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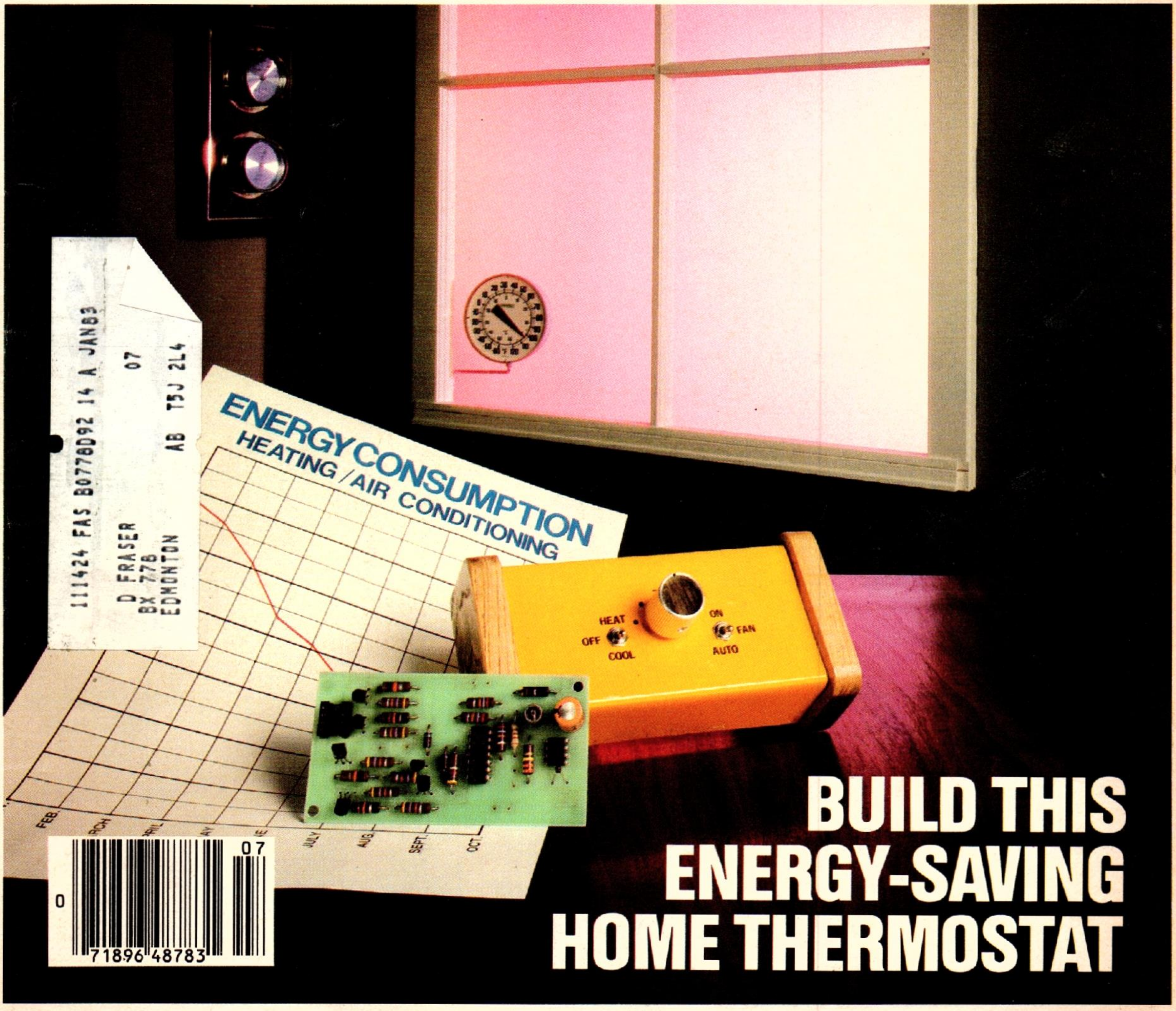

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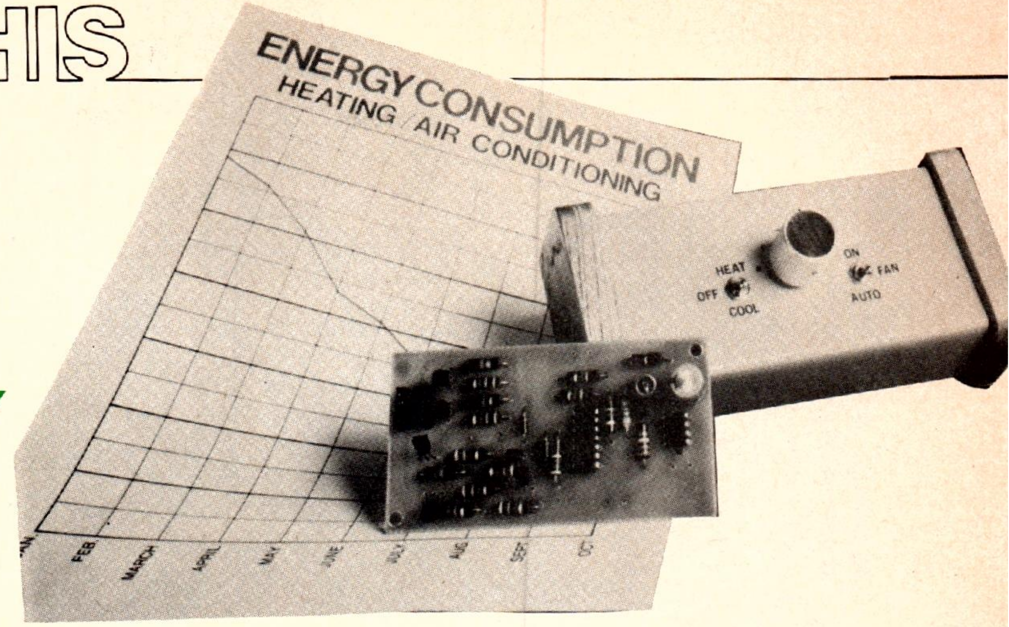
BUILD THIS ENERGY-SAVING HOME THERMOSTAT



ENERGY SAVING HOME THERMOSTAT

The expenses involved in heating and cooling a home have never been higher! This Environmental Control Center could save you up to 20% in energy costs.

TOM STULTS

THE RISING COST OF ENERGY USED TO SUPport home-heating and air-conditioning systems can be offset by using nature's own temperature cycles to supplement costly equipment operation. The house can be maintained at a chosen temperature setting without involving sacrifices in comfort.

The outside temperature rises and falls from daytime to night because of solar heat. As long as the coolest nighttime temperature remains above the "comfort" setting of your thermostat you must, of necessity, supply continuous air conditioning to your house. Generally, that only happens for six to eight weeks in the summer, depending on where you live. On the majority of cooler days, the outside temperature will be lower than the inside "comfort" setting from sometime in the evening to well into the next morning.

But, even though it's getting cooler outside, the inside of the house can still be warming up! That is because the warmth of the sun on an outside wall takes time to soak through the wall to the inside and while insulation can slow down the process, it can never stop it. How many times have you stepped outside on a cool fall evening and heard your air conditioner still running? It's obvious that, at times like this, we are unnecessarily cooling the house artificially (at great cost) when we could easily be using a limitless free source of energy, Mother Nature herself.

In cooler weather, the same principles apply in reverse. In the late fall and early spring the morning temperature will often rise above the thermostat setting and fresh air can be used to warm the house.

That is the function of the Environmental Control Center—to furnish free cooling or heating whenever possible by using outside air.

Like large commercial systems that have been using fresh air to help in heating and cooling for years, the Control Center can save an estimated 20% in operating costs and energy every year.

Environmental Control Center

The Control Center (Fig. 1) uses readily available IC's to do the switching and decoding needed to make the outside air available when required. Inside and outside temperatures are monitored by a pair of thermistors and a difference amplifier and converted into a digital signal for decoding. The decoded signal controls the operation of the mechanical components of the heating/cooling system.

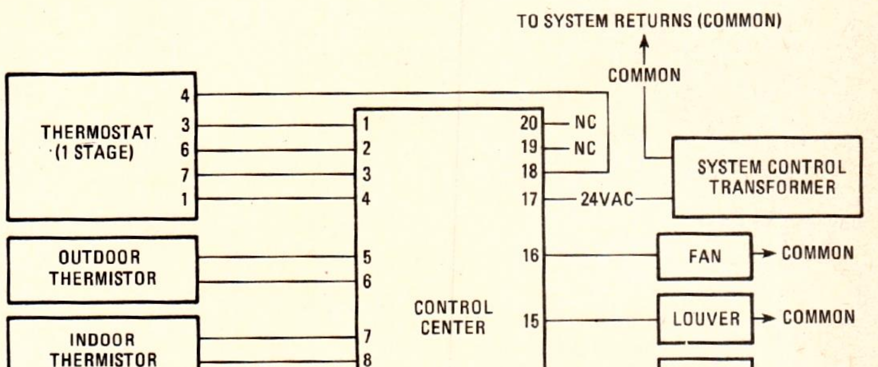


Fig. 1—BLOCK DIAGRAM of the Environmental Control Center showing the input sensors at left and the devices controlled at right. Note that the system may use either 24 or 117 VAC.

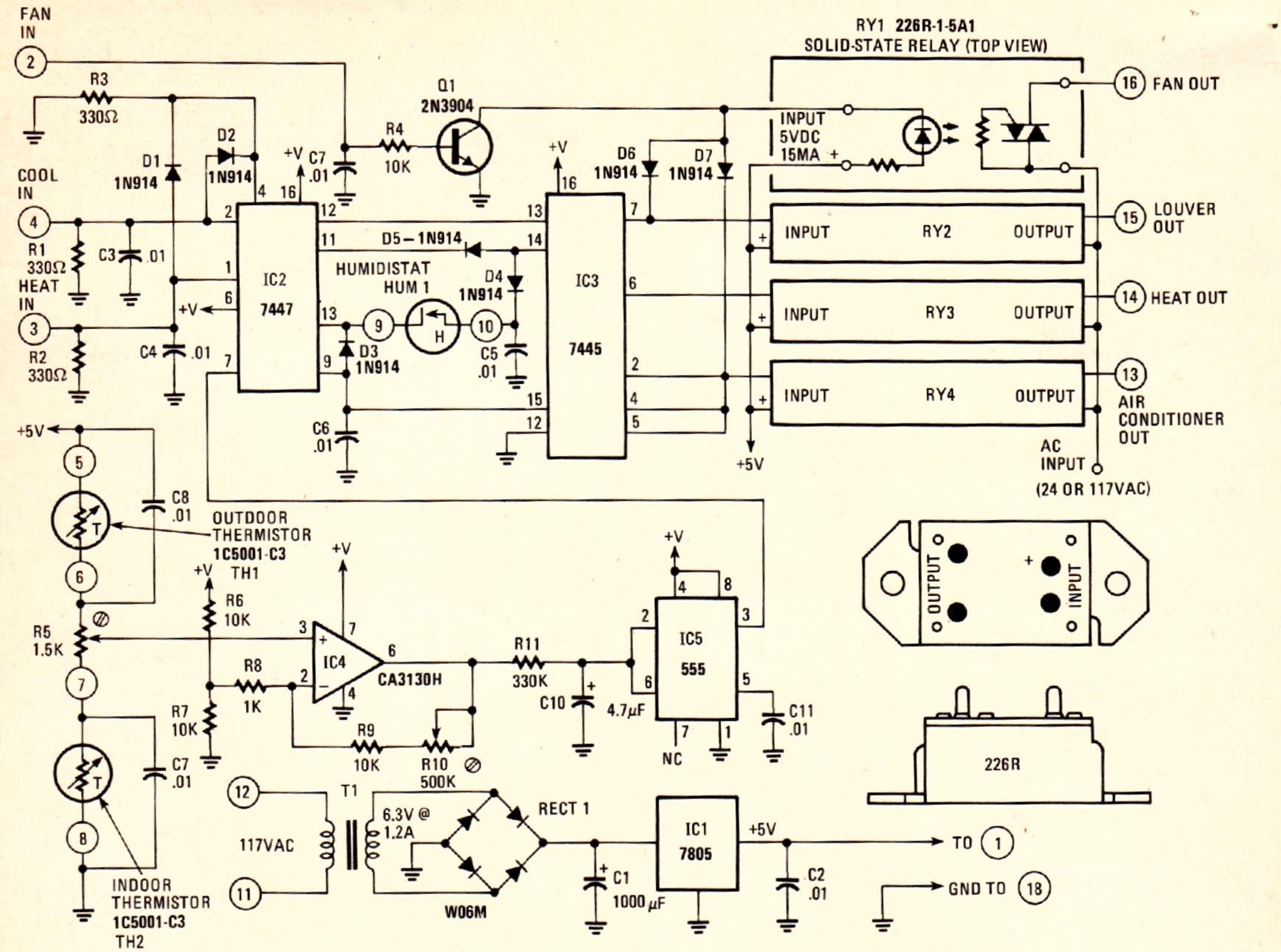
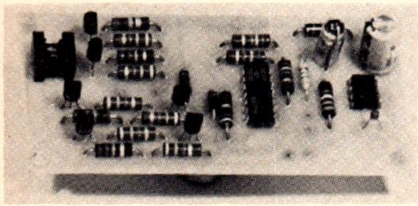


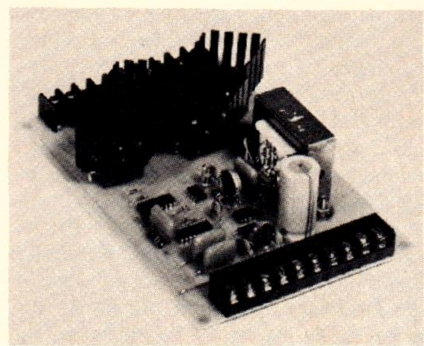
Fig. 2—SCHEMATIC DIAGRAM of Environmental Control Center. Circled numbers refer to Fig. 1. Solid-state relay is shown at lower right. Humidistat, HUM1, is located off PC board.



COMPLETED THERMOSTAT PC board. Socket at upper left is for plug to controller.

The schematic diagram of the control center is shown in Fig. 2. Thermistors TH1, TH2 and potentiometer R5 form a voltage divider that supplies a differential signal to the non-inverting input of the high-impedance amplifier, IC4. To calibrate the input, place voltmeter probes on pins 2 and 6 of IC4 and, with the voltmeter on its most sensitive scale, adjust resistor R5 until the voltmeter reads as near to zero volts as possible. In order to make that adjustment, submerge both sensors in a glass of water and wait until the reading on the voltmeter is stable. This will indicate that both sensors are at the same temperature and that R5 can be set accurately.

In practice, the resistance of the thermistor sensors will not change equally, producing a difference signal at the input of IC4. That signal will be amplified and applied to the input of IC5, a timer connected as a Schmitt trigger with hysteresis. Applied to pin 6 of IC5, 2/3 V_{cc} or more will cause pin 3, the output of the timer, to go low. A potential of 1/3 V_{cc} or less at pin 2 will cause the output to go high. With the two inputs tied together, the timer has a dead band between 1/3 and 2/3 V_{cc} where the timer will not switch. By adjusting the gain of the difference amplifier IC4, the temperature difference required to switch the output of the sensor circuit can be changed. To make that adjustment, set R10 to center-travel and momentarily short sensor TH1 at Control Center terminals 5 and 6, forcing IC5 to go low. Using an accurate thermometer, set up two glasses of water and cool one of them by 2°F with ice cubes. Remove the cubes when this difference has been reached. Submerge TH1 in the cooler glass and TH2 in the warmer. Allow time for the temperature to stabilize. Adjust IC4 output (pin 6 to ground) to 1/3 V_{cc}, the switching point of IC5. (It is not practical to measure that signal at the input of IC5 because of the time delay generated in R11 and C10.) This adjustment will set the temperature



CONTROL CENTER board. The solid-state relays must be adequately heat-sinked!

switching difference at two degrees and, in addition, the dead band will prevent fast cycling when the temperature outside hovers around the switching point and a vagrant breeze or gust might cause the Control Center to switch back and forth unnecessarily.

Input decoding is accomplished by IC2 and IC3. With no input from the thermostat, pin 4 of IC2 will be low and will shut the system down. Either input (pin 1 or pin 2) will cause pin 4 to go high and turn on the system. Given 5 volts on pin 1, a heating command, the output will be low at pin 11. However, if TH1 is warmer, pin 7 will be driven low by the temper-

PARTS LIST
Control Center

All resistors ½ watt, 10% unless otherwise noted

R1-R3—330 ohms
R4, R6, R7, R9—10,000 ohms
R5—1500 ohms, trimmer resistor, vertical PC mount (Mallory MTC152L1 or equal)
R8—1000 ohms
R10—500,000 ohms, trimmer resistor, vertical PC mount (Mallory MTC55L1 or equal)
R11—330,000 ohms
C1-1000 μF, 25 volts, electrolytic
C2-C9, C11—.01 μF ceramic
C10—4.7 μF, 16 volts, electrolytic
D1-D7—1N914
Q1-2N3904
RECT1—full-wave bridge rectifier, 600 PIV, 1.5 A, (General Instrument WO6M or equal)
IC1—7805
IC2—7447
IC3—7445
IC4—CA3130
IC5—555
TH1, TH2—thermistor, 5000 ohms @ 25°C, −4.4%, ±0.2°C, 0-70°C (Western 1C5001-C3, Fenwal UUA35J1, Yellow Springs Instruments 44007 or equal)
RY1-RY4—solid-state relay, (Sigma 226R-1-5A1)
HUM1—humidistat, makes on increase in humidity (Honeywell H46E1013 or equal)
T1—power transformer, secondary 6.3 volts @ 1.2 amps (Radio Shack 273-050)
Heat sinks for RY1-RY4—Wakefield 291-80ABC2 or similar for TO-3 devices.
Barrier strips—10 terminals on .375-inch centers for PC mount.

The following parts are available from LSE, Box 392, Yukon, OK 73099: PC board $11.95, Sigma 226R-1-5A1 solid-state relay $12.89 each, thermistors $5.06 each, humidistat $41.16 each. Oklahoma residents please include local sales taxes.

PARTS LIST
Two-Stage Thermostat

All resistors ½ watt, 10% unless otherwise noted

R1, R3—4700 ohms
R2—330K ohms
R4, R5, R6—270 ohms
R7—5000 ohm pot, linear taper
R9, R11, R13, R15, R16, R18—470 ohms
R10, R12, R14, R17—12,000 ohms
C1—68 μF, electrolytic
C2—4.7 μF, electrolytic
Q1, Q2, Q4, Q6—2N3905
Q3, Q5—2N3904
IC1—SN741N
IC2—LM339N
TH1—thermistor, 5000 ohms @ 25°C, −4.4%, +0.2°C, 0-70°C (Western IC5001-C3, Fenwal UUA35J1, Yellow Springs Instruments 44007 or equal)
S1—switch DPDT
S2—switch SPST
ouput connection—½ 16 pin DIP socket
D1, D2—1N4001

The following parts are available from LSE, Box 392, Yukon, OK 73099: PC board $7.25, Sensor $5.06. Oklahoma residents please include local sales tax.

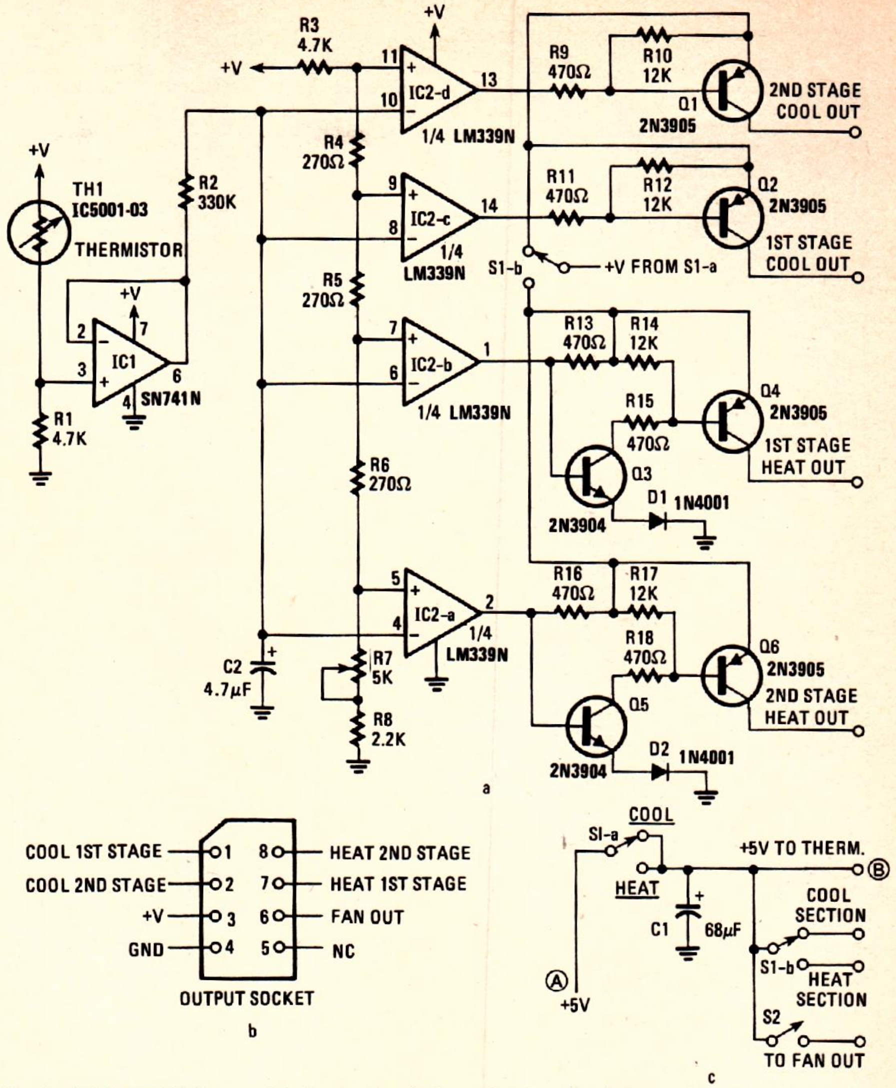


Fig. 3—TWO-STAGE thermostat. See text and Figs. 1 & 4 for description and hookup information. Output socket and switches are shown in *b* and *c*. Switch S1-b is shown twice.

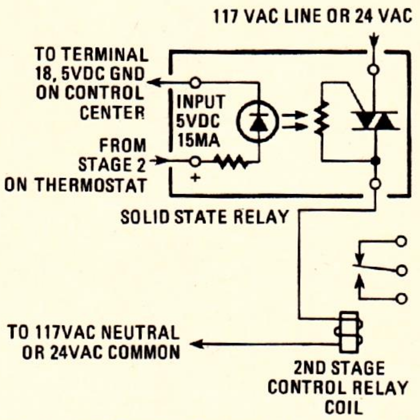


Fig. 4—ADDITIONAL RELAY hookup for 2-stage system. Refer to text for details.

ature comparison circuit and the output will be routed to pin 9 instead, calling for fresh air. With 5 volts on pin 2, an air-conditioning command, pin 12 will go low unless TH2 is warmer, in which case the output will be low at pin 13, calling for fresh air.

The outputs of IC2 drive IC3, which can generate a high humidity over-ride in the fresh-air cooling cycle. The humidistat contacts close when the humidity rises above a certain level and should be placed in the central system ductwork to monitor the humidity of the conditioned area. On a humid or rainy day, large amounts of moisture can be drawn into the house making it necessary for the next air-conditioning cycle to remove it and impairing efficiency. IC3 and the diodes D3, D4 and D5 make up a circuit that will cause the Control Center to switch from fresh-air cooling back to air conditioning when the humidity reaches a predetermined level. A relative humidity of 50% is comfortable. The humidistat has no effect in the heating cycle.

IC3 drives solid-state relays which turn on the central-system equipment. Diodes D6 and D7 turn on the fan used with the fresh air system or the air conditioner, a function that would be handled by the thermostat in a conventional system. The output relays, *when properly heat sinked*, will handle up to 7.5 amps, sufficient to handle a fan motor or a louver actuator. The output voltage of the relays can be either line voltage (117 VAC) or a control voltage (24 VAC) depending on the position of jumpers provided for on the Control Center PCB. Before soldering in those jumpers be sure to check the operating voltage of your equipment.

SOLID-STATE RELAYS

THE SIGMA 226R-1-5A1 SOLID-STATE relay specified is designed to use 5 volts DC to control a load with a nominal level of 120 volts RMS and a minimum of 80 volts RMS. For this reason, it would seem that this relay is not suitable for handling 24-volt AC control relays in heating or cooling systems. However, we have tested several of these relays and have found this type entirely satisfactory. With a 24-volt AC control relay as a load, we found that the *DC input turn-on voltage* is the critical factor.

With 5 volts DC applied to the control pins, the solid-state relay dropped 1.1 volts in the load circuit—insignificant as far as a 24-volt AC control relay is concerned. With 4 volts DC control, the load voltage dropped 1.2 volts. When the control voltage was reduced to 2 volts DC, the relay dropped 5.7 volts in the load circuit and the load relay chattered. These readings were averaged from measurements made on several relays with digital VOM.

Two-stage controls are used in most commercial heating and cooling systems and can also be found in some residential installations. In some homes you may find single-stage cooling and two-stage heating, or vice versa. You can tell a lot about the operation of your heating and cooling system by examining the thermostat. The operation and connections to the original-equipment thermostat can be identified as follows:

Terminal	Function
R	24VAC from control transformer
Y	output to cooling equipment
W	output to heater or furnace
G	output to fan relay
Y2	2nd stage cooling output
W2	2nd stage heat output

The universally followed wiring color code for a single-stage heating-cooling system is R—red, Y—yellow, W—white and G—green. There is no universal color code applied to either 2nd-stage heat or 2nd-stage cool. Examine the terminals on the original-equipment thermostat to see whether or not you require two stages when setting up the Control Center.

The thermostat

A two-stage thermostat (see discussion and explanatory information elsewhere in

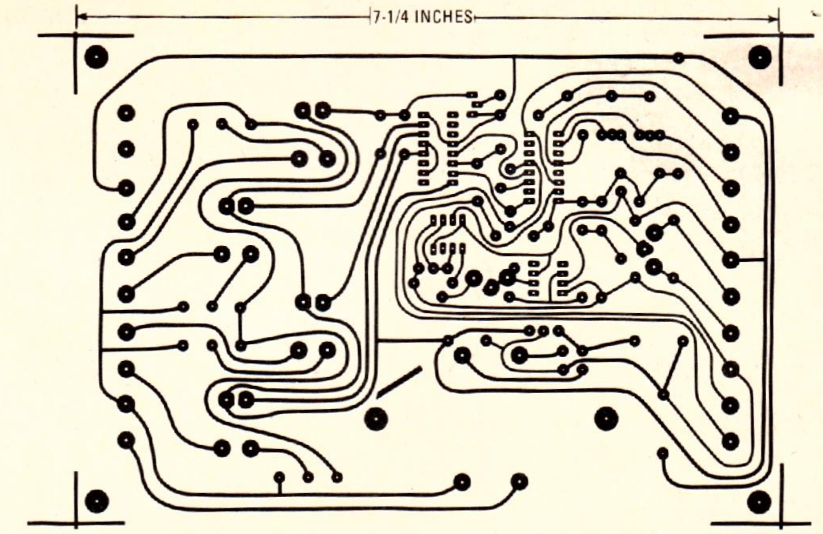


Fig. 5—FOIL PATTERN for the Control Center. Drill corner pads for mounting holes.

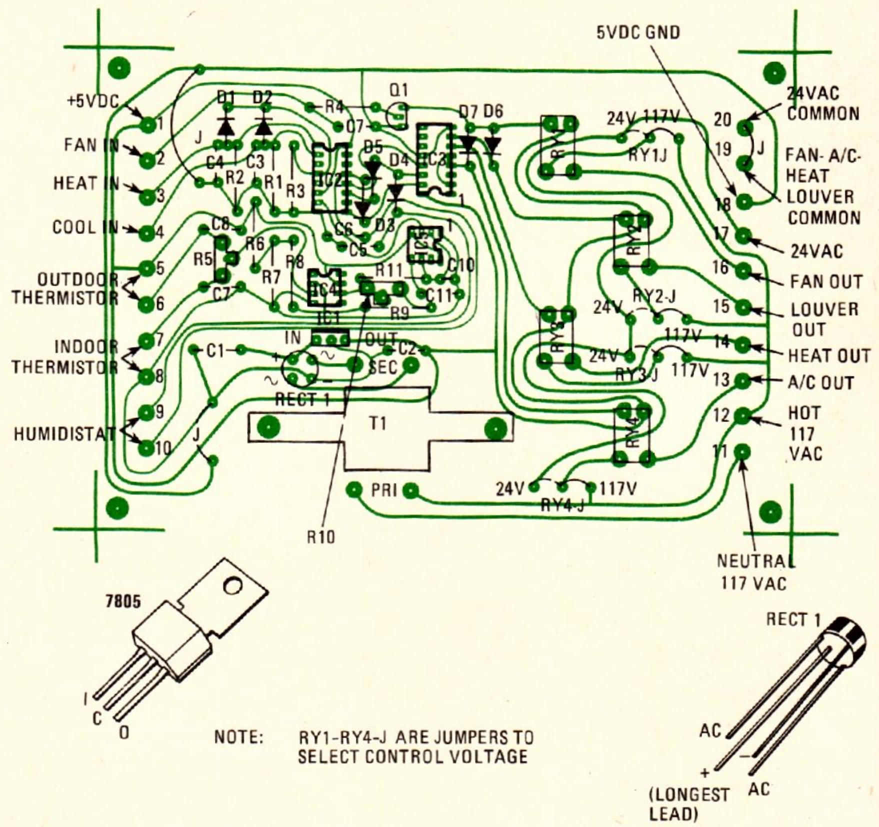


Fig. 6—PARTS LAYOUT for the Control Center. Outboard humidistat is connected to pads 9 and 10.

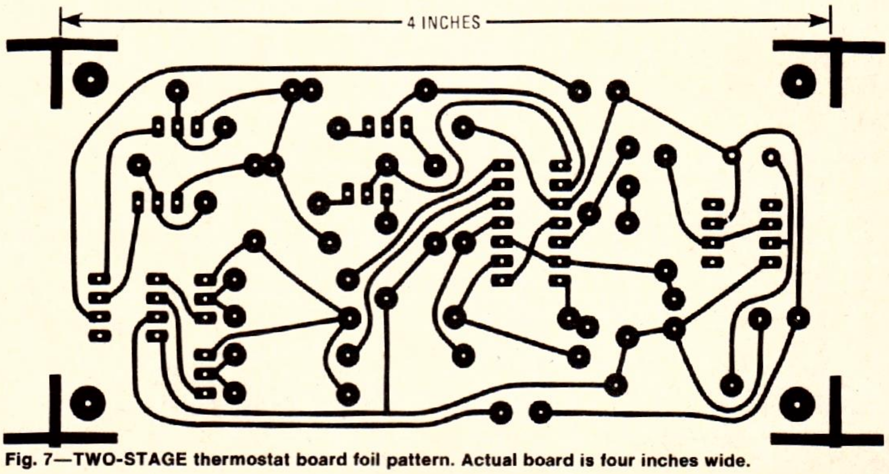


Fig. 7—TWO-STAGE thermostat board foil pattern. Actual board is four inches wide.

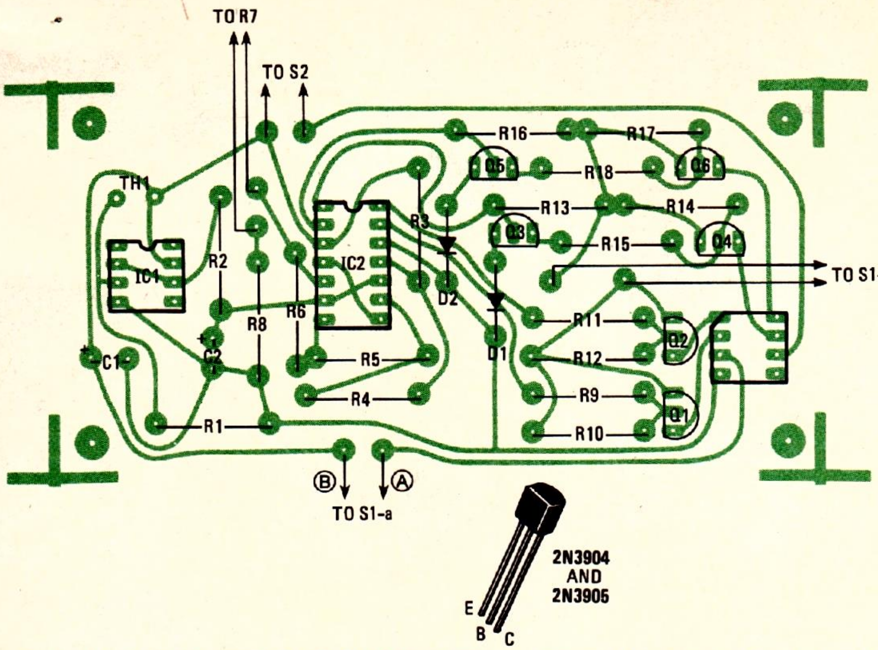


Fig. 8—PARTS PLACEMENT DIAGRAM for the thermostat. Unmarked 8-pin (or ½ 16-pin) socket at lower right is for DIP plug connecting thermostat with the Control Center.

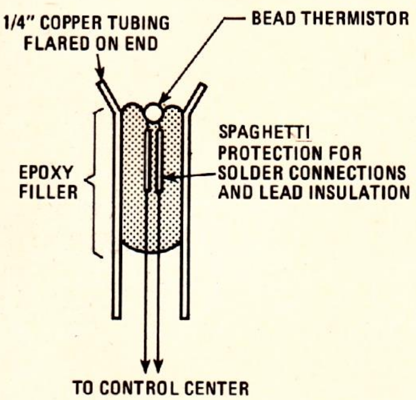


Fig. 9—CUTAWAY DRAWING of thermistor probe. See text for construction details.

this story) is shown in Fig. 3. In it, another 5K thermistor, isolated from the switching circuits by follower amplifier IC1, is the temperature-sensing element.

Resistor R2 and capacitor C2 generate a time delay to prevent short-cycling due to transient drafts at the thermostat.

IC2 is a four-level detector referenced by the voltage-divider string, R3 through R8. Resistors R4, R5, and R6 set the switching levels 2° apart. Assume that the system has been set in the heating mode by S1. At 4° below the level set by temperature-adjust pot, R7, no comparators will be tripped, and their collector outputs will be open. Transistors Q3 and Q5 will be biased on, turning on Q4 and Q6 to turn on the heat. The collector current of Q4 controls the first stage of the heating system through terminal 3 of the Control Center (Fig. 2) while Q6 is connected to the second stage of the heating system through a solid-state relay connected as in Fig. 4. The open-collector output of IC2-c and IC2-d as well as the open contact of S1-b will insure that Q1 and Q2 (air conditioning) are off. As the house temperature rises to less than 4°, but more than 2°, below the set-point, IC2-a will switch low turning off Q5 and Q6. Stage-1 heat, will be turned on. A further increase in temperature will switch IC2-b low, turning Q3 and Q4 off—leaving all outputs off and the Control Center in standby.

In the air-conditioning mode, an inside temperature 4° higher than the set-point will satisfy the inputs to IC2-c and IC2-d, turning on Q1 and Q2. Stage-1 and stage-2 cooling will be turned on. As the temperature decreases, IC2-d will turn off leaving only stage-1 active, and with a further decrease, IC2-c will turn off leaving the Control Center in standby.

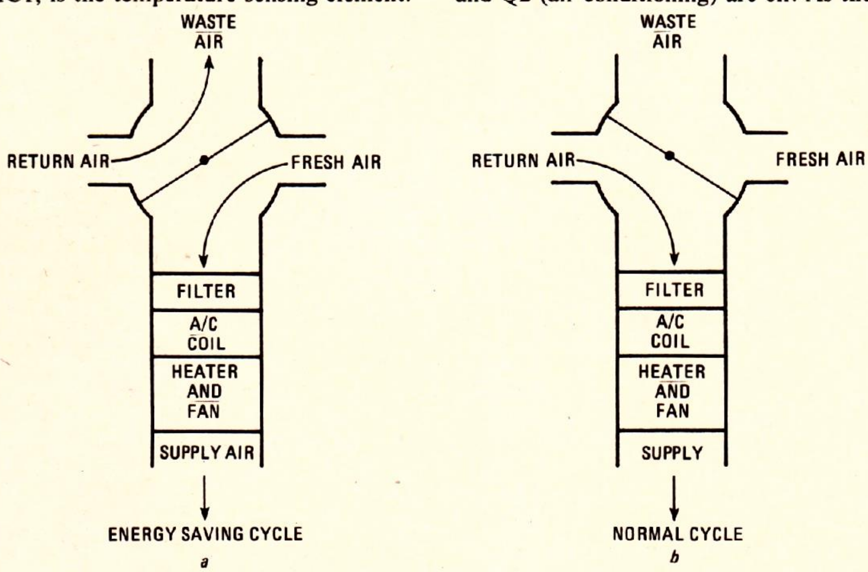


Fig. 10—AIR FLOW through ventilation system during *a*) energy-saving cycle and *b*) during normal cycle. Rotatable damper determines whether air is recirculated or not.

Construction

The environmental control system is constructed on two circuit boards. Figs. 5 and 6 show the foil pattern and parts placement for the control center, respectively. The electronic thermostat is on the smaller PC board. The foil pattern is in Fig. 7 and the parts placement guide in Fig. 8. The humidistat should be mounted in the system to monitor the humidity of the air supplied to the living area.

The two temperature sensors are easily assembled by flaring one end of a 4-inch length of ¼-inch copper tubing and embedding a 5K thermistor in epoxy compound as shown in Fig. 9. Use spaghetti (thin plastic tubing) to insulate the thermistor leads. Be sure to use enough epoxy compound to make the assembly completely watertight and weatherproof.

Installation and operation

Completely automatic operation of the heating and cooling outputs may be selected by jumpers on the board which will bypass switch S1-b and route power-supply voltage to both the heating and cooling outputs simultaneously. If that is done, S1-a should be retained as a SPST switch to provide an off function.

Not all central air-conditioning units have two stages, and if yours doesn't, then eliminate Q1, Q5 and Q6 from the PC board, along with their supporting resistors. If your unit *does* have two stages, connect the output of the thermostat in the second stage to the control voltages of the central unit with an additional relay of the type used in the Control Center. (see Fig. 4)

The Control Center is easily compatible with the Educated Thermostat featured in the July '79 issue of **Radio-Electronics** and the combination would result in an integrated system offering the highest possible efficiency and energy savings. Supply one side of the cold contacts in the Educated Thermostat with 5 volts from the Control Center and connect the other side of the contacts to the FAN, HEAT, and COOL inputs of the Control Center. No ground from the Control

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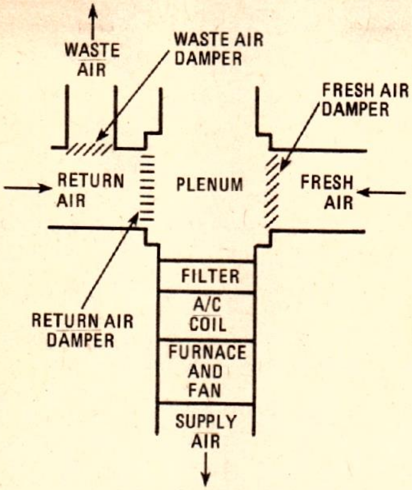

Fig. 11—ALTERNATE MEANS of air flow control. It is important that dampers close tightly.

Center power supply will be needed.

A special inlet must be added to your heating/air-conditioning system to supply the fresh air. That inlet should be placed under the eaves of the house so it will be shaded and not subject to the direct rays of the sun. The outside sensor should be installed near it. A filter grill, or at the minimum, a ¼-inch screen grid cover, is advisable at the opening. Attic air should not be used because of the extreme temperatures encountered in the summer.

The fresh air should be ducted into the return air plenum to enable the central-system fan to distribute the air equally throughout the conditioned area. An outlet for the waste air should be provided for use in the fresh-air mode and the air should be exhausted into the attic to keep the attic temperature closer to inside temperature, thus reducing the heating and cooling load. Diagrams showing the two methods of feeding fresh air into the home's climate-controlled environment are in Figs. 10 and 11. The integrity of the fresh air duct and louvers is important in that, if air leakage occurs, the efficiency of the heating or cooling units will be impaired. Finally, remember that this system is not proportional and that a simple open-close actuator will suffice. **R-E**