Pressure-Sensitive Resistors

By Forrest M. Mims III

There are many applications for pressure-sensitive resistors. For example, a pressure-sensitive resistor can serve as the transducer for an electronic scale or an accelerometer. When connected to an appropriate circuit, a PSR (from here onward, I will use "PSR" interchangeably with "pressure-sensitive resistor") can provide a warning when an object placed on it is moved. PSRs can also be used in various kinds of keyboards and computer graphic input devices.

I first wrote about pressure-sensitive resistors in the November 1982 issue of *Computers & Electronics* magazine. A few years later, that magazine published a letter from Scott Allner who suggested yet another application for these versatile devices. Mr. Allner wrote that he worked for an institution for severely mentally retarded and physically handicapped people, many of whom spend their days in wheelchairs. To protect these patients from receiving bed sores, Mr. Allner wrote, specially designed cushions are necessary. Therefore, he was working on a special cushion fitted with an array of 260 pressure-sensitive resistors. Mr. Allner's objective is to obtain a visual representation (LED array or computer screen) of the weight distribution of various patients seated on the test cushion.

The sensors about which Mr. Allner wrote were do-it-yourself devices fashioned from the conductive foam used to ship CMOS and other voltage-sensitive semiconductors. Many other kinds of PSRs are also available. In this month's column I'll discuss several kinds, emphasizing an inexpensive commercial device which has recently become available. I'll also present some specific circuit and computer applications.

Do-It-Yourself Pressure-Sensitive Resistors

In 1969, I was attempting to measure the forces exerted on a small, homemade infrared-seeking guided rocket suspended in a wind tunnel. The wind tunnel was fashioned from a length of stove pipe fitted with air compression, straightener, and expansion stages. When suspended from the passenger side of my 1966 Chevy, the wind tunnel achieved an airspeed of 90 miles per hour when the car was driven at 70 mph, the legal speed limit at that time.

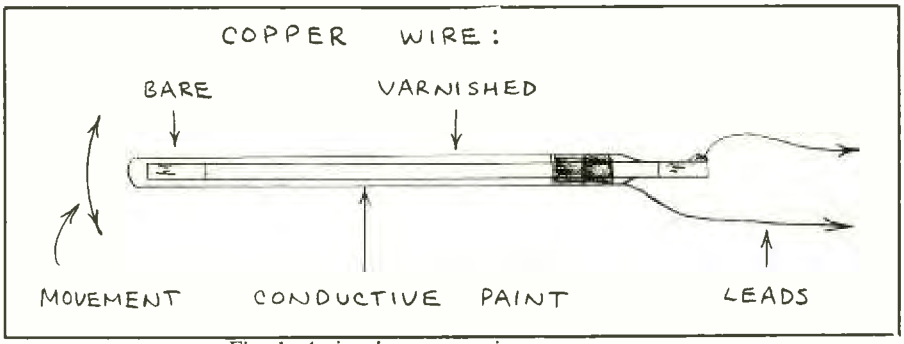


Fig. 1. A simple copper-wire pressure sensor.

One of the force-measuring devices I devised was a short piece of copper wire coated with an insulating film. As shown in Fig. 1, the insulating material was removed from a short length of each end of the wire. The wire was then dipped into a commercially available conductive paint, which was blended with minute particles of copper. After the paint dried, the coating formed a resistor whose resistance could be varied by bending the wire. Separate leads were attached directly to the exposed end of the copper wire and to the conductive paint by means of a strip of tape or small alligator clip.

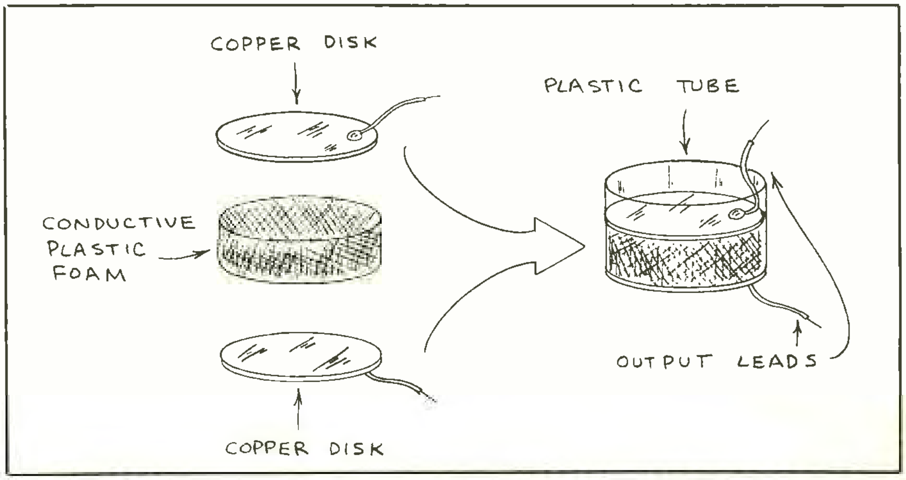
I attempted to use the resistor shown in Fig. 1 to measure variations in the forces on a rocket in my wind tunnel. However, the oscillations of the rocket prevented accurate measurements. Nevertheless, the basic resistor is easy to make and may have other, more practical applications.

Figure 2 shows a do-it-yourself pressure-sensitive resistor made from a small disk of electrically-conductive plastic foam of the kind in which CMOS ICs are sometimes shipped. Conductive foam plastic can also be purchased from Radio Shack and other electronics suppliers.

Contacts for the conductive foam are fashioned from two disks cut from copper foil available from a hobby or craft shop. Unetched, copper-clad circuit board can be used in lieu of copper foil. In either case, the copper surface should be buffed with a pencil eraser until it is shiny to prepare it for soldering. Solder a length of wrapping wire or standard hookup wire to each terminal.

The PSR is assembled by inserting the disks and the conductive foam into a

Fig. 2. A do-it-yourself pressure-sensitive resistor.



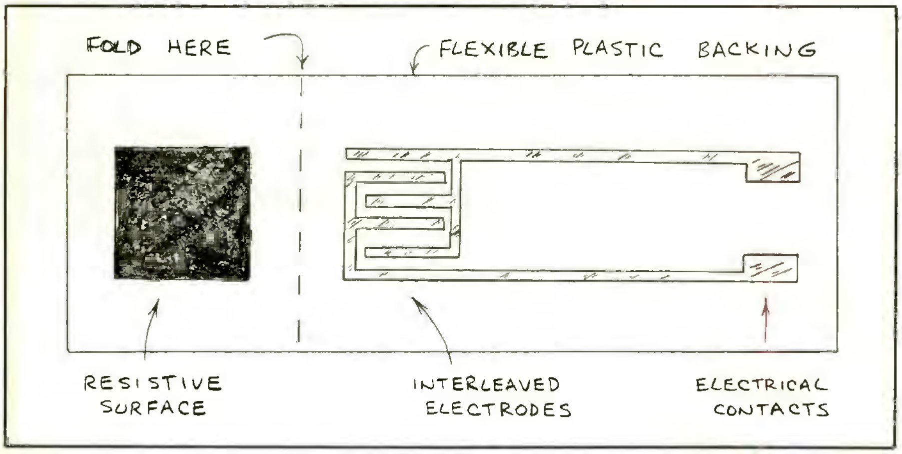


Fig. 3. Details of the Interlink pressure sensitive resistor.

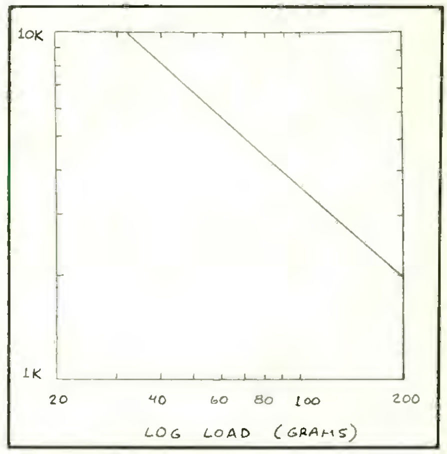


Fig. 4. This is the log-log plot of resistance-versus-force for the Interlink FSR.

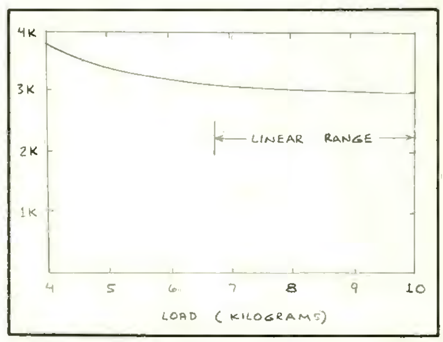


Fig. 5. High-load-value resistance plot for the FSR example in Fig. 4.

small plastic tube as shown. The resistance of the completed device will range from several tens of kilohms with no pressure applied, to a few hundred ohms with pressure applied.

The Fig. 2 assembly is one of many ways to assemble a do-it-yourself PSR. So long as the sandwich configuration of contact-foam-contact is preserved, resistors can be made in many different sizes and shapes. For instance, the contacts and the conductive foam can be formed into a square or rectangular shape. And miniature PSRs can be made by cutting the component materials with a ¼ inch mechanical paper punch and installing them in a small plastic tube like those in which points for lettering pens are sold.

The above are but two of many ways to assemble do-it-yourself PSRs. A third simple PSR can be made by mounting a spring on the control handle of a slide resistor. Though sensitivity might not be as good as that of other methods, results will be repeatable. Back in 1958, one of the first radio transmitters launched in a model rocket used just such a device for an accelerometer. I remember watching that launch from a field near Colorado Springs along with a crowd of high school model rocket enthusiasts and our dads.

Commercial PSRs

Many different kinds of commercial pressure-sensitive resistors are available. For instance, Vernitech (300 Marcus Blvd., Deer Park, NY 11729) makes a potentiometer-type PSR that incorporates an infinite-resolution potentiometer. This device offers a linearity of within 0.3%.

Also available are various kinds of electromagnetic and piezoelectric pressure-sensitive resistors. For information about manufacturers, see one of the electronics trade directories at a good technical library or inquire at companies that represent various electronics manufacturers.

To my knowledge, the least-expensive commercial PSRs are manufactured by Interlink Electronics, Inc. (331 Palm Ave., Santa Barbara, CA 93101). Figure 3 is a drawing of one kind of resistor made by Interlink Electronics. The company labels this device a Force Sensing Resistor or FSR. Three FSRs can be purchased from the company by sending $5 plus $1 for postage and handling to the address given above.

The FSR in Fig. 3 is printed on a thin sheet of clear, flexible plastic which can be easily cut with scissors. Referring to Fig. 3, on the left is a square-shaped deposit of material that has a moderately high resistance. On the right is a pair of interleaved electrodes brought out to two terminals. In operation, the side of the FSR that has the resistive coating is folded over the interleaved electrodes. When the resistive coating is squeezed against the electrodes, a variable resistance appears across the two terminals.

Figure 4 is a logarithmic plot of the resistance of an Interlink Electronics pressure-sensitive resistor versus an applied force. When the load applied to the FSR ranges from about 5 to 12 kilograms per square centimeter, the straight line log-log relationship plotted in Fig. 4 becomes the simple linear relationship shown in Fig. 5. Note how, at least over this range, the change in resistance with respect to the applied load is very small.

Incidentally, both Figs. 4 and 5 are adapted from "Force Sensing Resistors," an application note published by Interlink Electronics. Among the applications for FSRs listed in this note are point-contact graphic tablets for computers, theft detectors, robot grip sensors, musical keyboards, musical drum pads, and theft detectors.

Application Circuits

It's quite easy to demonstrate operation of a pressure-sensitive resistor with the help of a simple circuit. Both circuits that follow use the symbol, suggested by Interlink Electronics, the pressure-sensitive resistor shown in Fig. 6.

Figure 7 is a simple tone generator using a 555 timer chip configured as an astable oscillator. Oscillation frequency is governed by the values of *R1, R2* and *C2,* calculated as follows: $f_{(approx.)} = 1.44/[(R1 + 2R2)C1]$.

With the values given in Fig. 7 and when *R1* is an Interlink FSR, the tone generated ranges across the entire audio spectrum when the FSR is squeezed between thumb and forefinger. Tone range can be easily altered by changing the value of *C1*. Increase *C1*'s value to reduce the frequency range, and vice-versa.

Figure 8 is a straightforward comparator circuit that permits a pressure-sensitive resistor to switch an LED on or off as the pressure on the resistor is varied. Circuit switching threshold can be altered by changing the setting of *R3*. As shown, the circuit switches the LED on when the pressure on *R1* is increased. If the input connections to the op amp at pins 2 and 3 are reversed, the LED will switch off as the pressure on *R1* is increased.

The circuit in Fig. 8 can easily be modified. For instance, the LED can be replaced by a small relay, such as Radio Shack's No. 275-004, if *R5* is eliminated and the collector of *Q1* is connected directly to the positive supply.

Computer Applications

Computer graphics tablets, such as the KoalaPad™, employ a surface coated with a resistive material. Applying pressure to the surface of the pad gives an output signal that represents the location of the touched region.

Simple pressure-sensitive resistors also have computer applications. For example, any of the homemade pressure-sensitive resistors described above can be connected to the joystick input(s) of computers designed to accept variable-resistance (potentiometer-style) joysticks. In this manner, joystick functions can be achieved simply by pressing on a pressure-sensitive resistor, rather than by moving a joystick handle.

Several joystick circuit configurations are used by various computer manufacturers. In the simplest configuration, each joystick pot functions as a two-terminal variable resistor. This is the approach used in IBM's PC*jr*. A somewhat more complicated approach connects one side of the pots in a joystick to a positive voltage and the other side to ground. This forms a pair of voltage dividers in which the rotor terminals supply a voltage that varies between the positive supply and ground as the stick is moved. This is the approach used in Radio Shack's Color Computer.

Figure 9 shows the internal circuitry of a PC*jr* joystick. The two potentiometers are linear-taper devices with a resistance of 100,000 ohms. Two normally-open pushbutton "fire" switches are included.

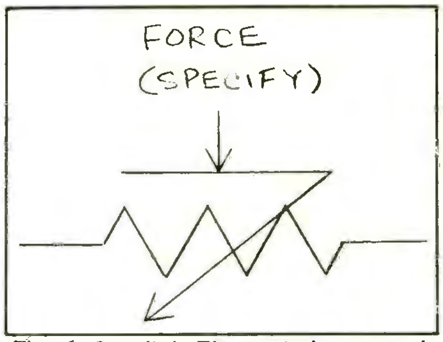


Fig. 6. Interlink Electronics' suggested schematic symbol for the FSR.

Fig. 7. A simple pressure-sensitive tone generator built around a 555 timer.

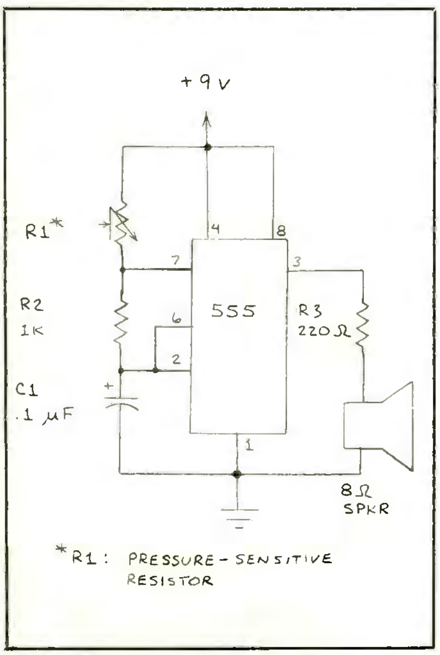
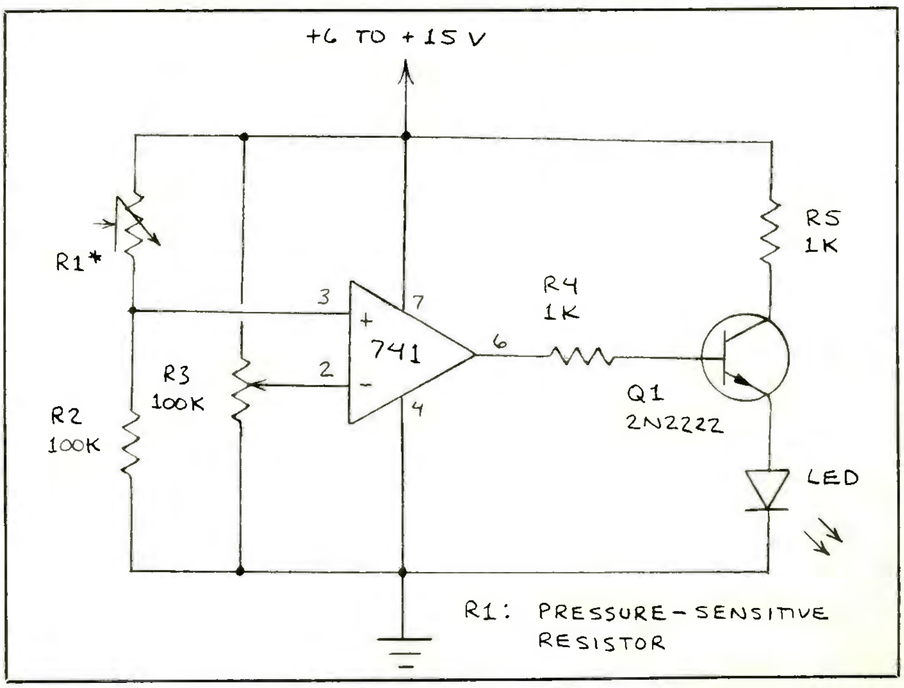


Fig. 8. A simple pressure-controlled comparator built around a 741 op amp.



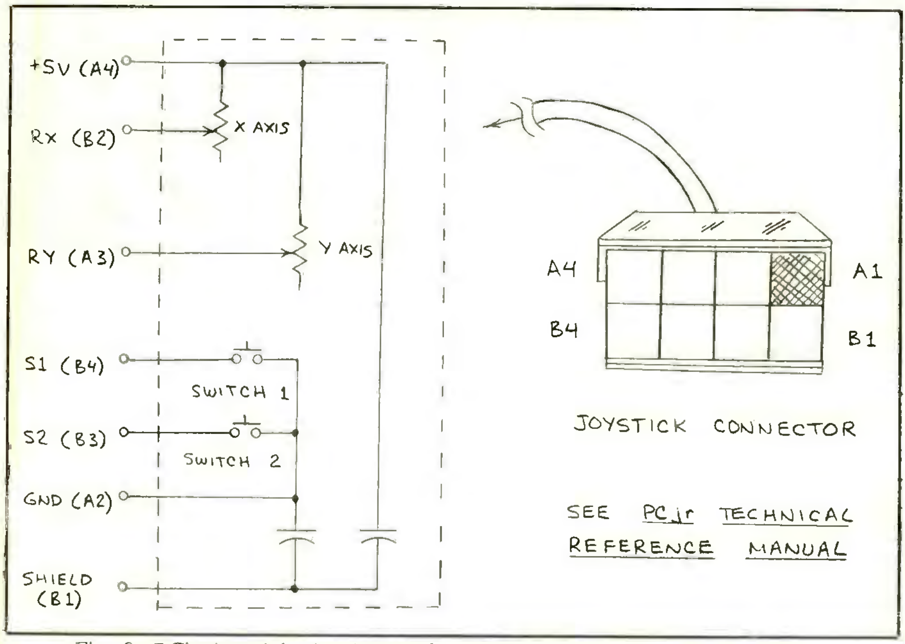


*Fig. 9. PC*jr *joystick circuitry and connector plug schematic diagrams.*

Figure 9 also shows the pin connections of one of PC*jr*'s joystick connectors.

Leads from a PSR can be connected directly to the joystick of the PC*jr*, easily done with a Wire Wrap tool. Alternatively, one or two miniature phone jacks can be added to a joystick to permit the resistors to be connected to the joystick itself. I used the latter approach, since the Berg-type connectors used in the PC*jr* are hard to find.

In either case, it's important to know that noise coupled into the joystick ports can cause erratic operation. That's why the joystick cables are shielded. For this reason, keep the leads to the pressure-sensitive resistor short or use two-conductor shielded cable and ground the shield.

This PC*jr* program will display the joystick value of a single pressure-sensitive resistor connected to the x-axis potentiometer:

```
10 CLS
20 X = STICK(0)
30 LOCATE 10,20
40 PRINT X
50 GOTO 20
```

When used with an Interlink Electronics force-sensing resistor, this program emphasizes the low range of joystick values (from about 3 to 15).

The following program permits an FSR to move a dot back and forth across the screen:

```
10 SCREEN (1)
20 CLS
30 X = STICK(0)
40 X = 10*X
50 Y = 20
60 PSET (X,Y)
70 PRESET (X,Y)
80 GOTO 30
```

Since the FSR works best with low joystick numbers, line 40 multiplies the retrieved value by 10. This provides the *x* coordinate for a horizontal line across the computer's display. As the FSR is alternately squeezed and released, a small dot moves back and forth along this line in 10-pixel increments.

If you have a Color Computer, you can connect one or more pressure-sensitive resistors to its joysticks if you first add a single fixed resistor in series with each sensing resistor. Connect the free end of one resistor to + 5 volts (available at the joystick port) and the free end of the remaining resistor to ground (also available at the joystick port). The junction of the two resistors then becomes the voltage divider output for the CoCo joystick port.

The value of the fixed resistor depends

on the resistance range of the pressure-sensitive resistors. Try values of from 1000 to 100,000 ohms. You can also experiment with which resistor is connected to +5 volts. For initial experiments, connect the free end of a fixed 1000-ohm resistor to ground. Connect the PSR's free lead to +5 volts.

Here's a listing that displays CoCo's joystick values:

```
10 CLSO
20 PRINT @ 133, JOYSTK(0);
30 PRINT @ 138, JOYSTK(1);
40 PRINT @ 148, JOYSTK(2);
50 PRINT @ 153, JOYSTK(3);
60 GOTO 20
```

Caution: Exercise care when attaching pressure-sensitive resistors or any other components to the joystick inputs of a computer. You may damage the computer, void its warranty, and disqualify it for repair by the manufacturer. Since digital computers use MOS integrated circuits that are susceptible to permanent damage caused by electrostatic discharge, remove any charge on your body by touching a grounded object. For best results, follow the precautions recommended for handling and working with CMOS ICs. Finally, use caution to avoid exposing yourself to the possibility of electrical shock while working with a line-powered computer.

Going Further

Pressure-sensitive resistors have numerous applications, many of which have yet to be fully developed. Experimenters can play an important role in developing new applications for these devices, since they can be easily assembled from common materials or purchased at low cost.

For more information about pressure-sensitive resistors, see the FSR application note published by Interlink Electronics. Also see "Making Your Own Pressure-Sensitive Resistors" (*Computers & Electronics,* Nov. 1982, p. 124). Thomas Henry of Transonic Laboratories wrote a brief application article on the subject titled "Conductive Foam Forms Reliable Pressure Sensor" (*Electronics,* May 19, 1982, p. 161).

If you wish to find out more about connecting PSRs to the joystick ports of personal computers, several references that cover the general subject of joystick interfacing will prove useful. One of the best is *TRS-80 Models I, III & Color Computer Interfacing Projects* by William Barden, Jr. (Sams, 1983, Chapter 23). Various kinds of joystick interfaces suitable for use with PSR resistors are also given in *Forrest Mim's Computer Projects* (Osborne/McGraw-Hill, 1985). You should also carefully review the documentation provided with the computer you plan to use. Especially important are the technical reference manuals available for machines like the PC*jr* and the Color Computer. **ME**