EXPERIMENTER'S CORNER

By Forrest M. Mims

Experimenting with an Air Pressure Switch

RECENTLY, I learned that an ultrasensitive air pressure switch is available from Edmund Scientific (101 East Gloucester Pike, Barrington, NJ 08007). I immediately ordered one and have been impressed with its capabilities.

The switch, a Honeywell Model PSF 100A, is actuated (closed) by an air pressure of only 0.02 pounds per square inch (psi). This is equivalent to the pressure of about 0.5 inch of water or a gentle puff of air from a distance of a few inches.

You might be able to purchase the PSF 100A directly from Honeywell. Otherwise, you can buy one from Edmund (Cat. No. 41,623) for $7.00, plus $1.30 for postage and handling.

The PSF 100A has two differential control ports—one for low—and the other for high-pressure operation. If one port is at atmospheric pressure (*i.e.*, open), the other will trigger the switch on pressure (high port) or vacuum (low port). If both ports are connected to external gas sources, the switch will close when the pressure difference between the two sources exceeds 0.02 psi.

Fairchild assigns a life of 1,000,000 on-off operations to the PSF 100A. Contact resistance of closed switch is 0.5 ohm.

The major drawback of the switch is its current rating of only 10 milliamperes dc. This means that, in many applications, external buffering is required. We will look at several buffering methods, as well as some practical applications for the PSF 100A shortly. First, let's review some of the applications listed in the Edmund data sheet:

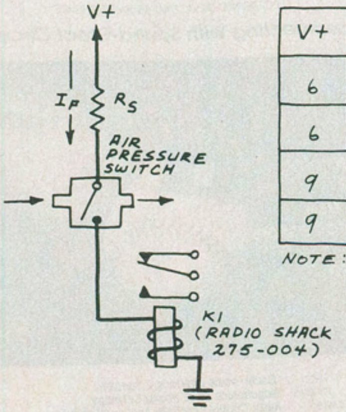
1. Replacement of vane-type flow switches.
2. High-wind detector.
3. Proximity sensor.
4. Counting sensor.
5. Clean-air system pressure-drop detector.
6. Edge sensor.
7. Fan or cooling system failure sensor.
8. Fixed-point temperature detector (in a closed system dependent upon the contraction and expansion of a fixed volume of gas).
9. Respiration rate sensor.
10. Venturi tube sensor.
11. Pressurization sensor for inflatable structures.

These applications in turn suggest others. For example, the high-wind detector idea could be used as a fixed-point airspeed indicator for a model rocket, aircraft, bicycle, or automobile. In each case, the input ports of the sensor require constriction to permit the switch to operate at higher air pressures. Or a higher threshold sensor switch can be used. Honeywell's PSF 100A-3, for example, has a switching threshold of 0.1 psi.

Buffer Circuits for a Pressure Sensor. As long as the current to be switched is less than 10 mA, the PSF 100A needs no buffering. This means the switch can directly actuate LEDs and some solid-state warning devices and alerters. For many applications, however, the rated current capacity of the PSF 100A is insufficient.

Figure 1 shows how to connect a low-current, inexpensive relay to the PSF 100A to increase its switching capability from 10 mA to a full ampere (at 125 volts). Since the relay coil current can safely exceed the 10-mA maximum rating of the PSF 100A's contacts, it is necessary to limit the current flow with an external resistor (R_S). Figure 1 gives the values of R_S for power supplies of both 6 and 9 volts which will allow the relay to pull in without exceeding the 10-mA rating.

I arrived at these values by actual measurements, and you may wish to verify my results. Though the relay coil is specified to have a resistance of 500 ohms, the unit I used actually measured 480 ohms. At 6 volts, this relay pulled in at 5.5 mA and dropped out when the current fell below 4.5 mA. Therefore, the currents given in Fig. 1 provide ample margin for proper operation of the relay.



V+	R_S (Ω)	I_F(mA)
6	270	8.2
6	330	7.2
9	470	8.8
9	680	7.3

NOTE: I_F MUST NOT EXCEED 10mA

Fig. 1. Using a relay to increase current capacity.

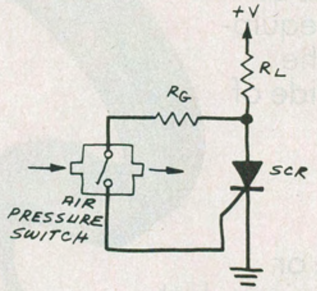


Fig. 2. An air pressure switch can be used to trigger an SCR as shown here.

Figure 2 shows how the PSF 100A can be used to trigger an SCR. The pressure switch is simply inserted in the SCR's gate circuit. Resistor R_G should provide ample SCR gate current while limiting the current through the switch.

Incidentally, remember that a triggered, dc-powered SCR stays on even after the gate signal is removed. Only when the forward current falls below what is termed the minimum required *holding current* does the SCR turn off. This occurs, of course, when the load is temporarily disconnected. It also occurs on the negative transition of an ac voltage.

Optoisolating the PSF 100A will electrically isolate the sensor from the circuit being controlled. Figure 3 shows how the PSF 100A is connected to the LED portion of a LED-phototransistor optoisolator (also called an optocoupler).

Current-limiting resistor R_S must be selected to limit the current through the LED, and therefore the PSF 100A, to less than 10 mA. The appropriate series resistance can be found with the simple formula: $R_S = (V_F - V_{LED})/I_F$, where V_F is the forward voltage, V_{LED} is the LED forward voltage, and I_F is the desired current in amperes.

GaAs LEDs having a forward voltage from 1.2 to about 1.8 volts are used in most optoisolators. Inserting a typical V_{LED} of 1.5 volts and a desired I_F of 5 mA into our formula gives the following values of R_S for a range of forward voltages:

V_F	R_S
3	300
4	500
5	700
6	900
7	1,100
8	1,300
9	1,500
10	1,700
11	1,900
12	2,100

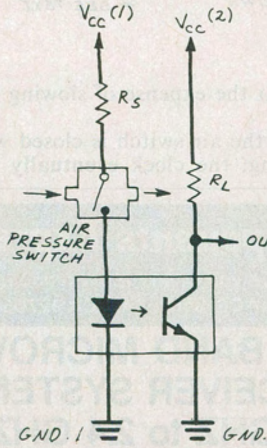


Fig. 3. The air pressure switch can be isolated from the controlled circuit by an opotoisolator.

Application Circuits. Having explored the operation of the PSF 100A and seen how its contacts can be buffered, we can now use the switch in practical applications. I've designed three circuits with biomedical applications in mind. Remember that these circuits are merely representative of the ways the PSF 100A can be applied. You can use the same techniques for applications of your own.

Puff/Sip Multi-Channel Controller. Several years ago I read about an electric wheelchair that could be controlled by puffing or sipping on one or more tubes connected to air pressure switches. The same method was used to turn on lights and appliances.

Figure 4 shows one way to implement a "puff/sip" controller. The circuit provides up to five channels of on-off control. More channels can be added by expanding the basic circuit.

The CMOS decade counter (*IC2*) is a 4017 with self-contained 1-of-10 output decoding. In operation, a clock formed by two NAND gates in *IC1* repeatedly cycles *IC2* through each of its ten outputs. The five control channels, only one of which is shown in Fig. 4, are provided by adjacent pairs of decoded outputs from *IC2*.

Channel 1 is controlled by pins 3 and 2 of *IC2*. At the beginning of a count cycle, pin 3—the lowest order decoded output from *IC2*—goes high while all other outputs remain low. This turns on Channel 1's ON LED, notifying the operator that the device or appliance controlled by Channel 1 can

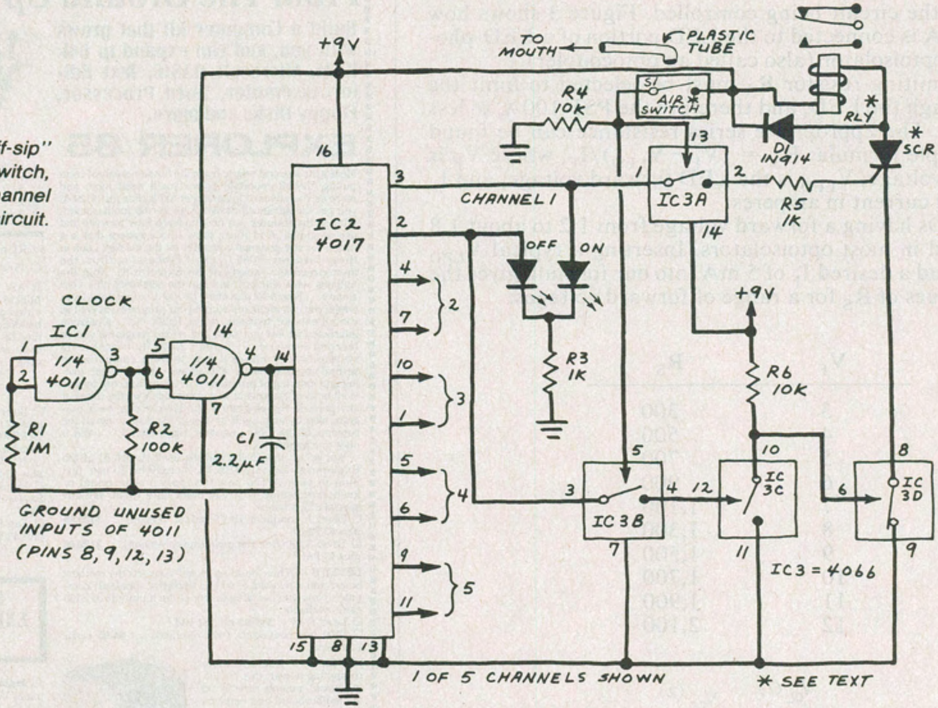


Fig. 4. A "puff-sip" single-switch, multi-channel controller circuit.

be turned on by puffing or sipping on the plastic tube connected to the circuit's single PSF 100A air switch. Depending upon the value of *C1*, the operator has up to a second to operate the air switch. If more time is required, the value of *C1* can be increased at the expense of slowing down the control cycle.

Whether or not the air switch is closed when Channel 1's ON LED is glowing, the clock eventually advances *IC2* to decoded output two (pin 2). This turns on Channel 1's OFF LED and notifies the operator that the device or appliance controlled by Channel 1 can be turned off by puffing or sipping on the air switch's tube. Again, whether or not the switch is closed, *IC2* continues to advance through the decoded outputs as the clock supplies pulses. If the switch is *not* closed, the controlled device or appliance remains either on or off.

The four transmission gates in a single 4066 analog switch (*IC3*) provide the necessary control logic for a single channel. If the air switch is closed when Channel 1's ON LED is glowing, *IC3A* closes, firing the SCR and pulling in the relay.

If the air switch is closed when Channel 1's OFF LED is glowing, *IC3B* closes. This, in turn, closes *IC3C*. Switch *IC3D* is normally in the closed state due to the voltage drop across *R6*, but when *IC3C* closes, the control pin (6) of *IC3D* goes to ground. This opens the current path through the SCR, turning off the SCR and allowing the relay to drop out.

When *IC2* advances to the next decoded output, *IC3B* and *IC3C* open and *IC3D* is again closed by the drop across *R6*. The SCR can then be triggered by a puff or sip the next time Channel 1's ON LED is glowing.

I used a low-current relay (Radio Shack 275-004) in the prototype of the circuit. The SCR can be any low-voltage, economy-grade unit.

Follow the circuit used for Channel 1 to add additional control channels. The PSF 100A in Fig. 4 should be connected to pins 5 and 13 of each additional channel's 4066. This permits one switch to control all channels. Connect the mouth tube to the switch's HIGH port for puff operation or the LOW port for sip operation.

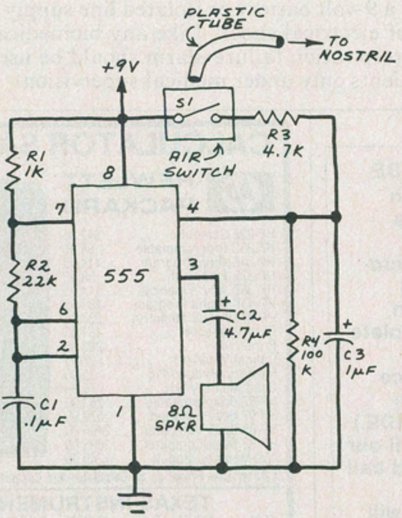


Fig. 5. Respiration indicator provides audible signal.

Caution: Do not exceed the relay's contact ratings. Avoid shock hazards by powering the circuit with a 9-volt battery and carefully insulating connections to the relay's contacts.

Respiration Indicator. The circuit in Fig. 5 provides a brief tone burst each time a person or animal being monitored inhales or exhales. The circuit is a straightforward 555 astable oscillator whose frequency is controlled by *C1*.

When the PSF 100A air pressure switch, *S1*, is open, the 555's reset input (pin 4) is held low by *R4* and the oscillator is disabled. When *S1* is closed, pin 4 of the 555 is made high via *R3* and the oscillator is enabled. Simultaneously, *C3* is charged through *R3* to the battery voltage. When *S1* is opened, pin 4 is held high by the charge on *C3* until it discharges through *R4*. The oscillator is then disabled.

The tone frequency of this circuit can be increased (or decreased) by reducing (or increasing) the value of *C1*. The length of the tone burst can be extended by increasing the value of *C3*, or the extended tone burst can be eliminated entirely by removing *C3*. The circuit will continue to provide a tone for each respiration cycle.

I tested the circuit by taping a length of flexible aquarium

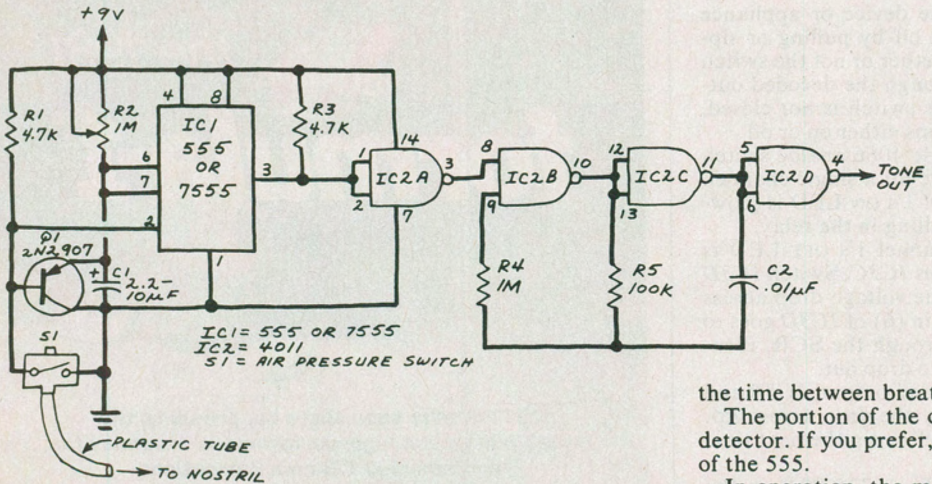


Fig. 6. This circuit monitors respiration and emits a warning tone when time between breaths exceeds a predetermined interval.

tubing under one nostril. When the remaining end of the tubing was attached to the PSF 100A's LOW port, the circuit beeped each time I *inhaled*. When the tube was connected to the HIGH port, the circuit beeped when I *exhaled*. Try both operating modes if you build the circuit.

This circuit provides a simple way for recording the breathing rates of animals for study and evaluation. It can also be used with human subjects such as athletes. It should be used with seriously ill patients only under medical supervision. In any case, power the circuit with a 9-volt battery or an isolated line-operated supply to avoid electrical shock.

Respiration Failure Alarm. When used under proper medical supervision, the circuit in Fig. 6 can save a life. It continuously monitors respiration and emits a warning tone when the time between breaths exceeds a predetermined interval.

The portion of the circuit involving *IC1* is a missing pulse detector. If you prefer, you can use a 7555, the CMOS version of the 555.

In operation, the missing pulse detector is reset each time *S1*, a PSF 100A air switch, is closed. Resistor *R2* controls the maximum time allowed between reset pulses. If the circuit is not reset before the allowed time expires, pin 3 of the 555 goes low. This actuates an astable oscillator made from *IC2B* and *IC2C*. If the 555 is subsequently reset, the oscillator will be disabled. Otherwise the oscillator will provide a continuous warning tone. The frequency of the warning tone can be changed by changing the value of *C2*.

You can test this circuit by using a length of aquarium tubing as described in the previous section. Be sure to power the circuit with a 9-volt battery or isolated line supply to avoid the possibility of electrical shock. Like any biomedical electronic device, the respiration failure alarm should be used with seriously ill patients only under medical supervision.