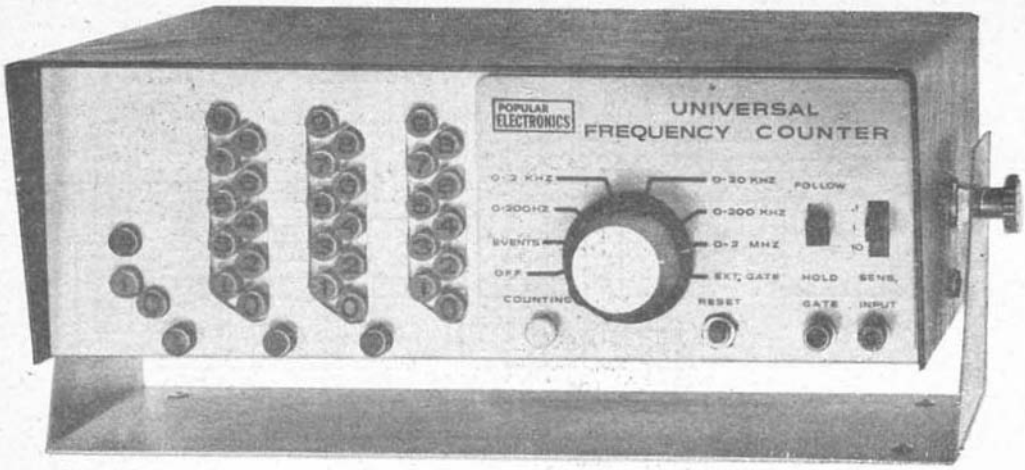

Popular Electronics Universal Frequency Counter

BY DON LANCASTER

Part 2

Note: *Construction of modules for the Counter appeared in the March issue.*

Assembly of Complete Unit. The circuit for the overall counter is shown in Fig. 17, while Fig. 18 shows the interior of the chassis. The vinyl-clad case that comes with the complete kit is punched and machined, and includes assembly instructions. If you select another type of enclosure, use Fig. 18 as a general layout guide. An optional dialplate (see Parts List for Fig. 17) adds a professional touch and also serves as a front-panel layout template.

Modules *M1* through *M6* are arranged in a line along the front of the case, supported by brackets similar to those used on the "Digital Volt-Ohmmeter" (POPULAR ELECTRONICS, December 1968). The three decimal-point indicator lamps are placed between the decade units as shown in the photo, while the Power Supply module (*M7*) mounts on the rear wall of the chassis with spacers and #6 hardware. The fuse (*F1*) and power transformer (*T1*) are mounted on the bottom of the chassis.

Note that the frame of input jack *J2* is isolated (insulated) from chassis ground and has an independent ground lead, called a "guard," running directly to the *M1* board. This lead is very important since it prevents any internally generated ground noise from interfering with the input. Use nylon washers to insulate the jack from the chassis.

Don't forget the individual ground leads from each module to the power

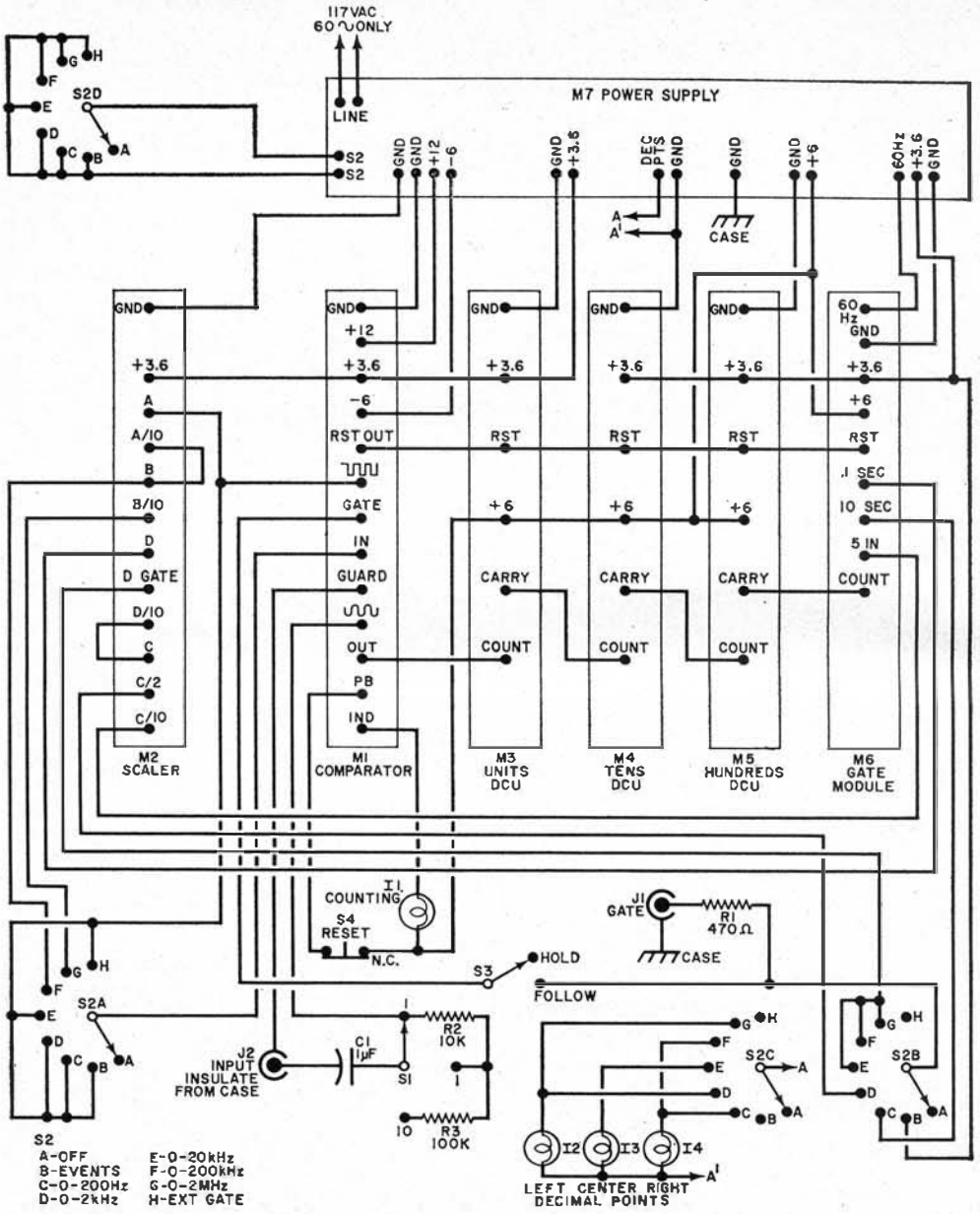

Fig. 17. Interconnections for complete frequency counter. Signal input jack J2 is insulated from chassis to prevent internal noise interference with the input signal.

supply ground buss.

The main selector switch (*S2*) has four decks, one of which is isolated from the other three by spacers. The isolated deck controls the 117-volt, 60-Hz power, while the other three (starting from the front) select the frequency, the timing, and the decimal point.

Preliminary Checkout and Operation. The frequency counter requires no calibration and has no internal adjustments. It is only as accurate as the 117-volt a.c. power-line stability and display resolution permit it to be. The following tests can be performed to check the general assembly for proper operation.

PARTS LIST
COMPLETE COUNTER

C1—1-μF, 400-volt Mylar capacitor
I1-I4—6.3-volt, 50-mA pilot lamp and lens assembly, three green, one white (Southwest Technical G-6.3 and W-6.3, respectively or similar)
J1—Phono jack
J2—Phono jack and nylon insulated mounting kit
M1—Comparator module
M2—Scaler module
M3-M5—DCU module (see text)
M6—Gate module
M7—Power supply module
R1—470-ohm, ¼-watt resistor
R2—10,000-ohm, ¼-watt resistor
R3—100,000-ohm, ¼-watt resistor
S1—Three-position, single-pole slide switch
S2—Four-deck, four-pole, eight-position, nonshorting miniature selector switch. Close space first three decks, isolate fourth with ¼" spacers. (Southwest Technical SW111S1 or equivalent)
S3—S.p.s.t. slide switch
S4—S.p.s.t. normally closed pushbutton switch
Misc.—3" x 5½" x 10" vinyl-clad, prepunched case and support assembly, dialplate, 1½-inch knob, mounting brackets for modules, mechanical hardware, #16 wire for grounds, #22 hookup wire, solder.*
**Anodized dialplate available from Reill's Photo Finishing, 4627 N. 11th St., Phoenix, Arizona 85014; in black and silver $3.00; red, gold, or copper $3.45, postpaid in USA.*
Note:—Complete kit of parts to build counter including case but not dialplate is available from Southwest Technical Products, Box 16297, San Antonio, Texas 78216. Order # 165C, $120, plus postage, 7 lb.

HOW IT WORKS
COMPLETE COUNTER

The frequency to be counted is applied to the sensitivity control, which reduces the input level by 1 or 10 to the approximately 100 millivolts required for normal operation. The signal is then sent to the Comparator module (*M1*) where it is converted from a sine wave to a square wave of the same frequency with sharp rise and fall times. Any noise that might be present in the input is also rejected in the Comparator. The Comparator output is fed directly to the range selector switch *S2* and also to a pair of decade scalers that provides divide-by-ten and divide-by-one-hundred outputs. The latter are also connected to the range selector switch.

The output of the Comparator (f) is selected for the EVENTS function, 0-200 Hz, 0-2 kHz, 0-20 kHz and for the external gate (EXT. GATE) operation. The output from the first decade scaler (f/10) is used for the 0-200 Hz position, and the output of the second scaler (f/100) is used for the 0-2 MHz position.

The time base starts with a 60-Hz reference from the power supply. This signal is filtered, squared, and divided by six (all in module *M6*) to obtain the 0.1-second gating reference. Two divisions by ten produce the 1-second and 10-second time references. These time intervals, along with a positive voltage for EVENTS and no input for EXT. GATE are routed to the range selector switch.

From the selector switch, the time commands go through the HOLD-FOLLOW switch which permits a choice of automatically updating the reading or holding the last reading.

Both the measure command and the selected input frequency go through the synchronizing circuit in the Comparator module. The measure command turns the electronic switch on and off, but it does it in such a way that only whole cycles of the input frequency are counted. This eliminates the one-digit bobble in the counting. The time-base gated frequency then goes to the counting and display circuits.

The counter can be reset to zero at any time by operation of the manual RESET pushbutton, but in normal modes of operation, the counters are automatically reset just before a new count begins.

The operation of the counter is fully automatic. The available measure commands are 10-s measure and 10-s display for 0-200-Hz operation; 1-s measure and 1-s display for 0-2-kHz operation; and 0.1-s measure and 0.9-s display for the other ranges. To keep the display on longer, flip switch S3 to HOLD.

Plug the counter into a source of 117-volt 60-Hz power and place selector switch *S2* on EVENTS and switch *S3* on FOLLOW. One, or possibly two, numerals in each decade should be illuminated. Momentarily depressing the RESET button should immediately produce a 0000 reading.

Check all supply voltages, particularly the +6 and +3.6 volts, to be sure that they are within 0.1 volt of their correct values. The −6 and +12-volt supplies should be checked at their respective terminals on *IC1* of the Comparator module *M1*.

Place the range selector switch on the 0-200 Hz position and observe the COUNTING light on the front panel. It should cycle on for 10 seconds and off for 10 seconds. Place the selector switch on 0-2 kHz. The COUNTING light should now cycle on for 1 second and off for 1 second. With the selector switch on any higher range, the light should flash on for 0.1 second, once each second.

To check the operation of the decimal-point indicators, place the range selector switch on the 0-2 MHz position and note that the left decimal point indicator is illuminated. For other switch positions, lights should be on as follows: 0-200 kHz, right; 0-20 kHz, center; 0-2 kHz, left; 0-200 Hz, right.

With the counter still energized, set the FOLLOW-HOLD switch to FOLLOW, the range switch to 0-2 kHz, and the SENS. (sensitivity) switch to .1. Insert a test lead in the INPUT jack and touch the other end of the test lead. Note that the counter starts operating erratically only when the COUNTING light is lit. The

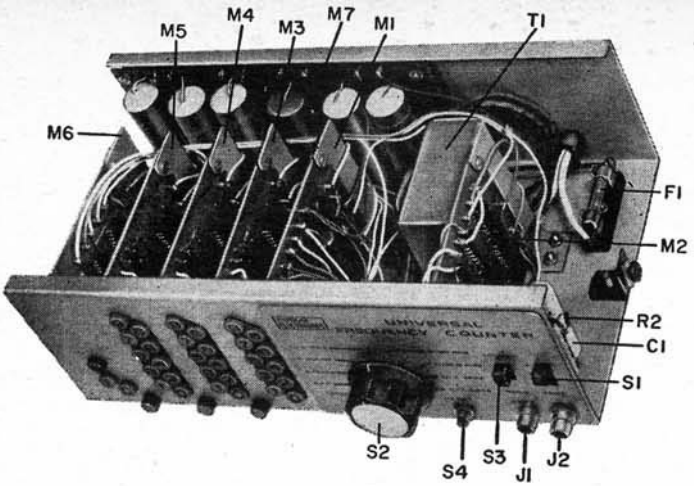

Fig. 18. Author's prototype may be duplicated or used as a guide. Because of the length of M7, the Power Supply module, it is mounted along the rear apron of the chassis. When using a different physical layout, remember that the Power Supply generates some heat and mount it out of the way where it will not affect the heat-sensitive components that are mounted on the other modules.

display should last only as long as the COUNTING light is dark. The counting units should start to count at the same instant that the COUNTING light comes back on. Placing the SENS. switch on either the 1 or 10 position should stop the counting operation.

If the counter passes all of these tests, it is probably working properly and is ready for use. As a final check, and to gain some experience in using the counter, use a bounceless pushbutton circuit (described in "Low-Cost Counting Unit," POPULAR ELECTRONICS, February 1968, or ELECTRONIC EXPERIMENTER'S HANDBOOK, Winter 1969) and a low-frequency audio oscillator. When using the counter, always start with the SENS. switch down to the 1 or .1 position as required to get a stable reading. Also, do not forget that an input lead (whether it is coaxial cable or phono lead) that is too long will attenuate (and load) a high-frequency signal.

Key Waveforms. The following information can be used if trouble is experienced in getting the counter to operate properly. The waveforms at various points in the circuit vary depending on switch settings and the nature of the input. However, there are some critical points at which the waveforms can be checked to determine whether the counter is working properly.

Comparator (M1) When sufficient input signal is applied, the output at the square-wave terminal of this module (connected to *D1* and *R7*) should be either a square or a rectangular wave from 0 to 2.4 volts positive. The output goes positive when the instantaneous input signal drops below +10 mV and drops to zero when the input exceeds +30 mV. The rise and fall times of this waveform should be about 60 nanoseconds.

The feedback to pin 2 of *IC1* should show a steep leading edge that reaches +80 mV, followed by a rapid decay (about 90 ns) to the +30 mV level. The trailing edge of this waveform should have a rapid transition to −40 mV and a rapid decay back to +10 mV. This signal is present only when an input signal is applied to the counter. Because of the very fast switching of this waveform, you will have to use a high-quality, lab-type oscilloscope to make exact measurements although the basic signal can be seen on a conventional service scope.

The synchronizing circuit in the Comparator can be tested by using a bounceless pushbutton and observing the DCU's and the COUNTING indicator light, in the 0-200-Hz range. The first count after the COUNTING light comes on should not be counted, and the first DCU should display starting at the second count. The first count after the COUNTING light goes off should be counted and the display should remain steady after that. Correct operation of this circuit guarantees that the device will only count whole input cycles.

Scaler (M2) The input to the A scaler should be identical to the square-wave output observed on the Comparator.

Output A/10 should be a rectangular

wave with a frequency 1/10 that of the input. It should be about 1.8 volts in amplitude and have a 6:4 duty cycle. This, of course, is also the input to the B scaler.

COUNTER SPECIFICATIONS

Function: Measuring frequency, events, events-per-unit-time, or the ratio of two frequencies. it is also a source of precision 0.1-, 1-, and 10-second timing signals.

Ranges: 0-200 Hz, 0-2 kHz, 0-20 kHz, 0-200 kHz, 0-2 MHz, events, and externally gated events or ratio.

Accuracy: Power-line stability plus or minus one-half count. Typical accuracy is 0.1%.

Resolution: One part in 2000 to full scale. 0.1 Hz on 0-200-Hz scale.

Sensitivity: Switch adjustable from nominal 0.1, 1, or 10 volts. For sine waves—30 mV r.m.s. from 50 Hz to 3 MHz; 300 mV r.m.s. from 5 to 50 Hz. For pulses—symmetric pulse, 100 mV p-p; narrow positive pulse, 50 mV p-p; narrow negative pulse, 700 mV p-p.

Input conditioning: Automatically provided for all but mechanical contacts. High-gain IC comparator provides snap action, 10-mV noise offset, and 20-mV hysteresis. Any reasonable wave shape is acceptable, including sine or square waves, or rectangular pulses of either polarity.

Input protection: D.c. blocking to 200 volts. Combination dual-diode limiter and d.c. restorer allows safe measurement in practically all test situations.

Input impedance: 10-volt range, 112,000 ohms; 1-volt range, 12,500 ohms; 0.1-volt range, 2500 ohms. Typical shunting capacity is less than 30 pF.

Gating: Fully synchronized master gate used to eliminate the one-count ambiguity associated with older counter designs. Last digit is constant rather than bobbling between two values.

Display: Switch selects hold or follow. Infinite display in hold function, automatic updating in follow. For 0-200 Hz, 10-second measure, 10-second display; for 0-2 kHz, 1-second measure, 1-second display; for higher frequencies, 0.1-second measure, 0.9-second display.

Miscellaneous: Automatic overrange indicator comes on when full-scale count is exceeded. Floating decimal points. Manual reset and override. Time gate outputs available at gate terminal during measurement. Modular construction adaptable to crystal time base for higher accuracy. Extendable with input scaling to 0-20 MHz or 0-200 MHz. All solid-state circuit uses 26 IC's, 43 transistors, and 14 diodes.

The frequency of output B/10 should be 1/10 that of A/10 and 1/100 that of the input to the A scaler. Its amplitude depends on the setting of the range selector switch, but it should range between 1.8 and 3.6 volts, positive. It should have a 6:4 duty cycle and rise and fall times of about 50 ns.

The GATE terminal of the D scaler should have a repeating waveform that goes positive about 2 volts for 0.1 second and to ground for 0.9 second.

The output at C/2 should be a repeating signal that is positive for 1 second and ground for 1 second, with an amplitude of about 2 volts.

The output at C/10 should be a repeating symmetrical square wave with a frequency of 0.2 Hz (5-second period), with an amplitude of about 2 volts, positive.

Gate (M6) There should be a clean 60-Hz sine wave at the junction of *D1* and *R3* on this module (terminal 60 Hz). It should be offset with the negative peak at −0.7 volts and the positive at +2.4 volts.

At pin 7 of *IC1* there should be a 60-Hz rectangular wave having 50-ns rise and fall times and an amplitude of about +2 volts. The output at pin 8 of *IC2* should be a 20-Hz rectangular wave with a 1:2 duty cycle and a 2-volt positive amplitude.

The 0.1 SEC output of this module should be a symmetrical, positive-going wave at 0.1 second, with 50-ns rise and fall times. The 10 SEC output should be positive for 10 seconds and ground for 10 seconds.

Reset. The reset buss (RST on all modules except *M2*) is at ground most of the time. Depressing the front panel RESET switch should raise the level of the buss to about 1.6 volts and all DCU's should promptly return to a zero indication. Also during normal operation, there is, on the reset buss, a brief pulse, about 2 microseconds long and 1.6 volts in amplitude, immediately after the leading positive edge of the selected time gate. This waveform erases the old counter indications and drops them to zero the instant a new measurement is to begin. This waveform can be seen best on a lab-type oscilloscope having both triggered sweep and vertical channel delay. —30—