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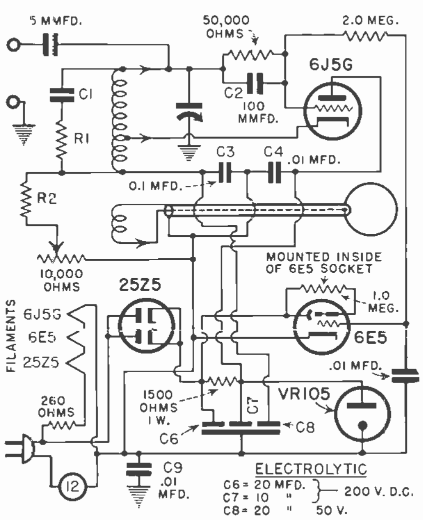
Use of the L-C Checker for R.F. Measurements

By the Engineering Department, Aerovox Corporation

A great many measurements can be made with the L-C Checker using simple accessories available to any radio experimenter. These include measurement of capacity of condensers, inductance of coils, and characteristics of antennae, transmission lines and tuned circuits in general.

Fundamentally the L-C Checker is a calibrated, compensated oscillator with an indicator to show the strength of oscillation. The oscillator is compensated for variation in line voltage and for constant strength of oscillation as the frequency of the oscillator is varied. It is these characteristics which make the instrument an invaluable aid in r.f. measurements. The L-C Checker is not a precision instrument, but its accuracy is sufficient for all practical purposes.

The circuit diagram of the L-C Checker is shown in Figure 1. It is well known that the grid current of an oscillator is an excellent indicator of the strength of oscillation of any self-excited oscillator. This method is extremely sensitive and slight variations in operating conditions of the circuit can be readily detected. Another fact that is well known is that the grid current of an oscillator decreases with load on the oscillator, no matter whether the load is inductively or capacitively coupled to the tank circuit.



RANGE	FREQ.	CATHODE RESIS.	CAP.	COMPEN.
A	50 — 175 KC.	2000	125	60,000
B	175 — 500 KC.	2000	100	35,000
C	500 — 1750 KC.	2000	250	35,000
D	1.75 — 4 MC.	400	150	10,000
E	4 — 12 MC.	0	5	4000
F	9 — 26 MC.	0	0	0

Fig. 1

To draw any load from an oscillator without coupling the load circuit too tightly, the load should be tuned to the oscillator frequency. Under such conditions considerable power may be transferred from the oscillator tank circuit to the load circuit. The effect of the load on the tank circuit is to decrease the grid current of the oscillator and thus change the opening of the eye. Thus the checker is a r.f. power supply of constant voltage output and an indicator (the 6E5) which shows when the circuit coupled to the checker is in resonance and the relative amount of power taken by the external circuit from the checker.

MEASUREMENT OF RESONANT CIRCUITS

The L-C Checker can be used to measure the resonant frequency of any tuned circuit. This is done by coupling to the tuned circuit by means of the loop and varying the

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frequency of the oscillator. At the resonant frequency the eye will open sharply. The amount of opening is determined by the resistance in the tuned circuit and the degree of coupling. Low resistance circuits tightly coupled will cause a large opening, while high resistance circuits will not cause as large an opening. For more accurate determination of the frequency the coupling is decreased until a barely noticeable flicker is noted as the checker is tuned.

Wherever the coil is enclosed in a metallic case which may prevent magnetic coupling, capacity coupling can be used. The two binding posts at the lower left hand corner of the panel are for this purpose. The black post is grounded to the case, the red binding post is coupled to the oscillator through a 5 mmfd. capacitor. The grounded terminal of the circuit to be measured is connected to the black binding post, and the high potential terminal to the red binding post. The L-C Checker is then tuned as before for the opening of the eye.

Capacity coupling may produce some shift in frequency calibration at the high frequency end of the scale. At the low-frequency end the frequency shift is negligible. The maximum shift will be less than 5%.

The method used to determine the frequency of IF transformers is as follows:

The black lead is connected to the ground or chassis of the receiver. The red lead is then connected to the grid cap or plate lead of the transformer to be tested and the Checker tuned as before. It may be necessary to short the unused winding to eliminate dead-end effects.

RESONANT FREQUENCIES OF R.F. CHOKE COILS

Since the impedance of a radio-frequency choke coil depends on the frequency, the maximum frequency at which a choke coil can be operated is of great importance. The fundamental frequency of any radio frequency choke can be found by coupling to the choke coil by means of the loop. Many resonance points may be found, so that the entire frequency range must be covered to determine the lowest resonant frequency of the choke coil. By checking the resonant frequency of choke coils as connected in a circuit, causes for weak reception or oscillations can be found. Similarly other resonant circuits or absorption loops in circuits can be found.

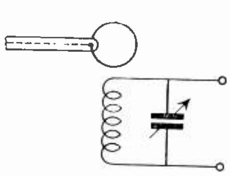

Fig. 2

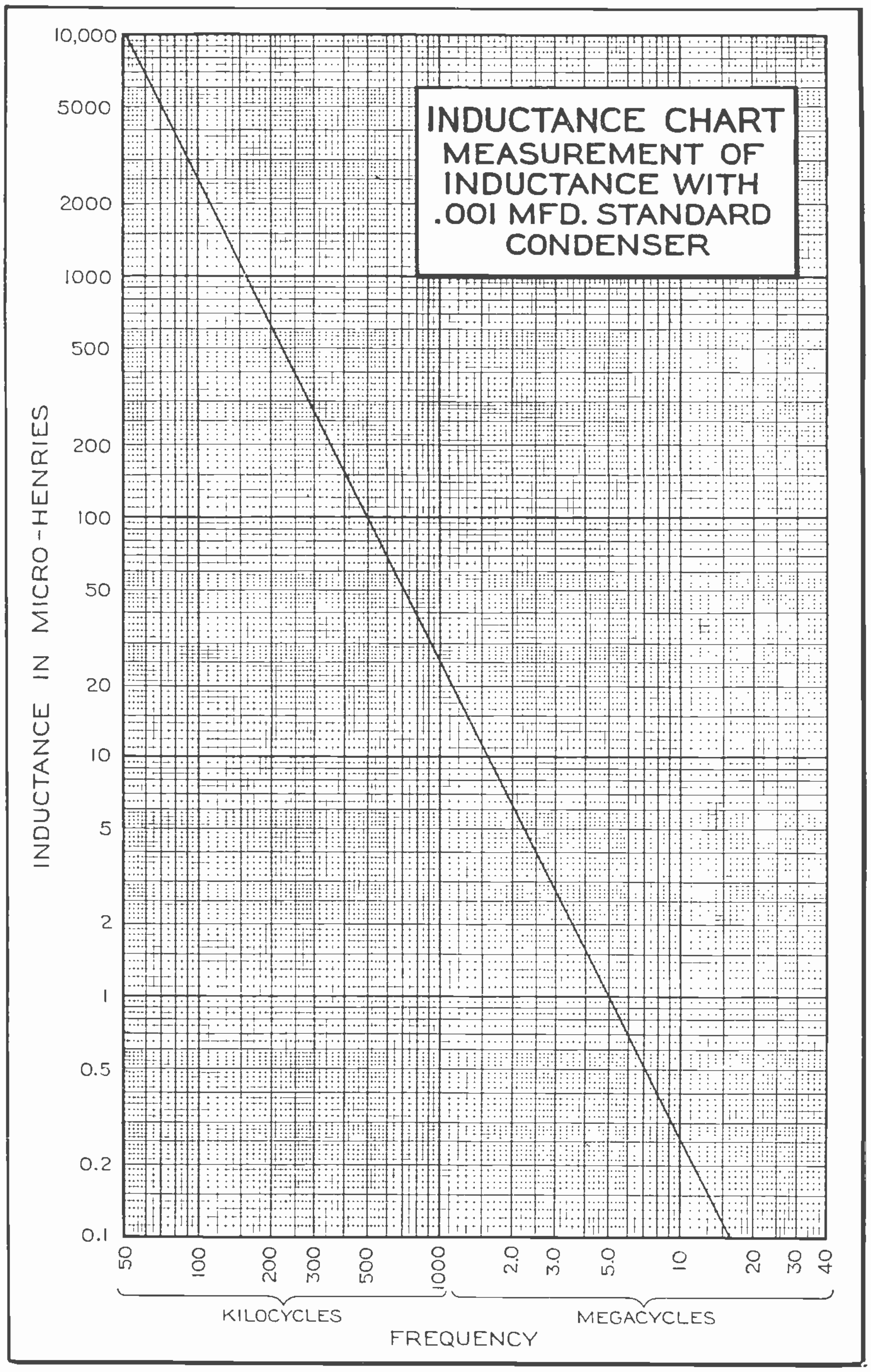

Fig. 3

MEASUREMENT OF CAPACITY

The capacity of a capacitor is measured by the L-C Checker by connecting the capacitor across a small fixed inductance and finding the resonant frequency of combination. Since the inductance is fixed it is possible to calibrate the scale in terms of capacity as well as in frequency. The inductance, across which the unknown capacitor is coupled, is made small so that its inductance is very low. It is also made of large cross-section so that the resistance is low. Therefore ohmic resistance of the tuned circuit, formed when the unknown condenser is connected across the coil, will be mostly in the capacitor. The "Q" of this circuit will depend on the capacitor and any increase of series resistance will show up on the indicator tube as a smaller opening as the checker is tuned through the resonant frequency

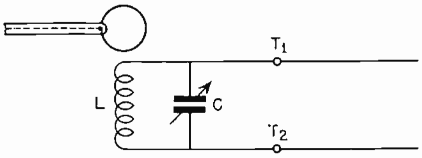

Fig. 4

of the system. Because of the extremely low inductance of the coil it is possible to measure capacitors connected into a circuit. The error will depend on the inductance of the circuit to which the capacitor is connected. Since the inductance of the fixed coil is very small. about .75 microhenries, the error is normally negligible.

It is important that the leads of the coil be connected as close to the section of the capacitor as possible. Inclusion of one inch of lead of a tubular capacitor may cause an error as great as 10 percent. Similarly, the capacitors may appear to be inductive at this frequency and the resonant frequency will shift down, giving an apparent increase in capacity. Inductively-wound capacitors will show up as having low "Q" and a capacity that is quite different from its rated value. Such capacitors, however, will read their rated capacity when measured at audio frequencies.

To measure capacitors below .0004 microfarads, a calibrated variable air condenser is of great help. This condenser should have a maximum capacity of 500 or 1000 micromicrofarads. A satisfactory capacitor can be made by mounting a two-gang broadcast receiver variable in a suitable case and paralleling the stators.

The variable may be calibrated by connecting it across a coil of approximately 200 microhenries and coupling the checker to this tuned circuit, as shown in Figure 2. The resonant frequency of the circuit is found for ten or more points on the dial of the variable. The capacity of the coil is found as described below. For each position of the variable the capacitance is found by use of the formula

$$C = \frac{25{,}400}{f^2 L} \text{ mmfds.}$$

when "f" is in megacycles and "L" is in microhenries. The capacities C, which are found in this manner, are plotted against the dial setting. This variable condenser and calibration will be of use for other measurements.

To measure small capacitors accurately, it is necessary merely to connect the calibrated capacitor across the same coil described above, or anv other coil of approximately the same size, and couple the circuit to the checker. The variable is set to maximum capacity and the checker tuned to resonance. The reading of the variable is noted and then the condenser to be measured is connected across the terminals of the variable and the variable condenser decreased until resonance, as indicated by the eye on the checker, is reached. The capacity of the variable is noted and subtracted from the first reading. The difference between the two readings is the capacity of the unknown. It is important to keep all leads as short and straight as possible.

MEASUREMENT OF INDUCTANCE

It is possible to measure the inductance of a coil by means of the checker if a known capacitor is available. This capacitor should be known to be within ± 2%, in order to give inductance to the same accuracy. A .001 mica standard capacitor is available as an accessory to the L-C Checker. Using the standard condenser across the coil of which the inductance is desired, the resonant frequency of the combination is found. The inductance "L" can be found from the equation

$$L = \frac{25{,}400}{f^2 C} \text{ microhenries}$$

"f" is in megacycles, "C" is in microfarads.

If the .001 mica standard capacitor is used, the inductance can be found from the chart of Figure 3. For other capacities the inductance can be found by using the chart, but the values found on the chart must be multiplied by the ratio of 1,000 to the capacity in micromicrofarads of the condenser actually used. For example:

If a 250 micromicrofarad condenser is used in the measurement of the inductance and resonant frequency of the coil, and the condenser is found to be 3 megacycles, the inductance of the cell is obtained by finding the inductance from the chart, 2.8 microhenries, and multiplying this value by $\frac{1{,}000}{250}$. The result is 11.2 microhenries as the inductance of the coil. This inductance is not the true inductance of the coil since there is a certain amount of distributed capacity caused by the spacing of the wire, the insulation of the wire, and the form on which it is wound. To find the true inductance and the distributed capacity, it is necessary to make two readings with two different sizes of capacitors across the coil. The true inductance is then given by the following equation:

$$L = \frac{1}{4\pi^2 (C_1 - C_2)} \left(\frac{1}{f_1^2} - \frac{1}{f_2^2} \right) \text{ henries}$$

When C is in farads and f in cycles per sec. The distributed capacity of the coil is given by—

$$C_0 = \frac{C_1 f_1^2 - C_2 f_2^2}{f_2^2 - f_1^2}$$

These values are of importance when it is necessary or desirable to make coils that are exactly alike, as is the case in tuned radio frequency stages,

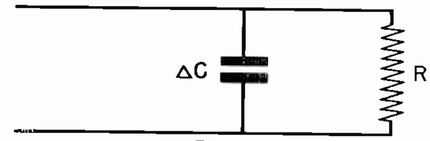

Fig. 5

where exact tracking of a number of circuits is desired. The values of inductance of the coils must be alike in order to give correct tracking at the lower frequency end of the band, while the distributed capacitance is the factor which determines the exact tracking at the high frequency end of the band. Any difference in these two values between two coils will prevent true tracking unless it is possible to parallel the coil, having the lower distributed capacity with a trimmer condenser so that its minimum capacity will be equal to the minimum capacity of the other coil. The inductances of the two coils must be alike if tracking is to be obtained at the lower frequency end of the tuning range.

MEASUREMENT OF TRANSMISSION LINES

It is possible to measure the natural period or wave length of a pair of parallel wires and also to determine their input impedance by means of the L-C Checker calibrated variable condenser and a non-inductive resistance. This can be done by connecting a coil and condenser to the input terminals of the transmission line as shown in Figure 4. To determine whether the input capacitance is inductive or capacitive for any given frequency, the checker is tuned to that frequency and then coupled to the coil and condenser with the transmission line disconnected from the terminals T_1 and T_2. The variable condenser C is then tuned to resonance. The coupling between the output loop of the checker and the coil should be decreased until no locking-in of the two circuits occurs. The reading of the variable condenser is noted and the transmission line is then connected to terminals T_1 and T_2. The condenser C should then be retuned to resonance and the reading noted. The difference between the two readings of the variable condenser will be the equivalent input capacity of the transmission line at that frequency. To measure the equivalent shunt input resistance of a transmission line it is necessary to connect a non-inductive resistance in parallel with C_1 from terminal T_1 to T_2, with the transmission line disconnected, as in Figure 5. This resistor should be of such size to give the same opening of the eye as is obtained without the resistors when the transmission line is connected across terminals T_1 and T_2. The actual input impedance of the line then can be said to consist of an equivalent parallel circuit having a capacity equal to the difference of the two variable condenser

(continued on next page)

readings, and a shunt resistance equal to the resistance found necessary to give the same opening of the eye as the transmission line.

$$Z_0 = \frac{RX_c^2}{R^2 + X_c^2} - j\frac{R^2 X_c}{R^2 + X_c^2}$$

$$= \frac{R}{4\pi^2 f^2 C^2 R^2 + 1} - j\frac{2\pi f C R^2}{4\pi^2 f^2 C^2 R^2 + 1}$$

π = 3.1416
f = frequency in cycles per second.
C = capacity in farads.
R = resistance in ohms.

Transmission lines which operate in or near ¼ wave length may have very high input capacitance or inductance. Under some conditions it may be necessary to connect the variable condenser C in series with the coil in order to obtain resonance. When this occurs the line has a very high input capacity. This is an indication that it is operating very near ¼ wave length. To find the actual length of the line, it is necessary to find two resonant frequencies of the line. This is done by connecting a small coil of 3 or 4 turns about two inches in diameter to the terminals of the line and coupling the output lead of the L-C Checker to this coil. The frequency of the checker is varied and the two successive resonant frequencies noted. The length of the line is then given by the equation:

$$D = \frac{V}{2(f_2 - f_1)} \text{ Miles}$$

$$= \frac{1082}{2(f_2 - f_1)} \text{ Feet}$$

for f_2 and f_1 are in megacycles.

When V is velocity of propagation - 186,000 miles per sec. for copper wires in free space. f_1 and f_2 are two successive resonant frequencies.

It is possible to obtain a natural period of an antenna by the same method. Sometimes it is possible to connect the antenna directly to the red output binding post on the front of the panel and measure the resonant frequency of the antenna by tuning the checker through the tuning range. A sharp opening of the eye will be noted at the natural period of the antenna.

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