Audio-Frequency

Generator

Here's an audio-frequency generator with a digital frequency-readout that is easy to build, align, and use, yet is precise enough for servicing today's sophisticated audio equipment.

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TO SAY THAT BOTH HOME AND PROFESsional sound installations have become extremely sophisticated would be an understatement. For example, a ⅓-octave band equalizer as well as lowpass and highpass filters are integral parts of virtually all professional sound systems. In fact, these days equalizers, tone controls, and lowpass and highpass filters are considered to be necessary even in home or auto systems.

Today's consumer demands more in the way of performance, which means more precision is required when servicing audio devices and circuits. Because of that, old-fashioned frequency generators often prove to be inadequate. Among other things, they suffer from inaccurate frequency dials, require range switching, and often their output level changes as the frequency is varied. What we need, then, is an audio-frequency generator that has an accurate output-frequency indicator, a "flat" output level as the frequency is varied, and one that is free of any range switching, thereby allowing the operator to "sweep" the entire audio range with

just a "twist of the wrist."

Well, look no further, because the audio-frequency generator described in this article has all the above-mentioned desirable qualities and a few more. Let's look at some of its features and specifications.

It has a frequency range of 10 Hz to 50 kHz. That range is continuous, which eliminates the need for range switching. For increased precision, two controls are used to set the frequency. The COARSE FREQUENCY control is used to set the approximate frequency while the FINE FREQUENCY control is used to zero it in precisely.

The amplitude of the generator's sinewave output is adjustable from 0- to 6-volts RMS into a high-impedance load or 0- to 3-volts RMS into a 600-ohm load. The device's output impedance is 600 ohms. The sinewave has a distortion figure of less than 1% (THD), and its output level doesn't vary more than a few tenths of a dB as the frequency is changed over the entire range. The unit also boasts a simultaneous squarewave output with a low source impedance and a fixed 5-volt level

for TTL or CMOS logic work.

One unique feature is a built-in frequency counter that continually monitors the output frequency. The device can also be wired so that the counter can be used to measure external signals. That frequency counter not only allows you to make precise frequency settings, but also eliminates the need for usual large, cumbersome dial with its myriad of marks and numbers. Generators using that type of frequency "readout" have always been difficult for the hobbyist to build and calibrate.

The frequency counter itself features autoranging and a large, four-digit LED display. For frequencies up to 9,999 Hz, the display reads out in Hz with 1-Hz resolution. For higher frequencies, the counter automatically switches to the kHz mode, which features 10-Hz resolution. You can tell which mode the generator is in the by the absence or presence of the decimal point. In the kHz mode, a decimal point appears after the first two significant digits.
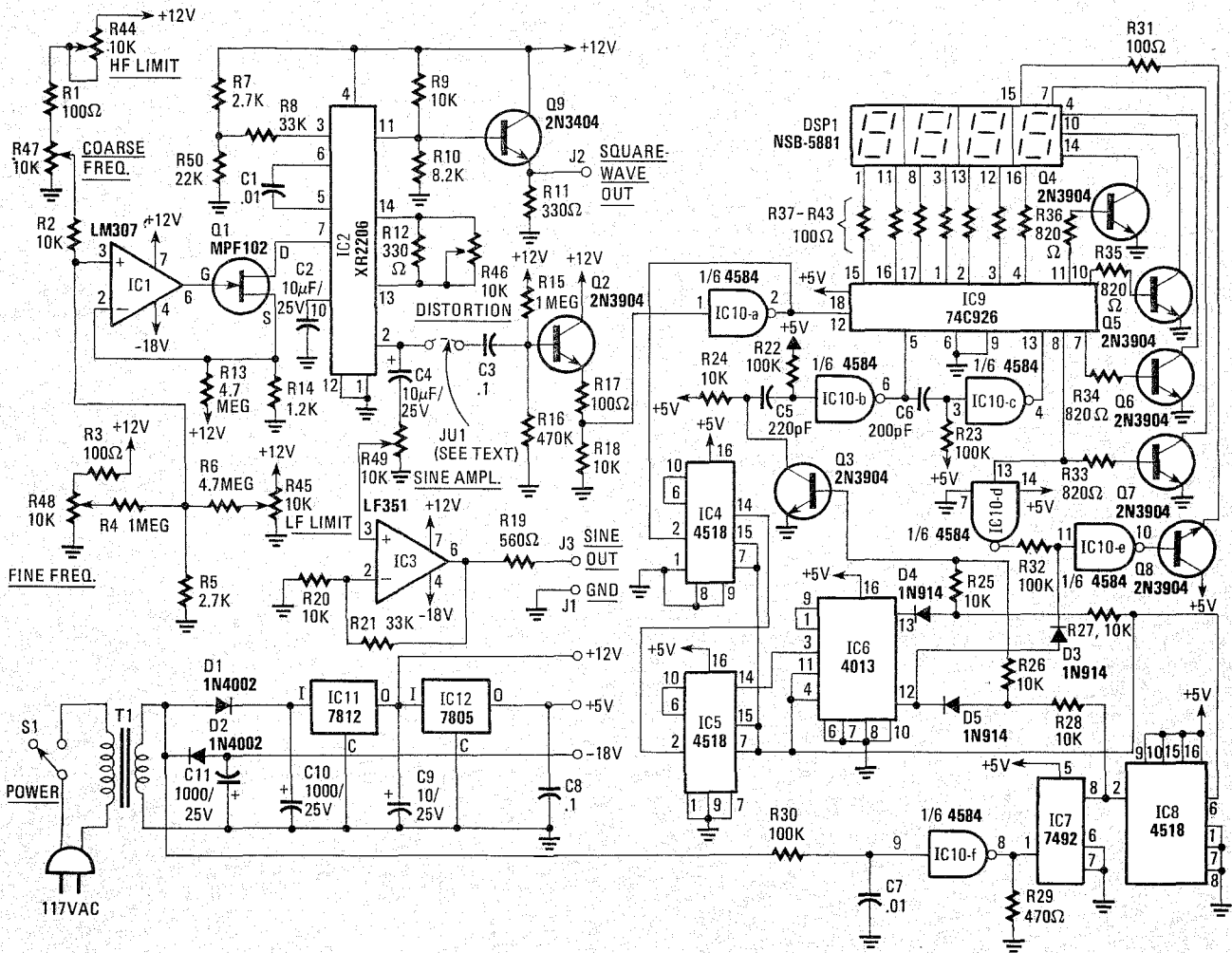
All of the components except the power

FIG. 1—SCHEMATIC DIAGRAM of the audio-frequency generator. If you want to use the built-in frequency counter to measure external signals, jumper JU1 should be replaced with a SPDT switch (see text).

transformer, potentiometers, display, and output connectors mount on a single PC board. The completed project can be housed in a small, metal cabinet.

In short, this is an audio-frequency generator that provides high-quality performance at a low cost, along with some unique features.

How the circuit works

A schematic diagram of the unit is shown in Fig. 1. Let's start with the audio-frequency-generator section. Positive voltage is applied to the COARSE FREQUENCY potentiometer, R47, through trimmer potentiometer R44 (labeled H.F. LIMIT) and resistor R1. In a similar manner, positive voltage is applied to the FINE FREQUENCY potentiometer R48, through resistor R3. Depending on the settings of those potentiometers, some voltage will be fed to the non-inverting input of op-amp IC1 through resistors R2 and R4. Note that a very small voltage will reach that same input through R6 in conjunction with trimmer potentiometer R45 (labeled L.F. LIMIT). That arrangement sets the low-frequency limit of the generator when the COARSE and FINE FREQUENCY potentiometers are set to their low-frequency positions, which, of course, is when both wipers are all the way toward ground. Trimmer potentiometer R44, in setting the maximum voltage that is applied to R47, in turn sets the generator's high-frequency limit when R47 is set to maximum.

Op-amp IC1, along with transistor Q1 and its associated components make up a voltage-to-constant-current converter, the current of which controls the output frequency of function-generator IC2. The sinewave output signal from IC2 (pin 2) feeds the SINE AMPLITUDE potentiometer, R49, through capacitor C4. Depending on the setting of the potentiometer, some voltage will be fed to the non-inverting input of op-amp IC3. That op-amp amplifies the signal, which is then fed to the SINE output binding post through resistor R19.

Note that the sinewave signal from IC2 also feeds the base of transistor Q2 through a jumper wire and capacitor C3. That transistor is configured as an emitter follower and acts as a buffer between the audio-frequency generator section and the frequency-counter section.

The squarewave output signal from

function generator IC2 (pin 11) feeds the base of transistor Q9. That transistor is configured as an emitter follower and serves as a level shifter, buffer, and impedance matcher to provide a squarewave level of 5 volts from a low-impedance source at the SQUARE output binding post.

Trimmer-potentiometer R46 (labeled DISTORTION) sets the sinewave distortion to its lowest possible point. The other capacitors and resistors associated with IC2 set its frequency range and sinewave-amplitude levels.

Let's now turn to the frequency-counter section. Sinewave signals from the output of emitter-follower Q2 (actually the junction of resistors R17 and R18) are fed to the input (pin 1) of one of the six Schmitt triggers contained in IC10. That stage "squares up" the sinewave signal and feeds it to the input (pin 12) of the four-digit counter IC9. That IC counts or totals the squarewave "events," and because the counter is reset at 1- or 1/10-second intervals, it causes the readout to display in either Hz or kHz. Resistors R37 through R43, along with transistors Q4 through Q7 and their associated resistors, make up the segment and digit-drive system.

Note that the "squared up" signal that feeds the four-digit counter also feeds the input (pin 2) of dual decade-counter IC4, and that IC4's output feeds the input (pin 2) of another dual decade-counter, IC5. Those four counters connected in cascade make up a divide-by-10,000 counter that produces an output only when the frequency to be counted is equal to or greater than 10 kHz. That serves as the detector that determines which mode the autorange system will settle on. The output of that counter (pin 14, IC5) feeds the input (pin 3) of flip-flop IC6. That device, and its associated components, serves to determine whether 1-second- or .1-second-period signals from the timebase (to be discussed shortly) ultimately reach the latch and reset points on the main four-digit counter, IC9.

Transistor Q3, IC10-b, IC10-c, and their associated components make up pulse generators that supply the latch and reset signals for the four-digit counter, IC9.

The circuit composed of IC10-d, IC10-e, Q8, and their associated components make up the gated decimal-point-drive system. That system works with signals from flip-flop IC6 to display a decimal point only when the frequency counter is in the kHz mode.

Next we turn to the timebase for the frequency counter. AC voltage from the secondary of power transformer T1 is fed to the input (pin 9) of Schmitt trigger IC10-f through resistor R30. That stage "squares up" the 60-Hz signal and feeds it to the input (pin 1) of the divide-by-six counter, IC7. The output of that counter (pin 8), with its frequency of 10 Hz and period of .1 second, is fed to a resistor/diode system that works with flip-flop IC6 and transistor Q3 to ultimately become the timebase for the kHz mode. That same 10-Hz signal is also fed to the input (pin 2) of divide-by-ten counter IC8. The output of that counter (pin 6), with its frequency of 1 Hz and period of 1 second, is also fed to the resistor/diode system to ultimately become the timebase for the Hz mode. That latter signal is also fed to the reset points on IC4, IC5, and IC6.

The regulated DC power supply is made up of two half-wave rectifiers configured in such a way as to produce both positive and negative voltages from the 12-volt secondary of power transformer T1. The positive voltage is fed to the input of voltage-regulator IC11, which produces at its output a stable 12-volts DC that powers the audio-frequency-generator section. That same 12-volts DC is fed to the input of voltage-regulator IC12, which produces at its output 5-volts DC, which powers the frequency-counter section. AC power is switched on or off with power switch S1.

We mentioned earlier that the frequency counter could also be used to monitor an external signal. That is where jumper JU1 comes in.

That jumper should be wired as shown on the schematic diagram if you want the frequency counter to always measure the output frequency of the generator. If you would prefer that the frequency counter be able to also measure external signals, then omit the jumper, and wire an SPDT switch with its pole connected to the input of the frequency counter (the jumper terminal that connects to C3). Of the other

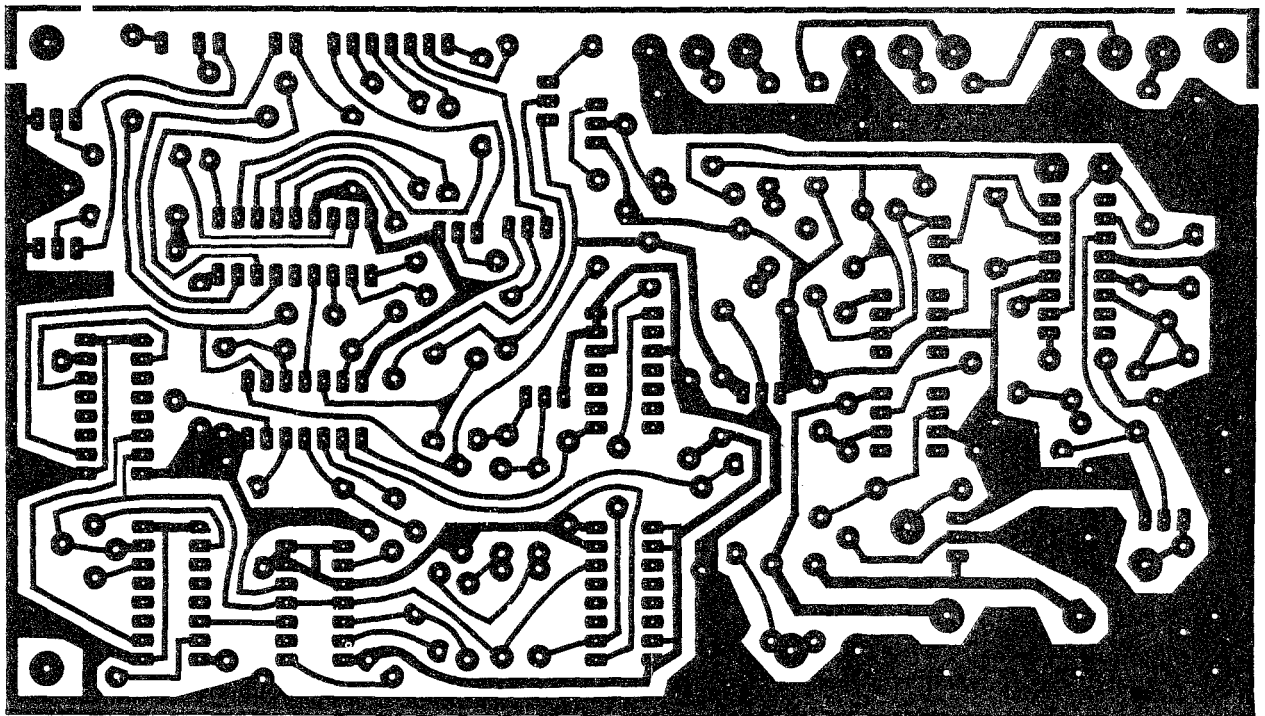|← ——————————————————— 6-9/16 INCHES ——————————————————— →|

FIG. 2—ALTHOUGH POINT-TO-POINT wiring could be used, it is recommended that the project be built using the PC board above. That board is shown full-sized.
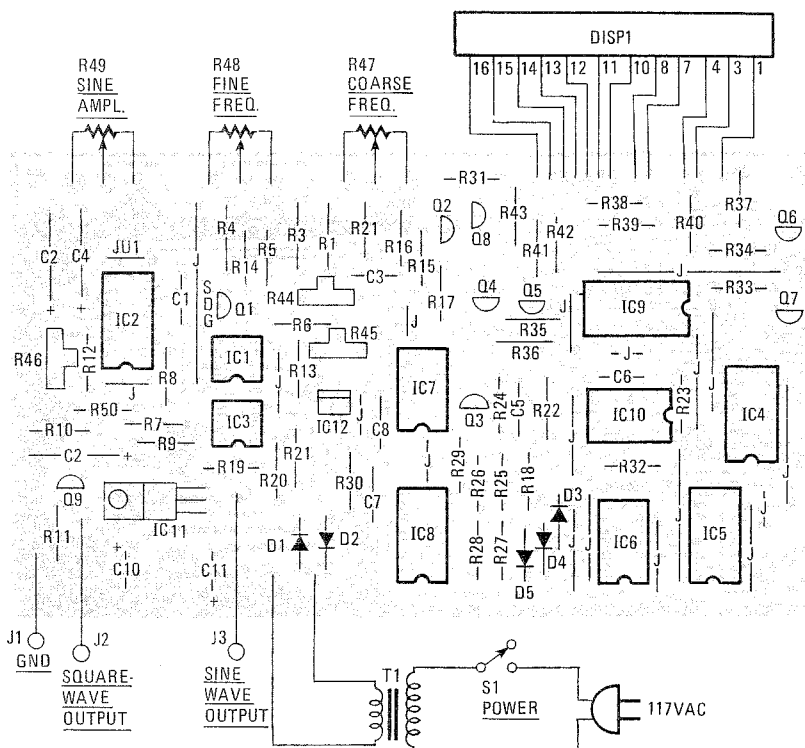
FIG. 3—THE PARTS-PLACEMENT diagram for the PC board shown in Fig. 2 is shown here. Note that even if you are using perforated construction board and point-to-point wiring it is recommended that you follow the layout shown.

each wire passes through the lug hole with the wire being wrapped several times around the lug and soldered. Be sure that when finally soldering the wires to the PC board that you not only make allowance for the required clearance, but that you keep that clearance uniform for all three potentiometers so as to have them reasonably in line horizontally.

In a similar manner, the four-digit display is supported mechanically by its twelve signal wires. The attaching of the wires is best done by soldering a two- to three-inch length of bare No. 22 solid wire to each of the twelve appropriate connectors on the display board. Note that there are 16 total connectors on the display, but that four of them are not used. As an aid to getting the wires soldered to the proper points, tape or clamp the display to your work table with the viewing surface facing downward and the solder connectors closest to you. The connector on the left front corner can be considered as connector 16 and the one on the right as connector 1.

Solder wires then to the following connectors: 16, 15, 14, 13, 12, 11, 10, 8, 7, 4, 3, and 1. Be very gentle in soldering and handling the display because the foils are very thin and breakable. When all the wires have been attached, bend them downward (toward you) with the right-angle bends made close to the connectors. The display with its attached wires can now be installed on the PC board. Insert the display wires into the appropriate PC-board holes and be sure to hold the display level with its horizontal center line about an inch above the PC-board surface before soldering the signal wires into place. After soldering, cut off any excess wire.

When choosing your cabinet be sure that it is large enough to accommodate the board and the off-board components comfortably. Also, using a vented cabinet is a good idea.

At some point, you will need to drill the various holes and a rectangular opening in the cabinet for the potentiometers, display bezel, PC-board mounting bolts, transformer, etc. Plan ahead and carefully measure everything so that it will all fit well. Although most cabinets have a thin coat of paint when purchased, the drilling process usually puts some nicks and scratches in it. Most find that re-painting at least the front panel and then applying press-on lettering gives the instrument a professional appearance.

The PC board is supported about 1¼ inches above the bottom of the cabinet with four ⁶⁄₃₂ × 1½-inch bolts. Each bolt has three ⁶⁄₃₂ × ¼-inch hex nuts attached; one holds the bolt to the cabinet and the other two sandwich the PC board at the proper height.

When all the PC-board components have been soldered in place, it's a good idea to thoroughly check the parts place-

two switch contacts, connect one to the jumper terminal that connects to pin 2 of IC2; the other switch contact becomes the "external" input terminal.

Construction

Several methods of construction are possible. You may choose to mount the components on perforated construction-board (with .1 inch hole spacing) and use point-to-point wiring. A much better idea is to use a PC board. A foil pattern for an appropriate board is shown in Fig. 2; a parts-placement diagram for the board is shown in Fig. 3. If you decide to use perforated construction-board and point-to-point wiring, it is recommended that you lay out the components much as they are in the PC board layout to avoid ground loops, noise, and other undesirable characteristics.

If you plan to use a PC board, and will be drilling it yourself, you will find that a No. 60 drill bit works well for all holes except those for the trimmer potentiometers and external wires. For those, a No. 55 bit is needed; and, of course, the holes for mounting the three terminal voltage regulators and the PC-board mounting holes will require a larger bit, say ⅛ inch.

After the PC board has been drilled, it should be throughly burnished with steel wool or very fine sandpaper to remove the photochemicals and tarnish. That will definitely contribute to better solder connections. All soldering should be done with a high-quality rosin-core solder and a pencil-type iron. The newer type metal-clad tips are highly recommended.

Use special care to properly install polarized components such as diodes, transistors, IC's, and electrolytic capacitors, because those are very unforgiving when put in backwards. If you follow the parts-placement layout shown in Fig. 3 you should have no problems.

Although IC sockets are not required, their use is recommended. If nothing else, it will make servicing and troubleshooting the instrument easier later on.

Note several things in regard to mounting the three-terminal voltage regulators. The 12-volt regulator, IC11, is mounted with a ⁶⁄₃₂ × 1½-inch brass bolt and a ¼-inch hex nut, with the excess bolt length extending upward. The bolt provides a small but adequate heat sink for the voltage regulator. The 5-volt regulator, IC12, mounts in a vertical position and it, too, has a brass bolt mounted to it for heat-sinking purposes. The excess bolt length should extend toward the rear of the PC board. Be sure to install the regulator with its bare-metal side facing the panel-mounted potentiometers (see Fig. 4).

The three panel-mounted potentiometers connect to the PC board by means of short wires that hold their solder lugs about ⅛ to ¼ inch above the surface of the PC board. That is done to allow the potentiometers some flexibility, so that when they are finally tightened against the front panel they will align properly without breaking. It would be best to attach those wires first to the solder lugs and then solder them to the board. Make sure that
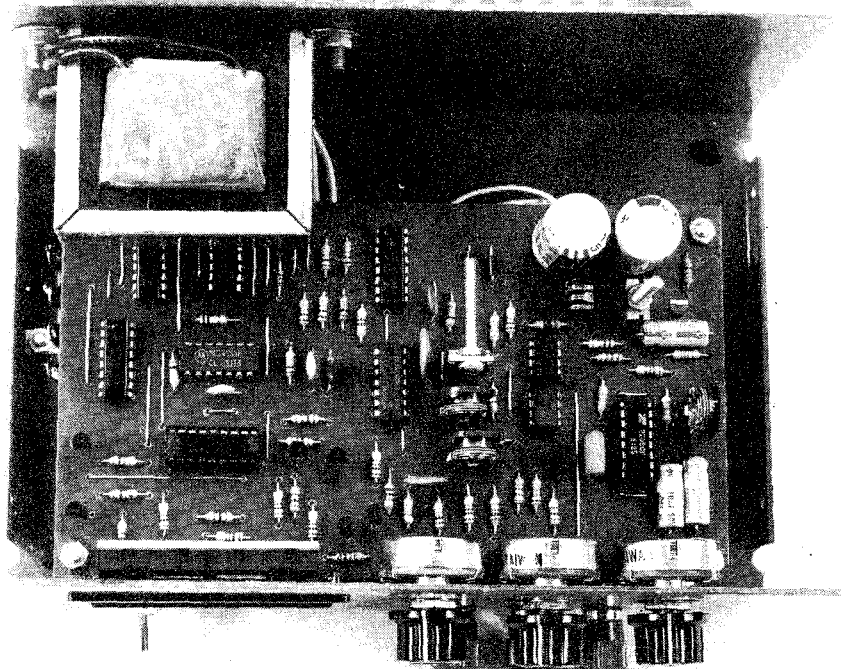
FIG. 4—THE COMPLETED BOARD is shown here mounted inside the case. Note the orientation of IC12.

ment, and the solder connections to be sure all is correct. When that has been done, it's time to "fire up" the device to test and calibrate it. Although that can be done with the PC board and transformer mounted in the cabinet, it is usually best to at least do the initial testing and calibration with the "electronics" out on the bench.

Testing and calibration

All you will need in the way of calibration equipment is an oscilloscope to check the squarewave and sinewave outputs. The frequency-limit adjustments, of course, can be made using the built-in frequency counter.

Before applying power, set all the trimmer and front-panel potentiometers to their approximate mechanical midrange. Connect the oscilloscope to the sinewave output and apply power. The oscilloscope should display a sinewave, although it may be distorted, and the frequency counter should display the frequency of the waveform. Confirm that the frequency changes as the COARSE FREQUENCY and FINE FREQUENCY controls are rotated. Set the frequency at approximately 1 kHz and adjust the DISTORTION trimmer potentiometer (R46) for a sinewave that looks normal on the oscilloscope. If you're a purist you'll need a distortion meter or spectrum analyzer for that adjustment, but for most of us, the eyeball method works well enough. Next, check the squarewave using the oscilloscope. It should look the way the name implies and have a peak-to-peak value of around five volts.

The next step is to adjust the L.F. LIMIT

and H.F. LIMIT potentiometers. Rotate the COARSE FREQUENCY and FINE FREQUENCY controls to their lowest-frequency positions (fully counter-clockwise) and adjust the L.F. LIMIT potentiometer (R45) for a frequency of 10 Hz. Then, rotate the COARSE FREQUENCY control to its highest-frequency position (fully clockwise) and adjust the H.F. LIMIT potentiometer for a frequency of 50 kHz. Check the FINE FREQUENCY control by rotating it to its extremes while observing the frequency change. It should have a total range of around 500–700 Hz, regardless of where the COARSE FREQUENCY control is set. That completes the testing and calibration procedure.

If you experience some problems, here are some troubleshooting hints that may be helpful:

As experience has shown, most problems in home-built instruments are caused by poor solder connections, solder bridges between two adjacent foils, or components installed backwards. It would be wise then to first check for those troublemakers.

If you still can't track down the problem, the use of a multimeter is required. With it, check the three major DC power-supply points at various points on the PC board with respect to the ground foil. The output side of the 12-volt regulator (IC11) should of course measure +12 volts ± .5 volt, and the output of the 5-volt regulator (IC12) should of course measure 5 volts ± .25 volts. The negative voltage bus (the negative side of C11) should measure around −17volts.

It should be noted that the voltage regulators normally operate quite hot to the

touch and the same holds true for the main four-digit counter IC. So, if the voltages are normal, don't let that be a source of concern.

If a problem exists in the frequency-counter section, some key points to check would be the 60-Hz, 10-Hz, and 1-Hz points on the time-base system and also the squarewave signal that constitutes the frequency to be counted. That latter point can be found at the input of the main four-digit counter IC9, at pin 12.   **R-E**