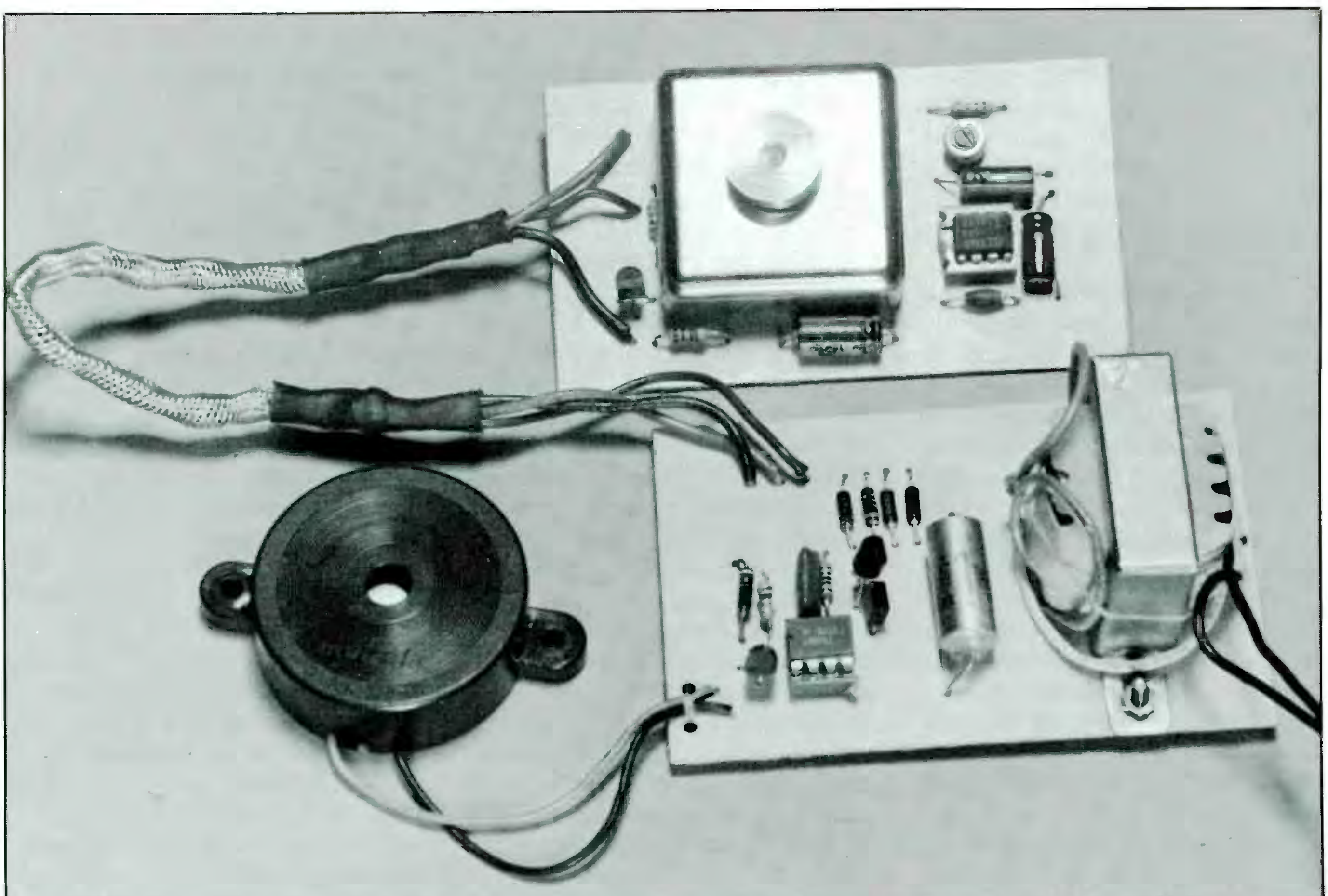
An Early-Warning Intrusion Alarm

Motion-detection system sounds an audible alert before an intruder or vehicle enters your property

By Anthony J. Caristi

Most alarm systems that announce the presence of an intruder do so either at the point he is about to gain entry or has already entered the protected premises. A much more realistic intruder-detection system would be one that senses the approach of a person on foot or in a vehicle at a far enough distance away to let you take appropriate action before he arrives. Just such a system, described here, can easily be implemented using a recently developed infrared detection module from Infrared, Inc. (Parlin, NJ).

Our Early-Warning Intrusion Detector is relatively low in cost and an easy to build infrared motion-detecting system. It is built in two separate sections to permit the ac-operated power supply with audible alerter and the sensor to be installed in physically separated locations. Locating the sensor at a distance from the remainder of the electronics gives the



project its ability to provide early warning of an approaching visitor at the entrance of your driveway or footpath.

If desired, you can add a simple lighting control circuit to the project to provide automatic illumination of virtually any time duration when a person enters or leaves the protected zone. This option is a convenience for invited guests and serves as a deterrent to uninvited individuals.

The sensor used in this project has enough sensitivity to detect the heat radiated by a human body at a distance of 10 to 15 feet. This distance can be increased substantially with a simple single lens optical system. Vehicles, also emitters of large amounts of infrared energy (heat) are also easily detected with or without an optical system. The detector is sensitive enough to respond to the IR energy radiated by a small animal, such as a dog or cat.

About the Circuit

The amount of infrared energy any given object radiates depends on the surface area of that object, its emissivity (how efficient a heat radiator it is) and its temperature. A perfect emitter of IR energy has an emissivity of 1. Most objects will emit less IR energy, while human skin has an emissivity rating of 0.95.

With the foregoing in mind, refer to the schematic diagram of the circuitry used in the project shown in Fig. 1. As you can see, the project consists of the power-supply/sound-generating circuit assembly shown at the left and the remote sensing assembly shown at the right. At the

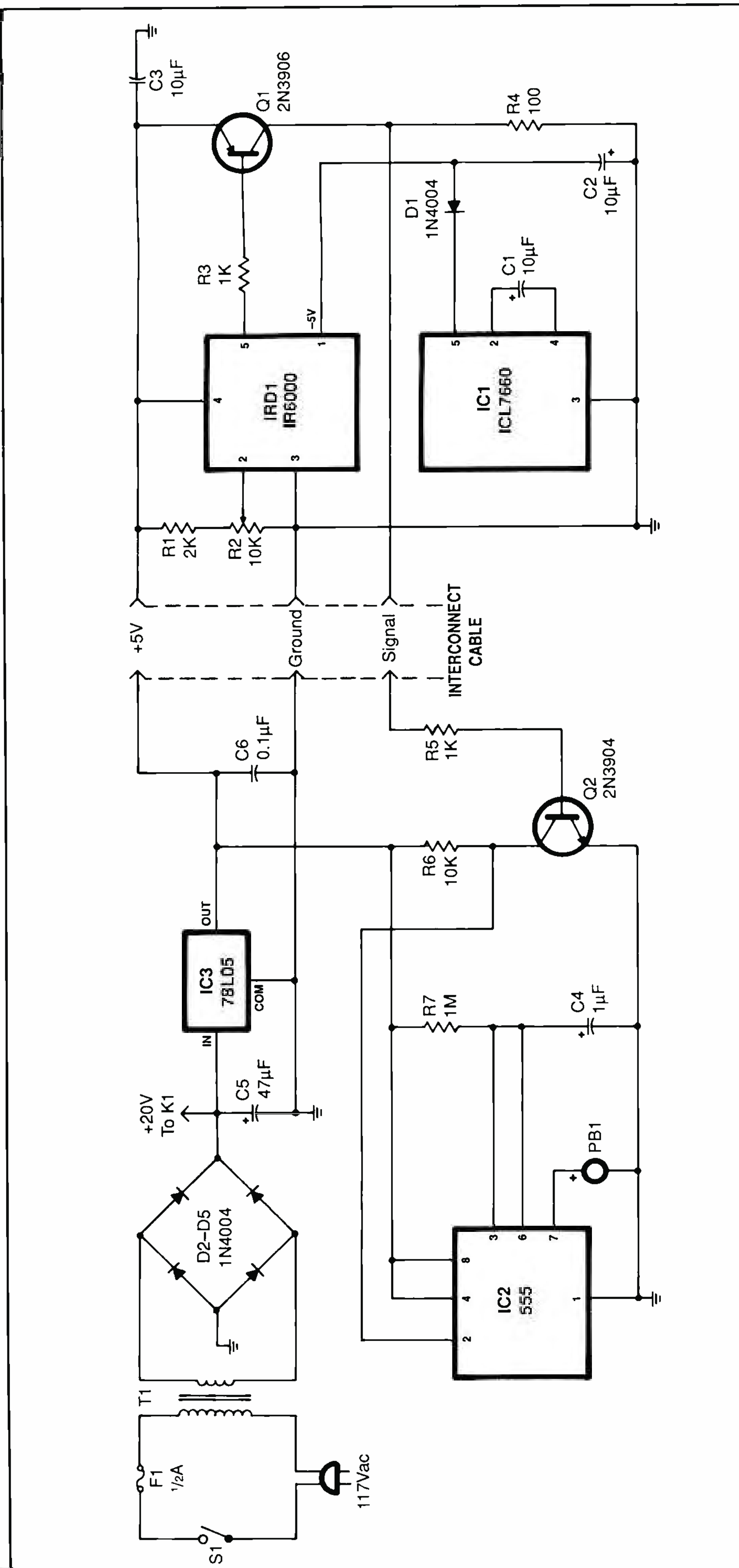


Fig. 1. Complete schematic diagram of the circuitry used in the basic project. The portion shown at the left is the power-supply/sound-generation section, while the portion at the right is the IR detection section.

PARTS LIST

Semiconductors
D1 thru D6—1N4004 or similar silicon rectifier diode
IC1—ICL7660 voltage inverter (Intersil)
IC2,IC4—LM555CN timer
IC3—78L05 fixed +5-volt regulator
IRD1—IRD1000 infrared detecting module (Infrared, Inc.)
Q1—2N3906 or similar pnp silicon transistor
Q2,Q3,Q4—2N3904 or similar npn silicon transistor

Capacitors
C1,C2,C3—10-µF, 16-volt electrolytic
C4—1-µF, 16-volt electrolytic or ceramic disc
C5—47-µF, 25-volt electrolytic
C6—0.1-µF, 25-volt ceramic disk
C7—220-µF, 16-volt low-leakage electrolytic

Resistors (¼-watt, 5% tolerance)
R1—2,000 ohms
R3,R5,R8—1,000 ohms
R4—100 ohms
R6,R9—10,000 ohms
R7—1 megohm
R11—270 ohms
R2—10,000-ohm pc-mount Cermet trimmer potentiometer
R10—2-megohm pc-mount trimmer potentiometer

Miscellaneous
F1—½-ampere slow-blow fuse
K1—12-volt dc relay with 10-ampere or greater contact rating (Radio Shack Cat. No. 275-218 or similar—see text)
PB1—Piezoelectric sound element (Radio Shack Cat. No. 273-065 or similar)
S1—Spst slide or toggle switch (optional—see text)
T1—12.6-volt, 300-mA power transformer (Radio Shack Cat. No. 273-1385 or similar)
Printed-circuit boards or perforate board with holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware (see text); suitable enclosures (see text); sockets for all DIP ICs; fuse holder for F1; ac line cord with plug; three-conductor cable or two-conductor shielded cable (see text); optical system (optional—see text); small rubber grommets; ½-inch spacers; machine hardware; hookup wire; solder; etc.

Note: The following items are available from A. Caristi, 69 White Pond Rd., Waldwick, NJ 07463: Ready-to-wire pc boards for power-supply/sound-generation and detector sections, $17.95; ICL7660, $5; LM555CN, $1.75; 78L05, $2; IRD1000, $39.50. Add $2.50 P&H per order. New Jersey residents, please add 6% sales tax.

heart of the circuitry is infrared-sensing module *IRD1*. This electronic assembly is designed to respond to *changes* in the amount of IR energy that strikes its detecting element.

Contained inside the the *IRD1* module is an infrared detector and signal conditioning circuitry that produces both analog and digital output signals in response to any change in IR energy in the field of view of the detector element. A steady level of IR energy produces no output from the module. Thus, the module can be effectively used in full sunlight where there is an abundance of IR energy.

Radiation produced by moving sources of energy located near the module changes the ambient level being sensed by the detector element. These signals are amplified and passed through an analog-to-digital (A/D) converter inside the module. The output of the A/D converter, a digital signal, is buffered and made available at the digital output terminal of the module for further processing by the circuit.

The logic level at the output of the module remains high as long as there is no variation in the ambient IR energy near the detector element. Should the ambient level be disturbed by the presence of a moving body or vehicle, the logic level momentarily falls to zero.

Since there is always some level of ambient IR radiation changes, such as warm air drafts, a dc reference input to the module is provided by potentiometer *R2* for adjustment of sensor sensitivity. This allows you to set the response characteristic of the detector to the desired sensitivity to obviate any false alarms from sounding.

Since the detector section of the project may be located at some distance from the power supply and sound-generating circuitry, the digital output from the sensing module is passed through *Q1*, which provides low-impedance drive for the connecting cable between the two sections of the project.

The logic level present at the collector of *Q1* is low at all times except when a change of IR energy strikes the detector element. When this occurs, the collector of this transistor generates an output pulse of approximately +5 volts in amplitude. The duration of the pulse is relatively short but is sufficient to trigger the alarm circuit in the power-supply module. When the infrared disturbance in the vicinity of the detector element persists, multiple output pulses are generated.

A bipolar dc power source is required by *IRD1* for proper operation of the infrared sensor. Voltage-inverting chip *IC1* is used to generate a negative voltage source from the +5 volts developed by the power-supply circuitry. A +5-volt input to this IC produces −5 volts at output pin 5, which is essentially equal in magnitude to (but in opposite polarity) the potential fed into *IC1* at pin 8.

In the power-supply/sound-generating section, power transformer *T1* steps down the incoming 117 volts ac to 12.6 volts ac across its secondary. This reduced ac voltage is applied to the bridge rectifier consisting of diodes *D2* through *D5*, which converts the ac into pulsating dc. Capacitor *C5* then smoothes the pulsating dc to pure ac, which is then fed to fixed voltage regulator *IC3*. Regulated +5

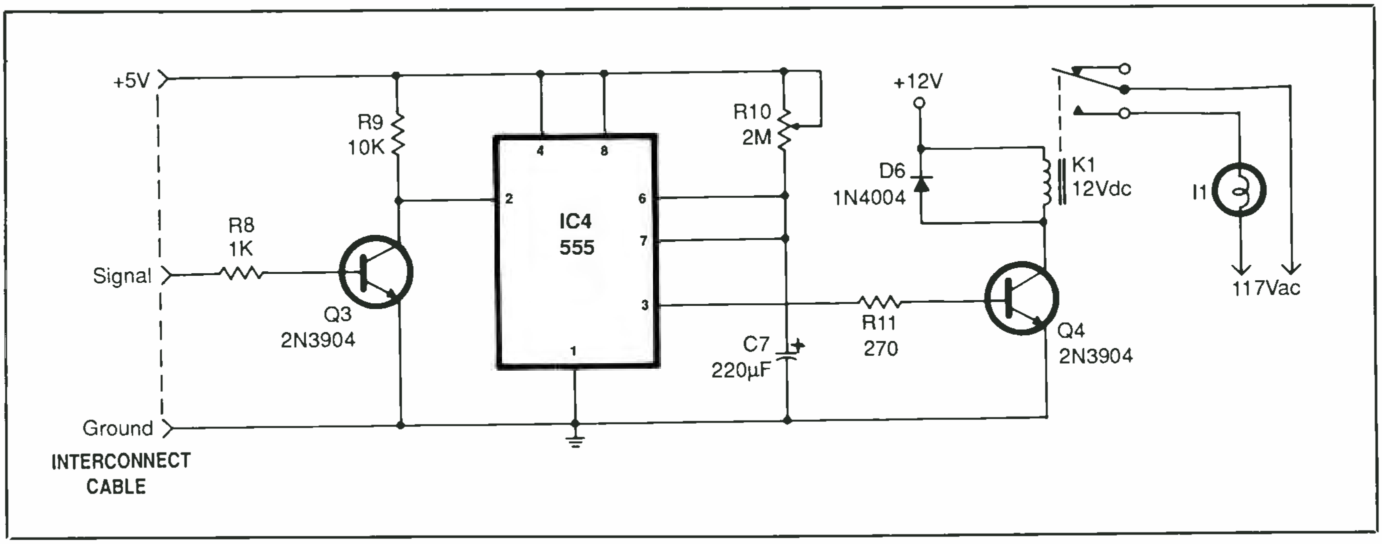


Fig. 2. Circuit details for an optional automatic lighting controller that can be activated by the basic project. You can use this circuit in place of or in addition to the sound-generation portion of the project.

volts at the output of *IC3* is then distributed throughout the circuitry.

The positive logic level produced by *Q1* in the remote section of the project when an intrusion is detected is applied to the base of *Q2*. The negative pulse generated by this action at the collector of *Q2* is applied to trigger input pin 2 of timer chip *IC2*. Note that the 555 timer chip in this application is operated as a monostable, or one-shot, multivibrator.

During standby, output pin 3 of *IC2* is held at zero volt. When a signal is detected by *Q2*, the timer chip is triggered. This causes pin 3 of *IC2* to rise to about +4 volts. At the same time, capacitor *C4* is permitted to charge through resistor *R7*. When the charge on the capacitor reaches about 66 percent of the supply voltage, *C4* suddenly discharges through *IC2*, causing pin 3 to return to zero volt.

Time duration of the output pulse at pin 3 of *IC2* is determined by the RC time constant produced by the values of *R7* and *C4*. With the values specified for these components, the time constant is approximately 1 second. During this 1-second time interval, piezoelectric buzzer *PB1* is energized and provides a 1-second duration that is independent of the pulse width generated by the detector module. Virtually any duration for the sound can be selected simply by choosing values for *R7* and *C4* that will yield the proper time constant.

If you wish to provide automatic area illumination when a visitor or intruder is detected, you can incorporate into the project the circuit shown schematically in Fig. 2. This circuit, which can be used in place of or in addition to the audible alerter, is also built around a 555 timer chip, identified here as *IC4*, operated as a one-shot multivibrator. The timer chip is triggered by the logic high output of the detector section, just as the audible alerter is. The timer circuit has an adjustable time constant that can be set for an on period of up to several minutes, as determined by the setting of potentiometer *R10*.

To obtain long time delays, such as 5 minutes or more, a low-leakage timing capacitor should be used for *C7*. The time constant of the circuit, in seconds, is approximately equal to the product of the *C7* value in microfarads multiplied by the value of the timing resistance represented by the setting of *R10* in megohms. If desired, a fixed value of resistance can be used for *R10*.

Once *IC4* is triggered, its output at pin 8 sends *Q4* into saturation. When *Q4* conducts, it energizes relay *K1*, causing its contacts to close. The contact rating of the relay must be sufficient to safely handle the load represented by the lamp being controlled. (The relay specified in the Parts List has a contact rating of 10 amperes, which will safely handle up to 500 watts of incandescent lighting.) This completes the circuit from the ac line through the lamp used for illuminating the protected area. Note that power for the *Q4/K1* circuit is obtained from the +12-volt line that comes directly from the output of the rectifier bridge before regulation in the power-supply section in Fig. 1.

Construction

As was pointed out in the beginning of this article, this project is built in two separate parts. Each section can be built on its own single-sided printed-circuit board or perforated board that has holes on 0.1-inch centers using suitable Wire Wrap or soldering hardware.

If you wish to fabricate your own pc boards, use the actual-size etching-and-drilling guides shown in Fig.

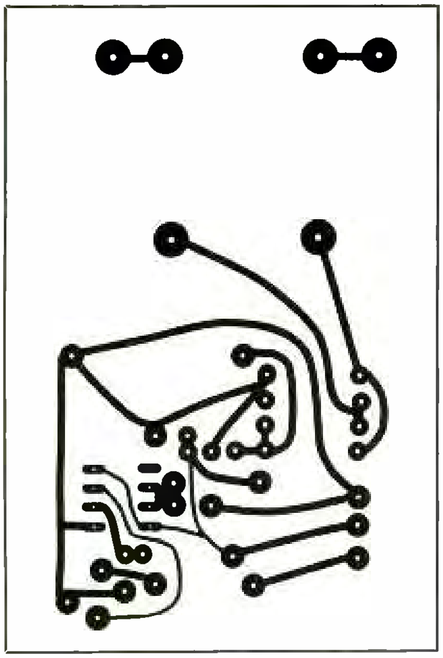


Fig. 3. Actual-size etching-and-drilling guide for printed-circuit board for power-supply/sound-generation circuitry.

3 for the power-supply/sound-generation section and Fig. 4 for the detector section. Alternatively, you can purchase ready-to-wire pc boards from the source given in the Note at the end of the Parts List. Whichever method of construction you decide upon, use sockets for the DIP integrated circuits.

From here on, we will assume you are wiring the circuitry on printed-circuit boards. Place the power-supply/sound-generation board on your work surface, oriented as shown in Fig. 5. Begin wiring this board by installing and soldering into place the eight-pin socket for *IC2*. Do *not* install the any ICs in their sockets during assembly until after you have conducted preliminary voltage checks and are certain your wiring is correct.

Continue wiring the power-supply/sound-generation board by installing and soldering into place the resistors, capacitors and rectifier diodes. Follow up with installation of the trimmer potentiometer, transistor and voltage regulator. Make certain that the diodes and electrolytic capacitors are properly oriented and that the transistor and voltage regulator are properly based before soldering any of their leads or pins into place. Mount the power transformer on the board, plug its primary and secondary leads into the appropriate holes and solder them into place. Then install and solder into place staking pins in the holes for the cable.

Set aside this circuit-board assembly and place on your work surface the detector printed-circuit board, oriented as shown in Fig. 6. Install and solder into place the socket for *IC1*. Then do the same for the resistors, capacitors, diode and transistor. Once again, make sure the diode and electrolytic capacitors are properly oriented and that the transistor is properly based before soldering any of their leads into place.

As you examine Fig. 6, you will note that pin 3 of the *IRD1* detector module is offset by 0.1 inch from the square layout of the pattern. This pin serves as an index for proper positioning of the module on the circuit board. Make certain that you install the sensor exactly as shown before soldering any pins into place. Install and solder into place staking pins in the holes for the cable.

When wiring the project on perforated board, follow the same general component layouts shown in Fig. 5 and Fig. 6. Then refer back to Fig. 1 for wiring details.

If you have decided to incorporate into your project the optional automatic illumination circuitry, wire the components for it on a separate printed-circuit board or perforated board that has holes on 0.1-inch centers using suitable Wire Wrap or soldering hardware.

Make sure the transistors are properly based and that the capacitor and diode are properly oriented before soldering their leads into place. The relay mounts off the board, and the lamp mounts external to the enclosure in which the circuitry will be housed. Again, install and solder into place staking pins in the holes for the cable.

House the two sections of the project (three sections if you are planning to incorporate the optional automatic lighting feature into the project) in their own separate enclosures. The enclosures that house the detector section and optional automatic lighting circuitry must be weatherproof, as must be the portions of cable that are exposed to the elements. The enclosure for the detector must also have a window through which infrared energy can enter it. You can use any type of enclosure for the power-supply/audible-alerter section.

Machine the power-supply/sound-generation section enclosure for mounting the piezoelectric buzzer, circuit-board assembly, fuse holder and switch (the last is an option you can forego to save on the cost of the project) and to provide entry for the ac line cord, three-conductor cable

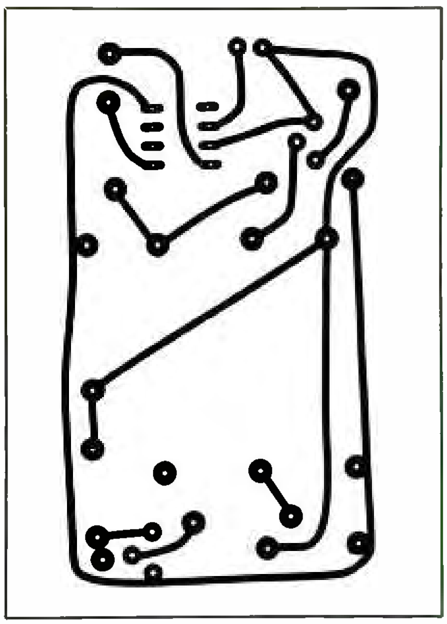


Fig. 4. Actual-size etching-and-drilling guide for printed-circuit board for IR detection circuitry.

and leads of the buzzer. If you drill any holes through metal, deburr them to remove sharp edges and line the holes for the line cord, cable and buzzer leads with small rubber grommets.

Route the free end of the line cord through its hole into the enclosure and tie a strain-relieving knot in it about 5 inches from the end inside the enclosure. Tightly twist together the fine wires in each conductor and sparingly tin with solder.

Mount the power transformer, fuse holder, buzzer and, if you are using it, the switch in their respective holes. Route the leads of the buzzer through their hole. Then crimp and solder the end of one conductor to one lug of the switch. Strip ¼ inch of insulation from both ends of two 3-inch-long hookup wires. If you are using stranded wire, tightly twist together the fine conductors at both ends and sparingly tin with solder. (Do this for all stranded wires you use in the project.) Crimp and solder the opposite ends of one wire to the unoccupied lug of the switch and one lug of the fuse holder.

Plug one end of the remaining wire into one hole labeled 117 VAC and solder it into place. Plug the free end of the remaining line-cord conductor into the other hole labeled 117 VAC, solder it into place and trim away the excess protruding from the bottom of the board. Then plug the free ends of the piezobuzzer leads into the PB1 holes, observing polarity, and solder them into place. Mount the circuit-board assembly into place with ½-inch spacers and 4-40 × ¾" machine screws, nuts and lockwashers.

Next, machine the enclosure for the sensor circuitry by drilling holes for mounting the circuit-board assembly and entry of the three-conductor cable. Also, drill a window hole directly in line with where the sensing element will be when the board is mounted inside the enclosure. Make this hole at least ½ inch in diameter. You can easily accomplish this by drilling a ¼-inch-diameter hole and then enlarge it as needed with a tapered reamer. Deburr all drilled holes to remove sharp edges and line the entry hole for the cable with a small rubber grommet.

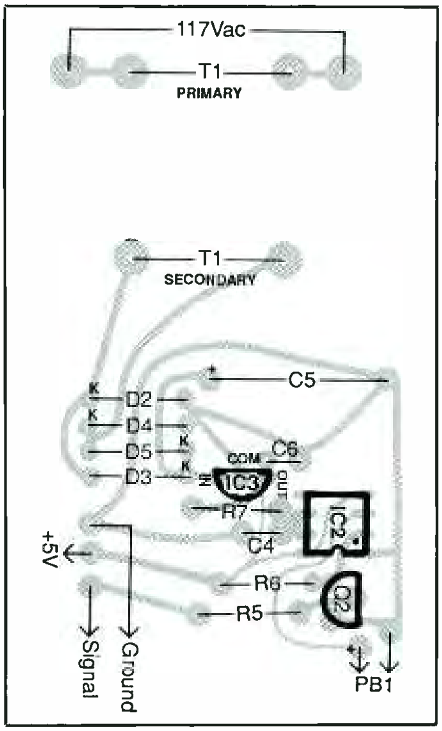


Fig. 5. Wiring diagram for power-supply/sound-generation pc board.

With no assistance, the project will have a range of about 10 to 15 feet for detection of a person. For a vehicle, which normally has a larger infrared "signature" because of the greater amount of heat it gives off, detection range will be slightly greater. If your intended location of the sensor with respect to the target is greater than this, you can enhance the sensitivity of the detector with a simple one-lens optical system, such as the one illustrated in Fig. 7. This will give you a range of up to 10 meters.

A good optional optical system can be had with a plastic Fresnel lens specifically designed for infrared applications, which you can purchase from Edmund Scientific Corp. (Barrington, NJ).

When designing the optical system, you must decide on the focal length of the lens, which can be as little as ½ inch. The lens must be positioned at a distance equal to its focal length from the detector element in the project, as illustrated in Fig. 8. For maximum light-gathering ability, use as large a lens as can be practically installed in the enclosure chosen for your project.

When using a lens, keep in mind that the field of view of the detector element will be reduced to a relatively narrow angle as compared to operation with no optical enhancement. The diameter of the beam is dependent upon the focal length of the lens and the distance between the lens and target. Reducing the field of view of the detector by means of an optical system has the advantage that extraneous IR signals from sources other than the target are less likely to produce false alarms.

When constructing the optical system, secure the lens in front of the detector element at the focal-length distance. If desired, a small metal or cardboard tube the same diameter as the lens can be placed in front of the detector element to restrict the field of view to retain system sensitivity when detecting IR disturbances in the target area while preventing false triggering from extraneous sources.

Whether or not you use optical assistance, it is mandatory that you cover the viewing window you make in the enclosure with glass or clear plastic cemented to the inside surface of the enclosure to maintain a weatherproof condition.

Mount the circuit-board assembly inside the enclosure with ½-inch spacers and suitable machine hardware.

Now machine the enclosure for the optional automatic illumination control circuit by drilling mounting holes for the circuit-board assembly and entry holes for the three-conductor cable and ac cable for the lamp load. Deburr all holes to remove sharp edges and line the cable holes with small rubber grommets. Mount the

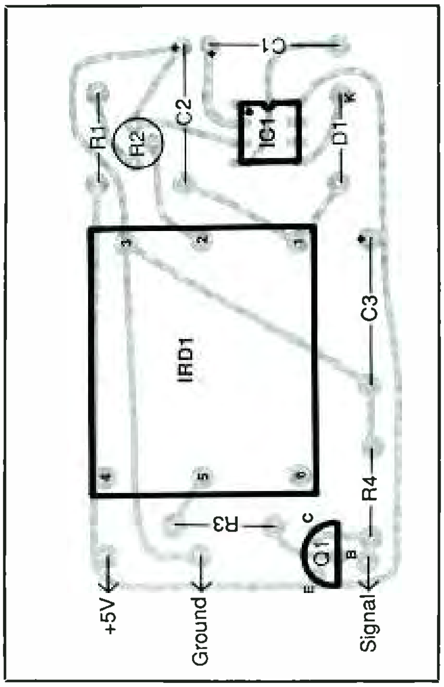


Fig. 6. Wiring guide for IR detection pc board.

circuit-board assembly in place with ½-inch spacers and suitable machine hardware.

Determine where you will be locating the two or three sections that make up your Early-Warning Intrusion Detector system and cut to length the required interconnecting cable(s). You can use either ordinary three-conductor cable for this or two-conductor cable with separate shield. In the latter case, use the shield as the ground conductor between the various sections that make up the project.

After cutting the cable(s) to length, route one end into the detector and lighting-control enclosures and tie a strain-relieving knot in them about 6 inches from the end inside the enclosures. Similarly, route the other end(s) into the power-supply/audible-alert enclosure and tie a strain-relieving knot in it (or them) as before.

Remove 3 inches of outer plastic jacket from both ends of the cable(s). If you are using shielded cable, undo the mesh of the wire shield back to the remaining plastic jacket and tightly twist together the fine wires. Do *not* connect the cable ends to the staking pins on the circuit-board assemblies until directed to do so.

Initial Tests

Begin your checkout procedure with the power-supply section. For this, you need a dc voltmeter or a multimeter set to the dc-volts function. Clip the common and "hot" leads of the meter to the negative (−) and positive (+) leads of of *C5*, and set the meter to a range of 25 or 50 volts full-scale. For any tests conducted in the power-supply circuit, keep foremost in mind that potentially lethal 117 volts ac is present. Exercise extreme caution when working in this circuit.

Turn on the meter. Then plug the line cord from the project into a convenient ac outlet. Set the power switch on the project to "on" (if you are using this switch) and observe the meter's display. If everything is okay, you should obtain a reading of about +20 volts. If so, touch the "hot" probe of the meter to pins 4 and 8 of the *IC2* socket, this time obtaining a reading between +4.5 and +5.5 volts.

If you do not obtain the proper readings, power down the project and disconnect the line cord from the ac line. Rectify the problem before proceeding. Check the orientations of the rectifier diodes as well as the voltage regulator and electrolytic filter capacitor. Measure the potential across the secondary leads of the transformer to ascertain that about 13 volts *ac* is available. Also, disconnect the project from the ac line and measure the dc resistance between the +5-volt and ground rails to determine if a short-circuit exists.

Once you are certain that the project has been correctly wired, power it down and install the 555 timer in the *IC2* socket. Make sure it is properly oriented and that no pins overhang the socket or fold under between IC and socket.

Again, power up the project. Strip ⅛ inch or so of insulation from both ends of a 3-inch length of solid hookup wire. Use this to momentarily jumper from the +5-volt bus to the unconnected end of *R5* to activate the sound generator. Make certain that you do not connect the wire to the junction between *R5* and base of *Q2*; if you do, you will destroy the transistor. If everything is okay, the piezobuzzer will sound for about 1 second and then shut off. Repeat this test a few more times to ascertain that the circuit is operating properly.

If the power supply is working satisfactorily but the audio generator does not work, check *IC2* for proper orientation and pins that are not plugged into the socket. Also check the basing of *Q2* and the polarity of the connections from *PB1*. Ascertain that *IC2* is operating by measuring the voltage at pin 3 while you trigger *R5* with the jumper wire. The potential should rise from 0 to about +4 volts for about 1 second and then drop back to 0 volt each time you trigger the timer.

When you are satisfied that the power-supply/sound-generating system is working properly, disconnect the project from the ac line. Then crimp and solder the conductors of the cable to the staking pins. Make note of which conductor connects to what pin so that you can repeat the sequence at the other end(s) of the cable(s). If you are using shielded cable, use the shield(s) as the common system ground connection.

Plug *IC1* into its socket on the detector circuit-board assembly. Make sure it is properly oriented and that no pins overhang the socket or fold under between IC and socket. If you built the lighting-control circuit, do the same for *IC4* in its socket.

Crimp and solder the free ends of the three-conductor or shielded cable(s) to the appropriate staking pins on the remaining circuit-board assemblies. Make absolutely certain that you follow the same sequence

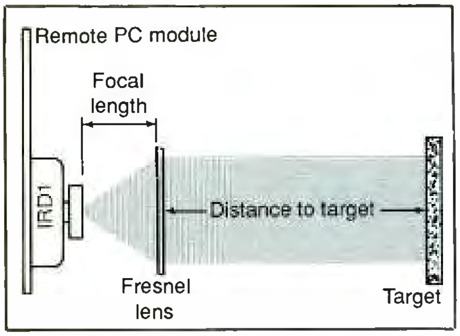


Fig. 7. Mechanical details for single-lens optical system for enhancing sensitivity of basic IR sensor element in project.

used in the power-supply/sound-generating portion of the project. Then apply a thick layer of silicone adhesive to the interior of the enclosure around the entry hole, rubber grommet and three-conductor cable in the sensor subsection. You want this adhesive to serve both as weatherproofing and mechanical anchor for the cable entry. Allow the adhesive to set completely overnight.

When you are satisfied that the cables are properly wired into the various sections of the project, set *R2* in the detector section to mid-rotation. Plug the line cord in the power-supply section into a convenient ac outlet and, if you are using it, set the optional power switch to "on." You may hear a 1-second burst of sound from the piezobuzzer when power is first applied to the circuit as a result of the transient turn-on from the power supply triggering *IC2* into operation.

Set the detector assembly so that the aperture of the sensing element is oriented in the horizontal plane. Now move about 5 feet away from the project and walk past the front of the detector to simulate an intruder. The 1-second burst of sound from the buzzer should be heard.

The project may generate two bursts of sound, since it detects the rise in IR radiation as you walk away. Each change in detected IR energy will thereafter produce a warning sound. Note that you must walk across the field of the detector to produce an abrupt change in IR energy at the sensor, owing to the fact that this is a motion-sensing device.

Experiment with the setting of *R2*. At one end of this control's rotation, the sound from the buzzer will be generated easier than at the other end. This is the result of maximizing the sensitivity of the detector. At the other extreme of rotation, fewer audible warnings are generated. The ideal setting for this control is the least-sensitive position that yields satisfactory results.

If you are not able to obtain the described results, troubleshoot the detector assembly by connecting the common lead of your dc voltmeter to circuit ground and measuring the potential at pin 8 and then pin 5 of *IC1*. If the circuit is working as it should, you should obtain readings of +5 and −5 volts, respectively, at these two pins. If not, check the interconnecting cable for correct connections to the power-supply section and check the orientations of components *IC1*, *D1*, *C1* and *C2*.

If +5 and −5 volts are present at the appropriate pins of *IC1* but you still do not obtain a response from the detector, check the orientation of the infrared module and *Q1*. Measure the potential at pin 2 of the module as you vary the setting of *R2*, which should yield readings that range from 0 to +4 volts. Set *R2* for a reading of +2 volts at pin 2 of the module and then measure the potential at pin 2 of the module. You should obtain a reading of about +5 volts at pin 2. Also, as you wave your hand across the front of the detector aperture, the reading should momentarily drop to 0 volt. Use an oscilloscope to observe the fast response of the detector.

To determine if your intrusion detector will operate as desired, place the sensor assembly in the best location for detection of a person or vehicle approaching your home or business. Remember to point the detector element so that the IR energy radiated by the intruder causes an abrupt change in level as the person or vehicle passes by.

Simulate an intruder by walking or driving past the detector at the desired distance and note if the response of the project is satisfactory. Also note if the detector keeps the buzzer silent when there is no approach of a guest or intruder. Bear in mind, though, that a gust of warm air will vary the level of IR energy received by the sensor and can cause the project to generate a false audible alert signal. You can correct for this by adjusting the sensitivity of the detector with *R2* as necessary.

Mount the various sections that make up the project in suitable locations. The power-supply/sound-generation and optional lighting-control sections should be located indoors near a supply of ac power. The IR detection section should be located out of doors where it will reliably pick up the IR signatures of approaching persons and vehicles. Choose a location that is fairly well isolated from the elements, and do not forget to weatherproof the installation with silicone adhesive around all enclosure joints and mounting hardware and the entry hole for the three-conductor cable.

The best way to integrate the optional lighting-control section is to wire it to an existing lighting fixture. If none is available, or you prefer to have a separate controlled lighting fixture, have an electrician install one in a location that will illuminate the protected area and wire it to the contacts of the relay and ac line.

If after installation you discover that your detector is far too sensitive to assure minimal false alarms, you can restrict the amount of IR energy that strikes the detector by placing a card that has a small aperture in front of the sensing module. This will restrict the field of view and minimize responses to extraneous IR signals.