FEATURE

Experimenting With "Homemade" Pressure Sensors

by Donald Wilcher

Forces surround our environment on a constant basis. Forces provide the motion necessary to transport humans, animals, automobiles and communications from one point to another. Physicists are constantly studying this provider of motion to better understand how our society interacts with these forces. Engineers are also interested in forces to see how bridges, automobiles and electricicyl/electronics are affected by this parameter. One form of force that affects such systems as robots, automobiles and airplanes is pressure.

The discussion that is to follow will describe how pressure can be detected and processed through electronic means to indicate the amount exerted upon an object. Besides detection and control circuits being described, an explanation on how to build a "homemade" pressure sensor using common parts will be presented as well.

Homemade Pressure Sensor/Construction And Operation

A pressure sensor is a device capable of detecting an exerted or applied force. The force in the case of this discussion is mechanical in nature. To further explain this definition, a force exerted in a downward direction on to an object causing it to move is known as a "pushing" or an external force. Every object that rotates or moves in a linear path utilizes such a force. The homemade sensor that will be explained shortly is capable of detecting a pushing force. The sensor that I constructed, depending upon the amount of force applied to it, ranges from several hundred kilo-ohms (no pressure) to a few hundred ohms (maximum pressure). The resistance range was measured using an ohmmeter.

To construct such a device is relatively easy to do. The basic component for this sensor is a piece of conductive plastic foam used to provide anti-static protection for CMOS (Complementary Metal Oxide Semiconductor) transistors and integrated circuits. The sensor is simply a sandwich consisting of conductive foam between copper foil conductors. The size of the sensor can have a diameter ranging from a pencil eraser to a silver dollar. Copper foil and related material can be purchased from a hobby and craft store. Figure 1 shows the construction of a homemade pressure sensor. If copper foil is not available, an un-etched copper-clad circuit board or two pennies can be substituted. In both cases, the copper should be buffed to prepare it for soldering. A length of small diameter hookup wire will be soldered to each copper piece. The conductive plastic foam is available from many sources. If you don't

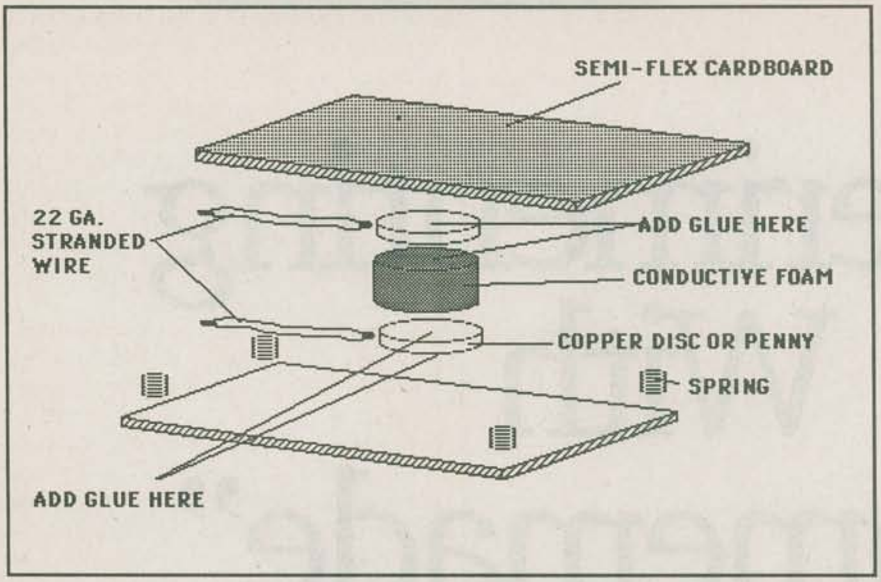

Figure 1. Construction of a Pressure Sensor Pad

happen to have any of this material lying around your lab or workbench, try an electronic supplier or university that purchases ICs in volume.

As discussed earlier, to verify that your sensor is assembled correctly, attach an ohmmeter to the device and by exerting a downward force onto the sensor note the change in resistance readings. With no pressure applied to the device, several hundred kilo-ohms should be displayed on the ohmmeter. As you apply more force, the reading should decrease. If you're unable to obtain such readings, visually inspect the sensor for poor solder connections and assembly of parts. If the sensor looks ok, check the setting of the ohmmeter for proper scale selection and measurement.

After verifying that the sensor works, to demonstrate its effectiveness as a pressure "variable" resistor, assemble the pressure sensor to a 1KΩ resistor as shown in Figure 2. With +5V applied across the resistive network and using a voltmeter to read the voltage, exert a force onto the sensor and note the voltage readings. Did the voltage go up or down as more force was applied to the device? The voltage should have increase because less resistance was in the circuit, the current level increased thereby, producing a higher voltage drop. This voltage divider network will be used quite extensively in the Hands On Projects and Experiments section of this article.

Applications

Pressure sensors can be found in circuits and systems that need to detect changes in pressure or force. A good example of this is that of a Load Cell used in electronic scales. Basically, a load cell is a "proving" ring which has pressure or force resistive components mounted inside of it. These resistive devices are wired in a Wheatstone Bridge configuration so that the two sides of the bridge tend to produce opposite changes in resistance. The voltage produced by the unbalanced condition of the bridge is then fed to a conditional amplifier where the signal is processed into a form which can be read in units of lbs. This information is then displayed on an LCD or LED readout. Figure 3 shows the proving ring configuration of the pressure sensors and a block diagram of an electronic scale.

Besides being able to tell how much force is produced by an object, pressure sensors can be used as safety devices in industrial applications. Pressure mats are quite often used in manufacturing and assembly facilities. Their purpose is to detect if a worker is present in a machine work envelope or zone. If a worker is detected in this zone via a pressure mat, the process equipment or machinery will be energized but will not initiate a machine cycle until the operator pushes the "START" cycle button. On the other hand, if an operator has not been detected the machine will be de-energized; therefore, few injuries will occur due to the pressure mat detecting the weight of a person within the equipment's work envelope.

Another useful and innovative approach to using pressure sensors is to control the speed of a dc motor. By applying pressure to the sensor using your hand, the speed of the motor will be reduced proportionally. Such a method of controlling a motor can be quite useful for power hand tools, blenders, and food processors. Instead of using ordinary switches, pressure sensors would be placed strategically on the unit according to how the hand grips the device. The life of the unit would be extended due to less mechanical wear of common mechanical

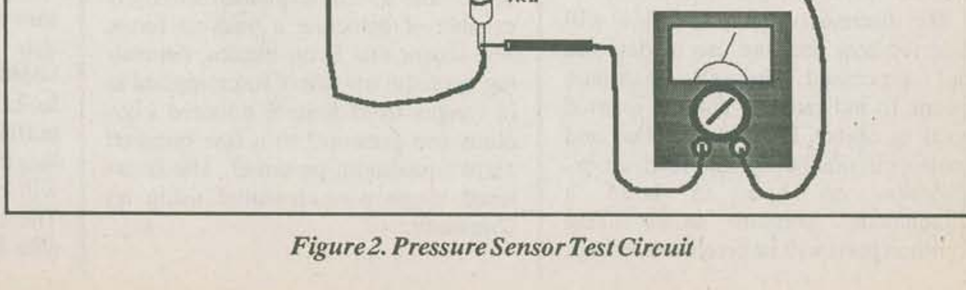

Figure 2. Pressure Sensor Test Circuit

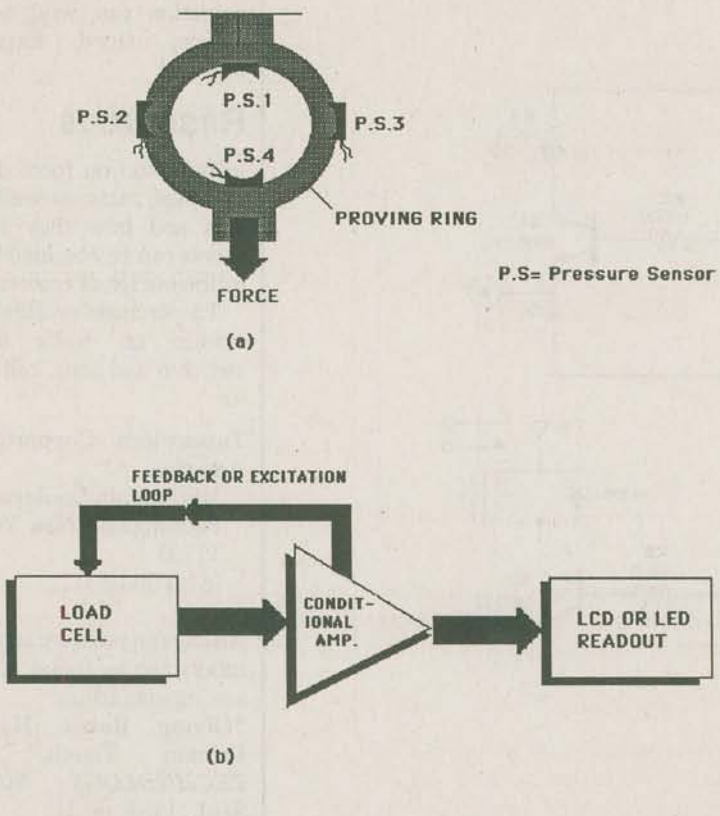

FIGURE 3
(a) Load Cell Configuration
(b) Block Diagram Of An Electronic Scale

switches. As stated before, the amount of force exerted by the hand would reduce motor speed. In the Hands On Project and Experiments section of this article, a circuit for controlling the speed of a dc motor will be described.

Finally, to wrap up our discussion of pressure sensor applications, this topic would not be complete without talking about robots and end effector or electromechanical grippers. In order for a robot to pick up an object, it has to detect its presence. Upon detection, the robot would then determine how large the object is and adjust its end effector or gripper accordingly. The amount of pressure that the end effector would exert on the object, again, is based on the force applied to the sensor and how large the object is. There are two excellent articles that describe how sensors help robots to sense and grip objects. See the **Resources** section for further information.

Hands On Projects And Experiments

Now that our homemade sensor has been assembled and tested, we are ready to construct some inexpensive circuits to investigate the sensor's interaction with outside forces.

Pressure Switch

Figure 4 shows the schematic diagram of a pressure activated switch. In operation, the switching limits of the comparator (configured using a 741 op-amp, P.S.(pressure sensor), R1 and R2) is set by the adjust potentiometer R3. Pressure applied to the sensor lowers its resistance, thereby increasing the voltage applied to the comparator's non-inverting input. Upon this voltage exceeding the reference limit determined by R3, the output approaches to near the positive supply voltage. Transistor Q1 is then turned on and illuminates the LED. The voltage at the anode point of the LED is fed to the transistor-relay driver circuit thereby, turning on Q1. Current flowing through the CE (Collector to Emitter) circuit of Q1 energizes the relay coil (K1) thereby, closing its associated contacts. The IN4001 silicon diode is used to suppress the inductive spikes generated by the energization/de-energization of the relay coil.

In terms of an application, this circuit could be used in a simple burglar alarm where the sensor(s) are placed at key locations around the perimeter of the house. Upon an intruder stepping on the sensor, the alarm will trip thereby (and hopefully) scaring off the assailant. There are many other applications for which this pressure switch could be used. Let your imagination run free with this circuit.

Pressure Sensitive Tone Generator

By applying force or pressure to the sensor in Figure 5, a tone of predetermined frequency would be generated. P.S., 1MΩ resistor and the .001µF capacitor establishes the timing and frequency of the tone heard through the speaker. If an oscilloscope is connected at pin 3 of the 555 timer and ground, the two waveforms illustrated in Figure 6 would be displayed. With no pressure applied, the output would be displayed as the top waveform of Figure 6. As more pressure is applied, the frequency would increase and the tone higher in pitch. This output response is illustrated as the bottom waveform of Figure 6. With this capability, this circuit would provide an audible alarm if the amount of weight of a preset value of a part in an industrial process control application was exceeded. As discussed in the previous circuit, see what other practical applications this circuit can be used in. Try changing the resistor and capacitor values and note the difference in output tones produced by this change.

Speed Controller For DC Motors

As discussed under the Applications section, the pressure sensor could be used to control the speed of a dc motor by the amount of force exerted on the

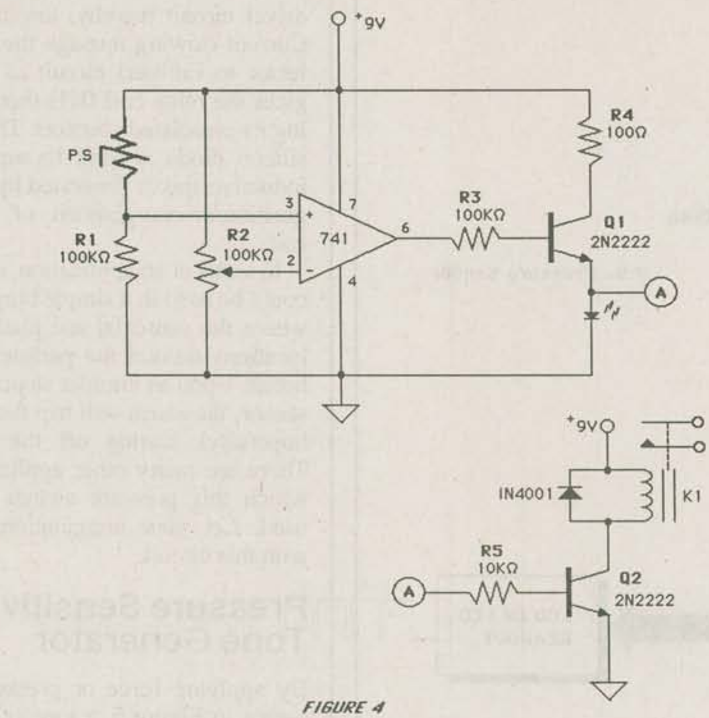

FIGURE 4
Pressure Switch

device. Figure 7 shows the circuit for a DC Motor Speed Controller. The 555 timer is wired as an astable or free running multivibrator circuit. As described earlier, P.S., 1MΩ resistor and the .001μF capacitor provide timing and frequency selection for the circuit. The output signal from pin 3 of the 555 is coupled to the transistor-motor driver circuit via 330Ω resistor. NOTE: When using transistors to drive dc motors, check the electrical specifications of the transistor to assure it has the current handling capabilities that the motor draws. Figure 8 shows the output waveforms measured between pin 3 of the timer chip and ground. Note that with no pressure applied, the square wave's time response between on and off is quite long. This condition would then allow the motor to run at maximum speed. But as more pressure is exerted, the time responses between on and off cycles is short, therefore, the speed of the motor is reduced.

Conclusion

It is hoped that the applications and circuits discussed here will spark new ideas for the homemade pressure sensor. So in closing, experiment, learn, have fun, and last but not least, let your circuit designing imagination run wild with this device. Good Experimenting! ! ! !

Resources

Information on force detection switches, mats, as well as sensors and how they apply to robots can be obtained from the following list of resources.

To purchase or obtain information on force detection switches and mats, call or write to:

Tapeswitch Corporation of America
100 Schmitt Boulevard
Farmingdale, New York
11735
(516) 694-6312.

Articles on pressure sensors and robots can be found in the following magazines:

"Giving Robot Hands A Human Touch," ***HIGH TECHNOLOGY*** **Magazine, Sept., 1985, pg 31.**

"Smart Skin: Robot Watch," ***Discover*** **Magazine, April 1990, pg 26.**

A 1 yr subscription to ***ROBOTICS NOW*** newsletter, which has informa-

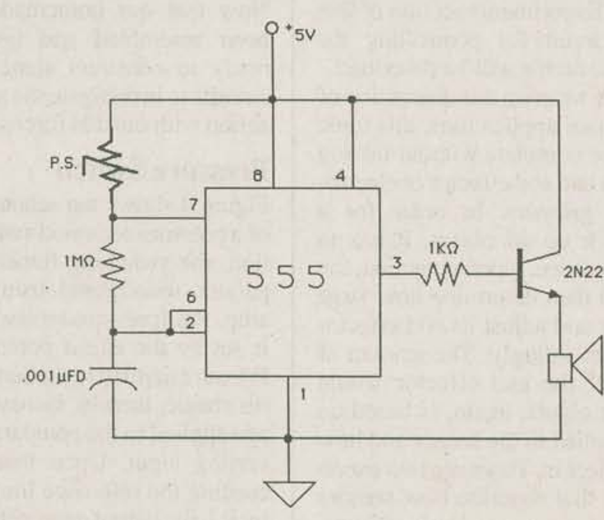

Figure 5. Pressure Sensitive Tone Generator

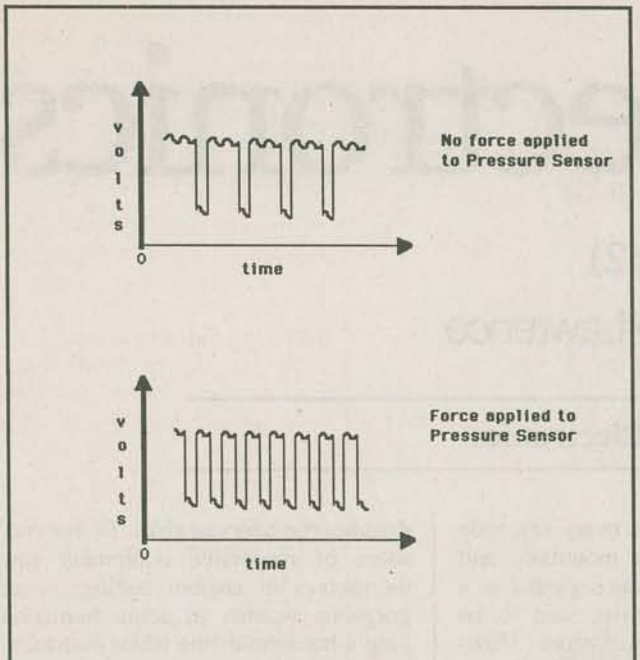

FIGURE 6
Waveform Patterns Generated By The Pressure Sensitive Tone Generator Circuit

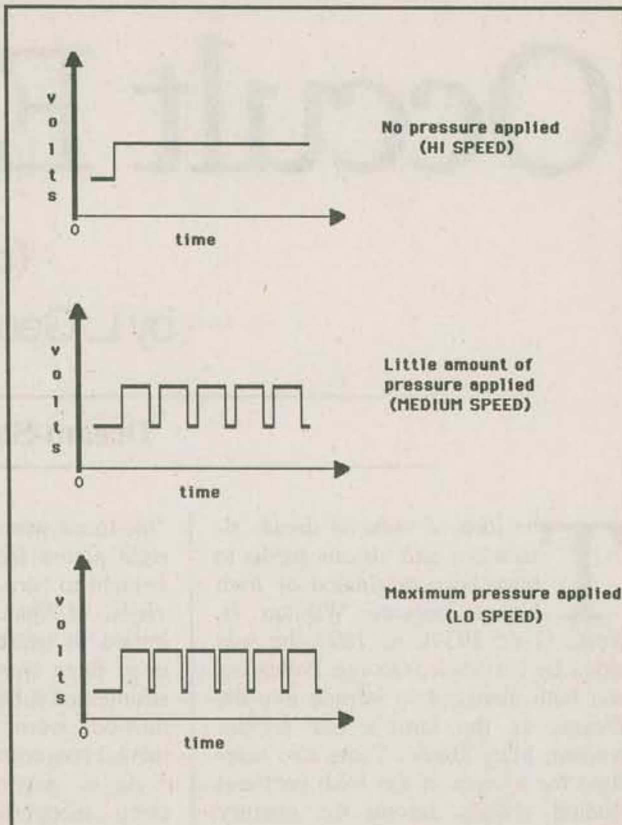

FIGURE 8
Waveform Patterns Generated By The DC Motor Speed Controller Circuit

tion on electronics/computers and how they relate to hobby robots can be obtained from:

Donald Wilcher
Experimental Robotics Group
19940 Archer
Detroit, MI 48219
(313) 533-7251. ❐

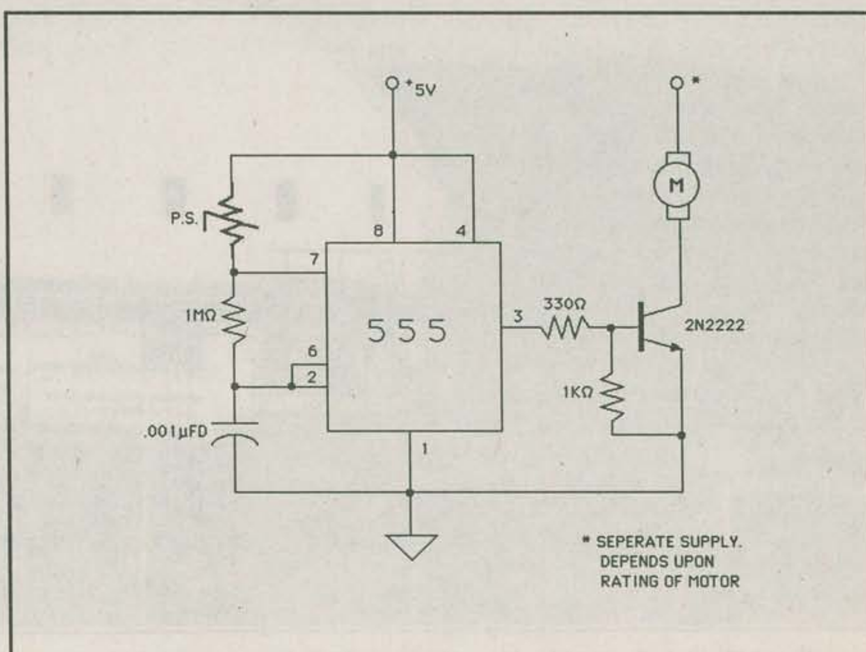

Figure 7. A DC Motor Speed Controller