

BUILD THIS EXPERIMENTOR'S CIRCUIT DESIGN STATION





CIRCUIT DESIGN STATION

Prototyping CMOS circuits becomes a breeze with this Experimenter's Work Station. With it, you're done almost as soon as you start!

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WHETHER YOU'RE A WEEKEND EXPERIMENTER wishing to duplicate circuits you've seen elsewhere, or a full-time circuit designer, the CMOS Experimenter's Work Station is for you. The Work Station centers around a solderless breadboard. Commonly called "Q" or "L" sockets, those devices allow components and jumper wires to be plugged in quickly and disconnected easily when no longer needed. That makes for a speedy buildup (and modification) of a circuit. They also allow the same components to be used over and over again.

In addition to a solderless breadboard and battery power-supply, the Work Station includes three features that are commonly used in experimental work. These are:

1. Buffered light emitting diodes (LED's)
2. Two-phase clock (oscillator)
3. Debounced switches

The Work Station integrates all the above items on a single PC board that also serves as the top cover. When designing or building up a circuit on the Work Station, you need not duplicate clocks, LED's, or debounced switches—they're already right there for your use!

This highly portable project is easy to construct, uses readily available components and can be built for under \$40.00.

How it works

The Work Station consists of 12 buffered LED's, two two-phase clocks, four debounced switches, a battery

power supply and the solderless breadboard. Each circuit is independent of each other; so, we'll discuss each separately.

Buffered LED's: Most logic circuits require some type of output indicator, the most common being a LED. Since a LED requires a current of between 10 and 20 mA to glow brightly, direct connection to most CMOS IC's is not recommended (they can't provide sufficient drive). Rather, the LED should be connected to a buffer circuit to allow a small current (in this case, fractions of a milliampere) to cause the LED to glow. The Work Station contains 12 identical buffered-LED circuits, four of which are shown in Fig. 1.

Taking LED1 as an example, current can flow from +V through R1 and LED1 to the output of CMOS NAND gate IC1-a. If pin 3 of IC1-a is high (approximately +V), then no current will flow through LED1 and it will remain dark. If pin 3 of IC1-a is low (approximately ground), current will flow through the LED and it will glow. NAND gate IC1-a can *sink* (route to ground) greater than 10 mA and, therefore, will suit our purpose well. For IC1-a to go low, *both* inputs must be high. Under any other conditions, pin 3 of IC1-a will be high. Let's assume that the GATE 1 input (IC1-a pin 2) is high; if we provide a high logic-level input to IC1-a via pins 1 or 8 of socket SO1, the LED will glow.

In most circumstances, the GATE 1

input will be connected to R25 by jumpering SO1 pin 2 to SO1 pin 7. This will provide a high logic-level input to pin 2 of IC1-a. The GATE input can be used in another way. Assume that we are designing a game where, at some time, all the LED's that are glowing must blink on and off. By connecting the GATE inputs of all the LED's to the same level, we can make all the LED's that are lit via their input's blink on and off. Access to the 12 LED's is via the six 8-pin DIP sockets, SO1 through SO6.

Two phase clock: The term clock is simply another name for an oscillator. A two-phase clock has two outputs that alternate between high and low states. Thus while one output is high, the other is low.

In many applications, it is desirable to be able to turn (or *gate*) the clock on and off. The Work Station contains two such two-phase clock circuits, as shown in Fig. 2. The two clock circuits are identical. For discussion purpose, we'll look at the Clock-A circuit which consists of IC4-d, IC4-c, R29, R49 and C2. The rate of oscillation is determined by the resistance of R29, and R49 (and the capacitance of C2). Pin 13 of IC4-d is the gating input. If pin 13 is high (as when jumpered to R27), the clock will run. If pin 13 is low (as when jumpered to ground on SO8), the clock will stop. If we were to jumper pin 13 to R27 and then connect a switch between ground and pin 13, we could turn the clock on and off simply by

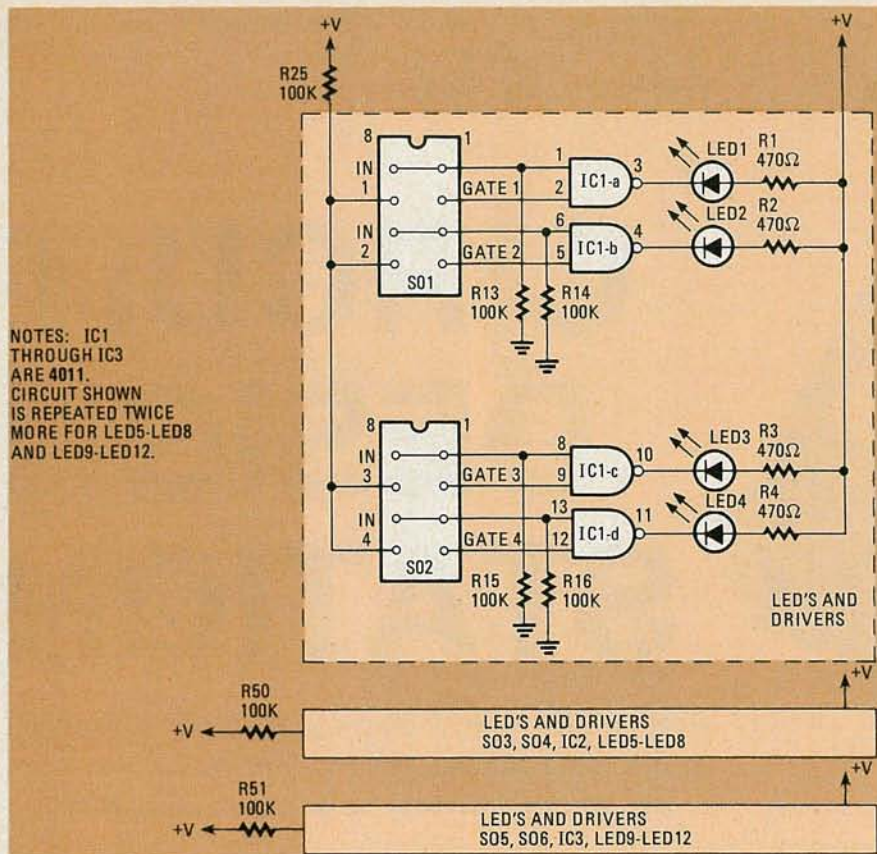


FIG. 1—BUFFERED LED's are included in the Work Station's design for use as output indicators. Buffer circuitry is required because many CMOS IC's cannot drive LED's directly.

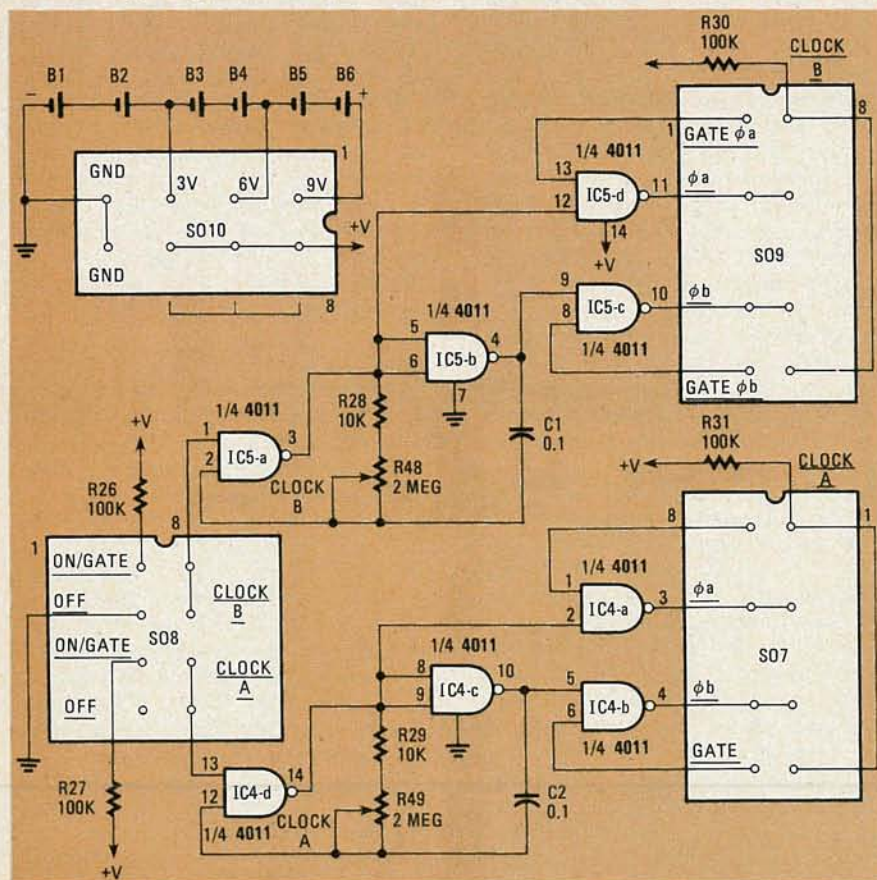


FIG. 2—TWO-PHASE CLOCK circuit includes buffering and permits gating of each phase, allowing a variety of pulse combinations. Power supply provides 3, 6 or 9-volts.

using the switch.

The two phases of Clock A are buf-

fered by IC4-a and IC4-b. Each buffering NAND gate also has available an

additional gating input. That is convenient if you would like to keep one phase of the clock high while letting the other phase run normally.

Figure 2 also shows the Work Station's power supply. Since CMOS devices require very little current, batteries can be used as the power source; that allows the Work Station to be highly portable. The six "C" cells are connected to SO10 so as to provide 3, 6, or 9-volts DC. Jumping the desired voltage to pins 6, 7, or 8 of socket SO10 will provide that voltage to the Work Station's circuitry. One of the remaining pins of those three can be used to jumper the selected voltage to the solderless breadboard. Power can be removed from the breadboard and the Work Station by removing the jumper in socket SO10.

Debounced switches: No switch is truly ideal. That is, the switch does not make (or break) contact at the instant you activate it. Actually, the mechanical contacts in the switch open and close quickly many times (bounce) before they come to rest. While that may not be of much consequence in your living-room lamp, the CMOS circuits you are using will more than likely see the operation as multiple switch closures. As a result, your circuit might seem to act quite erratically, although it is doing exactly what the switch is telling it to do! For that reason, switches should be *debounced*, or made to act more nearly in the "ideal" manner.

The Work Station contains four debounced switches as shown in Fig. 3. Taking S1 as an example, we see that prior to pressing S1, C3 is charged to +V. When S1 is closed, C3 rapidly discharges to ground. When the voltage across C3 goes below the CMOS logic-low level (about +V/2), pin 11 of IC8-d goes high. When S1 is opened again, C3 begins charging towards +V through R32. When the charge on C3 goes above the CMOS logic-low level, pin 11 goes low. That "STEP" output is available at pin 1 of socket SO11.

It is also desirable to have a very short duration (pulse) output that does not depend on how long the switch is depressed. The STEP output from pin 11 is processed by IC8-c, C4, R33 and IC7-d to produce a short positive going pulse that is available at pin 1 of SO11.

Construction

A PC board is recommended, although any other form of construction will serve as well. The foil pattern is shown in Fig. 4 and the component placement is shown in Fig. 5. When mounting the resistors and capacitors, save the excess leads for jumpers. IC sockets for IC1 through IC8 are recommended. Note that resistors R15 through R24, R28, and R29 are mounted on the *foil* side of the PC board. They are "tack"-soldered by melting a small

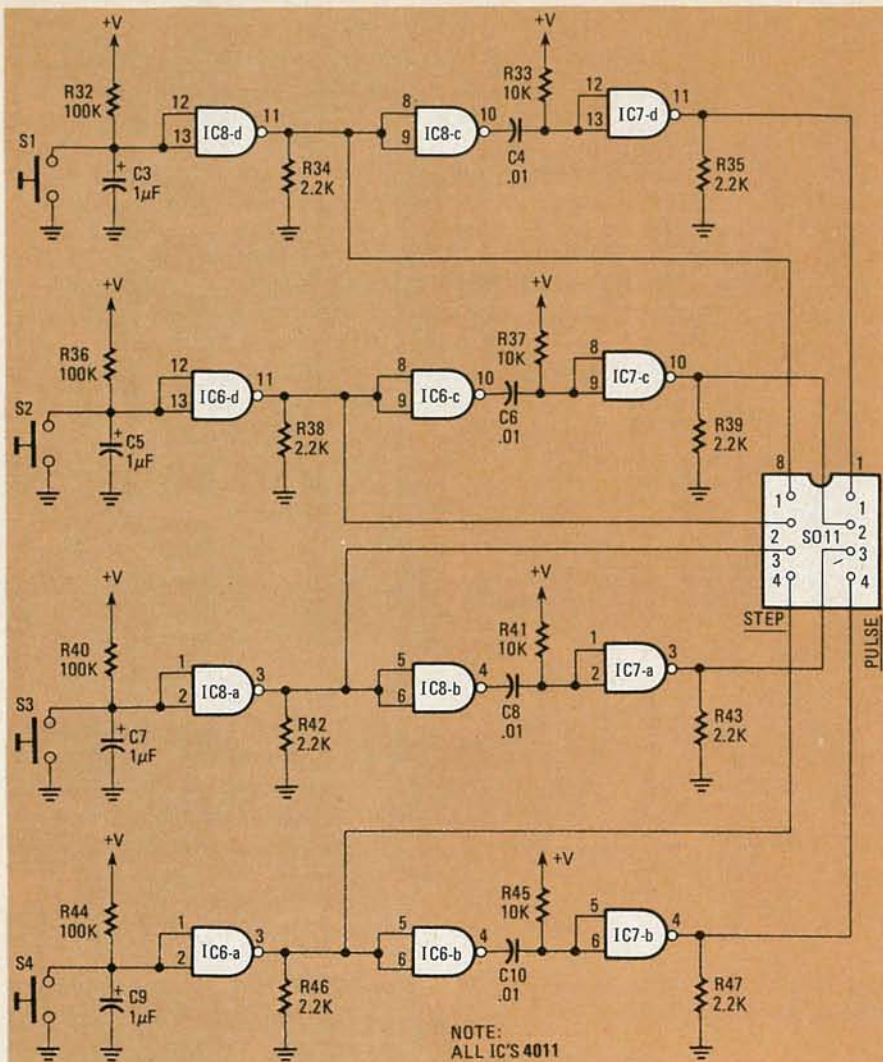
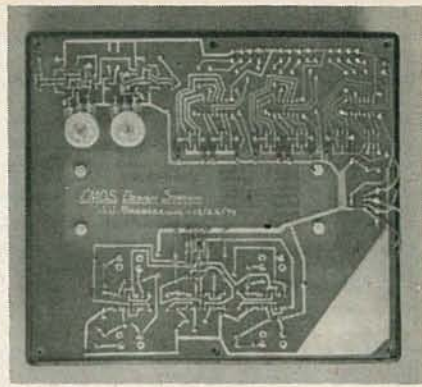


FIG. 3—FOUR DEBOUNCED SWITCHES are provided. STEP outputs remain active as long as switch is depressed; PULSE outputs provide brief, momentary change-of-state.

- PARTS LIST**
- All resistors ¼ watt, 5% unless otherwise noted
- R1-R12—470 ohms
 R13-R27, R30-R32, R36, R40, R44, R50, R51—100,000 ohms
 R28, R29, R33, R37, R41, R45—10,000 ohms
 R34, R35, R38, R39, R42, R43, R46, R47—2200 ohms
 R48, R49—2 megohms, potentiometer, linear taper
- Capacitors**
 C1, C2—0.1 µF ceramic disc
 C3, C5, C7, C9—1 µF, 15 volts, electrolytic
 C4, C6, C8, C10—0.01 µF ceramic disc
- Semiconductors**
 IC1-IC8—4011 CMOS quad, 2-input, NAND gate
 LED1-LED12—jumbo red LED
 S1-S4—momentary pushbutton switch, N.O., PC-mount (Digi-Key EQV-P1R or equivalent)
 SO1-SO11—8-pin DIP socket
 B1-B6—1½-volt "C" cell
- Miscellaneous:** solderless breadboard (Global Specialties EXP-300 or equivalent), PC board, case, three dual-"C" cell battery holders, two knobs, hardware, wire, solder, etc.



SOME COMPONENTS are mounted and tack-soldered on foil side of PC board.

amount of solder on the foil area and then reheating that solder while placing the component lead on the foil area. One lead of R28 is tack-soldered to variable resistor R48, and the same is done with R29 and R49. The battery connections are also tack-soldered to the foil side of the PC board. The battery connections should be of sufficient length to allow the PC board to be easily removed when batteries need replacement.

Eighteen "U" shaped jumpers should be formed from the excess component leads. Those jumpers can then be used in sockets SO1 through SO9 when the gating inputs are not being used.

It is advisable to mark the PC board in a fashion similar to that indicated in the photo of the author's mode. That can be accomplished with a felt-tipped pen or transfer lettering. If transfer lettering is used, the PC board should be marked before mounting any components on it.

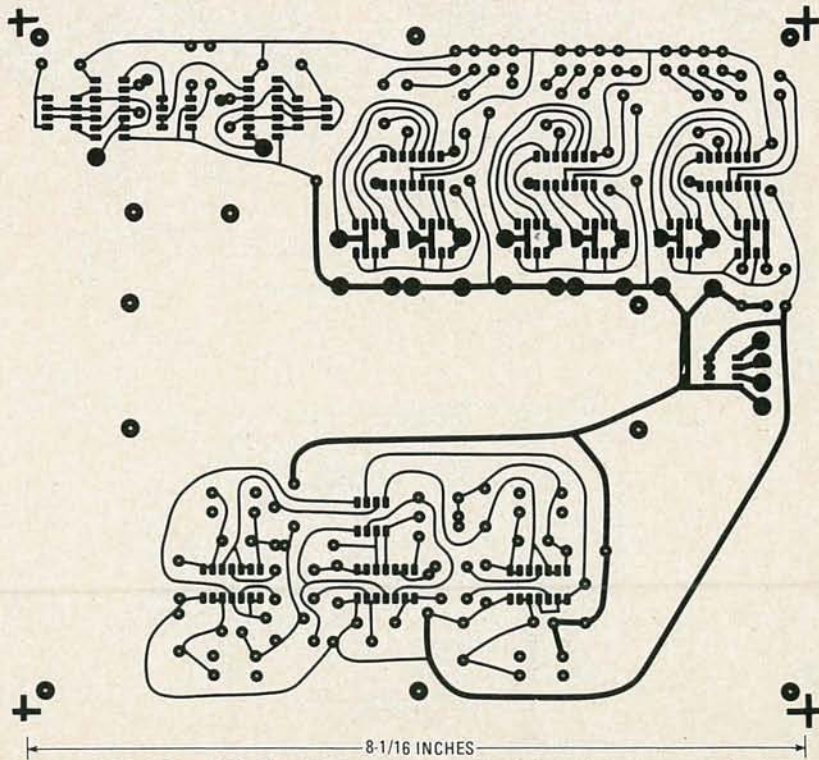


FIG. 4—LARGE PADS on foil side of PC board are used for tack-soldering components. Component side of board also serves as work surface.

Finally, obtain a 12-foot length of No. 20 or No. 22 solid-conductor insulated wire. From that, cut five 1-inch lengths, five 1½-inch lengths and so forth up to five 5-inch lengths. Strip ¼-inch of insulation from each end of each wire. Those 45 wires will serve as jumpers on the breadboard and for connections between sockets SO1 through SO11 and the breadboard.

Checkout

Place "U"-shaped jumpers between the pins of the sockets indicated in Table 1. All these connections are done from the top sides of the sockets, of course. Place an insulated jumper between pins 2 and 7 of POWER socket SO10. That will supply six volts to the Work Station. Place one end of a 5-inch jumper into pin 6 of SO10. Starting with SO1, touch the other end of the jumper to pin 1 and then pin 8. In both instances, LED1 should light. Repeat that procedure for the remaining 11 LED's. Again starting with SO1, move the end of the "U"-shaped jumper connected to pin 7 over to pin 8. Similarly move the jumper-end at pin 5 to pin 6. Now, place the free end of the 5-inch jumper into pin 7. You should see LED1 light. Move the 5-inch jumper end to pin 5. Now, LED2 should light. Repeat that procedure for the remaining 10 LED's. Finally, reposition the "U"-shaped jumpers.

Next we will check for proper oper-

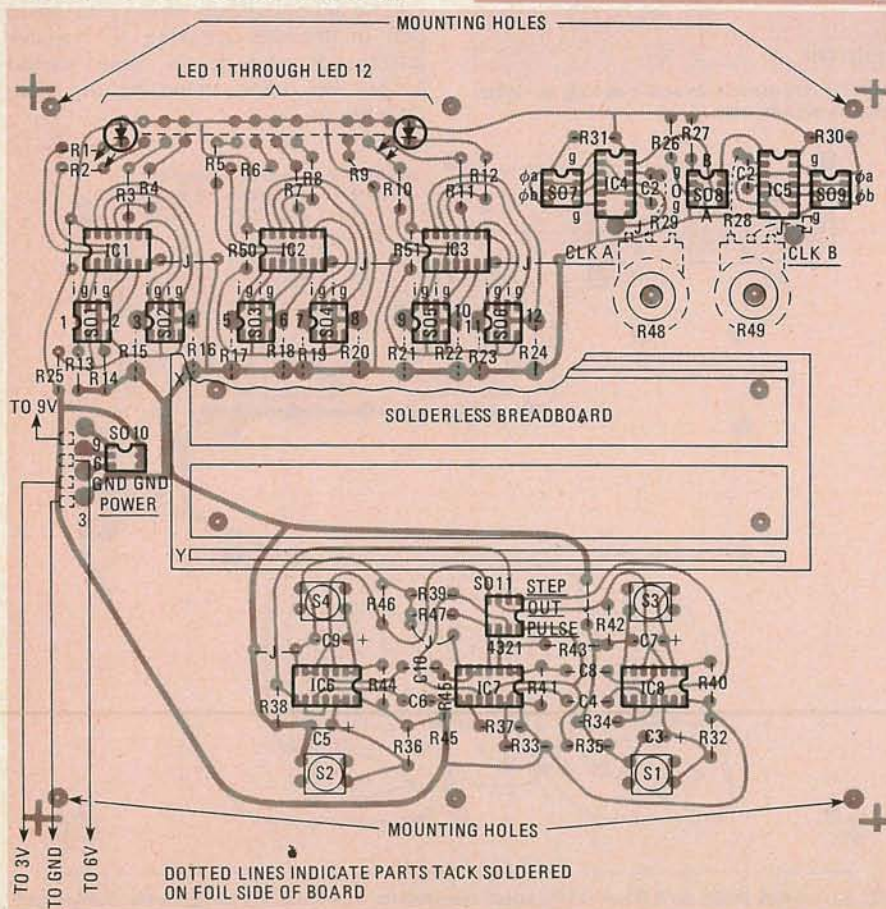


FIG. 5—SOLDERLESS BREADBOARD is mounted in middle of board using four sets of 6-32 hardware.

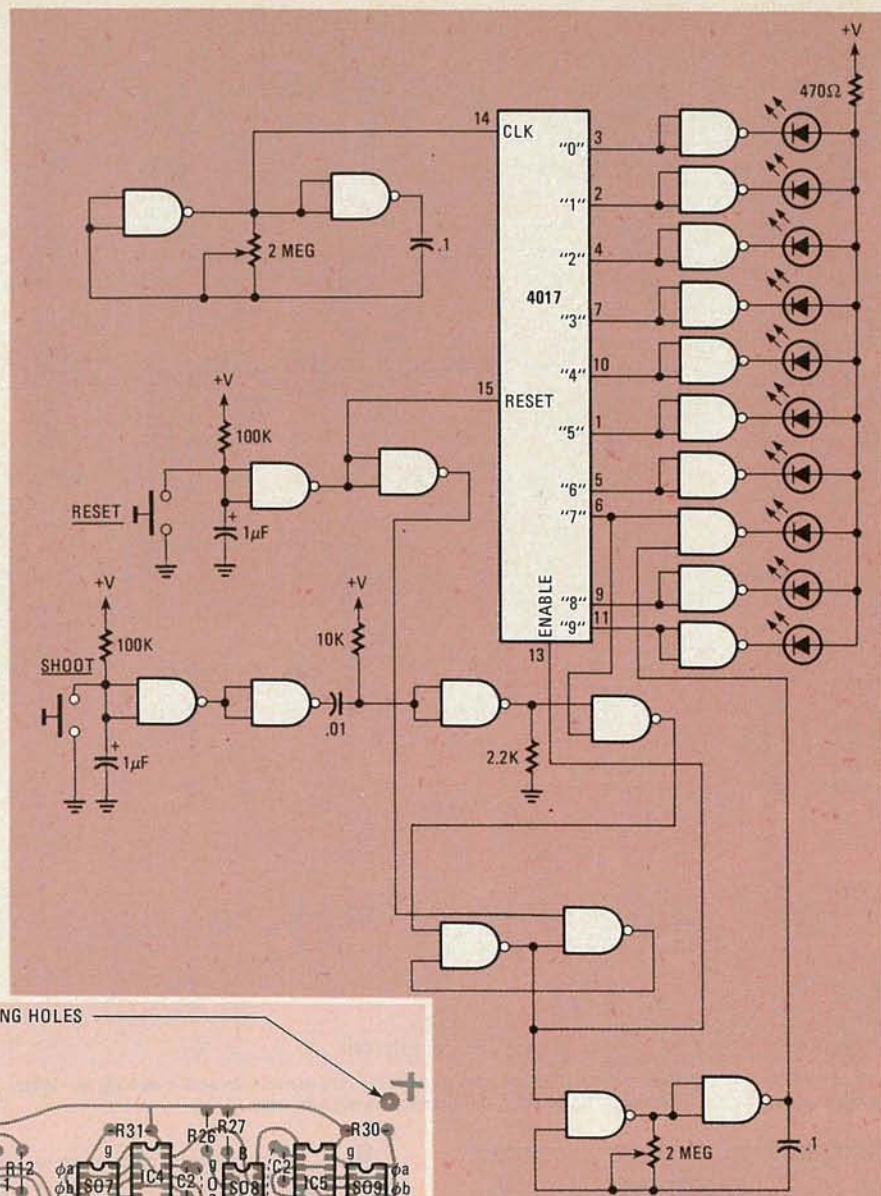


FIG. 6—TARGET-SHOOTING GAME circuit calls for among other things, seven integrated circuits, ten LED's and two push-button switches. Compare this with circuit in Fig. 7.

ation of the switches. Place one end of a 5-inch jumper in pin 1 of SO6 (LED11). Place the other end into pin 8 (Switch 1 STEP output) of SWITCH OUTPUT socket SO11. Press and hold S1. As long as S1 is depressed, LED11 should glow. Move the jumper end to pin 1 of SO11 (Switch 1 PULSE output). When S1 is depressed, LED11 should glow very faintly for an instant and then go dark. Release S1. Repeat that procedure for the remaining three switches.

Now we will check the operation of the clocks. Place a jumper between pin 8 of SO6 and pin 2 of SO7. Place another jumper between pin 6 of SO6 and pin 3 of SO7. That connects LED11 to φa of Clock A and LED 12 to φb of Clock A. Rotate R48 fully counterclockwise. You should see LED11 and LED12 blink alternately. As you rotate R48 clockwise, the rate should increase until both LED's appear to be on con-

tinuously. Place one end of a jumper into pin 8 of SO11 (Switch 1 STEP output). Rotate R48 fully counterclockwise and remove the "U" jumper from pins 4 and 5 of SO7. Place the jumper from S1 into pin 5 of SO7. That should result in LED12's staying lit. Pressing S1 should cause LED12 to blink again. Repeat that procedure with the S1 jumper in pin 8 of SO7 for LED11. Rotate R48 clockwise. Finally, move the jumper from S1 to pin 5 of SO8 (CLOCK A GATE). You should see LED11 go dark. Pressing S1 should cause LED11 to glow again. Repeat that procedure for Clock B, after replacing the jumpers in SO7.

At this point, we have determined that all circuits are operating properly. Now let's try out the Work Station.

Putting it to work

Let's make a target shooting game. We'll have 10 LED's in a row. When we start the game, LED1 will come on for a short time. When it goes dark, LED2 will come on for a short time, and so forth. After the tenth LED goes dark, the sequence will start again with LED1. We'll select one LED which we want to be the target (say LED8). If we press a switch when LED8 is on, the sequence will stop and LED8 will start to blink, indicating a "hit". Otherwise the LED's will continue circulating. We must also have a RESET switch that restarts the game when we want to continue.

One possible circuit for that game is shown in Fig. 6. You will note that seven IC's are required. Let's breadboard that circuit on the Work Station. The breadboard connections are shown in Fig. 7. Notice that with the Work Station, only two IC's are required.

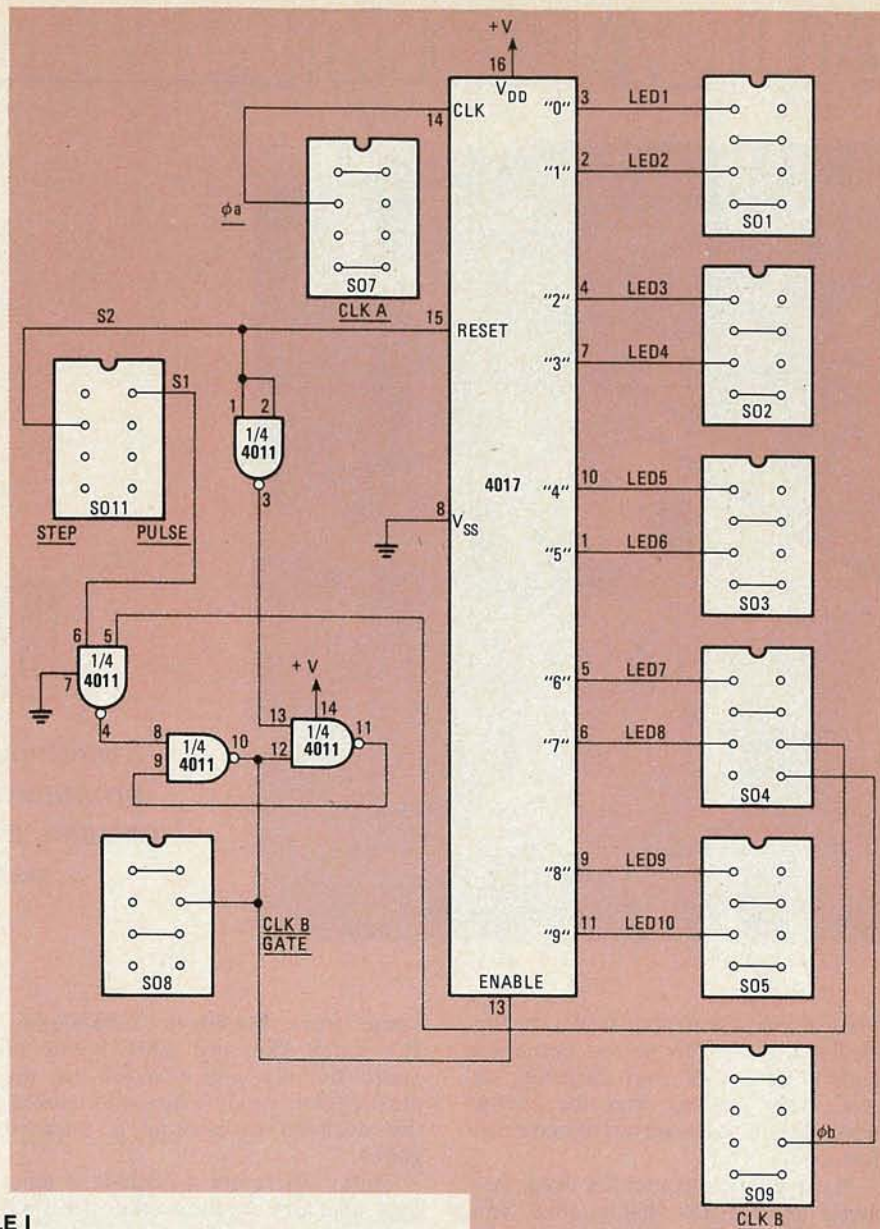


TABLE I

Socket	From pin	To pin	Function
SO1	2	7	LED1 GATE
	4	5	LED2 GATE
SO2	2	7	LED3 GATE
	4	5	LED4 GATE
SO3	2	7	LED5 GATE
	4	5	LED6 GATE
SO4	2	7	LED7 GATE
	4	5	LED8 GATE
SO5	2	7	LED9 GATE
	4	5	LED10 GATE
SO6	2	7	LED11 GATE
	4	5	LED12 GATE
SO7	1	8	ϕ a GATE (Clock A)
	4	5	ϕ b GATE (Clock A)
SO8	1	8	Clock B GATE
	3	6	Clock A GATE
SO9	1	8	ϕ a GATE (Clock B)
	4	5	ϕ b GATE (Clock B)

FIG. 7—GAME CIRCUIT shown in Fig. 6, as constructed using Experimenter's Work Station. The only components required are two IC's, along with jumper wires.

Once the circuit has been breadboarded, rotate R48 and R49 to mid-position and apply power. LED's 1 through 10 will begin lighting in sequence. Pressing S2 will reset the circuit and LED1 will remain lit as long as S2 is depressed. Release S2 and the sequencing will begin again. If S1 is depressed when LED 8 is lit, the sequencing will stop and LED8 will blink on and off. By rotating R49 more clockwise, the sequencing rate will increase, making the game more difficult. The blinking rate for LED8 can be adjusted with R48.

That is just one example of the use of the Work Station. From it you can see how the Work Station allows you to create circuits, quickly and easily, modify them at will, and reuse the components when the circuit is no longer needed.

R-E