More Piezoelectric Experiments

By Forrest M. Mims III

Last month's column covered basic piezoelectric principles, materials and applications. In addition, we experimented with a unique piezoelectric fan that has no rotating or frictional parts. This month, we'll conclude this two-part examination of piezoelectronics by experimenting with piezoelectric high-voltage trip hammers and sound disks. We'll also take a close look at a remarkable piezoelectric clear plastic film.

Piezoelectric High-Voltage Sources

Piezoelectric trip hammers provide ignition sparks for gas heaters, cigarette lighters, outdoor gas-type barbecue grills and gas lanterns. Hand-held piezoelectric sparkers are used to ignite pilot lights in gas furnaces and stoves and even the burners of hot-air balloons.

You can perform many interesting experiments with a piezoelectric high-voltage trip hammer. Trip hammers made by Vernitron Piezoelectric Division for use in outdoor barbecue grills generate about 18,000 volts when tripped. The active element is a small cylindrical slug of piezoelectric ceramic that measures only about $\frac{5}{8} \times \frac{3}{16}$ inch. This slug is installed at one end of a plastic cylinder, the remainder of which contains a plastic rod, a pair of springs and a cam and hammer.

When a push button at the end of the rod is pressed, the upper spring is compressed against the hammer. Initially, a small pin resting against a plastic shoulder holds the hammer securely in place. As the button is pressed farther down, however, a cam gradually moves the pin away from the retaining shoulder.

When the pin moves off the shoulder, the hammer is released. It then strikes the piezoelectric slug with great force to produce an 18,000-volt spike. The second spring in the igniter, compressed by the downward motion of the hammer, pushes the hammer back to its resting position when the push button is released.

You may be able to purchase replacement piezoelectric igniters from stores that sell or/and service outdoor gas cookers. (Another possible source is your local Sears store—Ed.) A cheaper alternative is to salvage the piezoelectric trip hammer mechanism from a cigarette lighter that is equipped with a piezoelectric igniter.

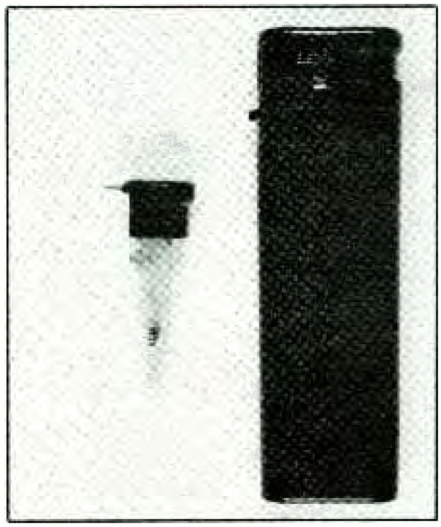

Fig. 1. A disposable cigarette lighter shown alongside the piezoelectric trip hammer that supplies the ignition spark.

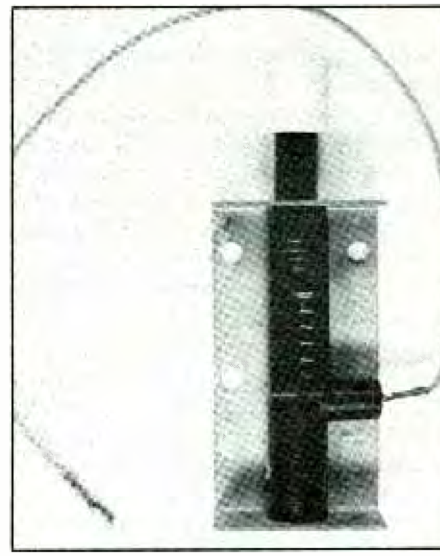

Fig. 2. A Vernitron piezoelectric sparker for outdoor gas barbecue grills.

Figure 1 is a photo of a Scripto Electra cigarette lighter alongside the piezoelectric trip-hammer mechanism that it contains. The piezoelectric slug inside the trip hammer measures less than $\frac{3}{16}$ inch on a side yet is capable of producing around 15,000 volts!

Shown in Fig. 2 is an older piezoelectric pushbutton with which I have experimented for several years, the Vernitron Model 3652. Figure 3 identifies the main components of this device. Note that this sparker is equipped with a single wire lead. A spark is generated between the end of this lead and the metal frame that holds the pushbutton assembly.

Piezoelectric igniters used in cigarette lighters have small metal terminals instead of leads. Be sure to use wire with high-voltage insulation if you connect an additional lead or leads to a piezoelectric pushbutton.

You can easily view the high-voltage arc produced by a piezoelectric igniter like the one pictured in Fig. 2. Mount the discharge wire so that its bare end is within $\frac{1}{8}$ inch of the frame of the igniter. For best results, operate the device in subdued light, and place dark paper behind

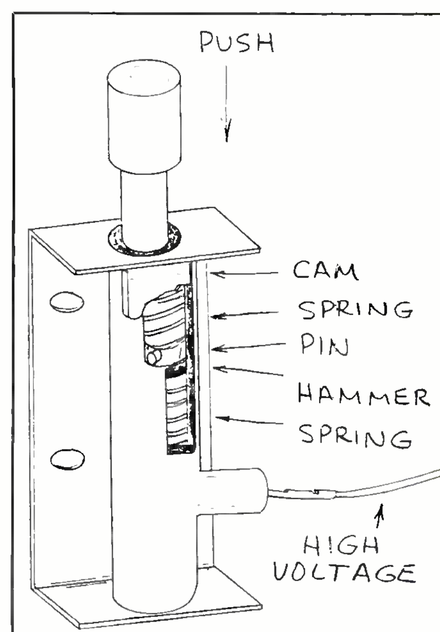

Fig. 3. Annotated drawing of the piezoelectric sparker shown in Fig. 2.

the discharge point to obtain a better view of the spark.

Each time you press the trip-hammer button, a spark should jump between the discharge wire and frame. Try moving the discharge wire farther away from the frame to increase the length of the spark.

You may have to modify this procedure for other kinds of trip hammers. For example, the miniature units used in cigarette lighters have no wire leads. You can use ordinary alligator-clip leads to make connection to the discharge point at the top end of the hammer and the metal terminal along the side of the hammer. The leads must not touch each other.

An interesting experiment to perform is to discharge a piezoelectric trip hammer through a xenon flash tube. Use clip leads to connect the discharge terminals of the tube to the trip hammer. When you actuate the trip hammer, a thin violet arc will discharge between the two electrodes inside the tube. There is no need to apply a voltage to the trigger terminal of the tube since the voltage produced by the trip hammer far exceeds the breakdown potential of xenon.

Caution: Be careful when experimenting with any high-voltage source, including piezoelectric trip hammers! The discharge from a piezoelectric trip hammer can produce a potent tingle. While this in itself may cause no harm, it may startle you or cause an involuntary muscle reflex action. Protect yourself from an accidental shock by working on an insulated work surface and using well-insulated connection wires. If you use only one hand at a time, you'll avoid a shock through your body.

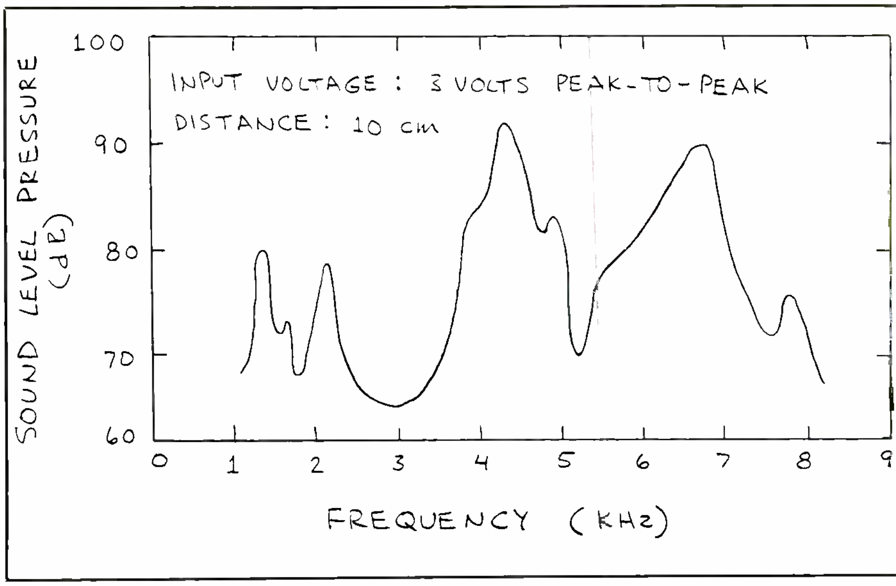

Fig. 4. Sound pressure output of MuRata No. PKM11-4AO piezoelectric disk.

Piezoelectric Sound Sources

Such piezoelectric sound transducers as phonograph pickups and microphones have been in use for many years. The high-frequency audio drivers known as "tweeters" often have a piezoelectric driver element. Various kinds of buzzers, warblers and sirens have become by far the most common users of piezoelectric audio transducers.

Most of these piezoelectric sound sources are made by bonding a thin disk of piezoelectric ceramic to a circular metal plate. When an alternating voltage is applied to the element, the ceramic becomes alternately concave and convex. This mechanical movement is amplified by the metal plate. The result is a sound wave that has the frequency of the applied signal.

Piezoelectric sound sources weigh only a few grams, but they can produce sound levels of from 60 to 90 decibels. When housed inside an enclosure that directs the sound into a directional beam, the sound pressure level can exceed an audibly painful 110 decibels.

As you might expect, piezoelectric sound generators have a particular resonant frequency at which they produce their highest sound level. They often resonate well at harmonic frequencies, and even at non-resonant frequencies can produce substantial sound pressure levels.

Figure 4 shows the output from a typical piezoelectric sound generator, MuRata's No. PKM11-4AO. As expected, this graph shows that the sound generator works much better over some narrow frequency ranges. It also shows that the device produces usable sound over a wide audio spectrum.

If you have experimented with piezoelectric sound sources, you've probably noticed that they can produce a very long pure tone. While this tone is ideal for warning and notification purposes, it can be annoying. Moreover, very pure audio tones can establish regions of constructive and destructive interference within a room that has smooth walls and little sound-absorbing material.

As you walk through such a room in which a piezoelectric sound disk is operating, you'll notice distinct changes in the amplitude of the sound. In regions of destructive interference, the sound level is substantially lower than in other areas. These regions can have very sharp boundaries and can be very small. Many times, I've noticed that moving my head a small fraction of an inch will cause a substantial change in the sound pressure level produced by a sound disk.

For optimum results, it is important that you mount a piezoelectric sound generator properly. To illustrate why this is so, I made a series of photographs of a sound disk that I connected to a signal generator. First I poured some white beach sand over the disk, as shown in Fig. 5(A). I then switched on the signal generator and noticed that, almost immediate-

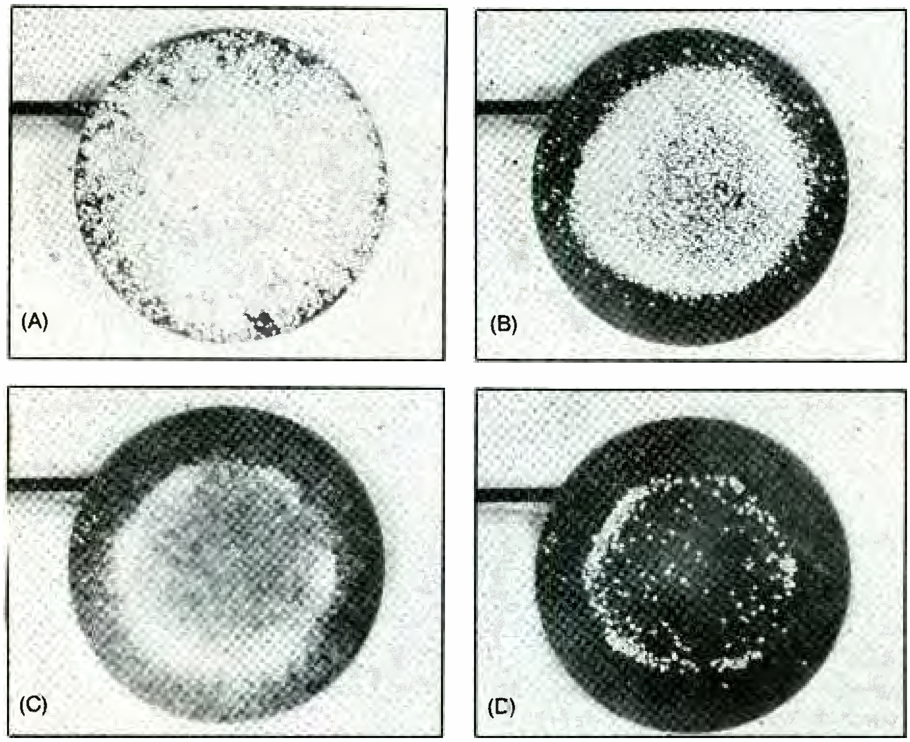

Fig. 5. A piezoelectric disk (A) silent and covered with sand; (B) a few moments after the driving signal is applied; (C) with sand vibrating away from center; and (D) the ring of sand that marks the annular mode of the disk.

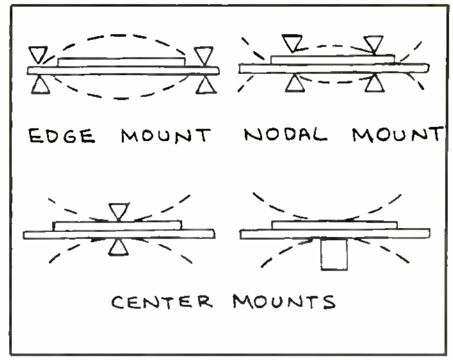

Fig. 6. Mounting arrangements for piezoelectric buzzer elements.

ly, the sand around the perimeter of the disk flew up and away from the disk, as shown in Fig. 5(B).

When I increased the amplitude level of the drive signal, the sand at the center of the disk began violently bouncing, as illustrated in Fig. 5(C). After several seconds, most of the sand in the center of the disk had bounced away, leaving behind the thin ring of sand shown in Fig. 5(D). This ring marks the annular node of the disk. This is the region of the disk that doesn't vibrate when the disk is driven by an oscillating frequency. This region can serve as one of several mounting points for the disk.

It is very important to mount a piezoelectric disk properly. If the vibrating portion of the disk is cemented or attached to a mounting support, the sound produced will be severely attenuated.

Shown in Fig. 6 are several methods that can be used to mount a piezoelectric sound disk. The nodal mount takes advantage of the non-vibrating, circular node shown in Fig. 5(D). The edge mount permits the entire disk to vibrate. The two center mounting methods illustrated in Fig. 6 permit the outer rim of the disk to freely vibrate.

Many different circuits can be used to drive piezoelectric sound disks. The nature of the drive circuit is dependent upon the design of the the sound disk's electrodes. Figure 7 shows both a standard sound disk and a disk that has a third electrode known as a feedback tab. The feedback tab produces a small voltage when the disk moves in response to a signal applied to the main electrodes.

Shown in Fig. 8 is the schematic diagram of a single-transistor driver circuit that can be used to drive disks that have a feedback electrode. Figure 9 is the schematic diagram of a standard oscillator built around a 555 timer chip that will drive both standard sound disks and disks that have feedback tabs.

You can better understand the operation of the feedback electrode with the help of the circuit whose schematic diagram is shown in Fig. 9. Connect the anode of a light-emitting diode to the unused feedback tab of the sound disk. When the driver circuit is switched on and the sound disk is emitting sound, the LED will emit a dim glow.

If you try this experiment, remember that the anode of the LED connects to only the feedback tab. There is *no* electrical connection between the feedback tab and the other electrodes on the sound disk. The LED is powered solely by the piezoelectricity generated by the ceramic in the vicinity of the feedback tab. This simple demonstration shows how a piezoelectric slab can be used as a solid-state signal isolator or transformer.

You need to be aware of some basic operating precautions that must be observed as you work with or use piezoelectric sound sources. The very high sound level produced by many of these devices can be annoying at best and dangerous to hearing at worst. You can reduce the sound level of a piezoelectric disk by reducing the amplitude of the drive signal. If the sound disk is installed inside a plastic housing, you can reduce the level of the sound by blocking the opening with tape, putty or clay.

A second precaution that must be observed is based upon the fact that piezo-

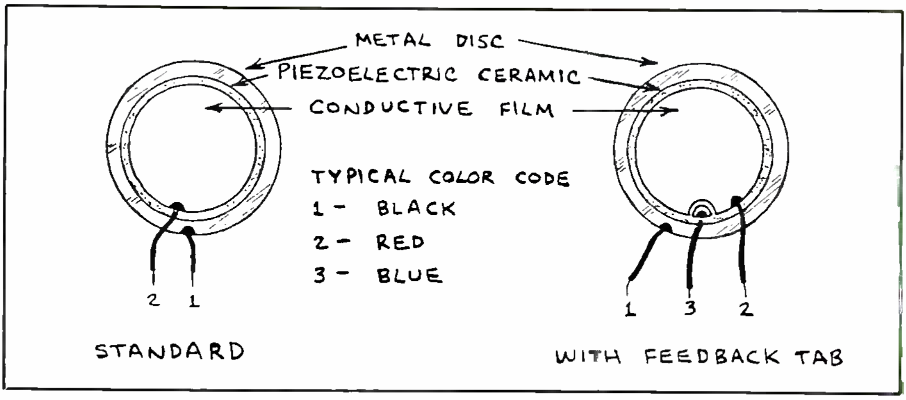

Fig. 7. Typical piezoelectric sound disks.

electric sound disks can produce a substantial voltage when they are subjected to mechanical shock or vibration. If great enough, this voltage can damage the drive circuitry. Proper mounting of a sound disk will reduce the chance of a mechanical shock of the kind that may produce a high-voltage spike. Connecting a zener diode across a sound disk will short-circuit any voltage that exceeds the breakdown voltage of the diode.

Piezoelectric Plastic Film

Piezoelectric plastic film is used in switches, microphones, speakers, earphones and in guitar and other stringed-instrument pickups. The material is also used in sensors that detect pressure, vibration, impact, liquid level and infrared radiation. It is also used to make motorless fans, ink-jet pumps and optical shutters. In fact, piezoelectric film has so many potential applications that it's impossible to describe all or even most of them in these pages.

As the sheet of piezoelectric plastic film shown in Fig. 10 clearly reveals, piezoelectric plastics and ceramics have little in common. Ceramics are rigid, brittle and restricted in size. Plastic films are flexible and can have very large surface areas. These films can be cut or stamped into many different shapes, and they can easily be laminated or incorporated into many different materials, including fabrics, plastics, wood and metal. Piezoelectric ceramics produce greater voltages than do films, but the latter is more sensitive to pressure and can withstand higher voltages.

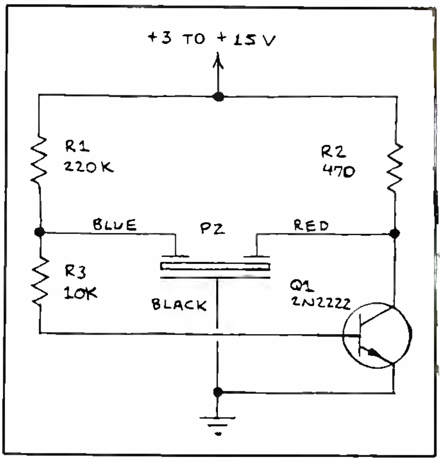

Fig. 8. Schematic diagram of a single-transistor piezoelectric buzzer driver.

The Kynar Piezo Film Department of the Pennwalt Corp. (P.O. Box 799, Valley Forge, PA 19482) manufactures polyvinylidene-fluoride (PVDF) piezoelectric film under the Kynar registered trademark. Kynar film is tough, flexible and transparent.

Pennwalt manufactures Kynar film in continuous sheets up to 3,000 feet in length and in various complex shapes. The company supplies the material with various kinds of screen-printed and sputtered conductive electrodes.

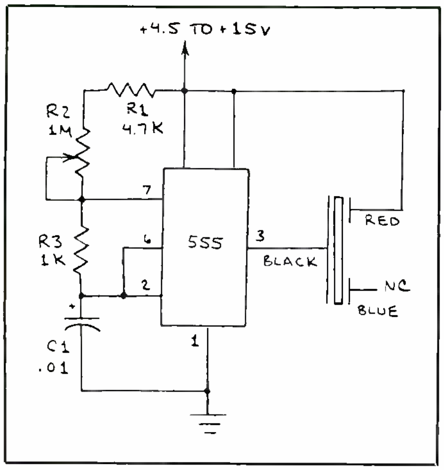

Fig. 9. Schematic diagram of a piezoelectric buzzer driver circuit built around the popular 555 timer chip.

Pennwalt sells many different kinds of piezoelectric components, including small rectangles of Kynar with and without attached wire leads, vibration detectors and bimorphs. A 15 × 20-mm sheet of Kynar without wire leads, which can be added for $2, costs only 50 cents. A bimorph with attached leads costs $15. The company also sells a variety of demonstration kits that include complete instructions and Kynar components. Shown in Fig. 11 is the Basic Design Kit made by Pennwatt.

For detailed information about these and other components and kits, write the company at the address given above. If you decide to place an order with Pennwalt, keep in mind that the company has a $50 minimum.

Experimenting With Kynar Film

Shown in Fig. 12 are some samples of Kynar film with which I have experimented. The small sample that has no electrodes was included in some literature sent to me by Pennwalt. It was taped to a card that describes several experiments that can be performed to quickly convince even a skeptic that Kynar has lots of potential applications.

The simplest experiment that can be conducted involves connecting the Kynar sample to an oscilloscope with a pair of clip leads. When you touch the film or press it against something, the scope indicates a fluctuating voltage waveform. When you breathe on the film, the scope also displays a fluctuating voltage waveform. This illustrates the pyroelectric property of the film.

A xenon strobe or flashbulb produces a much greater output. I used a plastic infrared Fresnel lens purchased from Edmund Scientific Co. to increase the detection range of the film. It detected my hand at a distance of several feet.

Another simple experiment that can be conducted with the sample piece of Kynar film involves connecting it to the output of a signal generator. In this experiment, the film will emit a clear tone as the generator is swept across the audible range of frequencies. If you don't have a signal generator, you can use a radio. Alternatively, you can build a simple oscillator using a 555 timer chip and use this to drive the Kynar sample.

You can obtain greater sound levels by taping the Kynar sample to an index card or even an inflated balloon. Another way to boost the level of the sound emitted by the Kynar film is to connect a step-up transformer between the signal generator and the Kynar sample. I've used a standard 117-to-6.3-volt power transformer for step-up purposes with good results.

A miniature high-voltage dc-to-dc converter transformer like those used in photographic strobe lights also works well as a step-up device. You can salvage dc-to-dc converter transformers from defective strobe units. Otherwise, you can purchase a brand new one for only $2 from The Electronic Gold Mine (P.O. Box 5408, Scottsdale, AZ). With this company, your minimum purchase order is $10; so get the company's catalog before you decide to place an order.

Incidentally, even very small pieces of Kynar film will function as sound sources. For example, I used scissors to cut a 0.25-inch square of Kynar film and used this to generate sound. Of course, the sound level was not nearly as great as that emitted by a larger sample, but the tiny piece of film did produce audible sound.

Another experiment you can conduct involves attaching the Kynar sample to an index card or a credit card with double-sided tape. In this experiment, the Kynar sample will generate a voltage when the

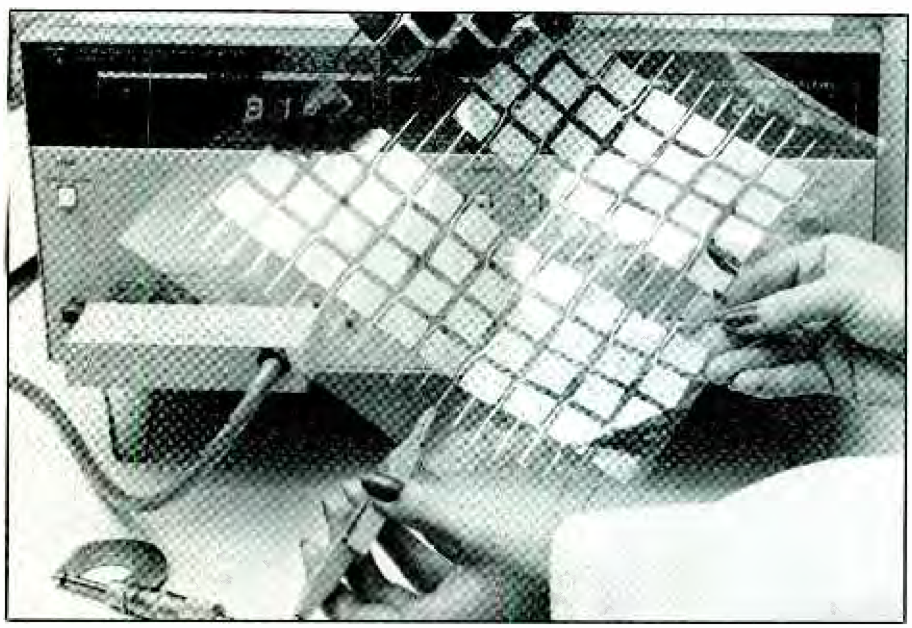

Fig. 10. Kynar flexible piezoelectric film. (Photo courtesy of Pennwalt Corp., Inc.)

Fig. 11. Kynar film demonstration kit. (Photo courtesy of Pennwalt Corp., Inc.)

card is bent in either direction. The polarity of the voltage depends on the direction in which the card is bent. This application illustrates how Kynar can be used as a strain gauge.

It's easy to make a Kynar microphone. Just connect a Kynar sample to the microphone jack of a small audio amplifier or tape recorder. If you want to be formal, tape each end of the Kynar sample to a business card, allowing the center of the sample to bow upward. Alternatively, simply allow the Kynar sample to hang from a pair of clip leads. In either case, the Kynar sample will function as a microphone.

You can increase the level of the signal generated by a Kynar microphone with a step-up transformer, as described above. The literature from Pennwalt suggests attaching the Kynar element to the bottom of a foam plastic drinking cup with double-sided tape.

You can make various kinds of switches with Kynar film. Kynar will generate a signal amplitude of up to 10 volts when it is struck by a domed snap button. Simply touching the film with a finger will also generate a voltage, though a smaller one.

Pennwalt's Kynar literature describes several interface circuits you can build. The material will directly drive liquid-crystal displays (LCDs) and CMOS circuits. It can also be connected to the inputs of operational amplifiers and comparators to serve as a drive signal source.

Going Further

If this two-part series about piezoelectricity has stimulated your interest, you'll undoubtedly want to read more on the subject. If you do, I direct you to the excellent literature on the subject available from some of the companies that manufacture piezoelectric materials. Literature published by Pennwalt, the manufacturer of Kynar plastic film, is particularly good. So are the various brochures and booklets published by Vernitron Piezoelectric Division (232 Forbes Rd., Bedford, OH 44146) and Burleigh Instruments (Burleigh Park, Fishers, NY 14553).

Many of the manufacturers of piezoelectric sound disks publish literature about their products. Especially good is the literature published by MuRata Erie North America, Inc. (2200 Lake Park Dr., Smyrna, GA 30080) and Projects Unlimited, Inc. (P.O. Box 14538, Dayton, OH 45414-2539).

Finally, more experimenter applications for piezoelectricity are included in *Forrest Mims' Circuit Scrapbook II* published by Howard W. Sams & Co., Inc. (1986); see especially pages 215 through 229 of this book. **ME**

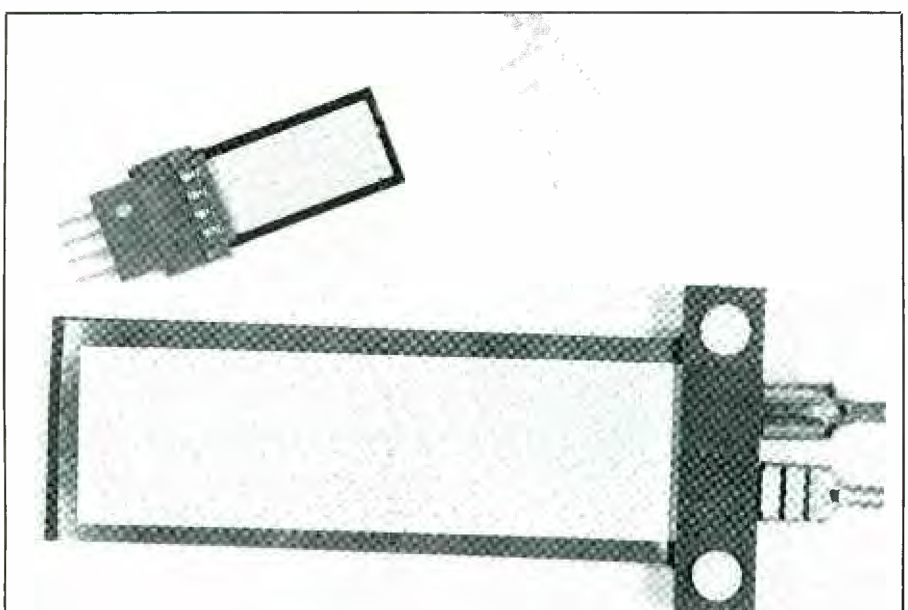

Fig. 12. Typical Kynar piezoelectric elements.