Build a 10-MHz Frequency Counter

Need a frequency counter that won't cost a mint? This hobbyist-grade instrument is just the ticket for budding techs on a tight budget!

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Anyone interested in electronics sooner or later (usually sooner) needs some sort of test equipment. Almost every electronics hobbyist has a digital or analog multimeter, but there are times when simple voltage, current, and resistance measurements just won't do. Sometimes, such as when working with digital circuits, a frequency measurement is needed. That's the time when you need an oscilloscope or frequency counter.

Unfortunately, a low-end oscilloscope or a frequency counter will cost $200 to $300, or more; that's more than many beginning hobbyists want to spend. Unless, of course, it is a **Popular Electronics** *10-MHz Frequency Counter*! Built around three integrated circuits, that useful instrument can be put together for about $40 by anyone who is reasonably adept at soldering.

Circuit Operation. Figure 1 shows the schematic diagram of the 10-MHz Frequency Counter. The circuit consists of an ICM7208 seven-decade counter (U1), an ICM7207A oscillator controller (U2), and a CA3130 BIFET op-amp (U3). Integrated circuit U1 counts input signals, decodes them to 7-segment format, and outputs signals that are used to drive a 7-digit display.

Integrated circuit U2 provides the timing for U1, while U3 conditions the input signal to provide a suitable waveform for input to U1. The 5.24288-MHz crystal frequency is divided by U2 to produce a 1280-MHz multiplexing signal at pin 12 of U2. That signal is input to U1 at pin 16 and is used to scan the display digits in sequence.

The cathodes of each digit are taken to ground several times each second, activating any segments of the digits whose anodes are high as the result of decoding by U1. The crystal frequency is further divided to produce a short "store" pulse at pin 2 of U2, followed (after about 0.4 milliseconds) by a short "reset" pulse at pin 14 of U2. The frequency of the pulses is determined by the state of U2 pin 11.

When pin 11 of U2 is taken to ground through S1, the pulses occur every 2 seconds and cause U2 pin 13 to go high for one second, which prevents additional input signals from entering U1. That causes the count latched in U1's internal counters to be transferred to the display.

Integrated circuit U2 pin 13 then goes low for one second, allowing a new count to be entered into the seven decade counters of U1. That cycle is repeated, continuously updating the display every two seconds.

When U2 pin 11 is taken to the positive supply rail (+5V), the "store" and "reset" pulses occur at 0.2-second intervals, resulting in a 0.1-second count period. Ten input pulses must be counted in order for a "1" to appear on the first digit, D1, so the frequency being measured is obviously ten times larger than the frequency that is shown on the display.

In that mode, the decimal points are driven by R1 and visually indicate that the 0.1-second count period is being used.

Display. The display must have at least seven 7-segment common-cathode multiplexed LED digits. Any common-cathode seven-segment display may be used, so no particular display is specified. If the display chosen has more than seven digits, the extras are not used. For example, the display used in the author's prototype, which was salvaged from an old calulator, has nine digits, only seven of which are used in this project.

Don't be put off by the term "multiplexed." Multiplexed simply means that all like segments of all digits are connected by a single conductor, and that the cathodes of all segments of any one digit are connected to a common terminal. That's accomplished by a printed circuit within the display and limits the number of wires or traces needed to operate the dis-

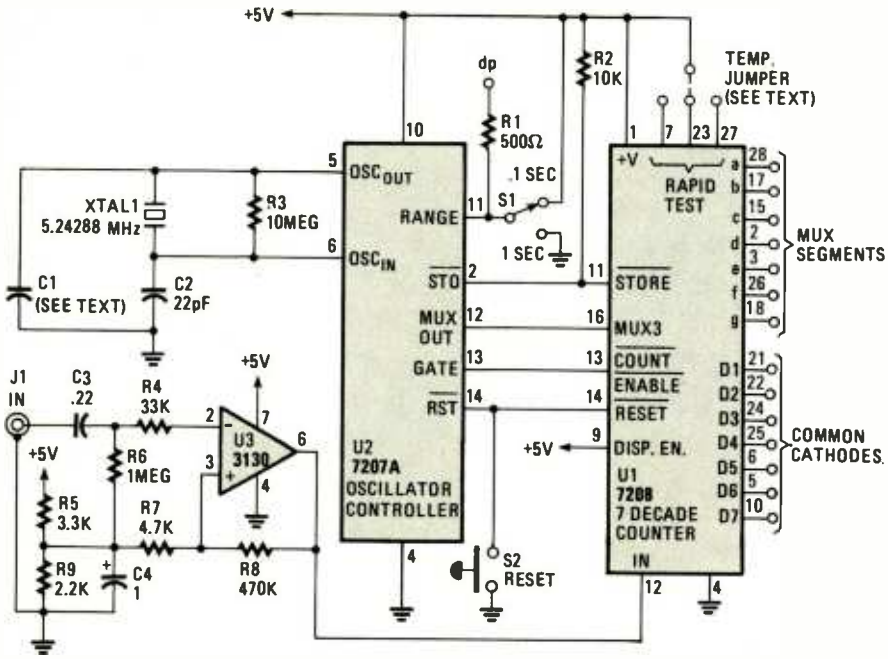

Fig. 1. The 10-MHz Frequency Counter consists of U1, an ICM7208 seven-decade counter; U2, an ICM7207 oscillator controller; and U3, a CA3130 biFET op-amp. The display for the circuit can be any seven-digit, seven-segment common-cathode multiplexed unit.

play. Such units may be salvaged from an appropriate old calculator or purchased from electronic surplus stores.

A multiplexed display can also be fabricated from discrete seven-segment display modules as shown in Fig. 2. More display modules can be added as needed. Duplicating the display shown in Fig. 2 is easy; simply connect all like pins in parallel as shown. For example, pin 1 of the first seven-segment unit—which, for this particular display, is segment "a"—is connected to pin 1 of all the other modules. Pin 3 is the common-cathode connection—it is not connected to the other pin 3 terminals in the set—which is used as the digit-driver (D1–D7) input.

Note that for the display modules used to illustrate the multiplexing concept, there are two common-cathode terminals, pins 3 and 14; since the two pins are internally connected, only one of those terminals need be connected to the circuit in order for the display to function properly, although connecting both would not cause any problems. While the pinouts may vary from one display type to another, the concept remains the same.

If you opt to go with a salvaged display unit, it will be necessary to determine the pinout and configuration; common cathode or common anode. To test a salvaged display when the pinout is not known, temporarily connect a 1000-ohm resistor from a 5- to 9-volt source to pin 1, then touch the source ground to each of the other pins in sequence. If any segment lights, the pin at the resistor is the anode for all like segments in all digits and the pin at ground is the common cathode for the digit with the lighted segment.

Repeat that procedure to identify all segments and cathodes by moving the resistor to the other pins. Make a record similar to that shown in Fig. 1-b for use as a reference during circuit assembly. If no segments light, but do light when the source leads are reversed, the unit is a common-anode type and is not suitable for use in the counter. Do not discard the display; make a record and save the display for some other project.

Power Supply. When all digits are lit, the circuit draws about 160 milliamps. A 5-volt bench supply that is rated at more than 1 ampere may be used, however, a heavy-duty 6-volt battery with a 1-ampere diode connected in series with one of the leads will work, and makes the unit portable.

Space is available on the circuit board (at the top) to mount a 5-volt regulator and capacitors, if desired. If a regulator is used, a 6- to 9-volt AC adaptor may be used to supply the basic DC voltage. To preclude damaging the integrated circuits, U1 and U2 must be powered up before or simultaneously with the application of input signals to U3. The entire circuit is designed to be powered by one common supply.

Assembly. See Fig. 3. The author's prototype of the 10-MHz Frequency Counter was built on a universal printed-circuit board (Radio Shack catalog number 276-170). Note that the horizontal holes in Fig 3 are la-

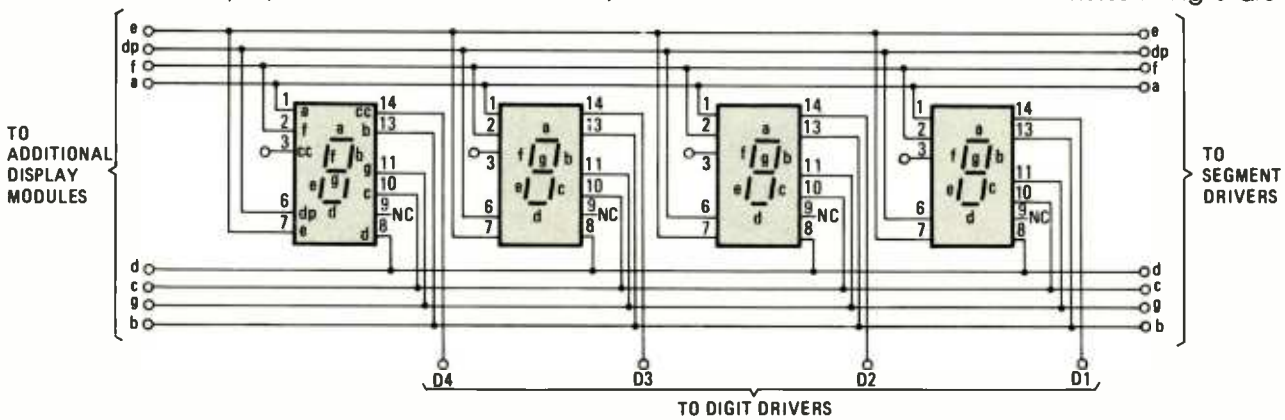

Fig. 2. A multiplexed display can be fabricated from discrete seven-segment display modules by connecting all like pins in parallel. For example, pin 1 of the first seven-segment unit connects to pin 1 of all the other modules.

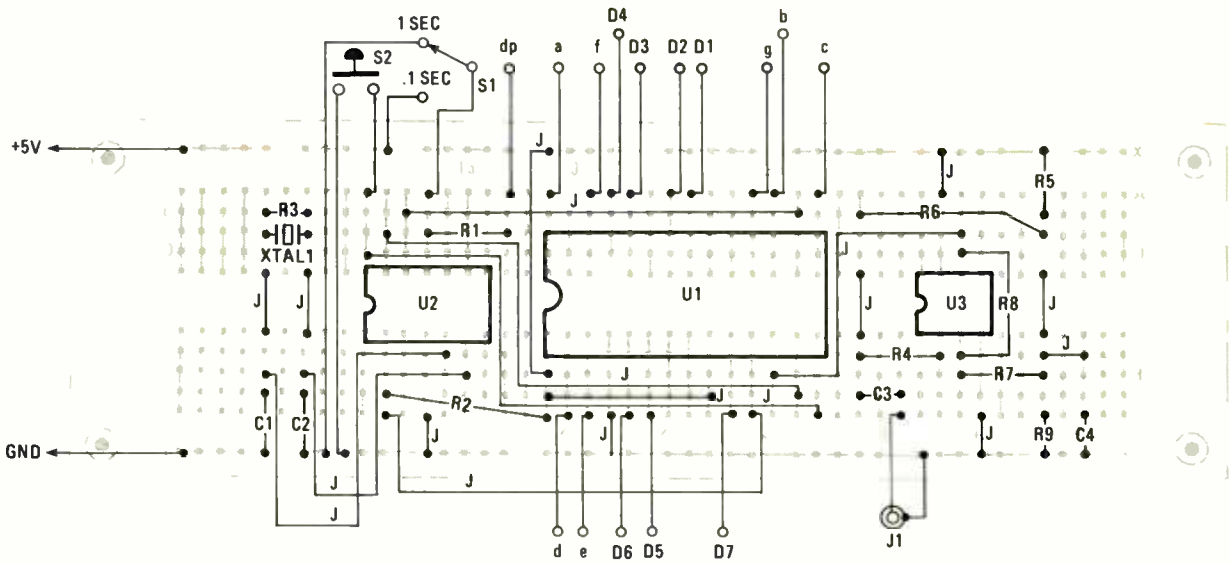

Fig. 3. Here is the parts-placement diagram for the author's prototype of the 10-MHz Frequency Counter. It was assembled on a universal printed-circuit board. Note that the display is not shown in the layout. However, by following the connection scheme outlined in Fig. 2, almost any common-cathode display can be used with the circuit.

beled A through J and that the vertical holes are number 1 through 47. Columns of holes designated X and Y are the +5V and ground buses, respectively.

Carefully locate the positions of the IC's and mark the pin 1 holes with a felt-tipped pen. For example, pins 1 of U1, U2, and U3 are located in holes 19G, 10F, and 37F, respectively. It's a good idea to use sockets (as the author did) for the IC's; aside from making IC replacement easier, doing so also prevents possible damage to those parts during soldering.

After the sockets have been mounted in the proper locations, install the jumper connections (designated J) guided by Fig. 3. The horizontal jumpers may be bare wire, all others should be insulated to prevent shorts. Next begin installing the support components, starting with the resistors, then the capacitors, and finally the crystal (XTAL1).

Solder extra-long color-coded wires to the board for the off-board components. Then, as the positions of the off-board components are established with respect to the case, cut the wires to the proper length and solder them to the components. If you suspect that the wires will interfere with IC installation, insert the IC's before soldering the wires to the off-board components.

Enclosure. Any suitable case may be drafted to house the finished circuit. Mount the power-supply terminals or jack, the input jack, the switches (S1 and S2), and the display on the front panel of the case. The circuit board may be trimmed to about 5-inches long to keep case size at a minimum.

Use a nibbling tool to cut an opening for the display, but do not secure the display to the case until wires from the board have been connected. If a trimmer capacitor is used for C1, as will be discussed later, drill a hole at the proper location to allow for any adjustments without removing the front panel of the enclosure.

PARTS LIST FOR THE 10-MHZ FREQUENCY COUNTER

SEMICONDUCTORS

U1—ICM7208 seven-decade counter, integrated circuit
U2—ICM7207A oscillator controller, integrated circuit
U3—CA3130 biFET op-amp, integrated circuit

RESISTORS

(All resistors are ¼ watts, 5% units, unless otherwise noted.)
R1—500-ohm
R2—10,000-ohm
R3—10-megohm
R4—33,000-ohm
R5—3300-ohm
R6—1-megohm
R7—4700-ohm
R8—470,000-ohm
R9—2200-ohm

CAPACITORS

C1—See text
C2—22-pF, ceramic disc
C3—0.22-μF, ceramic disc
C4—1-μF, 50-WVDC, subminiature electrolytic

ADDITIONAL PARTS AND MATERIALS

J1—Miniature closed-circuit phono jack
S1—Single-pole, double-throw toggle switch
S2—Single-pole, single-throw momentary-contact pushbutton switch
XTAL1—5.24288-MHz crystal
Universal printed-circuit board; seven-digit, seven-segment, common-cathode, multiplexed, LED display (see text); enclosure; IC sockets; power source (see text); wire; solder; hardware; etc.

Testing. To rapid-test the circuit with a frequency that is less than 100 Hz, use a temporary jumper to take U1 pin 7, 23, or 27 to +5V as indicated by the dashed line shown in Fig. 1. Integrated circuit U1 then applies the count to all digits higher than D2.

Data for U2 indicates that C1 may be a trimmer, however, a 22-pF fixed-disc capacitor is satisfactory for most applications, and provides accuracy to .005%. If a closer tolerance is required, use a 6–50-pF trimmer capacitor (such as a Radio Shack 272-1340). Set the range switch to 1 second, apply the multiplexing frequency from U2 pin 12 to the input of U3, and adjust the trimmer for a readout of 1280 Hz.

Frequency Counting. When S1 is in the 1-second position, the count range is 1 Hz to 1 MHz and can be read directly from the display. When S1 is in the 0.1-second position, the count range is 10 Hz to 10 MHz. The number then appearing on the display is 1/10 the frequency being measured. (1 kHz appears as 100).

When a new frequency is being

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FREQUENCY COUNTER

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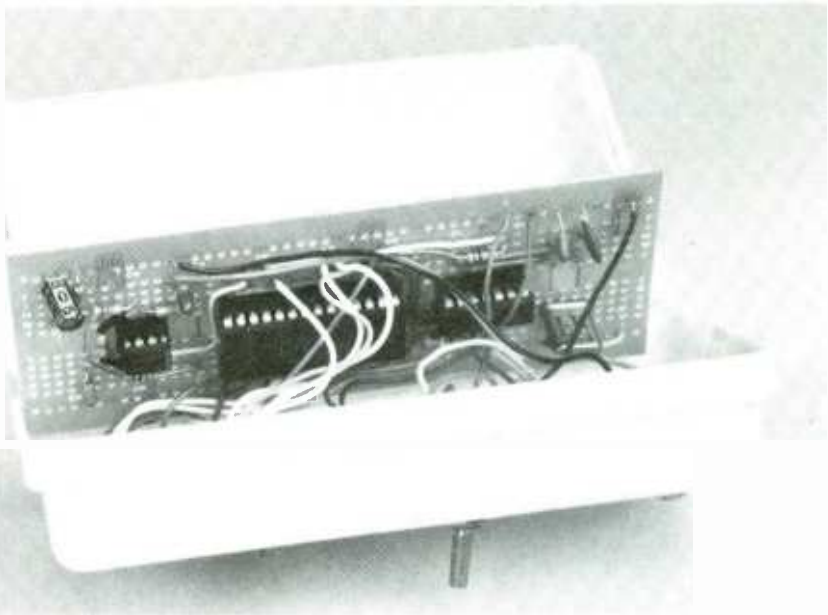
measured, the initial readout will be the previous frequency that was latched in the counters. Wait for two or more count periods for the circuit to stabilize on the new frequency. Optionally, the RESET switch (S2) may be pressed to reset the display to "00," and then released.

The display is basically jitter free and all digits are significant. If the frequency itself is somewhat unstable, D1 may vary by one or two counts.

Notes. The input signal voltage must not overshoot the +5V to ground limits, and rise and fall times may not exceed 10 nanoseconds. Integrated circuit U3 provides those safeguards, so do not be tempted to apply random signals directly to U1 pin 12. For special circumstances, knowledgeable builders may substitute other signal conditioning circuits for the CA3130, U3. Do not substitute a ICM7207 for the newer ICM7207A used in the circuit, and use only the 5.24288-MHz crystal specified.

You can use the Counter to perform numerous functions, including: Measure the input and output frequencies of digital devices, measure the speed of motor shafts, precisely adjust the output of signal generators, set audio signals to the exact pitch, determine the exact values of RC timing components, and measure any frequency between 1 Hz and 10 MHz.

It's a sure bet that once you've used your counter for a while, you won't be able to get along without it. ■



Assembled on a universal printed-circuit board, the Counter requires several jumper wires to complete the circuit paths.