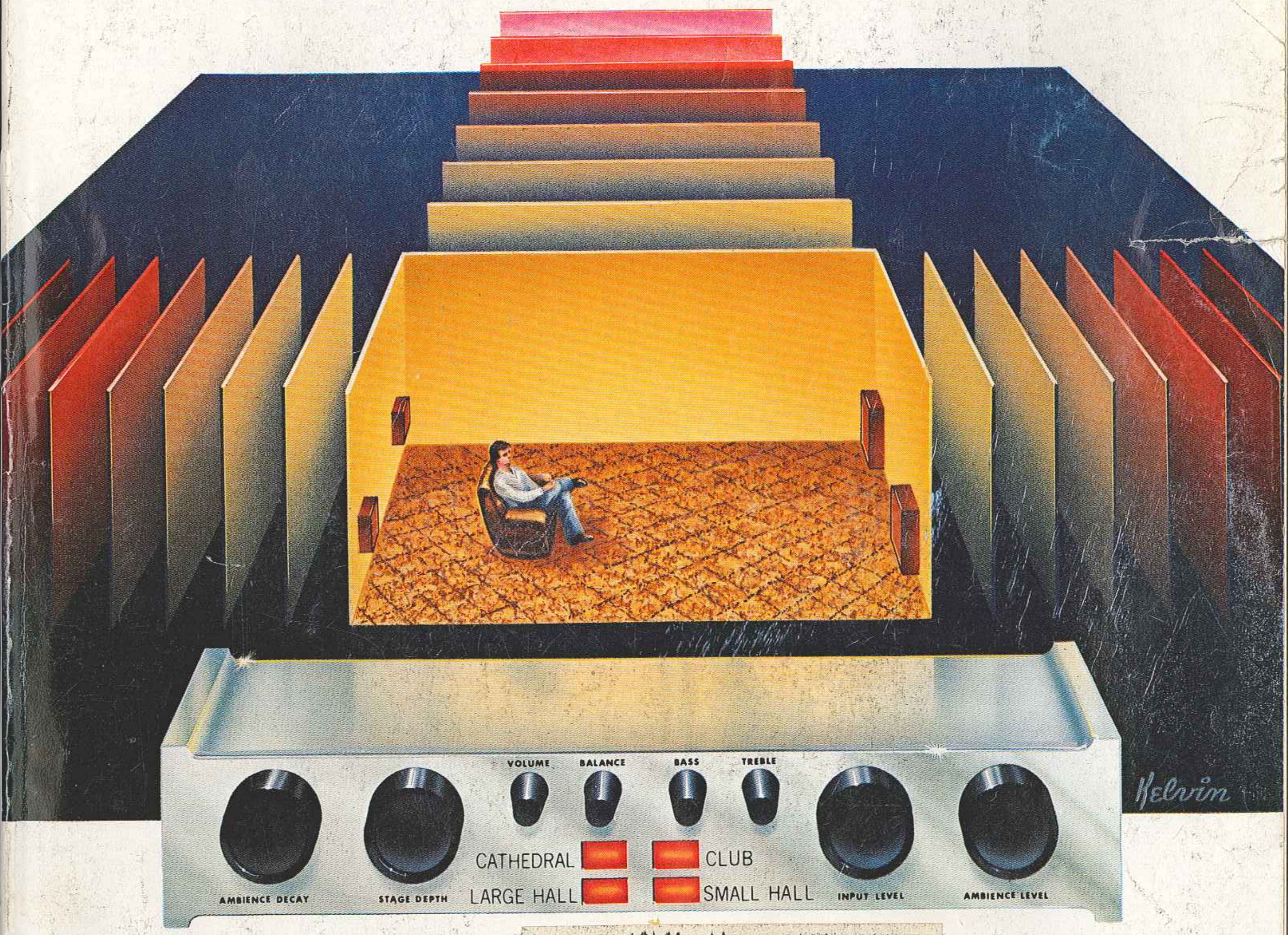

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A NEW APPROACH TO DATA STORAGE: BUBBLE MEMORIES

BY LESLIE SOLOMON
Technical Director

With attributes of both ROM and RAM, a typical bubble memory can store up to 92K bits with an access time of 4 ms.

A WHOLE new approach to mass data storage is soon to become available at reasonable cost. Called "bubble memories," the new storage devices have attributes of both the RAM and the ROM. Like a RAM, data can be written into and read from a bubble-memory device. And, like a ROM, once power is removed from the bubble memory, the data remains intact, ready to be read out when power is restored.

Typical bubble-memory devices contain at least 92K bits of data-storage capacity. With an access time of 4 ms and a 50K bits/second data rate, the bubble device "looks" more like a disk system than it does a cassette system. Note that the bubble memory system does not make a good substitute for a RAM system—unless you have lots of time.

A bubble-memory system, which might include several 92K bubble devices and their associated interface electronics, can be mounted on a single circuit board that can be plugged into almost any bus system. Since each bubble device requires less than 700 mW of power for continuous operation, the power supply in a microcomputer will not be strained.

Formation of a Bubble. A basic "bubble" begins as a magnetic domain that exists within a thin magnetic film and can assume any shape, as shown in Fig. 1A. These domains form in the film in a manner that minimizes the total magnetic energy of the film. Shown in Fig. 1A is a typical set of domains when there is no external magnetic field applied normal (at right angles) to the film.

If a small steady-state magnetic field, such as from a permanent magnet, is applied normal to the plane, the magnetic domains tend to shrink within themselves to form smaller domains. (Fig. 1B). As the strength of the external magnetic field increases, the domains continue to shrink until they are between 2 and 30 microns in size (Fig. 1C). If the external magnetic field's strength is increased, the bubbles essentially disappear. Experiments have revealed that the most stable bubbles are formed with an applied steady-state magnetic field of about 100 oersteds. Hence, the first hint of bubble operation is that magnetic bubbles are sensitive to applied magnetic fields.

Physical Construction. The basic arrangement of a bubble-memory chip is shown in Fig. 2. The actual bubble device (with one corner enlarged) reveals that the thin magnetic film is diffused on a nonmagnetic substrate, along with small bars that are shaped like the letters I and T.

The bubble device is mounted between two thin permanent magnets to create the tiny bubbles. Surrounding the bubble device is a pair of orthogonal coils (right angles to each other). Since we know that the magnetic bubbles are affected by magnetic fields, passing a current through the orthogonal coils, 90° apart and in-phase, will cause the bubbles to move around. Using the current flow shown in Fig. 2, the magnetic field will rotate.

Bubble Motion. Once a bubble has been established, it must be moved around so that it can be used as a data bit. How this motion is achieved is shown in Fig. 3. The "track" along which the bubble is to be moved is composed of a series of soft magnetic bars shaped like I's and T's that are also deposited on the nonmagnetic substrate. A "parent" bubble is located under a disc of magnetic material. Note in Fig. 3 that another bubble is located under the first T bar and is assumed to have moved to that location during a previous cycle.

The bubble memory held by an engineer contains two garnet chips and stores 250,000 bits. Sixteen chips are in system at rear, which was developed for the Air Force by Texas Instruments.

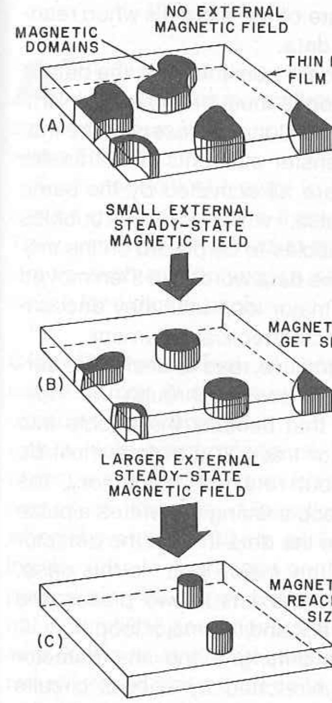

Fig 1. Small bubbles in magnetic film are shown at (A). With an external field applied, bubbles get smaller (B). They reach best size as field is increased (C).

The first I bar has a tiny hairpin wire loop covering one end. When the rotating magnetic field is as shown, and when a current of about 150 mA is applied to the loop for 500 ns, a portion of the parent bubble is transferred to the vicinity of the I bar. The parent bubble is not depleted because its size is strictly a function of the local magnetic conditions. As the rotating magnetic field continues, the newly created bubble moves across to the next T bar that has the temporary magnetization shown. As the applied magnetic field continues to rotate, the slender magnetic "link" between the parent bubble and the newly formed bubble under the T bar snaps, leaving a new bubble at the T bar (first T bar in bottom row).

As the applied magnetic field continues to rotate, the right side of the T bar assumes the magnetic characteristics shown in the top row (second bubble) and further field rotation causes the bubble to move along the track, going from T bar to I bar, and so forth. Each rotation of the applied magnetic field causes a bubble to move a distance of slightly greater than 20 microns.

There are other track formations besides the T and I bars. Examples are: a chevron-shaped set of bars, a Y-shaped set, and a set of contiguous discs.

Bubble Annihilation. When the bubbles reach the end of the track or when the data is no longer needed, a means must be provided for removing the unwanted bubbles. One method is to use a current pulse in a hairpin loop to disintegrate the bubble when it passes under the intense magnetic field. Another is to allow the bubble to run into a magnetic guard rail that surrounds the substrate. The bubble simply joins the magnetic field under the guard rail and vanishes. The magnetic field of the guard rail does not increase in size when this occurs. The field is a function only of the local magnetic conditions.

Bubble Detection. The most common way to detect the presence of a magnetic bubble is to measure the change in resistance of a magnetoresistive strip as the bubble passes over it. To reject the interference from the rotating field that drives the bubbles, a dummy detector, exposed to the magnetic field but not to the bubble, is also used. The signals from the two detectors are mixed and the difference between them (the effect of the bubble) forms the output signal.

Once the bubbles are allowed to flow to the detector (magnetoresistive) elements, the bubbles are "stretched" into wide strips. This increases their effect on the detectors and is equivalent to preamplification. Under these conditions, the detected signal can be several millivolts in amplitude.

Memory Operation. Since bubbles can be made to follow each other along a special "track," the easiest approach to obtaining memory operation is to create a long shift register. However, because bubble memories will be in the 100K range, such a long shift register would be awkward to create and would have a very long access time. Hence, a different technique such as that used by Texas Instruments and shown in Fig. 4 is used.

Bubbles are introduced into the major loop by applying a current through a hairpin wire loop that covers the GENERATE bar. Each bubble created during a 10-µs interval forms a 1, while the lack of a bubble during a similar interval signals a 0. Note that the 10-µs period is determined by the device's operating frequency, which is 100 kHz.

The major loop can transfer data to any of 157 minor loops (641-bit serial shift registers). If all minor loops are operating, the storage capacity becomes 100,637 bits. However, since the production of bubble devices is still in the developmental stage, the actual yields are low. Therefore, up to 13 minor loops are permitted to be defective. This means that total memory capacity can be as low as 92,304 bits. The defective loops are located during final device testing and a "map" is supplied to the end user who can eliminate the defective loops from his system.

A data block of 157 bits is shifted along the major loop until the first bit is

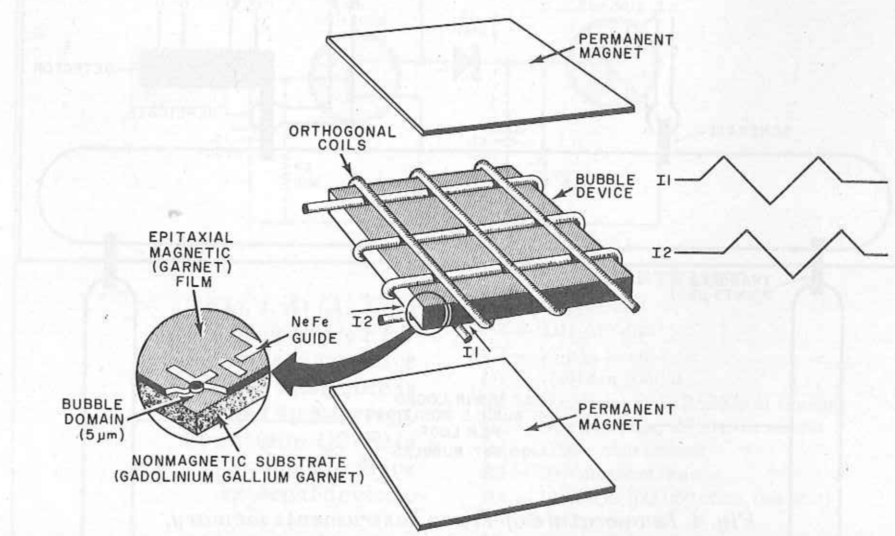

Fig. 2. Basic arrangement of a bubble-memory chip. Thin magnetic film is diffused on substrate with small bars in shapes of letters I and T.

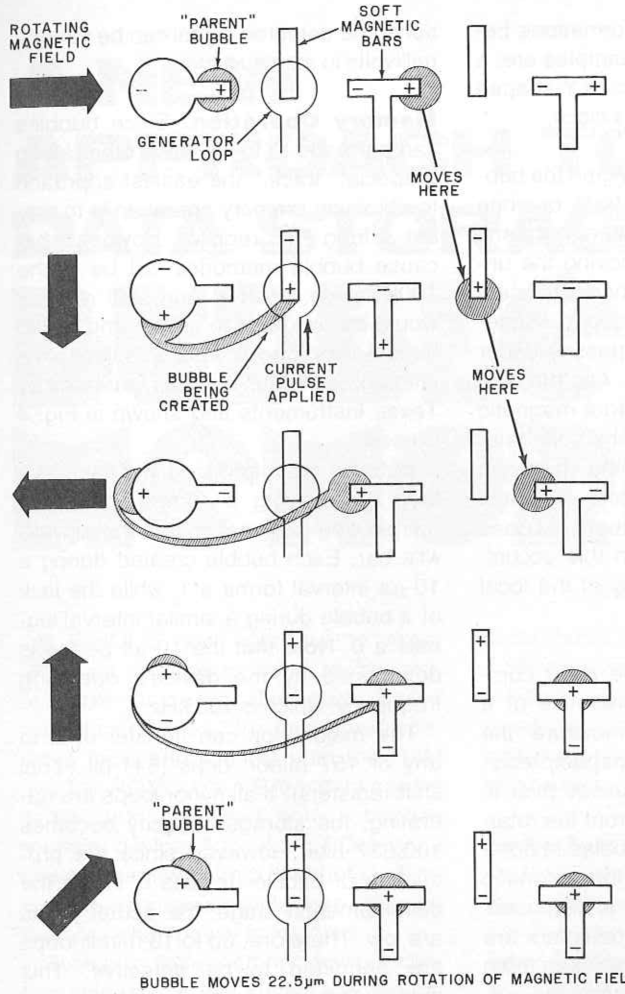

Fig. 3. A bubble, once established, is moved around between soft magnetic bars by rotating magnetic field at left.

aligned with the most remote minor loop (loop 1 in Fig. 4). At this time, all other data bits are aligned with the other minor loops so that when the TRANSFER-POINT elements all receive a simultaneous current pulse, the localized magnetic fields at each transfer point "dump" (actually replicate) the data into the minor loops. The major loop is shifted along for another 157 bits, and the process repeats itself.

Special circuitry is used to insert a 0 at each point where the major loop encounters a bad minor loop. Other circuitry takes care of the extra 0's when reading out the data.

To read data from memory, the data in the minor loops must be moved until the first bit in each loop is present at the major-loop transfer elements. The transfer elements are all activated by the same current pulse, which causes bubbles and nonbubbles to be placed on the major loop. The data words are then moved along the major loop until they encounter the detector/replicate element.

If a destructive read is desired, a current pulse is passed through the replicate loop that deflects the bubble into the detector track. If the data must be read out but retained in memory, the replicate loop's timing generates a pulse to replicate the data in both the detector track and the major loop. In this case, identical data exists in two places: the detector track and the major loop.

Bubbles drifting along the detector track are stretched by special circuits and made to pass over a bar made from magnetoresistive material. As the bubble passes across the material, it causes a change in the resistance, which is reflected as a small voltage change within the circuit that makes up the detector. After passing the detector, the "used" bubbles reach a guard rail, where they are annihilated.

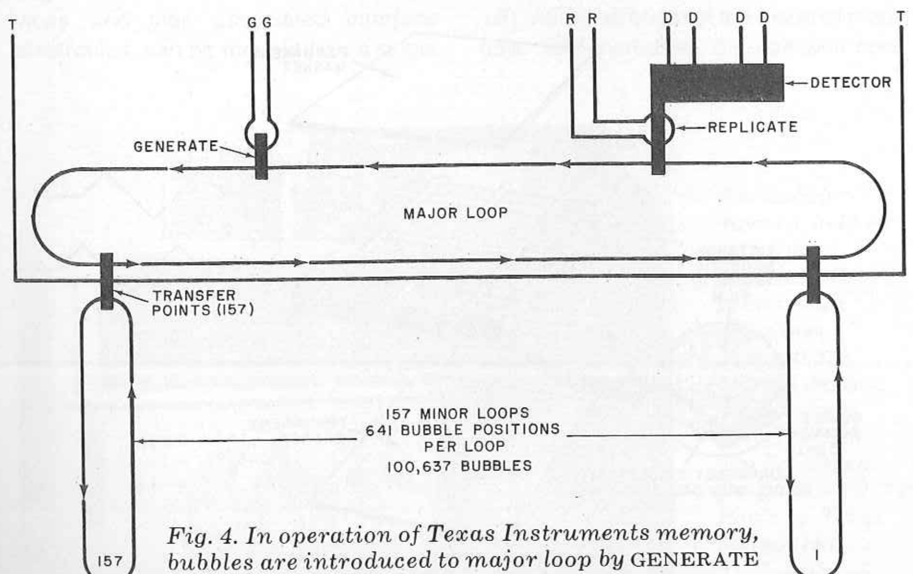

Fig. 4. In operation of Texas Instruments memory, bubbles are introduced to major loop by GENERATE bar and then transferred to one of minor loops. To read data, a pulse is generated in detector track.

Physical Package. A typical bubble memory package, Texas Instruments' TBM-0101, comes in a DIP configuration that is 1" (25.4-mm) square by ⅜" (9.5-mm) thick. It has both coils and bias magnets built in. The pinout for this package is shown in Fig. 5.

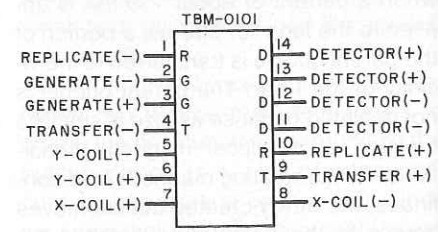

Fig. 5. Pinout for TBM-0101, made by Texas Instruments.

The operating frequency of the typical bubble memory device is 100 kHz. Its average access time is 4.0 ms, average cycle time is 12.8 ms, and data rate is 50K bits/second. The package weighs 25 grams and has a shielding capability of 40 oersteds.

Several IC's are used as support for a bubble-memory system. These include a controller, timing generator, coil drivers, and a detector circuit. ◇

A SIMPLE TOUCH CONTROL SWITCH

BY GEORGE PETERKA

Single FET amplifier circuit can be used to control relay or other low-current device

A TOUCH control is an electronic switch that can be activated simply by touching a small conductive plate with a fingertip.

Such controls are easy to build and can be used to enhance many projects. They can also be added to an existing circuit, such as forming an alarm "off" switch for a digital clock.

Circuit Operation. A basic touch control circuit is shown in Fig. 1A. Essentially, it consists of a FET amplifier with a high input impedance (10 megohms) and a conductive touch plate connected to its gate. Operation occurs when the ambient 60-Hz ac field flooding the area is impressed on the touchplate during the finger contact. This signal is amplified and appears at the drain as a 60-Hz square wave, alternating between ground and supply voltage.

Capacitor *C1* shunts any r-f picked up by the "antenna effect" of the touchplate, while capacitor *C2* acts as a transient suppressor.

The drain of *Q1* can be connected to the alarm-off pin of a clock chip, since most of these ICs require that the alarm-off pin be momentarily connected to the supply voltage to silence the alarm.

The circuit of Fig. 1B uses the same FET input stage, but, via *D1*, rectifies the ac waveform at the *Q1* drain and uses the generated positive voltage to turn on transistor *Q2*. The positive voltage developed across *C3* will keep *Q2* turned on until the capacitor is discharged by base current and resistor *Rx*. The value of this latter resistor determines how rapidly the switch will shut off and should be between 10,000 and 100,000 ohms.

The load on *Q2* can be a low-current relay or a resistor (1000 to 5000 ohms) with the signal generated across the resistor used to turn on a high-power transistor. Using the transistor shown for Q2, any device that requires 50 mA or less can be powered.

Construction. Any form of construction may be used since the circuit is relatively simple. It should be powered from an ac-line supply for reliable operation.

The touch plate should be relatively small—several square inches are enough. It must be insulated from ground. But it need not be a discrete metal plate; a metal door-knob on a wooden door will suffice. This latter type of touchplate makes an excellent sensor in an alarm project. ◇

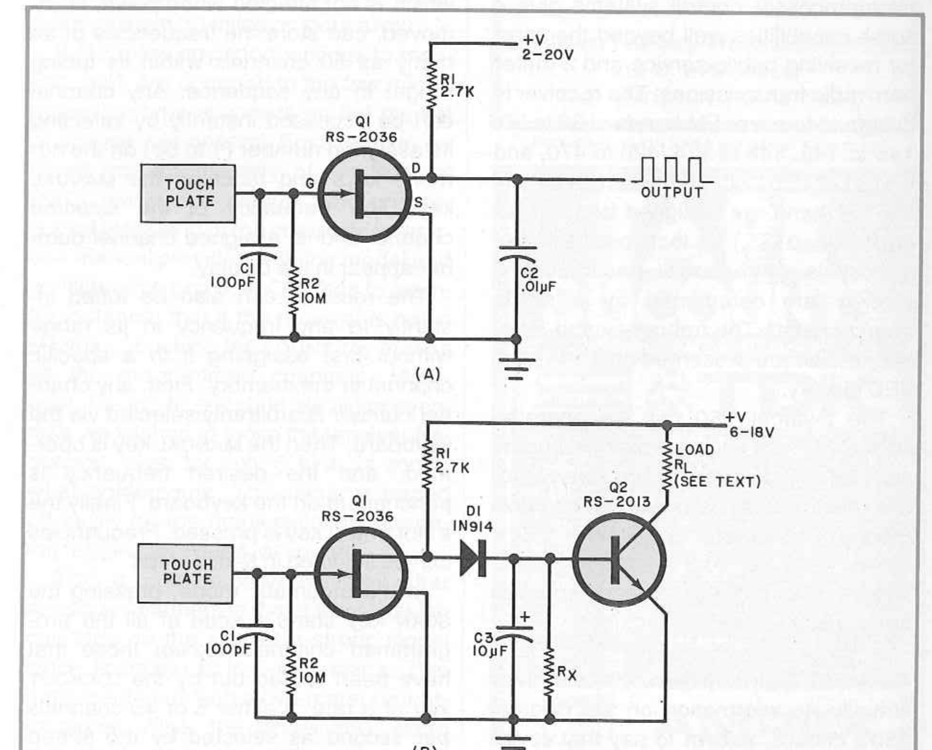

Fig. 1. At (A), high input impedance FET developes a square-wave output when gate is touched by fingertip. Transistor Q2 (B) is added to drive external devices.

PARTS LIST

C1 — 100-pF, disc
C2 — 0.01-μF, disc
C3 — 10-μF, electrolytic
D1 — 1N914 or similar
Q1 — N-channel FET, RS2036 or similar
Q2 — Npn transistor, RS2013 or similar
R1 — 2700 – ohm resistor
R2 — 10 – megohm resistor
Rx — 10,000 to 100,000 ohms (see text)
Touchplate — see text.
Misc. — Perf board, mounting hardware, power supply, etc.