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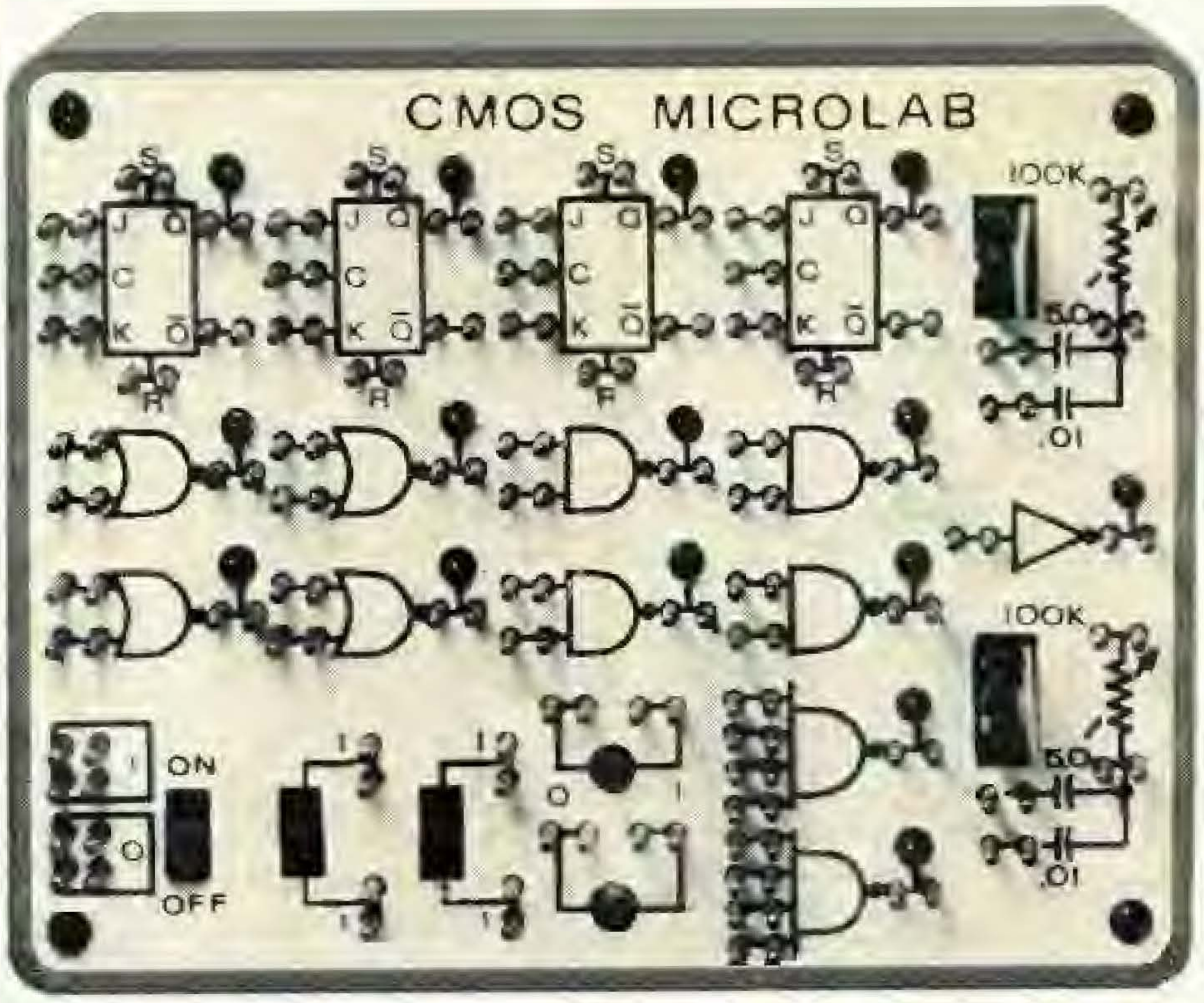

BUILD THE CMOS MICROLAB

Teach or learn digital logic . . .

Breadboard or test digital circuits . . .

With this state-of-the-art CMOS system

BY DON LANCASTER

EXPERIMENTING is an important part of the learning process, so anyone interested in understanding digital logic will want to have this CMOS Microlab to gain practical experience. It contains four JK/RS flip-flops, four NOR gates, six NAND gates and an inverter/TTL driver. Each section has all terminals available on the front panel and they can be easily interconnected with a solder-free push-on patchcord system. Each logic block also has its own LED to indicate the state of the block. The Microlab can be constructed for about $35, is battery powered and fits in a 5" by 7" by 2" box.

The logic functions are controlled by two bounceless slide switches and two bounceless pushbuttons. Two RC networks provide for visual rate or oscilloscope rate (mid-audio) clocks, astables, monostables, and pulse networks. The single inverter can be used as a source or sink for 8 mA, making the system compatible with TTL, DTL, RTL, PMOS, or other CMOS units. Four additional TTL unity-fanout outputs are also available.

A feature of the Microlab, for learning purposes, is that making the wrong connections between units cannot cause any damage. Also, if a connection that is not too important is forgotten, the circuit anticipates what the experimenter is trying to do and tries to provide a response anyway. For instance, without external connections, all unused logic blocks are turned off; and gates with only one input automatically convert to inverters. A flip-flop without J and K connections tries to toggle; without R and S connections, direct inputs are disabled.

About the Circuit. There are 21 independent circuits in the Microlab. Only one of

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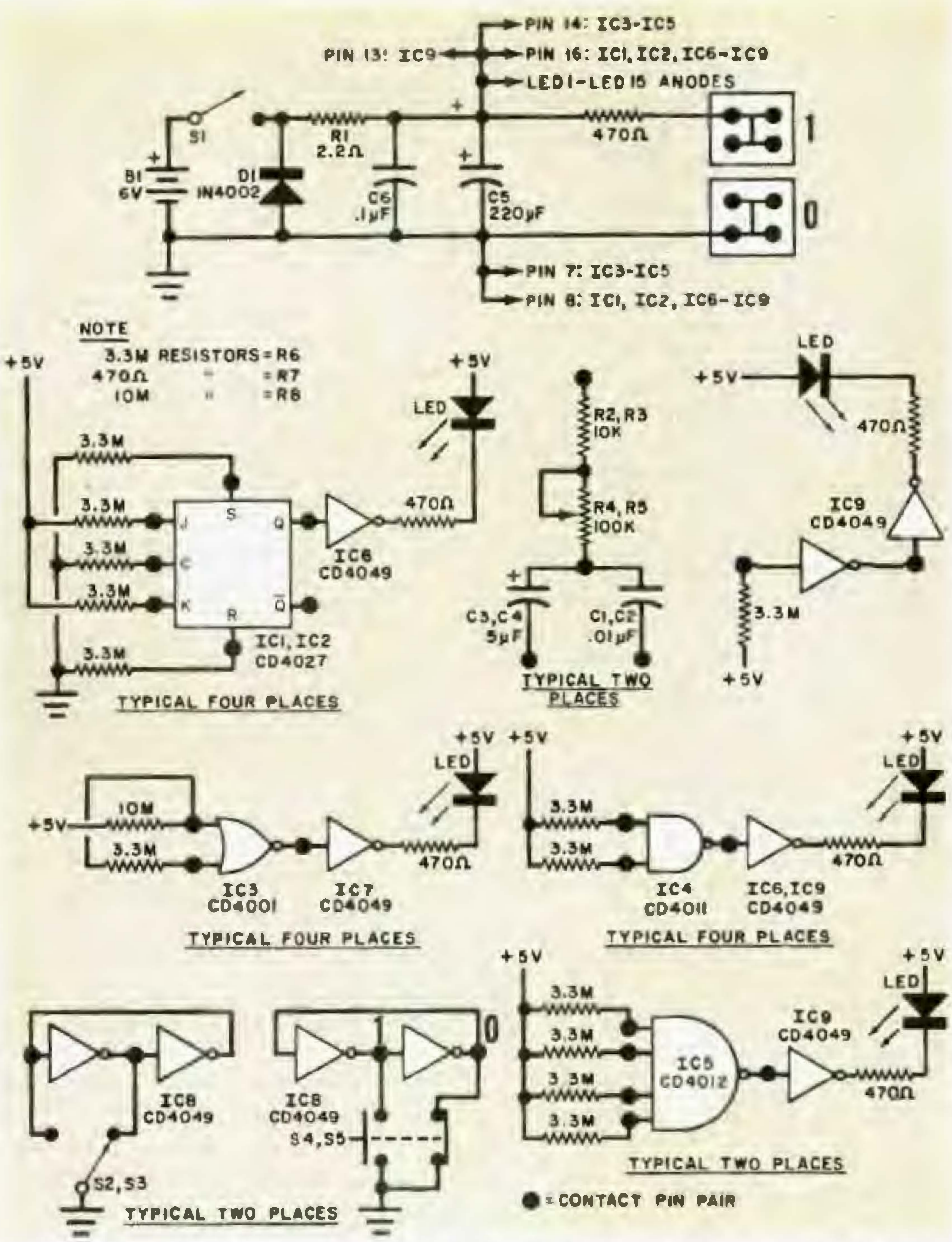


Fig. 1. One of each type of logic block is shown. Power supply is at top.

PARTS LIST

B1—Four 1.5-V D cells
C1, C2—0.01-μF Mylar capacitor
C3, C4—5-μF aluminum electrolytic (not tantalum)
C5—220-μF, 6-volt electrolytic capacitor
C6—0.1-μF, 10-volt disc capacitor
D1—1N4002 silicon power diode (or similar)
IC1, IC2—CD4027, MC14027 (CMOS dual JK/RS flip-flop)
IC3—CD4001 (CMOS quad NOR gate)
IC4—CD4011 (CMOS quad NAND gate)
IC5—CD4012 (CMOS dual NAND gate)
IC6-IC9—CD4049 (CMOS hex inverter)
LED—0.2" diameter light-emitting diode (15 required)
R1—2.2- or 2.7-ohm, ½-watt resistor
R2, R3—10,000-ohm, ¼-watt resistor
R4, R5—100,000-ohm upright trim potentiometer (Piher Mfg. or similar)
R6—3.3-megohm, ¼-watt resistor (40 required)
R7—470-ohm, ¼-watt resistor (16 required)
R8—10-megohm, ¼-watt resistor (4 required)
S1—Spst slide switch
S2, S3—Spdt slide switch
S4, S5—Spdt pushbutton switch, non-shorting
Misc.—Pins (0.093" diameter, Bead Chain or Molex R93-12, 168 required); terminals (Molex 02-09-1118 or 02-08-1101); suitable plastic case (Nobex 875); front cover (matched to pc board); mounting hardware; quad D-cell holder (Keystone 200); heat-shrinkable tubing; stranded hookup wire; etc.
Note: The following are available from Southwest Technical Products, 219 W. Rhapsody, San Antonio, TX 78216: pc board, etched and drilled, at $8.75; complete kit of all parts (except for D cells) at $34.95, plus postage for 3 lb. ***Actual-size pc foil patterns and component installation diagrams are free on request.***

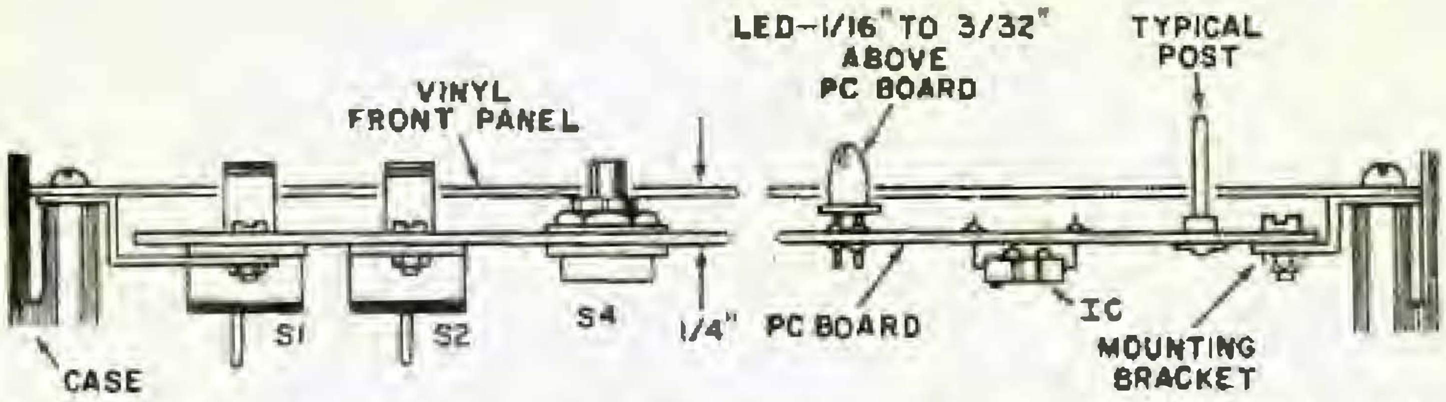


Fig. 2. Mounting details and component spacing for circuit board.

each type is shown in Fig. 1. The power supply, which is common to all, is also shown.

Note that each circuit has a pin connector (dark circle) at each active input or output. This actually indicates a pair of solderless push-on connectors. Each circuit (except for the 0-1 switches) also has its own inverter-LED driver. The two pushbutton switches are made bounceless by a pair of inverters arranged as a set-reset flip-flop.

A high resistance is used on the active inputs (connected either to ground, the supply, or another input) so that the LED is off if a block is unused. It also converts a gate into an inverter if only one input is used and changes a flip-flop into a binary divider if only the clock input is connected.

Four D cells are used for power. Since each LED uses about 7 mA, several hundred hours of operation can be obtained from one set of batteries. With such low power consumption, ordinary D cells work better than the more expensive alkaline types. Reverse polarity protection is provided by diode *D1*.

Construction. The circuit board is double-sided, preferably with plated-through holes. Foil patterns and component layout diagrams are available *free* from the source given in the Parts List.

Assemble the five switches, the LED's and posts as shown in Fig. 2. Note that only the LED's, the two thumbwheel potentiometers, and the 168 connecting pins are mounted on one side of the board. Install the resistors, capacitors, and the diode on the other side of the board, along with the Molex IC terminals (if used). Do not install the IC's at this time.

Be sure that all connecting pins are cleanly soldered to the non-component side of the board and that they are square to the board. Keep in mind that the pins must pass cleanly through the mating holes on the front panel. When installing the LED's note that the flat side of the LED goes to the inverter and current-limiting resistor. If one of the LED's leads is longer than the other, the longer one is the anode and goes to the positive supply.

Install the LED's so that they are about 1/16" or 3/32" above the board. If you have trouble soldering under the LED, first solder it in place with a slightly higher spacing. Then heat the pins from the underside of the board while pushing the LED into final position. Remember also that the LED's must fit into a mating hole on the front panel.

The power supply should be assembled next and connected to the pc board with the four pins marked "1" at +5 volts and the four "0" pins at ground.

Now make up the push-on interconnecting wires as shown in Fig. 3. Crimp and solder each end of the flexible stranded hookup wire to a connector. You will want about 24 of these wires, varying in lengths from 6" to 10". After they are fabricated, slip heat-shrinkable tubing over the joints between the connectors and wire so that the wire, solder joint, and connector are covered. You can use the ceramic portion of a soldering iron for the heat source. Pre-condition each connector by slipping it on and off a pin several times until it works freely.

For the following steps, connect a milliammeter across power switch *S1*. If the current ever exceeds 7 mA per LED (when lit) stop and check the circuit.

Install *IC7* (hex inverter) and *IC3* (quad

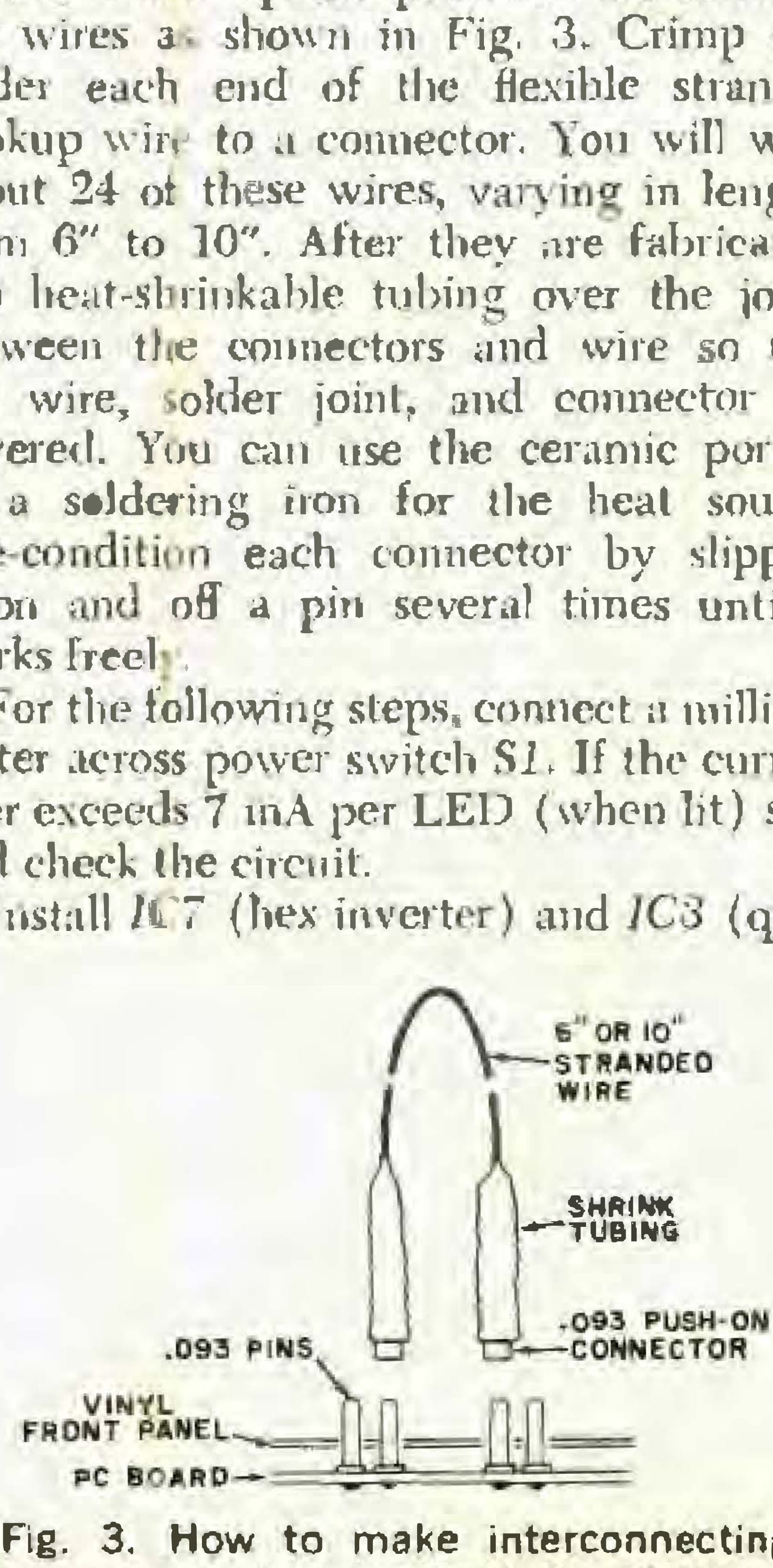


Fig. 3. How to make interconnecting jumpers. Make up about 24 of them.

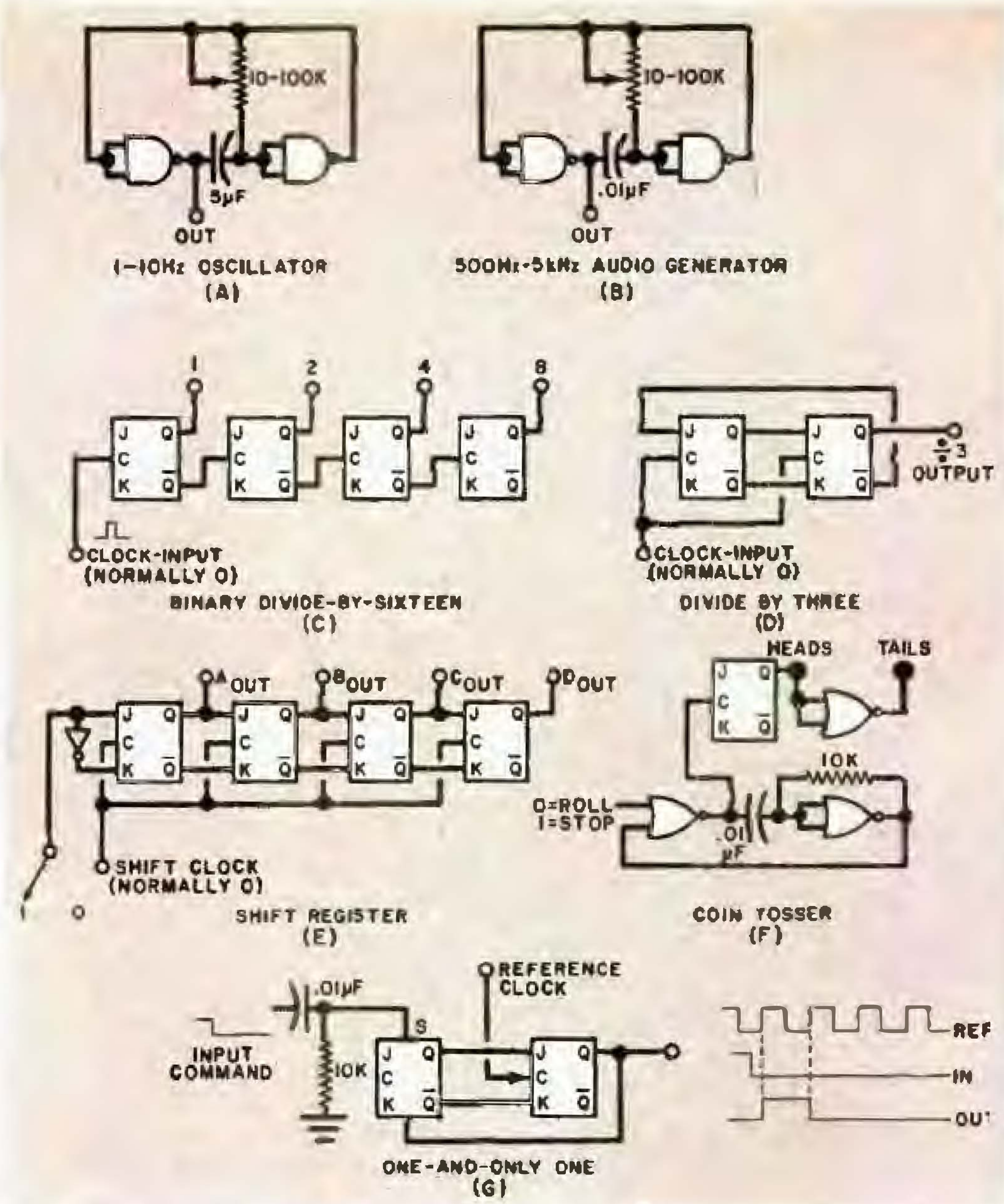


Fig. 4. Some examples of the circuits that can be built up using the Microlab. There are many others, of course, that will be of interest.

NOR gate) noting the notch-and-dot code on the IC and on the component installation drawing.

Connect one end of a test cable to one of the "0" points on the lower left corner of the board. Touch the other end of the cable to all four pins at each NOR gate. The associated LED should come on when the contact is made.

Next install *IC5* (dual NAND gate) and *IC9* (hex inverter), observing the notch-and-dot code. Again, touching the "0" lead to each of the input pins should cause the associated LED to light.

Install *IC6* (hex inverter) and *IC4* (quad NAND gate), and repeat the test with the "0" lead.

Install the remaining hex inverter and check the operation of the four "0" and "1" bounceless switches by using them as the driving signals for one of the gates.

Install *IC1* and *IC2* (dual flip-flop). At this point, it is advisable to build the low-frequency oscillator shown in Fig. 4A, using a pair of NAND gates and one of the time-constant circuits. When this is done, you will note that the LED associated with each NAND gate blinks on and off at a frequency dependent on the setting of the potentiometer.

Using a long test lead, connect one of the NAND-gate outputs to the "C" input of the first (left side) flip-flop. The associated LED will blink on and off at half of the oscillator rate. Connect the not-Q output of that flip-flop to the "C" input of the next flip-flop and note that its associated LED blinks at half rate. Repeat this procedure with the final two flip-flops, noting that each flip-flop LED blinks at half the rate of the preceding one. (Actually you will be building the divide-by-16 circuit shown in Fig. 4C.)

WHY CMOS?

Devices for digital logic circuits are constantly being improved. Today, just about the best type of logic, operating at a reasonable speed, is the CMOS family (Complementary Symmetry Metal Oxide Semiconductor). What makes CMOS so good? There are three main reasons.

First, CMOS requires very little power from the supply—in the nanowatt range if the switching speed is low. This property of CMOS is due to the fact that the inputs are essentially open circuits. They only sense voltage variations, so that there is simply a low-impedance path, either to the positive supply or ground, but never both. Thus, they don't draw current from the preceding stage, nor do they feed current back from the supply.

Secondly, CMOS does not require complicated circuit designs. The power supply can be anywhere between 3 and 18 volts, without regulation or exceptional bypassing. What's more, since all inputs are voltage-sensing one logic block can easily drive 50, 100, or more inputs. Worries about fan-out, fan-in, and loading are thus eliminated. The open-circuit inputs provide many possibilities for designing pulse-shaping circuits or astable, monostable, and Schmitt triggers—all using large-value resistors and small-value capacitors. Unlike most other types of logic, CMOS logic can be triggered with either polarity of the initiating pulse. The latter can be a negative pulse from the supply or a positive pulse from ground). This feature is useful in designing oscillators, contact conditioners, pulse generators, and time-interval generators. And the number of components used in these circuits is low. For example, only one resistor and one capacitor are needed for a free-running oscillator.

The third big plus for CMOS is its exceptional noise performance. It generates no large spikes during switching. Since it switches at one half of the supply voltage, any noise less than 40 to 45% of the supply is generally ignored. In addition, CMOS rise and fall times are usually slower than its transition times, so that noise is attenuated instead of being passed on to the following logic stage.

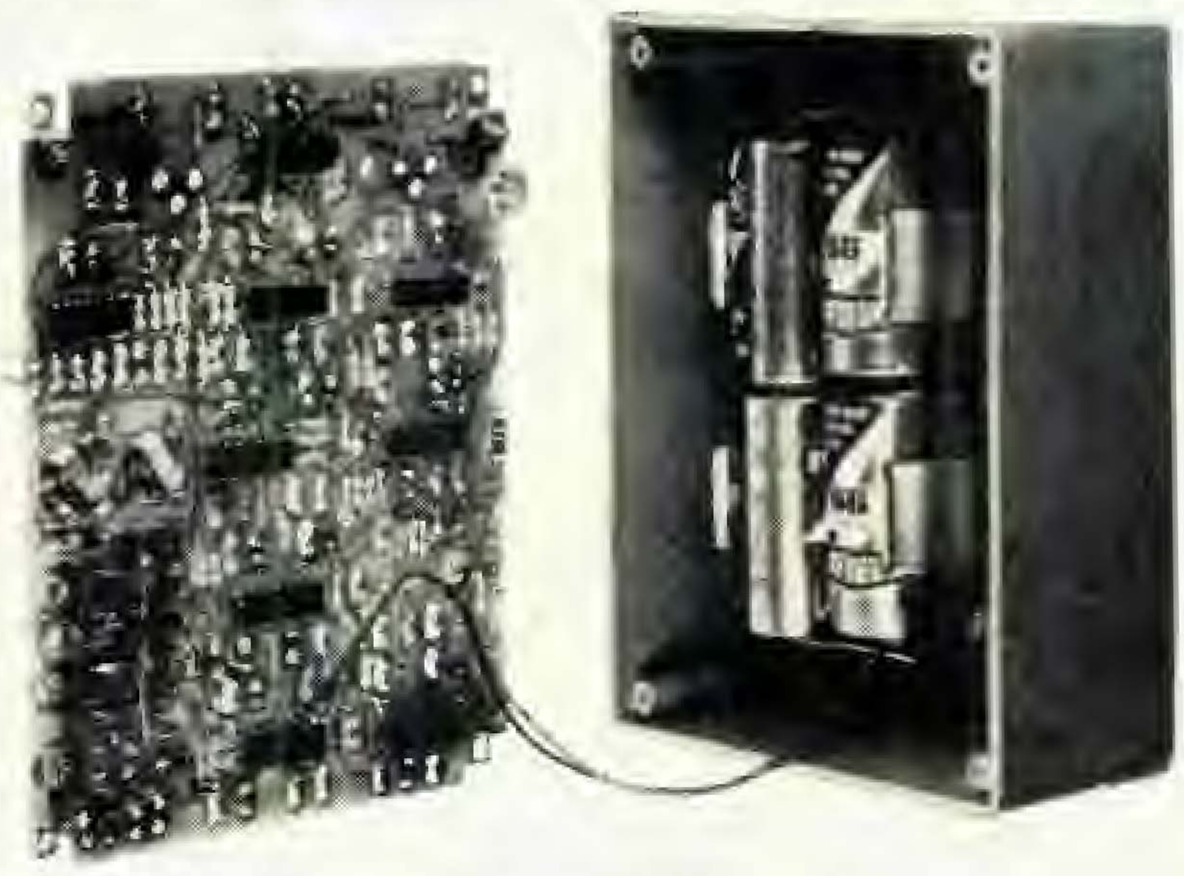
Right now, CMOS is not the cheapest type of logic; but, at $2 for a dual JK/RS flip-flop and $1 for a quad gate, it is competitive for most applications.

You can now connect the output of any flip-flop to any of the inputs of any of the gates or the inverter and note that the associated LED goes on and off in step with the input signal.

Using the Microlab. Some basic logic circuits for "starters" are shown in Fig. 4. An astable oscillator, using a pair of NAND gates is shown in Fig. 4A. With the 5-μF capacitor, the rate can be varied from about one to 10 per second. This can be observed on the associated LED's. Changing the capacitor to 0.01 μF makes an oscillator whose frequency ranges from 500 Hz to about 5 kHz.

A conventional four-stage binary counter is made as shown in Fig. 4C and the states are readily shown by the LED at each flip-flop. If you use the low-speed oscillator as the clock input, you can watch the progression. Figure 4D is a divide-by-three counter, while Fig. 4E demonstrates the operation of a shift register.

An elementary game can be built using the "heads/tails" circuit of Fig 4F. The on/off gating can use one of the switches at the bottom of the board. The very useful "one-and-only-one" circuit in Fig. 4G produces one whole cycle when the switch command is executed.



The photo shows the back of Microlab circuit board as it is attached to power supply.

For a test sequencer, use the inverter as a TTL output with a fanout of five or more. For more TTL outputs, parallel the inputs of one NOR gate. ◈