

## A BYTE OF POWER

*Triacs are one way of switching alternating current. Because they are solid-state and operate from logic-level signals, they are well-suited to interfacing computers with electrical devices. Here are plans for an 8-channel board to do just that.*

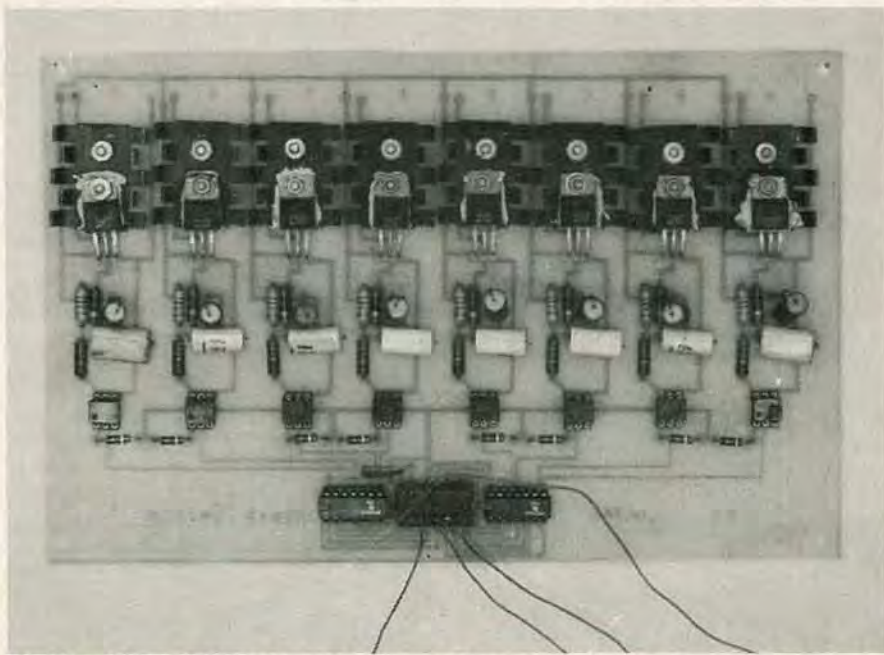
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WITH THE ADVENT OF MICROCOMPUTERS a whole new world has opened up wide for the home-electronics enthusiast. processing are but a few of the uses that have become routine. An often overlooked area, and one where microprocessors excel, is in household controllers. Those may be environmental controls, room-lighting sequencers, darkroom aids, fire alarms, burglar alarms, appliance controls, sprinkler system controls, etc.... The list is bounded only by your imagination. One common requirement for most of those controls is the need to switch household AC power. The circuit described in this article contains eight separate AC power switches—a byte of power.

Each switch is isolated from the other seven. All of them use triacs to provide true bidirectional current flow. By choosing the appropriate resistor/capacitor values, either sensitive ( $I_{GT} < 15$  mA) or non-sensitive ( $15$  mA  $< I_{GT} < 50$  mA) triacs may be used. ( $I_{GT}$  is the gate trigger-current.) Two of the eight power switches have all three triac lines brought out to the edge of the printed circuit card; that permits those on-board triacs to trigger two high-current triacs external to the PC board. The latter would be mounted on heat sinks and their terminals cabled to the printed-circuit board. The triacs are turned on or off with a logic gate—10 mA maximum current. The logic input is photo-optically isolated from the AC power-output stage.

### About the circuit

As stated earlier, the printed-circuit card contains eight identical switching circuits. Figure 1-a shows the circuit to use for an inductive load with a sensitive-gate triac. Fig. 1-b provides



**BYTE OF POWER AC CONTROLLER board uses eight optoisolator-driven triacs to provide computer control of "outside world" AC-operated devices.**

the inductive load-configuration for the non-sensitive-gate triac, and Fig. 1-c illustrates the setup for resistive loads. Each triac is driven by a MOC3011 optically-isolated triac driver which, in turn, is driven by a 74125-type buffer acting on instructions from a computer.

The optically-isolated triac drivers are fabricated using a gallium-arsenide, infrared light-emitting diode that is optically coupled to a silicon bilateral switch. The electrical insulation is about 7500 peak volts. The LED trigger current required to latch the output is typically 5 mA; the maximum is 10 mA. Since the input is driven by an open-collector gate operating at +5 volts, then the value of resistor R1

is chosen to provide greater than 10 mA of current through the diode. The value calculated for that circuit was 390 ohms.

The output driver has a terminal voltage, off-state, of 250 volts. At 70°C, the on-state current (full-cycle 60 Hz) is 50 mA; at 25°C the on-state current is 100 mA. Resistor R2 sets the current level for the output driver. For the sensitive-gate inductive-load circuit in Fig. 1-b, resistor R3 has a value of 2,400 ohms and capacitor C1 is equal to 0.1  $\mu$ f. For the nonsensitive inductive-load circuit, resistor R5 is 1.2 K and capacitor C1 is 0.2  $\mu$ f. Resistor R4 and capacitor C2 are used to reduce false triggering due to line transients caused by the inductive load

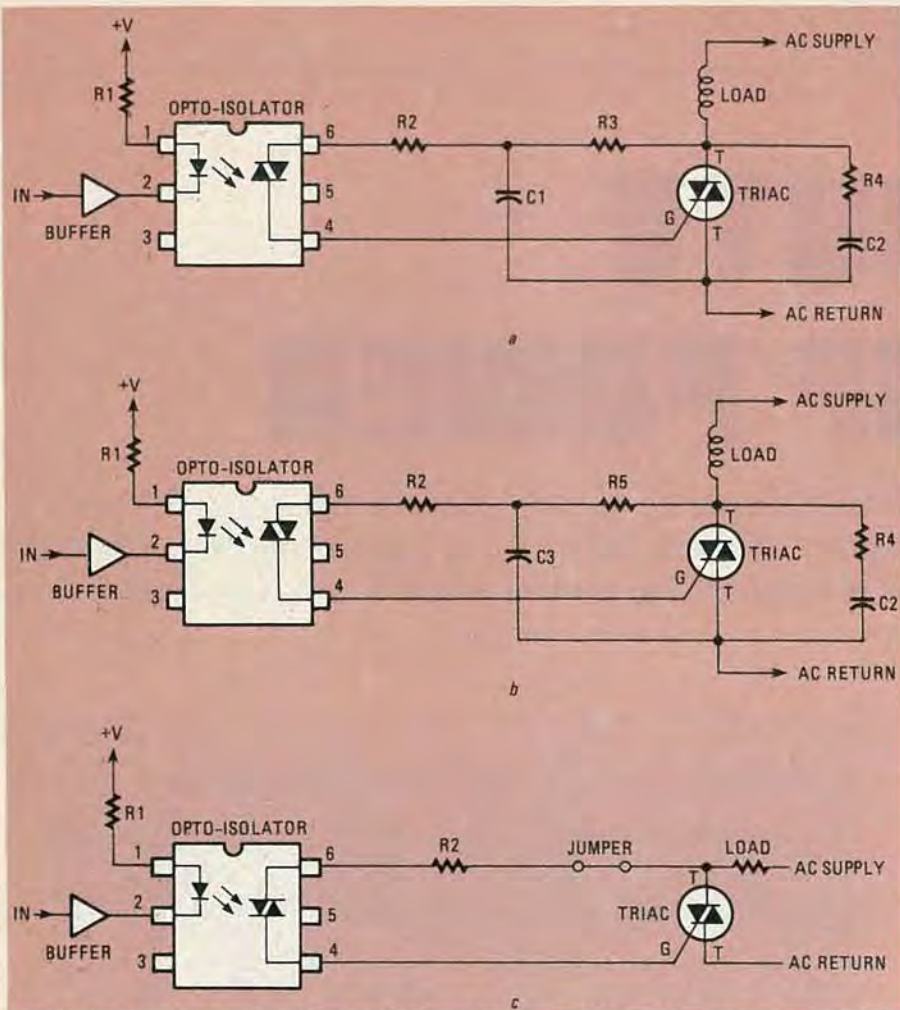


FIG. 1—USE THE TOP TWO CIRCUITS, a and b, with sensitive and non-sensitive-gate triacs, respectively, for inductive loads. Circuit c is for use with resistive loads.

element. A value of 10 ohms for R4 and 0.1  $\mu$ f for C2 seems to do the job quite well.

If a non-inductive load is to be switched, then the circuit can be simplified as shown in Fig. 1-c. Capacitor C2 and resistor R4 are not needed since no inductive "kick-back" will be seen. Also, resistor R3 and capacitor C1 are unnecessary. Place a jumper wire where resistor R3 would have been located.

### Thermal considerations

On the printed-circuit board, space is provided for a small, 1 x 1-3/16-inch, TO-222-style heat sink. The maximum current that can be passed through the AC switch is a function of its power dissipation. That factor is defined by the thermal resistance between the silicon chip and its environment, the ambient temperature, and the maximum junction temperature. Before beginning construction, one must decide the amount of power needed. If more power is needed for the load than can be handled by the triac and its heat sink, then a heavier-duty, off-card triac and heat sink must be connected to the board.

To determine how much current

can be passed through a triac, you must first determine the amount of power that can be dissipated by the silicon chip into its environment. Heat (power) can be removed by any of three means: conduction, convection, or radiation. Heat transfer by *conduction* is very effective in moving energy from the chip to the heat sink. *Convection* is the mode of transfer that transfers heat from the heat sink into the air. A portion of the heat is also *radiated* from the heat-sink fins.

Since most readers are familiar with the basics of electrical energy

flow, a comparable model will be used to illustrate heat flow. Electrical resistance is defined by Ohm's law. Ohm's law states that *resistance to the flow of an electrical current (in ohms) will equal the potential divided by the current ( $R=E/I$ )*.

The potential will be measured with reference to ground; that is, potential will be the difference in voltage available from the energy source and the ground level ( $E = E_S - E_G$ , where E is the potential,  $E_S$  is the potential level of the source, and  $E_G$  is the potential level at ground). Thus, an equation for the electrical resistance is  $R = (E_S - E_G)/I$ . Generally  $E_G$  will be zero since it is defined as system ground. Current flow is represented by I.

For thermal resistance, a similar equation exists; potential is the difference between the source temperature and the ambient temperature; energy flow is the power (heat) dissipation. Therefore,  $\theta_{JA} = (T_J - T_A)/P_D$ ; where  $T_J$  is the junction temperature in degrees Celsius,  $T_A$  is the ambient temperature in degrees Celsius,  $P_D$  is the power dissipation in watts, and  $\theta_{JA}$  is the thermal resistance from the silicon chip's junction to its environment in degrees Celsius per watt.

Heat must flow from the junction of the chip to the triac's case, then from the case to the heat sink, and then from the heat sink to the air. At each of those interfaces a certain amount of thermal resistance is encountered. If we were discussing electrical energy flow, a simple resistor network as seen in Fig. 2-a could be drawn. Let us use an analogous method to represent the thermal energy flow in Fig. 2-b. Three resistors, the thermal interfaces, are connected in series. One end is connected to the heat source and the other is the environment, which is at a lower energy potential. The first resistor would represent the thermal resistance from the chip's junction to the triac's case,  $\theta_{JC}$ ; from Motorola's specification sheet for the 2N6349A triac, a value of

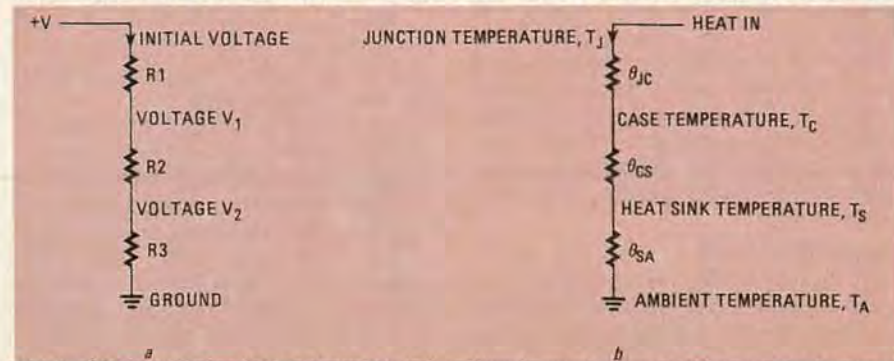


FIG. 2—JUST AS ELECTRICAL POTENTIAL (voltage) is referenced to ground (a), so can the temperature of a semiconductor junction be referenced to the temperature of the air in its vicinity (b).

$2^{\circ}\text{C}/\text{W}$  is given for  $\theta_{JC}$ . The next resistor represents the thermal resistance between the 2N6349A's case and the heat sink. Assuming that thermal grease is used, the value of  $\theta_{CS}$  is  $0.8^{\circ}\text{C}/\text{W}$ . The author used a heat sink with an  $\theta_{SA}$  (thermal resistance from sink to environment) rating of  $19^{\circ}\text{C}/\text{W}$ . Therefore, the total thermal resistance is a sum of these three resistances:  $\theta_{JA} = \theta_{JC} + \theta_{CS} + \theta_{SA}$ . The value of  $\theta_{JA}$  is  $21.8^{\circ}\text{C}/\text{W}$ .

If we assume a temperature of  $60^{\circ}\text{C}$  inside the cabinet that the printed circuit will be housed in, and use the maximum junction temperature from the thermal equation presented earlier, then the maximum power dissipation at the junction will be  $2\frac{1}{4}$  watts. From the curve shown in Fig. 3, one can determine that the maximum current,  $I_T$ , at  $60^{\circ}\text{C}$  will be on the order of  $2\frac{1}{2}$  amps. This means that, at 117 volts AC, devices up to about 290 watts can be switched. That is a *maximum* rating; For practical applications keep your current level to between  $1\frac{1}{2}$  and two amps. If more current is required, use the triac off-card on a heat sink with a lower  $\theta_{SA}$  rating. Note: Two of the eight switches have all three of the required lines brought out to the edge of

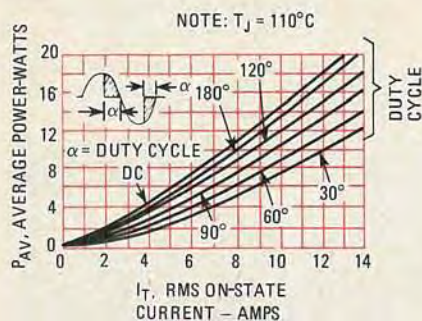


FIG. 3—POWER DISSIPATION plotted against current. Use DC curve for your calculations.

#### PARTS LIST—AC SWITCH

All resistors  $\frac{1}{2}$  watt, 10%, unless otherwise noted

R1-R8—390 ohms,  $\frac{1}{4}$  watt, 5%

R9-R16—180 ohms

R17-R24—2400 ohms or 1200 ohms (see note below)

R25-R32—10 ohms

#### Capacitors

C1-C8, C17— $0.1 \mu\text{F}$  or  $0.2 \mu\text{F}$  (see note below)

C9-C16— $0.1 \mu\text{F}$

#### Semiconductors

IC1-IC8—MOC3011 optoisolated triac driver (Motorola)

IC9-IC16—2N6349A or equivalent triac

IC17, IC18—74125 quad bus buffer

Miscellaneous: PC board, heatsinks (8), hardware, etc.

Note: The part numbers above are related to those given in the text and in Fig. 1 as follows: R1-R8 = R1, R9-R16 = R2, R17-R24 = either R3 or R5, R25-R32 = R4, C1-C8 = either C1 or C3, C9-C16 = C2.

the card so that extra triacs and heat sinks can easily be employed.

#### Construction

Construction is relatively simple

because the circuit is so straightforward. On his prototype, the author used 2N6349A devices. Since the typical gate current ( $I_{GT}$ ) for this triac can be as high as 25 mA, it is clas-

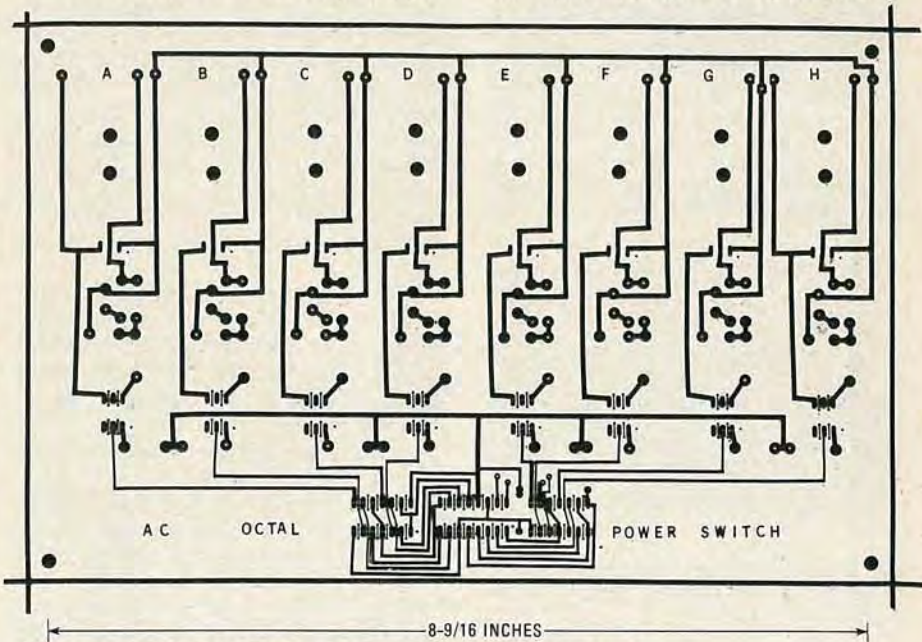


FIG. 4—AC CONTROLLER is built using an easily laid out PC board.

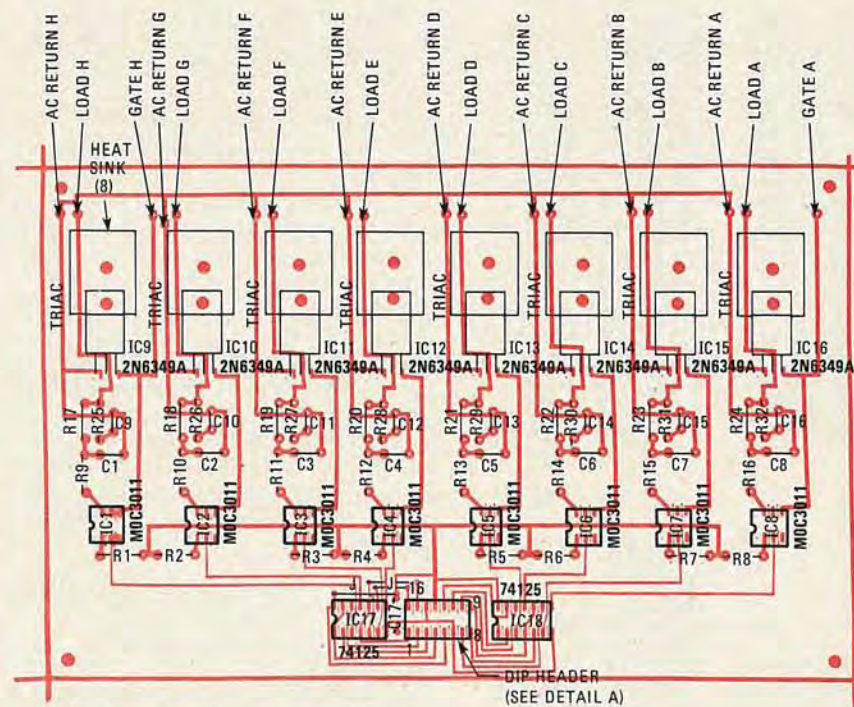


FIG. 5—ALL THREE LEADS of the outermost triacs are brought out to edge of board (see text). Detail "A" shows pinout of DIP header for connection to computer.



FIG. 6—CONNECTION to the AC controller is made through DIP header. Ribbon cable may be used instead of individual wires.

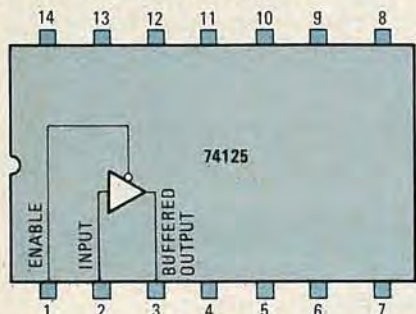


FIG. 7—ONE GATE of 74125 quad buffer. No output will be obtained unless both INPUT and ENABLE are at logic "0".

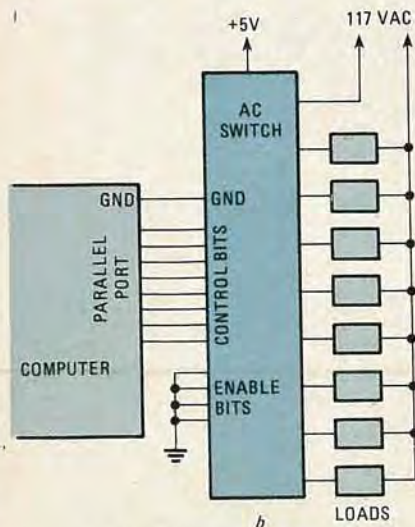
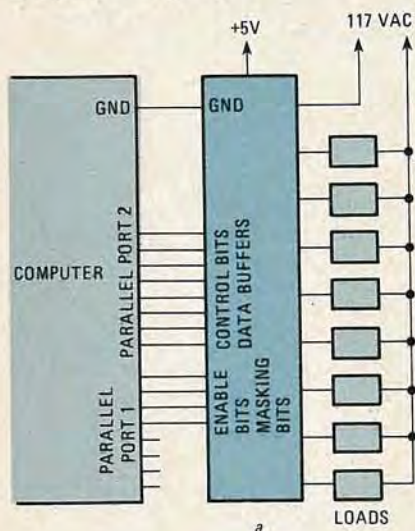


FIG. 8—IF SEVERAL PARALLEL PORTS are available at computer, use hookup shown in a; with only one port, use that in b.

sified as a non-sensitive gate type, and the circuit from Fig. 1-b was used.

If you have a sensitive-gate triac with similar pinouts (on the 2N6349A, pin 1 is main terminal 1, pin 2 is main terminal 2, pin 3 is the gate, and the tab is connected to pin 2), then use the resistor/capacitor values recommended for that gate-current range. (Refer back to Fig. 1-a.) And if only resistive loads—such as toasters, lamps, and coffee pots—are to be used, then you may omit capacitors C1 and C2 along with resistors R3 and R4 and install a jumper in place of resistor R3 as shown in Fig. 1-c.

The circuit uses a single-sided PC board, whose foil pattern is given in Fig. 4. It is quite simple to fabricate; but for those who don't have the facilities, a source for the etched board is given in the parts list.

When installing the triacs on the printed circuit card as per Fig. 5, use a liberal amount of thermal grease between the triac and its heat sink. Also, make sure that the fins of each heat sink clear the fins of its neighbor. The optoisolated triac drivers may be soldered to the board or plugged into sockets. Make sure they are oriented as shown.

After all the components have been installed and soldered into place perform a final inspection. Use Figs. 5 and 6 to check your work. Now connect a TTL driver, a 74125, to one of the input lines via the DIP header (refer to Fig. 5).

At the appropriate triac output connect the common AC line via a fuse to one wire of a line cord; from the other AC output line run a wire to an appropriate load. Connect the other terminal of the load to the remaining line-cord wire. Plug the line cord into an AC outlet. By toggling the input of the 74125 driver, the AC load should be turned on and off. Repeat that procedure for the other seven power switches. **Be careful—the output portion of this circuit has live 117-volt AC power!**

#### Interfacing to a computer output port

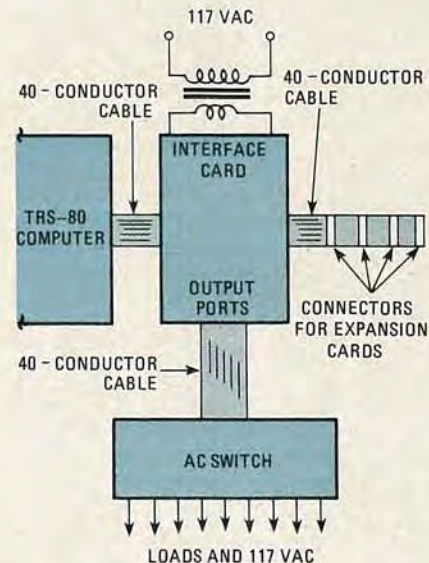
The AC switch is connected to the computer by means of the 16-pin DIP header located between the two 74125's. A control-bit input for each of the eight triacs is provided for, as well as four enable bits—one enable bit for each pair of triacs.

The reason for using two bits (control and enable) for each triac is, primarily, for the sake of security. Even if the computer outputs a control bit to turn on a given triac, the triac will not turn on until an enable signal is also sent. Figure 7 shows one section of a 74125 and Fig. 5 illustrates the DIP header configuration.

Figure 8-a shows the best way to control the AC switch, using two 8-bit

parallel ports. One port sends out the control (input) bits for the triacs you want to turn on, and half of the other is used to send the enable bits for those triacs.

If your computer has only a single parallel port, you'll have to do things somewhat differently. That port will



NOTES:  
+5 VOLT POWER FOR AC SWITCH IS ON PINS 37 & 38. OUTPUT PORT ENABLE LINES MUST BE GROUNDED

FIG. 9—INTERFACE CARD allows AC controller to be used with TRS-80 while providing buffering for addition of other boards.

#### PARTS LIST—TRS-80 INTERFACE

- Resistors, 1/4 watt, 5%**  
R1, R2—2200 ohms  
R3—100 ohms
- Capacitors**  
C1—100  $\mu$ F, 25 volts, electrolytic  
C2, C3—2.2  $\mu$ F, 20 volts, tantalum  
C4-C8, C10—.01  $\mu$ F  
C9—100 pF
- Semiconductors**  
D1-D4—1N4003  
IC1—74LS30  
IC2—7805 five-volt regulator  
IC3, IC5, IC6—74LS244  
IC4—74LS04  
IC7—74LS245  
IC8, IC9—74LS364  
IC10—74LS15  
IC11—74LS02  
IC12—74LS25
- Miscellaneous:** PC board, IC sockets, 40-pin ribbon-cable sockets (3), ribbon cable with connectors, hardware, etc.

The following are available from Quest-Star Electronics Co., 5412 Burntwood Way, Las Vegas, NV 89108: AC SWITCH: Kit of all parts \$115, PC board only \$14.95, MOC3011 \$5.50 each.

TRS-80 INTERFACE: Kit of all parts (except case and cables) \$102.75, PC board only \$21.95. Cables are about \$20 each—write for exact prices.

Please add \$1.75 for shipping and handling. Nevada residents add 3 1/2% tax.

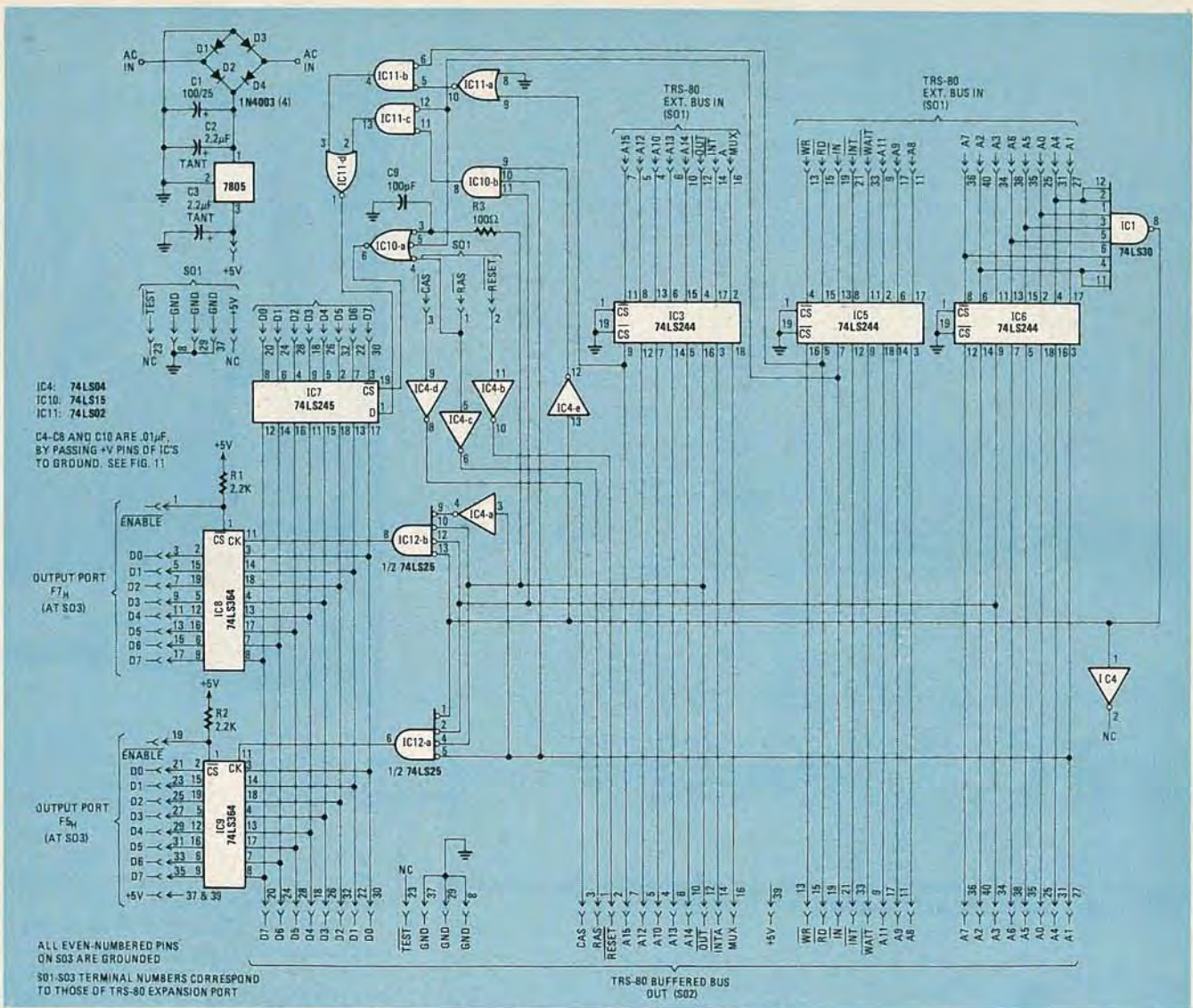


FIG. 10—BUFFERS ON TRS-80 interface card prevent loading down computer's unbuffered port. Bars over signal designations indicate logic "0" control signals.

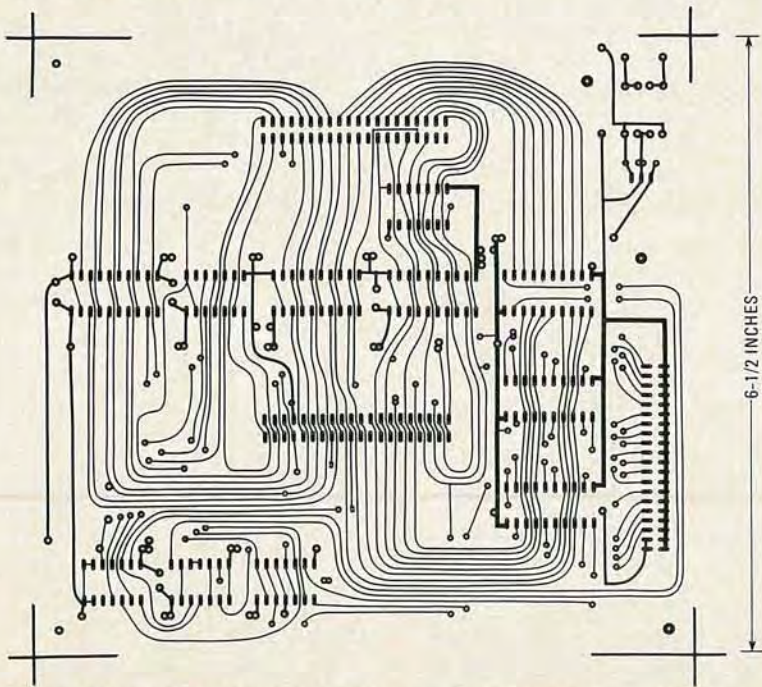


FIG. 11—SINGLE-SIDED PC BOARD is used for construction of TRS-80 buffered interface.

be used to send the control (input) bits, but all the triacs will be permanently enabled by tying the ENABLE lines at the DIP header to ground. (The 74125 will not pass a signal—such as a control bit—unless the ENABLE line is low.) Any bit-masking—making sure that only the bits you want the computer to output actually are—will have to be done in software, rather than through use of the ENABLE lines. That approach is illustrated in Fig. 8-b.

#### Interfacing the AC switch to a TRS-80

The Radio Shack TRS-80 computer has no external I/O ports to use for interfacing with the AC switch card, but it *does* have an external bus. Unfortunately, the bus is only rated for a single TTL load, but it's adequate if you only want to drive a single IC, and in our case we could do just that. You will probably want to use that bus for further expansion of the system, though. To accomplish that, you'll have to add output ports and buffer the external bus. Figure 9 shows how the final hookup would appear.

A schematic of the TRS-80 bus

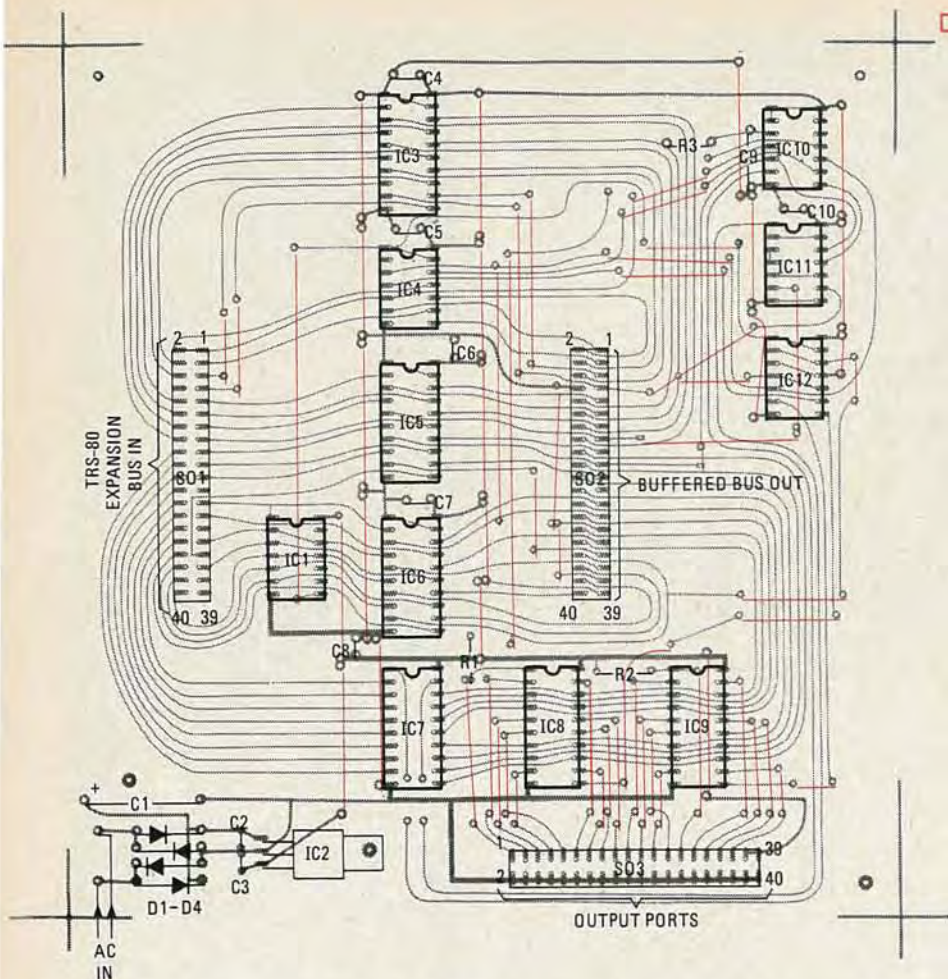


FIG. 12—EXTENSIVE USE OF JUMPERS makes single-sided design possible. They should be the first parts installed. One-ampere, 8 to 12-volt transformer is required.



FIG. 13—USE THE TRS-80 INTERFACE as shown or, better, enclose it in a protective case for security.

buffer and output-port expansion circuit is presented in Fig. 10. It isn't as complex as it looks. Basically, each line coming in from the TRS-80 expansion port has a buffered counterpart leaving the interface board. The data lines are buffered bidirectionally, so that data can flow in both directions. Since the TRS-80 already uses the lower 32K of memory and I/O port FF (hex), the interface board is set up to permit only data transfers to and from the upper 32K of memory, and to use the remaining 255 I/O ports. The two output ports used for the AC switch are F5 and F7 (hex), using IC9 and IC8, respectively.

The foil pattern for that board is shown in Fig. 11, although an already-prepared board is available (see parts list). A parts-placement guide is given in Fig. 12. The board requires a number of jumpers, being single-sided, and those should be installed first. The IC sockets may then be mounted and, after that, the resistors and capacitors. When they have all been soldered in place, the three 40-pin ribbon-cable sockets can be installed. Finally, insert the IC's into their sockets and double-check everything.

You may want to add feet or legs to the board, or mount it in an aluminum chassis box, to prevent anything from shorting out on the bottom. The completed board should look like the one in Fig. 13. The board is powered by an out-board 8- to 12-volt transformer, rated at about one amp.

You will need three 40-conductor ribbon cables to attach the board to the computer and AC switch, and to provide expansion capabilities. Their connection is shown in Fig. 9, referred to earlier.

Whether you use this AC controller with a large computer, a TRS-80 or a single-board, dedicated control system, it will serve you well.

R-E