STATE OF SOLID STATE

Measuring relative humidity

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A KNOWLEDGE OF THE RELATIVE HUMIDity at any given time can permit us, or others around us, to make decisions that can affect our health, comfort and personal safety. In addition, the measurement of relative humidity (abbreviated RH) is vital in such areas as food processing, air conditioning, packing, photography, paper and lumber production, and chemical manufacturing. Knowing the RH—along with the temperature—can allow airport operators to predict fog and runway icing. Similarly, farmers and nurserymen can predict dew and frost; and highway safety authorities can forecast dangerous fog and icing on bridges.

Electronic circuits for humidity measurement have rarely appeared in the press because humidity-sensitive transducers have been expensive and seldom available to the electronics constructor and hobbyist. Now, for about ten-dollars-worth of semiconductors and discrete components, and less than sixty dollars for the humidity sensor, you can build a direct-reading electronic hygrometer. The device, described in National Semiconductor's Application Note AP 256, is designed around the PCRC-55 humidity sensor, from Phys-Chemical Research, and a linear 0 to 10-volt DC meter.

The sensor

The electro-humidity sensor has a hygrometric element whose impedance changes with changes in relative humidity. The hygrometric portion of the sensor is on the surface of a chemically treated styrene copolymer plastic wafer. Water vapor is sorbed or desorbed by means of adsorption (the adhesion of molecules to a surface; not the same as *ab*sorption). That

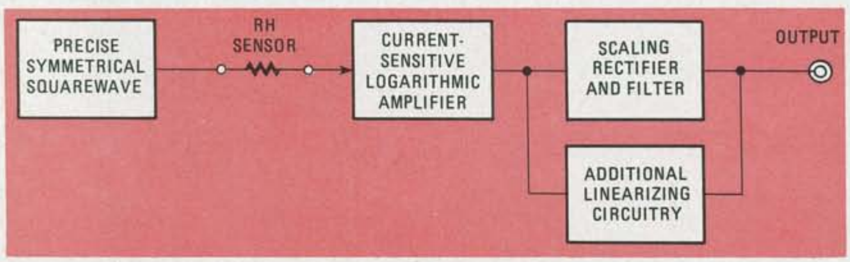

FIG. 1

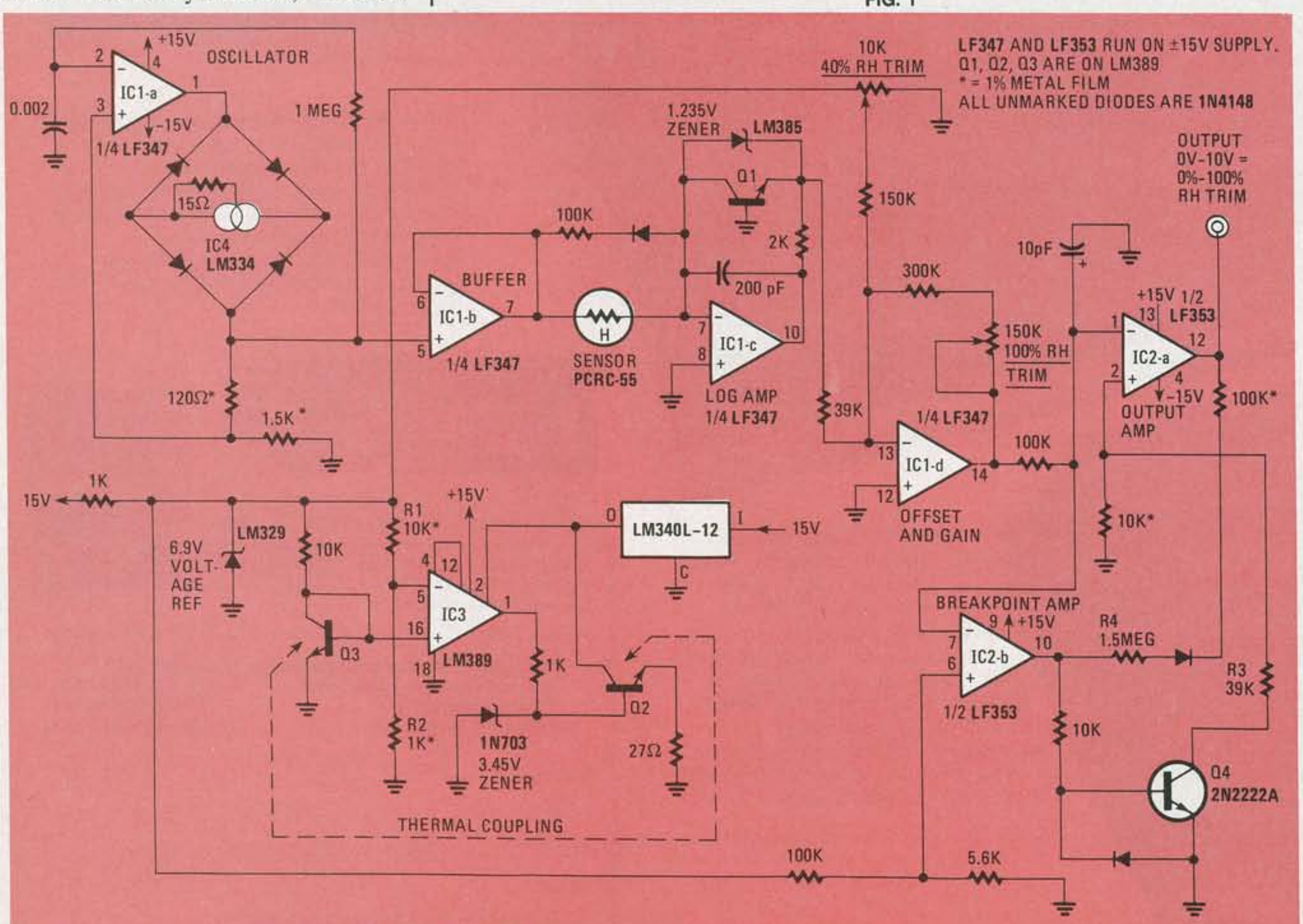

FIG. 2

results in the sensor's having a very rapid response to changes in relative humidity. A single sensor covers the complete range of relative humidity—from 0 to 100%.

The sensor should be excited only by AC voltages (preferably sinusoidal waveforms) of at least 20 Hz with no DC component. Sustained operation with a DC voltage, or AC with a DC component, causes a shift in calibration. The maximum allowable current is one mA.

Figure 1 is a block diagram of the electronic hygrometer. An amplitude-stabilized squarewave drives a precise alternating current through the sensor. The sensor's output current feeds a current-sensitive logarithmic amplifier to linearize the response. The output of the log amplifier is scaled, rectified, and filtered to provide a 0–10-volt DC-output representing RH's from 0 to 100%.

A practical circuit

In Fig. 2, a symmetrical squarewave is generated by IC1-a, an op-amp with positive feedback applied to cause it to oscillate. The combination of constant-current source IC4 and its associated diode-bridge clamps the squarewave output of IC1-a at +8 volts. IC4 has a positive temperature coefficient of 0.033%/°C, which almost completely compensates for the negative 0.036%/°C temperature coefficient of the PCRC-55 sensor. (Mount IC4 close to the sensor so they will be at the same ambient temperature; that way the temperature coefficient of the complete instrument will approach zero.)

The squarewave is buffered, and then fed through the sensor into the summing junction of IC1-c. On negative-going halves of the squarewave, the V_{BE}/I_C characteristic of Q1, in the IC1-c feedback loop, gives the amplifier a logarithmic amplitude-response. On positive-going half-cycles of the squarewave, feedback through the diode to the summing junction ensures that this point remains at a virtual ground so the sensor always "sees" the required symmetrical drive-waveform.

The output of the log amplifier goes to IC1-d, an op-amp used to sum-in the calibration at the 40% RH point, and to provide adjustable gain for trimming the output to the proper level for a 100% RH reading. The output of IC1-d is filtered to DC by the 100K resistor and 10 μF capacitor and then fed to IC2-a, the output amplifier

IC2-b compensates for the sensor's departure from linear response below 40% RH. It does that by altering the gain of the output amplifier when its input drops to about 0.36 volt—corresponding to 40% RH. The inverting input of IC2-b, the breakpoint amplifier, is tied to the non-inverting input of the output amplifier. When the input to those paralleled gates drops below 0.36 volt, the output of IC2-b swings positive; that turns on transistor Q4 to produce the required change in the output amplifier. Transistor Q4 is turned off for RH values above 40%, so linearity is then determined solely by the log amplifier.

Transistor Q1, in the log-amplifier feedback loop, is extremely temperature sensitive and can adversely affect the performance of the amplifier. To compensate for that, the designers at National Semiconductor came up with a unique circuit application. Transistors Q1, Q2, and Q3 are discrete NPN devices on the same substrate as the audio power-amplifier in IC3, an LM389. Transistor Q3 serves as the on-chip temperature sensor while Q2 is used as the on-chip heater. The audio amplifier senses the temperature-dependent V_{BE} of Q3 and uses it to drive Q2 and heat the chip to a temperature (typically 50°C) set by the reference voltage at the junction of R1 and R2. That circuit stabilizes Q1's temperature and makes it immune to changes in ambient temperature.

To adjust the temperature-stabilizing circuit, ground Q2's base, apply power and then measure Q3's collector voltage. Make a note of the ambient room temperature. Now, calculate what Q3's collector voltage will be at 50°C; allowing −2.2mV/°C. Adjust the value of R2 to develop a voltage close to the calculated 50°C potential at IC3's inverting (−) input. The range of values for R2 can be fairly wide because the exact chip temperature is not important as long as it is stable. Finally, remove the ground from Q2's base and the chip should reach the predetermined stable operating temperature within 100 ms. You can check temperature stability by reading Q3's collector voltage while blowing on IC3. The measured voltage should remain constant within 100 μV (0.05°C).

Calibration

To calibrate the electronic hygrometer, connect a 35K resistor in place of the sensor and adjust the 150K 100% RH TRIM pot for 10 volts output. Now, substitute an 80-megohm resistor for the sensor and set the 40% RH TRIM pot for 4 volts at the output terminal. Repeat the 100% RH TRIM and 40% RH TRIM adjustments until they no longer interact with each other. Finally, substitute a 60-megohm resistor for the sensor and select a 39K resistor for R3; that will develop a 2.4-volt output corresponding to 24% RH. It may be necessary to select a particular 1.5-megohm resistor for R4 to minimize jitter in the meter reading around the 24% RH point.

As this is written, the sensor is priced at $57.00, $54.00, and $51.50 each, in lots of 1 to 24, for devices with RH deviations of ±1%, ±1.5%, and ±3%, respective-

UNDERSTANDING ATMOSPHERIC MOISTURE

Water covers over three-fourths of the Earth's surface, and there is always some moisture in the Earth's atmosphere—even over the driest desert. At times, as much as 4–5% of a portion of the atmosphere is water vapor or water in a gaseous state. The variation of the amount of moisture in the air (*humidity*) is influenced by geographic location, temperature, and wind currents. The most important of those is *temperature*. Heat causes some of the molecules of the Earth's surface water to escape into the asmosphere.

Saturation occurs when, at some temperature, the rates of evaporation and condensation balance. The space above the liquid contains all the water vapor it can hold. When that happens, the air is *saturated*. The amount of vapor a volume of air can hold before becoming saturated depends on the temperature; the higher the temperature, the more moisture the air can hold. Air can hold four times more moisture at 70°F than it can at 32°F.

Absolute humidity is a measure of the actual amount of moisture in the air at a given temperature. It is expressed either as the number of *grains* (one seven-thousandth of a pound) per cubic foot of air, or in terms of pressure in millibars or in inches of mercury.

Relative humidity is the moisture content of the air *expressed as a percentage*. It is the ratio of the absolute humidity to the greatest amount of moisture the air is capable of holding at the same temperature. As an analogy, consider a quart bottle that is half full of liquid. The ratio of its actual contents (one pint) to its capacity (one quart) is 50% Similarly, a mass of air that is holding half the moisture possible at a given temperature has a relative humidity (RH) of 50%

When the relative humidity is high (60% to 85%) we say the weather is muggy. Evaporation of perspiration is slow and we feel overheated. We are uncomfortable as it accumulates on our skin and clothing.

When the relative humidity is too low, perspiration evaporates too rapidly and we are uncomfortably chilly. Prolonged exposure causes our throat and nasal passages to become dry. When it comes to personal comfort, temperature and relative humidity are closely related. We enjoy relative humidities in the range of 45% to 55%.

Indoors in the winter when relative humidity is low, the comfort range is around 68°–74°F. Warm-air heating systems dry out the air and we often use humidifiers to raise the moisture content to a comfortable level. On a muggy summer day, we may use a dehumidifier to make indoor air drier. An air conditioner dehumidifies as it cools.

Dew point is the temperature at which air, as it cools, becomes saturated (RH is 100%) and water droplets condense on cool surfaces such as grass and plants. If the dew point is above 32°F, the condensate is dew. When the dew point is 32°F or lower, the condensate forms ice crystals that we call frost. **R-E**

ly. To obtain the latest pricing and data on the humidity sensor, write to Phys-Chemical Research Corp., 36 W. 20th St., New York, NY 10011. Be sure to specify the PCRC-555 because the company has other sensors whose characteristics are not suitable for the circuit that has been described here.

Semiconductor catalog

SGS Shortform '82 is a 72-page catalog listing pertinent application information and technical data on the SGS line of small-signal and power transistors; and linear, low-power Schottky TTL, MOS, and CMOS 4000/4500 logic-series IC's. Also included in a list of SGS data books, technical notes, design notes, and the names and addresses of distributors and reps throughout the U.S.—**SGS Semiconductor Corp.,** 7070 E. 3rd Ave., Scottsdale, AZ 85251.

Instrumentation Amplifier IC

The standard three-op-amp instrumentation amplifier with its more than a half-dozen discrete external components has been replaced by National's LM363. A low-cost, high-performance monolithic instrumentation amplifier, the LM363 (and the LM163 military version) comes in an 8-pin TO-5 package. It requires no external resistors for accurate fixed gains of either 10, 100, or 500 (one gain per package). The device has a super-beta bipolar input stage that yields a very low input-voltage noise, and a high common-mode rejection ratio (CMRR). For added versatility, the internally set gains can be increased by adding external resistors. A 16-pin DIP-packaged device, which should soon be available, will feature pin-strappable gain options of 10, 100, and 1000. The LM363 is priced as low as $9.60 in 100-piece lots.—**National Semiconductor,** PO Box 70818, Sunnyvale, CA 94086.

Super-fast op-amp

The Harris HA-2539 op-amp features a 600V/μs slew rate and a 600-MHz gain-bandwidth product, making it an ideal device for use in pulse- and video-amplifiers, wideband amplifiers, high-speed sample-and-hold circuits, and RF oscillators. Full ±10-volt output swing and high open-loop gain make this Harris device useful in high-speed data-acquisition systems.

Power bandwidth is 9.6 MHz, offset voltage is 3 mV, and input-voltage noise is 15 nV/Hz. The device is packaged in a 14-pin ceramic DIP. The HA-2539-2, manufactured for military use, operates in the −55° to +125°C temperature-range. The HA-2539-5, intended for commercial applications, operates in the 0°C to +75°C temperature-range.—**Harris Corp.,** Analog Products Div., PO Box 883, Melbourne, FL 32901. **R-E**