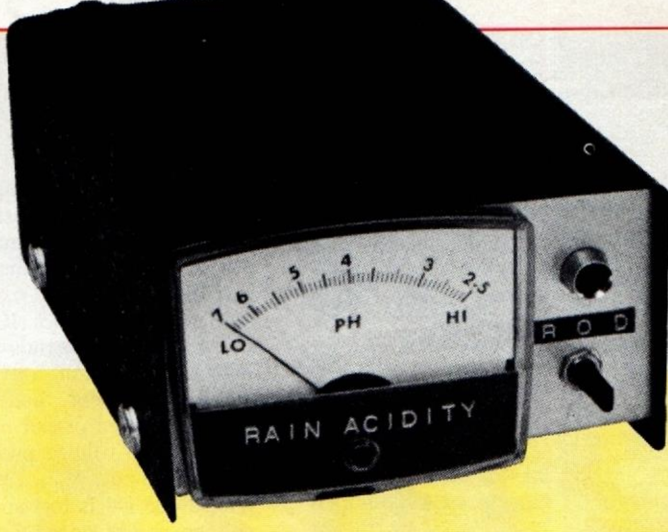
Concerned about acid rain? This inexpensive monitor will keep you informed.



WALTER D. SCOTT

ACID RAIN MONITOR

THE EFFECTS OF ACID RAIN HAVE BEEN widely debated, often with little hard evidence to back up either side's point of view. Actually, it's not difficult to provide hard evidence. A simple one-transistor circuit can be used to sense the acidity of local rainfall (and other liquids). Accuracy is as good as the source used to calibrate the meter. The project can be built for about $30 using all new parts; many of the parts are of the junkbox variety, so with just a little bit of luck the cost could be even less.

The sensor can be mounted in a remote location; it has a built-in solenoid-operated drain valve. The meter indicates acidity in terms of pH, which refers to the concentration of hydrogen ions in a solution. The meter's range is from 7 (neutral) to 2.5 (highly acidic).

How it works

The schematic diagram of the circuit is shown in Fig. 1. A simple bridge rectifier and 12-volt regulator powers the MOSFET sensing circuit. The unregulated output of the bridge rectifier operates the drain solenoid via switch S1. The sensor itself is built from two electrodes, one made of copper, the other of lead. In combination with the liquid trapped by the sensor, they form a miniature lead-acid cell whose output is amplified by MOSFET Q1. The maximum output produced by our prototype cell was about 50 µA.

MOSFET Q1 serves as the fourth leg of a Wheatstone bridge. When sensed acidity causes the sensor to generate a voltage, Q1 turns on slightly, so its drain-to-source resistance decreases. That resistance variation causes an imbalance in the bridge, and that imbalance is indicated by meter M1.

Construction

The circuit is simple, but the sensor must be built exactly as shown for calibration to be accurate. As shown in Fig. 2 and Fig. 3, the electrodes must have a diameter of ¼ inch, and they must be spaced ⅜ inch apart in a plastic funnel with a handle to ensure accurate calibration. The positive electrode is a 1½" length of ¼" copper tubing. The negative electrode is a strip of lead that is formed to the same size and shape as the copper electrode. You should be able to get lead strip from a sporting-goods store; it's used to make fishing sinkers. Otherwise, try a junkyard.

Use flux-less solid-core solder to make connections to the electrodes, and waterproof all exposed joints and wiring. Seal the electrodes in the bottom of the funnel by melting the plastic with a soldering iron, or plug the funnel with epoxy putty. Use a good-quality waterproof cable to connect the electrodes and solenoid to the control box.

The solenoid assembly must be waterproof, otherwise, water may leak into the solenoid housing and cause a short. But first, remove the valve and coat the plunger with grease, preferably silicone, for temperature resistance. Also, coat all metal solenoid parts with acrylic spray or clear lacquer. Then epoxy the solenoid's valve to the funnel stem through a 1" washer with a drain hole. Mount the solenoid in a 35mm film canister or other waterproof container. It may be necessary to trim off some of the valve's exit tube in order to fit it inside the 35mm film canister.

The method of fitting the solenoid to the cap of the film canister and the mount-

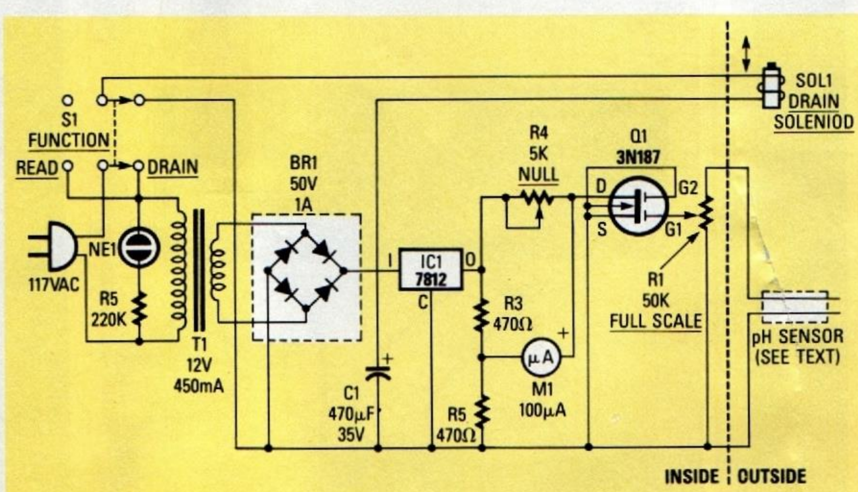


FIG. 1—THE DRAIN-TO-SOURCE RESISTANCE of Q1 varies depending on the acidity of the sample presented to Q1's gate circuit. That variable resistance varies the current flowing through the bridge; that current is proportional to pH.

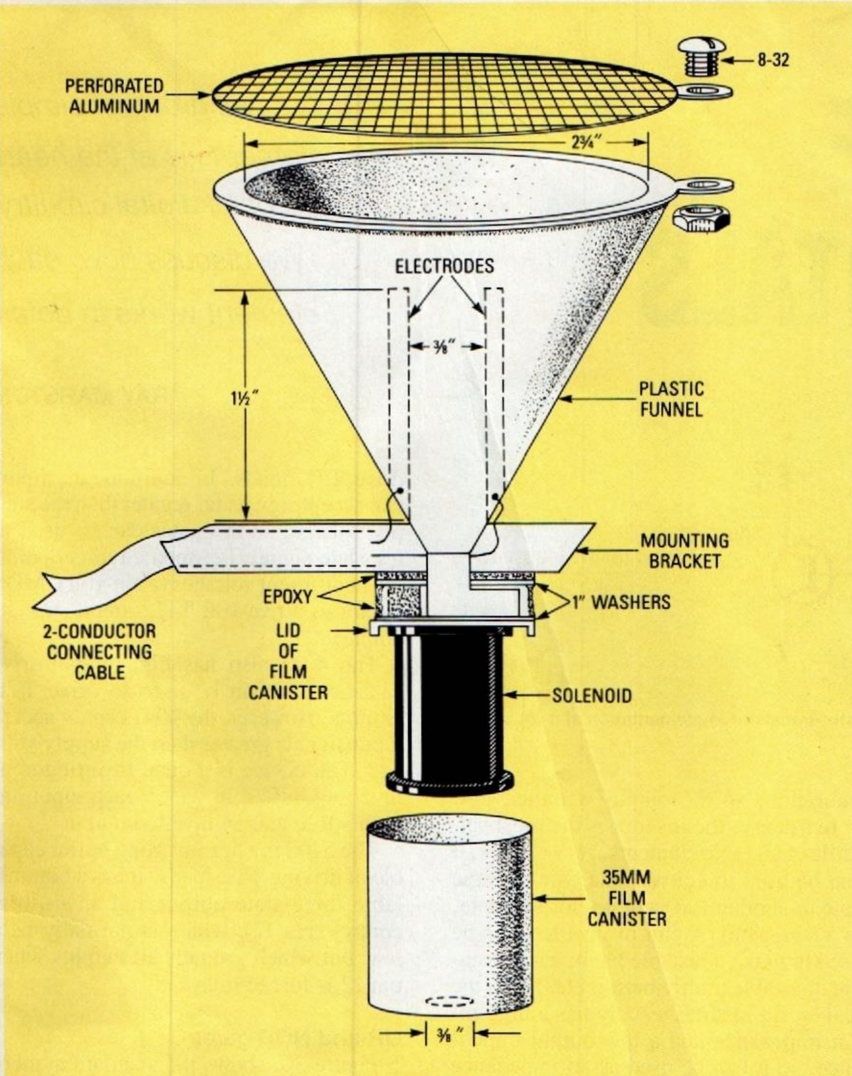


FIG. 2—TWO ¼-INCH ELECTRODES, made of copper and lead, are mounted inside the funnel, spaced ⅜-inch apart. A solenoid valve attached to the mouth of the funnel is used to drain it as necessary.

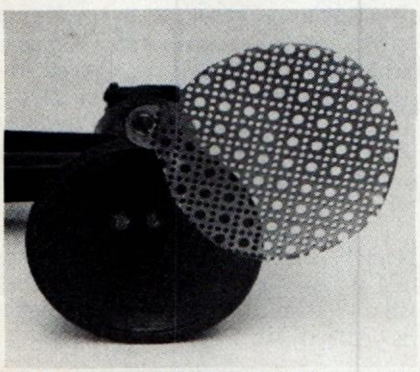


FIG. 3—CLOSE-UP OF THE FUNNEL assembly: the screen keeps foreign matter, which could affect pH, out of the funnel.

ing bracket will depend on the type of solenoid you have. Use epoxy, screws, or both.

As shown in Fig. 4, a swing-away filter cut from perforated sheet aluminum is bolted to the funnel's handle. In addition to preventing drain-clogging or electrode-shorting by air-borne particles, the screen prevents false pH readings that might be caused by pine needles, oak leaves, or other acidic contaminants. You should also coat the filter with lacquer to prevent aluminum-oxide contamination. Plastic screening is also available and may be used.

All parts were mounted and wired point-to-point on a piece of perfboard; the perfboard was then mounted in a case, as shown in Fig. 5.

PARTS LIST

All resistors are ¼-watt, 5% unless otherwise noted.

R1—50,000 ohms, pc-mount, linear potentiometer
R2, R3—470 ohms
R4—5000 ohms, PC-mount, linear potentiometer
R5—220,000 ohms

Capacitors

C1—470 µF, 35 volts, electrolytic

Semiconductors

IC1—7812, 12-volt regulator
Q1—3N187 MOSFET transistor
BR1—50-volt 1-amp bridge rectifier

Other components

M1—100-µA panel meter
NE1—Neon lamp
S1—DPDT, 117-volt, toggle, center off
SOL1—12-volt DC solenoid valve
T1—12-volt 450-mA power transformer

TABLE 1—CALIBRATION

pH	µA
3	82
3.5	76
4	68
4.5	64
5	61
5.5	59
6	56
6.5	53

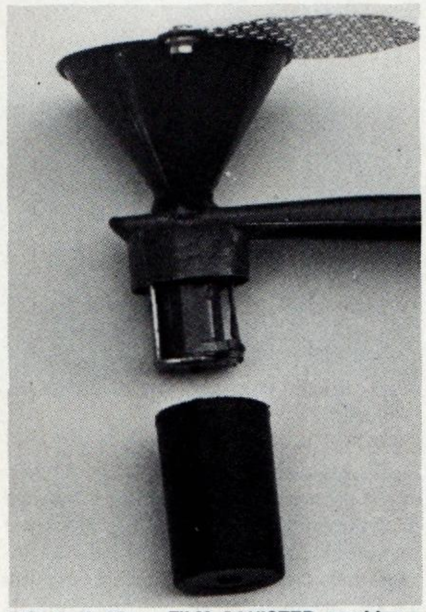


FIG. 4—A 35mm FILM CANISTER provides a water-tight enclosure for the solenoid valve.

Calibration

Our prototype was calibrated against a professional pH meter using precisely-diluted sulphuric acid (which is, by the way, a major ingredient of industrial pollution.) After setting the zero and full-scale points, you can calibrate the meter using Table 1. Otherwise, you can, as we did, measure known solutions with your meter and a professional meter, and mark your meter's scale accordingly.

The first step is to null the meter; 0 µA represents neutrality, a pH of 7. With the sensor connected through the same cable that will be used for the final installation, set R1 for lowest resistance and fill the receptor funnel with distilled water. Adjust R4 until the meter reads exactly zero.

You'll need to connect a 1.5-volt battery in series with a 5,000-ohm linear potentiometer to calibrate the remaining

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points. Connect the circuit to a VOM, and adjust the potentiometer for a reading of 94 μA. Then disconnect the sensor assembly from the main circuit and connect the battery-potentiometer combination in its place. Adjust R1 until the meter reads exactly 100 μA, which corresponds to a pH of 2.5.

The other pH points are established by

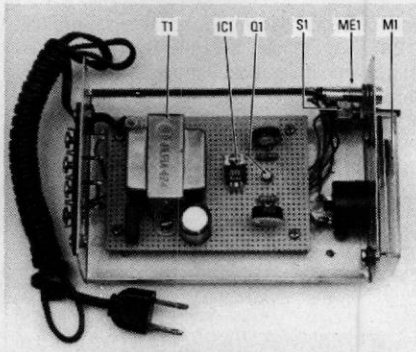

FIG. 5—THE ELECTRONIC COMPONENTS mount on a piece of perfboard; they are connected by point-to-point wiring. The terminal strip provides connections to the remote-mounted sensor and solenoid.

feeding a known current to the circuit and noting the position of the needle. Those positions correspond to the pH's shown in Table 1. If you want to interpolate in-between values, keep in mind the fact that the scale is not linear.

Installation and use

The best location for the sensor assembly is on a post, as shown in Fig. 6, away from trees and buildings. If it's mounted on the side of a house, be sure that the bracket you use is long enough to place the funnel beyond roof or eave run-off.

Don't be alarmed if the meter indicates some acidity. A pH of 6.0 to 6.5 is normal and unharmful. However, environmentalists warn of dire consequences for continuously higher readings.

For example, at continuous pH levels of 5.0 to 5.5, lawns and garden plants will

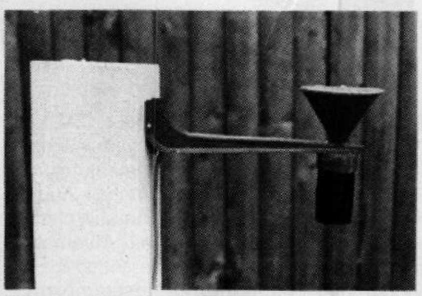

FIG. 6—THE SENSOR ASSEMBLY should be mounted on a long bracket that is screwed to a post. The post should be mounted away from overhanging eaves; and don't mount it under a tree.

begin to turn brown, and soil will need added lime. A pH of 4.5 in ponds and lakes will start killing fish, and, when pH reaches a level of 4.0, a clear blue appearance, although beautiful, will indicate a "dead" body of water. A pH of 3.5 will cause rapid deterioration of painted surfaces. A continuous pH of 3.0 will result in erosion of structural limestone, and entire forests will die. Last, if the meter indicates 2.5 or less, you may be living near an active volcano!

After taking readings from accumulated rainfall, the funnel should be drained, leaving S1 in the DRAIN position only long enough to drain the funnel, as most inexpensive solenoid valves are not designed for continuous duty. Inspect the electrodes several times a year, and if any corrosion forms, swab it off with a weak ammonia-water solution, and then flush the electrodes with distilled water.

For studying the long-term effects of acidity, the output of the meter could be connected to a chart recorder. And the meter may also be used to test your local tap, pond, and stream water by pouring a sample into the funnel. **R-E**