Gas and smoke detector uses low-leakage MOS transistor

by Al Pshaenich and Roger Janikowski
Motorola Semiconductor Products Inc., Phoenix, Ariz.

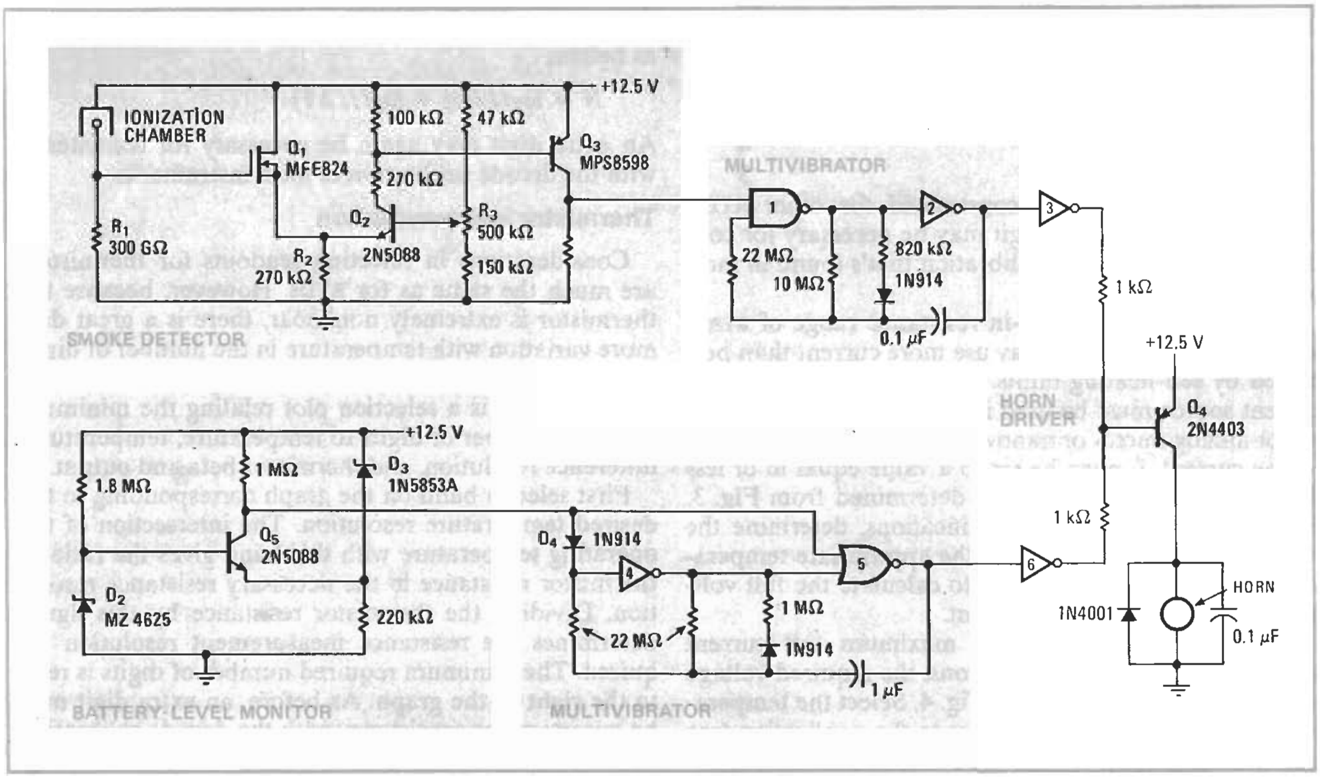
With metal oxide semiconductor field-effect transistors (MOS FETs) that have very low leakage current, combustion gas detectors can now be inexpensively built to run on battery power. This type of detector consists of an ionization chamber and a solid-state amplifier. Besides sounding an alarm in the presence of gas or smoke, the detector warns when the battery is dying.

An ionization chamber consists essentially of a collector electrode extending into a metal chamber, which forms the other electrode. A minute amount of radioactive material in the chamber emits alpha particles that bombard the air molecules and ionize some of them. When an electric potential is placed across the electrodes, the attracted ions produce an extremely small current—in the range of 10 to 30 picoamperes. Combustion-gas molecules that enter the chamber tend to attach themselves to the ions. The enlarged ions move more slowly in the electrical field, reducing the current across the electrodes of the detector.

If the ionization chamber is placed in series with a high-impedance reference, the pair forms a voltage divider. When the current decreases in the presence of gas or smoke, the voltage across the reference element decreases, and a comparator detects the change.

In the battery-operated detection circuit in the diagram, Q_1 and Q_2 form a MOS-bipolar differential amplifier. Q_1 is a high-impedance buffer, which has an input leakage current of about 1.0 pA—at least one order of magnitude less than the chamber current, so that it doesn't load the circuit. The reference resistor R_1 has an impedance approximately equal to that of the ionization chamber in the absence of smoke, thus setting the voltage at the FET gate to about 6 volts. The FET source current is about 30 microamperes, and the gate-to-source voltage is about 2 V, which places the source—the terminal connected to R_2—at 8 V. The threshold control, R_3, is set to back-bias Q_2, typically at about 500 millivolts.

Tests with smoke levels at 2% and 4% obscuration produced a negative voltage shift at the buffer gate of about 2 V and 3 V, respectively. This is enough to turn off Q_1 and turn on Q_2 and Q_3, which applies a logic 1 at one input of the NAND gate 1. This gate, together with inverter 2 and the associated discrete components, forms a nonsymmetrical astable multivibrator, which



Detector. A MOS FET transistor, Q_1, with high input impedance monitors the voltage level at a divider, one half of which is an ionization chamber. Differential amplifier Q_1-Q_2 picks up any decrease in this voltage and triggers a multivibrator that sounds a pulsating alarm. Low battery voltage triggers a second multivibrator that uses the same horn to sound a "beep . . . beep . . . beep" warning.

begins to oscillate when Q_3 turns on. In the multivibrator, the capacitor charges quickly and discharges slowly; while it is discharging, it causes the horn to sound via the inverter 3 and driver transistor Q_4. The horn blows continuously for 2.5 seconds, then turns off for 0.2 seconds while the capacitor recharges. This pulsating alarm continues as long as smoke is present.

A comparator, consisting of one transistor and two zener diodes, determines when the battery is low. Diode D_2 carries only about 5μA, so that the base voltage at Q_5 is about 3 V. The other diode, D_3, couples the full change in battery voltage to the emitter of Q_5. These diodes, which have zener breakdowns of about 4.5 V and 8.2 V, respectively, turn on and quickly saturate Q_5 when the voltage of the expiring battery sags to approximately 10.5 V. This drops its collector from near the battery voltage, maintained by D_4 at the input of inverter 4, to about 2.5 V, which is below the threshold of NOR gate 5. This is part of another astable multivibrator that also blows the horn via the same driver. But this capacitor is larger, and the network charges it slowly and discharges it quickly, so that the horn makes a 1-second toot every 23 seconds. This alarm is not only distinctly different from the smoke alarm, but it also conserves the energy remaining in the battery.

A single complementary-MOS integrated circuit, MC14572, can be used to build the four inverters, one NAND and one NOR, from which the two multivibrators are assembled. The other components in the multivibrators, and those in the smoke-detection and the battery-monitor circuits, are discrete. □