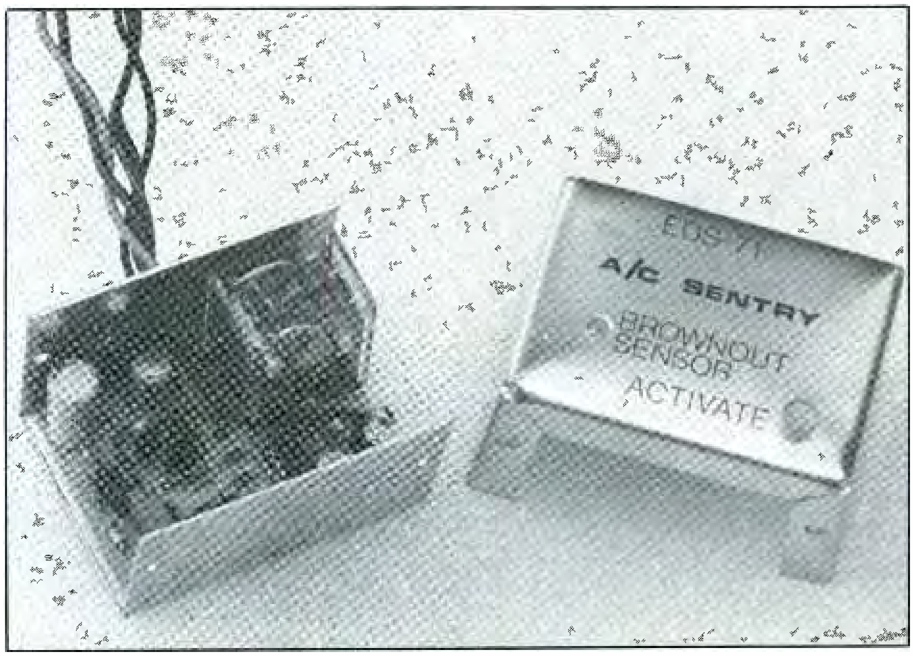
Air Conditioner Brownout Protector

Low-cost device prevents air conditioner compressor damage due to brownouts or blackouts, and also boosts operating efficiency up to 15 percent

By David Miga, CET



It costs a lot of money to repair or replace the compressor in a home air conditioner. Since this expensive component can be easily damaged by an intermittent power condition, such as a commonplace electric power brown-out or black-out, the simple protective device described here should interest anyone with home air conditioning.

Called the "A/C Sentry," it's designed primarily for use with central air-conditioning systems, where installation is very easy. It can be used to protect a room window air conditioner, too, with the addition of a low-voltage power transformer and some extra labor.

Before we examine the relevant circuitry, let's first discuss air-conditioning principles and how the A/C Sentry overcomes home air conditioner design inadequacies that expose the compressor to costly damage.

A/C Basics

Air conditioning (and refrigeration) works on the thermodynamic principle that heat naturally transfers itself to a colder object. The object losing heat gets colder, while the one receiving heat gets warmer. Among key elements in an air-conditioning system that make use of this law of physics are a gaseous refrigerant called Freon, a compressor, a condenser, and an evaporator, with a supportive cast of blower motors, relays, filter, etc.

For cooling, the compressor is switched on. Typically powered by 220 volts ac, the compressor's electric motor draws the low-pressure Freon gas from the line and compresses it to a high-pressure (200 to 300 psi), high-temperature gas. The hot gas moves through condenser coils, where it's cooled through a heat-exchange process that transfers heat to the outside air with the help of a large fan blower motor, and condensed to a liquid.

The liquid then flows through an expansion valve (or "capillary tubes" on smaller systems), where pressure is lowered to between 30 and 65 psi. It then moves through evaporator coils, evaporating to a gas as it absorbs heat from filtered warm air surrounding it that was relayed from the return-air blower. Theory aside, just recall that when a liquid evaporates, it creates a cooling condition, and you've got the principle of air conditioning down pat.

While the newly cooled air continues on its merry way through ducts to various outlet grilles in rooms, the now-heated refrigerant is quickly sucked into the compressor, where the cycle starts again to get rid

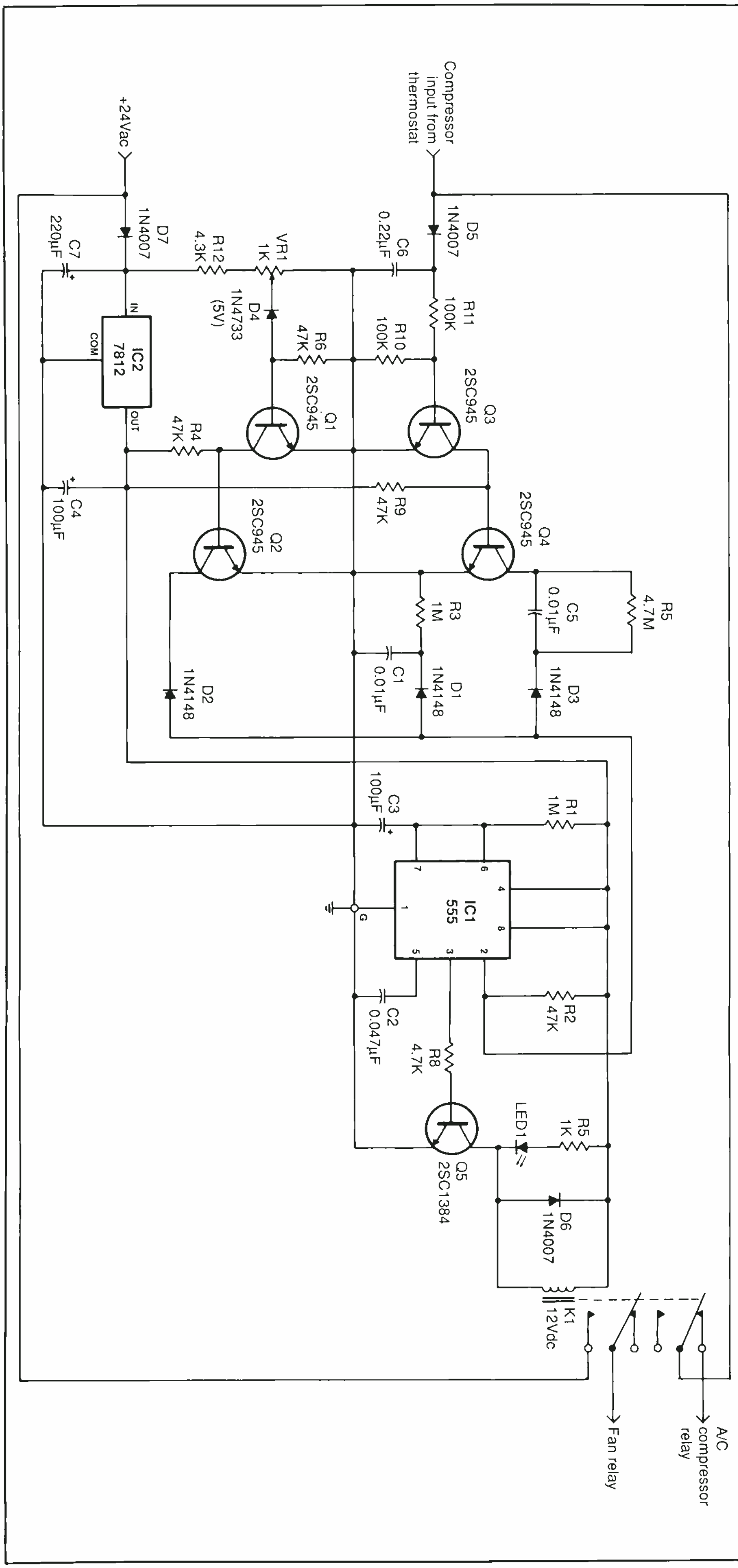


Fig. 1. Complete schematic diagram of A/C Sentry's circuit.

of the heat and supply cooled refrigerant anew to absorb heat from a home's air.

It's apparent from the foregoing discussion that the compressor is a particularly hard-working component. Furthermore, if anything goes wrong with it, you can't repair it because it's hermetically sealed. To make matters worse, its motor-driving mechanism isn't very powerful, making it susceptible to damage during the electrical brownout and blackout occurrences that increasingly plague our developed society.

Here's why intermittent-power conditions can be so deadly to an a/c compressor. When the compressor first turns on, the pressure at its input and output has usually equalized. Consequently, the compressor motor has just enough strength to start up. After operating a few seconds, the pressure on the inlet to the compressor may drop to 50 psi, while the pressure on the outlet side may be 275 psi.

As long as the motor continues to run, inertia maintains motion. However, if power to the compressor should fail for a few seconds and then reappear, the weak compressor motor cannot restart against such a high pressure differential. What results is a locked rotor that will quickly cause the motor's windings to overheat and eventually burn out.

Although there are some safety devices installed in central air-conditioning systems, such as a main circuit breaker, these do *not* operate quickly enough to prevent damage from occurring in the system. In fact, the main function of these safety devices is prevention of fire and explosion—not for preventing damage to the air-conditioning system! These safety devices usually let a problem exist for a minute or so before activating, which is more than long enough to do irreparable damage to the compressor system. Also, if a brownout should occur, there will in effect be no safety devices at all in the system; hence, an already weak motor will rapidly overheat and lock up.

To provide effective protection for your air-conditioning system, the A/C Sentry is designed to continuously monitor the ac power line. At the slightest hint of a power-line problem, the project shuts down the compressor for 3 minutes, which has been determined to be long enough for Freon pressures at the input and output sides of the compressor to equalize. The project then restarts the compressor.

The A/C Sentry is designed to be used with almost any home central air-conditioning system. The sensitivity of its threshold voltage prior to triggering the time-delay countdown as well as the duration of the time delay itself are both adjustable to suit virtually any possible system requirements.

The A/C Sentry does more than just protect your air conditioner's compressor during normal operation. Instead of both the compressor and fan shutting down when the desired room temperature is reached, the A/C Sentry continues to run the fan for 3 minutes longer to prevent wastage of the cool temperature around the evaporator. By forcing the cool air into the room, the off time of the compressor is extended, thus saving you both energy and money.

This project will work with any standard 24-volt ac thermostat in central air, HVAC systems with air conditioning and heat or HVAC systems with reverse cycle. The project was designed primarily for use with central air-conditioning systems. It can be adapted to protect window air conditioners, too, but you will have to supply it with a source of 24 volts ac because individual units normally do not have power transformers.

PARTS LIST

Semiconductors

D1,D2,D3—1N4148 or 1N914 small-signal diode

D4—1N4733 or similar 5-volt, 1-watt zener diode

D5,D6,D7—1N7007 or similar 1,000-volt, 1-ampere silicon rectifier diode

LED—Super-bright light-emitting diode (Radio Shack Cat. No. 276-066 or similar)

IC1—NE555N timer/oscillator

IC2—7812 +12-volt regulator

Q1 thru Q4—2SC945 or similar 60-volt, 200-mA general-purpose npn silicon transistor

Q5—2SC1384 or similar 75-volt, 1-ampere general-purpose npn silicon transistor

Capacitors

C1—0.1-μF, 50-volt Mylar

C2—0.047-μF, 50-volt Mylar

C3,C4—100-μF, 25-volt electrolytic

C5—0.01-μF, 50-volt Mylar

C6—0.22-μF, 50-volt Mylar

C7—220-μF, 50-volt electrolytic

Resistors (¼-watt, 5% tolerance)

R1,R3—1 megohm

R2,R4,R6,R9—47,000 ohms

R5—1,000 ohms

R7—4.7 megohms

R8—4,700 ohms

R10,R11—100,000 ohms

R12—4,300 ohms

VR1—1,000-ohm, 10-turn, pc-mount trimmer potentiometer

Miscellaneous

RLY1—12-volt dc relay with 4-poles and 3-ampere/pole capacity (Radio Shack Cat. No. 275-214 or similar)

Printed-circuit board; suitable enclosure (2.75″ × 2.0″ Radio Shack Cat. No. 270-235 or similar); small L brackets; clip light for LED; machine hardware; hookup wire; solder; etc.

Note: The following items are available from Electronic Design Specialists, Inc., 951 SW 82 Ave., N. Lauderdale, FL 33068: ready-to-wire pc board with layout, $15 + $3 P&H; complete kit of parts, including enclosure and instructions, $49 + $6 P&H. Florida residents, please add state sales tax.

About the Circuit

Shown in Fig. 1 is the complete schematic diagram of the A/C Sentry's circuit. As you can see, the circuit derives its power directly from the 24 volts ac that already exists at the central air-conditioner's control relay box. This 24 volts ac is rectified to pulsating dc by *D7* and filtered to dc by *C7*. The dc potential is about 34 volts (24 volts rms × 1.414). This is continuously monitored by the *R12* through *Q2* brownout-sensing ("glitch") circuit, whose sensitivity is adjustable via trimmer control *VR1* and can be set to the ideal brownout trigger potential of 100 volts ac.

Even though the sensor circuit is actually monitoring a dc potential, any drop in the ac voltage fed to the circuit will show up as a decrease in the dc voltage. So, *R12* through *Q2* are indirectly keeping tabs on the ac potential. To make the response time of the glitch detector circuit less than 0.25 second, the value of *C7* provides a minimum of filtering.

Except for the glitch-detector circuit, the rest of the project requires a 12-volt dc power source. To obtain this, the 34 volts dc at the output of the rectifier/filter combination is passed through voltage regulator *IC2*. Additional pre- and post-regulation filtering are provided by *C7* and *C4*, respectively.

In Fig. 1, 555 timer *IC1* can be triggered by three different conditions through *D1*, *D2* and *D3*. On any blackout that lasts longer than 0.25 second, *C1* triggers *IC1* into its high state through *D1*. This sends *Q5* into conduction and energies *K1*. When this occurs, one set of contacts disconnects the line from the thermostat to the compressor relay, and the other parallels the thermostat's switch to the fan relay, turning on the fan. With *LED1* wired across the relay's coil, the light-emitting diode will be on whenever *RLY1* has been energized.

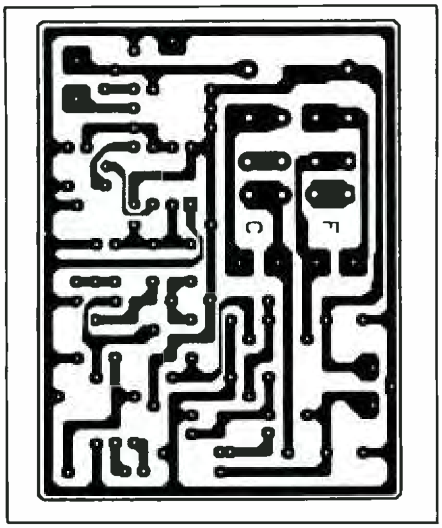


Fig. 2. Actual-size etching-and-drilling guide for project's printed-circuit board.

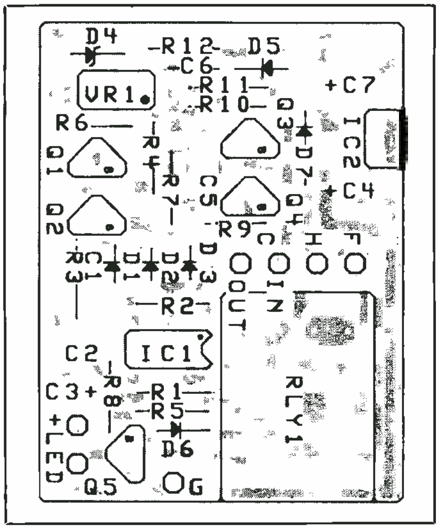


Fig. 3. Wiring guide for pc board. Use this as a rough layout guide if you use perforated-board construction.

Connected across *C1* as shown, *R3* serves as a discharging device for this power-on trigger capacitor so that the A/C Sentry will be ready for another blackout within 1 second or so. The brownout circuitry doesn't simply trigger *IC1* through *D2*; it holds the timer chip in its high state for as long as the brownout is in effect. To achieve this, a lesser-known feature of the 555 timer chip is utilized, with the chip neither in a retriggerable or a non-retriggerable monostable state but somewhere between the two.

Through *D3* is the third way of triggering *IC1* . The circuit to accomplish this is made up of *D5* through *Q4*, which monitors the compressor relay output line from the thermostat to the compressor relay. When the compressor is switched on by the thermostat, the collector of *Q4* is brought to a high-impedance state. This allows *C5* to build up equal voltage on both sides by *R7*. When the compressor is switched off under normal operating conditions by the thermostat, *Q4*'s collector goes low and triggers *IC1*. When this occurs, *RLY1* energizes and applies power to the fan for 3 minutes to move whatever cool air is still in the evaporator chamber into the living area.

You can vary the length of *IC1*'s time delay (the period during which the fan remains on) by changing the value of *C3*. For example, if your compressor requires only 1.5 minutes of rest for Freon pressure to equalize, use a 47-microfarad capacitor for *C3*. On the other hand, if your compressor requires more than 3 minutes to achieve the balanced-pressure state, use a 220-microfarad capacitor. If you aren't sure of the required time, you can call the manufacturer of the air conditioner or the dealer from whom you purchased it for the exact time, but a 3-minute delay should work for most a/c units used in private homes.

Construction

Being that this circuit deals basically with dc potentials, there is nothing critical about component layout and wire routing. Therefore, just about any traditional wiring approach can be used to build the project, including a printed-circuit board and perforated board with holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware. Printed-circuit construction is highly recommended, however, because it will withstand temperature and vibration extremes better than most point-to-point wiring will.

From here on, we'll assume you're using pc construction. You can fabricate your own pc board using the actual-size etching-and-drilling guide shown in Fig. 2. Alternatively, you can purchase a ready-to-wire board from the source given in the Note at the end of the Parts List.

When the board is ready to be wired, orient it as shown in Fig. 3. Start populating the board by installing and soldering into place the resistors, then the transistors, capacitors, 555 timer chip, relay and regulator chip, in that order. Hold off installing the LED until you've selected an enclosure in which to house the circuit-board assembly. Your choice may require the LED's leads to be lengthened with hookup wires for it to mount on one wall of the enclosure and still reach the appropriate holes in the board. After installing them, make certain that the electrolytic capacitors are properly polarized and that the diodes and LED are properly oriented before soldering their leads to the copper pads on the bottom of the board. Use plenty of solder on each connection you make to the circuit-board assembly but not so much that it creates unwanted solder bridges.

When all components have been installed, strip ¼ inch of insulation from both ends of five 18- to 24-inch lengths of *stranded* hookup wire. Use wires with different colors of insulation—preferably yellow, red, green, black and orange—to identify where each wire is to go. The first three colors conform to the color-coding scheme commonly used in a/c wiring (see Fig. 5). Black and orange can be used for the OUTPUT and system common or ground. Tightly twist together the fine wires at both ends of all wires and sparingly tin with solder. Plug one end of each of these wires into the holes labeled F, G, H, IN and OUT. Insulation

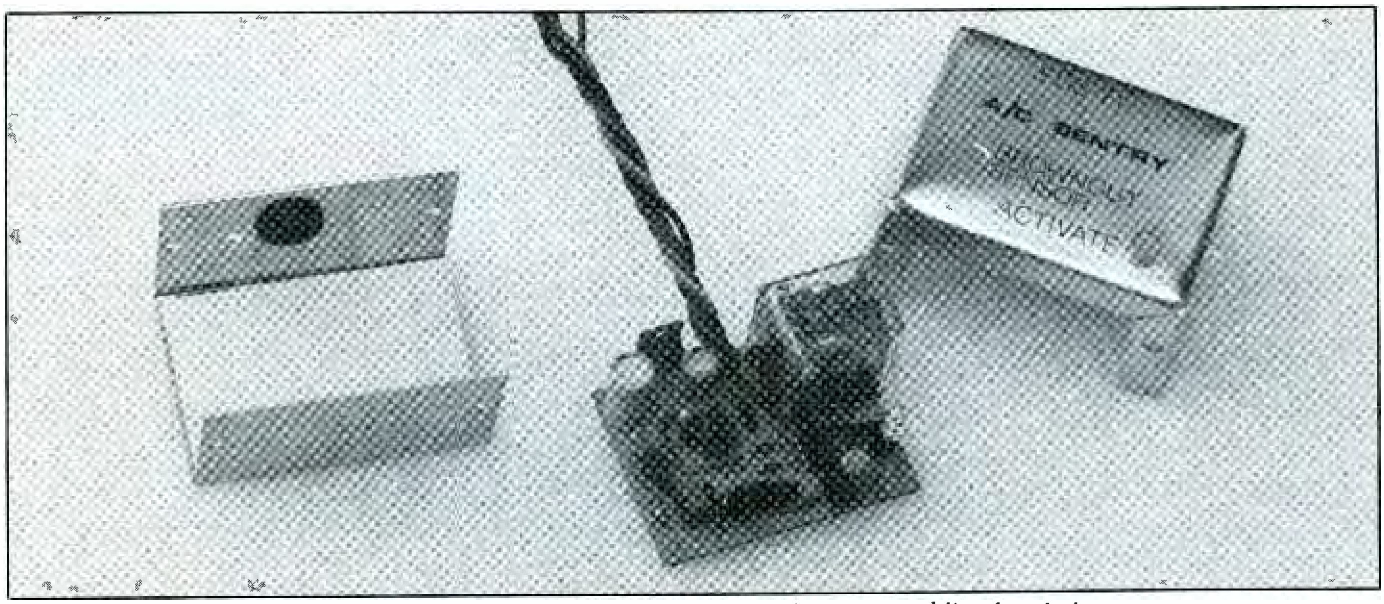


Fig. 4. Interior view of completed project prior to assembling box halves.

color coding is as follows: green for the F (fan) hole, black for G (system ground), red for H (24 volts ac), yellow for IN (input) and orange for OUT (output) and solder into place.

Select an enclosure for the project that's large enough to accommodate the circuit-board assembly. A small metal utility box like that shown in the lead photo is an ideal choice. Machine the enclosure as needed by drilling an exit hole for the five conductors that connect to your air-conditioning system's wiring (⅜ inch), a mounting hole for the LED (¼ inch), an access hole to the adjustment slot on trimmer *VR1* (5/32 inch), and a mounting hole for the voltage regulator (5/32 inch).

Before drilling the LED and trimmer holes, make sure you accurately locate their positions on the panel with reference to the locations of the two components on the circuit board when the latter is finally mounted in place. While you're at it, drill small holes to accommodate sheet-metal screws that will secure a pair of small L brackets to the enclosure for mounting the project in the selected location, or replace two of the screws supplied with the box with slightly longer ones and mount the L brackets in place with these when you assemble the box.

With the circuit-board assembly in place in the lower half of the enclosure, plug the leads of the LED into their holes and hold the device vertical to the board's surface while sighting across the two upright walls. If the domed case of the LED sticks up beyond the height of the case's walls, solder the leads into place, first making sure that the LED is properly polarized.

If the domed case doesn't sit higher than the enclosure's walls, the LED's leads must be lengthened with hookup wire. To do this, strip ¼ inch of insulation from both ends of 2-inch red- and black-insulated wires. If you're using stranded wire, tightly twist together the fine conductors at both ends and sparingly tin with solder. Plug one end of the red-insulated wire into the LED hole identified with a + and solder into place. Then solder one end of the black-insulated wire in the other LED hole. Slip over the free ends of both wires a 1-inch length of small-diameter heat-shrinkable or insulating plastic tubing.

Identify the cathode lead of the LED and trim it to length of ½ inch. Form a small hook in the remaining lead stub and crimp this to the free end of the black-insulated wire. Solder the connection. Do the same with the red-insulated wire and anode lead. Then slide the tubing up over the connections until it is flush with the bottom of the LED's case. If you're using heat-shrinkable tubing, shrink the tubing into place.

Push a "cliplight" into the LED's hole. Before installing the circuit-board assembly inside the box, cement a thick layer of insulating cardboard (like Bainbridge or other heavy art board) to the floor. Set the circuit-board assembly in place, and secure the voltage regulator to the enclosure's wall with a 4-40 machine screw. Place a mica insulator between the regulator and wall and use a shoulder fiber washer with the machine screw. No part of the circuit, including the regulator, should be allowed to make electrical contact with the enclosure! Shown in Fig. 4 is the completed project just before the utility box in which it is housed is finally assembled.

Place a small rubber grommet in

the hole drilled for the five wires that connect the project into your air-conditioning system through the grommet-lined hole. Then route the wires through the grommet. Slide the LED into it if it's connected to the circuit board via wire leads or carefully slide the top half of the enclosure onto the bottom half, making sure the LED's case enters the open end of the clip, if the LED is mounted directly on the board.

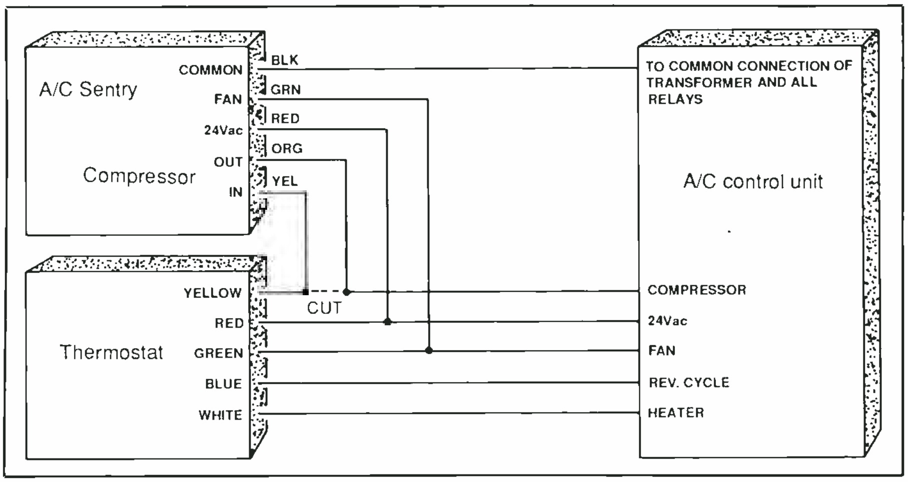


Fig. 5. A typical HVAC wiring diagram, with connections shown for project.

Installation & Alignment

Figure 5 is a typical HVAC (heating/ventilating/air conditioning) wiring diagram, with areas labeled where the A/C Sentry is to tie into the system. Whether your system is central air only, HVAC (heating and cooling) or a reverse-cycle unit, hookup is still the same.

A five- or six-conductor cable usually connects the thermostat to the air-conditioning system's control relay. Insulation colors for these wires is an industry standard: red for the source of 24 volts ac, green for the fan relay, yellow for the compressor relay, and (in HVAC systems) white for the heater coil. In reverse-cycle systems, blue insulation is used on the wire to the reversing relay.

Note in Fig. 5 that the project requires connection to only three of the five or six wires in the system. It does, however, require a fourth connection to the system's electrical ground. This is *not* in the thermostat, but at the unit's relay control box. Therefore, you'll want to mount the project close to the relay box.

To locate the system's common conductor, first find the 24-volt ac power transformer and trace its output wires. One will connect to the red-insulated wire in the harness to that goes to the thermostat; this is your 24-volt ac line. The other wire from the transformer will connect to the common coil connections of all relays in the system; which identifies it as the common "ground" for the system and the logical tie point for the project's ground lead.

Before you do anything electrical in the a/c system, *turn off ac power to it*. Do this by flipping off the circuit breaker or removing the fuses. Then when ac power is completely disabled, wire the A/C Sentry into the system exactly as shown in Fig. 5. Note that the red-insulated, green-insulated and common system wires are simply tapped into. You must cut the yellow-insulated compressor relay wire and join the cut ends with the INPUT and OUTPUT wires coming from the project as shown. Before restoring ac power to the system, turn the adjustment screw of *VR1* at least 10 turns counterclockwise. Make sure that the thermostat is set to coldest so that the system doesn't cycle on and off while you are aligning the project.

Turn on the circuit breaker or replace the fuses and set the system for cooling, fan on automatic. The fan will come on but the compressor will remain off, and the project's LED will be on. After the 3-minute delay, the LED will extinguish and the compressor will operate.

Now use a small screwdriver to slowly adjust the setting of *VR1* clockwise. At about five turns or so, the LED should light and the compressor turn off, signaling that the brownout sensor adjustment was turned beyond threshold. Adjust *VR1* counterclockwise one-half turn and wait for the delay to time out.

When the compressor turns on again, adjust *VR1* clockwise even more slowly than before. Note the exact point at which the LED turns on and readjust the setting of the trimmer control counterclockwise *exactly* half a turn. This calibrates the A/C Sentry to turn off the compressor with a 10-volt drop. Some older homes have marginal electrical systems, which will cause the project to falsely trigger too often. To correct for this condition, turn *VR1* counterclockwise three-quarters of a turn, which will now give a 15-volt "window."

A final note: If you installed an "en-ergy-efficient" programmable ther-mostat and have come home to find your air-conditioning system's breakers off, this is because the thermostat switched from warmer day period to the cooler night period before the compressor had sufficient time to power down. This kind of thermostat, when used by itself, can damage your compressor. The Air-Conditioner Sentry will prevent such damage because it allows the compressor to power down for 3 minutes even though the thermostat may be attempting to run the compressor **ME**