Calibration Sources for Service Test Equipment

(Continued)

A sufficient number of calibrating capacitors should be provided to allow checking of several points in each range of the instrument. It is not imperative that these capacitances be integral values, as long as their true values are known. It is also not necessary that the units be expensive precision standards. Accurately-measured silvered mica capacitors will suffice for all service equipment testing. Larger values may be supplied by oil and electrolytic types.

Several test capacitors of suitable value may be connected around a rotary selector switch to provide an easily switched decade type capacitance standard. For ruggedness, the assembly may be enclosed in a small metal box.

Standard Variable Capacitor. A good adjustable standard for small capacitance values is a case-mounted variable capacitor with a maximum setting of 1000 mmfd., having a dial direct reading in micro-microfarads.

The variable unit may be of the ordinary experimental and radio instrument type, having a total of 43 or so plates. But for best stability, it should have rigid mechanical construction and ceramic insulation.

The capacitor must be calibrated beforehand at as many dial points as practicable. If the experimenter does not have access to a bridge or other source for calibrating this variable standard, a reasonably accurate capacitance calibration may be made in terms of frequency in the following manner:

A single-layer coil is connected in parallel with the capacitor to provide a resonant circuit, and this coil is coupled to the output of a freshly calibrated oscillator or signal generator. At any capacitor dial setting, the resonant frequency of the coil-capacitor combination is located with the oscillator. The capacitance at that setting may then be calculated from the equation:

$$C = \frac{1}{39.4 f^2 L} \text{ FARADS} \qquad (4)$$

WHERE f IS THE RESONANT FREQUENCY IN MEGACYCLES AND L IS THE INDUCTANCE OF THE COIL IN MICROHENRIES

The operation is repeated at a number of dial settings until an adequate direct-reading dial is obtained.

COMMUNITY STANDARDS

It is suggested that, whenever possible, all of the servicemen and experimenters in one locality share the expense, labor, and skill necessary to acquiring standards and making calibrations. The calibrating equipment thus becomes group property available to any member desiring to calibrate his equipment. In this way, we believe each individual may benefit by the immediate availability of good standards and that strain on equipment manufacturer and customer alike may materially be reduced.

Radio Editors of magazines and newspapers are hereby given permission to reprint in whole or in part, with proper credit to the Aerovox Corporation, the contents of this issue of the Aerovox Research Worker.

The AEROVOX Research Worker

The Aerovox Research Worker is a monthly house organ of the Aerovox Corporation. It is published to bring to the Radio Experimenter and Engineer authoritative, first hand information on condensers and resistances for radio work.

VOL. 16, NO. 4 APRIL, 1944 50c per year in U.S.A. 60c per year in Canada

Calibration Sources for Service Test Equipment

By the Engineering Department, Aerovox Corporation

AT this writing practically all manufacturers of radio and amplifier service test equipment are engaged full-time in war work. Time and facilities for any but the most essential civilian business are very limited, when they are to be found at all. The burden of repairing and recalibrating privately-owned test equipment accordingly rests with the owners themselves.

In this article, we will outline the various comparatively simple calibration sources or means which are available to most owners of service test equipment in the present emergency. Each of the sources or methods described offers sufficient accuracy for all service purposes and some general experimental purposes as well.

The instruments which the serviceman and experimenter usually need to calibrate include r.f. oscillators, audio oscillators, voltmeters, ammeters (including milliammeters and microammeters), ohmmeters, microfarad meters, and small bridges (for resistance, capacitance, inductance, or any combination of the three).

R. F. OSCILLATORS

WWV Signals. For checking r.f. oscillators of all types, the finest generally available standards are the standard frequency transmissions from the National Bureau of Standards station, WWV. These transmissions are broadcast from the vicinity of Washington, D. C. on 2.5 Mc. (7:00 P. M. to 9:00 A. M. EWT), 5 Mc. (continuously day and night), 10 Mc. (continuously day and night), and 15 Mc. (continuously daytime at Washington only).

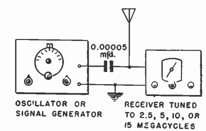


Figure 1

Each of the signals carries two audio-frequencies simultaneously; 440 and 4000 cycles per second, except the 2.5-Mc. transmission which is modulated only at 440 cycles. The accuracy of both carrier and audio components is better than one part in ten million.

The frequency calibration of r.f. oscillators may be checked directly against WWV transmissions by coupling the oscillator to the standard-signal receiver and zero beating harmonics of a number of oscillator dial frequencies against one of the standard frequencies (See Fig. 1).

The highest oscillator frequency which may be checked directly in this manner is equal to the standard frequency. Frequency points beyond this limit are reached by means of an auxiliary standard-frequency oscillator (See Fig. 2).

The auxiliary oscillator, circuit schematics for which are given in Figure 3, is first set exactly upon 1000 kc. by bringing its fifth harmonic to zero beat with the 5-Mc. WWV signal, its tenth with the 10-Mc. signal, or its fifteenth with the 15-Mc. signal. The auxiliary oscillator will then provide spot frequency calibration points exactly 1 megacycle apart. The test oscillator dial points may then be checked with the receiver by zero beating against these spot frequencies.

Broadcast Carriers. In the absence of WWV signals, the i.f. and broadcast ranges of a test oscillator may be checked with good accuracy by zero beating dial frequencies against broadcast station carriers. The latter are maintained well within the legal tolerance of plus or minus 20 cycles and therefore serve as good frequency standards. For best accuracy, zero-beating should be carried out during "quiet" intervals when the carrier is free of speech and music.

AUDIO OSCILLATORS

WWV Signals. Audio oscillators may be checked at two dial points (440

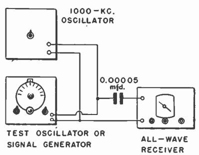


Figure 2

and 4000)*directly* by reference to the tone modulation on WWV standard frequency signals, and *indirectly* by referring harmonics and subharmonics of 440 and 4000 c.p.s. to the WWV modulations by means of Lissajou's figures.

The WWV broadcasts are modulated simultaneously at both 440 and 4000 c.p.s. except the 2.5-Mc. carrier which is modulated only at 440 cycles. In order to receive the higher frequency, the receiver must be detuned slightly to either side of center of the carrier frequency.

The comparison audio frequency may be delivered by a loudspeaker or headphones and the audio test oscillator output (delivered into a second speaker or headset) compared aurally by setting the variable unit to zero beat (Figure 4). Or the comparison may be made oscilloscopically, as indicated in Figure 5. A *stationary* circular pattern on the screen shows that the test oscillator is set to the standard frequency. A double circle (figure "8" pattern) indicates that the oscillator frequency is at 2nd harmonic of standard frequency, etc., etc.

AC Line. The ac power line (25, 50, or 60 c.p.s.) is another audio calibration source which by itself will suffice in some cases. One test oscillator dial point (the one corresponding to the line frequency) may be calibrated directly against the line by the methods shown in Figures 4 and 5. Test oscillator frequencies in harmonic relation to the line frequency may be referred to the same source by means of an oscilloscope arranged for Lissajou's figures.

Wien Bridge. A simple Wien bridge set up as an audio frequency meter (see Figure 6) may be used to measure audio frequencies in terms of known values of resistance and capacitance.

For its useful operation, this circuit depends upon the fact that the bridge may be balanced for only one input frequency at a time. When R_1 is made equal to twice R_2 and C_1 equal to C_2, R_4 and R_5 will always be equal at null and the input frequency will equal:

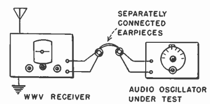


Figure 4

$$f_r = \frac{1}{6.28RC} \qquad (1)$$

WHERE R IS IN OHMS AND C IN FARADS

If it is desired to make the bridge continuously variable and to have it cover the entire audio range, R_4 and R_5 should be the two halves of a dual rheostat. The entire range 20-15,000 c.p.s. may be covered if R_4 and R_5 are each 500,000 ohms and C_1 and C_2 each 0.0133 mfd.

In operation, the unknown frequency is presented to the bridge through the input transformer, T, and the R_4-R_5 combination adjusted for null in the headphones. A sharper null is obtained by then adjusting the potentiometer, R_3. A dial attached to R_4-R_5 may be graduated directly in cycles per second This.calibration may be performed by accurately measuring the resistance of each setting of R_4 and R_5, accurately measuring the capacitance of C_1 and C_2, and making computations as indicated by Equation (1). The best calibration of the bridge will be one made against a good, freshly-calibrated oscillator, however. Increased accuracy of adjustment may be realized by using a high-impedance ac vacuum-tube voltmeter in place of the headphones.

Piano. Audio oscillator dial frequencies may be referred aurally also to notes struck on a critically tuned piano. Notes are chosen whose frequencies correspond to easily-read points on the oscillator dial. Examples are middle C with a frequency of 256, the next highest A at 440, etc., etc.

The oscillator is tuned to the piano note by adjusting the former to "zero beat". This consists of making a final setting to eliminate all waxing and waning between the two tones until they reinforce each other cleanly.

Multivibrators. If the experimenter owns a reliable secondary frequency standard, such as a 100-kc. crystal oscillator, multivibrators may be provided to yield audio calibration frequencies which are subharmonics of 100 kc. The multivibrator output is delivered to one set of oscilloscope plates (see Figure 5), while the audio oscillator output is presented to the other set; and calibration is carried out by means of Lissajou's figures, as explained earlier in this article.

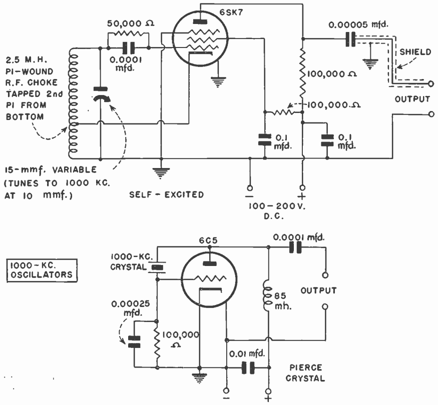


Figure 3

AEROVOX BUILT BETTER CONDENSERS AND RESISTORS

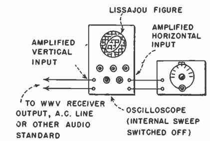


Figure 5

For working data on practical multivibrator circuits, the reader is referred to the article *Theory and Operation of Multivibrators* in the November 1940 issue of the Aerovox Research Worker.

DC VOLTAGE

Drop Across Precision Resistor. When a reliable current-indicating meter (ammeter or milliammeter) is available, together with an accurately known resistor, standard voltages for meter calibration may be produced as voltage drops set up across this resistor by known values of current through it.

A simple circuit for the production of standard voltages is shown in Figure 7. The precision resistor, R_2, is connected to a battery in series with a rheostat, R_1, and the current meter, M_1. The voltmeter to be calibrated (M_2) is connected across the precision resistor.

As R_1 is adjusted, various values of current flow through the precision resistor and are indicated by the current meter. These currents produce voltage drops, equal to the current meter reading multiplied by the ohmage of the precision resistor.

$$E = IR_2 \qquad (2)$$

Cells. Various cells and batteries, when new, may be employed as practical dc voltage standards. A dry cell from *fresh stock* may be depended upon to deliver 1.4 to 1.5 volts. A storage cell or battery is much more dependable, however, since 2.06 volts per cell will be delivered by the common lead-acid type as long as the specific gravity of the electrolyte, as tested with a hydrometer, is between 1.300 and 1.200 for most makes.

Bias Cells. Where there will be no practical current drain, as in testing a high-impedance-input dc vacuum-tube voltmeter (like the VoltOhmyst), bias cells, singly or connected in series, may be used to supply calibrating voltage. However, it must be borne in mind that the manufacturer's tolerance on these units is plus or minus 10% and the 1-volt cell therefore will deliver between 0.9 and 1.1 v.

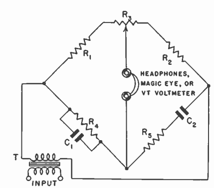


Figure 6

AC VOLTAGE

AC Line. The ac power line is readily available for use as a calibrating voltage source. By means of a calibrated potentiometer, lower voltages than that of the line may be secured.

Nearly every shop has some means of measuring line voltage with fair accuracy. But in cases where even this is lacking, the line voltage may be assumed to be of the average value common to the community (i.e., 110, 112, 115, etc.) and calibrations made on this basis.

Variac Dial. Experimenters possessing a Variac will find that the direct-reading voltage dial on that device is sufficiently accurate for most practical calibrations of service ac voltmeters where the line voltage is 115.

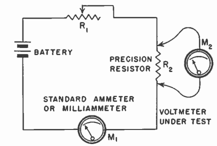
On the dials of the smaller-model Variacs, RMS voltages between 10 and 130 may be read directly at intervals of 5 volts and may be estimated closely at intermediate 2½-volt intervals.

If higher voltages than the Variac dial-limit are required, a step-up transformer of known turns-ratio should be connected to the Variac. Dial voltage readings will then have to be multiplied by the turns ratio to indicate the voltages delivered by the transformer secondary.

DIRECT OR ALTERNATING CURRENT

Precision Resistor. Calibrating currents of known value may be obtained for checking ammeters, milliammeters, and microammeters by applying a series of known voltages across a series circuit embracing the meter under test and a single precision resistor. The circuit is shown in Figure 8.

The source of voltage, P, is a battery for dc calibrations and is a transformer winding for ac testing. The test circuit includes precision resistor R_2 and the current meter under test, M_1. The precision resistor must be non-inductive if ac calibrations are made. Voltage applied to this circuit is obtained through potentiometer, R_1,



VOLTAGE DELIVERED TO M_2 = READING OF M_1 MULTIPLIED BY VALUE OF R_2

Figure 7

and its various levels are indicated by voltmeter M_2. The calibrating current values are then determined by dividing the reading of the voltmeter by the value of the precision resistor:

$$I = \frac{E}{R_2} \qquad (3)$$

RESISTANCE

Standard Resistors. Ohmmeters and resistance bridges are calibrated best by means of resistors of known value. There is no alternative. The serviceman or experimenter should keep on hand several closely-rated resistors which will allow him to check a number of points on his ohmmeters or resistance bridges. In some localities, one individual keeps the standards which may be borrowed, when needed, by any of several other technicians.

Calibrating resistors should be carefully stored, preferably in a cool dry place and in a topped jar containing a sprinkling of calcium chloride, Silica Gel, or similar dessicating agent. The resistors need not be expensive precision units if these cannot be afforded, but may be service-type resistors carefully selected at the supply house and carefully stored between calibrations.

CAPACITANCE

Standard Fixed Capacitors. Standard capacitors will be required for checking microfarad meters, capacitance bridges, capacitance-testing oscillators, and similar instruments. Unfortunately, no substitution is possible in this case.

(Continued on next page)

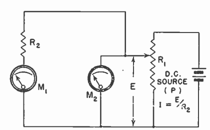


Figure 8