

Determining Unknown Impedances in Transformers

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A simple method for obtaining information about the characteristics of unknown transformers.

IN MANY AUDIO INSTALLATIONS the technician is sometimes faced with the problem of determining quickly and with reasonable accuracy the unknown impedances of transformer windings. At other times the technician may find himself with a transformer that could be put to good use, but unfortunately he is unable to obtain sufficient data on the impedance capabilities of the transformer to make it usable in a practical application. At other times he may find that he has available several of the 400-cps power transformers of the type used in surplus military equipment. These transformers can often be used in audio installations where the power requirements are not too great—depending, of course, upon the internal insulation of the power transformer but “spec” sheets on winding impedances for audio service are not available for this type of transformer.

Once the impedances of primary and secondary windings of any transformer are known the transformer then becomes valuable and usable as a component in construction of new equipment or replacement in equipment already in use. However, unless the technician experiments by cut-and-try, he is not apt to know, even in a general sense, just what tubes or other components the transformer will allow him to match. Since cut-and-try requires a lot of time, and since there is no logical place to start, the transformer is likely to be relegated to the junk box where it will kick around until it eventually finds its way to the ash can. Good equipment can be saved from such a fate with a little effort and a minimum of equipment.

Calculation Methods

There are several possible transformer impedance calculation methods and techniques available which will give results of reasonable accuracy. Although not of the caliber of laboratory measurements, the tolerances are accurate enough for average service.

Most audio technicians own or can borrow a volt-ohm-milliammeter (pre-

ferably of the vacuum tube type); a 1,000-cps audio oscillator can be built easily. With these two pieces of equipment, plus a few odds and ends, the unknown impedances of any transformer winding or choke can be quickly computed.

Figure 1 is the schematic of a 1,000-cps audio oscillator which will prove a valuable asset to the workshop and laboratory in addition to the specific use about to be described. It is inexpensive to build since parts are held to a minimum and may be selected from spare part components.

In making impedance calculations, it is well to remember that one of its constituents is reactance. Reactance of a given coil or transformer winding changes with the frequency applied. Because reactance changes with frequency, it follows that impedance also changes.

We are therefore interested in an oscillator as a source of voltage at 400 to 1,000 cps because it allows us to obtain a greater degree of accuracy in making

impedance checks on a transformer that will eventually be used in the voice-frequency range. A 60-cps test voltage source is somewhat less accurate especially if the transformer has poor response at 60 cps.

With the meter and test oscillator we can conduct our impedance determining experiment on the assumption that *voltage ratio is proportional to the turns ratio and that the impedance of a winding varies as the square of the turns*. This is expressed by the formula:

$$\frac{Z_2}{Z_1} = \left(\frac{V_2}{V_1}\right)^2 \quad (1)$$

Where Z_2 is the known primary impedance.

Z_1 is the unknown impedance.

V_2 is the known applied voltage.

and

V_1 is the voltage measured across the unknown winding.

Note the statement, “where Z_2 is the known primary impedance.” This value

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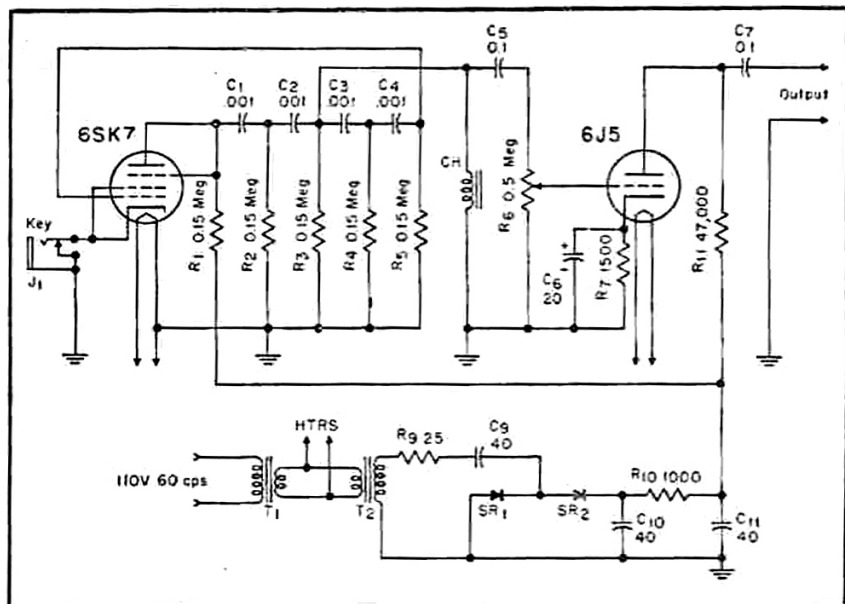


Fig. 1. Simple 1000-cps oscillator which can be constructed readily and which is useful in making measurements of the type described in this article. CH is small a.c.-d.c. filter choke; SR₁ and SR₂ are 60-ma selenium rectifiers; T₁ and T₂ are 6.3-volt, 1.5 amp filament transformers “back to back.”

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must, of course, be found first in order to make the formula operative.

Impedance, being made up of resistance, can be determined by Ohm's Law applied to those circuits having impedance. The formula for Ohm's Law in a.c. circuits is:

$$Z = \frac{E}{I} \quad (2)$$

Where E = e.m.f., in volts
 I = current, in amperes
 Z = impedance, in ohms.

Procedure

Adjust the output of the audio oscillator to about 25 volts on the meter. Apply this voltage to one winding of the transformer under test and at the same time measure the current drawn. (See Fig. 2.) Since reflected impedance from

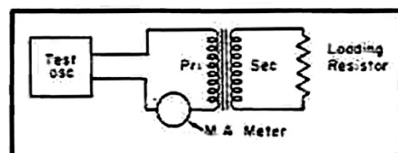


Fig. 2. Schematic of arrangement used for measuring voltage ratio between transformer windings preliminary to calculating impedance ratios.

secondary to primary under load will have an important bearing on the final result, the secondary of the transformer under test should carry a load. This can be a resistor, a speaker or a pair of headphones as an example. If a resistor is used it should be of the non-inductive carbon type to avoid reflected reactance. Once two known values are found, the impedance may be calculated from the above formula.

A more accurate method of making the measurements is to treat the primary of the transformer as a choke, leaving the secondary unloaded for the moment, and determine the inductance of the winding and find its reactance. This can be done by substitution as shown in Fig. 4.

Adjust R so that the voltage drop across R balances and equals the voltage drop across the primary. The voltage drop across the transformer primary is, of course, not due to inductance alone, but is caused by its impedance. Measure the d.c. resistance of that section of R in which the voltage drop occurs, then solve for the inductance of the primary with the formula: $L = \frac{R}{2\pi f}$. Once the in-

ductance is known, the inductive reactance (in ohms) of the primary may be found by the formula: $X_L = 2\pi fL$. Then the impedance may be found by measuring the d.c. resistance of the winding with an ohmmeter and solving for the impedance with the formula:

$$Z = \sqrt{R^2 + X_L^2} \quad (3)$$

Where Z = impedance
 R = d.c. resistance
 X_L = Net reactance.

Since we are substituting X_L (inductive reactance) for X_n in the above formula, it is assumed that the net reactance is equal to the inductive reactance. This

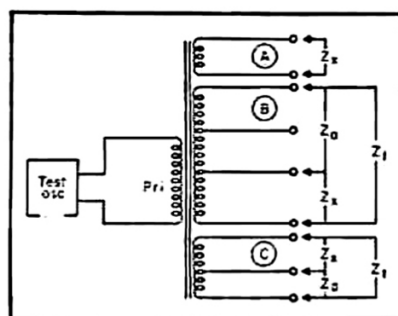


Fig. 3. (A) Method of measuring voltage ratio of simple transformer. (B) Tapped transformer measurements give sufficient information for complete calculations. (C) Example of tapped transformer.

is not completely accurate, but the result is sufficiently close to make the transformer usable in many audio applications.

With the proper load on the secondary the impedance reflected back to the primary would be such as to lower the primary impedance considerably. For general application this can be assumed

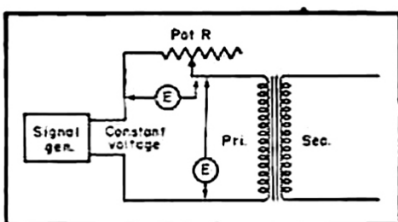


Fig. 4. Method of making measurement by substitution. Signal Generator voltage is kept constant while adjustments are made. The technique is described and formula given in the text.

to lower the primary impedance to one fourth. This gives the primary impedance at the lowest frequency responses of the transformer.

With the impedance of the primary winding known and with the output of the audio oscillator still applied to the

primary, but with R removed, voltage ratio measurements can be made on the secondary winding, as at A in Fig. 3, and its impedance determined by the formula (1). Succeeding measurements and calculations can be made on any number of multiple secondary windings.

Tapped Winding Calculations

Now suppose we have a transformer with a tapped winding in which the impedance of two sections is known, but the third unknown, as at B in Fig. 3. The impedance of the unknown section can be calculated from the formula:

$$Z_x = Z_t \left(\sqrt{\frac{Z_t}{Z_a}} - 1 \right) \quad (4)$$

Where Z_x = unknown impedance;
 Z_a = impedance of known section
 and
 Z_t = total impedance of sections Z_x and Z_a .

In order to make our impedance calculations complete for a given transformer, it is not only necessary to know the impedance of individual windings and tapped sections, but also those tapped windings on the same core in combination. The commercially made variable impedance transformers have this information in chart form for easy reference. Such ready information makes the transformer more versatile for any given application and saves the builder much time and many a headache. We can index the impedance for our transformer in the same manner. The third and last formula makes this completeness possible.

Suppose we have a transformer in which we have a two-section tapped winding having impedances of 500 ohms and 10 ohms respectively, as shown at C in Fig. 3.

Substituting in the formula:

$$Z_x = 10 \left(\sqrt{\frac{500}{10}} - 1 \right)^2 = 368 \text{ ohms.}$$

The impedance of any other tapped winding combinations can be calculated in the same manner.

Note also that in this formula it is not necessary to know the primary impedance. The calculations deal with only the knowns and unknowns of the secondary windings. The resultant values apply to tapped windings on the same core; this fact should be kept in mind when making calculations employing the last formula.