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SIMPLE METHODS OF MEASURING INDUCTANCE OF AIR-CORE AND POWDERED-IRON-CORE COILS

Most servicemen and experimenters own adequate equipment for the measurement of current, voltage, resistance, and capacitance but have no instruments for checking coils of the air-core and powdered-iron-core types. Repair operations and experimental work often are aided when the inductance of these coils can be measured.

While the inductance of air-core and slug-type coils can be determined readily with an inductance bridge, Q-meter, or some adaptation of the grid dip oscillator, these instruments seldom are found outside of laboratories. For the benefit of the practical radio man who cannot afford such instruments but nonetheless is confronted with the problem of inductance measurements, we are devoting this article to an explanation of several test methods which require only common radio instruments. These methods, which offer various degrees of accuracy but are entirely satisfactory in most practical applications, have been chosen to cover most cases. In short, they show the radio man how he can use his oscillator, v. t. voltmeter, and receiver to do the job of coil testing.

The reader is advised to study the entire article carefully and to select the measurement method which utilizes parts and instruments he already possesses and which most nearly suits his particular requirement. Seven methods are described.

Q-Circuit Method

This method has so been called because the circuit it employs often is used as a simple Q-meter for checking coil or capacitor quality. The circuit is shown in Figure 1 (A).

In this circuit, the unknown inductance, L_x, is checked against an accurately-known capacitance, C, which may be an air or mica capacitor of any value between 10 and 1,000 uufd. The r. f. test oscillator may be a service type instrument. For best re-

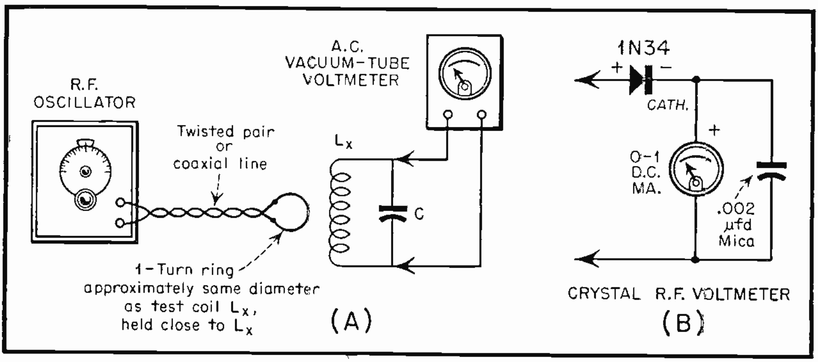

Fig. 1.

sults, the high-voltage output jack of the oscillator should be used. Most modern service test oscillators have a 1-volt output jack. The a.c. vacuum tube voltmeter must have a low-voltage scale and must be equipped with an external r. f. probe having low input capacitance. In the absence of a suitable v. t. voltmeter, a simple r. f. voltmeter may be constructed with a Type 1N34 crystal diode, 0-1 d.c. milliammeter, and 0.002-ufd. mica capacitor, as shown in Figure 1 (B). The full-scale deflection of this instrument will be approximately 0.6 volt r. m. s.

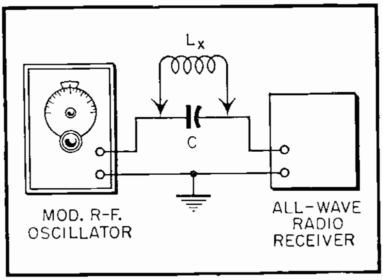

Fig. 2.

To make the inductance test: (1) Connect the test coil, L_x, to the capacitor by the shortest possible leads. (2) Hold or place the coupling ring close to the coil. (3) Starting at the lowest dial frequency, tune the oscillator until a deflection of the meter is obtained. (4) At the peak upswing of the meter, read the oscillator frequency. (5) Determine the unknown inductance value from the equation:

$$(1) \quad L_x = \frac{25{,}400}{f^2\,C}$$

Where L_x is the unknown inductance (uh)

f is the oscillator frequency (Mc.)

C is the capacitance of the test capacitor (uufds.)

Always employ the loosest possible coupling (widest spacing) between the coupling ring and the coil which still will give a readable deflection of the meter. When checking lattice-wound or honeycomb coils, it may be necessary to replace the ring with a single turn of insulated wire wound tightly around the outside of the coil, in order to obtain sufficient coupling.

Wave-Trap Method

This method is somewhat similar to the preceding Q-circuit method in that the unknown coil is checked against a known capacitance (see Figure 2). Its main difference, however, lies in its use of an all-wave radio receiver in place of the v. t. voltmeter, and its dependence upon a minimum signal (null) rather than maximum signal to indicate resonance. This will be a preferred method when a v. t. voltmeter of sufficient sensitivity is not available.

In this circuit, the unknown inductance, L_x, forms a wave-trap with the capacitance C. For maximum flexibility, C should be a 0.001-ufd. variable capacitor with a dial reading direct in micromicrofarads. However, if such a variable unit is not available, any fixed air or mica capacitor between 10 and 1,000 uufd. may be used. The receiver should be provided with an output meter, although somewhat less accurate results may be obtained by listening to the modulated signal in the loudspeaker or headphones.

The receiver and the modulated oscillator must be tuned simultaneously (a two-handed job), starting at the lowest frequency of both the receiver and oscillator. The a. v. c. in the receiver must be interrupted, otherwise it will obscure the indication. At some point along the tuning range, the wave trap formed by L_x and C will resonate to the frequency to which the receiver and oscillator are tuned, and the receiver output will fall sharply. At frequencies on each side of resonance, the output will rise. At the lowest point in the output dip, the oscillator frequency (f) is read, and the unknown inductance is determined in terms of f and C by means of equation (1).

This method is somewhat less accurate than the preceding Q-circuit method for several reasons, one being that the null point is rather broad. By employing an output meter (a.c. voltmeter connected across the loudspeaker voice coil), instead of the ear, the results will be satisfactory for most practical purposes. All connections in the wave trap circuit must be kept as short as possible.

Impedance Meter Method

This method takes its name from its use of a popular impedance measuring circuit. This method (see Figure 3) employs an audio-frequency signal.

Here; the unknown inductance, L_x, is connected in series with a calibrated rheostat, R, whose dial reads directly in ohms. If a direct-reading rheostat is not available, the settings of an ordinary one may be read with an ohmmeter or bridge. A decade resistance box is ideal for use in this circuit. The rheostat resistance need not exceed 10,000 ohms for air-wound and powdered-iron-core coils, but should be readable to a very low value.

The a.c. vacuum tube voltmeter is arranged with a switch, S, so that it may be connected either across the coil or the resistor. In position 1 of this switch, the voltage drop across the coil is read; in position 2, the voltage across the resistor. When the two voltages are equal, the impedance of the coil is equal to the resistance setting of the rheostat.

To check the inductance of L_x: (1) Set switch S to position 1. (2) Set the oscillator to 1,000 cycles and advance its output until a good, readable deflection is obtained on the lowest meter range. (3) Throw switch S to position 2 and adjust rheostat R until the same voltage deflection is obtained. (4) Throw switch S back to position 1 and readjust R. (5) Work back and forth between positions 1 and 2, continuing to adjust R, until the meter reading no longer shifts as the switch is thrown back and forth. At this point, the resistance setting of rheostat R is equal to the impedance (Z) of the coil, L_x. (6) Remove the coil from the circuit, and measure its d.c. resistance with a resistance bridge or good ohmmeter. Record this value as R.

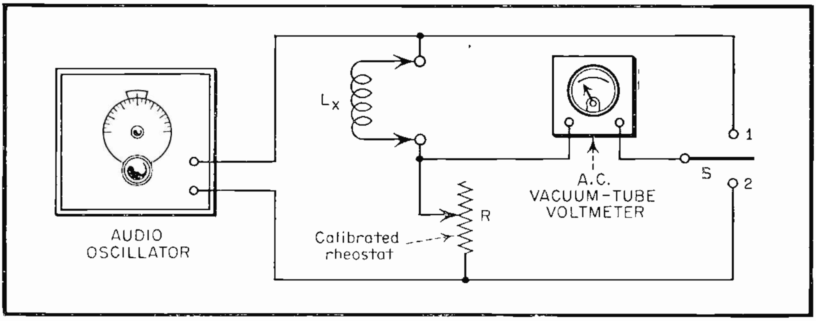

Fig. 3.

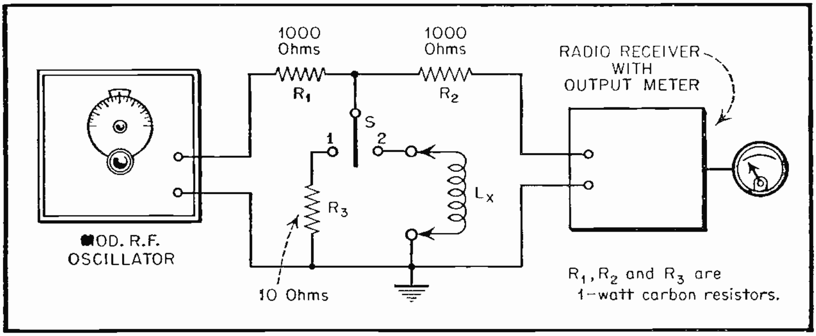

Fig. 4.

Calculate the inductance of the coil L_x by means of the equation:

$$(2)\quad L_x = \frac{\sqrt{Z^2 - R^2}}{0.00628} \text{ microhenries}$$

If the d.c. resistance (R) of the coil is too small to measure, use the equation:

$$(3)\quad L_x = \frac{Z}{0.00628} \text{ microhenries}$$

If some frequency other than 1,000 cycles is used in the test (for example, 400 cycles from the audio terminals of an r. f. test oscillator), change the denominator in Equations (2) and (3) to 0.00000628F, where F is the frequency in cycles.

T-Network

In this system, a T-network, operated between a modulated r. f. oscillator and a radio receiver, is formed by the test coil (L_x) and two resistors, as shown in Figure 4. The network is enclosed in a small shielding metal can with two external binding post terminals for connecting the coil. The oscillator must have a calibrated output attenuator reading in microvolts.

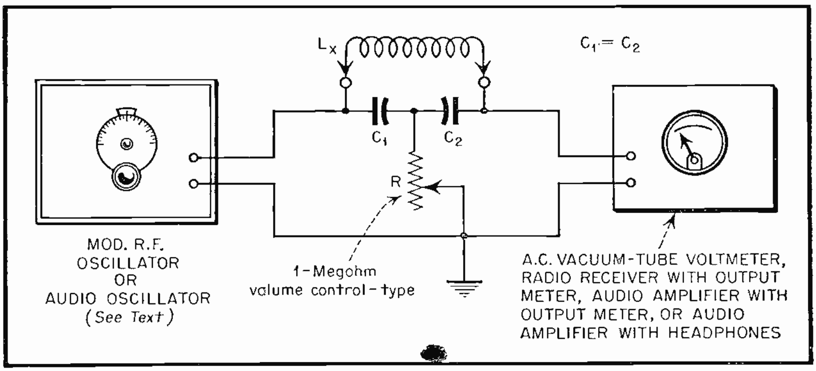

Fig. 5.

The switch, S, must be an anti-capacity unit.

To operate the device: (1) Temporarily interrupt the a. v. c. in the receiver. (2) Throw switch S to position 1. This connects the 10-ohm resistor into the circuit. (3) Set the modulated oscillator to 1,000kc. and tune-in the signal on the receiver. (4) Advance the attenuator in the oscillator until the output meter in the receiver is deflected to the upper portion of its scale. Note the value of this deflection carefully. (5) At this point, record the attenuator microvolts reading as E_1. (6) Throw switch S to position 2 and re-set the attenuator to obtain the same output-meter reading as in Step 4. Record this new attenuator setting as E_2. (7) Calculate the impedance (Z) of the coil from the equation $Z = (10\,E_1)/E_2$. (8) Remove the coil from the circuit and measure its d.c. resistance (R) with a resistance bridge or good ohmmeter. (9) Using these values of Z and R, calculate the inductance of the coil L_x from the equation:

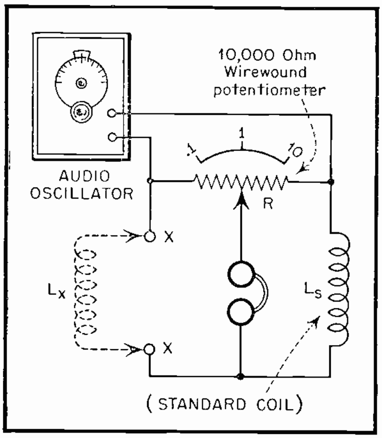

Fig. 6(A).

$$(4)\quad L_x = \frac{\sqrt{Z^2 - R^2}}{6.28} \text{ microhenries}$$

Graduate dial of potentiometer R from left to right as follows:

Resistance (measured in left half of potentiometer)	Dial Reading
910 ohms	0.1
1667	0.2
2308	0.3
2858	0.4
3334	0.5
3750	0.6
4112	0.7
4445	0.8
4737	0.9
5000	1.0
6666	2.0
7500	3.0
8000	4.0
8334	5.0
8572	6.0
8750	7.0
8889	8.0
9000	9.0
9091	10.0

Figure 6(B)

If the d.c. resistance of the coil is too small to measure, use the equation:

$$(5)\quad L_x = \frac{Z}{6.28} \text{ microhenries}$$

If some test frequency other than 1,000kc. is used in the measurement, change the denominator in Equations (4) and (5) to 0.00628 f, where f is the frequency in kilocycles.

Bridged-T Network

This method (see Figure 5) is similar to the preceding one, except that the oscillator frequency and the setting of rheostat R must be adjusted to give a null reading of the meter; that is, the lowest deflection or dip. C_1 and C_2 are identical air or mica capacitors which may have any convenient value between 50 and 1,000 uufd. At null, the unknown inductance may be determined by means of the equation:

$$(6) \quad L_x = \frac{5 X 10^{10}}{f^2 C_1} \text{ microhenries}$$

f is in kilocycles

C is in uufd.

Simple Inductance Bridge

When the reader has available a coil whose inductance is known very accurately, other coils may be checked against it in the simple bridge circuit shown in Figure 6(A). While it is customary to operate this bridge with a 1,000-cycle signal from an audio oscillator, the signal can be of some other frequency, such as 60 cycles obtained from the a.c. power line through a step-down transformer. The null detector may be an a.c. vacuum tube voltmeter, oscilloscope, electron-ray indicator tube, or simply a pair of high-resistance headphones.

The bridge potentiometer, R, and its dial are calibrated according to the chart given in Figure 6(B). The dial is seen to read from 0.1 to 10 times the inductance of the standard coil. Thus, a 1-millihenry standard coil (L_s) would permit measurements from 0.1 m. h. (100 uh.) to 10 m. h. It is not advisable to extend the range beyond this 0.1-1-10 region for any one standard coil. If the unknown inductance does not fall inside this range, an inductance standard of higher or lower value should be placed in the circuit.

Use of the bridge is simple: Tune for null. Then multiply the inductance value of the standard coil L_s by the potentiometer dial reading. This gives the value of the unknown inductance, L_x.

Voltmeter-Ammeter Method

When no other instruments are available, the voltmeter - ammeter method (see Figure 7) may be employed. This method, which affords the least accuracy of all the systems described in this article, is based upon the fact that the impedance of a coil may be determined from the voltmeter (E) and milliammeter (I) readings ($Z = E/I$) and the inductance may be calculated from this impedance and the d.c. resistance of the coil.

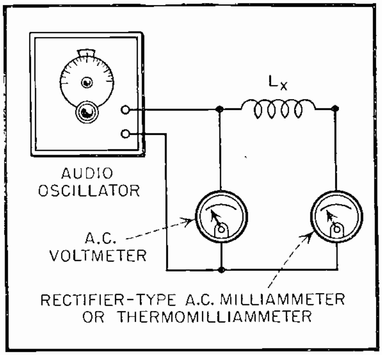

Fig. 7.

After finding the impedance (Z) by means of the circuit shown in Figure 7, remove the coil and measure its d.c. resistance (R) with a resistance bridge or good ohmmeter. Then substitute the Z and R values in Equation (2) if the measurement frequency is 1,000 cycles or Equation (4) if the frequency is 1,000kc. Always use the highest possible frequency when employing the voltmeter-ammeter method. However, it is rather difficult to employ a high radio frequency because of the bypassing effect of stray capacitances in the test circuit.