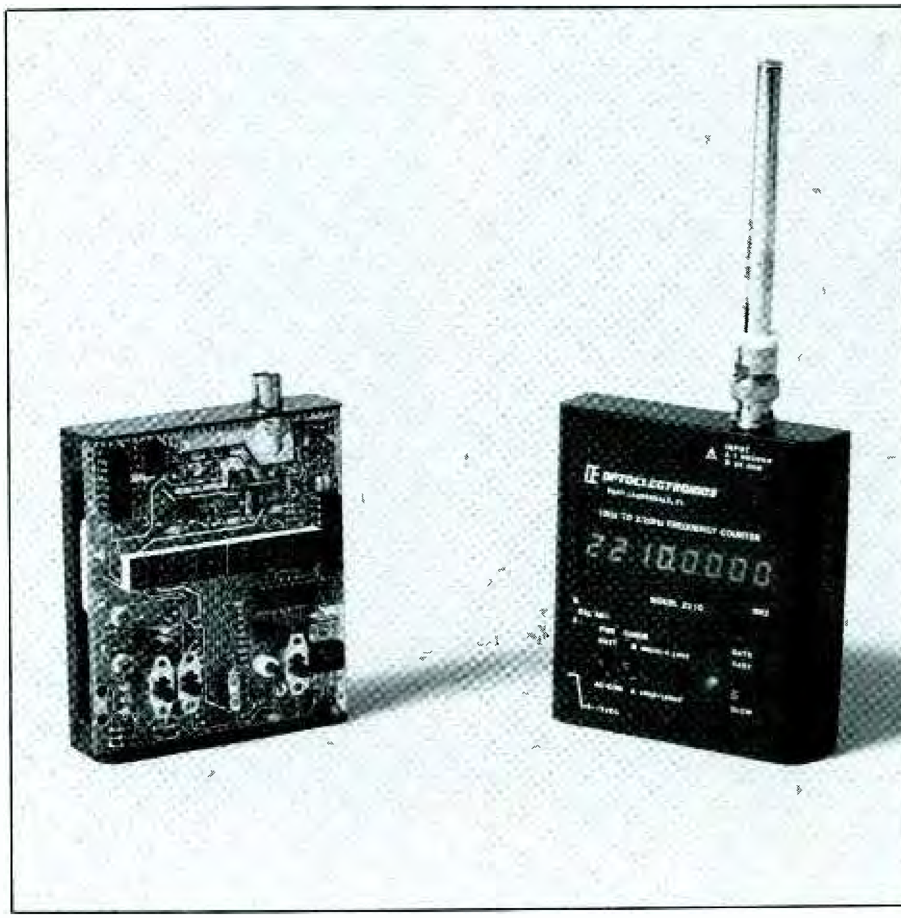
A 10-Hz to 2.2-GHz Frequency Counter

A hand-held general-purpose counter that performs like an instrument costing many times more than its moderate price

By Bill Owen



A frequency counter that operates from the low audio range to beyond 2.2 GHz has traditionally been very expensive and quite bulky. Now you can *build* such a counter for $100 in electronic components package and the printed-circuit board. Add another $50 to equip it with ac and dc powering options and a durable metal enclosure. Furthermore, the new instrument can fit into a jacket pocket and delivers big counter performance.

The basic counter has input amplifiers and two temperature-stabilized crystal oscillator timebases that assure sensitive, accurate operation and reads out measured frequencies in an eight-decade LED display.

Our general-purpose instrument can count frequencies down to 10 Hz and up to and beyond 2.2 GHz in two user-selectable ranges. It permits both antenna and direct input connections, making it suitable for a wide range of applications. For example, you can use it to check the clock frequency in a computer or pick up a cellular or cordless telephone signal or a ham, marine or aircraft vhf transmitter signal. With the antenna, its sensitive input can pick up a strong police, fire or public-service transmission, whose indicated frequency can then be punched up on a scanner for listening.

This counter's diminutive size and dual powering options make it ideal for service work on your testbench and in the field. It easily fits into a tool kit or even a jacket pocket. If you wish, you can also build this compact counter into a piece of equipment that has space for it and use it as a permanent panel-meter function of the equipment.

About the Circuit

Shown in Fig. 1 is the block diagram of the frequency counter. A signal whose frequency is to be counted en-

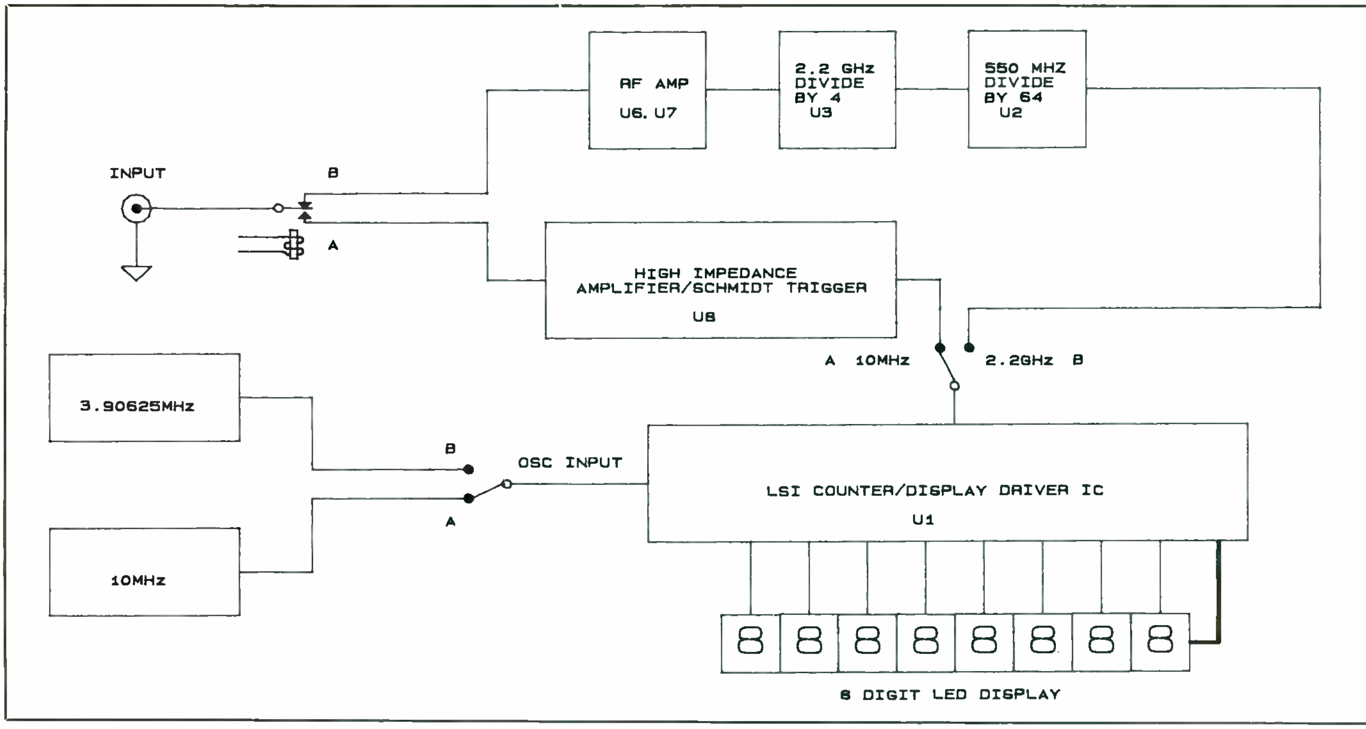


Fig. 1. Block diagram of the 10-Hz to 2.2-GHz counter's circuitry.

ters through the BNC connector labeled INPUT. A relay then routes this signal via either path A or path B. Path A is the direct input that bypasses the scaling circuits for signals whose frequencies are less than 12 MHz. Signals whose frequencies are greater than 10 MHz are routed via path B for prescaling. This is needed here because main LSI counter/display driver chip *U1* cannot reliably operate at frequencies beyond 12 MHz or so.

Signals to be counted in path A are amplified in several stages. For details of the A input amplifier, turn now to the complete schematic diagram of the counter shown in Fig. 2. Exiting the relay, the signal passes through coupling capacitor *C1* and is limited to approximately 0.7 volt by back-to-back diodes *CR1* and *CR2*. Resistor *R13* limits current through the diodes, and resistor *R32* is predominant in determining the low-frequency input impedance.

N-channel junction field-effect transistor *Q7*, along with pnp bipolar transistor *Q2*, make up a high-impedance, low-capacitance wide-band unity-gain buffer, the output of which is capacitively coupled to the first stage of an MC10116 triple line receiver. This ECL (emitter-coupled logic) device provides amplification with its first two stages and Schmitt-trigger action with its third stage. Schmitt-trigger action is accomplished with positive feedback through *R29*.

Low-frequency and noisy signals must be converted to clean fast-rise-

New Bipolar Technology

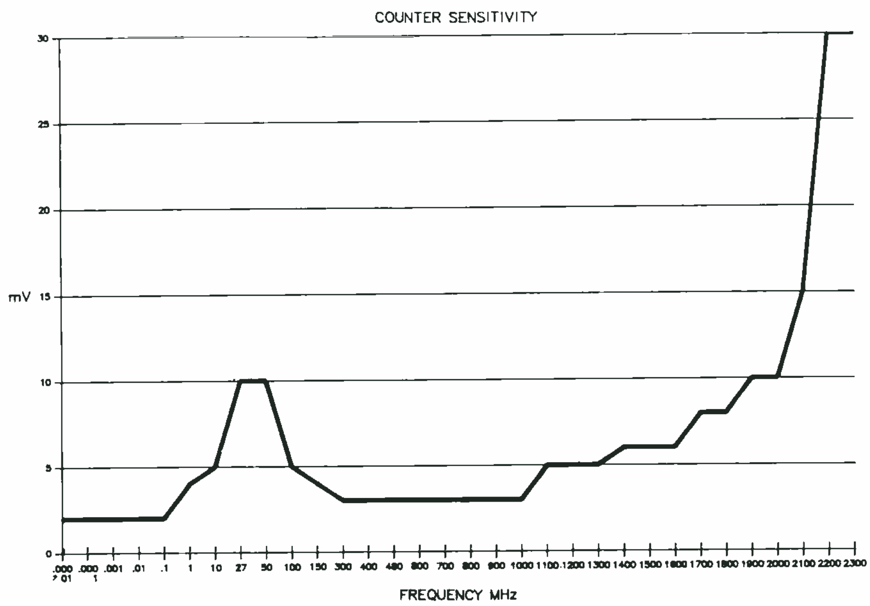
Though MOS technology seems to be getting all the publicity these days in the speed area, makers of silicon bipolar devices are quietly improving their products. Our frequency counter is the beneficiary of recent developments in this technology. In fact, the key components in the counter—a prescaler and a pair of microwave miniature integrated-circuit (MMIC) amplifiers—are new silicon bipolar devices. These new high-technology components are responsible for our frequency counter.

NEC's B582C 2.2-GHz prescaler chip is responsible for the counter's microwave performance. NEC states that the chip's ". . . high performance can be attributed to a newly developed process called Direct Nitride Passivated Base Surface II, which permits production of transistors with less parasitics, improved passivation and emitter line widths of 1 micron. The result [is an] f_T as high as 10 GHz, improved noise figures and reliability."

The microwave miniature integrated circuit amplifiers used in the counter are also a fairly new development. These Mini-Circuits MAR-6 devices are also a product of silicon bipolar technology. They are small surface-mount ICs that each provide 20 dB of gain and a 2-GHz bandwidth. For complete information on these devices, see the Table in a "1-MHz to 2-GHz Amplifier" in the September 1988 *Modern Electronics*.

Frequency Counter Specifications

	Input A	Input B
Range	10 Hz to 12 MHz	10 MHz to 2.2 GHz
Input impedance	1 megohm/30 pF	50 ohms
Sensitivity	(see Counter Sensitivity graph below)	
Timebase frequency	10 MHz	3.90625 MHz
Stability (20° to 40° C)	±2 ppm	±2 ppm
Aging	4 ppm/yr	
Calibration adjustment	Screwdriver adjust through front panel	
Resolution/gate period		
Fast	10 Hz/0.1 second	1 kHz/0.25 second
Slow	1 Hz/1 second	100 Hz/2.5 seconds
Display	8-decade 0.28" orange LED	
Dimensions	3.9"H × 3.5"W × 1"D	
Weight	9 ozs.	
Power requirements	9 volts dc at 200 mA from 117-volt ac 60 Hz plug-in adapter; 2 hours operation	
Internal battery	Rechargeable Ni-Cd; gives 2 hours operating time; recharges in 16 hours while operating from ac adapter	



time pulses by the Schmitt trigger. Because the characteristic ECL output of this circuit is not compatible with our circuit, bipolar npn transistor *Q5* provides level shifting for CMOS counter *U1*.

Signals that are routed via path B are amplified by *U6* and *U7* and enter *U4* where frequency division by a factor of 4 takes place. The signal exiting *U4* is coupled to *U2*. where it is prescaled again, this time by a factor of 64. The total prescale factor is then 256. Hence, one pulse enters *U1* for every 256 periods of signal entering the counter.

According to the above, if the prescale factor is a multiple of 10, it would be a simple matter to move the decimal point in the display to the appropriate location to permit direct display of the counted frequency without having to interpret the numbers. In this case, however, the counter's clock frequency must be changed to compensate for the divider ratio.

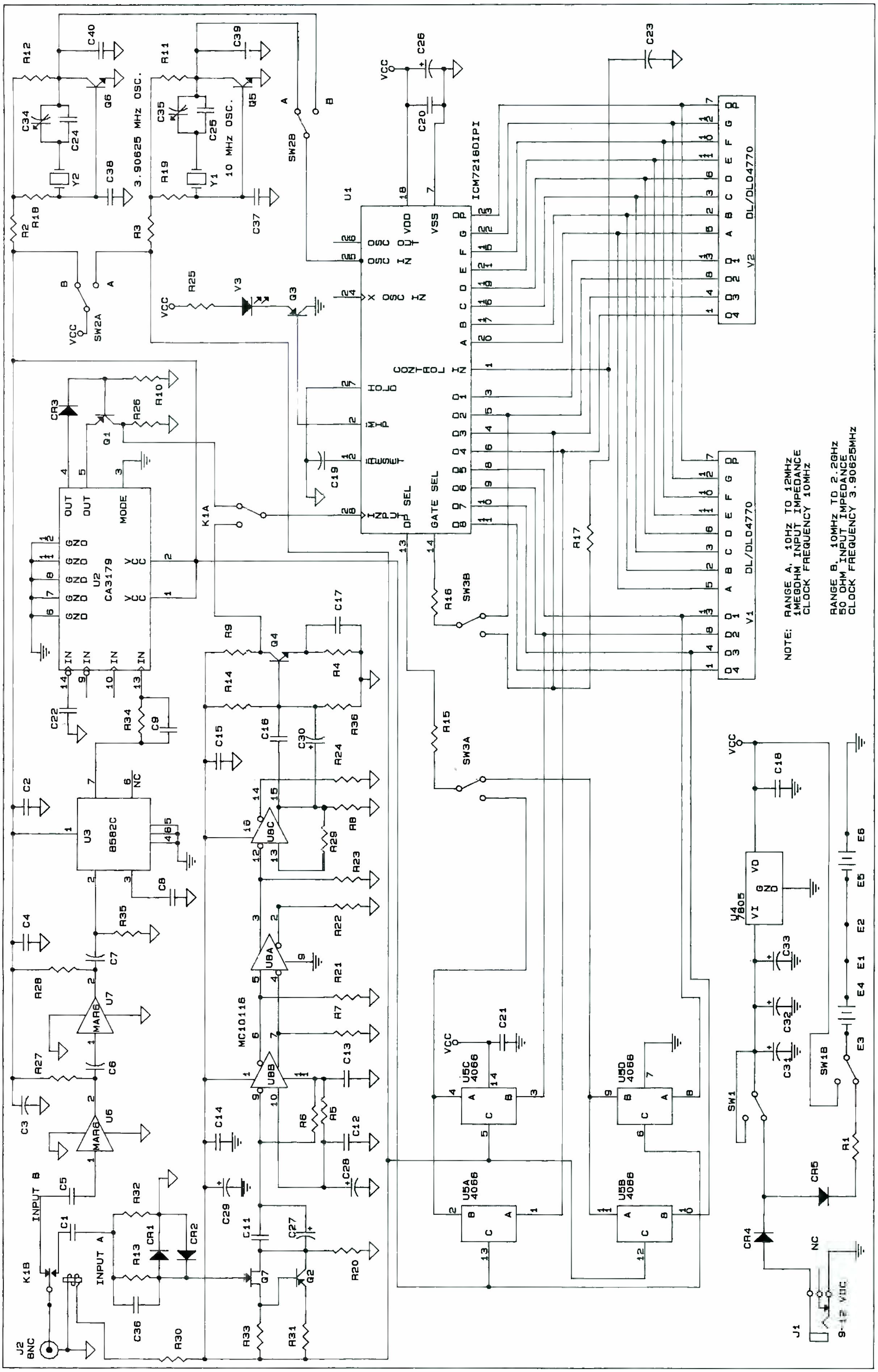
A frequency counter is an electronic device that gives a decimal display of the number of cycles of electrical events that occur during a given period of time. The unit of frequency is the Hertz (Hz), which is equal to one complete cycle per second. This counter uses millions of Hertz or megahertz (MHz) as its unit of measurement. To assure accuracy, the counter uses a clock reference to control the amount of time pulses are counted by it's electronic counters. All of this activity occurs inside *U1*, which is designed to use a 10-MHz clock for its reference.

Any deviation from the 10-MHz clock frequency results in a corresponding change in the length of time the counters inside *U1* will count. This is used to advantage in our counter. When the 2.2-GHz maximum signal frequency is prescaled by 256, the result is a frequency of 8.593750 MHz. Therefore, the clock frequency must be reduced so that the counters accumulate pulses for a longer period of time.

Since the counter uses a display made up of eight decades (digits), 22000000 is the number that should be displayed at the counter's maximum operating frequency. With the standard 10-MHz clock frequency, the displayed figure would be 8593750 after 1 second. To give the correct display, the counter would have to accumulate pulses for 2.56 seconds, which is a lengthening the gate time by a factor of 2.56.

To arrive at the correct clock frequency, you would divide 10 MHz by 2.56 to obtain 3.90625 MHz. At this clock frequency, the FAST and SLOW

Fig. 2. Complete schematic diagram of counter's circuitry.


NOTE: RANGE A. 10Hz TO 12MHz
1MEGOHM INPUT IMPEDANCE
CLOCK FREQUENCY 10MHz
RANGE B. 10MHz TO 2.2GHz
50 OHM INPUT IMPEDANCE
CLOCK FREQUENCY 3.90625MHz
ICM7216DIPI
CA3179
8582C
MC10116
DL/DL04770
3.90625 MHz OSC.
10 MHz OSC.
INPUT A
INPUT B
J2 BNC
9-12 VDC

PARTS LIST

Semiconductors
CR1,CR2,CR3—1N4148 or similar small-signal diode
CR4,CR5—1N4005 or similar rectifier diode
Q1—PN3625A pnp transistor
Q2,Q3—PN5139 pnp transistor
Q4,Q5,Q6—PN2369 npn transistor
Q7—J309 n-channel field-effect transistor
U1—ICM7216 counter/timer/display driver
U2—CA3179/9321-012 prescaler
U3—B582C prescaler
U4—7805 +5-volt fixed regulator
U5—CD4066 quad bilateral switch
U6,U7—MAR-6 MMIC r-f amplifier
U8—10116P triple line receiver
V1,V2—DL/DLO4770 common-cathode 4-decade, 7-segment LED display
V3—T1 red light-emitting diode

Capacitors
C1 thru C4—0.1-μF surface-mount chip
C5 thru C10—1,000-pF surface-mount chip
C11 thru C22—0.1-μF, 50-volt monolithic
C23—100-pF disc
C24,C25—15-pF NPO disc
C26—100-μF, 6.3-volt electrolytic
C27 thru C30—47-μF, 6.3-volt electrolytic
C31,C32,C33—330-μF, 16-volt radial-lead electrolytic
C34,C35—1-to-23-pF pc-mount trimmer
C36—220-pF monolithic
C37,C38—390-pF monolithic
C39,C40—47-pF monolithic

Resistors (⅛-watt, 5% tolerance)
R1—100 ohms
R2,R3,R4—100 ohms
R5 thru R12—1,000 ohms
R13 thru R17—10,000 ohms
R18,R19—100,000 ohms
R20 thru R26—510 ohms
R27,R28—150 ohms
R29—2,200 ohms
R30—a2.7 ohms
R31—51 ohms
R32—1 megohm
R33—680 ohms
R34—3,600 ohms
R35—27,000 ohms

Miscellaneous
B1—6-volt Ni-Cd rechargeable battery (4 AA cells in series)
J1—Pc-mount dc power jack (to match 9-volt dc plug-in power supply)
J2—Chassis-mount female BNC connector (modify as described in text)
K1—Pc-mount 5-volt dc relay with dpdt contacts
SW1,SW2,SW3—Miniature slide or toggle dpdt switch
Y1—3.90625-MHz solder-mount crystal
Y2—10-MHz solder-mount crystal
Printed-circuit board; socket for U1 (see text); 9-volt dc, 300-mA plug-in power supply; suitable enclosure; machine hardware; solder; etc.

Note: The following items are available from Optoelectronics Inc., 5821 N.E. 14 Ave., Ft. Lauderdale, FL 33334 (800-327-5812; in Florida, 305-771-2050): Kit of all components, but not enclosure, $99. Available separately; double-sided pc board with plated-through holes, No. PCB-2210, $25; 9-volt dc, 300-mA plug-in power supply, Part No. AC-22, $9.99; Ni-Cd battery, Part No. NiCad-22, $20; enclosure & hardware, Part No. CAB-22, $20.00. Also offered is an assembled and calibrated unit, Model 2210, for $189. Add 5% for P&H. Florida residents, please add 6% state sales tax.

gate times become 0.256 and 2.56 seconds, respectively, with the resolution or least-significant digit 1,000 and 100 Hz, respectively. Selection between the FAST and SLOW gate times is via *SW3B*, while *SW3A* switches the decimal point as needed in the *V1/V2* display via *U1*.

Notice in Fig. 2 that two clock oscillators are provided. One or the other is manually selected according to desired range by switch *SW2A*. In position A, the 10-MHz clock is used since path A directly couples into counter chip *U1* without undergoing prescaling. Position B of *SW2A* switches the 3.90625-MHz clock into the line during the prescaling operation. Both clock oscillators have separate calibration trimmer capacitors that permit adjustment for maximum accuracy.

Both clock oscillators are a modified Pierce design built around bipolar npn transistors *Q5* (10 MHz) and *Q6* (3.90625 MHz). Power to each oscillator is switched by RANGE switch *SW2A*. The other half of this switch, *SW2B*, routes the oscillator outputs to COUNT IN pin 25 of *U1*.

Count accuracy is determined by accuracy of the timebase clock oscillator. Trimmer capacitors *C34* and *C35* permit you to adjust each oscillator so that it is precisely on frequency. A precisely known reference frequency must be read by the counter and each oscillator must be adjusted until the frequency in the counter's display is "on the money."

After calibration, normal aging will cause the oscillators' frequencies to change over a period of time. This aging is caused by several factors. One is that microscopic particles may get knocked off the quartz of which the crystals are made over a period of time, slightly changing the mass of the quartz and, thus, the frequency at which it oscillates. Another is that the plating on the crystal will undergo some oxidation, even though the crystal housing is filled with inert gas. Also, the plating may undergo stress relief.

These processes will slow down after the first year to a more predictable rate. Until then, though, it is wise to check calibration as often as possible and make whatever adjustments are needed to compensate for the aging effects.

Temperature will also effect the accuracy of the crystal oscillators. If calibration is done at room temperature and a reading is taken at a higher or lower temperature, there will be some error in the displayed figure. This is why it is desirable to have some type of temperature compensation. Larger counters can use a crystal oven where temperature is precisely maintained. This counter does not have an oven.

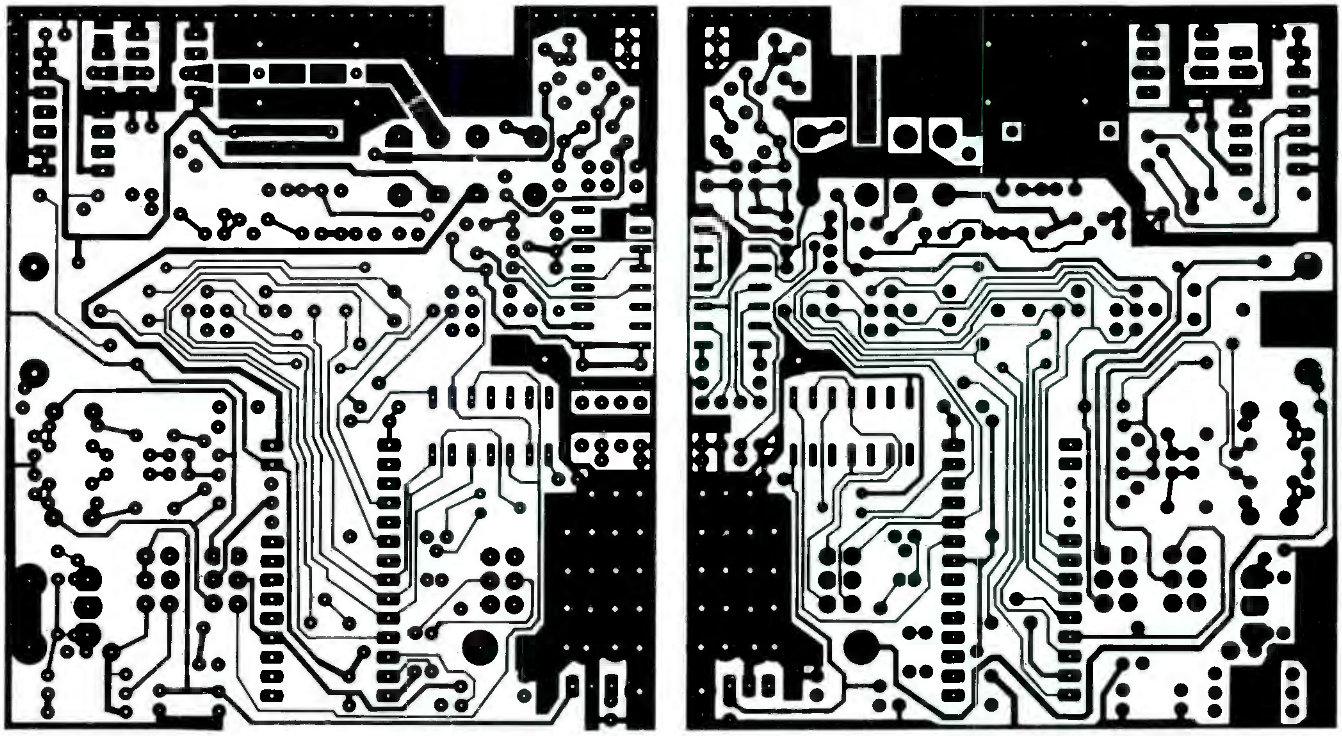


Fig. 3. Actual-size top (left) and bottom (right) etching- and-drilling guides for project's printed-circuit board.

An additional factor that affects the accuracy of this counter is its quantization error. During one gate period, the gate may close while a pulse is being counted, but during the next period it may close between pulses, even though the same frequency was being counted in both cases. Because of this possibility, the count observed in the display should always be viewed as being within ±1 count in the least-significant (farthest-right) decade.

As the frequency being measured increases, the impact of the quantization error decreases. At 1,000 MHz (1 GHz), the least-significant digit may be 100 Hz, which corresponds to an error of only ±0.1 part per million (ppm). At low frequencies, an altogether different situation exists. At 100 Hz with 1 Hz resolution, the error is 1 percent, which greatly overshadows the timebase error. With decimal-point selection, there are four different combinations, two for range A and two for range B. To allow for four possible states without using multiple-pole mechanical switches, CD4066 analog switch *U5* is used. This chip has on-board four internal switches and is controlled by switching the positive supply rail as needed, using *SW3A*.

Since this frequency counter is designed to be portable, it must operate from a battery in locations where ac line power is not available. In this design, four AA nickel-cadmium (Ni-Cd) cells can be used to provide power for the counter for several hours before recharging is needed.

For bench use and in the field where ac power is available, a 9-volt dc, 300-milliampere wall transformer can be used to power the counter. This transformer can also be used to charge the battery while the counter is in use. Resistor *R1* regulates charging current.

When powered from the ac line via the adapter/charger, 7805 regulator *U4* delivers 5 volts dc to the circuits that make up the frequency counter. When operating from a battery, no regulation is needed. This scheme works quite well, but do note that the counter remains on continuously as long as it is plugged into the charger. To maintain steady, clean dc supply power, bypass capacitors and filter capacitors are used liberally throughout the circuit.

The ICM7216DIPI used for *U1* has been around for a number of years now and is a proven performer. Before this chip appeared on the scene, it took 20 to 40 integrated circuits to perform all the functions this single IC does. The 7216 drives the seven-segment light-emitting diode display digits, of which there are eight decades. This chip has a total of 16 display-drive lines, one for each segment and one for each digit. Using multiplex drive, the chip is able to fill the display only one decade at a time. Because the scan rate is quite

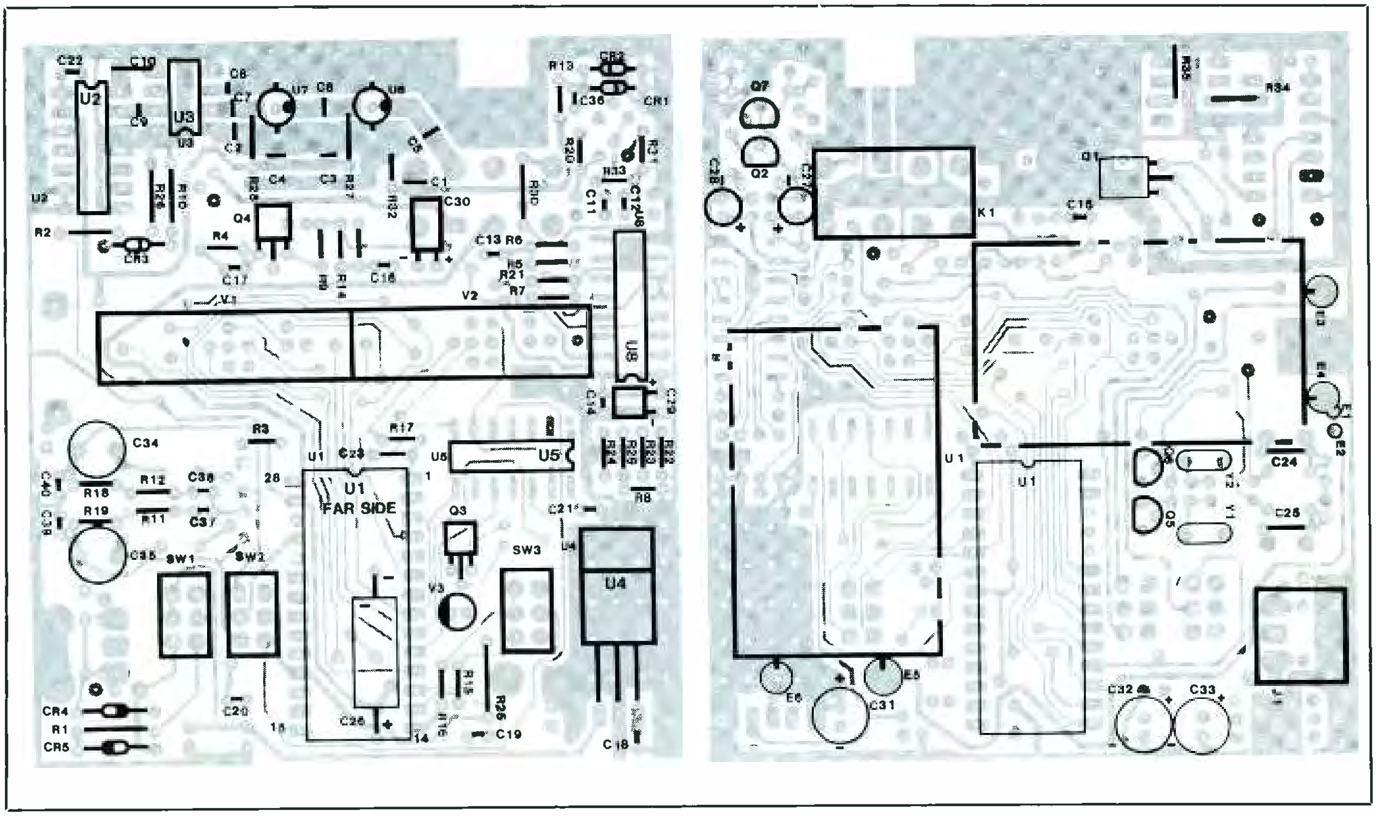


Fig. 4. Wiring guides for top (left) and bottom (right) of the pc board. All components mount directly on the pc board, including a cluster of surface-mount capacitors and IC amplifiers at upper-left in top view.

fast, however, all digits in the display appear to be on continuously.

Pin 2 of *U1*, labeled MIP is a measurement-in-progress status output indicator. When a count is being made, the signal at this point sends *Q3* into conduction and turns on light-emitting diode *V3*.

Construction

Printed-circuit construction is a must for this project. This board should be double sided. You can fabricate your own pc board or purchase a ready-to-wire board from the source given in the Note at the end of the Parts List. If you make your own board, lack of plating-through for the holes will require that you solder all component leads and pins to the copper pads on *both* sides of the board and that you make provisions to continue conductors from one side to the other of the board where soldering access is not possible at a component. Use the actual-size etching-and-drilling guides given in Fig. 3 to fabricate your board.

Note in the wiring guides for the board given in Fig. 4 that components mount on *both* sides. The "top" side of the board is the one on which the numeric displays and majority of the components that make up the circuitry mount. The bottom of the board will have on it *U1*, the relay, the AA cells that make up the battery and a handful of discrete components.

Before installing any components on the pc board, prepare a chassis-mount female BNC connector to fit into place over the edge of the pc board in the notched area. Do this by cutting a slot across the threaded portion of the shell with one side offset just enough so that it is in line with the connector's center conductor pin and the other side spaced the thickness of the board away. Do this by clamping the connector in a vise between two pieces of soft wood and slicing very carefully with a hacksaw. Make the slot just wide enough to fit over the edge of the board without biting into the copper cladding.

Set the connector in place, as in the "bottom view" illustration in Fig. 4. Solder the center-conductor pin to the narrow pc trace at the bottom of the notch in the board. Make sure this pin touches only the specified trace when you are done. Then use a high-wattage soldering iron or a soldering gun to liberally solder the connector shell to the copper cladding on *both* sides of the board and on both cut edges on the same side.

Next, install and solder into place the relay on the bottom side of the board. Flip over the board and refer to the "top view" drawing in Fig. 4 to install and solder into place ICs *U2* and *U3*. Make sure each is properly oriented before soldering any pins.

There are 10 chip capacitors (*C1* through *C10*) and two integrated-circuit amplifiers (*U6* and *U7*) that are surface-mount devices. All are located in the upper-left in this drawing. The capacitors have no leads, and the amplifiers have very short pins. There are no holes in the board for leads for any of these components. You install the capacitors and amplifiers by setting them in place on the copper-trace pattern and soldering one lead down with a small-tip soldering iron.

Begin with the capacitors. There are two values for these chip capacitors, the smaller ones being 1,000-picofarad (0.001-microfarad) units that are identified with the legend 103) and the larger being 0.1-microfarad (identified with 104) units. Install each in the proper locations, referring to the Parts List.

Set the first capacitor in place and use a needle to hold it there with gentle pressure as you solder one end to the trace it touches. Use the needle to reposition the capacitor if it moves during the soldering operation. Do the same for the remaining nine capacitors. When you are done, gently solder the other sides of all capacitors to the other pads on the board. Take care to avoid stressing these tiny fragile chip capacitors. Also, to avoid damaging them with heat, do *not* solder the second end to their traces immediately after soldering the first.

Next, solder the tiny MAR-6 amplifiers into the U6 and U7 locations. These devices should fit snugly into the holes in the board to help in soldering. Keep in mind that the white dot on the case of each device *must* point towards the relay.

Bend the pins of the 7805 voltage regulator back at a 90-degree angle (toward the metal tab) ⅜ inch from where they join the plastic case. Before installing the regulator, you might want to fill the large holes in the board in the U4 location with solder to aid in heat sinking. This done, position the regulator in the U4 location, plug its pins into the indicated holes and solder them into place. Then liberally solder the regulator's metal tab to the large copper pad under it on the board.

Once the surface-mount devices are in place, install the resistors and capacitors on the top of the board. Be sure to properly orient the electrolytic capacitors and diodes before soldering their leads into place. Also, note that capacitors *C29* and *C30* must lie flat against against the board. Bend their radial leads at a 90-degree angle to their cases before installing these capacitors. The same applies to transistors *Q3* and *Q4*. Bend their two outer leads ⅛ inch and their inner leads ¼ inch from the cases at a 90-degree angle toward the rounded rear of the cases. Plug the leads into the indicated holes and solder them into place.

Now install integrated circuits *U5* and *U8* in their respective locations on the top of the board. Do *not* use sockets for these ICs (the only IC that should be installed in a socket is *U1*, which mounts on the bottom of the board). Make certain you orient these devices properly before soldering their pins into place.

Install and solder into place two seven-segment LED numeric displays in the V1 and V2 locations. Make certain that the decimal points in both displays are oriented toward the bottom of the board before soldering any pins into place.

Use a 0.1 × 0.25-inch nylon spacer to mount GATE light-emitting diode *V3* in place. Be sure to properly polarize this LED before soldering its leads into place. The cathode lead goes into the left hole.

Plug the lugs of the switches into the holes for them in the board and solder them into place. This completes wiring of the top side of the board. Turn over the board and carefully clip all protruding leads and pins as close as possible to the board's surface.

Now wire this side of the board, beginning with installation of the resistors and capacitors (observe polarity with the electrolytics). Then install and solder into place the remaining transistors. Only *Q1* mounts flat against the board's surface in the same manner as those on the top of the boar. The other transistors mount upright in the traditional manner. Be sure to plug the transistor leads into the appropriate holes before soldering them into place.

Install and solder into place the power jack in the J1 location and the two crystals in the Y1 and Y2 locations. Be sure with regard to the latter that you plug the correct-frequency crystal into each location.

Place two rechargeable Ni-Cd AA cells in opposition orientation to each other. Line up their ends and wrap with plastic or strapping tape. Solder a short length of insulated hookup wire from the positive (+) pole of one cell to the negative (−) pole of the other. Strip ¼ inch of insulation from both ends of two 1-inch hookup wires. Set the two-cell arrangement before you flat on your work surface with the remaining positive pole to your left. Tack-solder one end of one wire to the positive pole with the free end pointing away from your work surface. Do the same with the other wire and negative pole of the battery. Wrap together the battery pair, top to bottom, with more tape. Then repeat all steps for the remaining two AA cells.

Plug the free ends of the wires you soldered into the poles of one pair of cells into the holes labeled E3 and E4, with the positive-pole wire going to the E3 hole and the negative-pole wire going to the E4 hole. Similarly, plug the free ends of the wires on the other cell pair into the holes labeled E5 (+) and E6 (−), respectively. Place a wide strip of ⅛-inch-thick double-sided foam tape between each cell pair and the circuit-board assembly to provide resilient mounting.

Now install and solder into place a

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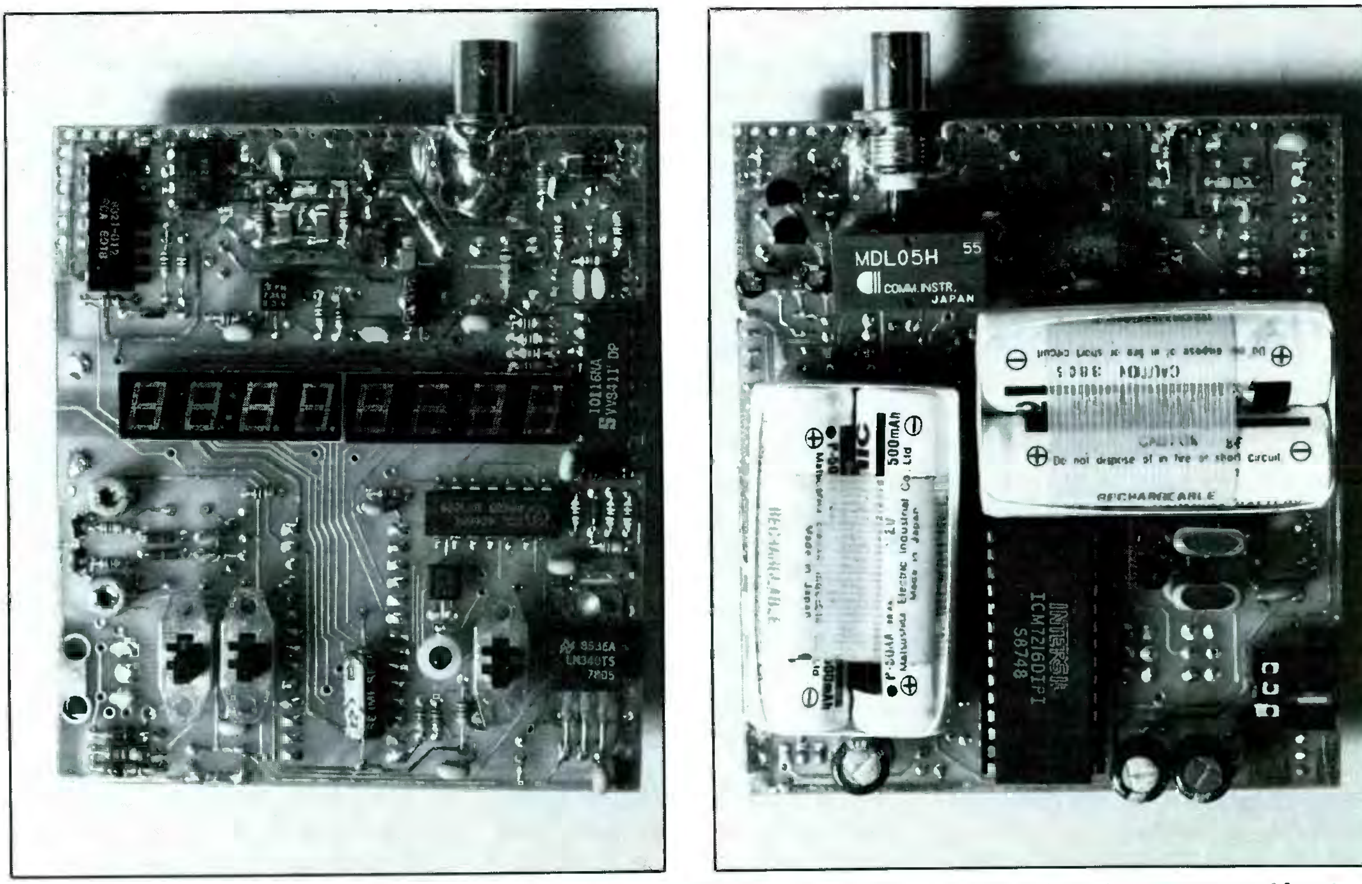

Fig. 5. These photos show fully wired circuit-board assembly from top (left) and bottom (right) perspectives. Note in both photos how BNC connector mounts on board with its threaded section straddling both sides.

28-pin DIP socket in the U1 location. Then exercise the same handling technique for MOS devices to install *U1* in the socket. Make sure you properly orient the IC in the socket and that no pins overhang the socket or fold under between IC and socket during installation.

Pictured in Fig. 5 are both sides of a fully assembled frequency-counter circuit-board assembly just prior to installation in its enclosure. The photo on the left is of the top, the one on the right the bottom of the board.

Any enclosure that will comfortably accommodate the circuit-board assembly can be used to house the counter. An all-metal enclosure that measures 3¾ × 3⅜ × 1 inches should do just fine. Otherwise, as mentioned above, you can build the project into an existing piece of equipment and use it as you would a panel meter.

Machining of the enclosure can be a tedious task. Four rectangular slots must be cut and three holes must be drilled in the front panel. One slot is the long and narrow display window that goes almost clear across the front panel; the three other slots are small enough only to permit normal operation of the three switch slides. The drilled holes are for mounting the LED and accessing the tuning slots of the trimmer capacitors.

A large hole for the BNC connector to exit the enclosure must be drilled in the top panel, and a suitable hole for the ac adapter/charger's jack must be drilled in the left side panel. No holes need be drilled for mounting the circuit-board assembly in place. When the enclosure has been machined, paint it if you wish and then use a dry-transfer lettering kit to label the front panel (see lead photo for details). Spray two or more light coats of clear acrylic over the lettering to protect it from wear. Allow each coat to dry before spraying on the next. Then cement a transparent red plastic lens over the display window inside the enclosure.

You can eliminate having to do all this metal work, of course, by purchasing a machined, painted and silk-screened enclosure with plastic window from the source given in the Note at the end of the Parts List.

Checkout & Calibration

Now that your counter is completely assembled, give it a thorough visual inspection. Check to make sure that all components are installed in their respective locations and that those that are orientation-sensitive are installed properly. Also check your soldering. Solder any missed connections, reflow the solder on any connection that appears questionable and use desoldering braid or a vacuum-type desoldering tool to remove inadvertent solder bridges.

When you are confident that everything is okay, plug the ac adapter/charger into the jack on the side of the instrument and into an ac outlet. Setting the PWR switch to AC-CHG should cause some if not all of the digits in the display to come on and the GATE LED light to light. If everything is okay, you will note that the 7805 voltage regulator at the lower-right on the top side of the circuit-board assembly runs warm to the touch. This is the normal operating condition for this regulator.

After proper operation is verified, set the RANGE switch to position A and feed a signal in the low A range into the input of the frequency counter, using a precision reference source and note the displayed frequency. If this frequency does not agree with the rated precision reference frequency, adjust the setting of trimmer capacitor *C35* until it does. Use a non-metallic tuning tool to make the adjustment.

Set the RANGE switch to position B and feed another precision reference frequency in the range between 10 MHz and 2.2 GHz into the counter and note the reading in the display. If this reading does not agree with the specified reference frequency, adjust the setting of trimmer capacitor *C34* until it does. Again, use a non-metallic tuning tool to make the adjustment.

Now that your frequency counter is ready to be put into service, there are many new applications that you can find for this very sensitive wide-range portable instrument. Next month, we will explore some of the many possible uses for this counter and show you some useful techniques to use for making measurements. We will also include counter surveillance, troubleshooting, servicing of two way radios, obtaining scanner frequencies and other topics. ME