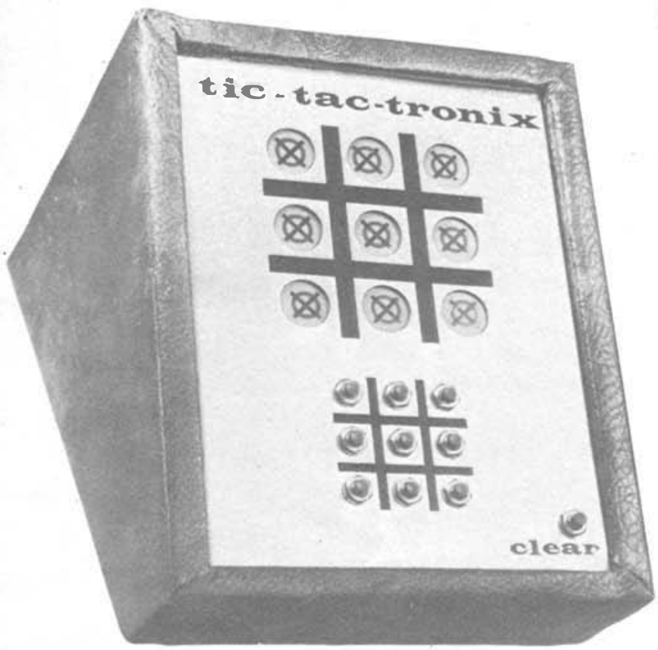
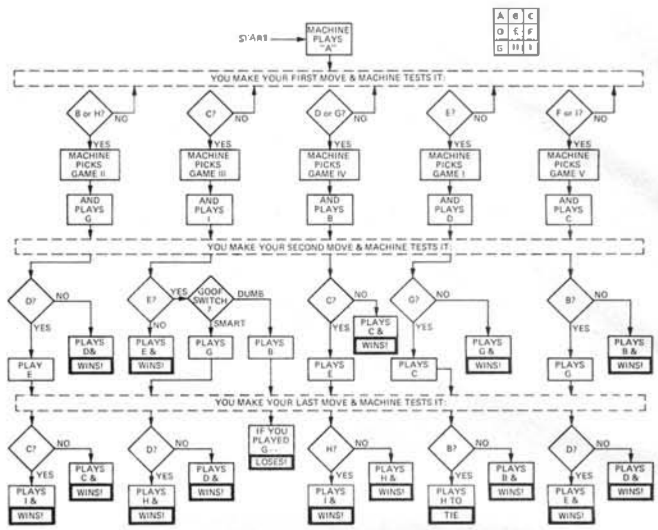
can you beat TIC-TAC-TRONIX?



If you follow the plans and don't cheat when playing you'll never beat Tic-Tac-Tronix



by DON LANCASTER

IF YOU'RE LOOKING FOR A REALLY ADVANCED digital computer project or a sure-fire attention getter for an exhibit, promotion, or display, TIC-TAC-TRONIX is for you.

Tic-Tac-Tronix is a compact, special-purpose digital computer programmed to play an unbeatable game of Tic-Tac-Toe against all comers—unbeatable *unless* you have flipped the hidden GOOF SWITCH. Then, you or anyone who knows the secret can indeed beat the machine. You can build this all-solid-state project for around $45.

The program

Any digital computer follows a predetermined set of rules by way of a series of sequential steps. The rules are often called *algorithms,* and the steps by which these rules are obeyed are called *program steps.* Tic-Tac-Tronix is a permanently programmed computer that has been taught the Tic-Tac-Toe strategy by means of fixed internal connections. This is also called a *hard-wired* or a *fixed* program. One exception is provided in Tic-Tac-Tronix where the GOOF SWITCH is brought out to let you as a programmer choose one of two programs, a beatable one and an unbeatable one. The sequential thought processes or *flow chart* of the machine is in Fig. 1 (at top of this page).

Each square of the Tic-Tac-Toe board is identified by a letter; **A** through **I**. The game begins by the machine playing square **A.** You then make a move and the computer recognizes that you have played and *tests* to find out where you played. As a result of the testing, the machine first picks one of five *strategies* or *program branches.* and then answers your move. The machine then awaits your second move, after which it again tests and plays either to win immediately or to set up a potential win on the next move. The machine always sets up a "critical square" situation and tests that square on its next move to see if you played on it. The third move is similar to the second, and the computer usually wins on the third move. Further moves are ignored by the computer.

Although it takes the computer only a few billionths of a second to move each time, a two-second time delay is introduced after each move, for effect, to let the computer "think things over". With the goof switch in the SMART position, the computer *always* wins if you play anything but the middle square (**E**) on your first move. Even then, it can win if you are careless.

Suppose you try to beat the computer by playing the lower righthand corner (**I**). The game begins with the computer playing **A** followed by your **I** response. The computer tests, sees that you played **I,** picks strategy **V,** and plays **C.**

On the next move, if you haven't played **B,** the machine does and wins. If you have played **B,** the machine plays **G,** letting it win next move either **A-D-G** or **C-E-G.** On your next move, the computer tests square **D.** If you played here, the computer plays **E** and wins. If not, it plays **D** and wins. The strategies for the other moves are similarly based.

For variety, all possible winning forks have been set up in the computer, including three corners; two corners and the middle; and one corner, the middle, and an adjacent side. Should you answer with the middle square **E,** the computer decides on a defensive strategy and forces you to block its moves.

The goof switch tampers with strategy **III** if it is set to the DUMB position. This gives the machine one wrong move, allowing the player to win.

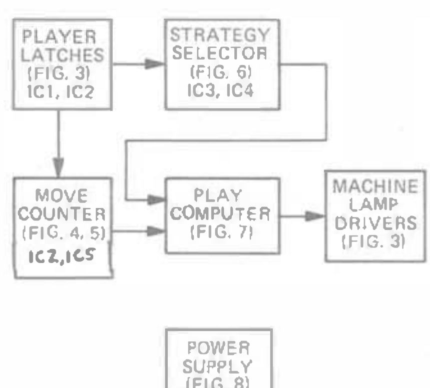
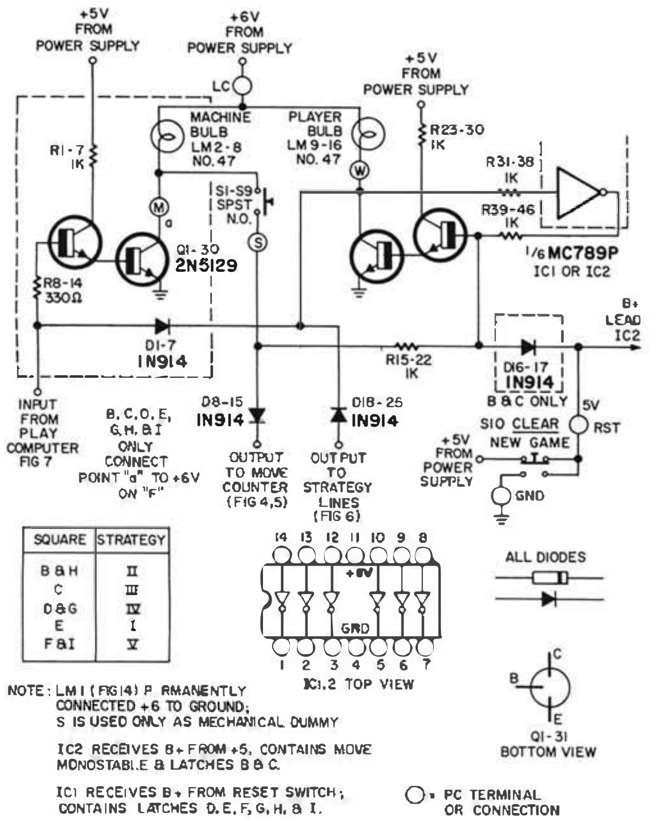


FIG. 2—BLOCK DIAGRAM OF TIC-TAC-TRONIX. Schematics of sections in Figs. 3 to 8.

Tic-Tac-Tronix circuitry

The circuit is made up of five IC's, 31 transistors, and a resistor-diode computer array. The block diagram of the



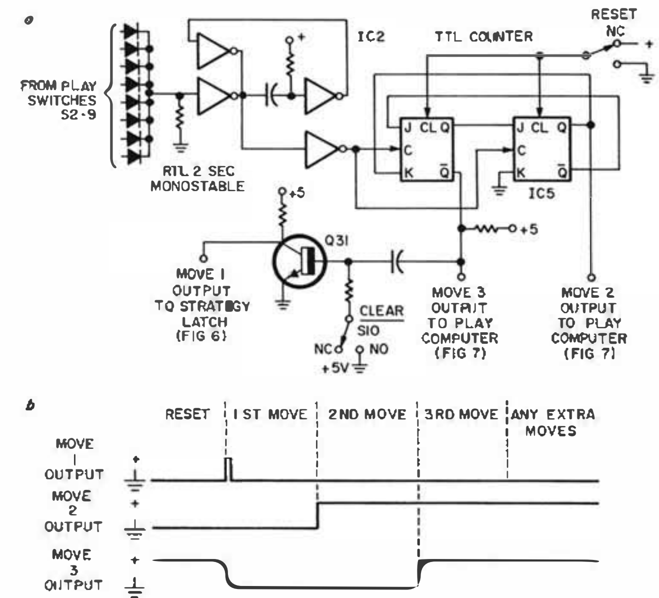
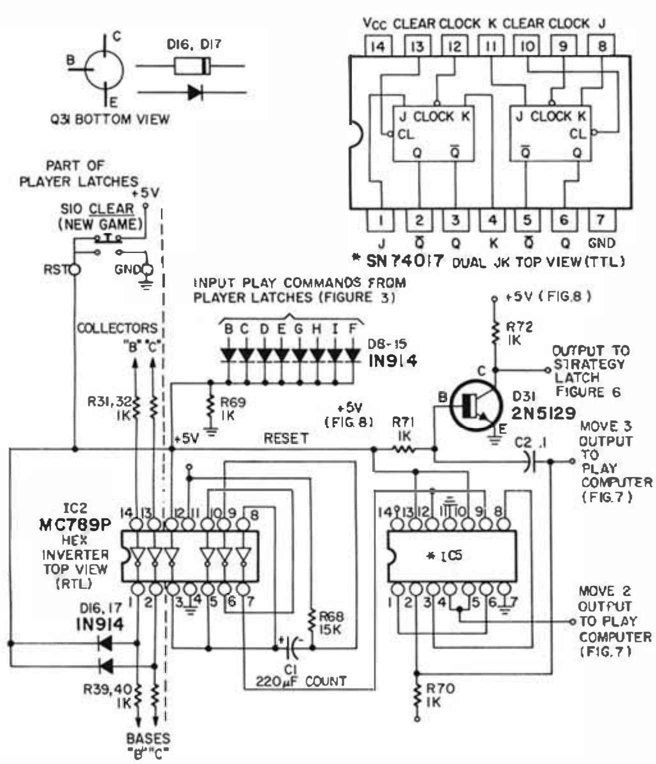
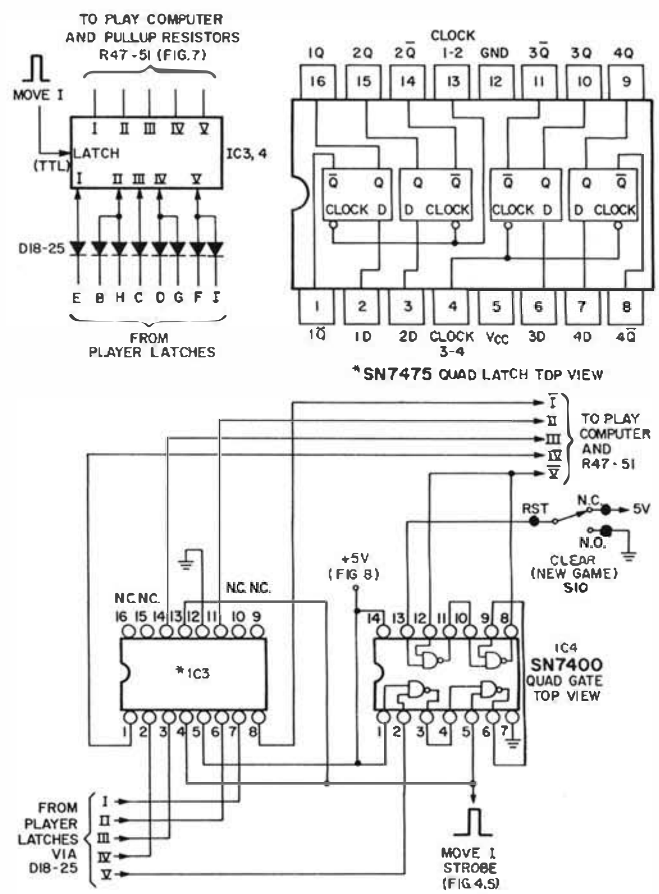


FIG. 3 (top left)—PLAYER LATCHES and machine drivers light proper lamps. FIGS. 4 and 5 (above and lower left)—LOGIC AND SCHEMATIC diagrams of the move counter which keeps track of game's progress. FIG. 6 (below)—STRATEGY SELECTOR picks and holds one of five possible strategies based on prior player moves.



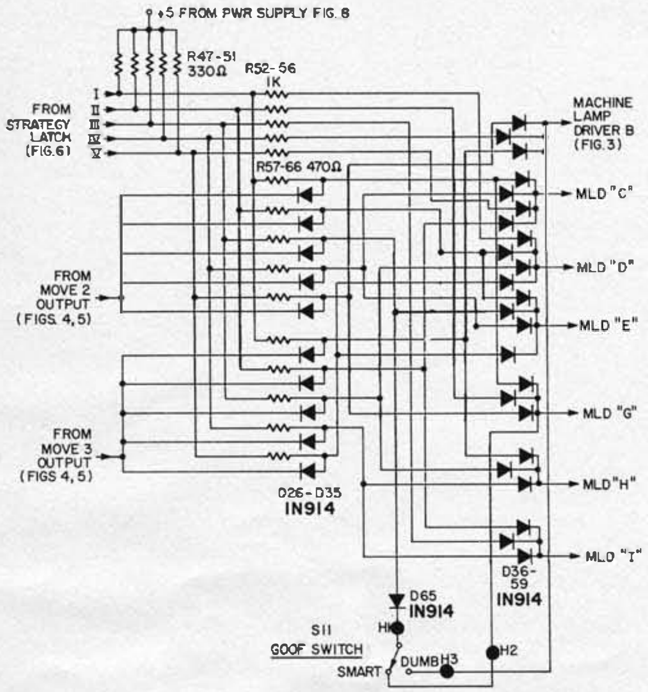


circuit is shown in Fig. 2, while the schematic is in Figs. 3 through 8, broken up into modular chunks.

The player latches and machine drivers are shown in Fig. 3. A player's move shows up as a lit blue pilot lamp; the machine's by a lit red lamp. These two illuminate a red X and a blue 0 in each display cubicle, resulting either in a black X on a blue background, or a black 0 on a red background.

Player latches are needed for squares **B** through **H**. *Machine drivers are not needed at* **A** and **F** since **A** is permanantly lit and since square **F** never has to be played by the machine.

Each player latch consists of a set-reset flip-flop using an integrated circuit inverter and a Darlington lamp driver. Pushing a valid select pushbutton sets the flip-flop and lights the bulb. It also delivers a play pulse to the move counter via one of diodes D8 through D15. The pushbutton is interlocked



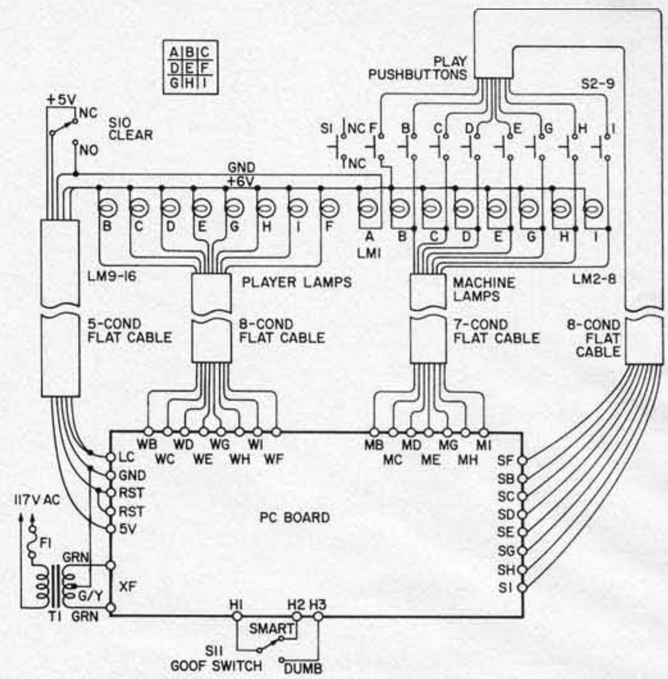


FIG. 7 (top left)—PLAY COMPUTER is DTL array used as the brain-center of the game. Three diode-resistor networks determine moves. FIG. 14 (above)—WIRING DIAGRAM shows how multi-lead cables are used to simplify the wiring and as an aid when troubleshooting.

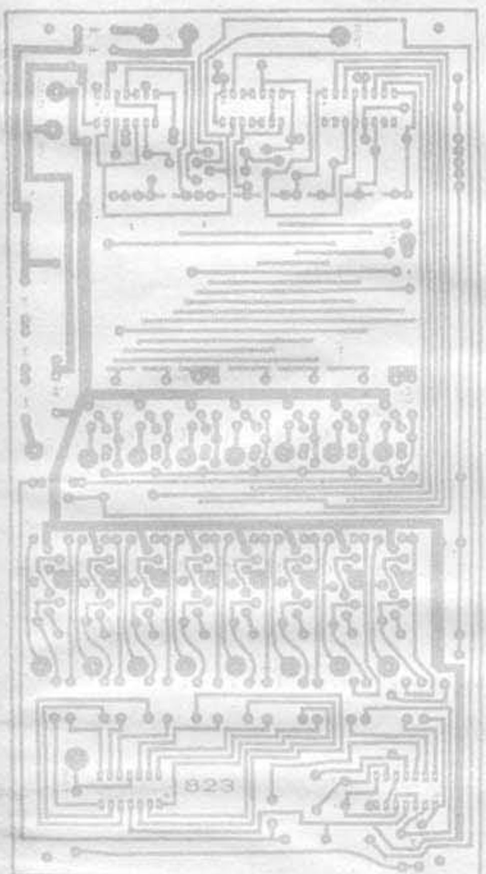


FIG. 9—FOIL PATTERN OF COMPUTER BOARD is reproduced here exactly half-size so you can make your own if you desire.

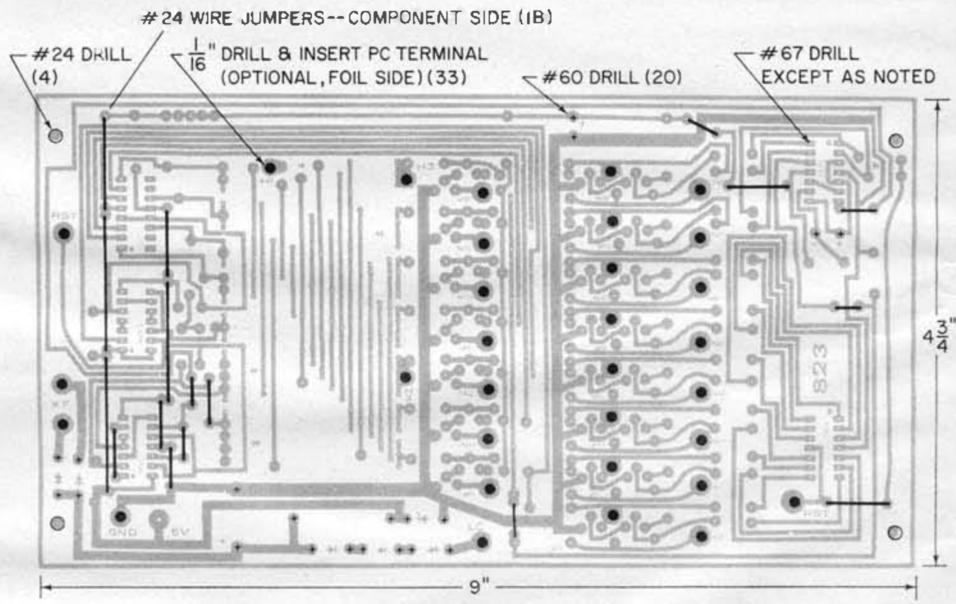


FIG. 10 (middle right)—DRILLING GUIDE shows hole sizes and the location of jumpers to be installed on componant-side of the board.

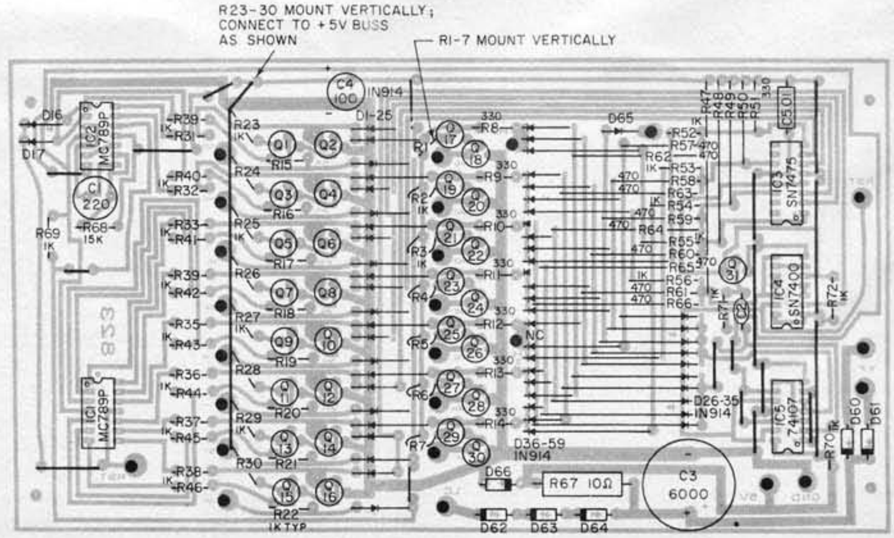


FIG. 11 (right)—COMPONENT LAYOUT shows the position of all parts. Use small iron, thin low-temperature solder and extreme care.

with the machine bulb so that the player can't cheat and attempt to play on top of a square the machine has already used. If the machine bulb is lit, no voltage is available for the pushbutton and it won't set the player latch or advance the move counter.

Diodes D18 through D25 provide a reference of what square has been played. This information is later used by the strategy latch when it has to pick a game strategy after the first move.

The player latches must be reset for each new game. This is done either by removing the inverter supply voltage or by shunting Darlington current with diodes D16 and D17, depending on the particular player latch being reset. S10 is the reset (CLEAR) switch. It does several things. It resets the player latches; it resets the move counter; and it loads a "no play" strategy into the strategy selector.

PARTS LIST

R1 thru R7, R15 thru R48, R52 thru R56, R69 thru R72—1000 ohms, ¼ watt (48 total)
R8 thru R14, R47 thru R51—330 ohms, ¼ watt (12 total)
R57 thru R66—470 ohms, ¼ watt
R67—10 ohms, 2 watts
R68—15,000 ohms, ¼ watt

C1—220 μF, 6-volt electrolytic
C2—0.1 μF, 10-volt disc ceramic
C3—6000 μF, 10-volt electrolytic
C4—100 μF, 6-volt Electrolytic
C5—0.01 μF, mylar

D1 thru D59, D65—1N914 or equal (60 total)
D60 thru D64—1 amp, 50 piv, silicon power diode
D66—1N4733, 1-watt Zener diode, 5.1 volts

F1—0.5-amp fuse & holder

IC1, IC2—MC789P MRTL Hex Inverter
IC3—SN475 or MC7475 Quad Latch TTL
IC4—SN7400 or MC7400 Quad Gate TTL
IC5—SN74107 dual JK flip-flop TTL

LM1 thru LM16—No. 47 pilot light; 6.3 volts, 150 mA

Q1 thru Q31—2N5129

S1 thru S9—spst pushbutton
S10—spdt pushbutton
S11—spdt slide

T1—filament transformer: primary, 117 Vac; secondary, 12.6 Vct, 2 amps

Miscellaneous: PC Board (see text and Figs. 9, 10, 11): No. 24 wire jumpers; PC terminals (33; optional); flat cable or wiring harness (see Fig. 12); subchassis assembly; ⅜" ID grommets (16); Silichrome lamp filters APM Hexseal No. 1813/27-R5 RED (8) and No. 1813/27-B1 BLUE (8); front viewing filter kit; front panel; vinyl-clad case; line cord and strain relief; switch hardware; misc hardware; wire; solder; lacing twine.

NOTE: The following items are available from Southwest Technical Products, 219 W. Rhapsody, San Antonio, Texas, 78216:
Printed Circuit Board Etched & Drilled
No. PC-962 $8.65
Set of all listed electronic parts and hardware less display assembly & cabinet
No. 962K $42.25
Postage & insurance additional. Shipping weight: 3 lbs, 5 oz.

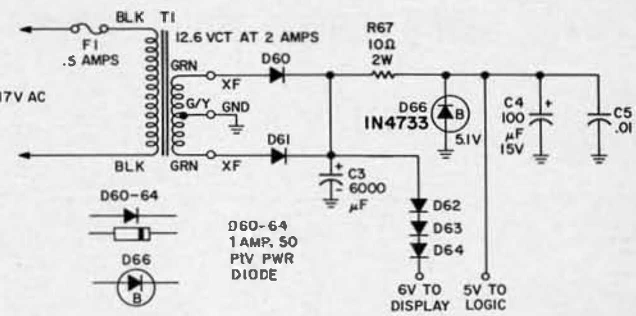
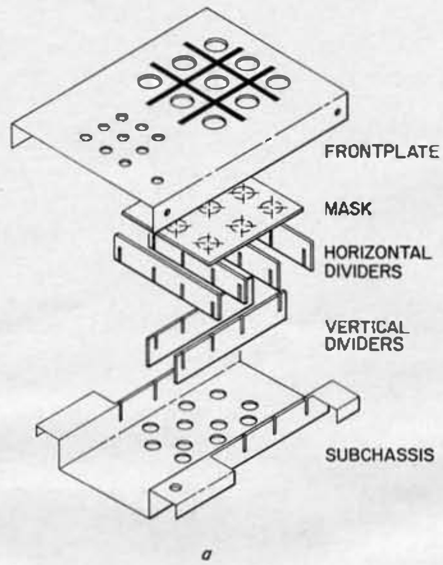
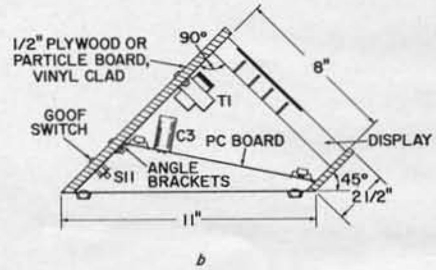
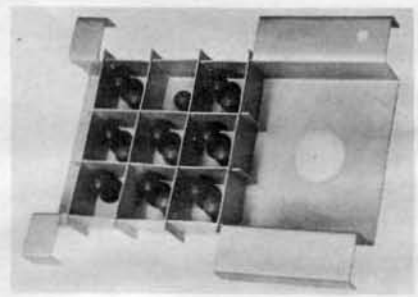


FIG. 8—POWER SUPPLY delivers 5 volts regulated to solid-state devices and 6 volts dc to the lamps.







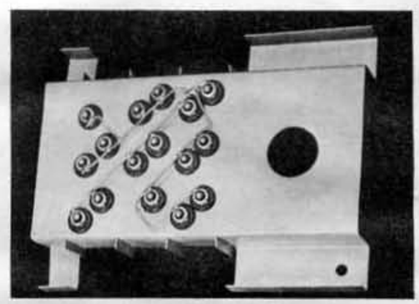


FIG. 12—DISPLAY ASSEMBLY construction is shown in drawings (a and b) and in the photographs above.

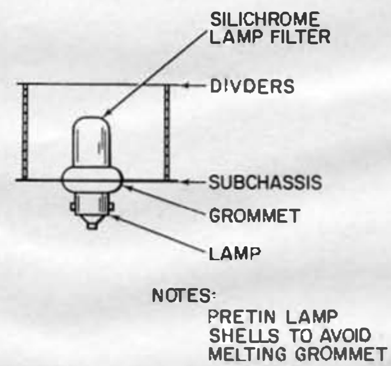


FIG. 13—HOW DISPLAY LAMPS ARE MOUNTED. Pre-tin lamp shells for low-heat soldering.

The machine drivers do not have to latch as they are continuously driven by the play computer. They are also Darlington lamp drivers. If the input from the play computer is made positive, the lamps light. A new game starts when the reset switch returns the play computer and the strategy selector to an all-outputs-low condition.

Diodes D1 through D7 serve an important function. They are the way the computer tests to see if a square is occupied. If the player lamp is lit, the diode robs the machine driver of its base current and prevents the computer from playing on top of the player.

The machine keeps track of the moves with the move counter, shown logically in Fig. 4 and schematically in Fig. 5. The move counter is made up of a 2-second delay monostable IC2, a four-state counter IC5, and a strategy select pulser Q31.

Depressing any valid play pushbutton trips the monostable in IC2 and provides a two-second delay. At the end of the two-second delay, the move counter advances one state. The move counter starts out in a reset condition. On the first move, the strategy-selector is pulsed by half-monostable Q31, while both the move-2 and move-3 logic lines are grounded, preventing any premature move-2 and move-3 plays. On the next play, the move-2 line is allowed to go positive and the second play moves are made. On the next play, the move-3 line is released and allowed to go positive, completing the play. The
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move counter then remains in this last state regardless of any additional plays until it is reset.

Although the move-3 logic output is positive during the reset time, no move-3 lamps will light prematurely as this occurs *before* a strategy is selected.

The strategy selector is shown in Fig. 6. Its purpose is to pick and hold one of five possible program branches or strategies in response to a test made during move one and is aimed at finding the initial player response. On the player's first move, one and only one red player lamp will be lit, and one of diodes D18-25 will be grounded at the lamp end and allowed to conduct. These diodes are OR'ed together to form five strategy lines, with the computer playing the same game with a B or an H initial response; for a D or a G; or for an F or an I.

At the end of move-1, a move-1 output pulse is generated by the move counter. This causes the strategy latch to catch and hold whichever input was grounded, thus remembering where the player went on his first move.

A quad latch is used for IC3, forming four of the strategy latches, while a quad two-input gate IC4 is connected as a fifth latch. On all five latches, the complimentary output connection is used. Thus, *before* a strategy is selected, all outputs are *grounded. After* a strategy is selected and for the remainder of the game, one selected output is *positive*, while the remaining four stay grounded. Depressing reset button S11 returns the latches to an all-outputs-grounded state.

Looking back over Figs. 4 through 6, we see that there are seven *logic lines* provided by these circuits. One of five strategy lines goes positive after the first move. A *move-two* line goes positive after the second move and stays there, and finally a *move-three* line goes positive after the third move.

The logic states on these seven lines are converted into moves by the play computer shown in Fig. 7. This diode-transistor logic array is the brain center of Tic-Tac-Tronix. Move-1 responses are associated with R56 through R56, while move-2 responses are handled by R57 through R61, and move-3 responses are handled by R62 through R66.

A move is made by allowing current from the +5V supply to reach the desired bases of the machine lamp drivers. The +5 volts arrives via resistors R47 through R51. These are all clamped to ground by the strategy selector before move-one, and after move-one, a single resistor is allowed to go positive. During move-one, the move-two and move-three logic lines keep their resistors clamped to ground. On move-two, the move-two line goes positive allowing completion of the second move, and finally on move-three, the move-three line goes positive, allowing completion of the game.

The play computer's outputs are used in conjunction with diodes D1 through D7, which provide the required testing for the second and third moves. Goof switch S11 operates by tampering with the second computer response of strategy III. In the SMART position, things are normal, while in the DUMB position, the wrong square is played, allowing the player to win.

The power supply is shown in Fig. 8. It provides 6.3 volts of moderately filtered dc for the lamps and a regulated 5 volts for the logic and the rest of the circuit.

How to build it

A printed circuit board is essential for this project. The foil pattern of the board is in Fig. 9.

Fig. 10 is a drilling guide that also shows how the 18 jumpers of No. 24 solid wire are positioned on the component side. PC terminals may also be optionally set on the com-

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ponent side: 23 are needed.

Components are located as shown in Fig. 11. The IC's are identified by a notch and dot between pins one and fourteen. They are shown top view everywhere in this article. Use a small iron and fine solder when installing. Be very careful in observing the polarity of all the diodes. To save some board space, two groups of resistors mount upright. R1 through R7 mount vertically in individual holes, while R23 through R30 mount vertically and a common bus is run along their top ends and terminated to +5 volts as shown.

Case and display

Everything mounts in a sloping vinyl-clad wooden case with the circuit board, goof switch, and power transformer near the bottom and the display on top. Fig. 12 shows how the display assembly goes together. A subchassis is used that holds the lamps and their color filters. The lamps press into grommets as shown in Fig. 13. Six dividers go above the lamps, eggcrate style, forming nine individual cubicles for each of the squares. The insides of each divider should be very shiny.

The playing screen

A frosted Mylar mask is made of drafting Mylar. Translucent X's and O's are added using the translucent red and blue printed-circuit tape sometimes used in two-sided PC board layout work. A front plate secures the entire assembly as well as holding switches S1 through S10. These switches are operated by the player to conduct his game.

Wiring is shown in Fig. 14. Sixteen-conductor flat cable is broken up into two 8-conductor sections, a 5-conductor section, and a 7-conductor section; and used as a wiring harness. Note that lamp A is lit all the time, and that S1 is not connected and used simply as a mechanical dummy. **R-E**