April 24, 1962 W. M. MURPHY, JR 3,031,609

BALANCED TRANSFORMER

Filed June 24, 1959 2 Sheets-Sheet 1

Fig. 1 PRIOR ART

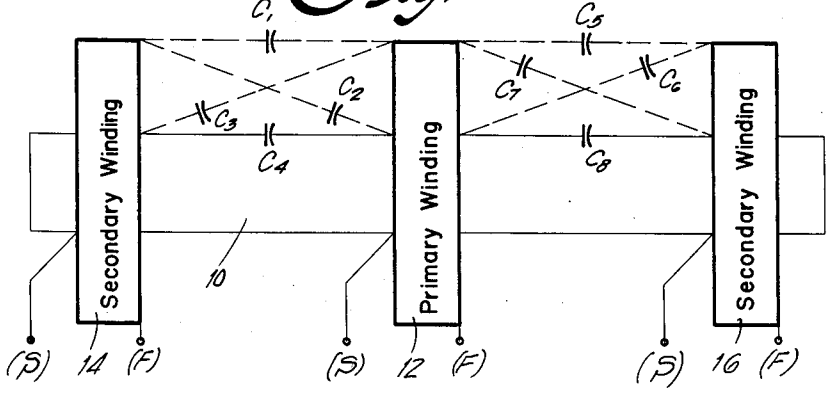


Fig 2 PRIOR ART

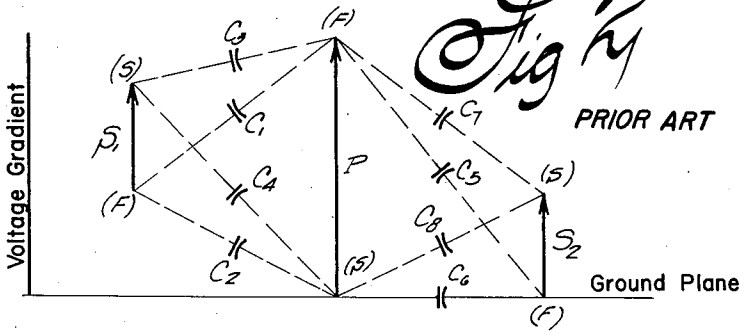
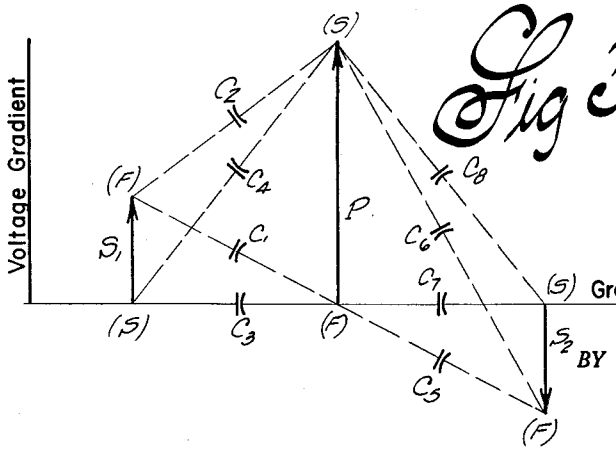


Fig 3



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BALANCED TRANSFORMER

Filed June 24, 1959 2 Sheets-Sheet 2

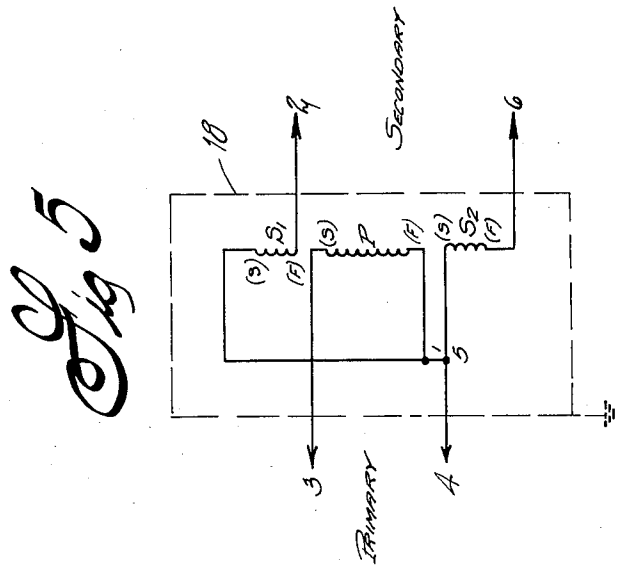


Fig. 5

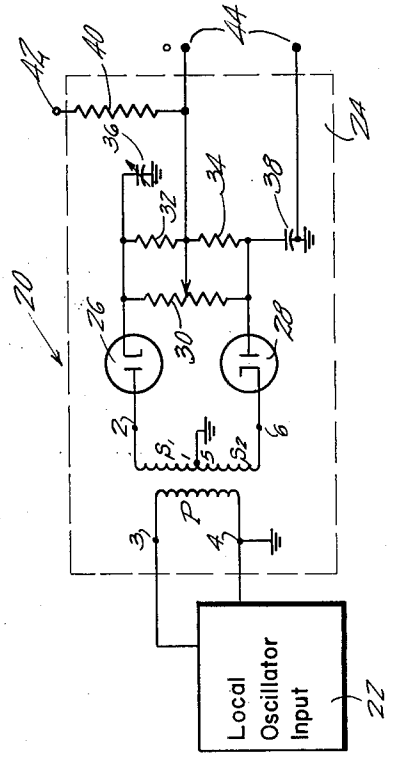


Fig. 4

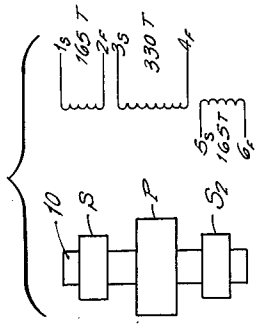


Fig. 6

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BALANCED TRANSFORMER

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1 Claim. (Cl. 323—48)

This invention relates to transformers and more particularly to capacitive balanced transformers.

One object of the invention is to provide a transformer wherein all of the principal interwinding capacitances are substantially equalized and shunted to ground.

Another object of the invention is to eliminate the use of winding shields or the like in a transformer.

In conformity with these objects, the preferred embodiment of the invention is characterized by an elongated core member having a primary winding thereon together with a pair of opposed and axially spaced secondary windings. The two secondary windings are connected in series and center-tapped to ground and one of the secondary windings is reversely wound. All three of the windings are wound from start to finish on the core in the same axial direction. This winding configuration together with the connective arrangement of the windings substantially equalizes all of the principal interwinding capacitances of the transformer and shunts these interwinding capacitances to ground.

These and other objects of the present invention will become readily apparent to those skilled in the art from the following detailed description of a preferred embodiment thereof taken in connection with the accompanying drawings, wherein:

FIG. 1 is a schematic illustration of a transformer showing the interwinding capacitances between the windings thereof;

FIG. 2 is a vectorial representation of the interwinding capacitances shown in FIG. 1;

FIG. 3 is a vectorial representation of the interwinding capacitances in a transformer constructed in accordance with the present invention;

FIG. 4 is a schematic illustration of a modulator utilizing the transformer of the present invention;

FIG. 5 is a schematic illustration and wiring diagram of the preferred embodiment of the invention; and

FIG. 6 is another schematic illustration of the preferred embodiment of the invention.

Referring more particularly to FIG. 1, there is shown a conventional three winding or three pi-type transformer including a core means or core **10** having a primary winding **12** thereon together with a pair of series connected secondary windings **14** and **16**. The secondary windings **14** and **16** are positioned on opposite sides of the primary winding **12** and are axially spaced along the core **10** a predetermined distance from the primary winding. All three windings are wound in the same direction (either clockwise or counter-clockwise) and in being applied to the core **10** are wound from start (S) to (F) finish in the same direction axially of the core. With a transformer so constructed and so wound, the principal interwinding and stray capacities or capacitances can be represented by c_1, c_2, c_3, c_4, c_5, c_6, c_7 and c_8.

The components of the transformer shown in FIG. 1 together with the interwinding capacitances can be vectorially represented as shown in FIG. 2 wherein P represents primary winding **12**, S_1 represents secondary winding **14** and S_2 represents primary winding **16**. With the secondary winding S_1 not connected to the ground plane, the interwinding capacitances are clearly unbalanced.

By reverse winding one of the secondary windings and changing the ground and center tap connections, the transformer of FIG. 2 may be illustrated vectorially as shown

in FIG. 3, which vectorial illustration is illustrative and exemplary of the present invention. An examination of FIG. 3 will reveal that both secondary windings S_1 and S_2 are connected to the ground plane with winding S_2 being reversed in direction and that the more troublesome interwinding capacities are shunted to ground. The capacitances c_2 and c_6 in particular, going from (S) to (F) and being unequal in magnitude, are in general negligibly small. This minuteness of c_2 and c_6 results from the fact that the area of the capacitor plate for (F) is much larger than the area for (S) and that the distances between them are relatively large. With the interwinding and stray capacitances being thus distributed and shunted to ground, it will readily be appreciated that winding shields such as Faraday shields or the like would not be necessary.

Referring now to FIGS. 5 and 6 and the preferred embodiment of the invention, it can readily be seen (FIG. 5) that all three windings P, S_1 and S_2 of the transformer are connected to a ground in the form of metal housing or the like **18** (shown in phantom). The primary winding P extends between points **3** and **4** with the (F) or finish end of the winding being connected to ground. The two secondary windings S_1 and S_2 are connected in series and are connected to ground from a common junction of the two (S) or starting ends of the windings, i.e. point (**1**, **5**). The (F) or finish ends of the two secondary windings, points **2** and **6** constitute the output of the transformer secondary.

It will be especially noted in FIGS. 5 and 6 that the primary winding P and the secondary winding S_1 are both wound in the same direction while the secondary winding S_2 is wound in the opposite direction. It is also significant to note that all of the windings are wound from start (S) to (F) finish in the same direction, i.e., axially of the core in one direction in FIG. 6 or from top (S) to bottom (F) in FIG. 5.

In this preferred embodiment of the invention, all of the windings are wound with No. 41 S.S.E. wire with the primary winding being comprised of 330 turns and both of the secondary windings being comprised of 165 turns apiece. Using No. 41 S.S.E. wire, the windings will be relatively small, the primary P having a thickness of approximately ⅛" and a maximum outside diameter of approximately 0.355". The secondary windings will have a thickness of approximately 1/16" and of course will be much smaller in diameter than the primary winding P. The three windings are wound upon core **10** which in this instance has a diameter of approximately 0.145" and a length of approximately 0.450". The electrical properties of the three windings in the preferred embodiment of the invention should measure substantially as follows:

Winding	Inductance	D.C. Resistance, ohms
P to ground	1.86 millihenries	29.3
S_1 to ground	2.97 microhenries	8.6
S_2 to ground	3.02 microhenries	8.8

From the dimensions and the electrical properties of the components in the preferred embodiment of the transformer, it can thus readily be seen that a transformer constructed in accordance with the present invention can be made extremely small and compact, although it will also readily be appreciated that the principles and teachings of the invention could obviously be utilized in making a transformer of much larger dimensions or of any desired size.

FIG. 4 shows an environmental application of the transformer of the present invention wherein the preferred embodiment of the transformer is utilized as a compo-

nent in a balanced modulator generally indicated by the reference numeral **20**. The primary P of the transformer is connected to a local oscillator **22** and both the primary winding P and secondary windings S_1 and S_2 are grounded to a metallic housing or the like **24** (shown in phantom) which encases the modulator. The secondary windings S_1 and S_2 are center-tapped to ground and are connected to a pair of reversely positioned diodes **26** and **28** which in this instance take the form of a pair of CK606 diodes. A balance potentiometer **30** is connected across the two diodes together with a pair of identical swamping resistors **32** and **34** each having in this particular embodiment of the modulator a value of 8 thousand ohms. A variable capacitor **36** and a fixed capacitor **38** are also connected to ground across the two diodes, variable capacitor **36** having a capacity varying between 1.5–8 microfarads and capacitor **38** having a capacity of 5 microfarads. The output of modulator **20** is taken across terminals **44** while the video input signal is fed into the modulator at terminal **42** and across resistor **40**, resistor **40** having in this instance a value of 4700 ohms.

Utilizing the balanced transformer of the present invention, the performance of the modulator **20** was obtained experimentally as follows: In determining the efficiency of the modulator **20**, the modulator output terminals **44** were connected in standard fashion to a 155 kc. IF stage, i.e. output through a 100-micro-microfarad capacitor to the center tap of a standard B–2 IF coil. The plate tuned circuit of the IF stage was loaded down with a 10,000 ohm resistor. The gain of the IF stage was measured with a 600 ohm signal generator connected from grid to ground.

The overall 155 kc. gain was then measured by feeding in the 155 kc. signal at the modulator video input terminal **42**. The gain over that which was measured with the 600 ohm signal generator was approximately 6 decibels as expected due to the 2:1 step up of the grid coil connection.

The overall conversion gain was measured by feeding in a 15 kc. video signal and a 7.0 v. R.M.S. local oscillator drive signal at 170 kc. The difference in the gains as measured in feeding in the 155 kc. and 15 kc. video signals yielded the efficiency in decibels. The maximum efficiency as measured using this method was found to be minus (—) 11 decibels. This value of the efficiency was maximized in testing modulator **20** by selection of the proper input resistance value. The optimum value of resistance was found to be 4700 ohms.

The modulator **20** was also tested for balance or the ratio of a 1 v. R.M.S. video input signal to the corresponding local oscillator feedthrough as measured at the modulator output terminals **44**. This ratio or balance was obtained by using a spectrum analyzer, and adjusting the level of a 15 kc. video sideband equal to the local oscillator feedthrough and then measuring the video input level required to produce the sideband. The balance for modulator **20** was found to be 75 decibels when a 15 kc. video signal was used and the local oscillator drive was set to 7.0 v. R.M.S.

With regard to balance stability, the modulator **20** was found to be sensitive to changes in temperature, local oscillator level, filament voltage level and to a much lesser local oscillator output impedance and video generator output impedance. The balance was found to be most sensitive to change in the local oscillator level. For a ± v. change, i.e. from +6 v. to +8 v. R.M.S., the balance changed ±26 decibels. The maximum variation of balance with level was found to be 34 decibels. The system exhibited very little hysteresis with level change, i.e. balance recoverable with reciprocal level change. For a ±1 v. change in filament voltage with diodes in parallel, the balance change was ±16 decibels. Very little hysteresis effect was noted with filament variations.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claim the invention may be practiced otherwise than as specifically described.

What is claimed is:

A pi-type transformer comprising an elongated core; a primary winding carried by said core, the outer terminal of said primary winding being grounded; a pair of secondary windings carried by said core on opposite sides of said primary winding and axially spaced therefrom, said secondary windings being connected in series and grounded at their junction, the primary winding and one secondary winding being wound in one direction and the other secondary winding being wound in the opposite direction so as to substantially equalize the interwinding capacitances of said transformer and shunt said interwinding capacitances to ground.

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