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HYBRID TRANSFORMER EMPLOYING BALANCING RESISTORS TO INCREASE ISOLATION BETWEEN LOADS

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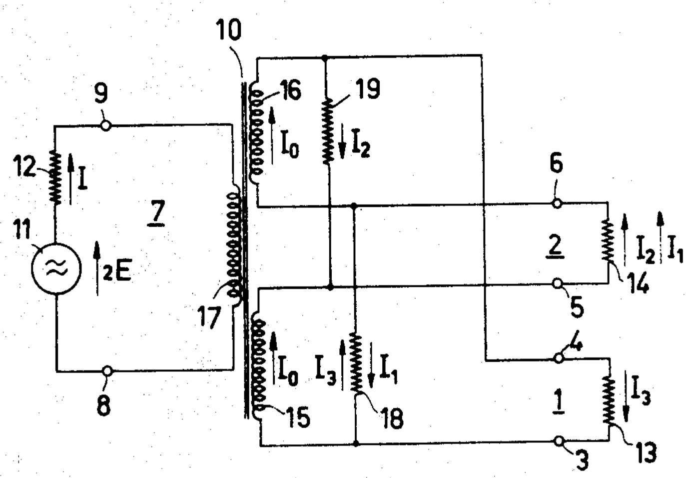

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HYBRID TRANSFORMER EMPLOYING BALANCING RESISTORS TO INCREASE ISOLATION BETWEEN LOADS

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The invention relates to a transmission fork of the balanced type, in which two relatively decoupled fork branches are coupled to a common fork branch by a transformer. Such transmission fork may be used, for example, to connect two two-wire lines to a single two-wire line, in order to supply two independent loads. Transmission forks of the balanced type have the advantage that a central tapping point of each of the relatively decoupled fork branches can be connected to ground. As a result, balanced forks have a more complicated structure than the transmission forks of the unbalanced type, in which only one point of the two relatively decoupled fork branches can be connected to ground.

In practice transformer forks are widely used for their particularly attractive electrical properties, since the relatively decoupled fork branches can be accurately adapted to the common fork branch, and no energy is dissipated in the fork itself during the transmission of signals. Such forked transformers have, however, a complicated structure. They may comprise, for example, five transformer windings with ten external connecting wires. Such structure require particular care in design and fabrication to satisfy the requirements of the forks.

With resistor forks comprising resistors, this complicated structure of forked transformers is eliminated, but since resistor forks employ resistors, they have the serious disadvantage that an appreciable loss of energy occurs in the transmission forks. This loss may amount, for example, to 10.7 db.

The invention has for its object to provide a transmission fork which is distinguished electrically and structurally from each of the aforesaid transmission forks, and which is particularly suitable for the miniature structures desirable in transistor systems.

According to the invention a transformer comprises two identical coupling windings, which are inductively coupled with a third winding connected to the common fork branch. The ends of the third winding comprise the connecting terminals for the common fork branch. Corresponding ends of the two identical coupling windings are connected to each other by way of separate fork resistor. The connecting terminals for each of the two decoupled fork branches comprise one end of one coupling winding and the end of the other coupling winding which is not connected the same fork resistor. The resistances of these fork resistors are substantially equal to the characteristic terminal impedances of the decoupled fork branches.

The device according to the invention will now be described more fully with reference to the figure which shows one embodiment of a transmission fork according to the invention.

The transmission fork shown in the figure is of the balanced type and comprises two relatively decoupled fork branches **1**, **2** with the associated connecting terminals **3**, **4** and **5**, **6** respectively and a common fork branch **7** with the associated connecting terminals **8**, **9**. The common branch is coupled to the two relatively decoupled fork branches **1**, **2** by means of a transformer **10**. The transmission fork of the figure may, for example, be used in transistor-equipped line repeaters for carrier-wave telephone transmission. In this case the line repeater supplies a cable connected to the terminals **5**, **6**, and a measuring instrument is connected to the terminals **3**, **4**. The figure illustrates the line repeater diagrammatically by the signal source **11**, having a voltage 2E and by a series-connected resistor **12**, which represents the internal resistance of the line repeater. The loads at the terminals **3**, **4** and **5**, **6** (i.e. the measuring instrument and the cable respectively) are represented by the resistors **13** and **14** respectively.

In order to provide a transmission fork which is electrically and structurally desirable, the transformer **10** comprises, in accordance with the invention, two identical coupling windings **15**, **16**, which are inductively coupled with a winding **17**, connected to the common fork branch **7**. The ends of winding **17** comprise the connecting terminals **8**, **9** for the common fork branch. Corresponding ends of the two identical coupling windings **15**, **16** are connected to each other by way of fork resistors **18** and **19** respectively. In other words, the resistor **19** is connected between the upper ends of windings **15** and **16**, and the resistor **18** is connected between the lower ends of windings **15** and **16**. The connecting terminals **3**, **4** and **5**, **6** for the two decoupled fork branches **1**, **2** are each formed by one end of one coupling winding **15** and the end of the coupling winding **16** which is not connected to the same fork resistor. The resistances of resistors **18**, **19** are being rendered substantially equal to the characteristic terminal impedances of the decoupled fork branches **1**, **2**. Central tappings of the load resistors **13** and **14** of this device may be connected simultaneously to ground without modification of the circuit.

In the normal operating state of the transmission fork, the fork branches **1**, **2** are loaded by load resistors **13** and **14** respectively, having resistances equal to the characteristic terminal impedances R, so that each of the resistors **18**, **19**, **13**, **14** of the fork has the same value as the characteristic terminal impedance R. The signal source **11** with the internal resistance **12** is matched to the load formed by the transmission fork, so that the internal resistance **12** of the signal source **11** is equal to the load formed by the transmission fork. This may always be accomplished by a suitable choice of the transformation ratio between the winding **17** and the two coupling windings **15**, **16**. If, for example, the internal resistance **12** of the signal source is ½ R, the transformation ratio of 1:1:1 is selected for matching the load and source.

If under these conditions the voltage of the signal source **11** is represented by 2E and the current flowing through the internal resistance **12** is designated by I, a voltage of

$$2E-\tfrac{1}{2}IR \qquad \text{(I)}$$

will appear across the winding **17**. Since the transformation ratio is 1:1:1, this voltage also appears across each at the coupling windings **15**, **16**. The currents passing through the two coupling windings **15**, **16** are identical, due to the symmetry of the transmission fork, and is designated as the current I_0. Since the total number of ampere turns of the transformer **10** is equal to zero the relationship between the currents I_0 and the current I passing through the winding **17** is known. In the embodiment shown in which the number of turns of the winding **17** and each of the two coupling windings **15**, **16** is the same, it follows that:

$$I=2I_0 \qquad \text{(II)}$$

Thus each of the coupling windings **15**, **16** will be traversed by a current I_0 and the voltage across each of these coupling windings will be to $2E-I_0R$.

In spite of the use of the fork resistors 18, 19 in the transmission fork, no losses occur in the transmission fork in the above-described matched state, and the power fed by the signal source 11 to the transmission fork is divided equally between the load resistors 13, 14. This is evident from the following network analysis. The variation of the current passing through the transmission fork may be defined in a simple manner. Assuming that the voltage across the coupling winding 15 produces a current I_1 in the fork resistor 18 and the voltage across the coupling winding 16 produces a current I_2 in the fork resistor 19; the current through the load resistor 13 is designated by I_3. In the figure the assumed directions of the various currents are indicated by the arrows.

The following equations may be found to define the currents I_1, I_2 and I_3:

Considering the circuit including coupling winding 15, load resistor 14, fork resistor 18, and coupling winding 15:

$$2E-I_0R=2I_1R+I_2R-I_3R \quad \text{(III)}$$

Considering the circuit including coupling winding 16, fork resistor 19, load resistor 14, and coupling winding 16:

$$2E-I_0R=2I_2R+I_1R \quad \text{(IV)}$$

Considering the circuit including coupling winding 16, load resistor 13, fork resistor 18, and coupling winding 16:

$$2E-I_0R=2I_3R-I_1R \quad \text{(V)}$$

In addition:

$$I_0=I_2+I_3 \quad \text{(VI)}$$

From these equations it is found that:

$$I_1=\frac{E}{R} \quad \text{(VII)}$$

$$I_2=0 \quad \text{(VIII)}$$

$$I_3=\frac{E}{R} \quad \text{(IX)}$$

Then the fork resistors 18, 19 are not traversed by current, so that no power is dissipated in these resistors 18, 19, whereas each of the load resistors 13, 14 is traversed by a current which is equal to

$$\frac{E}{R}$$

corresponding to a power of

$$\frac{E^2}{R}$$

This is exactly equal to half of the power furnished by the signal source 11 to the fork, since the power from the source is equal to the voltage across the winding 17 ($2E-I_0R$), multiplied by the current traversing the winding 17 $2I_0$ and hence equal to

$$\frac{2E^2}{R}$$

The power produced across the internal resistance 12 of the signal source 11 of the value ½ R is also equal to

$$\frac{2E^2}{R}$$

which only means that the signal source with the internal resistance 12 is matched to the fork, as stated above.

In the device shown the load resistors 13, 14 are relatively decoupled in an effective manner by proportioning each of the fork resistors 18 and 19 so as to be equal to the characteristic terminal impedance R of the fork. This means that a variation in load at the connecting terminals 3, 4 does not produce a current variation at the connecting terminals 5, 6. If, for example, in the device shown one of the load resistors 13 or 14 is varied, equalization currents will flow through the fork resistors 18, 19 (as is evident from the Formulae I–IV with the given dimensions of the fork resistors 18, 19 equal to the characteristic terminal impedance R) so that the current passing through the other resistor 14 or 13 respectively and hence also the voltage across the resistors 14 and 13 respectively remains constant. Even with an excessive variation of, for example, the load resistor 13, such as by an interruption or a short-circuit, so that the current passing through the load resistor 13 or the voltage across it is equal to zero, no variation occurs in the current passing through the other load resistor 14. This current then remains equal to the value

$$\frac{E}{R}$$

as in the matched state of the fork. Conversely, with a shortcircuit or an interruption of the load resistor 14 the current passing through the load resistor 13 will remain equal to the value

$$\frac{E}{R}$$

as in the matched state of the fork.

Apart from the above-stated advantages of the transmission fork shown, i.e. no loss of energy in the matched state and an effective decoupling of the fork branches 13, 14, the transmission fork according to the invention has the important advantage, from an electrical standpoint, that the requirements for the forked transformer are materially simplified, since the parasitic transformer impedances which might affect the fork properties are found to be very low. In addition, the particularly simple structure of the transformer, which comprises only three windings with six connecting wires, renders this fork extremely suitable for the miniature structures actually used in transistor systems.

In the foregoing description it was assumed that the transformation ratio between the winding 17 and the coupling windings 15, 16 is 1:1:1. These considerations, however, apply with the same accuracy to a different transformation ratio for the matching of the signal source 11 to the fork.

The following data are given for a practically thoroughly tested fork of the type described:

Winding 17: 59 turns
Winding 17: 10 mh.
Coupling windings 15, 16: 42 turns,
Coupling windings 15, 16: 5 mh.
Resistors 14, 13, 18, 19: 150 ohms
Transformation ratio windings 17, 16, 15: 1.41:1:1

For the ferromagnetic core of the transformer 10 use is made of a cross-shaped core of the dimensions 14 x 20 x 20 mm. of ferroxcube, which material consists mainly of high-permeable, non-conductive ferrites, whereas the dimensions of the total transmission fork are 16 x 22.5 x 22.5 mm.

It should be noted for the sake of completeness that the device shown may be used for other purposes. For example, a two-wire line may be connected to the terminals 8 and 9, and a transmitter branch and receiver branch may be connected to the terminals, 3, 4 or 5, 6 respectively. An effective relative decoupling between the transmitter branch and the receiver branch is obtained in the manner described above.

What is claimed is:

1. A circuit for connecting a first two-wire line to second and third two-wire lines, said circuit comprising a transformer having a first winding inductively coupled to second and third windings, said second and third windings being identical to each other, means connecting

said first winding to said first line, first and second resistors, means connecting said first resistor between first ends of said second and third windings, means connecting said second resistor between second ends of said second and third windings, and means connecting said second and third two-wire lines between first ends of said third and second windings respectively and second ends of said second and third windings respectively, said first and second resistors each having a value substantially equal to the characteristic impedance of said second and third two-wire lines.

2. A circuit for connecting a first two-wire line to second and third two-wire lines, said circuit comprising a transformer having a first winding with first and second terminals, said first windings being inductively coupled to a second winding having third and fourth terminals and a third winding having fifth and sixth terminals, said second and third windings being identical to each other, means connecting said first two-wire line between said first and second terminal, a first resistor connected between said third and fifth terminals, a second resistor connected between said fourth and sixth terminals, means connecting said second two-wire line between said third and sixth terminals, and means connecting said third two-wire line between said fourth and fifth terminals, said first and second resistors each having a value substantially equal to the characteristic impedance of said second and third two-wire lines.

3. A circuit for connecting a source of signals to first and second two-wire lines, said circuit comprising a transformer having first, second and third inductively coupled windings, said second and third windings being identical to each other and having first and second terminals, respectively, and third and fourth terminals, respectively, means connecting said source to said first winding, first resistor means connected between said first and second terminals, second resistor means connected between said third and fourth terminals, means connecting said first two-wire line between said first and fourth terminals, and means connecting said second two-wire line between said second and third terminals, said first and second resistor means each having a value substantially equal to the characteristic impedance of said two-wire lines.

4. The circuit of claim 3, wherein said source has an internal resistance substantially equal to the load on said source formed by said transformer.

5. The circuit of claim 3, comprising third and fourth resistors connected between said first and fourth, and second and third terminals, respectively, said third and fourth resistors each having a value substantially equal to said characteristic impedance.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,181,087 April 27, 196

Petrus Cornelis Maria Almering

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 1, line 54, for "resistor" read -- resistors --; column 2, line 58, for "at" read -- of --; same column 2, line 72, strike out "to".

Signed and sealed this 2nd day of November 1965.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents