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Build Infrared Sensor

IR "HOTBOX DETECTOR" HAS FANTASTIC SENSITIVITY

HAVING a fire alarm in a house or office is a good idea—sometimes, it's a life saver. However, most commercial alarms use sensors that only operate at some critical temperature before they actuate the alarm. Under these conditions, if a fire starts some distance from the sensor, a lot of building can burn away before an alarm is given. What is needed is a device that can detect the infrared (IR) radiation from a smoldering or unusually hot object. This radiation can be sensed from a distance.

In the realm of burglar alarms, most low-cost units use either a frangible trip wire or a light beam to detect intruders. Trip wires, in many cases, can be seen and light beams can either be seen directly or can be detected by the dust motes in the air. This, or course, nullifies the alarm. What is needed here is an invisible beam of IR and a detector

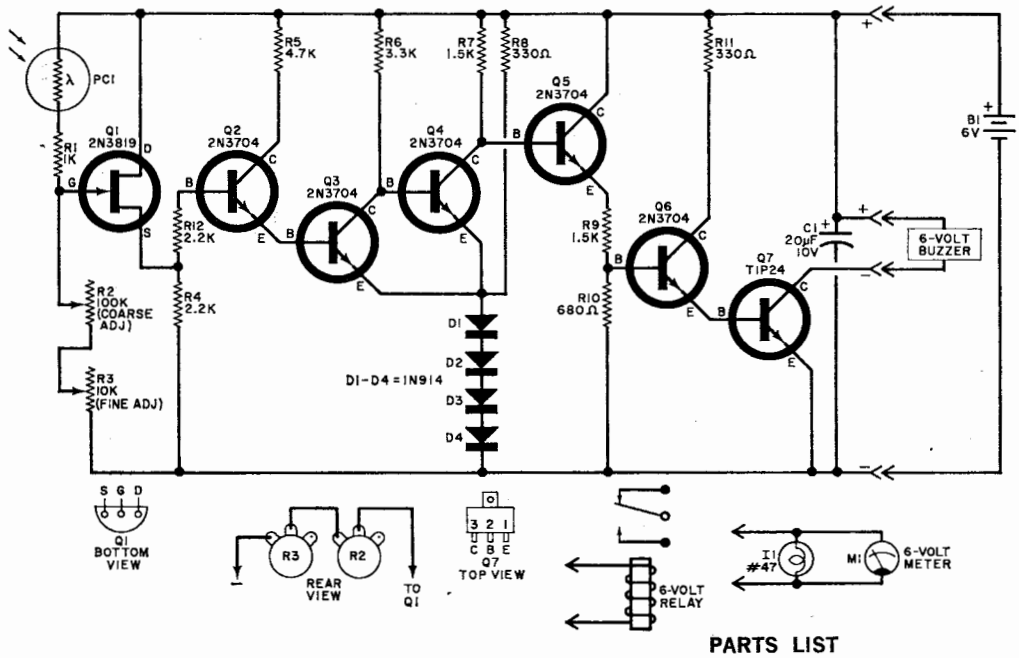


Fig. 1. No power is applied to output indicator until PC1 "sees" a predetermined level of infrared.

PARTS LIST

B1—6-volt lantern battery
C1—20-μF, 10-volt electrolytic capacitor
D1-D4—1N914 diode
PC1—Infrared detector kit, including reflector and filter (Radio Shack #276-035 or similar)
Q1—2N3819 field-effect transistor (see text)
Q2-Q6—2N3704 transistor (see text)
Q7—Power transistor (Texas Instruments TIP24 or similar, see text)
R1—1000-ohm
R4, R12—2200-ohm
R5—4700-ohm
R6—3300-ohm
R7—1500-ohm
R8, R11—330-ohm
R9—1500-ohm
R10—680-ohm
All resistors ½-watt
R2—100,000-ohm potentiometer
R3—10,000-ohm potentiometer
I1—#47 indicator lamp and holder
M1—6-volt meter movement
Misc.—Plastic case and cover (Harry Davis type 260 or similar), 6-volt d.c. buzzer (optional), 6-volt d.c. relay (optional), miniature jack and plug with earphone-type lead, perf or PC board, camera pistol grip (optional), knobs (2), cement or epoxy, mounting hardware wire, etc.
Note—An etched and drilled PC board may be purchased from Excello Circuits Co., 847 W. 23 St., Houston, Texas 77008, for $3.95.

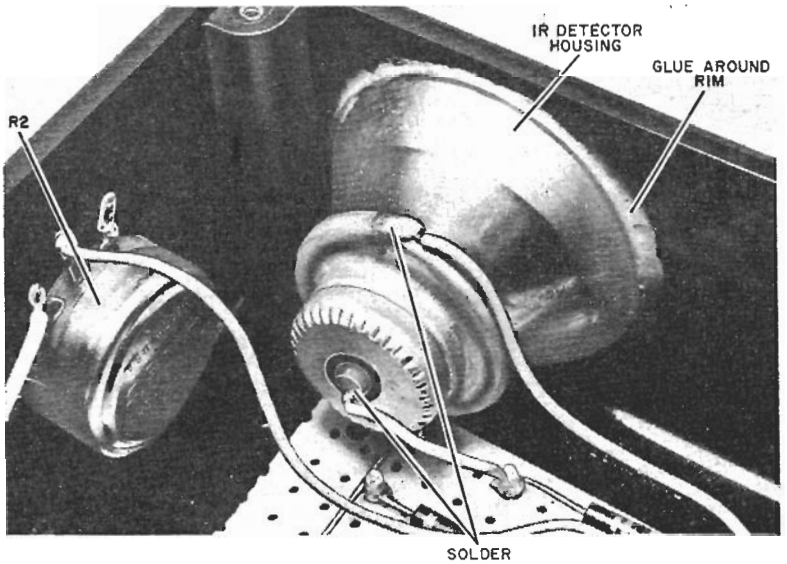
that responds only to IR and not to visible light.

Incidentally, the infrared portion of the electromagnetic spectrum lies between the highest radio frequencies and visible light. Because all material emits IR radiation if its temperature is above absolute zero, the amount of IR radiated is a measure of heat (not necessarily actual flames).

The "Hotbox" IR detector described here not only makes an ideal fire or burglar alarm, but has many other uses. For example, it can check for over-heating conditions in electrical and mechanical equipment or detect the difference between a cloudy and a clear sky. When not serving some truly practical purpose, it can tell you when your soldering iron is up to temperature, turn on your hi-fi or TV when you light a cigarette, or provide a low-cost test instrument for studying the IR properties of various materials.

Because the Hotbox is, by necessity, a low-cost device, its IR range is limited. It responds only to objects that are at least 75°C hotter than the ambient temperature of the detector. Therefore it does not respond to the warmth of a human body. Commercial IR detectors are submerged in cryogenic (extremely low temperature) chambers making the detector sensitive not only to humans, but also to very low levels of IR.

Similar to visible light, IR can be reflected around corners by shiny sheets of metal or conventional mirrors, thus enabling the device to "see" around cor-



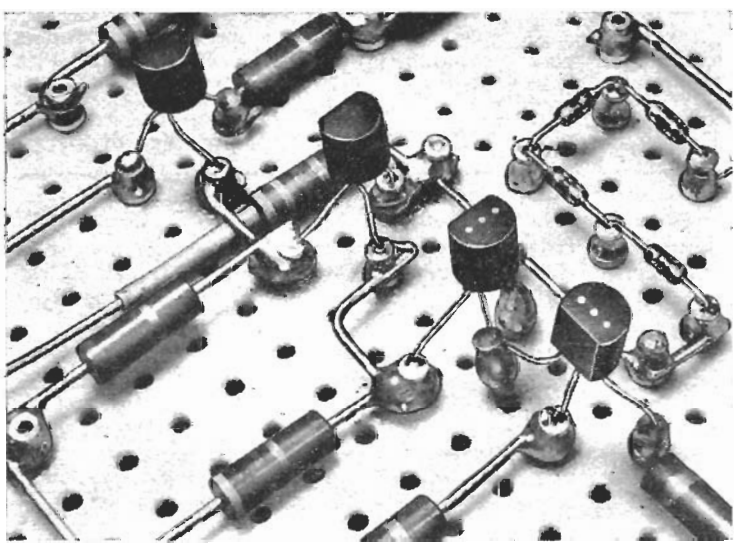
When soldering the lead to the IR detector housing, work fast so that you do not overheat the IR element within the reflector. Other connection is made to bulb tip.

ners if desired. The reflector unit specified in the Parts List for Fig. 1 is as directional as a flashlight, so that the device can be pointed very precisely at the IR source.

Construction. Putting the Hotbox together is simple and straightforward. Lead dress is not critical and the circuit (shown in Fig. 1) is very flexible with regard to resistor values and transistor parameters. In fact, almost any silicon *npn* transistors can be used for *Q2* through *Q6*. Most *n*-channel FET's will work for *Q1*, while almost any *npn* power transistor can be used for *Q7*.

The author used perf-board construction (see photos), although a printed-

This is what good perf-board construction looks like. Note the clean, almost polished look of the solder connections and the neat arrangement of parts.



HOW IT WORKS

The heart of the circuit is a threshold detector composed of transistors *Q2*, *Q3*, and *Q4* and their associated components. Each of silicon diodes *D1* through *D4* has a constant 0.6-volt drop when forward biased with a few milliamperes. Under all conditions, current flows through *R8* and forward biases the four series-connected diodes so that the voltage at the emitters of *Q3* and *Q4* is fixed at 2.4 volts. This fixed voltage establishes the operating point for the circuit.

If the detector, *PC1*, is shielded from IR radiation, *Q2* and *Q3* are turned off, and current flows through *R6* into the base of *Q4*. Thus *Q4* is turned on and appears as a short circuit between its collector and emitter. The collector voltage of *Q4* is therefore close to 2.4 volts.

Emitter follower *Q5* acts as a buffer between the threshold detector and the output stage. Because its base-emitter junction behaves like a forward-biased diode, the emitter of *Q5*, under all circuit conditions, is about 0.6 volt below the collector of *Q4*. When *Q4* is conducting, the emitter of *Q5* is at about 1.8 volts. Voltage divider *R9* and *R10* presents slightly less than one third of *Q5*'s emitter voltage to the base of *Q6*. With 1.8 volts on the emitter of *Q5*, the voltage at the base of *Q6* is about 0.55 volt, which is not enough to turn on *Q6*. Since no current flows through *Q6*, *Q7* does not receive base drive and is turned off. If an indicator is connected in series with the collector of *Q7*, it is not energized as long as *Q7* is in the off state.

Assume now that the voltage at the base of *Q2* increases. This transistor must be conducting in order for *Q3* to conduct. However, this requires a bias of at least 3.6 volts on the base of *Q2* to overcome the emitter bias on *Q3*. When this condition is satisfied, *Q2* and *Q3* both turn on, and the base-emitter junction of *Q4* is bypassed. This turns *Q4* off and its collector voltage jumps from 2.4 volts to about 5.5 volts. The emitter voltage of *Q5* jumps correspondingly from 1.8 to about 4.9 volts. Under this condition, voltage divider *R9* and *R10* provides a forward bias for *Q6*, causing it to conduct. This turns *Q7* on and the output indicator is energized.

Field-effect transistor *Q1* is connected as a source follower with the detector *PC1* and a pair of trimming potentiometers, *R2* and *R3*, determining its gate voltage. The sensitive area of the detector is lead sulphide whose resistance decreases when exposed to infrared radiation. If the detector is shielded from IR and the trimmer potentiometers are adjusted for a *Q1* gate level of 3 volts, then, when *PC1* is exposed to IR, the voltage at the gate of *Q1* goes above 3.6 volts. The remainder of the circuit is then triggered on. Adjustment of the coarse and fine potentiometers determines at what IR level the Hotbox produces an output signal.

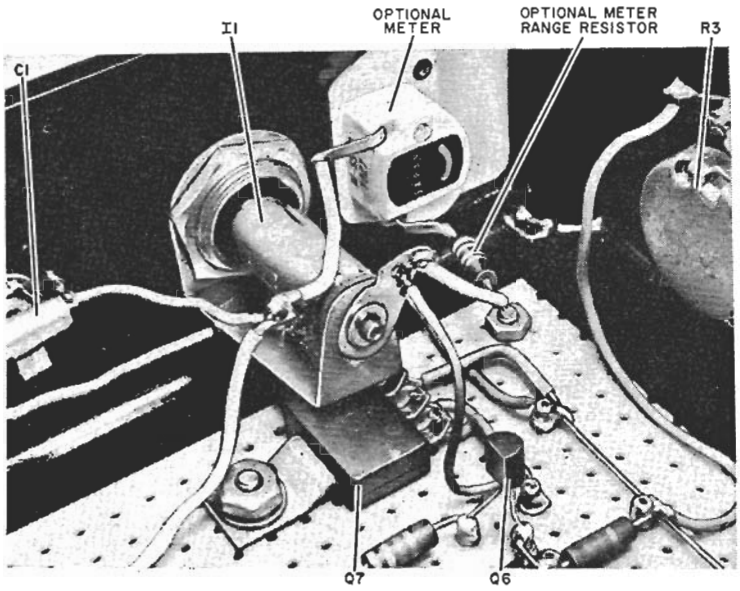
circuit board is available. The components layout for the perf board is shown in Fig. 2.

To prepare the case, use a circle cutter or fine saw to cut a hole in one end of the case slightly smaller than the rim diameter of the IR detector reflector. Secure the reflector to the case using high-quality cement or epoxy. The filter provided with the IR detector must be cut to size, with the protective paper left on it during the cutting process. Cut the filter slightly larger than the diameter of the reflector hole. When you are ready to affix the filter, remove the paper from both sides and glue the filter into place, covering the reflector.

At the top of the case, drill holes for the two potentiometers, *R2* and *R3*. In the end opposite the IR reflector, drill appropriate holes for indicator lamp *I1* and a miniature phone jack for the battery power leads. The author used the type of phone jack and earphone cable and plug usually furnished with imported transistor radios. The battery is carried on the waist belt. If desired, a hole can be cut out for an optional 6-volt meter. This meter is used for daylight indications when the glow of the lamp may be obscured by bright light.

Once the case has been prepared, mount the perf board (or PC board) in the case, using a standoff at each corner. Connect the circuit board to the other components according to Fig. 1. The schematic also shows the correct way to wire potentiometers *R2* and *R3*. One of the connections to the IR detector must be made to the reflector. Use a small file to clean away the protective coating. Tin this area soon after filing, avoiding excessive heating of the detector. If you want to use the Hotbox to trigger an external relay, mount a pair of binding posts near the power input jack. Connect the binding posts in parallel with the indicator lamp.

Checkout. Check all wiring for circuit errors, wrong component installation, and faulty soldering. Assuming that all is well, connect the 6-volt battery to the circuit being careful to get the polarity correct. Aim the IR detector end of the Hotbox so that it does not "see" any incandescent lamp, hot soldering iron, or other source of IR energy. With both *R2* and *R3* completely counterclockwise, the indicator light should be off (and the optional meter should indicate zero). Slowly rotate *R2* clockwise. At some point, the indicator light will come on. Once it is on, back off on *R2* until the light



The optional meter range resistor converts the low-current meter into a 6-volt full-scale indicator. The resistor value depends on the type of meter. The meter reads the voltage drop across I1.

goes off. Now turn *R3* clockwise until the light comes on again. Then rotate *R3* slowly counterclockwise until the light just goes off. The detector is now set for maximum sensitivity. Potentiometer *R2* is used as the coarse control while *R3* is the fine adjustment. The settings of these controls determine at what level the Hotbox responds. If a particular device normally runs hot, set the controls

(*Continued on page* 110)

Fig. 2. Internal arrangement of the detector. The optional camera pistol grip is secured with its own screw and makes portable use very convenient. With it, you can aim the detector where desired.