The Aerovox Research Worker

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Practical Methods of Testing Condensers

PART 6

By the Engineering Department, Aerovox Corporation

CONCLUSION

THE treatment of capacity measurements would not be complete without a discussion of minimum circuit capacity. It is often necessary to know the minimum circuit capacity of a tuned circuit. This consists of the minimum capacity of the tuning condenser, the distributed capacity of the coil plus the capacity of the wiring and the tube capacity. Due to the presence of the coil, the circuit cannot be directly connected to any of the standard measuring instruments. However, the tuning condenser can be disconnected and the minimum capacity measured on a bridge or by other convenient means. To find the remaining part of the minimum circuit capacity one might proceed as follows. With the tuning condenser connected, tune the test circuit to a signal of known frequency—a radio station is often convenient since its frequency is accurately known. Without disturbing the setting of the condenser disconnect it and measure the capacity. Let us call this capacity C_1 which was obtained with a frequency f_1. Connect the condenser again and tune to a signal of a different frequency, f_2, disconnect and measure the capacity again and now find C_2. Then the minimum circuit capacity (C_x) not including the minimum capacity of the condenser is

$$C_x = \frac{C_2 - \left(\frac{f_1}{f_2}\right)^2 C_1}{\left(\frac{f_1}{f_2}\right)^2 - 1}$$

Instead of employing broadcast stations it may sometimes be more convenient to employ a signal generator. In that case the equation can be simplified if the two frequencies are harmonics of each other and the actual frequencies then need not be accurately known. If f_1 is the second harmonic of f_2 ($f_1 = 2f_2$), the equation becomes

$$C_x = \frac{C_2 - 4C_1}{3}$$

It is also possible to find the minimum circuit capacity including that of the tuning condenser at once. Set the tuning condenser at minimum and leave it there for the duration of the test. Connect a calibrated variable condenser in parallel with the tuning condenser and note its setting C_1 and C_2 for the frequencies f_1 and f_2. Then, applying either of the previous equations C_x is the total minimum capacity.

When the minimum circuit capacity is known it is a simple matter to find the true inductance of the coil and the required additional capacity (above the minimum capacity) to tune to any given frequency. The true inductance is

$$L = \frac{253 \times 10^8}{(C_1 + C_x) f_1^2} = \frac{253 \times 10^8}{(C_2 + C_x) f_2^2} \text{ MICROHENRIES}$$

C IN MMFD. f IN Kc.

The capacity, C, to be added to the minimum capacity in order to tune to any frequency F is found from

$$C = (C_1 + C_x)\left(\frac{f_1}{F}\right)^2 - C_x = (C_2 + C_x)\left(\frac{f_2}{F}\right)^2 - C_x$$

In conclusion we present more detailed information on power supplies and detectors.

POWER SUPPLIES

Measurements at power line frequencies are usually carried out at 60 or 120 cycles; the latter is preferred because the electrolytic condenser is often used in full-wave rectifier filters.

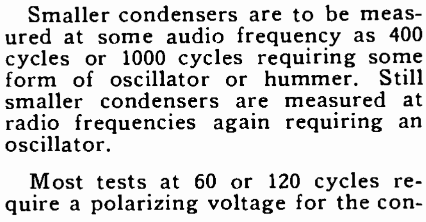

Figure 1

Smaller condensers are to be measured at some audio frequency as 400 cycles or 1000 cycles requiring some form of oscillator or hummer. Still smaller condensers are measured at radio frequencies again requiring an oscillator.

Most tests at 60 or 120 cycles require a polarizing voltage for the con-

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denser. If this polarizing voltage can be introduced in series with the a.c. signal it can simply consist of batteries or a power pack whch is adequately bypassed. Such an arrangement for 60 cycles is shown in Figure 1. This circuit is applicable when the value of the polarizing voltage does not have to be varied. The a.c. voltage can be varied by employing a transformer with a tapped secondary or by employing a transformer supplied by a variable auto-transformer.

When the required a.c. voltage should have a frequency of 120 cycles per second, the most economical way to obtain it is with a full-wave rectifier. The output of such a rectifier contains a ripple of twice the line frequency but of a non-sinusoidal wave shape. Some sort of filtering is required in order to improve the wave shape since there are many types of measurements where the presence of a large harmonic percentage causes errors. In Figure 2 a suitable circuit is shown employing the full-wave rectifier at the same time as the polarizing voltage source. In order to get away from the harmonics, the ripple is first carefully filtered out and is then reintroduced by a transformer, T_2, which has its primary connected ahead of the filter. The secondary is tuned to the 120 cycles to improve the wave-form.

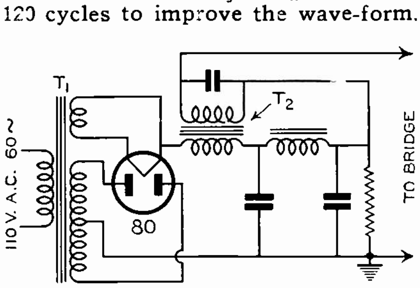


Figure 2

A variable polarizing voltage in conjunction with the above a.c. sources is often convenient since condensers of different voltage rating have to be measured. Often the requirement can be met by simply tapping the voltage divider of the d.c. source. When a continuously variable source is wanted, it could be done if the voltage divider were replaced by a heavy duty potentiometer. However, such units are expensive and consume too much power. It is far simpler to employ a tube to do the regulating. A variable d.c. power supply employing a standard triode as a grid-controlled rectifier is shown in Figure 3. This circuit was developed in the Aerovox laboratory.

The power supply consists of the usual power transformer and a standard triode output tube such as a 2A3 used as a half-wave rectifier. The full voltage of the transformer secondary is applied to the plate of the triode through the load. The voltage at the grid of the triode is regulated by means of a high-resistance potentiometer, P, across the transformer secondary. Thus the grid voltage can be made to vary from zero to a value equal to the plate voltage while it is always in phase with the plate voltage. This variable grid voltage provides a means of varying the tube's plate resistance and allows the output voltage to be varied. The maximum variation with any given transformer voltage allows a ratio of 4:1 between maximum and minimum d.c. output voltage.

The tube employed should be one

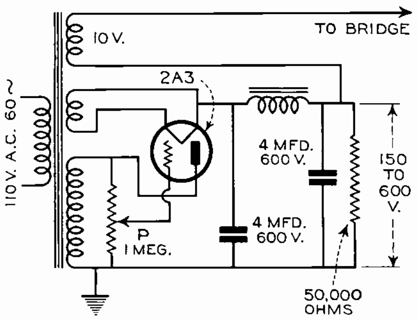


Figure 3

with a low plate resistance so as to have minimum voltage drop in the tube and best regulation. The 2A3 and the 45 tube have been used successfully with maximum loads of 30 ma. and a maximum output of 600 volts.

When combining this variable power supply with an a.c. source, 60 cycles can be introduced by insufficient filtering. If the harmonics are objectionable the scheme of Figure 3 may be employed. Obtaining the a.c. voltage from the ripple results in an a.c. voltage which varies with the polarizing voltage and is always a definite percentage of it. In many cases this may be desirable but it must be remembered that the sensitivity becomes lower with lower polarizing voltages making it sometimes hard to obtain a good balance on low voltage electrolytic condensers.

A 120 cycle signal can be obtained from a separate full-wave rectifier since the power supply is only half-wave. Although it appears possible to make a full-wave variable power supply employing two grid-controlled rectifiers and a double potentiometer, this has so far not been done.

The type of potentiometer employed is a standard 1 megohm unit with left hand logarithmic taper. The average receiving type volume control is satisfactory if one makes sure that the insulating washer in the cover is in its proper place.

OSCILLATORS

In cases where oscillators are used, the polarizing voltage supply is generally not required. Here the problem resolves itself into getting a satisfactory wave form, at a steady frequency and with sufficient power to obtain the required sensitivity.

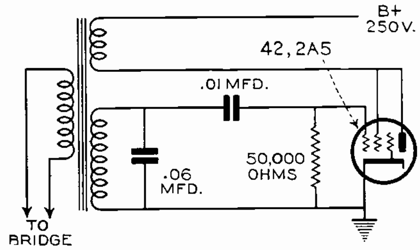


Figure 4

One satisfactory type of oscillator which has been used at 1000 cycles consists of a 2A5 or 42 tube as a triode in a conventional oscillator circuit as in Figure 4. The transformer here was of special design so as to obtain 1000 cycles and a good wave form. It is of course possible to get some sort of oscillation with nearly any type of audio transformer but then the frequency range may be limited and the coupling may be too tight so as to cause a complex wave.

In this particular case it was found that the highest output was obtained with the tube connected as a triode. The pentode connection provided less power. The maximum power was 400 milliwatts in a load of 1000 ohms and with a plate supply of 270 volts.

In most cases this single tube is a satisfactory power source but sometimes when measuring very large condensers or small inductances, the bridge impedance is very low. There were certain load values which made the oscillator stop functioning or change its frequency. This can be helped somewhat by employing a transformer of suitable ratio for the

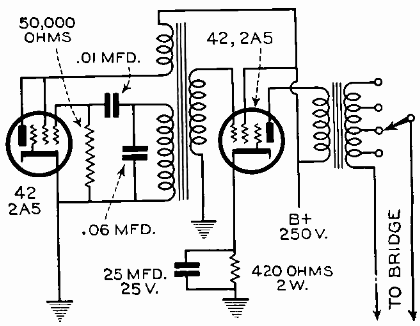


Figure 5

particular application at hand. The best solution, however, is to use a power amplifier which will make the functioning of the oscillator independent of the load. Another 42 or 2A5 as a pentode amplifier has been found very useful—see Figure 5. A common power supply for the two is satisfactory. This power source should be placed some distance from the bridge and from the detector amplifier so as to avoid stray pick-up and the leads to the bridge should be shielded. The output transformer of the power amplifier can be supplied with several taps so as to fit various requirements.

In a pinch a filament transformer is suitable for matching the amplifier to a bridge of low impedance.

The radio-frequency oscillator has been treated in a previous installment of this series.

DETECTORS

The most popular detectors are phones, an amplifier with phones, or an amplifier with an indicating meter. Sometimes an amplifier is used with both phones and an indicating meter. There is very little to say about the use of phones alone except that one must be careful if the phones are not at ground potential when a Wagner ground may be required. It is also possible that the phones pick up a signal from the oscillator transformer by magnetic induction; this is solved by moving the oscillator.

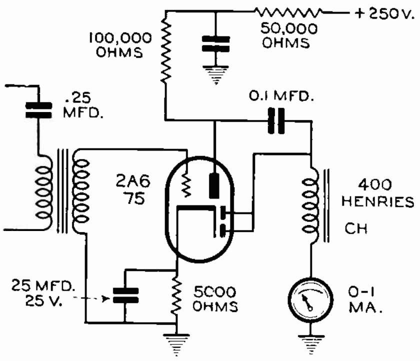


Figure 6

When an amplifier is employed, the position of the phones can no longer affect the bridge balance. A suitable amplifier which may be employed with phones or with a meter or both is shown in Figure 6. It consists of a 2A6 or 75 tube with the triode section employed as an amplifier while the diode is used in connection with an 0—1 ma. meter as a visual indicator.

In many cases it will be necessary to employ an input transformer depending on the type of bridge. This transformer may be inside the bridge unit or inside the amplifier unit but wherever it is it should be located for minimum coupling with the oscillator transformer and the leads between bridge and amplifier should be completely shielded. It is preferable to shield the complete amplifier also and if it is run from the same power supply as the oscillator and its amplifier, an extra filter section should be used. This extra section, consisting of a 50,000 ohm resistor and a 1 mfd. condenser, is shown in Figure 6.

The choke CH serves to keep the load on the triode high when the bridge is near balance. When the bridge is off balance, the diode current lowers the inductance and the gain of the tube providing some sort of automatic regulation which prevents blowing the meter. This choke should have a very high inductance such as 400 henries and may have a resistance of 5000 to 7500 ohms. When phones are needed, they can be connected across the choke.

The sensitivity of this amplifier can be increased, if necessary, by placing a resistance coupled amplifier ahead of it, consisting of a 6C6, a 57 or a 6J7 tube. The amplifier then becomes very sensitive and greater precautions should be taken against stray pickup. The whole amplifier should be enclosed in a metal case and should be connected to the power supply by cable. A volume control should be provided to protect the ears and the meter.

Another type of detector is shown in Figure 7. It utilizes one of the new double triode tubes with two separate cathodes, the 6C8G. The first section of the tube is again used as an amplifier while the second section functions as a grid-leak detector. The circuit has the advantage of sensitivity and economy, no chokes being required. However, it is not suitable for use with phones.

As in all types of grid-leak detectors, the meter shows maximum reading when there is no signal and dips when a signal comes in. Therefore we must adjust for maximum reading. The plate voltage on the second section is adjusted for full scale meter reading when the input signal is zero. The meter can of course never go off scale.

Maximum sensitivity is obtained with a high resistance grid leak. In the diagram 5 megohms is indicated; the coupling condenser must then be made correspondingly smaller keeping the time constant low. If this were not done the meter would appear very sluggish.

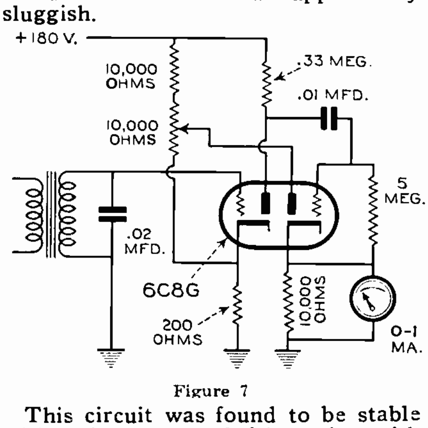


Figure 7

This circuit was found to be stable with resistance-coupled input but with transformer input it had a tendency to oscillate. A bypass condenser across the secondary stopped the oscillation. The transformer must again be located for minimum inductive pickup.

If a rectifier type meter is employed, any audio amplifier is suitable provided it has an output transformer.

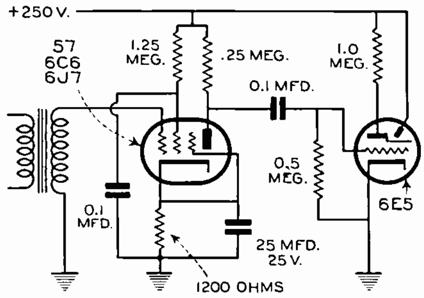
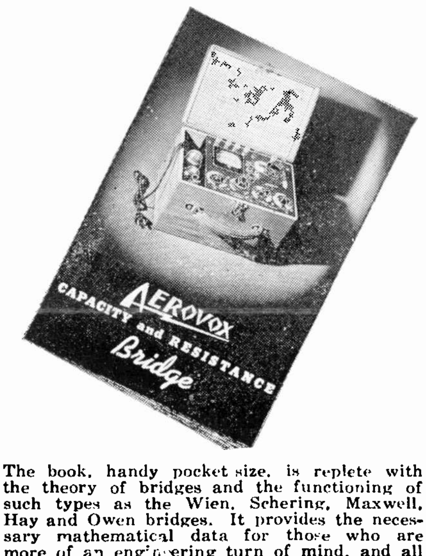


Figure 8

Finally, the cathode-ray tuning indicator tube can be employed as a visual indicator. If the tube is preceded by a voltage amplifier as the 57, 6C6 or 6J7 tube, the detector becomes quite sensitive. A suitable circuit is shown in Figure 8. The usual precautions against stray pick-up should be taken. A rectifier tube is not necessary here because the cathode-ray tube will close its shadow at each half cycle. Due to the persistence of vision it appears that the shadow has narrowed and rectification is not needed.

Just Out - New Bridge Manual

The Aerovox Corporation has just published a 24-page manual on the subject of bridges.



The book, handy pocket size, is replete with the theory of bridges and the functioning of such types as the Wien, Schering, Maxwell, Hay and Owen bridges. It provides the necessary mathematical data for those who are more of an engineering turn of mind, and all necessary practical instructions for the servicemen.

In addition, the manual is devoted to various tests and measurements that can be made with the Aerovox Bridge, including detailed cir uit diagrams accompanying the specific operations.

The manual is supplied without charge to each purchaser of the Aerovox Bridge. However, those not owning one may obtain one or more copies of this concise work, while the limited supply lasts, at 50c per copy, from all Aerovox jobbers or direct from Aerovox Corporation.

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1 **Meter Range Switch** . . . the "brains" of the Aerovox Bridge. Provides external milliammeter first three positions; external voltmeter next three positions, ranging from 60 to 600 v. at 1000 ohms per volt; "Bridge" indicates power on and balancing position. Also provides vacuum-tube voltmeter and insulation resistance test at "VTV"; leakage test through X terminals at "L 60 MA" and "L 6 MA" positions; and polarizing voltage readings on proper meter range at "PV" position.

2 **Polarizing Voltage Control.** Inner knob serves as transformer tap switch. Outer knob is vernier control indicating continuously variable voltage 15 to 600 volts in 3 steps. Voltmeter automatically switched to proper range 0-60, 0-300, 0-600. Variable voltage available between terminals +X and Ground for meter calibration, load tests, amplifiers, etc.

3 **Power factor control and switch** for insulation resistance test.

4 **Bridge Range control** . . . for reading capacity:

10	—	100 mfd.
1	—	10 mfd.
.1	—	1 mfd.
.01	—	.1 mfd.
.001	—	.01 mfd.
.0001	—	.001 mfd.

Multiplying factor for both capacity and resistance indicated on face of control.

5 **Zero Adjustment** for vacuum-tube voltmeter and bridge detector.

6 **Push Button** for insulation resistance test.

7 **Main Dial,** linear calibrated, for capacity and resistance readings.

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