A Wide Range Audio Sweep Oscillator

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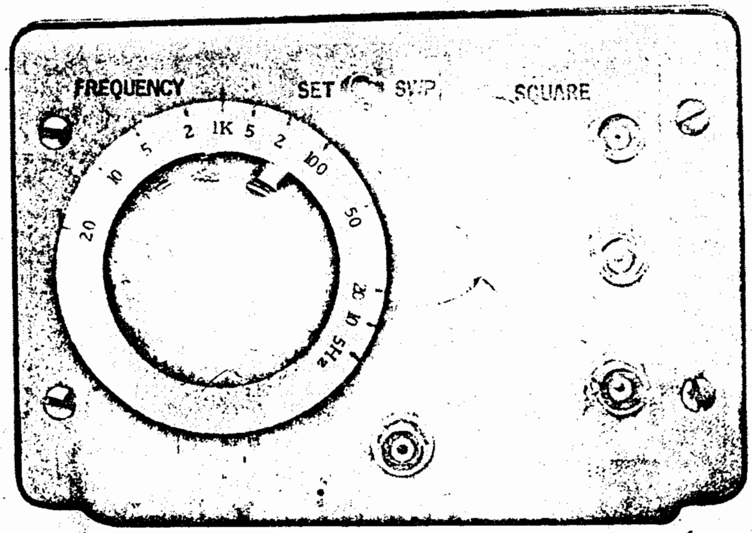
A USEFUL piece of test equipment for acoustical and electronic work is a sinewave generator capable of automatically performing a sweep of the entire audio spectrum. Such a sweep oscillator will reveal resonances and standing waves more quickly than the method of hand plotting data point-by-point: one need only listen for intensity peaks or watch a voltmeter needle to pinpoint frequency response problems. If a chart recorder is available, frequency response curves can be plotted automatically. The conventional Wien bridge oscillator, although capable of producing sine waves with very low distortion, does not maintain a precisely constant amplitude when swept, nor is its frequency electronically variable. The usual function generator circuits [1] provide accurate control of amplitude and frequency, but lack sufficient frequency range to span the entire audio spectrum without switching. This article will describe a simple sweep oscillator, suited for home (or laboratory!) construction, which will permit rapid testing and measurement of amplifiers, loudspeakers, and room acoustics.



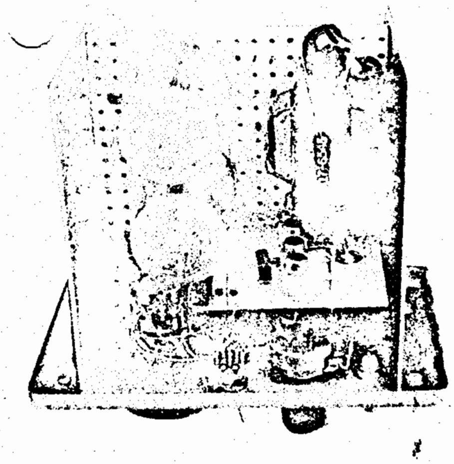
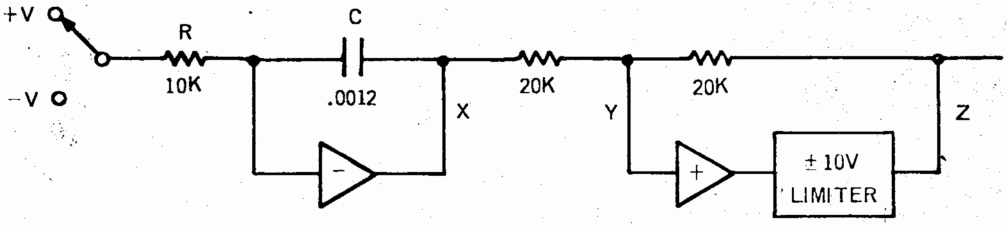


Fig. 1—Basic triangle generator circuit. The switch at left is controlled by the limiter. Triangle waves are available at point X and square waves at point Z.



The circuit to be described is based on the triangle wave generator shown in Fig. 1. In this circuit, two integrated-circuit operational amplifiers are cascaded. One of these has negative feedback applied to it by way of the capacitor C; it is an integrator whose input is either +V or -V depending upon the position of the switch. The other operational amplifier is supplied with positive feedback and functions as a sensitive voltage detector: when its input (point Y) becomes even a fraction of a millivolt negative, its output switches rapidly from the positive supply voltage to the negative supply voltage, and the limiter swings from +10 volts to -10 volts. To complete the feedback loop we stipulate that when the limiter output is positive, the switch will contact the +V input, and conversely a negative limiter output will cause the switch to move to the -V position. To follow its operation, suppose that point Y is indeed positive and Z is at +10 volts. A positive current flows into the integrator through resistor R, and voltage X moves negatively at a rate dX/dt = -V/RC. When X reaches -10 volts, Y reaches zero, whereupon the second amplifier, the limiter, and the switch change state. Since this reverses the drive to the integrator, point X now moves positively at a rate dX/dt = +V/RC. This state persists until X reaches +10 volts, where again Y = 0 and a new cycle begins. The resulting triangle wave at point X has an amplitude of 20 volts peak to peak and a frequency f = V/40RC; for the values shown in the figure, f = 2 kHz × V. The wide frequency range of this oscillator is made possible by the extreme voltage accuracy of modern IC operational amplifiers: an error of 1 millivolt is seen with this formula to correspond to a frequency uncertainty of 2 Hz. At the same time a full scale control voltage

(V = 10 volts) corresponds to a maximum frequency of 20 kHz. The ratio of these frequencies, about 10000 : 1, illustrates the wide dynamic range of the basic triangle generator circuit.

This generator is then a linear voltage-to-frequency converter whose output is a fixed amplitude triangle wave. The complete design shown in Fig. 2 consists of this converter plus the additional circuitry needed to define the control voltage ± V, to perform rapid and accurate electronic switching of the integrator's input, to accurately limit the feedback voltage for amplifier A4, and to convert the triangle wave into an approximately sinusoidal waveform.

The frequency control voltage is initially established by the dual cascaded potentiometer VR1, when the frequency mode switch is in the position marked SET. The zener diode across VR1 permits good voltage stability at this point in spite of possible power supply variations. Both sections of VR1 should have an audio taper to spread out the first 0.1 volt (200 Hz) over the first 50% of dial rotation. A large dial is desirable for VR1 to permit accurate frequency calibration and easy reading. Amplifier A1 isolates the integrator load current from the potentiometer circuit. Amplifier A2 is connected as a unity gain inverter to generate the required negative voltage -V. Note that the large value capacitor C1 is held charged at +V by the potentiometer circuit as long as the mode switch remains in the SET position. When switched to the SWEEP position C1 is slowly discharged towards ground through the 100K resistor R1. This

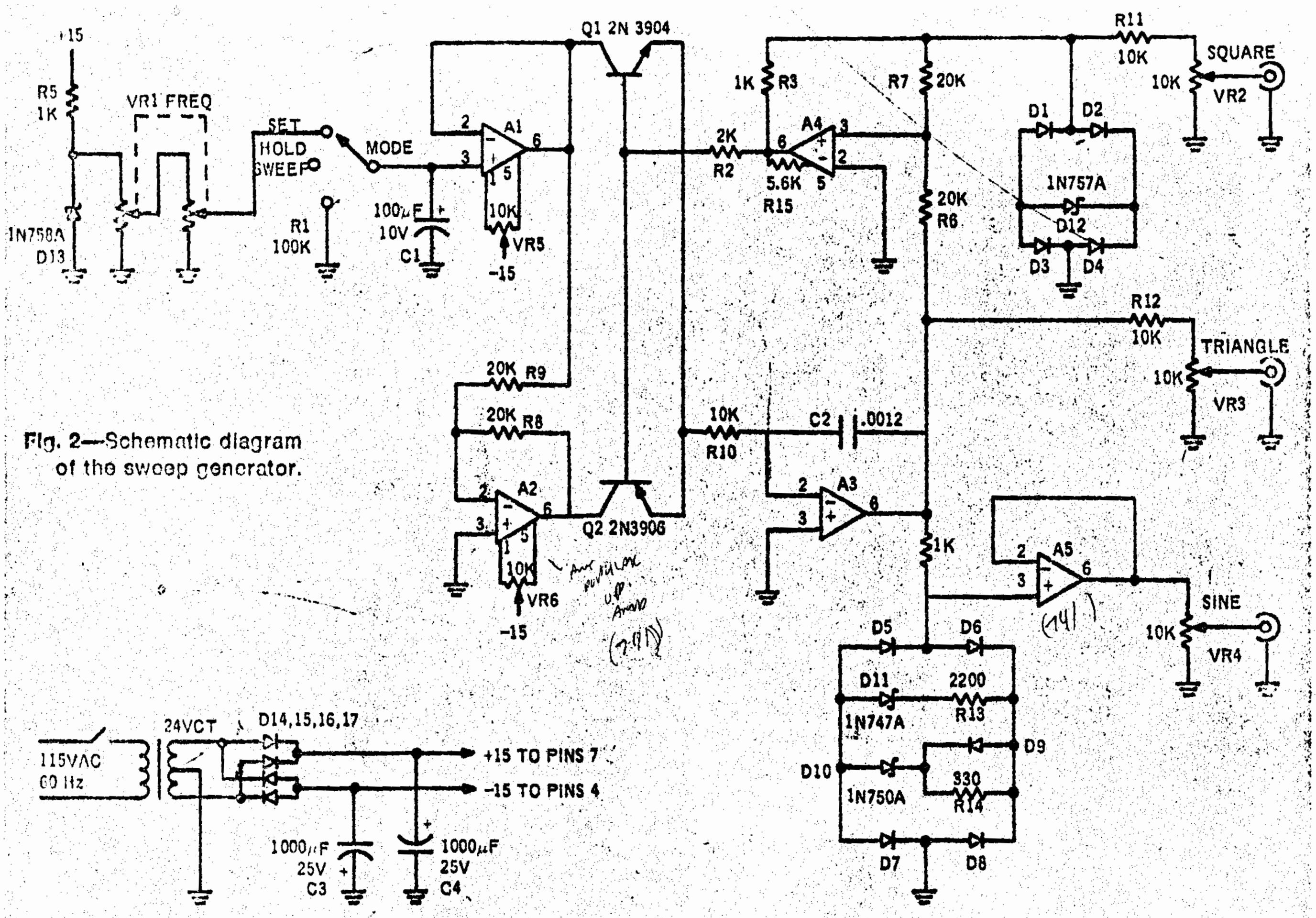
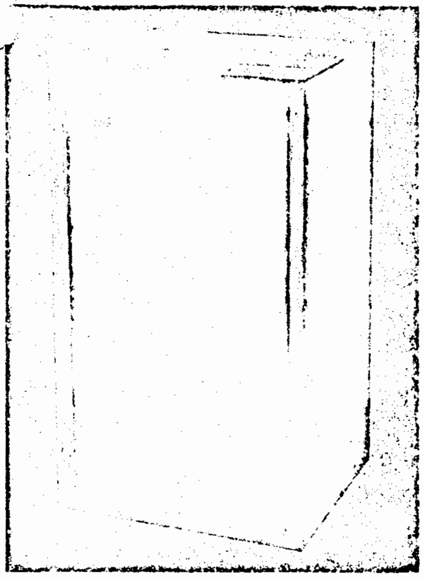


Fig. 2—Schematic diagram of the sweep generator.

discharge will be accurately exponential if C1 is free of leakage and dielectric nonlinearity (a high quality solid tantalum type is recommended). The values shown give a factor of two decay in voltage in 7 seconds, which corresponds to a frequency sweep rate of 7 seconds per octave or 23 seconds per decade. The network can of course be easily modified for other sweep rates. At any point, the sweep can be interrupted by moving the mode switch to the HOLD position; this feature is useful for sitting on a resonance identified during a sweep.

In order to achieve an exponential frequency sweep accurate down to a few Hz, the voltage sweep must be accurately exponential down to a few millivolts, both at the +V and the -V points. For this reason both amplifiers A1 and A2 are shown connected to the optional and otherwise unnecessary trimmer potentiometers. The trimmer VR5 at A1 should be set for an end-of-sweep frequency of about 1 Hz. The trimmer VR6 at A2 should be set for best triangle wave symmetry at frequencies below 10 Hz. These adjustments will interact somewhat, but need be made only once for a given pair of amplifiers. They should be set before the frequency dial at VR1 is calibrated since they do slightly affect the low end frequency calibration. For A1 a low bias current op amp is clearly desirable owing to the rather high impedance of the sweep network; the Motorola MC1456CG is recommended. For A2 any popular op amp will serve.

Transistors Q1 and Q2 form a pair of saturating switches employed in the inverted (common collector) configuration. Used in this way, they permit d.c. offset errors less than one millivolt to be achieved, as opposed to the 10 to 100 millivolts typical of the normal (common emitter) configuration.



The triangle wave generator consisting of A3 and A4 operates just as described previously. An important consideration in choosing an IC type for use as A3 is slew rate, i.e. the maximum speed with which A3's output voltage must change. For a 20 kHz, 20 volt p-p triangle wave, a slew rate of 0.8 volt/microsecond is required. This is well within the capabilities of the MC1456CG which will typically slew at rates as fast as 2.5 volt/microsecond. Although this same op amp type could also have been used for A4, better switching performance is obtained from an uncompensated IC such as the MC1439G. Its feedback voltage is symmetrically limited to ±10 volts by the 1N757A zener diode and associated rectifier bridge.

The triangle wave generated by this oscillator is converted into an approximately sinusoidal waveform by the nonlinear attenuator made up of the 1N747A and 1N750A zener diodes and their associated components. As the triangle wave rises past 4 volts, the 1N747A conducts through R13, which diminishes the rate of rise of the network's output voltage. Above 5.5 volts, the 1N750A conducts through R14, which of course introduces further attenuation. Just beyond 6 volts the 1N750A directly clamps the waveform by way of the diode shunting R14. This nonlinear attenuation technique gives rather nicely rounded sine waves rather than sharp cornered polygons due to the gradual onset of conduction in low voltage zener diodes. Zeners are normally manufactured with a ±5% tolerance, and it may prove necessary to trim the circuit to achieve minimum

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Fig. 3—Three simultaneous waveforms at 500 Hz, 1 volt/div. vertical, 1 millisecond/div. horizontal. Square-wave rise time is 0.2 µ sec.

Parts List

Controls	
VR1	Dual pot., audio taper, 10k + 10k
VR2,VR3, VR4	Audio taper, 10k
VR5,VR6	Trimpots, 10k linear
Resistors	
R1	100k, ½ watt
R2,R3, R4,R5	1000 ohms, ½ watt
R6,R7, R8,R9	20k ohms, ½ watt
R10,R11, R12	10k ohms, ½ watt
R13	2200 ohms, ½ watt
R14	330 ohms, ½ watt
R15	5.6k ohms, ½ watt
Capacitors	
C1	100 µF, 10 V, Tantalum, Sprague
C2	.0012 µF
C3,C4	1000 µF, 25 V

Diodes	
D1,D2,D3, D4,D5,D6, D7,D8,D9	1N914A
D10 Zener	1N750A
D11 Zenier	1N747A
D12 Zenier	1N757A
D13	1N758A
D14,D15, D16,D17	Silicon rectifiers, 100 P.I.V.
Transformer	
115 V, 60 Hz,	24 V CT output (Triad F-45X)
Op Amps	
A1,A2,A3,A5	MC1456CG
A4	MC1439G
Transistors	
Q1	2N3904
Q2	2N3906
Miscellaneous	
One 3-position, single-pole switch	
Three sockets	

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total harmonic distortion for applications where this is important. An oscilloscope is useful here. The essential requirement is to have the peak clipping voltage of the nonlinear network (measured with R13 and R14 disconnected) equal to 64% of the peak triangle voltage (measured ahead of the 1K attenuator resistor). If it is not, the triangle itself must be adjusted in amplitude at R6. With this set, acceptable waves will be generated with a total harmonic distortion (THD) of about 1%. Further improvement in the THD can be achieved by trimming R13 and R14 for minimum THD as read on a distortion meter; in this way a distortion of 0.7 to 0.8% can be reached. Although this is inadequate for amplifier THD measurements, the waveform is sufficiently sinusoidal for intermodulation and frequency response measurements, particularly when the extreme amplitude stability of the waveform is taken into account.

The remaining circuit details are given in Fig. 2. Separate level controls and outputs are shown for the square wave and the triangle wave inherently produced by the oscillator. These are useful for transient testing and risetime measurements, and for checking the linearity of wideband amplifiers. The simultaneous output feature is desirable for such tasks as oscilloscope triggering and frequency counting while making low level sinewave amplifier measurements. The required ± 15 volt d.c. power is obtained from a conventional unregulated transformer rectifier supply.

Many modifications and adaptations of this design are possible. For example, the oscillator's frequency range may be compressed to 1 kHz or extended to 50 kHz by the simple expedient of substituting a different integrating capacitor. Another possible use for this circuit (which is, in essence, a highly linear voltage-to-frequency converter) is to permit digital voltage measurements to be made with an ordinary frequency counter. The unknown 0 to +10 volt d.c. signal is applied to A1's input, and the resulting oscillator frequency is digitally counted. Larger input signals can be accommodated with an attenuator. In conclusion, the present design is an inexpensive and versatile instrument which can simplify many kinds of audio measurements. Æ

Reference

1. Norman Crowhurst, "The Function Generator," AUDIO, Vol. 54, No. 11, Nov., 1970, p. 22.

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