United States Patent [19]

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[54] **COMPENSATED TRANSFORMER CIRCUIT UTILIZING NEGATIVE CAPACITANCE SIMULATING CIRCUIT**

[75] Inventor: **Frederick J. Kiko,** Sheffield Village, Ohio

[73] Assignee: **Lorain Products Corporation,** Lorain, Ohio

[*] Notice: The portion of the term of this patent subsequent to May 6, 1992, has been disclaimed.

[22] Filed: **June 2, 1975**

[21] Appl. No.: **582,858**

Related U.S. Patent Documents

Reissue of:

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Issued: **Aug. 27, 1974**
Appl. No.: **426,826**
Filed: **Dec. 20, 1973**

[52] **U.S. Cl.** .... **333/24 R;** 333/80 R; 323/44 R; 323/48

[51] **Int. Cl.**² **H03H 7/00;** H03H 11/00

[58] **Field of Search** .... 323/6, 44 R, 48, 60, 323/112; 333/12, 17, 24 R, 24 C, 80 R, 80 T; 336/69; 330/107, 109

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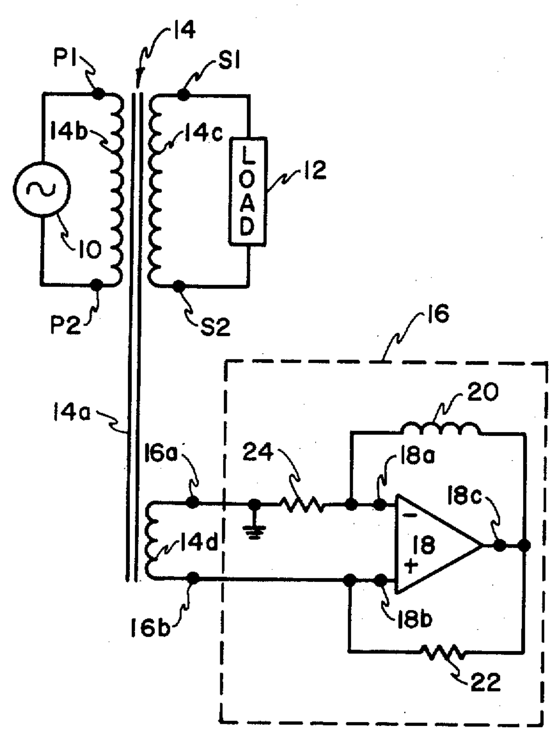
Primary Examiner—Paul L. Gensler
Attorney, Agent, or Firm—Edward C. Jason

[57] **ABSTRACT**

A circuit for reducing or eliminating the effect of the stray capacitance of the windings of a transformer on signals coupled through that transformer. Circuitry is provided for generating voltages and currents which simulate the presence of a negative capacitance and for coupling those voltages and currents to a transformer in cancelling relationships to the stray capacitance thereof. Circuitry is also provided for imposing an upper frequency limit beyond which capacitance cancellation will not occur. The upper frequency limit stabilizes the circuitry and allows signal transmission to be limited to a predetermined desired band of frequencies.

11 Claims, 15 Drawing Figures



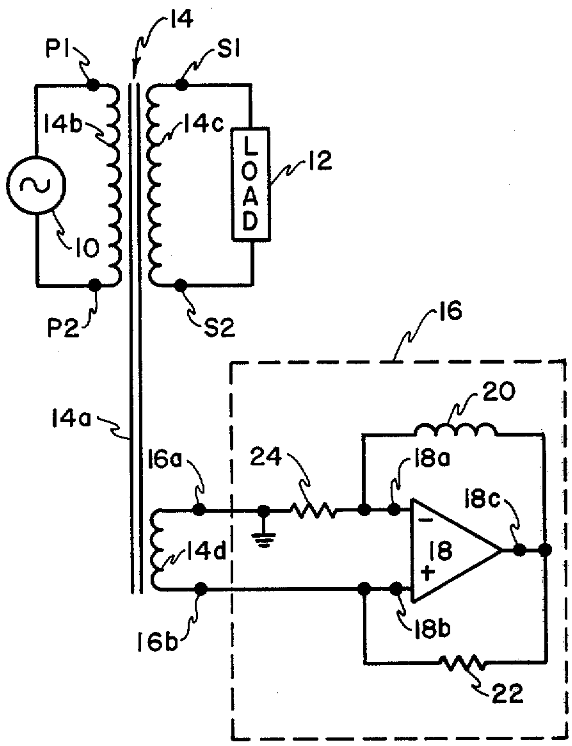


FIG. 1

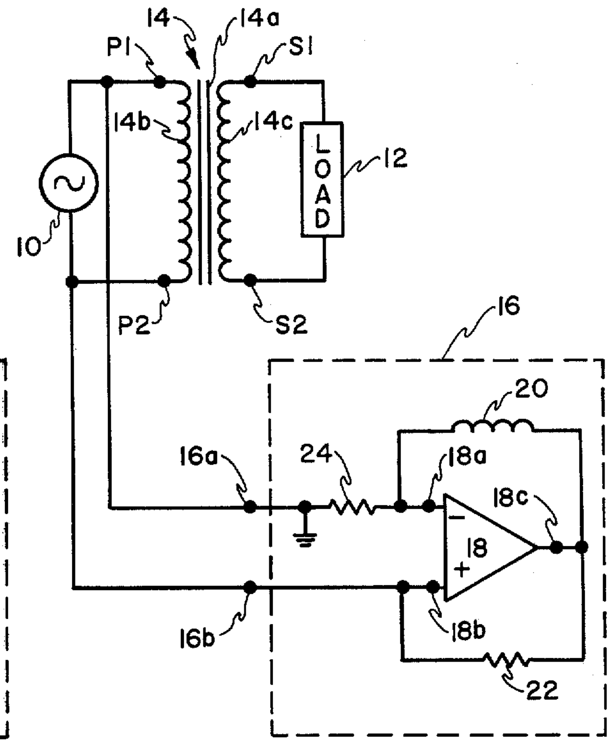


FIG. 1a

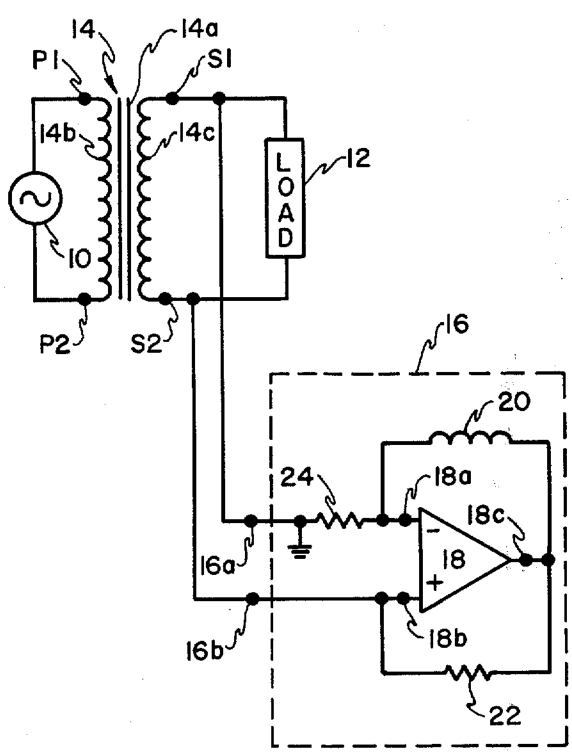


FIG. 1b

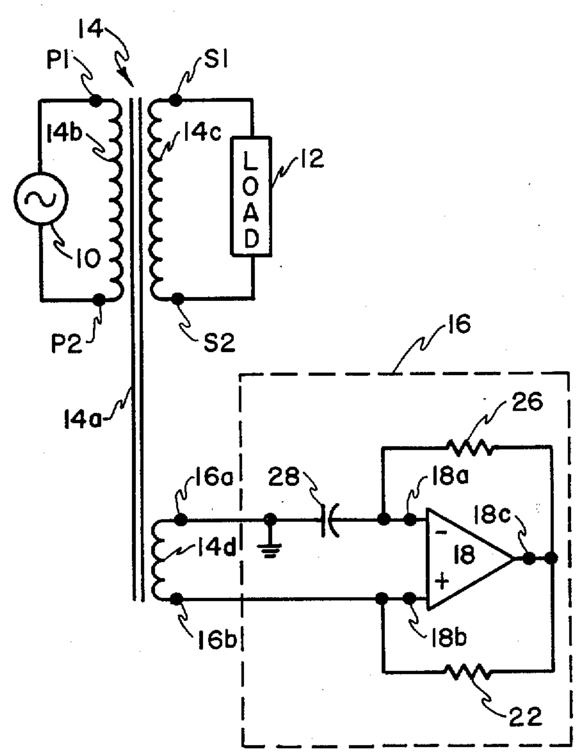


FIG. 2

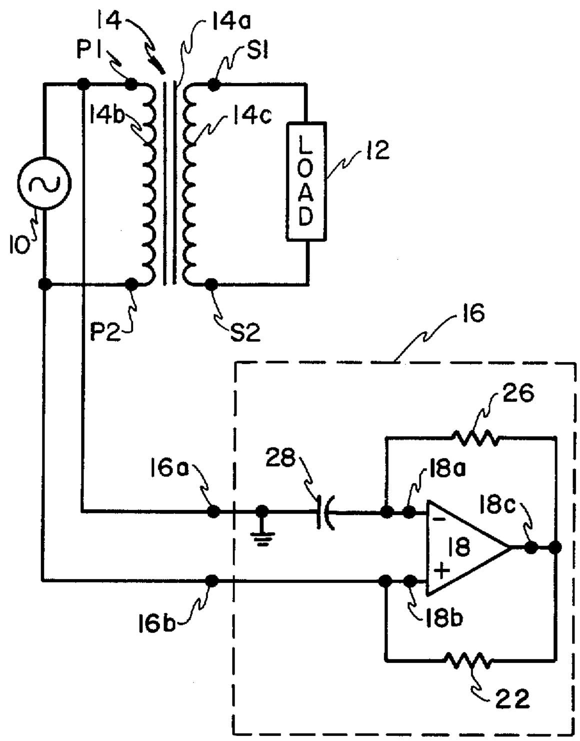


FIG. 2a

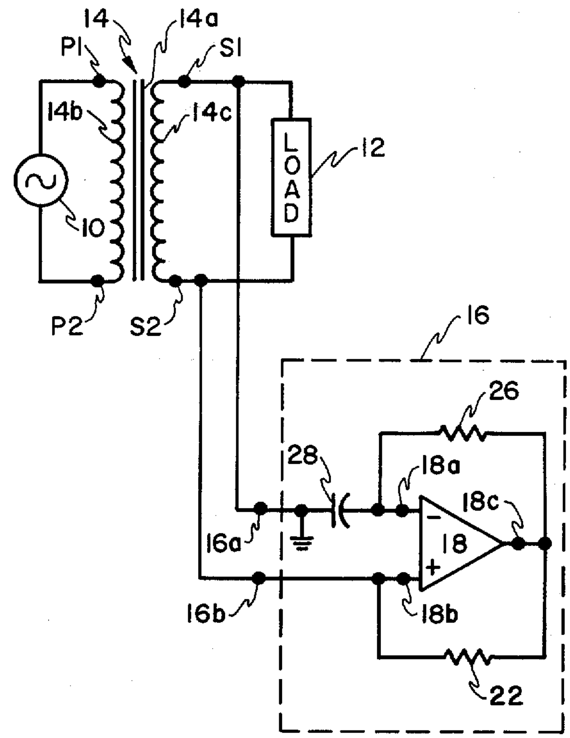


FIG. 2b

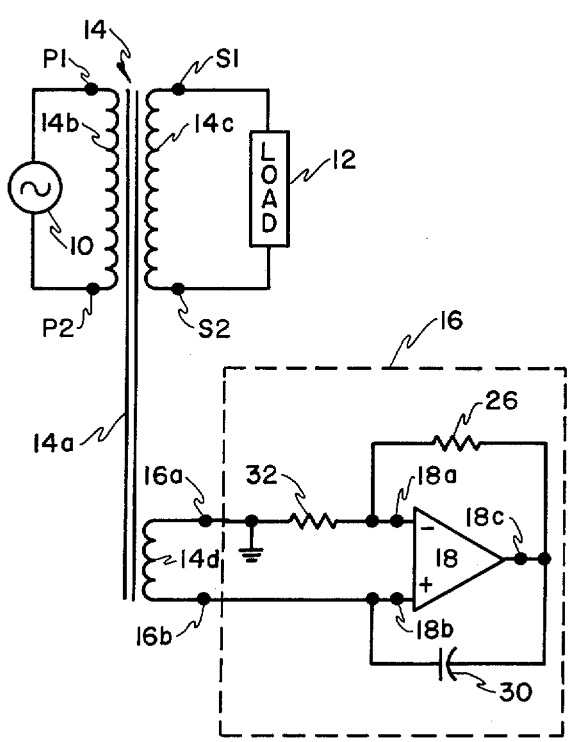


FIG. 3

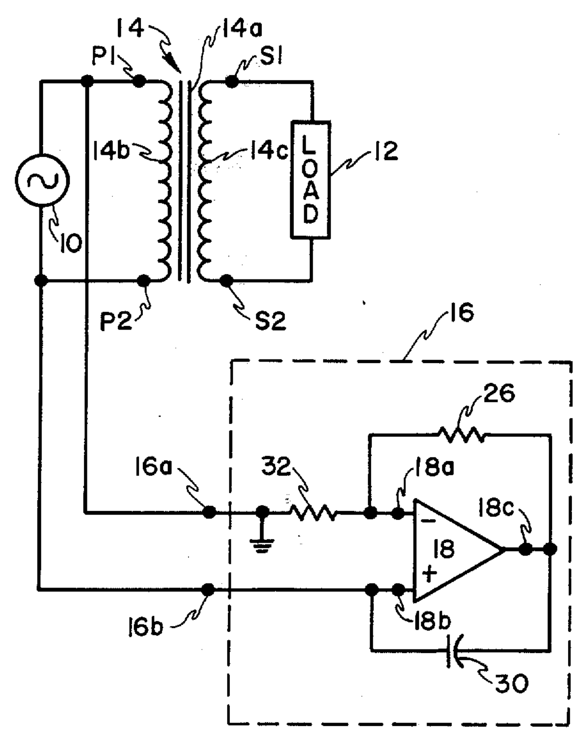


FIG. 3a

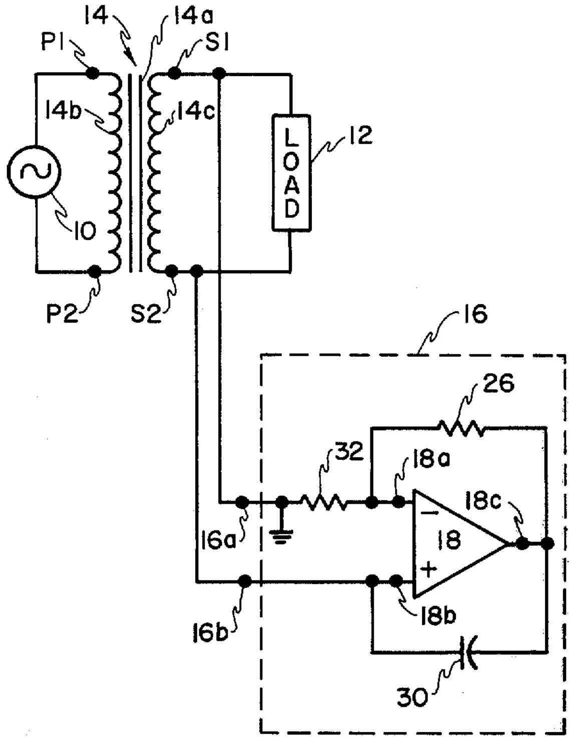


FIG. 3b

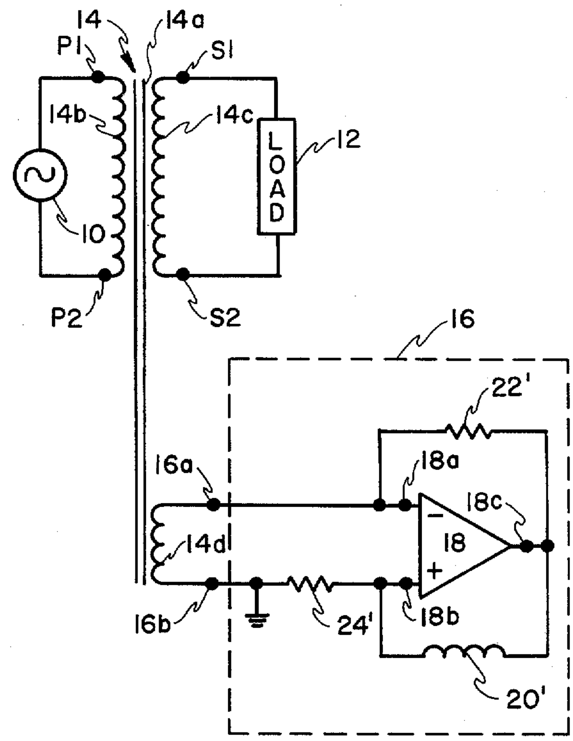


FIG. 4

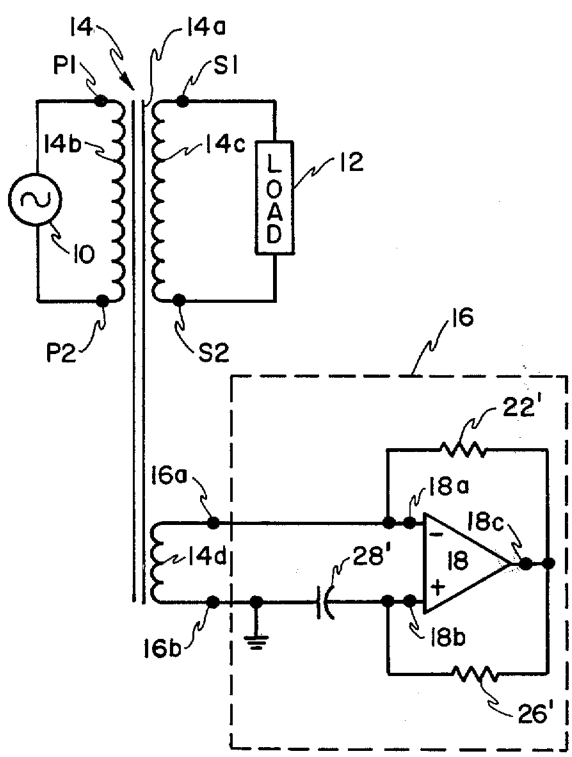


FIG. 5

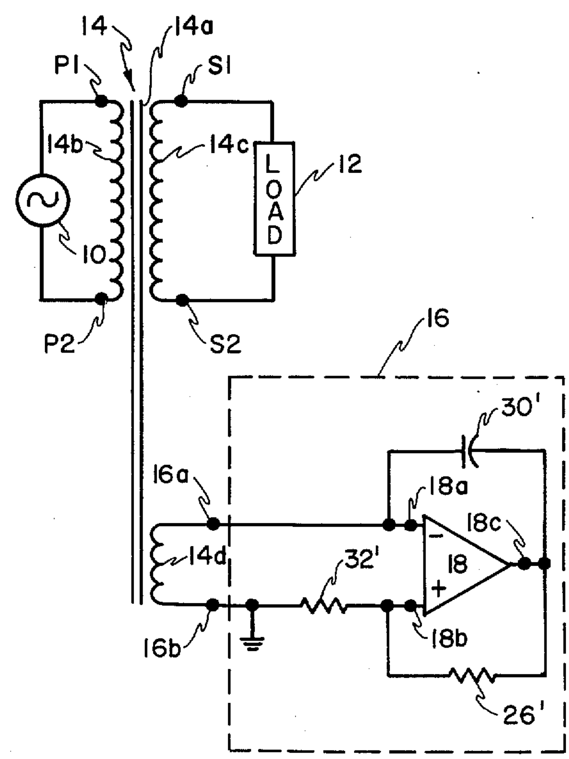


FIG. 6

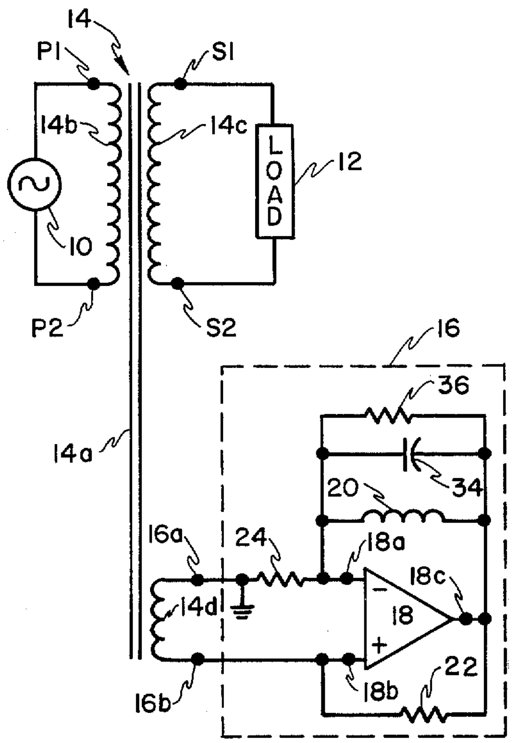


FIG. 7

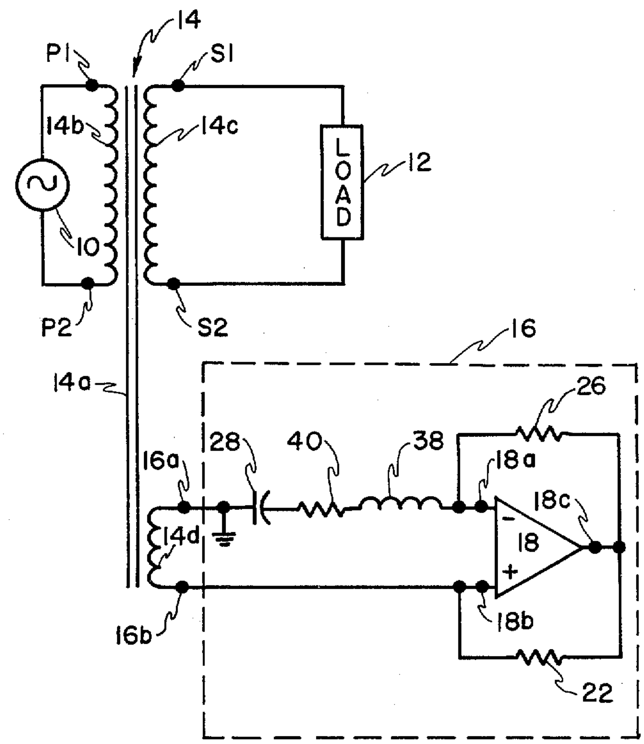


FIG. 8

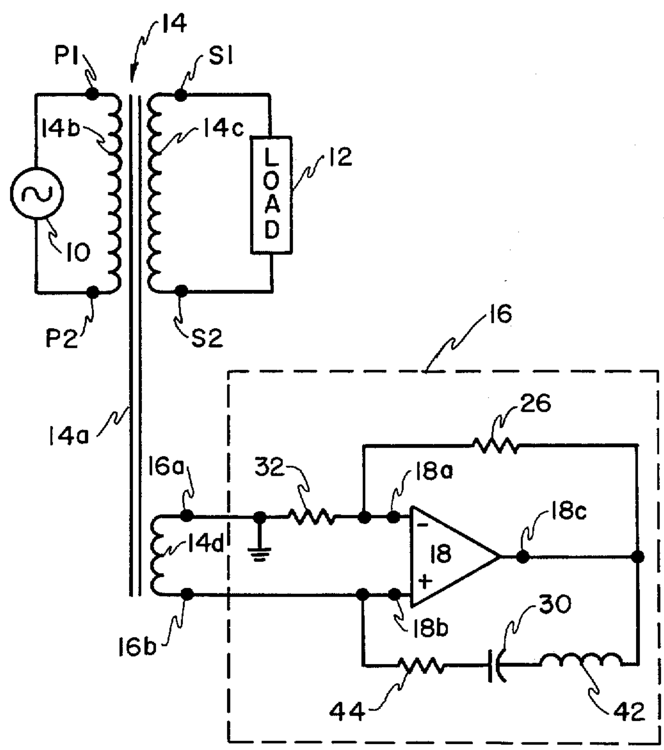


FIG. 9

COMPENSATED TRANSFORMER CIRCUIT UTILIZING NEGATIVE CAPACITANCE SIMULATING CIRCUIT

Matter enclosed in heavy brackets[ ]appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

BACKGROUND OF THE INVENTION

The present invention relates to compensating circuits for transformers and is directed more particularly to circuits for reducing the effect of stray capacitance on signal transmission through transformers.

Because of their usefulness in providing isolation, impedance matching and voltage and current transformations, transformers have become widely used in circuits such as voice-frequency amplifiers. In a voice-frequency amplifier circuit such as, for example, that described in the U.S. Pat. of Charles W. Chambers, Jr., No. 3,706,862, entitled "Amplifier Circuit For Transmission Lines," transformers play a useful role in coupling the amplifier circuitry in series with and across a telephone line.

One serious problem with utilizing transformers for coupling voice-frequency signals is that the windings thereof exhibit a stray, distributed capacitance between the turns of the windings thereof. This stray capacitance causes a portion of the driving signal current to traverse the terminals of the primary winding without inducing corresponding currents in the secondary windings, particularly at the high end of the transmission band. The presence of this stray capacitance has been found to worsen the impedances of transmission lines which include such transformers.

Prior to the present invention it has been the practice to minimize the effect of stray capacitance by utilizing transformers having winding configurations which minimize the distributed capacitance between the turns. The improvement which could be effected in this manner was, however, quite limited and not subject to change once the transformer was made. In addition, such improvements could not be made in existing transformers.

In accordance with the present invention, there is provided capacitance compensating circuitry which improves the high frequency response of transformers having ordinary core materials and ordinary winding configurations. More specifically, the compensating circuitry of the invention is adapted to substantially cancel the stray capacitance of transformers and thereby extend the band of frequencies which may be coupled through the transformer without significant frequency dependent effects. In addition, the circuit of the invention is adapted to allow the desired capacitance cancellation to occur over a controllable band of frequencies extending far beyond that normally provided by ordinary transformers and to suppress that capacitance cancellation for signal frequencies outside of the desired band.

SUMMARY OF THE INVENTION

It is an object of the invention to provide circuitry for improving the signal distortion characteristics of ordinary transformers.

Another object of the invention is to provide compensating circuitry for substantially reducing or eliminating the effect of frequency dependent current flow through the stray capacitance of transformer windings.

Yet another object of the invention is to provide circuitry which substantially cancels the effect of the stray, distributed capacitance of the windings of transformers.

Still another object of the invention is to provide circuitry of the above character including circuitry for suppressing capacitance cancellation at frequencies beyond the band in which capacitance cancellation is desirable.

Another object of the invention is to provide circuitry of the above character which can be used in existing transformers.

DESCRIPTION OF THE DRAWINGS

FIGS. **1, 1a** and **1b** are schematic diagrams of one illustrative embodiment of the compensated transformer circuit of the invention,

FIGS. **2, 2a** and are schematic diagrams showing a second embodiment of the compensated transformer circuit of the invention,

FIGS. **3, 3a** and **3b** are schematic diagrams of a third embodiment of the compensated transformer circuit of the invention,

FIGS. **4, 5** and **6** are schematic diagrams of further embodiments of compensated transformer circuits of the invention, and

FIGS. **7, 8** and **9** are schematic diagrams of embodiments of the invention which include band-limiting circuitry for setting an upper frequency limit beyond which compensation does not occur.

DESCRIPTION OF THE INVENTION

Referring to FIG. **1** there is shown a source of a-c voltage **10** for energizing a load **12** through a transformer **14.** Source **10** may, for example, comprise a transmission line which is energized by a remote voice-frequency source and load **12** may comprise a repeater circuit which amplifies the transmission of signals through that transmission line. In transmission line-repeater systems of this type, a transformer such as **14** is desirable to electrically isolate the repeater circuit from the transmission line and vice-versa.

In the present embodiment, transformer **14** comprises a suitable magnetic core **14a** around which are disposed a primary winding **14b,** a secondary winding **14c** and a tertiary or auxiliary winding **14d.** Because of the adjacency of the turns of windings **14b** and **14c,** transformer **14** exhibits a stray capacitance which may be visualized as a first lumped capacitance connected between primary winding terminals **P1** and **P2** and a second lumped capacitance connected between secondary winding terminals **S1** and **S2.** Alternatively, the lumped, stray capacitance may be visualized entirely across primary winding terminals **P1** and **P2** or entirely across secondary winding terminals **S1** and **S2.** The effect of this stray capacitance is to shunt signal current across the turns of the primary and secondary windings and thereby reduce the percentage of the signal from source **10** that is transformed in transformer **14.** The magnitude of the current through the stray capacitance is ordinarily so low in the low and middle frequency regions of, for example, the voice-frequency band that the effect thereof may be neglected. At the high end of the voice-frequency band, however, the current through the stray capacitance is substantial and prevents an appreciable portion of the high frequency components of the signal from affecting load **12.** This condition results in signal distortion and, in the case of use in a transmission line, in a worsening of the impedance of the transmission line.

To the end that the effects of the stray capacitance of transformer **14** may be substantially reduced or eliminated, there is provided a capacitance simulating network **16** which, in the embodiment of FIG. **1,** is coupled to transformer **14** through tertiary winding **14d.** As will be described more fully presently, simulating network **16** serves to establish at terminals **16a** and **16b** thereof, voltages and currents which effectively cancel the stray capacitance of transformer **14.** As a result, simulating network **16** allows signal transmission through transformer **14** to proceed as if that transformer had no stray capacitance and thereby greatly reduces the distortion of the high frequency components of the signal.

In accordance with one feature of the present invention, the desired capacitance cancellation is produced by simulating between terminals **16a** and **16b** the presence of a negative capacitance having a magnitude which, through winding **14d,** approximately equals the real stray capacitance of transformer **14.** The result of applying this simulated negative capacitance to transformer **14** is that the negative or simulated capacitance combines in parallel with the positive or real stray capacitance, according to the usual parallel combination rules, to generate an equivalent combined capacitance having a value approximately equal to zero. The latter condition effectively prevents transformer **14** from affecting the high frequency components of signal transmission from source **10** to load **12.**

In the present embodiment, simulating network **16** includes an operational amplifier **18** having an inverting input **18a,** a noninverting input **18b,** and an output **18c.** Simulating network **16** also includes feedback means comprising a negative feedback impedance here shown as an inductor **20** connected between amplifier output **18c** and inverting amplifier input **18a,** a positive feedback impedance here shown as a resistor **22** connected between amplifier output **18c** and non-inverting amplifier input **18b,** and an input feedback impedance here shown as a resistor **24** connected between input terminal **16a** and inverting amplifier input **18a.** The relationship governing the magnitude of the impedance Z_{in} looking into terminals **16a** and **16b** of this type of circuit, that is, a circuit wherein the input feedback impedance is connected to the inverting amplifier input is given by the formula $Z_{in}=-Z_2 \cdot Z_3/Z_1$, where Z_1 is the negative feedback impedance, Z_2 is the input feedback impedance and Z_3 is the positive feedback impedance. This relationship allows the values of inductor **20** and resistors **22** and **24** to be selected to afford the necessary value of negative capacitance.

In the event that it is desirable to provide stray capacitance cancellation in transformers which do not have a tertiary winding as, for example, where it is desirable to add the compensating circuit of the invention to an existing two-winding transformer, this may be accomplished by connecting simulating network **16** to the existing transformer in the manner shown in FIG. **1a** or **1b.** The circuits of FIGS. **1a** and **1b** are generally similar to that of FIG. 1 and like functioning parts are similarly numbered. It will be understood, however, that the component values utilized in the circuits of FIGS. **1a** and **1b** are not necessarily the same as those utilized in the circuit of FIG. 1.

As shown in FIG. **1a,** the input terminals of simulating network **16** may be connected across primary winding **14b** of transformer **14.** In this position, simulating network **16** operates in the manner described in connection with the circuit of FIG. 1 to substantially cancel the stray capacitance of transformer **14.** Similarly, as shown in FIG. **1b,** capacitance cancellation may be provided by connecting the input terminals of simulating network **16** across the secondary winding **14c** of transformer **14.** Thus, the circuit of the invention may be applied to existing two-winding transformers as well as to specially wound three-winding transformers.

The desired negative capacitance may also be realized with the feedback circuitry shown in FIG. 4. The circuit of FIG. 4 is similar to that of FIG. **1,** like functioning parts being similarly numbered. The circuit of FIG. 4 differs from that of FIG. 1 primarily in that in FIG. 4 inductor **20′** is a positive feedback element connected to non-inverting amplifier input **18b,** resistor **22′** is a negative feedback element connected to inverting amplifier input **18a** and resistor **24′** is an input feedback element connected to non-inverting amplifier input **18b.** In circuits of the type shown in FIG. 4, that is, circuits wherein the input feedback impedance is connected to the non-inverting amplifier input, the relationship governing the magnitude of the impedance Z_{in} looking into terminals **16a** and **16b** is given by the formula $Z_{in}=-Z_2 \cdot Z_1/Z_3$, where Z_1 is the negative feedback impedance, Z_2 is the input feedback impedance and Z_3 is the positive feedback impedance. Thus, capacitance simulating circuit **16** may be realized with an inductive reactance in either the negative or the positive feedback path. It will be understood that capacitance simulating circuit 16 of FIG. 4 may be coupled to transformer **14** by metallic connections across the primary or secondary winding, as shown in FIGS. **1a** and **1b.**

The circuit of FIG. 2 shows an embodiment of the invention in which capacitance cancellation is afforded without utilizing an inductor in the feedback path of amplifier **18.** The circuit of FIG. **2** is generally similar to that of FIG. 1 and like functioning parts are similarly numbered. The circuit of FIG. 2 differs from that of FIG. 1 primarily in that in the circuit of FIG. 2 the simulation of negative capacitance between terminals **16a** and **16b** is accomplished by means of a capacitive reactance **28** connected in the input feedback path of amplifier **18,** rather than by an inductive reactance in the negative feedback path of amplifier **18,** as shown in FIG. 1. The effect produced by the circuit of FIG. 2 and the manner in which it is produced is, however, the same as that described in connection with the circuit of FIG. 1.

FIGS. **2a** and **2b** show embodiments of the invention wherein the simulating network of FIG. **2** is connected, respectively, across the primary and secondary windings of transformer **14.** As in the case of FIGS. **1a** and **1b,** the primary and secondary winding connections shown in FIGS. **2a** and **2b** allow simulating network **16** to be applied to existing two-winding transformers. Thus, the circuits of FIGS. **2a** and **2b** bear the same relationship to the circuit of FIG. 2 that the circuits of FIGS. **1a** and **1b** bear to the circuit of FIG. 1.

Referring to FIG. **5,** there is shown another embodiment of the invention in which a capacitive input feedback impedance is utilized to simulate the desired negative capacitance between terminals **16a** and **16b**. The circuit of FIG. 5 is similar to that of FIG. 2 and like functioning parts are similarly numbered. The circuit of FIG. 5 differs from that of FIG. 2 primarily in that the input feedback capacitor **28'** of FIG. 4 is connected to non-inverting amplifier input **18b** rather than to inverting amplifier input **18a**, as shown in FIG. 2. Thus, the circuit of FIG. 5 will be seen to bear the same relationship to the circuit of FIG. 2 that the circuit of FIG. 4 did to the circuit of FIG. 1. It will be understood that a circuit of the type shown in FIG. 5 may also be coupled to transformer **14** by metallic connections across the primary or secondary winding as shown in FIGS. **2a** and **2b**.

The circuit of FIG. 3 shows an embodiment of the invention in which capacitance cancellation is afforded by a simulating network having a capacitor **30** in the positive feedback path of amplifier **18** and resistors **26** and **32** in the respective negative and input feedback paths thereof. The effect produced by simulating network **16** of FIG. 3 and the manner in which that effect is produced is, however, the same as that described in connection with the circuit of FIG. 1.

FIGS. **3a** and **3b**, show embodiments of the invention wherein the simulating network of FIG. 3 is connected, respectively, across the primary and secondary windings of transformer **14**. As in the cases of FIGS. **1a** and **1b**, and **2a** and **2b**, the primary and secondary winding connections shown in FIGS. **3a** and **3b** allow simulating network **16** to be applied to existing two-winding transformers. Thus, the circuits of FIGS. **3a** and **3b** bear the same relationship to the circuit of FIG. 3 that the circuits of FIGS. **1a** and **1b**, and **2a** and **2b** bear to the circuits of FIGS. 1 and 2, respectively.

Referring to FIG. 6, there is shown another embodiment of the invention in which a capacitive feedback impedance is utilized to simulate the desired negative capacitance between terminals **16a** and **16b**. The circuit of FIG. 6 is similar to that of FIG. 3 and like functioning parts are similarly numbered. The circuit of FIG. 6 differs from that of FIG. 3 primarily in that capacitor **30'** of FIG. 6 is connected in the negative feedback path of amplifier **18** rather than in the positive feedback path of amplifier **18**, as shown in FIG. 3. Thus, the circuit of FIG. 6 will be seen to bear the same relationship to the circuit of FIG. 3 that the circuits of FIGS. 4 and 5, respectively, bore to the circuits of FIGS. 1 and 2. It will be understood that a circuit of the type shown in FIG. 6 may also be coupled to transformer **14** by metallic connections across the primary or secondary winding as shown in FIGS. **3a** and **3b**.

In view of the foregoing, it will be seen that the compensated transformer circuit of the invention may be realized with either inductive or capacitive feedback elements and that such inductive or capacitive elements may be connected in the negative feedback path, the positive feedback path or the input feedback path. It will further be seen that each of the embodiments of the invention may be realized by connecting the capacitance simulating network to the transformer through a tertiary winding, by a metallic connection across the primary winding or by a metallic connection across the secondary winding.

To the end that the capacitance simulating activity of network **16** may be suppressed at frequencies above the band of frequencies within which capacitance cancellation is desired, there is provided herein bandlimiting circuit which is applicable to each of the previously described embodiments of the invention. Referring to FIG. 7, for example, there is shown a compensated transformer circuit of the type shown in FIG. 1 which includes a band-limiting network here shown as a capacitor **34** in parallel with a resistor **36**. At the low and middle frequency regions of the desired band, capacitor **34** and resistor **36** have only a negligible effect and allow inductor **20** to cooperate with resistors **22** and **24** to produce the desired negative capacitance simulation. At frequencies beyond the high end of the desired band, however, the effect of capacitor **34** increases with frequency to cancel an increasing proportion of the capacitance simulating effect of inductor **20**. This occurs because the reactance of capacitor **34** decreases with frequency and thereby causes overall impedance of the negative feedback path to decrease with frequency, even though the reactance of inductor **20** increases with frequency for frequencies beyond the desired transmission band. Thus, capacitor **34** reduces the magnitude of the simulated negative capacitance, as a function of frequency, for frequencies beyond the desired transmission band.

In order to stabilize capacitance simulating network **16** in the presence of the parallel resonance condition which arises between inductor **20** and capacitor **34**, a resistor **36** may be connected in parallel with inductor **20** and capacitor **34**. The effect of this resistor is to place an upper limit on the magnitude of the impedance of the negative feedback path and thereby limit the gain of amplifier **18**. In other words, the resistor **36** may be said to "spoil the Q" of the tank circuit including inductor **20** and capacitor **34**.

Referring to FIG. 8 there is shown a compensated transformer circuit of the type shown in FIG. 2 which includes a band-limiting network here shown as an inductor **38** and resistor **40**. The latter elements are connected in series with input feedback capacitor **28** to cancel the capacitance simulating effect of capacitor **28** for frequencies beyond the upper end of the desired transmission band. This occurs because the reactance of inductor **38** increases with frequency and thereby causes the overall impedance of the input feedback path to increase with frequency, even though the reactance of capacitor **28** decreases with frequency for frequencies beyond the desired transmission band. Thus, inductor **38** decreases the magnitude of the simulated negative capacitance, as a function of frequency, for frequencies beyond the desired transmission band.

In order to stabilize capacitance simulating network **16** in the presence of a series resonant condition in capacitor **28** and inductor **38**, as resistor **40** may be connected in series in the input impedance path. The effect of this resistor is to place a lower limit on the magnitude of the impedance of that branch and thereby limit the gain of amplifier **18**. In other words, resistor **40** may be said to "spoil the Q" of the series resonant circuit including capacitor **28** and inductor **38**.

Referring to FIG. 9, there is shown a compensated transformer circuit of the type shown in FIG. 3 which includes a band-limiting circuitry here shown as an inductor **42** and a resistor **44**. The latter elements are connected in series with capacitor **30** in the positive feedback path of amplifier **18**. In this location, inductor **42** serves to cancel the capacitance simulating effect of capacitor **30** for frequencies beyond the upper end of the desired transmission band in a manner generally similar to that described in connection with FIGS. 7

and 8. As in the case of resistors 36 and 40 in FIG. 7 and 8, resistor 44 is provided to stabilize the response of the capacitance simulating network at frequencies near those at which capacitor 30 and inductor 42 approach a condition of resonance.

In view of the foregoing, it will be seen that the band-limiting circuitry of the invention may be applied in embodiments of the invention wherein a reactance is connected in the negative feedback path, in the positive feedback path or in the input feedback path. It will further be seen that the applicability of the band-limiting circuitry of the invention is unaffected by the manner in which the capacitance simulating circuitry is coupled to transformer 14, that is, whether the coupling is by means of a tertiary winding such as 14d or by metallic connections across the primary or secondary windings.

It will be understood that the embodiments shown herein are for illustrative purposes only and may be changed or modified without departing from the spirit and scope of the appended claims.

What is claimed is:

[1. A compensated transformer circuit comprising, in combination, a transformer including a primary and a secondary winding, capacitance simulating means for establishing voltages and currents which affect the circuitry to which said voltages and currents are applied as if a negative capacitance were connected to said circuitry, said negative capacitance having a magnitude substantially proportional to the stray capacitance of said transformer, and coupling means for coupling said capacitance simulating means to said transformer to substantially cancel the effect which said stray capacitance has on the voltages across and currents through said primary and secondary windings.]

[2. A compensated transformer circuit as set forth in claim 1 in which said coupling means comprises a tertiary winding in said transformer.]

[3. A compensated transformer circuit as set forth in claim 1 in which said coupling means includes means for connecting said capacitance simulating means across said primary winding.]

[4. A compensated transformer circuit as set forth in claim 1 in which said coupling means includes means for connecting said capacitance simulating means across said secondary winding.]

[5. A compensated transformer circuit as set forth in claim 1 including band-limiting means for placing an upper frequency limit on the band of frequencies within which said capacitance simulating means cancels said stray capacitance.]

[6. A compensated transformer circuit including, in combination, a transformer having a primary and a secondary winding, a capacitance simulating circuit comprising a plurality of terminals, an amplifier, a plurality of feedback elements and means for connecting said feedback elements to said amplifier to establish between said terminals an effective negative capacitance having a magnitude substantially proportional to the stray capacitance of said transformer, said compensated transformer circuit further including coupling means for coupling said terminals to said transformer to substantially cancel the effect which said stray capacitance has on the transformation of voltage and current in said transformer.]

[7. A compensated transformer circuit as set forth in claim 6 including band-limiting means for placing an upper frequency limit on the band of frequencies within which said capacitance simulating circuit cancels said stray capacitance.]

[8. A compensated transformer circuit as set forth in claim 6 in which said amplifier is an operational amplifier of the type which includes an inverting input, a non-inverting input and an output and in which said plurality of feedback elements includes a positive feedback impedance, a negative feedback impedance and an input feedback impedance.]

[9. A compensated transformer circuit as set forth in claim 8 wherein said input feedback impedance is connected to said inverting input.]

[10. A compensated transformer circuit as set forth in claim 8 wherein said input feedback impedance is connected to said noninverting input.]

[11. A compensated transformer circuit as set forth in claim 8 including band-limiting means for placing an upper frequency limit on the band of frequencies within which said capacitance simulating circuit cancels said stray capacitance.]

[12. A compensated transformer circuit as set forth in claim 8 wherein one of the feedback impedances comprises a reactance and wherein the remaining feedback impedances comprise resistors.]

[13. A compensated transformer circuit as set forth in claim 12 including band-limiting means for cancelling the effect of said reactance for frequencies beyond the band of frequencies within which the cancellation of stray capacitance is desirable.]

[14. A compensated transformer circuit as set forth in claim 8 wherein said negative feedback impedance comprises an inductor and wherein said positive and input feedback impedances comprise resistors.]

[15. A compensated transformer circuit as set forth in claim 8 wherein said input feedback impedance comprises a capacitor and wherein said positive and negative feedback impedances comprise resistors.]

[16. A compensated transformer circuit as set forth in claim 8 wherein said positive feedback impedance comprises a capacitor and wherein said negative and input feedback impedances comprise resistors.]

[17. A compensated transformer circuit as set forth in claim 8 wherein said positive feedback impedance comprises an inductor and wherein said input and negative feedback impedances comprise resistors.]

[18. A compensated transformer circuit as set forth in claim 8 wherein said negative feedback impedance comprises a capacitor and wherein said positive and input feedback impedances comprise resistors.]

19. A transformer circuit which provides an uninterrupted path for the flow of primary and secondary current and which compensates for the frequency dependent attenuation of transformer signals that is introduced by the stray capacitance of the windings of the transformer comprising, in combination, a magnetic core, primary, secondary, and tertiary windings disposed on said core, an impedance simulating network including feedback circuitry for establishing voltages and currents which affect the circuitry to which said voltages and currents are applied as if a negative capacitance were connected to said circuitry, said negative capacitance having a magnitude substantially proportional to the stray capacitance of said transformer, and coupling means for coupling said impedance simulating network to said tertiary winding to effectively cancel the stray capacitance of said transformer.

20. A transformer circuit as set forth in claim 19 including band-limiting means for placing an upper fre-

quency limit on the band of frequencies within which said impedance simulating network cancels said stray capacitance.

21. A transformer circuit as set forth in claim 19 in which said impedance simulating network includes an operational amplifier having an inverting input, a non-inverting input and an output, a positive feedback impedance, a negative feedback impedance, and an input feedback impedance.

22. A transformer circuit as set forth in claim 21 wherein said input feedback impedance is connected to said inverting input.

23. A transformer circuit as set forth in claim 21 wherein said input feedback impedance is connected to said non-inverting input.

24. A transformer circuit as set forth in claim 21 wherein one of the feedback impedances comprises a reactance and wherein the remaining feedback impedances comprise resistors.

25. A transformer circuit as set forth in claim 21 wherein said negative feedback impedance comprises an inductor and wherein said positive and negative feedback impedances comprise resistors.

26. A transformer circuit as set forth in claim 21 wherein said input feedback impedance comprises a capacitor and wherein said positive and negative feedback impedances comprise resistors.

27. A transformer circuit as set forth in claim 21 wherein said positive feedback impedance comprises a capacitor and wherein said negative and input feedback impedances comprise resistors.

28. A transformer circuit as set forth in claim 21 wherein said positive feedback impedance comprises an inductor and wherein said input and negative feedback impedances comprise resistors.

29. A transformer circuit as set forth in claim 21 wherein said negative feedback impedance comprises a capacitor and wherein said positive and input feedback impedances comprise resistors.

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