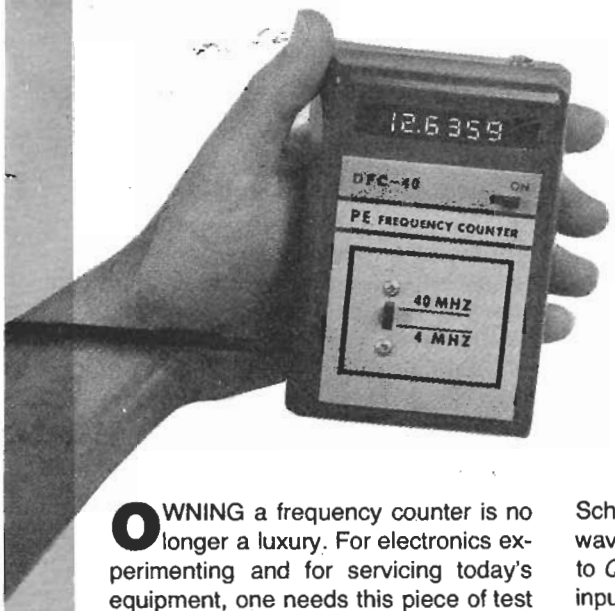


A 40-MHz FREQUENCY COUNTER

Portable counter features six-digit LED display and 10-Hz to 100-Hz resolution.

BY BILL GREEN

OWNING a frequency counter is no longer a luxury. For electronics experimenting and for servicing today's equipment, one needs this piece of test gear to count clock rates, adjust oscillators, and so on. Here's a handy, low-cost, portable counter that can serve admirably for these purposes.

It will count from less than 100 Hz to more than 40 MHz and display the input signal's frequency on a six-digit, multiplexed LED display. The counter uses CMOS and low-power Schottky IC's, bipolar transistors and a FET, allowing operation from alkaline and rechargeable Ni-Cd batteries.

About the Circuit. The frequency counter is illustrated schematically in Figs. 1 and 2. Input signals are coupled by *C1* to transistors *Q1* and *Q2*, which comprise a unity-gain buffer with a high input impedance. Diodes *D1* and *D2*, together with *R3*, protect the buffer from excessive input signal levels. A 10,000-series ECL triple line receiver, *IC1*, amplifies the voltage developed across *R5*. The third stage of this IC is used as a Schmitt trigger to square up the signal waveform. The output of *IC1* is applied to *Q3*. A TTL-compatible version of the input signal is available at the collector of this transistor. Hot-carrier diode *D3* is placed across the collector/base junction of *Q3* to prevent saturation, thus keeping the transistor's switching speed high.

Depending on the position of *S2*, (see Fig. 2), the output signal from *Q3* is applied to either *IC2* or *IC5*. When the switch is in the 4-MHz position, the signal is routed to *IC5*, an inverting buffer. When *S2* is placed in the 40-MHz position, *IC2*, a divide-by-10 prescaler, is inserted. The output of *IC2* is then buffered by *IC5*. Switch S2 performs two other functions. The second switch pole passes current to the appropriate decimal point on display *DIS1*. The third pole selects one of two pull-up resistors (*R22* or *R23*) for the open-collector output of *IC5*. These resistors, along with *C14*, provide additional signal conditioning before the waveform is applied to CMOS counter *IC4*. This LSI chip contains all the circuitry necessary for counting, latch, decode and drive functions, and interfaces directly with the display.

Integrated circuit *IC3* is the master clock. It consists of a crystal-controlled oscillator running at 6.5536 MHz and several dividing counters. Among its outputs are a 1600-Hz multiplex control signal and reset and gating pulses for *IC4*. Supply voltages of +5 and +10 volts are required. In the author's prototype, they are derived from series strings of four AA Ni-Cd and three AAA alkaline cells. Jack *J1* is used with an external charger, and R_X is chosen to limit charging current to a safe value. Power supply bypassing is performed by *C3, C4, C5* and *C13*.

Construction. Suitable etching and drilling and parts placement guides are shown in Fig. 3. Begin by installing the six jumpers on the pc board. Then install IC sockets or Molex Soldercons, followed by the resistors. Mount all fixed capacitors on the component side of the board, except for *C6* and *C13*. These capacitors and trimmer *C12* are installed on their sides on the foil side of the

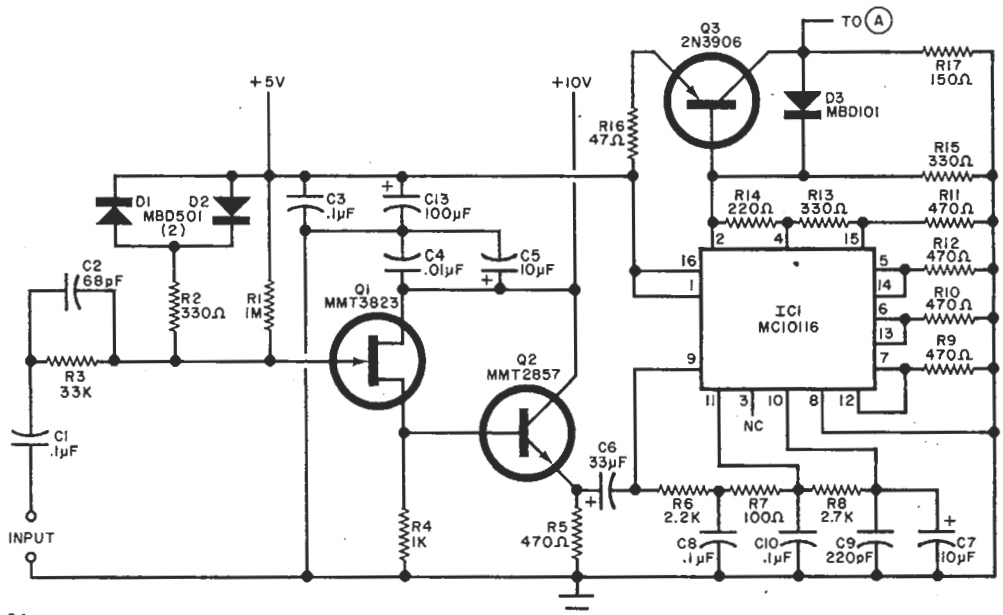


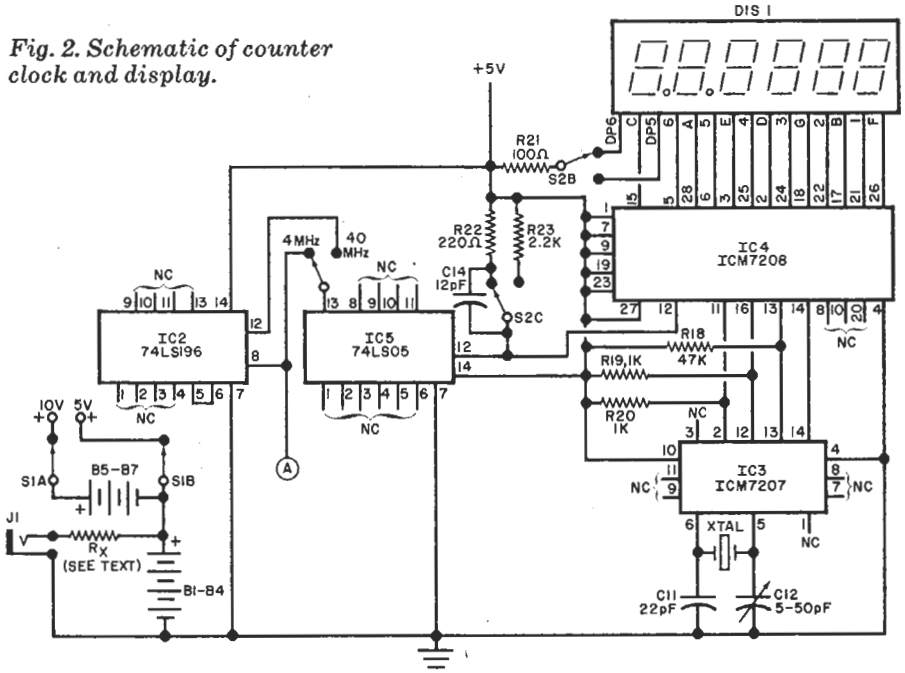
Fig. 1. Schematic diagram of counter's input stage.

PARTS LIST

B1 through B4—AA Ni-Cd cell
B5 through B7—AAA alkaline cell
C1,C3,C8,C10—0.1-μF, 600-V disc ceramic capacitor
C2—68-pF disc ceramic or silver mica capacitor
C4—0.01 μF disc ceramic capacitor
C5,C7—10-μF, 16-volt tantalum capacitor
C6—33-μF, 16-volt tantalum capacitor
C9—220-pF disc ceramic or silver mica capacitor
C11—22-pF disc ceramic or silver mica capacitor
C12—5-to-50-pF trimmer capacitor
C13—100-μF, 16-V electrolytic capacitor
C14—12-pF disc ceramic or silver mica capacitor
D1,D2—MBD501 diode
D3—MBD101 diode
DIS1—Multiplexed LED display (see note)
IC1—MC10116 ECL triple line driver IC
IC2—74LS196 Schottky decade counter IC
IC3—ICM7207 LSI CMOS oscillator/divider IC (Intersil)
IC4—ICM7208 LSI CMOS counter IC
IC5—74LS05 Schottky inverting buffer IC
J1—Suitable jack for battery charger
Q1—MMT3823 n-channel FET (Motorola)
Q2—MMT2857 npn silicon transistor (Motorola)
Q3—2N3906 pnp silicon transistor
The following resistors are ¼-watt, 10% tolerance.
R1—1 megohm
R2,R13,R15—330 ohms
R3—33,000 ohms
R4,R19,R20—1000 ohms
R5,R9 through R12—470 ohms
R6,R23—2200 ohms
R7,R21—100 ohms
R8—2700 ohms
R14,R22—220 ohms
R16—47 ohms
R17—150 ohms
R18—47,000 ohms
S1—Dpst switch
S2—3pdt switch
XTAL—6.5536-MHz quartz crystal
Misc.—Suitable enclosure, batteries and charger, battery holder, magnifying lens, solder, hook-up wire, IC sockets or Molex Soldercons, shielded cable, suitable probes, machine hardware, epoxy cement, electrical tape, etc.
Note—The following are available from Alpha Electronics (Texas), Box 64726, Dallas, TX 75206: Kit of parts and case (No. DFC-40) less input cable and probes, batteries and battery holder: $50.00 plus $3.00 postage and handling. Parts also available separately: 6.5536-MHz crystal, $7.50 postpaid; etched and drilled printed circuit board (No. 280776) $8.50 postpaid; DIS1 display (No. AE-9), $6.00 postpaid; Bag of semiconductors including D1 through D3, IC3, IC4, Q1 and Q2, $35.00 postpaid.

board. Observe polarities on all aluminum and tantalum electrolytic capacitors. The remaining fixed capacitor, *C14*, is mounted on the lugs of *S2*. Quartz crystal *XTAL* is installed on the foil side by bending its leads 90° and inserting them into the holes on the board.

Fig. 2. Schematic of counter clock and display.



Be sure the body of the crystal clears the foil under it before soldering.

Mount diodes *D1, D2, D3* and transistor *Q3* on the board, paying close attention to basing. The MMT transistors (*Q1* and *Q2*) are soldered to the foil side of the board. Note that these transistors are color coded. Install *Q1* so that its yellow dot is on the foil side and *Q2* so that its orange dot is on the component side of the board.

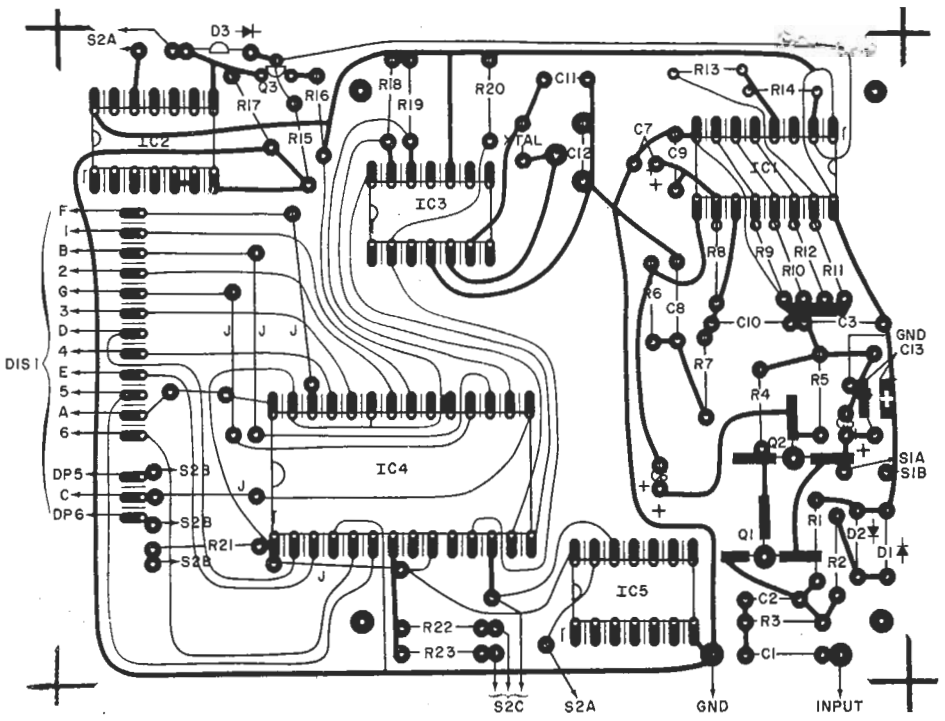
The display assembly must be prepared before installation. Orient the assembly so that the numbers etched on the component side are toward you. Cut the cathode leads (the third from the left or middle lead on the bottom of the displays) of digits 1, 2 and 9 at the displays and unsolder them from the board. Cut the DP (decimal point) lead (fifth from the left at the bottom of the displays) at the board—not the displays—of digits 3 and 4 *only*. Clear the solder from the holes where the cathode leads of digits 1 and 2 went through the board. Run a short length of insulated wire from the hole where digit 1's cathode lead was connected to the decimal point lead of digit 3. Then repeat this procedure for the DP lead of digit 4 and the cathode hole for digit 2.

From now on, refer to digit 8 as denoted by the etched numeral as digit 1, digit 7 as digit 2 . . . and digit 3 as digit 6. Solder a straight pin into each display board hole except the fourth from the left and right-most holes. The pin heads should be flush with the component side of the display pc board. Place the display board over the main board and insert the pins into the holes in the main pc board. Space the boards 5/16" (8 mm) apart and solder the pins to the main board. Clip the excess pin lengths from the foil side of the main board. Bend the display assembly so that it is at a 15° angle to the main board. When the counter is installed in its case, the display will be aligned for centered and properly magnified digits.

Bend the lugs of *S1* and *S2* 90° and connect them to the pc board with short lengths of insulated hook-up wire. With *S1* in the OFF position, wire four AA Ni-Cd cells in series between ground and *S1B*. Also connect a battery holder for three AAA alkaline cells between *S1A* and *S1B*. Wire a suitable charger jack to ground and to *S1B* via resistor R_X. Select the value of R_X to prevent (if necessary) your battery charger from overcharging the batteries. Connect the charger to *J1* and allow the batteries to charge.

Install the IC's, following the standard precautions for handling MOS devices. Apply power by closing *S1*. Digits 1 and 2 (at the least) should light. Apply a 200-mV signal at 4 MHz or less across the counter input. With *S2* in the 4-MHz position, check for a stable and accurate reading. Repeat this procedure with *S2* set to 40 MHz and a 200-mV signal at 40 MHz or less.

Cut a display magnifier to size and install it in the counter's enclosure with epoxy cement. Mount *S1* and *S2*. Install the pc board so that the display is properly centered and aligned. Then drill holes for *J1* and the input cable. Insulate the batteries and the battery holder with electrical tape to prevent accidental shorts. Select suitable cable or wires for the input lead. Coax such as RG-58/U can be used, but its impedance is low and will tend to load down high-imped-



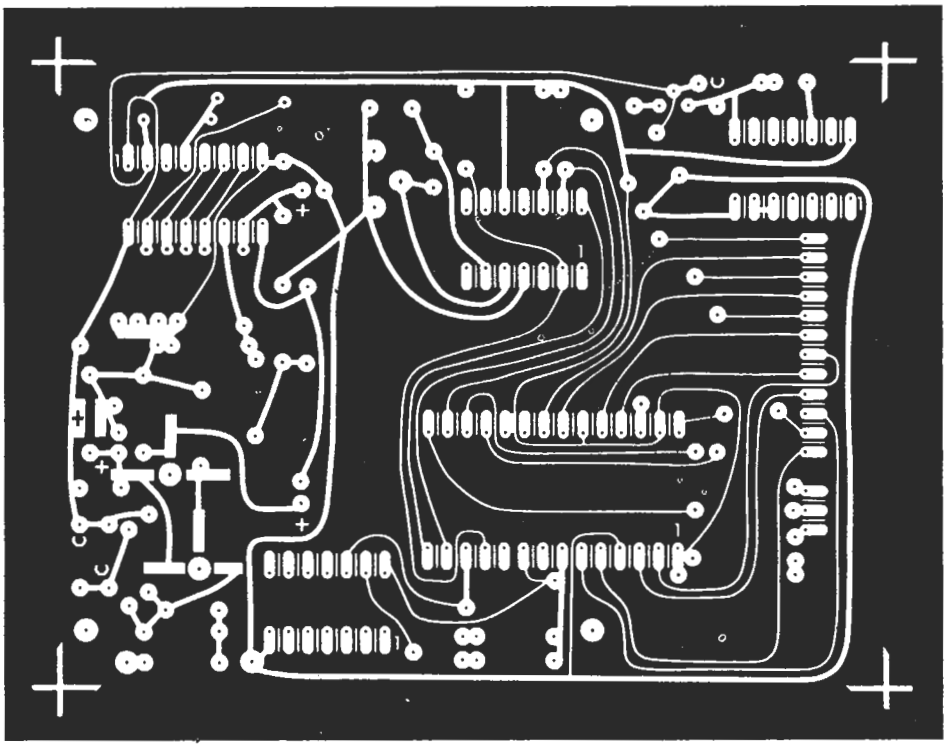


Fig. 3. Etching and drilling guide for pc board (left) and component layout (above).

ance circuits. Two separate shielded leads will work well and exhibit less of a loading effect. Solder the input lead(s) to the foil side of the pc board and run it (them) out through the hole in the enclosure. Mount *J1* and place the alkaline cells in their holder.

Calibration. If a frequency counter or frequency standard is available, calibration can be performed merely by connecting a signal source of known frequency to the counter input and adjusting *C12* for an accurate reading. If no standard or counter is available, a signal generator can be zero-beat against WWV and used as a reference. The counter's accuracy can approach or exceed 0.00001%, depending on calibration accuracy.

Using the Counter. The sensitivity of this counter is nominally 200 mV from 100 Hz to 40 MHz. Operation beyond these limits is possible if greater input levels are applied. Keep in mind that the input stage is protected to 50 volts. If the counter is to be used with an r-f transmitter, a short length of heavy, insulated wire may be used as an antenna to measure the output frequency. A ground is not required in this mode of operation. Frequencies will be displayed with 10-Hz resolution in the 4-megahertz range, and 100 Hz in the 40-megahertz range. ◇