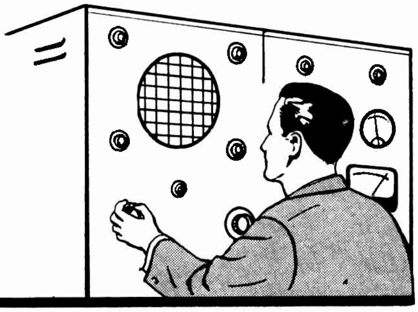
AEROVOX RESEARCH WORKER



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Audio Frequency - Measuring Requirements

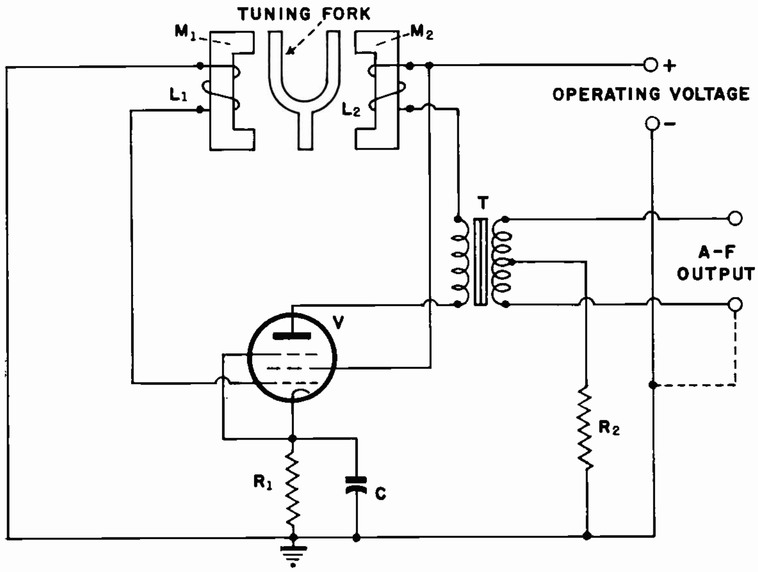
Part 1

By the Engineering Department, Aerovox Corporation

A great deal of space has been devoted in the engineering literature to precision measurement of radio frequencies. This is true also in semi-technical literature. Even the neophyte soon becomes conversant with such topics as frequency standards, frequency meters, standard-frequency broacasts, and zero-beat and interpolation methods.

The picture seems somewhat different with respect to audio frequencies. Some students have a vague impression that audio frequencies somehow are generated with such precision and remain so stable that they seldom need measurement, or that precision is not needed in the a-f spectrum. While the latter may be true in some examples such as the generation of simple tone signals, there are countless instances in which audio frequencies must be known and maintained with high accuracy. The success of many electrical measurements performed with an a-f tester signal depends upon close knowledge of the frequency.

Since radio frequency standards seem to be much more generally familiar than those for audio frequencies, it is well at this point to examine the configuration and characteristics of several audio frequency standards.



FORK-TYPE AUDIO FREQUENCY STANDARD.

FIGURE 1

AUDIO FREQUENCY STANDARDS

Several types of instruments are available as audio frequency standards. As is true of radio frequency standards, these instruments provide different degrees of accuracy, and the selection depends upon individual demands. Unlike most radio frequency standards, the demand for purity of waveform generally is greater in audio frequency standards. The chief reason for this is that fundamental audio frequencies usually are employed in standardization, while a radio frequency standard is called upon to supply a great number of harmonics.

Fork-Type. This is an electromechanical instrument having as its basis for the tuning fork. The frequency is governed by the physical dimensions of the fork, and the frequency stability with respect to temperature depends upon the temperature coefficient of the metal from which the fork is made. Stability is improved by operating the fork inside a constant-temperature oven.

The tuning fork is employed as the frequency-determining element of an electronic oscillator. Figure 1 shows a typical circuit. Here, the tuning fork ground precisely to vibrate at a specified frequency is mounted rigidly between two magnet pole pieces, M_1 and M_2. Each pole piece is surrounded by a field winding (L_1 and L_2, respectively). Coil L_1 is connected in the grid circuit of Vacuum Tube V, and Coil L_2 in the plate circuit. Since these coils are phased for positive feedback, a simple tickler-type oscillator circuit is produced. This circuit maintains the fork in vibration at its natural frequency. Audio-frequency output is taken from the plate circuit through the coupling transformer, T.

Supply voltages to the oscillator are regulated. Particular care is taken to minimize power supply hum in the system. The feedback level is set, by properly proportioning the inductance ratio of L_1 and L_2 and the coupling in the feedback loop, to minimize distortion. The entire oscillator, or at least the fork and magnet assembly, is placed within a constant-temperature oven. These measures maintain purity of waveform and minimize frequency drift.

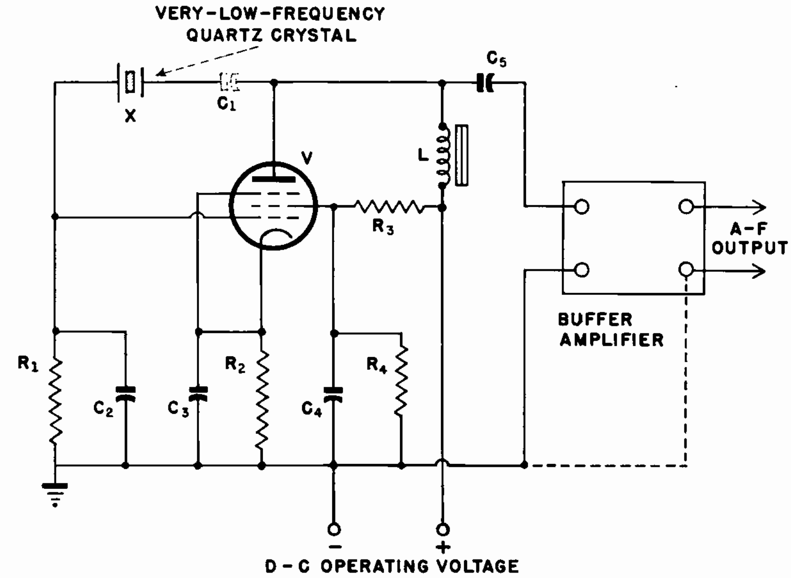
Commercial, vacuum-tube driven forks similar to this arrangement usually are supplied for 400—, 500—, or 1000—cycle operation but other frequencies are available. Depending upon type and model, accuracy of the order of 0.05% is obtainable at room temperature (25°C), and up to 0.001% or better with close temperature control. Thus, frequency is maintained as closely as 1 part in 10,000 without temperature control, and 1 part in 100,000 with temperature control. In a typical oven-controlled model, the temperature coefficient of frequency is —0.008% per °F, and the frequency is independent of output loading. Depending upon model, the output power into a matched load varies from approximately 1.5 to 50 milliwatts.

Fork-type frequency standards are provided for both battery and a-c power line operation and in transistorized as well as tube types.

Reed-Type. In a similar system, the tuning fork is replaced with a ferrous-metal reed which vibrates between the pole pieces. The natural frequency of the reed is dependent upon the length, width, and thickness of the latter and to some extent upon the metal used. A number of single audio frequencies are provided by commercial oscillators of various types.

The reed-type oscillator is somewhat inferior in most specifications to the fork-type. However, when temperature controlled and operated from a voltage-regulated d-c power supply, it is satisfactory for use as an a-f frequency standard in applications which do not require the higher accuracy of the fork.

Crystal-Type. While not so generally known, quartz crystals are commercially available at low frequencies. One manufacturer, for example, offers mounted crystals for frequencies as low as 3000 cycles per second. 10- and 20-kc types are available in many models. When these crystals are temperature-controlled any enclosure in constant-temperature ovens, high stability and accuracy are obtained.



CRYSTAL-OSCILLATOR TYPE STANDARD.

FIGURE 2

The techniques of using a quartz crystal to control the frequency of an audio oscillator are similar to the common methods of crystal-controlling a radio-frequency oscillator. Some difficulty is to be expected, however, in obtaining highest operating efficiency with conventional grid — or plate-tuned circuits because of the reduced possibility of obtaining high-Q inductors at audio frequencies. The simplest application would be the "untuned" Pierce-type oscillator, such as shown in Figure 2. Here, the oscillator frequency is set by the very-low-frequency crystal, X, connected directly between the plate and grid of Pentode Tube V. The blocking capacitator, C_1, may be required to protect a particular crystal from d-c polarization. The oscillator is followed with a buffer-amplifier, comprised by one or two pentode stages, to isolate the Pierce circuit from output-load variations.

Low-frequency crystals are, in general, less active than the more conventional r-f types. Their vibration amplitude usually must be kept lower than that of the r-f types, in order to prevent breakage. For this reason, the d-c plate and screen voltages of the oscillator tube usually are lower than conventional.

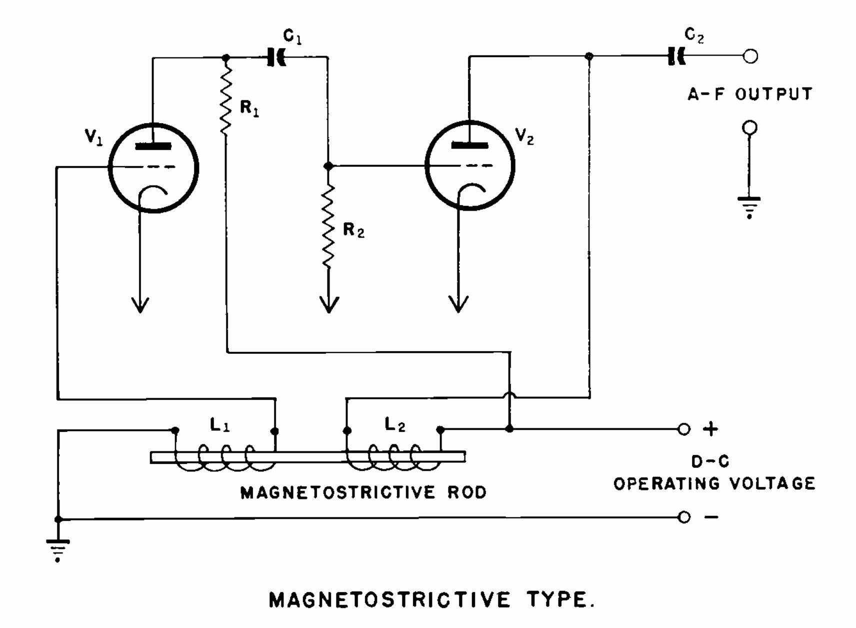
The temperature coefficient of frequency of the very-low-frequency quartz crystal varies with type and model but can be of the order of 30 parts per million per °C. Thus, at audio frequencies high stability is to be expected when the crystal temperature is oven-controlled.

Magnetostriction-Type. Although the magnetostriction oscillator is not widely used in the United States nor readily available here commercially, its use as an audio frequency standard merits review.

The control element in this type of oscillator is a nickel-alloy rod. Certain nickel alloys have the property of magnetostriction; that is, longitudinal vibration when exposed to an alternating magnetic field. A magnetically-polarized rod of this kind will vibrate at the frequency of an applied field. The natural frequency of the magnetostrictive rod is $v/2l$, where v is the velocity of sound in the rod and l the length of the rod.

Figure 3 shows one type of circuit in which a magnetostrictive rod (supported at its center) is used to control the frequency of oscillation. In principle, this circuit is seen to resemble Figure 1 with the rod replacing the fork. Positive feedback is supplied by inductive coupling through the frequency-control circuit comprised by Grid Coil L_1, Plate Coil L_2, and the rod. Audio-frequency output, transmitted through Capacitor C_2, usually is presented to the high-impedance input of a buffer-amplifier stage inserted to isolate the oscillator from the effects of load variations.

In the absence of temperature control, conventional magnetostriction oscillators operating at 1000 cps or higher provide frequency stability of the order of three parts per million per °C. Close oven control of



MAGNETOSTRICTIVE TYPE.

FIGURE 3

the temperature of the rod and feedback coils improve this stability.

The conventional magnetostriction oscillator is somewhat bulkier in size than comparable fork reed, or crystal-controlled oscillators.

Crystal Oscillator-Multivibrator Type. The conventional frequency standard employed for r-f standardization can supply highly-precise audio frequencies as well. Both primary and secondary radio frequency standards are adaptable to this service. The accuracy of laboratory-type primary and secondary frequency standards (such as General Radio Types 1100-AP and 1100-AQ, respectively) is 0.5 part in 100 million per year. Frequency stability during short intervals, such as during measurement periods, is such that frequency fluctuations are less than 1 part in one billion. The high precision of the instruments is due to a combination of factors such as low-drift quartz crystals, close control of temperature, and close regulation of operating voltages. The precision of service-type secondary frequency standards is much lower, 5 to 50 parts per million per °C being typical in the absence of temperature control and voltage regulation.

A frequency standard consists of a crystal-controlled oscillator (usually operated at 50, 100, or 1000 kc) which, in turn, controls several lower-frequency multivibrators. Standard audio frequencies (such as 10 kc, 1 kc, 100 cps, 50 cps) are derived from the multivibrators and have the same accuracy as the controlling oscillator. The oscillator is periodically standardized by setting it to zero beat with WWV transmissions. If the unit is a primary standard, it may be calibrated by comparing its frequency (as referred to operation of an electric clock from one of the low-frequency multivibrators) to standard time. The waveform of the a-f signal voltages is purified through the use of suitable output filters.

The block diagram in Figure 4 shows the arrangement of a frequency standard. In this setup, a precise 100-kc crystal controlled oscillator is at the basis of the system. The oscillator is followed by multivibrators operated at 10, 1, 0.1, and 0.05 kc and synchronized with the oscillator. Each multivibrator and the oscillator are provided with output amplifiers for isolation. Audio-frequency outputs are derived from the multivibrators, at 10,000, 1000, 100, and 50 cps, respectively, through bandpass filters which purify the waveform of these signals. Other frequencies are obtainable by changing the multivibrator operating frequencies. However, the frequencies specified in Figure 4 will permit standardization and frequency measurement throughout the audio spectrum and much of the supersonic range as well.

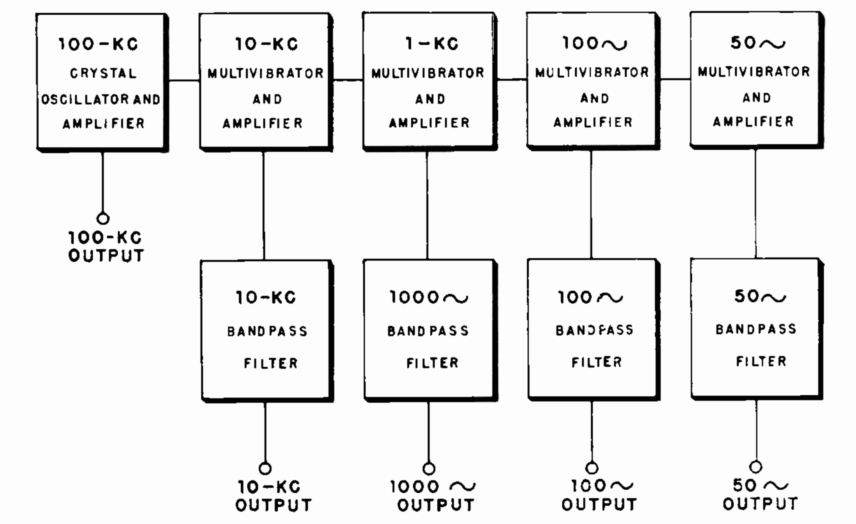
When the waveform of the audio signal is unimportant in a particular application, a-f output may be taken directly from the multivibrator stage and the corresponding bandpass filter may be dispensed with.

Use of BuStan Signals as Audio Frequency Standard. The standard frequency signals broadcast from Stations WWV and WWVH of the National Bureau of Standards are amplitude modulated during specific intervals at 440 and 600 cps, both sinusoidal.

These two audio frequencies are highly accurate and, when obtained from a distortion-free audio channel of a non-oscillating radio receiver tuned to WWV or WWVH, may be used as audio frequency standards.

The carriers are modulated during the first four minutes of each five-minute interval, starting on the hour. During the first four-minute period, the audio frequency is 600 cps; and during the second four-minute period, it is 440 cps. The two modulation frequencies are alternated in this manner each five minutes throughout the hour.

Transmissions from WWV are on 2.5, 5, 10, 15, 20, and 25 Mc. Those from WWVH are on 5, 10, and 15 Mc.



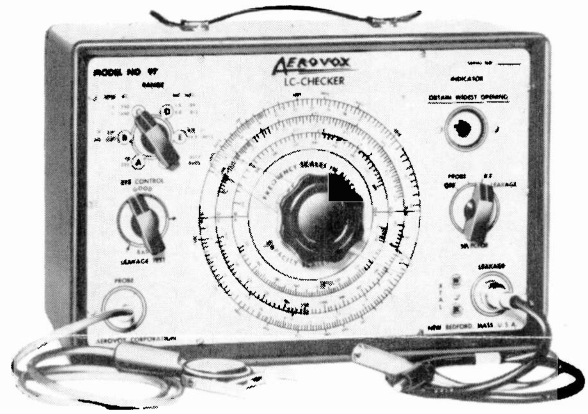
SETUP OF FREQUENCY STANDARD.

FIGURE 4

AEROVOX MODEL 97 L-C CHECKER

DESIGN FEATURES

- Capacitance range of 200 mmfd. to 3.5 mfd. in five overlapping ranges.
- Frequency range of 75 kc. to 44 mc. in six overlapping ranges.
- Voltage regulated power supply for extreme stability.
- Plug-in socket for use of crystals as precise frequency controls.
- Filament transformer reduces stray AC fields for maximum accuracy.
- Case and chassis isolated from AC line through a .01 mfd. capacitor.
- Vernier tuning and magnifying pointer insure accurate settings without backlash.
- Large easy to read calibrated dial has capacity scale indicated in red and frequency scale indicated in black.
- Adjustable probe to accommodate capacitors of different sizes.
- Rugged all-metal case with recessed front panel, carrying handle and line cord storage bracket.
- Top quality hardware for trouble-free performance.
- Low power consumption.
- This instrument will check capacitance in circuit without disconnecting either lead, regardless of the resistance value in parallel with the capacitor under test. This check will give an indication of relative "Q" and effectiveness of capacitor near its critical frequency.



AEROVOX MODEL 97
L-C CHECKER

The Aerovox Model 97 L-C Checker is designed to afford the operator extreme versatility in use, and incorporates the latest printed circuit techniques to ensure maximum efficiency and stability in operation.

The L-C Checker circuit consists of a highly stable modified Hartley type oscillator. A 6E5 tuning eye tube is connected to the oscillator circuit in such a manner as to give very sensitive indication of slight variations in oscillator loading, and special circuit refinements greatly increase the versatility of this instrument. Listed below are some of the many functions the L-C Checker will perform:

1. **Measure capacitance and relative "Q" of capacitors in circuit.**
2. **Indicates capacitor insulation resistance.**
3. **Align r-f and i-f circuits.**
4. **Check super-het oscillator tracking with set "hot-or-cold."**
5. **Align i-f channels in FM receivers and independent alignment of i-f transformers.**
6. **Determine resonant absorption points.**
7. **Locate resonant points in unused portions of coil assemblies in multi-range oscillators.**
8. **Align video and sound i-f systems in TV sets.**
9. **Precise alignment of 4.5 mc inter-carrier sound i-f channels.**
10. **Determine natural resonant points of r-f chokes.**
11. **Determine natural period of antennas and transmission lines.**
12. **Measure fundamental crystal frequencies and operation at harmonic levels.**
13. **Measure transmitter buffer, amplifier and tank circuits for parasitic current loops with power off or on.**
14. **Measure correct wave-trap and filter tuning.**
15. **With a standard plug-in crystal, can be use as an accurate signal generator for signal substitution and precise signal sources.**
16. **Measures inductance.**

Weight: 6½ lbs.

Dimensions: 13" x 8½" x 6"

Power Consumption: 30 watts at 115 volts AC, 60 cps.

Tube Complement: 1 — 6C4, 1 — 6E5, 1 — 0A2.

Capacitance Range: 200 mmfd. to 3.5 mfd.

Frequency Range: 75 kc. to 44 mc.

The L-C Checker is supplied complete with guarantee card and 20 page instruction manual. $69.95

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