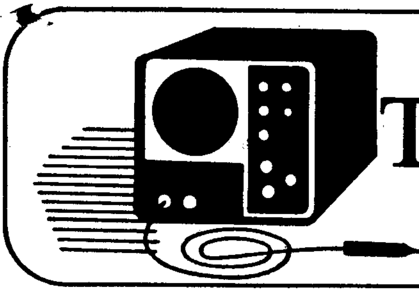

Test Equipment Scene

By Leslie Solomon, Technical Editor

Audio Generators: How They Work

A COMMON piece of test equipment on many benches is the audio signal generator. They are usually sine-wave generators, although other waveforms are also available. Let's find out how these instruments work—with an eye toward solving future test and servicing problems.

To start with, we'll consider the sine-wave devices since they are the most popular. These generators should have the following characteristics: low harmonic content, stable operating frequency, stable output amplitude, low spurious outputs (hum, noise, jitter, extraneous modulation), and good dial and range accuracy coupled with good dial and range repeatability. They should also have enough output (usually variable) to drive a broad range of loads. What about the frequency range? Well, they should cover more than the entire audio spectrum from below 20 Hz to above 30 kHz (with a maximum between 50 and 100 kHz probably a good choice).

Most of today's generators use a Wien-bridge circuit such as that shown in Fig. 1A. The network consisting of *R1C1* and *R2C2* determines the oscillation frequency. The resistors are usually made variable to "tune" the exact frequency, while the capacitors are usually switched to provide ranging. Interestingly enough, this basic circuit will not oscillate properly with only these components providing positive feedback. It is necessary to introduce a non-linear element into a negative feedback loop; in Fig. 1A, this element is *R3*. This resistance usually takes the form of an incandescent lamp whose resistance at start-up is low, permitting the circuit to start to oscillate. As more and more current flows through the lamp, its resistance increases, which increases the negative feedback and reduces the oscillation level. After a few cycles, the resistance just "balances" the circuit for best oscillation. So that little lamp in your audio generator is not an internal chassis illuminator! If the lamp should need replacement, be sure that you use an identical substitute.

The low-frequency limit of a Wien-bridge oscillator is about 1 Hz due to the thermal "speed" of the lamp, while the upper limit is determined by the amplifier and is usually about 1 MHz.

The phase-shift oscillator (Fig. 1B) uses a three-section phase-shifting RC network and an amplifier having a gain of 29. Each section of the network has 60° of phase shift at the frequency of interest thus totaling 180°. When this is added to the 180° phase shift of the amplifier (plus its gain), the circuit is primed for oscillation. Actual oscillation starts with a small disturbance in the amplifier (usually the application of power). This disturbance is amplified, shifted in phase by 180°, and applied back to the input of the amplifier where it is amplified and shifted again by 180°. This circuit is used primarily for only one frequency (whose waveform is excellent), and can be "fine tuned" by making one of the resistors variable.

Some systems (especially home-made versions) use the twin-T approach as shown in Fig. 1C. This will be recognized as a

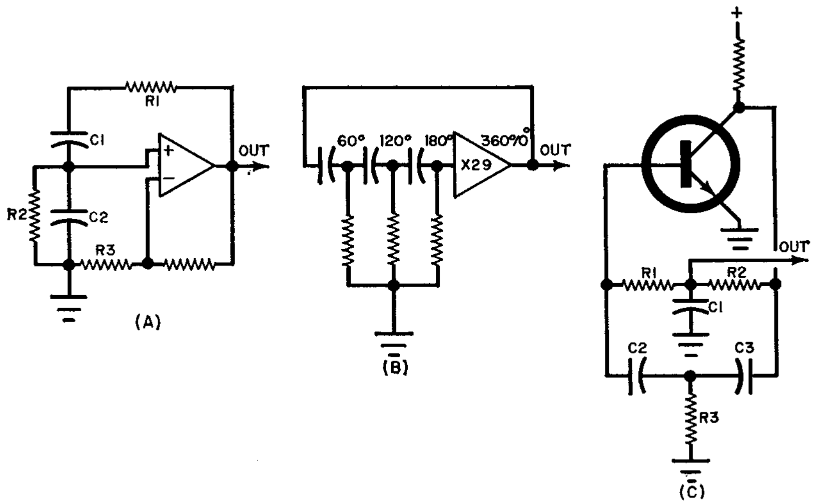

Fig. 1. Various methods of generating sine waves. The Wien bridge is shown at A; the phase-shift oscillator at B; and the twin-T configuration at C.

basic organ tone generator. In this circuit, *R1, R2,* and *C1* form a low-pass filter, while *C2, C3,* and *R3* are a high-pass filter. Since the phase shifts of these two networks are opposite, the only frequency at which the device can oscillate is where the total phase shift across the two networks is 180°. It is at this frequency that oscillation takes place. The best results occur when *C1* is about twice the capacitance of *C2* and *C3* (which have the same value) and *R3* is about one tenth the value of *R1* and *R2* (which also have the same value). The circuit is trimmed by *R3*, and the output is taken from across *C1*, where the harmonic distortion is lowest. The output of this circuit must be coupled through a high-impedance buffer to prevent loading. The transistor must have a high beta.

Synthetic Sine Waves. The synthetic sine-wave approach is used in some expensive laboratory types of generators. The theory is to create a number of small straight-line segments joined together so that the result looks like a sine wave—but with a number of tiny steps in it. The wave is thus like the top of a picket fence whose tips have been cut to resemble a sine wave. Obviously, the more segments, the better the approximation to the desired waveform.

The circuit in Fig. 2 illustrates the use of 12 diodes and associated resistors to synthesize a sine wave from a triangle wave to within 0.25% rms error. Why a triangle wave? Because this is an easy waveform to produce with op amps—which are now being used extensively in test equipment.

The 12 diodes are arranged in pairs and connected to a bias network as shown. The input triangle waveform is applied to the common junction of each pair. The network consisting of *R1A* through *R7A* biases the upper row of diodes (with respect to the reference output) in a voltage progression that represents the *positive* peaks of each

Fig. 2. This diode circuit synthesizes a sine wave from a triangle wave. The bias arrangement determines at which point in the triangle each of the diodes comes in.