WIDE-RANGE AUDIO GENERATOR

A wide-spectrum source of audio signals is a necessity for much bench work. Here's one you can construct for about $30.

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AS AN ELECTRONICS TECHNICIAN, I TEST and repair a large number of oscilloscopes, recorders, amplifiers, filters, etc. This work requires the almost continual use of an audio-type signal source.

I work in a shop where I can lay my hands on a lot of sophisticated test equipment, and yet I usually reach for my Wide Range Audio Generator. Why? Because it's small, light, easy to operate, and it supplies the signals I most often need. Besides, it's good-looking and I built it myself.

Whether you're a technician, engineer, or just an electronics hobbyist, I believe you'll find that the instrument described in this article is one of the most useful pieces of equipment you could own.

For instance, note its frequency range of 10 Hz to 50,000 Hz, without any range switching—that represents a spread of 3½ decades. This feature is really great for checking the frequency response of amplifiers or filters, because with just a twist of the wrist you can sweep the whole audio spectrum and then some. A FINE FREQUENCY control is also provided to give the extra frequency resolution that is sometimes needed.

The generator can supply a sinewave signal of over 4 volts RMS into a 1000-ohm load with a distortion figure of around 1%. It can also produce a simultaneous squarewave signal that will drive the popular 5-volt TTL circuits.

Another nice feature is its DC-coupled voltage-controlled-frequency input (VCF) so you can use the instrument as a sweep-frequency generator, a step-frequency generator, or an FM-theory demonstrator.

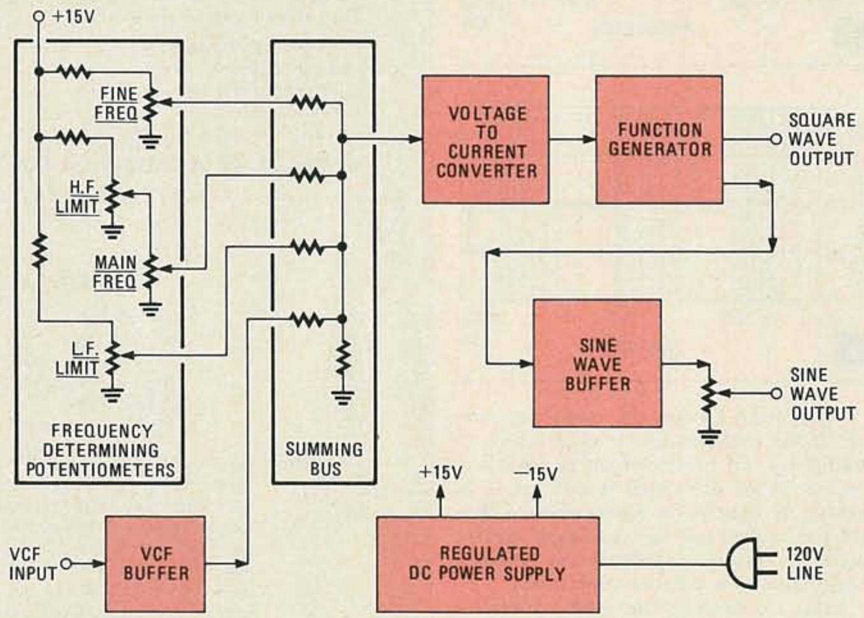


FIG. 1—BLOCK DIAGRAM of the Wide Range Audio Generator. Shaded areas indicate major components. Note, also, the frequency-determining section and suming bus.

All its input and output circuitry is fully buffered, protected and DC-coupled, which contributes to its super-flat (constant-amplitude) output over the entire frequency range (with a total variation of less than 0.25 dB).

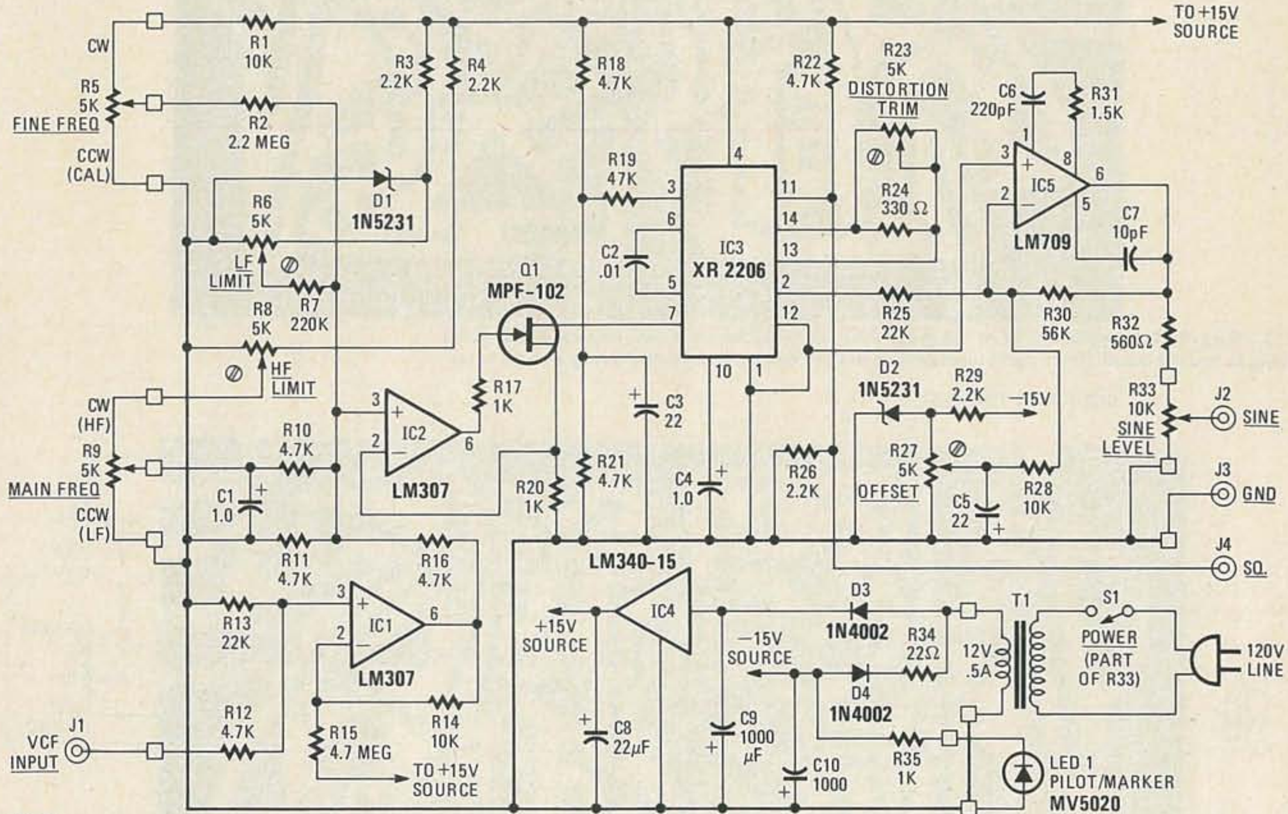
Its on-board regulated power supply ensures that its output frequency and amplitude remain constant even under adverse line-voltage conditions.

Add to all of this a 3- × 5-inch etched circuit board that contains most of the components, plus the fact that the whole instrument can be constructed for around $30—and I think you'll agree it's a fine little instrument.

How it works

Refer to the block diagram in Fig. 1 and note the following basic components:

1. The frequency-determining potentiometers and their associated trimmers for setting the upper- and lower-frequency limits.
2. The VCF input with its associated buffer stage.
3. The summing bus that receives signals from the frequency-determining potentiometers and/or the VCF stage.
4. The voltage-to-current converter.
5. The function generator.



NOTE:
IC1, 2, 5:
PIN 4 TO −15V; PIN 7 TO +15V.
CAPACITOR VALUES IN μF UNLESS OTHERWISE NOTED

FIG. 2—FULL SCHEMATIC of the Wide Range Audio Generator. Power supply appears at lower right. VCF input (J1) permits external control of output frequency.

WIDE-RANGE AUDIO GENERATOR SPECIFICATIONS

Frequency Range: (MAIN FREQUENCY control)	10 Hz—50 kHz, with no range switching
Frequency Range: (FINE FREQUENCY control)	100—200 Hz total, regardless of MAIN FREQUENCY control setting
Sinewave Output Level:	0—4 volts RMS into 1000 ohms
Sinewave Distortion:	Approximately 1% over entire frequency range
Sinewave Output Level Variation vs. Frequency Change:	Less than 0.25 dB over entire frequency range
Squarewave Output Level:	4 volts peak, positive from ground current-sink type compatible with most TTL circuits
Squarewave Rise and Falltimes:	Less than 0.5 μs
VCF (Voltage Controlled Frequency) Input:	27,000-ohm input impedance, DC-coupled, with a voltage-to-frequency relationship of 0.120 volt-per-kHz. A voltage swing of approximately 6.1 volts will sweep the frequency 3½ decades.
Size:	Approximately 5½ × 3 × 6 inches

6. The sinewave buffer stage and its associated output-level control and output terminal.
7. The regulated DC power supply.

Briefly, here's how the instrument works: The function generator produces the sinewave and squarewave signals. The sinewave signal is amplified, buffered and fed to the output control and terminal. The squarewave signal becomes attenuated and fed to its output terminal.

The frequency of these signals is controlled by the current that flows out of the frequency-control input of the function generator. This current is produced by the voltage-to-current converter, which is controlled by the summing-bus output. The summing-bus output level is controlled by signals reaching it from the frequency-determining controls and/or the VCF stage.

Let's analyze the circuit in more detail. The heart of the instrument, of course, is the XR2206 IC function generator.

Actually, two factors control its output frequency:

1. The value of the capacitor that is connected between pins 5 and 6 (in this case, 0.01 μF).

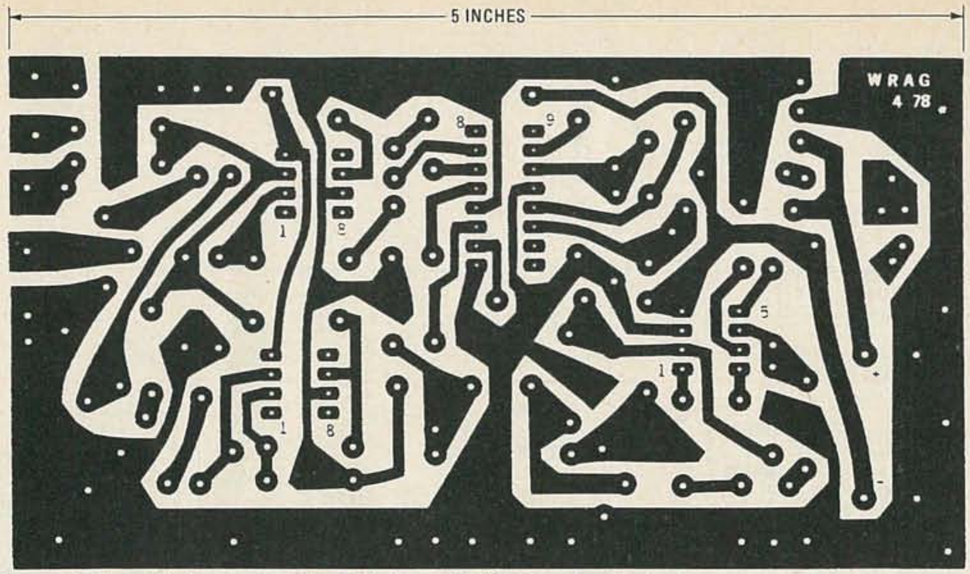


FIG. 3—FULL-SCALE reproduction of foil pattern of the Wide Range Audio Generator for those wishing to use PC board. Since parts placement is not critical, perforated board may also be used.

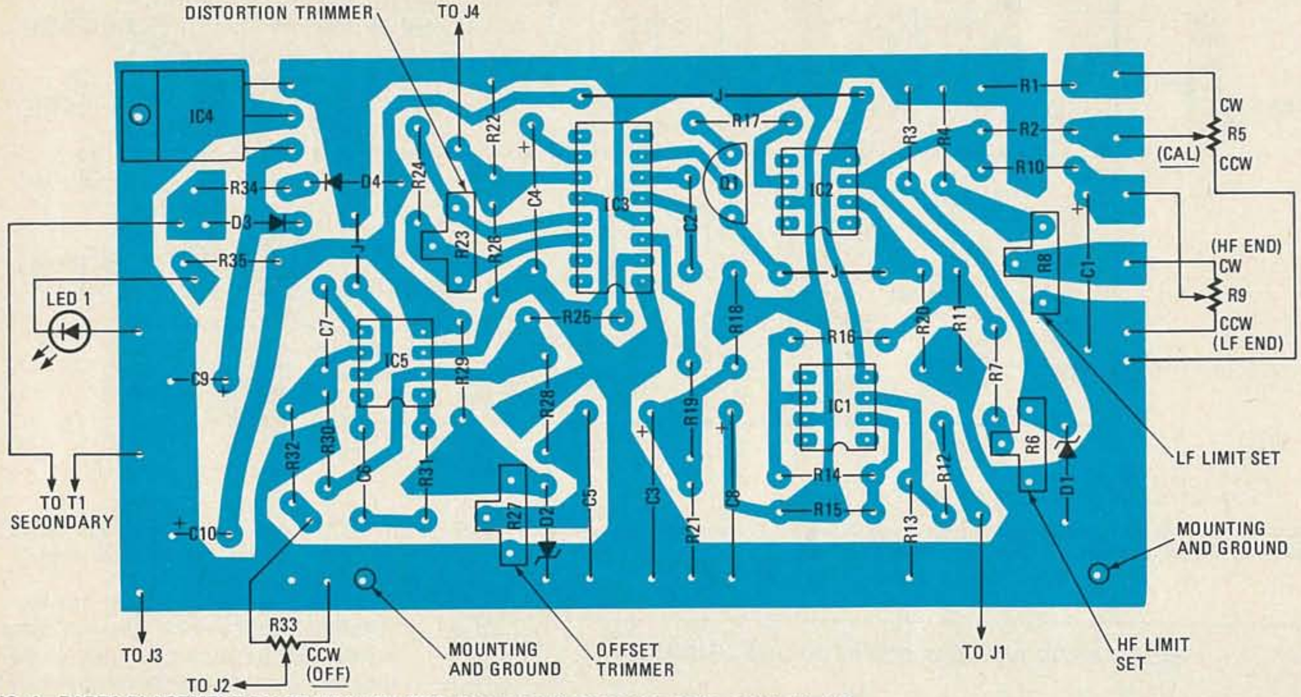


FIG. 4—PARTS PLACEMENT DIAGRAM for the Wide Range Audio Generator. Make certain that the polarities of diodes, transistors, IC's and electrolytics are observed!

2. The current that flows from its frequency-control point (pin 7) to ground.

To make the generator frequency respond to voltage instead of current, a voltage-controlled current-sink was added. It is shown as the voltage-to-current converter in Fig. 1. By referring to the schematic diagram of Fig. 2, you can identify its basic parts: op-amp IC2, R17, R20 and Q1.

The circuit design is such that the FET is inside the negative-feedback loop of the op-amp. Any current that flows out of the function generator's frequency-control point (pin 7) must also flow through the FET and the 1000-ohm resistor (R20) to ground. The positive voltage that is developed across the resistor is directly proportional to the current flowing through it. The op-amp supplies the same voltage across the resistor that it "sees" at its noninverting positive input.

This means that the current is proportional to the input voltage of the op-amp, and thus, we have a voltage-to-current converter. In this configuration, as the input voltage goes more positive, the frequency increases and vice versa. The voltage never goes negative with respect to ground.

Note the simple resistor summing bus connected to the input of the voltage-to-current converter. You can see from Fig. 2 that voltages from the frequency-control potentiometers and/or voltages from the VCF circuit will be summed and will affect the generator's frequency.

Both of the frequency-control potentiometers have positive voltage applied to their elements. The voltage applied to the MAIN FREQUENCY control is set by trimmer R8, which determines the upper frequency limit. The lower frequency limit is set by trimmer R6, which adds a small positive voltage to the summing bus when both the frequency controls are in their fully counterclockwise position. The high-resistance value of R2 in the FINE FREQUENCY control circuit limits the frequency change to around 100 Hz, regardless of where the MAIN FREQUENCY control is set. The FINE FREQUENCY control has its full counterclockwise position labeled CAL (calibrated) to make the MAIN FREQUENCY dial calibration marks applicable.

The VCF stage consists of op-amp IC1 and several associated resistors. This stage is basically a noninverting amplifier with unity gain and an intentional DC offset at its output. A voltage divider consisting of resistors R12 and R13 reduces the input signal level and also protects the op-amp. The output of this VCF stage feeds the summing bus and, of course, influences the generator frequency. The VCF input has a definite voltage-to-frequency relationship that works out to be 0.120 volts-per-kilohertz at any MAIN FREQUENCY control setting.

Now, let's look at the sinewave buffer/amplifier stage. Sinewave signals from pin 2 of the function generator are fed to the inverting (negative) input of op-amp IC5 through resistor R25. Feedback resistor R30 sets the gain of this stage at 2.5, which is adequate to produce an output of around 4.5 volts RMS (into an open-circuit load).

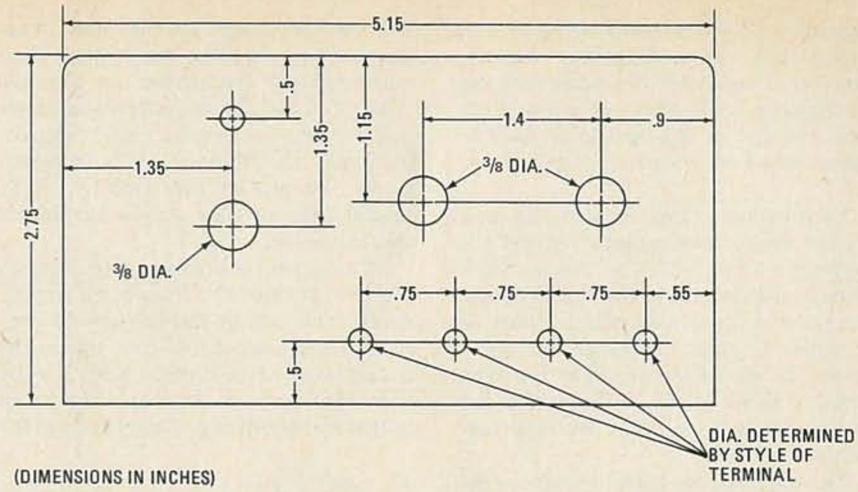


FIG. 5.—DRILLING GUIDE for location of front panel components (not drawn to scale). Use masking tape over drilling areas to avoid scratching the finished surface.

GENERATOR PARTS LIST

Resistors, ¼ or ½ watt, 5%
R1, R14, R28—10,000 ohms
R2—2.2 megohms
R3, R4, R26, R29—2200 ohms
R5, R9—5000 ohms, potentiometer, audio taper, panel mount (Radio Shack 271-1720 or equal)
R6, R8, R23, R27—5000 ohms, trimmer, PC mount
R7—220,000 ohms
R10–R12, R16, R18, R21, R22—4700 ohms
R13, R25—22,000 ohms
R15—4.7 megohms
R17, R20, R35—1000 ohms
R19—47,000 ohms
R24—330 ohms
R30—56,000 ohms
R31—1500 ohms
R32—560 ohms
R33—10,000 ohms, potentiometer, audio taper, panel mount with SPST switch (Radio Shack 271-215 or equal)

Capacitors
C1, C4—1 μF, 25 volts, electrolytic, axial leads
C2—.01 μF, 50 volts, Mylar
C3, C5, C8—22 μF, 25 volts, electrolytic, axial leads
C6—220 pF, 50 volts, Mylar or mica
C7—10 pF, 50 volts, Mylar or mica
C9, C10—1000 μF, 25 volts, electrolytic, PC leads

Semiconductors
D1, D2—1N5231 or 1N751 Zener diode, 0.1 volts, ½ watt, 25% tolerance or better
D3, D4—1N4001, rectifier diode, 50 PIV or better, 1 amp
Q1—MPF102 FET transistor (Motorola)
IC1, IC2—LM307
IC3—XR-2206 (Exar), see Market Center ads in back of magazine
IC4—LM340-15 or 7815 3-terminal voltage regulator, T-220 case
IC5—LM709
LED1—MV5020 or similar general-purpose type

Miscellaneous
T1—power transformer, 12–14 volts secondary, 500 mA
S1—part of R33
J1, J2, J4—RED insulated banana jack or 5-way binding post
J3—BLACK insulated binding post or 5-way binding post
Cabinet—Radio Shack 270-253 or equal
Knobs—2 Radio Shack 274-415 or one 274-391
IC sockets, line cord, small angle brackets, hookup wire, etc.

Trimmer R27 and its associated Zener diode, capacitor and resistor comprise a negative voltage system to null out or offset the positive DC component present at the sinewave-output point on the function generator. This adjustment is normally set so that the sinewave output of the instrument has a zero DC component.

The values of compensation capacitors C6 and C7 were chosen to give the amplifier stage a flat frequency response well beyond the 50-kHz upper limit of the instrument. Trimmer R23 provides a means of adjusting the sinewave for minimum distortion.

Note that the squarewave signal from the function generator is fed directly to its output terminal. Resistors R22 and R26 limit the peak voltage to around 4 volts, which is adequate to drive TTL circuits.

The power supply is fairly conventional, using a 12–15-volt transformer and two half-wave rectifiers to produce both positive and negative voltages. The positive voltage of around 20 is fed to a three-terminal voltage regulator (IC4) that produces a stable +15 volts. The negative voltage from the rectifier system is left unregulated, and, among other functions, it provides current for the LED pilot light.

Most of the other components we have not discussed yet are used for stability and biasing purposes.

Construction

Several construction methods are open to you. You can choose either the perforated-board, or the PC-board methods; however, the following information will, for the most part, apply to PC-board construction.

If you decide on using a PC board, you can construct your own board using the foil pattern shown in Fig. 3.

If you plan to drill the circuit-board holes, a No. 60 drill bit works well for all the holes, except for the trimmer potentiometer holes, which should be drilled with a No. 55 bit. You will also need a ⅛-inch bit for the voltage-regulator mounting hole and the two circuit-board mounting holes.

After the drilling has been completed, thoroughly burnish the copper foil with fine sandpaper or steel wool to remove any photo-resist and tarnish.

Soldering should be done with a high-grade 60/40 solder and a pencil-type soldering iron with a 35-watt/650°–700° rating.

Take special care to properly install polarized components such as diodes, transistors, IC's and electrolytic capacitors. If you carefully follow the parts-placement diagram in Fig. 4, you should have no problem.

Sockets or Molex pins are recommended for installing the IC's. The IC's can be soldered in place, but with a sacrifice in their serviceability. Jumper wires should be made of around 22-gauge, solid, tinned wire and installed on the component side of the PC board.

When all the components have been installed on the board, it is wise to make a final close inspection to confirm the parts are properly placed and the soldering is complete. The board is now ready for installation in the cabinet and for testing and adjustment.

You may want to make some preliminary tests and adjustments on the circuit board out on the bench, by temporarily wiring the transformer, potentiometers, output terminals, etc., to the board; or you may want to install all the parts into the cabinet with the board in its finished form. In either case, you should use the following testing and adjustment procedure.

Testing and adjustment

The testing and adjustment procedure

requires a VTVM or DMM along with an oscilloscope and a frequency counter; however, if you don't own a counter or an oscilloscope, we'll show you a few tricks near the end of this article on how to adjust your instrument using only a meter.

Let's assume, however, that you have all the desired equipment. Connect the meter (set to the 5–10 VAC range), oscilloscope and counter to the sinewave output point on the circuit board. Preset all trimmers to their mid-range and apply power. If the LED pilot light has been wired, it should glow, indicating that the power supply is probably working correctly.

The oscilloscope should display a sinewave (possibly distorted) that varies in frequency as the MAIN FREQUENCY control is turned. Use this control to set the frequency to around 1 kHz as indicated on the counter, and adjust distortion trimmer R23 to produce a sinewave that "looks normal" on the oscilloscope. If you're a "purist," a distortion meter will achieve this adjustment best, but eyeballing works for most of us. At this point the meter should indicate a sinewave level of around 4.5 volts that the oscilloscope will show as around 13 volts P-P.

If your oscilloscope is DC-coupled, adjust trimmer R27 for zero DC offset on the sinewave. Next, use the oscilloscope to check the squarewave, it should look symmetrical and have a peak positive amplitude of around 4 volts.

Now, turn the MAIN FREQUENCY and FINE FREQUENCY controls to their full counterclockwise position (lowest frequency), and adjust low-frequency limit trimmer R6 for a 10-Hz frequency, as shown on the counter. Then, turn the MAIN FREQUENCY control to its full clockwise position, and adjust high-frequency limit trimmer R8 for a 50-kHz frequency. Check the range of the FINE FREQUENCY control. This control should vary the frequency around 100 to 200 Hz, regardless of where you set the MAIN FREQUENCY control.

Because of interaction between the low- and high-frequency limit adjustments, it may be necessary to repeat the adjustments several times. Also, if you have trouble getting the instrument to work at 10 Hz, try interchanging IC1 with IC2. This may provide a "better" op-amp in the somewhat critical voltage-to-current-converter circuit.

Once these upper and lower frequency-limit adjustments have been made, then you can place calibration marks on the MAIN FREQUENCY control knob. It's advisable for the instrument to be in its final form for this step.

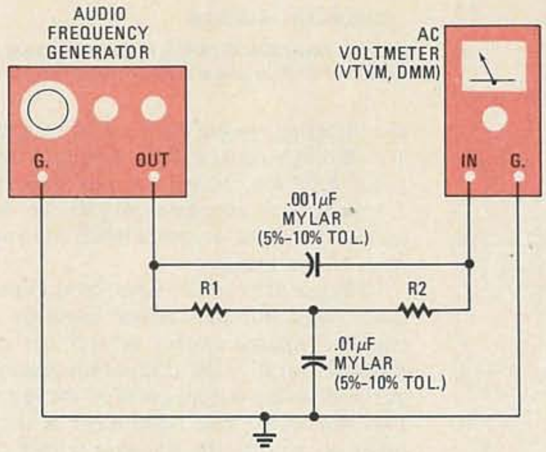
The prototype unit was calibrated using small letters and a corresponding chart to identify the various frequencies. This system works well for many applications; however, you will have to decide on how many frequency-point markings you will need or perhaps you may want to use conventional fine-line marks with their corresponding frequencies on the dial itself. You can obtain the press-on letters and numbers for this from most electronic-supply distributors or hobby-craft stores. To protect the lettering, apply several coats of clear acrylic lacquer on the front panel.

You can use the drilling guide shown in Fig. 5 to position the front-panel components. You will probably have to construct some angle brackets to mount the circuit board to the cabinet. Keep in mind that these brackets must hold the board so that its bottom edge is very close to the cabinet floor, because otherwise the top edge of the board won't allow the cabinet cover to fit properly.

Make sure to expose some bare metal on the floor of the cabinet in the area around the angle brackets so as to ground the circuit-board foil to the cabinet for shielding purposes.

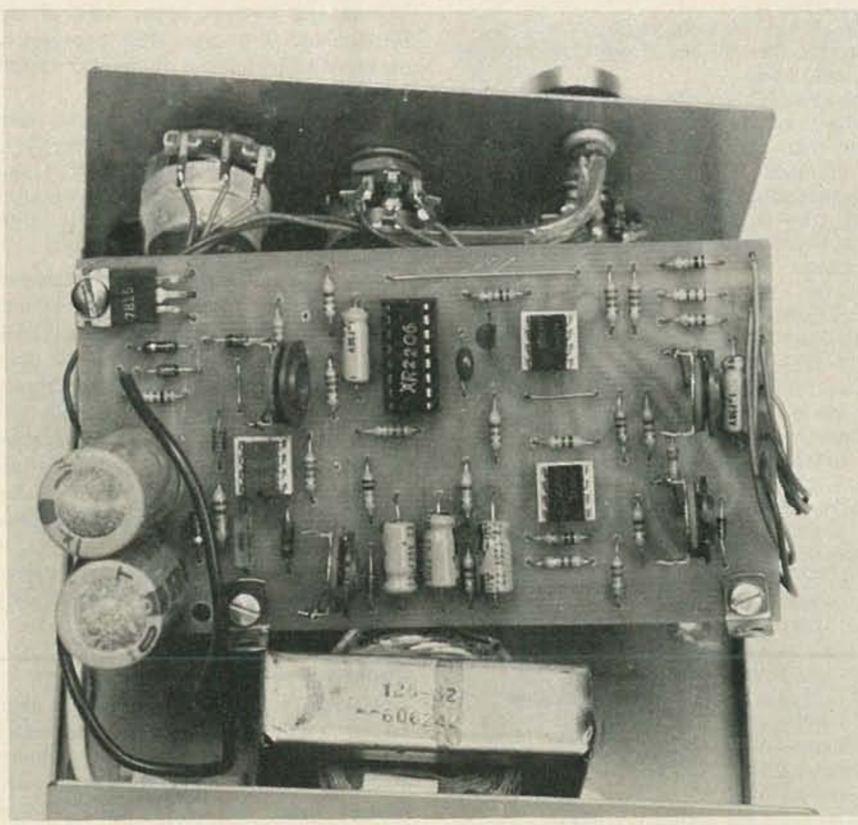
In our model, the LED pilot light/dial indicator was mounted in a small vinyl grommet and secured with glue, but you could use a standard LED mounting clip just as easily.

Although the Radio Shack cabinet (described in the Parts List) comes in attractive colors, you may want to repaint it to

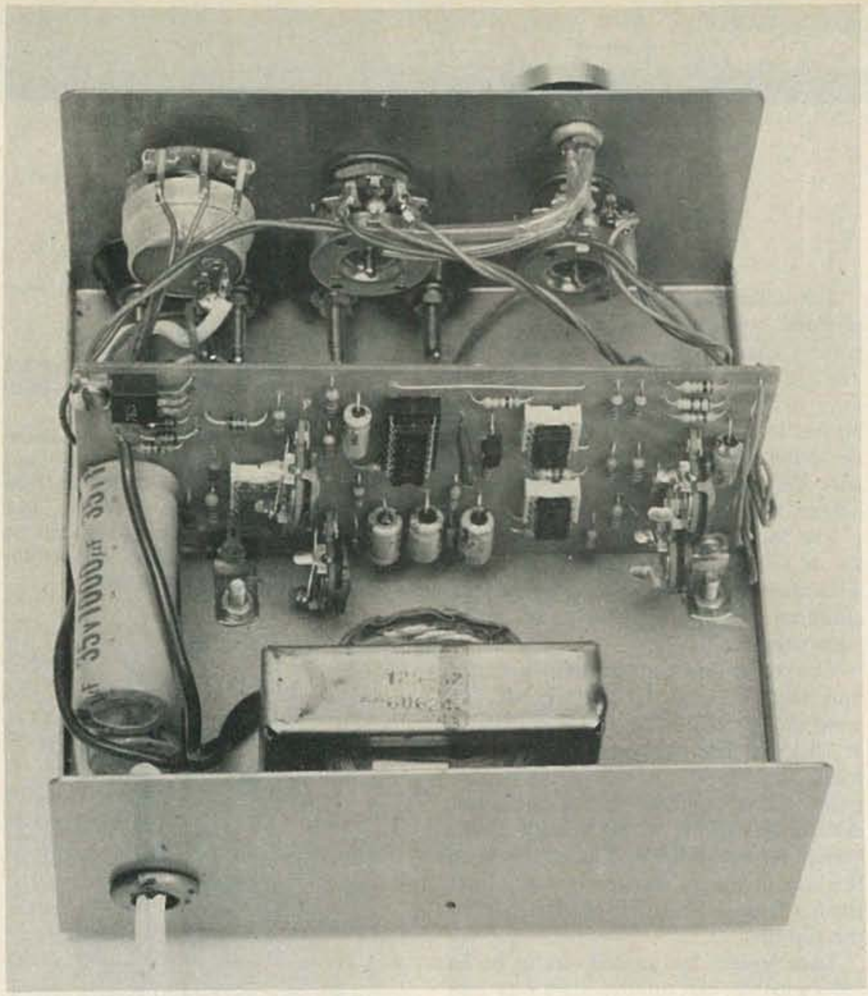


NOTCH FREQUENCY		R1	R2
10	Hz	5.1 M	5.1M
22	Hz	2.4 M	2.4 M
34	Hz	1.5 M	1.5 M
51	Hz	1 M	1 M
82	Hz	620K	620K
130	Hz	390K	390K
190	Hz	270K	270K
220	Hz	240K	240K
340	Hz	150K	150K
510	Hz	100K	100K
820	Hz	62K	62K
1300	Hz	39K	39K
1900	Hz	27K	27K
2200	Hz	24K	24K
3400	Hz	15K	15K
5100	Hz	10K	10K
8200	Hz	6.2K	6.2K
13	kHz	3.9K	3.9K
19	kHz	2.7K	2.7K
22	kHz	2.4K	2.4K
34	kHz	1.5K	1.5K
51	kHz	1K	1K

FIG. 6—DIAGRAM AND COMPONENT TABLE for use in construction of bridge network for calibrating Wide Range Audio Generator with only VTVM or DMM.



COMPLETED CIRCUIT BOARD prior to installation in cabinet. Note angle brackets at bottom of board for mounting purposes. The use of lockwashers is a good idea.



INTERIOR VIEW of fully-assembled unit showing details of point-to-point wiring. Angle brackets should contact bare metal in cabinet to assure good ground for shielding purposes. Binding posts are located just beneath front panel controls.

cover up the small nicks and scratches that usually occur during drilling. This repainting also gives the instrument a customized look, and it seems to make the press-on lettering procedure work better. A tilt-up stand was made from an old rack panel handle mounted with two angle brackets.

Calibration without a counter

As promised, here are a few ways to calibrate the frequency dial without using a frequency counter.

If you have a well-calibrated signal generator and an oscilloscope, why not try the old Lissajous-pattern method of identifying an unknown frequency by comparing it with a known frequency? To do this, simply feed the known frequency signal to the vertical or Y-input of the oscilloscope, and feed the unknown frequency signal to the horizontal or X-input of the oscilloscope; then, when the unknown signal matches the known signal, you will observe a stationary or a slowly turning circle or ellipse pattern.

If your oscilloscope is a more professional model with a triggered, calibrated timebase, you can measure the unknown frequency (f_x) by reading the period or time of one or more cycles of the waveform, and then calculating the frequency by using the formula, $f_x = 1 \div t$ where t is the time interval measured in seconds (on the scope screen) of one complete cycle.

And here is another method to use if your *only* means of calibration is a VTVM or DMM:

This method uses a simple bridged-T network that acts as a notch filter or attenuator at its known resonant frequency. By connecting it between the generator's output and the voltmeter's input (as the unknown frequency is varied), it can be identified by the definite dip or null that appears on the voltmeter as the unknown signal approaches and reaches the known resonance of the filter.

Construct the network using the diagram and frequency-determining resistor chart shown in Fig. 6. Lay it out in such a way that you can easily change the resistors, which will be necessary to change the various resonant frequencies. Use as close-tolerance components as possible. The chart shown in Fig. 6 lists the resistors needed to produce 22 useful resonant frequencies. Connect the filter as shown in Fig. 6, and you should be able to identify at least these 22 frequency points on the instrument's dial.

Useful hints

Here are a few miscellaneous hints you might find useful:

Although the Parts List calls for audio-taper-type potentiometers for the MAIN FREQUENCY, FINE FREQUENCY, and OUTPUT LEVEL controls, you can substitute linear-taper controls for at least the FINE FREQUENCY and OUTPUT LEVEL controls. The MAIN FREQUENCY control could also be a linear type, but the low-frequency end of the dial calibration would be so compressed that the marks would be difficult to read and the frequency hard to adjust.

Because most AC meters (as well as some oscilloscopes and counters) work poorly at a 10-Hz frequency, try using an LED as a frequency indicator when calibrating the MAIN FREQUENCY dial at its counterclockwise, 10-Hz end. To do this, simply connect an LED to the sinewave-output terminals and adjust the output level high enough to provide a bright illumination. With the MAIN FREQUENCY dial set to its full counterclockwise position, slowly adjust low-frequency limit trimmer R6 to the highest frequency you can comfortably count by observing the LED flicker; this frequency will be about 4–6 Hz. Then, adjust trimmer R6 to slightly increase the frequency, just to the point where the LED flickers are beyond what the eye can follow, and the frequency will be close to 10 Hz.

When you wire the LED pilot light indicator, remember that the terminal closest to the flattened edge connects to R35 on the circuit board, and the other terminal connects to ground.

You can check the squarewave output without an oscilloscope by using a DC voltmeter. If all is correct, the meter will measure about +2 volts (if the waveform is four volts peak-to-peak, the portion of the waveform measured by a DC meter will be two volts). Also, the sinewave DC offset can be adjusted by connecting the DC voltmeter to the sinewave output and setting OFFSET TRIMMER R27 for zero DC on the meter.

If you want the instrument to cover a different frequency range from that specified here, you can do this easily by simply adjusting the low-frequency and high-frequency limit trimmers. For example, you can set the frequency range for 20 Hz—20 kHz, or 50 Hz—10 kHz, or other frequencies. Changing the value of C2 allows a 3½-decade spread in a different part of the frequency spectrum; for example, if C2 is changed to 0.005 μF, the frequency can be set for 20 Hz—100 kHz; or if C2 is 0.1 μF, the frequency range will be 1 Hz—5 kHz. So, by changing either the frequency limits or the value of capacitor C2, the instrument's frequency range can be altered to suit your needs.

With these hints, you should have no trouble at all in calibrating your instrument properly. **R-E**