PATENT SPECIFICATION

DRAWINGS ATTACHED

Inventor: EDMUND RAMSAY WIGAN

1,008,482

1,008,482

THE PATENT OFFICE LONDON

Date of filing Complete Specification Jan. 21, 1964.

Application Date Nov. 9, 1962. *No. 42533/62.*

Complete Specification Published Oct. 27, 1965.

© *Crown Copyright 1965.*

Index at acceptance:—G1 U(5M4B, 5M4C, 5P12, 13B4, 13BX)

Int. Cl.:—G 01 r

COMPLETE SPECIFICATION

Improvements in Potentiometric Measuring Circuits

We, GRIFFIN & GEORGE LIMITED, a British Company, of 285, Ealing Road, Alperton, Wembley, Middlesex, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to potentiometric measuring circuits and has for an object to provide an instrument which is capable of comparing vectorially complex voltages in A.C. circuits over a wide range of frequencies with a high degree of accuracy and consistency but without recourse to a large number of delicate precision components. The instrument envisaged is thus a voltage comparison instrument as opposed to one which measures absolute voltage values.

Another object is to provide an instrument which can be made relatively economically from standard components and will withstand frequent use.

If two networks, each consisting of different kinds of impedance having electrically matched counterparts in the other network, are connected across a source of alternating current in the appropriate manner, then two potentials, equal in magnitude but exactly displaced by 90°, can be obtained, one from each network; and by suitable provision for tapping off varying proportions of each of these potentials, an analysis of an unknown voltage can be made in either cartesian or polar coordinates. Each network consists basically of three impedances arranged to present two paths through the network, two of these impedances being such—*e.g.* a resistor and a capacitor—that their characteristic phase angles differ by substantially 90°. These impedances are connected in series across the source of alternating current.

There are two alternative ways of connecting the networks across the A.C. source. In the first, they are in parallel with each other, and in the second they are in series.

In the first arrangement, each network has first and second impedances, whose characteristic phase angles differ by 90°, connected in series, but in one network the first impedance is shunted by the third impedance whilst in the other network the corresponding second impedance is shunted by the corresponding third impedance. In this circuit arrangement, the currents in the two shunt impedances differ in phase by the phase angle between the respective first and second impedances, and in magnitude by the ratio between the values of the first and second impedances at the frequency of excitation.

In the second arrangement, each network has the respective first and second impedances in parallel paths, but in one network the first impedance is connected in series with the third impedance (*i.e.* the first and third in series are shunted by the second) whilst in the other network the second impedance is connected in series with the third impedance (*i.e.* the second and third in series are shunted by the first).

In both forms of circuit, according to the present invention, the third impedances are constituted by loaded transformers, the characteristics of which are matched over the working frequency range. The load on the secondary of each transformer includes a potetiometer, which is thus electrically isolated from its counterpart in the other network, so that complete freedom of interconnection of the output circuits is provided. In this way, the output potentials or currents can be added or subtracted algebraically, and the circuit can be arranged to operate in cartesian or polar

[*Price 4s. 6d.*]

coordinates. Furthermore, vector comparisons can be carried out in all four quadrants.

By using a transformer ratio other than 1:1, and connecting the transformers so as to step down the voltages across their respective potentiometers, the ohmic resistance of each potentiometer can be reduced for the same input impedance of the loaded transformer—*i.e.* the value of the third impedance referred to above—so that increased tolerances can be accepted for these components without risk of compromising the quadrature relationship between the potentials developed across them. Hence, standard commercial components can be used in place of precision articles without impairing the overall accuracy of the instrument.

Preferably, the main impedances used in the two networks are capacitors and resistors only, thus avoiding the errors due to leakage fields and resistance components inherent in inductances. The transformers are not used as inductive impedances in the derivation of the quadrature relationships, but only as couplings, the absolute errors in the loaded transformers being insignificant so long as they are accurately matched over the working frequency range.

Advantageously, the capacitors in the networks can be changed with change of frequency so as to maintain substantially constant the input impedance of the instrument.

The facility with which the instrument can be used to explore the magnitudes and phase angles of unknown voltages in a circuit under examination is materially enhanced by the addition of a phase shifting network. This may be placed either between the instrument and the energising A.C. source or between the latter and the circuit under examination. Although, in the first alternative, the phase shifts will give rise to some loss of output current from the A.C. source, which has the effect of reducing the currents in the loaded transformer secondaries, there is a compensating advantage in the fact that its variable capacitor can be ganged with the variable capacitors in the two networks, so that a single frequency adjustment can be used for both circuits.

Practical embodiments of the invention will now be described, by way of example only, with reference to the drawings accompanying the Provisional Specification in which:

Figure 1 is a simplified circuit diagram of a parallel-network instrument according to the present invention;

Figure 2 is a modified circuit diagram;

Figure 3 is a block diagram of a series-network instrument;

Figure 4 is a more detailed circuit diagram of the instrument of Figure 3;

Figures 5—7 illustrate alternative circuit connections for the loads on the network transformers of Figure 1, Figure 2 or Figure 4, and

Figure 8 is a modification which is particularly applicable to polar coordinate measurements.

Referring first to Figure 1 of the drawings, two networks at A and B respectively are connected in parallel across the secondary of an input transformer T_1, the centre tap 10 on the secondary being earthed. Each network consists of capacitative and resistive impedances, the total capacity and the total resistance in each network, being equal to those in the other network.

In network A, a resistor R_A is connected in series with two equal capacitors C_{A1} and C_{A2}. The resistor R_A constitues one and the two capacitors C_{A1}, C_{A2} constitute the other of the two series-connected impedances referred to earlier. Across the resistor R_A is connected a transformer T_A whose secondary is loaded by a potentiometer resistor P_A. The slider 11 of this potentiometer is connected to one input terminal 12 for connection to the source of unknown voltage. The centre tap 13 on the secondary of the loaded transformer T_A is connected to one end of the primary of a detector coupling transformer T_2.

In network B, a capacitor C_B is connected in series with two equal resistors R_{B1} and R_{B2}. The capacitor C_B constitutes one and the two resistors R_{B1} and R_{B2} together constitute the other of the two series-connected impedances referred to earlier, the value of the capacitor C_B being equal to half that of either of the capacitors C_{A1}, C_{A2} whilst the two resistors R_{B1} and R_{B2} are each equal to half the value of the resistor R_A. Hence the capacitative impedances of the two networks A, B are equal, as also are the resistive impedances. Across the capacitor C_B is connected a loaded transformer T_B whose secondary is shunted by a potentiometer resistor P_B, the slider 14 of which is connected to the other input terminal 15 for the unknown voltage. The centre tap 16 of the secondary of the loaded transformer T_B is connected to the other end of the primary of the detector coupling transformer T_2.

The two transformers T_A, T_B are not necessarily of high precision provided that they are so matched that their errors are similar over the working frequency range. They must both present closely similar input impedances, when loaded, throughout this range in order that there should be no disparity in voltage ratio due to frequency change. Even so, a considerable latitude—in terms of precision instruments—may be tolerable in transformer inequalities. For example, tests were made on an instrument connected basically in accordance with the circuit of Figure 1 wherein the open-circuit inductances of the two transformers T_A and T_B differed by a ratio of 2:1. At an energising frequency of 100 c.p.s., a quadrature error at the terminals 12, 15 of no more than 3° was measured, and this error was reduced to an unmeasurable value at

1000 and 5000 c.p.s. It nevertheless remains highly desirable to select as the transformers T_A and T_B a pair whose errors are as nearly identical as possible.

In the circuit of Figure 1 as so far described, no provision is made for maintaining the impedance values reasonably constant over the working frequency range. If commercial components are used throughout, there will doubtless be some errors in the resistors R_A, R_{B1}, R_{B2}, P_A, and P_B and losses in the capacitors C_{A1}, C_{A2}, and C_B. Also, there may be series and shunt losses at the transformers T_A, T_B, and current ratio imperfections in both magnitude and phase between the currents in the potentiometer resistor loads P_A, P_B and the inputs of the respective transformers. Within the practical limits of tolerance imposed by these conditions, however, the nominal values of the capacitors C_{A1}, C_{A2} and C_B must be selected to cover the working frequency range.

In order to maintain the necessary balance of the networks A and B, all capacitors in them must be adjusted, inversely as the frequency at which the instrument is to be used, both simultaneously and to the same degree, and hence in a practical form of instrument each capacitor C_{A1}, C_{A2} or C_B will, in fact, be a bank of capacitors which can be selectively switched into circuit by a ganged multi-contact switch indicated schematically in the drawing by chain lines S_1 interconnecting the several capacitors.

The circuit diagram of Figures 1 includes also a multi-bank ganged change-over switch S_2, the various contacts of which are shown in the normal operating position. When the switch S_2 is moved to its other positions the impedances R and C are connected as a Wien bridge so that the frequency of excitation can be adjusted as necessary to ensure that the values of the impedances are balanced.

In using an instrument as described above, the output from the potential divider P_A represents the real term of a complex voltage whilst that from the potential divider P_B represents the quadrature term. In order, therefore, to examine a passive circuit, the A.C. source which energises the instrument input transformer T_1 is adjusted to the required frequency and the appropriate values of the capacitors C_{A1}, C_{A2} and C_B are selected by the ganged switch S_1. The passive circuit is energised in parallel with the instrument and is explored by applying unknown voltages generated in the circuit successively across the terminals 12, 15. The sliders 11, 14 are then adjusted for each test of an unknown voltage until a null balance is detected by the detector connected across the transformer T_2. The readings of the potentiometer sliders 11, 14 at balance then indicate the magnitude and phase of the unknown voltage.

Typical circuit values for the instrument shown in Figure 1 are as follows:

all transformers	ratio 1:1
resistor R_A	3184Ω
resistors R_{B1}, R_{B2}	each 1592Ω
capacitors C_{A1}, C_{A2}	„ 1μF at 100 c.p.s.
capacitor C_B	0.5μF „ „ „
pot. resistors P_A, P_B	„ 5kΩ

The transformers are preferably screened and the screens earthed.

From inspection of the circuit of Figure 1 it will be apparent that it is electrically symmetrical about the earth line.

Figure 2 illustrates a modified circuit which is asymmetrical, but otherwise basically similar to that of Figure 1. Two networks A and B are connected across the output of an input transformer T_1 which is energised from an A.C. source at S. Each network A, B consists of a respective capacitor C_A, C_B in series with a respective resistor R_A, R_B, the appropriate values of the capacitors C_A and C_B being selected by means of a ganged selector switch represented by the dotted line S_1.

Across the resistor R_A (shown as adjustable for matching or lining up) is shunted a loaded transformer T_A, the load being constituted by a potentiometer resistor P_A, the slider 11 of which is connected to the unknown voltage input terminal 12. Across the capacitor C_B is shunted a loaded transformer T_B, the load being constituted by a similar potentiometer resistor P_B whose slider 14 is connected to the other unknown voltage input terminal 15. The terminals 12 and 15, and any wander leads connected thereto, are colour coded for ease of identification during testing so as to minimise the risk of any unintentional phase inversion. The centre taps 13, 16 of the secondaries of the loaded transformers T_A, T_B are connected to the primary of the detector coupling transformer T_2.

Typical component values for the circuit of Figure 2 are:

T_1, T_2, T_A, T_B		ratio 5:1
$R_A=R_B$		10kΩ
$C_A=C_B$	at 50 c/s	0.2μF
$P_A=P_B$		7.9kΩ

Ferquency range: 50c/s and 100c/s—10kc/s in 100 c/s steps

The asymmetrical arrangement of Figure 2 reduces the number of matched resistors and capacitors compared with Figure 1, and hence reduces cost and sources of possible error.

It is of considerable practical convenience to provide some facility for rotating the vectors in order that scale readings of the sliders 11, 14 of the potentiometers can be directly interpreted in either cartesian or polar coordinates. To this end, the circuit of Figure 2 includes a phase shift circuit F connected across the input auto-transformer T_1, which conveniently provides the appropriate voltages for the impedance networks A, B and for the phase shift circuit F. The latter consists of a blank of capacitors 20, whose value can be selected by the switch S_1 which also selects the values of the capacities at C_A, C_B. The bank 20 is connected in series with a variable resistor 22 across the entire winding 24 of the auto-transformer, and in series with a potentiometer 21 to a tapping 25 on the autotransformer. The slider 23 of the potentiometer 21 is connected to the primary of a phase shift transformer T_3.

The output of the phase shift transformer T_3 is shown connected to a pair of terminals X to which the circuit under test can be connected. Alternatively, however, a change-over switch (not shown) can be provided over switch (not shown) can be provided be energised from the phase shift circuit F instead of directly from the transformer winding 24.

Furthermore, if the instrument networks A, B are energised from the phase shift network F, it can be shown that for a given value of resistance 21, there will always be the same phase shift irrespective of frequency so long as the load imposed by the potentiometer instrument can be regarded as negligible—provided that the value of the capacitor at 20 is changed with frequency. Even if the input impedance of the potentiometer instrument is taken into account, however, its practical effect will be negligible since, although reactive, it is independent of frequency so long as the capacitors C_A, C_B in the networks A and B are selected to suit the working frequency.

Since the same A.C. source energises both the instrument and the external circuit under examination, there is a fixed (though initially unknown) relationship between every current and potential in the instrument and every current and voltage in the external circuit. The main function of the phase shift circuit F is to adjust this relationship so that the balance potentials derived from the potentiometers P_A, P_B can be conveniently read off from their scales. For example, when balancing the first unknown voltage in the external circuit, the phase shift circuit F may be adjusted so that the readings are 100 on the in-phase potentiometer and +j0 on the quadrature potentiometer. The adjustment of the phase shift circuit is then left unaltered for all subsequent balance measurements. Hence the relative magnitudes and phase relationships of all the voltages and currents in the external circuit can be read directly from the potentiometer slider scales, and this makes the instrument very versatile in practice.

The feature of ganging the phase shift circuit capacitor bank 20 with the capacitors C_A, C_B in the instrument circuit has the further advantage that the phase shifter will provide the same amount of amplitude and phase adjustment throughout the frequency range. This is due to the fact that the reactive component of the circuit impedance which is attributable to the capacitor 20 is rendered substantially invariable irrespective of frequency.

In the particular case where the phase shift network F is placed between the A.C. supply S and the instrument, the maximum potential across each potentiometer P_A, P_B is related to the A.C. supply voltage by a constant factor which is unaffected by frequency changes. Thus, once the phase shifter has been set, at any one frequency, to give a null balance reading of, say 100+j0 on the instrument against, say, the input voltage to the external circuit under examination, this same phase setting will produce the same or substantially the same null balance reading at all other frequencies.

The circuits of Figures 1 and 2 shows parallel arrangements of the impedance networks A and B. Figure 3 shows the series arrangement in block diagram form and Figure 4 is the series counterpart of Figure 2. In Figure 3, the blocks X and Y are the matched impedances and the blocks Z are the loaded transformers which provide the quadrature balance potentials.

Figure 4 shows a more detailed circuit of the instrument layout of Figure 3 and comprises two series-connected matched impedance networks A, B. The network A consists of a variable capacitor C_A shunted by a series circuit consisting of a resistor R_A and the primary of a loaded transformer T_A. The network B consists of a resistor R_B of the same value as the resistor R_A shunted by a series circuit consisting of a variable capacitor C_B of the same value as the capacitor C_A and the primary of a loaded transformer T_B. The transformers T_A, T_B are matched as in the circuits of Figures 1 and 2. The networks A and B are connected in series at adjacent ends of the transformer primaries, and the capacitors C_A, C_B are ganged for simultaneous adjustment.

The secondary of the transformer T_A is loaded by a potentiometer P_A with a slider 11 and is centre-tapped at 13, whilst the secondary of the transformer T_B is loaded by a potentiometer P_B with a slider 14 and is centre-tapped at 16. The centre taps 13, 16 feed the primary of a detector transformer T_2 across the secondary of which is connected a null balance detecting instrument G. The sliders 11, 14 are connected to the test probes 12, 15 respectively for exploring the voltages produced in a test circuit indicated formally at K and energised from the same source S as that which energises the instrument networks A, B.

The circuit K under test is energised from the A.C. source S through a phase-shift network 20 . . . . . 24 of the same general kind as that shown at F in Figure 2. The capacitor bank 20 of this network is ganged with the instrument capacitors C_A, C_B so that the potentiometer sliders 11, 14 can be read direct in terms of relative magnitude and phase for any one test circuit.

It is important to note that in the above-described circuit the potentiometers P_A, P_B are electrically isolated from earth, so that it is possible to explore in the network K unknown voltages whose vectors may lie in any or in all four quadrants.

Figures 5—7 illustrate the adaptation of the instrument of Figure 1, Figure 2 or Figures 3 and 4 to polar coordinate readings of the potentiometer sliders 11, 14. Referring first to Figure 5, the secondaries of the two loaded transformers T_A, T_B share a common four-armed resistance bridge network 26, 27, 28, 29 all arms of which are of equal value. The secondaries are connected to the non-conjugate points of this network—the secondary of the loaded transformer T_A being connected across the points 30 and 31 (Figure 5) whilst the secondary of the loaded transformer T_B is connected across the points 32 and 33. Thus the transformers have equal total loads.

The arms 26 and 28 are constituted by potential dividers, the sliders 34, 35 of which are ganged to move symmetrically in unison. At any instant, therefore, each slider divides its respective resistor 26 or 28 into two parts of value p and $1-p$. Provided that the capacitors in each network A and B (Figures 1, 2 and 4) are correctly chosen for the working frequency so that the reactive impedance (X) is equal to the resistance (R), it can be shown that the output potential measured across the sliders varies with p as follows:

$$\text{Modulus } e=\sqrt{2p^2-2p+1}$$
$$\text{Argument } \phi=\tan^{-1} p/(1-p)$$

Thus ϕ varies by 90° as p changes from 0 to 1, but the relationship is non-linear. So long as ϕ does not exceed 90°, each slider 34, 35 can be calibrated in degrees of angle. For a difference of 90° in ϕ, the four-armed network must be rotated through 90° as represented diagrammatically in Figure 6, and this is effected in practice by means of a four-position switch. This switch is calibrated to indicate the factor to be applied to the scale reading on the slider to obtain ϕ:

Position 1—ϕ=natural scale reading;
„ 2—ϕ=scale $-180°$;
„ 3—ϕ=scale $+180°$;
„ 4—ϕ= $-$scale.

Figure 6 also shows a modulus correction potential divider 36 connected across the sliders 34 and 45. Its impedance is high, so as to constitute a negligible load on the diamond network, and it is so wound as to correct for the non-linear law of the modulus. The slider 37 of this potential divider is ganged to the sliders 34 and 35, and the output potential is measured across the slider 37 and one end of the potential divider 36. The winding of the potential divider reduces the output potential by 0.707 at each end of the travel of the slider relative to unity at the mid-position.

Instead of being located as shown in Figure 6, the modulus corrector potential divider 36 may be arranged to modify the input signal to the instrument (Figure 1, 2 or 4)—for example, by controlling the gain of an input amplifier. Alternatively again it may be arranged to control the gain of the intermediate stage or stages of an output amplifier.

Figure 7 shows a simplified circuit diagram of an arrangement for comparing potentials relative to earth. In this circuit, a detector coupling transformer T_2 is connected between one slider 34 and earth, and the other slider 35 is connected to the source of the unknown voltage to earth. If the secondary to the detector transformer T_2 is short circuited, the instrument may be used as a signal generator for producing at tap 35 potentials of known argument relative to a reference voltage vector.

A drawback of the polar coordinate circuits of Figures 5—7 is that, in each case, the instrument will only operate as a true null balance instrument in respect of unknown voltages referred to earth. Figure 8 illustrates a polar coordinate measuring instrument in which neither of the terminals between which the potential is to be measured need be earthed. In this circuit, each loaded transformer T_A, T_B is connected across its respective matched impedance R_A, C_B through a reversing switch 38 or 39. The secondary of each transformer is then connected to the slider 11 or 14 of its associated potentiometer P_A or P_B through a graded variable resistor 40, 41 or 42, 43 so arranged that, when the sliders 11 and 41 or 14 and 43 are appropriately ganged, each secondary feeds into a constant resistance network.

Across the winding of each potentiometer P_A or P_B is connected a profile potentiometer 44 or 46, the slider 45 or 47 of which is ganged to that of the other profile potentiometer and is shaped so that, when it is rotated, a potential of constant magnitude but variable phase is derived. The law governing the profile of the slider 45 on the potentiometer 44 is that the ratio of derived potential to input potential is the sine of the angle of adjustment of the slider 45 while the corresponding law for the slider 47 on the profile potentiometer 46 is a cosine law.

The ganged sliders 45, 47 of the profile potentiometers 44, 46 are connected to respective probes 12, 15 to be applied to the circuit under examination, and a null balance detector circuit T_2, G is connected across the ends of the secondaries of the transformers T_A, T_B which are common with the corresponding ends of the respective potentiometers.

In the circuit of Figure 8, the ganged sliders 11, 14 of the potentiometers P_A, P_B are calibrated to read the modulus and the ganged sliders 45, 47 are calibrated to read the argument of an unknown voltage. The independently operated reversing switches, 38, 39 serve to select the quadrant of the voltage vector. The control knobs or levers of the reversing switches are marked as for the four-position switch described above with reference to Figure 6.

WHAT WE CLAIM IS:—

1. An A.C. potentiometer comprising two impedance networks connected across a pair of conductors, each network comprising three impedances each of which is electrically matched with a counterpart in the other network whilst two have significantly different characteristic phase angles and either (a) are connected in series in their network whilst the third is connected in shunt with one of them in one network and with the other in the other network when the networks are connected in parallel across the conductors, or (b) are connected in parallel in their respective networks, one of the two being shunted by the other of the two and the third impedance in series whilst in the other network the counterpart of the other of the two is shunted by the counterpart of the one and the third in series, when the networks themselves are connected in series across the conductors, the third impedance in each network, in either alternative circuit arrangement, being transformer-connected thereo.

2. An A.C. potentiometer according to claim 1 wherein the loaded transformers have the same turns ratio.

3. An A.C. potentiometer according to claim 2 wherein the loaded transformers have a step-down ratio.

4. An A.C. potentiometer according to claim 1, 2 or 3 wherein the loaded transformers have accurately matched input impedances over the working frequency range of the potentiometer.

5. An A.C. potentiometer according to any preceding claim wherein the two impedances having significantly different characteristic phase angles are constituted respectively by a resistor and a capacitor.

6. An A.C. potentiometer according to claim 5 wherein the capacitors in the two networks are variable and ganged together for equal and simultaneous adjustment of their capacities.

7. An A.C. potentiometer according to any preceding claim wherein the secondaries of the two transformers are inter-connected by a detector for indicating a state of balance when potentials derived from the respective third impedances balance the respective in-phase and quadrature components of the an unknown voltage in a test circuit energised from the same A.C. source as that which energises the potentiometer.

8. An A.C. potentiometer according to claim 7 wherein the secondaries of the transformers are connected across opposite diagonals of a four-armed bridge network all the arms of which are of equal value.

9. An A.C. potentiometer according to claim 8 wherein two opposite arms of the four-armed network are potential dividers whose sliders are ganged for adjustment in unison.

10. The combination with an A.C. potentiometer according to any preceding claim of a phase-shift circuit connected in series with the potentiometer.

11. The combination according to claim 10 wherein all the main capacitors in the phase-shift network and the potentiometer are ganged for simultaneous adjustment.

12. An A.C. potentiometer substantially as described with reference to the accompanying drawings.

13. The combination with an A.C. potentiometer according to claim 12 of a phase-shift network substantially as hereinbefore described with reference to Figure 2 or Figure 4 of the accompanying drawings.

For the Applicants:
HOLLINS & CLARK,
Chartered Patent Agents,
14, Woodlands Parade,
High Street,
Watford,
Hertfordshire.

Leamington Spa: Printed for Her Majesty's Stationery Office by the Courier Press.—1965.
Published at The Patent Office, 25, Southampton Buildings, London, W.C.2, from which copies may be obtained

FIG.1.

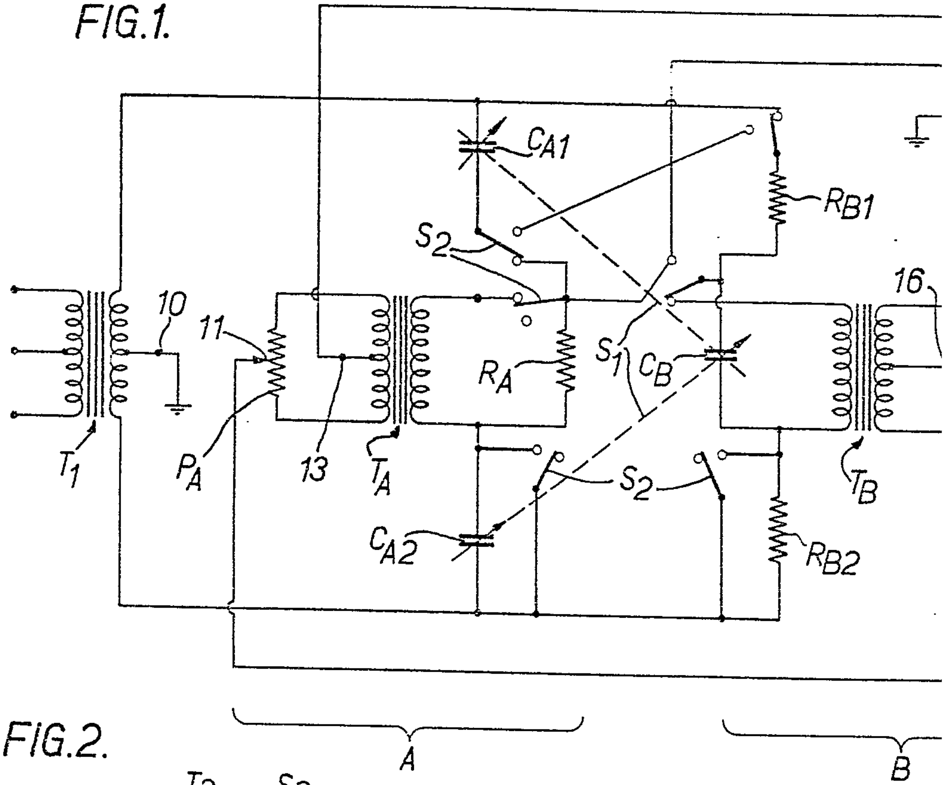
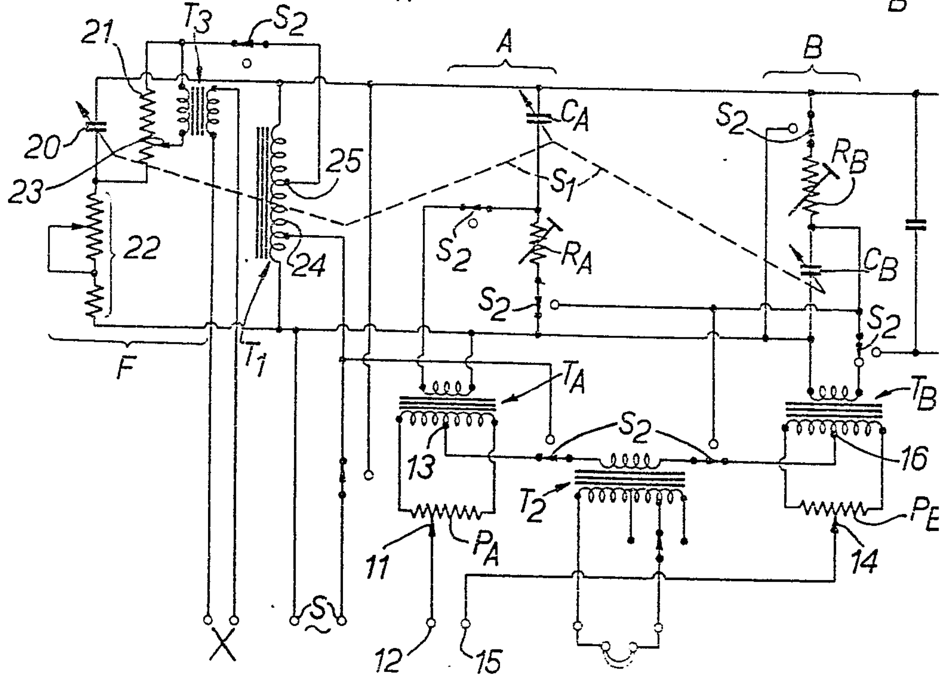

CA1
RB1
S2
10
11
16
S1
CB
RA
T1
PA
13
TA
S2
TB
CA2
RB2
A
B

FIG.2.


T3
S2
21
A
B
20
CA
S2
RB
25
S1
23
22
S2
RA
CB
24
S2
S2
F
T1
TA
TB
S2
13
16
T2
11
PA
PE
14
S
12
15

1008482 PROVISIONAL SPECIFICATION

3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

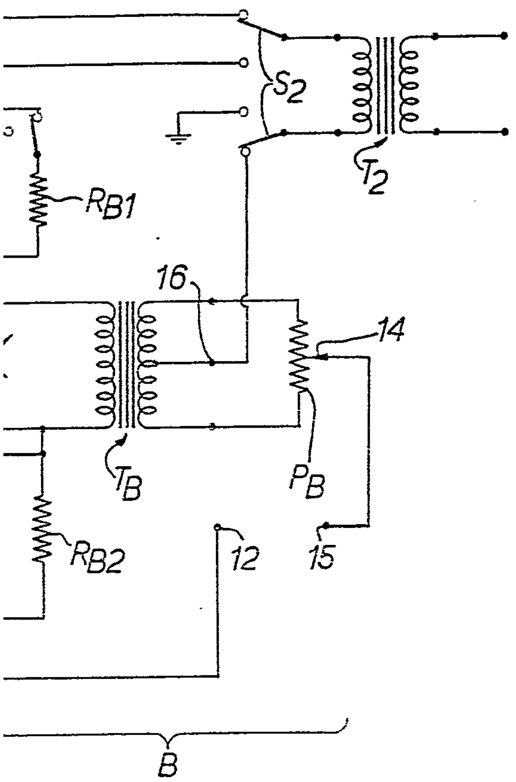
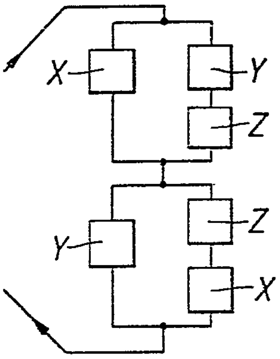


FIG.3.



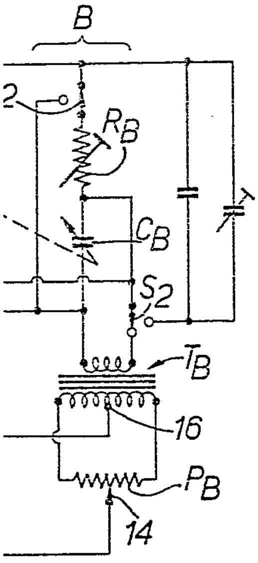
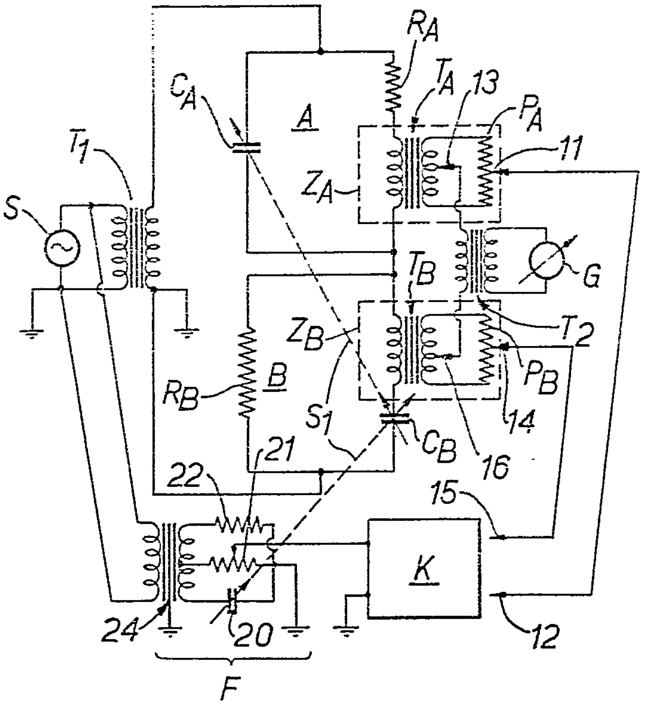


FIG.4.



1008482 PROVISIONAL SPECIFICATION
3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*
Sheet 1

FIG.1.

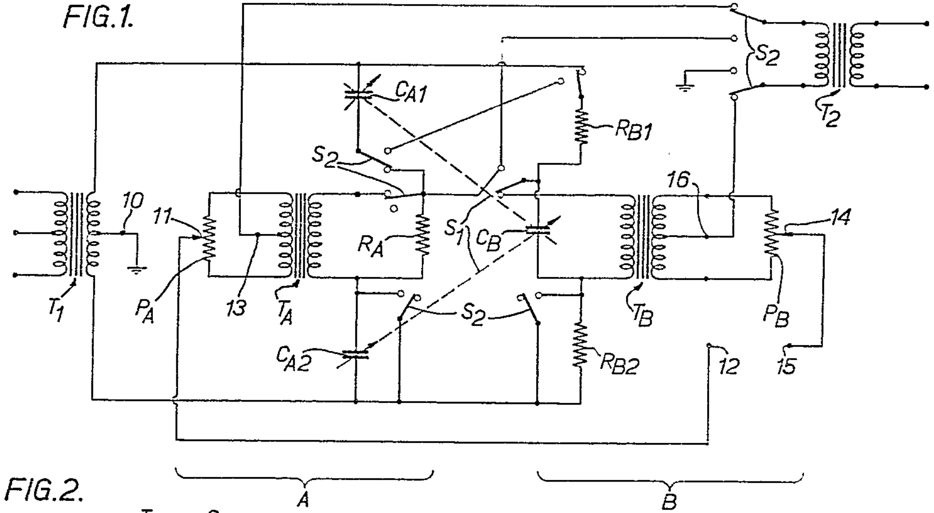


FIG.2.

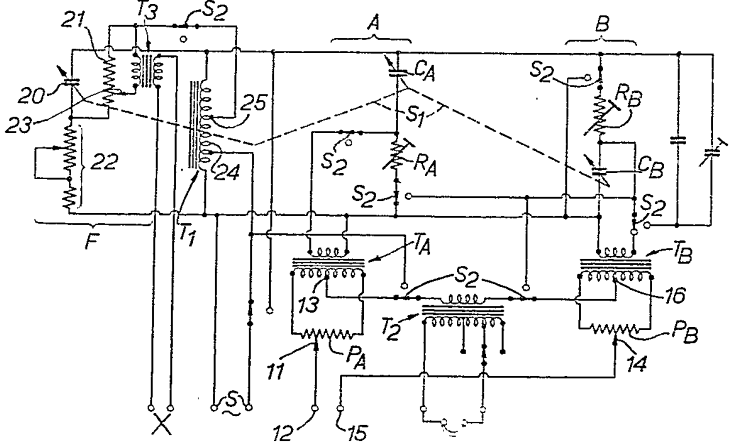


FIG.3.

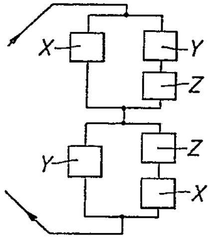


FIG.4.

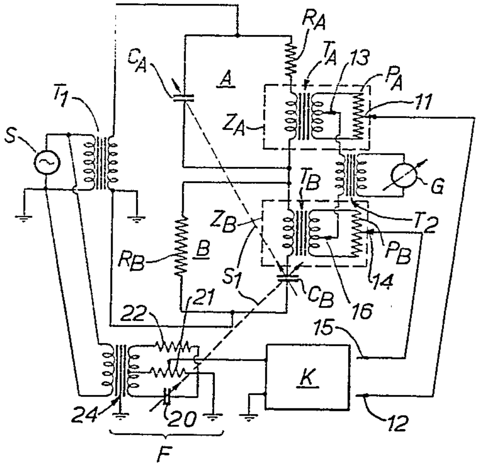


FIG.5.

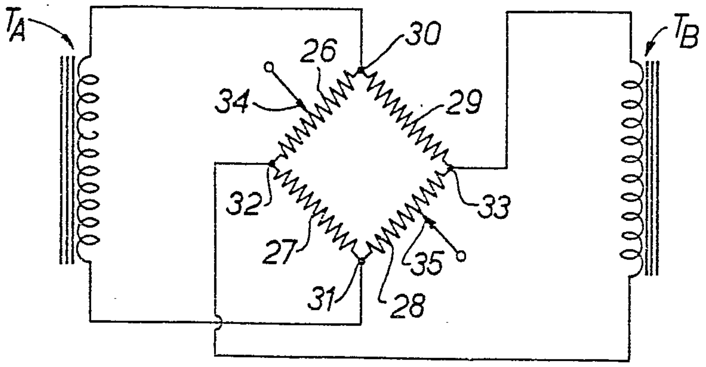
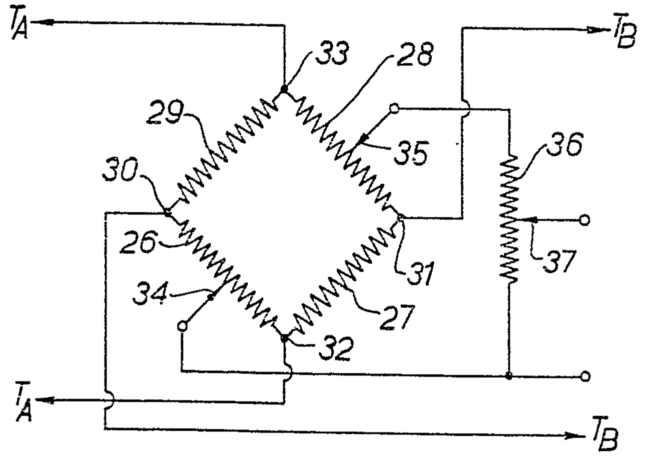


FIG.6.



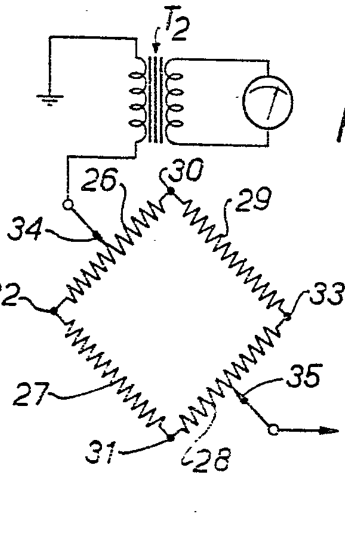
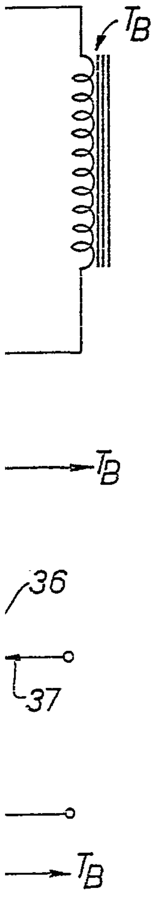


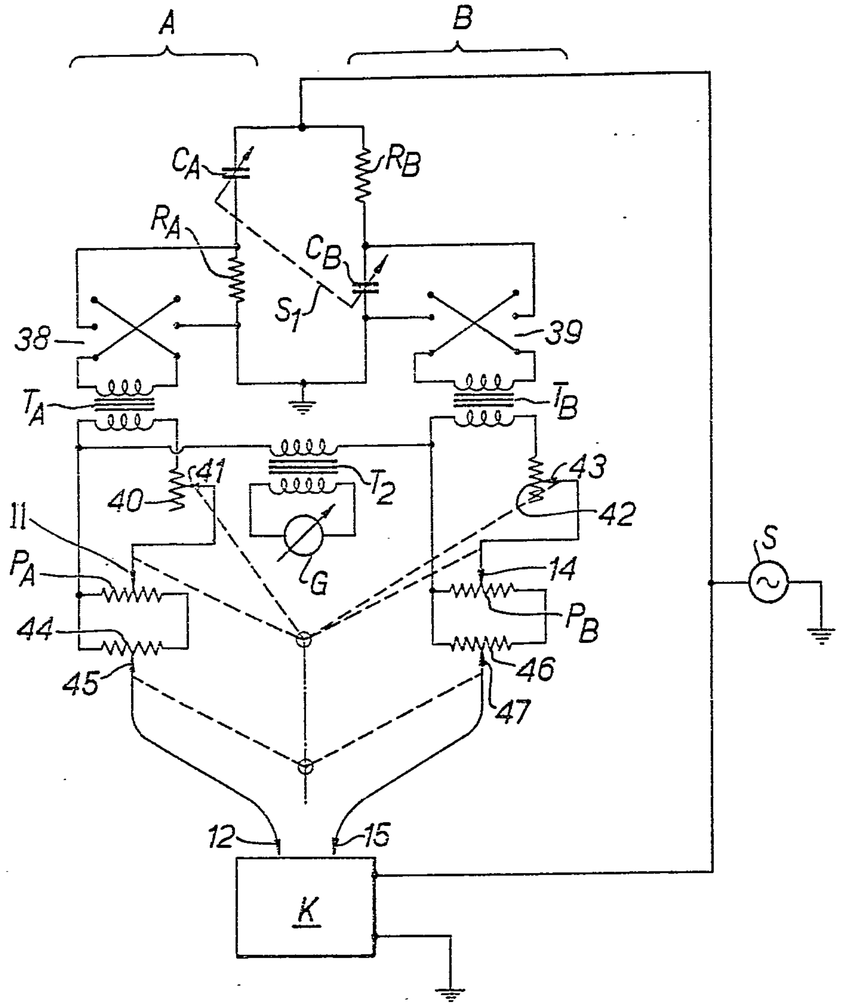
FIG.7.

1008482 PROVISIONAL SPECIFICATION
3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*
Sheets 2 & 3



G.7.

FIG.8.



1008482 PROVISIONAL SPECIFICATION
3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*
Sheets 2 & 3

FIG. 5.

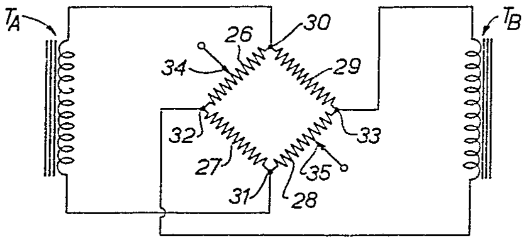


FIG. 6.

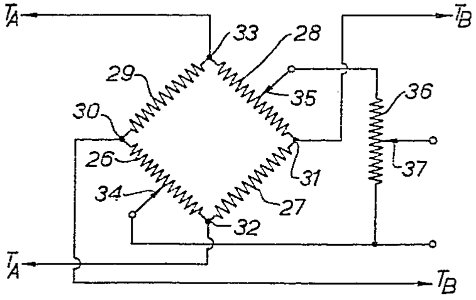


FIG. 7.

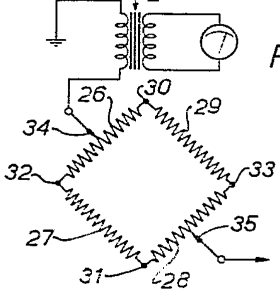


FIG. 8.