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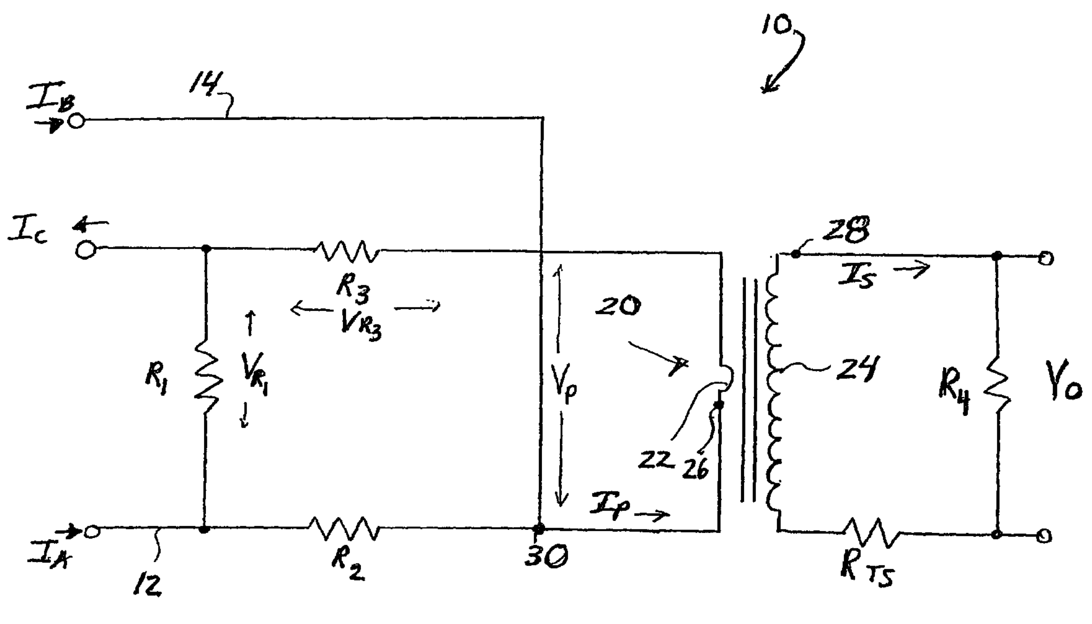

(57) **Abstract:** A dual-rated current transformer circuit (10) has a first current line (12) which delivers a first current (IA) and a second current line (14) which delivers a second current (IB). A current transformer (20) is coupled to both the first and second current lines, wherein the transformer generates a current proportional to the current of each of the first and second current lines. The circuit can be miniaturized due to the input circuit which lowers the input current to the transformer and design techniques of the transformer which allow for size reduction.

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DUAL-RATED CURRENT TRANSFORMER CIRCUIT

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

The present invention relates to a dual-rated current transformer circuit, and more particularly to a miniature dual-rated transformer circuit for use in a protective relay.

DISCUSSION OF THE PRIOR ART

The use of protective relays for or in a circuit breaker or other electrical apparatus is well known. Traditionally, the relay detects a condition and generates a signal to operate, for example, a trip coil in a low ampere industrial rated circuit breaker. A current transformer assembly is utilized to provide operating power to the trip coil. Traditionally, a single current transformer core fits within the circuit breaker and supplies a sufficient current and operating power to the trip unit circuit for a number of ampere ratings.

One manner of decreasing size constraints but still allowing a circuit to operate over a wide range of ampere ratings is to utilize a fixed transformer size and a fixed secondary winding thereon. The number of primary turns are varied inversely with the circuit ampere rating. See U.S. Patent No. 5,015,983, assigned to the assignee of the present invention. However, varying the number of primary turns in a current transformer circuit will not allow different input current ratings to produce the same current through the primary winding.

Moreover, larger breakers for industrial or utility applications traditionally utilize protective relays that have their own enclosures. The protective relays have a source of power to operate other than from the current transformer. The output of the protective relay is normally a contact or solid-state device to connect the trip coil to a source of power independent from the relay. For this application, the current transformers are used to replicate and isolate the input current and are normally rated one ampere or five amperes. The current transformer must work over a large current range that includes fault current, which is much greater than rated current for protection and metering, and metering current which can be less than rated current. Traditionally, a typical current transformer for a one ampere input rating would have a twenty turn primary and a separate design for a five ampere input rating which would have four turns.

SUMMARY OF THE INVENTION

It would be economically desirable, therefore, to provide a dual-rated current transformer circuit which allows for at least two different current input ratings to be delivered to the transformer. Moreover, it is desirable to utilize a circuit which can be miniaturized.

One aspect of the present invention is to provide a dual-rated current transformer circuit which utilizes a transformer having a reduced size.

Another aspect of the invention is a transformer circuit which will meet the application requirements using a typical magnetic material that has a relatively low cost. The number of turns can vary due to changes in the magnetic material or application.

Still another aspect of the invention is a transformer circuit which is designed to produce the same output current with a first rated current or a second rated current.

According to presently preferred embodiments of the present invention, a dual-rated current transformer circuit has a first current line which delivers a first current and a second current line which delivers a second current. A transformer is coupled to both the first and second current lines, wherein the transformer generates a current proportional to the current of each of the first and second current lines. The transformer of the circuit incorporates design features which reduce its overall size.

BRIEF DESCRIPTION OF THE DRAWINGS

Other features and advantages of the present invention will become apparent from the following description of preferred embodiments of the invention which refers to the accompanying drawings, wherein:

Fig. 1 is a schematic diagram of a first embodiment of the dual-rated current transformer circuit of the present invention.

Fig. 2 is a schematic diagram of a second embodiment of the dual-rated current transformer circuit.

Fig. 3 is a schematic diagram of a third embodiment of the dual-rated current transformer circuit.

Fig. 4 is a side view of a transformer used in the circuit of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The dual-rated transformer circuit, and the miniature size of the transformer incorporated therein allows for a protective relay having a reduced size. It should be appreciated that the circuit of the present invention is not limited to use in protective relays, but can be used in a plurality of different applications.

A dual-rated current transformer circuit 10 is illustrated in Fig. 1. Circuit 10 includes resistors R_1, R_2 and R_3 connected in series. A first current I_A or a second, different current I_B is fed via current lines 12 and 14. A common current I_C represents a common return path for both I_A and I_B.

A current transformer 20 communicates with both currents I_A and I_B. Transformer 20 is a dual-rated transformer as both of the different currents rates I_A or I_B will produce the same current within the primary coil of the transformer, which will be described further herein. Thus, transformer 20 generates a current I_P proportional to either current I_A or I_B.

Transformer 20 includes a primary coil 22 and a secondary coil 24. For example, transformer 20 can be a ferromagnetic core transformer. Primary coil 22 is single turn while the secondary coil 24 has multiple turns, for example, 13,000 turns. The stepped-down current I_S of secondary coil 24 is proportional to the current I_P through primary coil 22, said current I_P being the same for both current rates I_A or I_B. The circuit of the present invention is designed for both I_A or I_B such that a standard transformer could be used for the most common relay input currents.

Secondary coil 24 is designed to provide a low reflected resistance to primary 22 and a low burden to the transformer. Secondary coil 24 includes resistance R_{TS}. A fourth resistor R_4, together with $R_{TS,}$ reflects to the primary. The polarity of primary coil 22 is noted at 26 and the polarity of secondary coil 24 at 28. An output burden which is low minimizes the transformer size. Ultimately, the output burden should be lower than the transformer secondary resistance R_{TS}.

The resistor network R_1, R_2 and R_3 provides for two different current inputs I_A or I_B to supply a current to transformer primary 22 at a value lower than I_B. Referring again to Fig. 1, working from node 30, current I_B is delivered along line 14 to node 30, and because of the shunt arrangement of the circuit, results in the current I_P through the transformer primary. Current I_A travels to node 30 via line 12 and also produces the same current I_P. The voltage across $R_{1,}$ for current I_A, can be derived from the following equation:

$$V_{R1} = \frac{I_A\, R_1(R_2 + R_3)}{R_1 + R_2 + R_3}$$

Thus, the current I_P can be derived from current I_A by the equation 2:

$$(2)\quad I_P = V_{R1} / R_2 + R_3 = I_A\, R_1 / R_1 + R_2 + R_3$$

Likewise, V_{R3} and I_P can be determined by using the current I_B and the voltage V_{R3} across resistor R_3 by the following equations:

$$V_{R3} = I_B\,(R_1 + R_2)\, R_3 / R_1 + R_2 + R_3$$

$$(3)\quad I_P = V_{R3} / R_3 = I_B\,(R_1 + R_2) / R_1 + R_2 + R_3$$

Equating equations (2) and (3):

$$I_A = I_B\,(R_1 + R_2) / R_1$$

$$I_A / I_B = (R_1 + R_2) / R_1$$

$= 1 + R_2 / R_1$

(4) $R_2 / R_1 = I_A / I_B - 1$

An example of a dual-rated current transformer circuit according to the present invention is as follows:

Assume $I_A = 5$ amperes

$I_B = 1$ ampere

$I_P = 0.45$ amperes

$R_{TS} = 4000\ \Omega$

$R_4 = 2000\ \Omega$

$V_O = 0.0692$ volts, at rated input current

$N_P = 1$

Wherein N_P is the number of turns of the transformer primary and N_S is the number of turns of the transformer secondary. Because the number of ampere turns of the primary must equal the number of turns in the secondary, the number of turns in the secondary coil can be determined as follows:

(5) $N_S = N_P I_P / I_S$

From Ohm's Law:

$V_O = I_S R_4$, where V_O is the voltage across R_4.

Thus, $V_O = I_P N_P R_4 / N_S$

$N_S = N_P I_P / I_S = N_P I_P R_4 / V_O$

$N_S = 1 \cdot 0.45 \cdot 2000 / 0.0692$

$N_S = 13006$ turns

From equation (5):

$N_S I_S = N_P I_P$

$I_S / I_P = N_P / N_S$

$V_S = (R_{TS} + R_4) I_S$, where V_S is the voltage across secondary 24.

Thus V_P, the voltage across primary 22, is:

(6) $V_P = V_S \times N_P / N_S$

Letting R_P be the value of the secondary resistance reflected to the primary:

$$R_P I_P = (R_{TS} + R_4) I_S N_P / N_S$$

$$R_P = (R_{TS} + R_4) \cdot I_S / N_S \cdot N_P / I_P$$

$$R_P = (R_{TS} + R_4) \cdot N_P / I_P \cdot N_P / I_P$$

$$R_P = (N_P / N_S)^2 (R_{TS} + R_4)$$

$$= (1/13006)^2 (4000 + 2000)$$

$$R_P = 35.5 \times 10^{-6} \text{ ohms}$$

Because any voltage that is reflected to the primary will circulate a current, $R_1 + R_2 + R_3$ must be very high compared to 35.5×10^{-6} ohms. Therefore assume that:

$$R_1 + R_2 + R_3 = 3.55 \times 10^{-3} \text{ ohms}$$

Then from equation (2):

$$R_1 = I_P (R_1 + R_2 + R_3) / I_A$$

$$= 0.45 \times 3.55 \times 10^{-3} / 5$$

$$R_1 = 320 \times 10^{-6} \text{ ohms}$$

From equation (4):

$$R_2 = (I_A / I_B - 1) R_1$$

$$= 320 \times 10^{-6} (5/1 - 1)$$

$$R_2 = 1.28 \times 10^{-3} \text{ ohms}$$

From equation (2):

$$I_P == I_A R_1 / R_1 + R_2 + R_3$$

$$R_3 = (I_A R_1 / I_P) - (R_1 + R_2)$$

$$= (5(320 \times 10^{-6})/ 0.45) - (320 \times 10^{-6} + 1.28 \times 10^{-3})$$

$$R_3 = 1.96 \times 10^{-3} \text{ ohms}$$

Since I_A or I_B are current sources which come from a current transformer of the power system which typically has a source impedance greater than 100 Ω, they typically would have an impedance more than two orders of magnitude higher than the sum of $R_1 + R_2 + R_3$.

Then the voltage across the primary can be calculated from the equation:

$$V_P = I_P (R_{TS} + R_4) / N_S^2$$

$$= (0.45 \times 6000) / (13{,}006 \times 13{,}006)$$

$$V_P = 15.96 \times 10^{-6}\ v$$

Letting the circulating current of $R_1 + R_2 + R_3$ be I_{PC}, which will subtract from I_P.

$$I_{PC} = V_P / R_1 + R_2 + R_3$$

$$= 15.96 \times 10^{-6} / 3.55 \times 10^{-3}$$

$$I_{PC} = 4.50 \times 10^{-3}\ A$$

Thus, I_{PC} is approximately 1 % of I_P and can be corrected by lowering the secondary turns.

An alternative embodiment of the circuit of Fig. 1 is shown in Fig. 2. As shown in Fig. 2, transformer 20 includes a first primary coil 22 through which current I_{AP} flows and a second primary coil 34 through which current I_{BP} flows. If R_3 (Fig. 1) becomes zero, I_B will equal the current through the primary I_P, see equation (3). Because the connection from I_B to I_C will have some resistance, the current should flow through second primary 34. The end of the second primary for I_{BP} is connected to I_C at the same node 36 as R_1 to prevent current flowing through R_1 in series with R_2. The current I_B which is equal to I_{BP} flows through primary coil 34 and back to I_C. The voltage across R_1 can be derived from the following equation:

$$V_{R1} = \frac{I_A R_1 R_2}{R_1 + R_2}$$

From Ohm's Law:

$$I_{AP} = V_{R1} / R_2$$

Thus, the current I_{AP} can be derived from current I_A by the equation:

$$I_{AP} = V_{R1} / R_2 = I_A R_1 / R_1 + R_2$$

If I_B =1A and I_A = 5A, and since $I_{BP} = I_{AP} = I_B$, the resistance ratio $R_1 / R_1 + R_2$ can be calculated as follows:

$$R_1 / R_1 + R_2 = I_{AP} / I_A$$

$$= 1/5$$

$$R_1 / R_1 + R_2 = 0.2 \text{ ohms}$$

The above is a special case where $I_B = I_{BP}$ and where having two, single turn primaries does not effect the relay design.

Referring to Fig. 3, another embodiment of the invention is shown, wherein the voltage burden of transformer 20 is reduced by approximately the value of R_4 by the addition of an inverting amplifier 40. Amplifier 40 includes an inverting input terminal 42 marked (-), noninverting input terminal 44 marked (+) and an output terminal 46. The circuit also includes secondary coil 24 having a polarity shown at 32.

Because the voltage at the input to the inverting amplifier is near zero, I_S flows through R_4 and produces an output voltage equal to the V_O of Fig. 1, with the same current flowing. Because the amplifier is inverting the polarity of the secondary must be reversed to keep V_O the same as in Fig. 1.

The transformer output does not see the burden of R_4 which would allow for a higher input current rating. Because the burden is reduced, the transformer size can be reduced with the same input current rating.

Referring to Fig. 4, the transformer 20 incorporated in the circuit will be described further. The transformer includes a bobbin 50 which has three flanges, 52 54 and 56. The bobbin has a first winding area 58 between flanges 54 and 56 and a second winding area 60 substantially larger than area 58 between flanges 52 and 54. The primary coil 22 is wrapped by at least one turn around the bobbin in area 58 and the secondary coil 24 is wrapped around the larger area 60. Thus, the majority of the winding in transformer 20 is the secondary winding which will produce a low resistance. This reduces the flux excursion and current excitation of the magnetic material 62 which is wrapped about the bobbin. Magnetic material 62 is a low excitation material. Using most of the winding area for the secondary winding and using a low excitation material for the magnetics are two design techniques which enable the size of the transformer to be reduced.

In summary, the dual-rated current transformer circuit of the present invention allows for two different current input ratings to be delivered to the transformer.

Moreover, the circuit can be miniaturized due to the input circuit which lowers the input current to the transformer and design techniques of the transformer which allow for size reduction.

Although the present invention has been described in relation to particular embodiments thereof, many other variations and modifications and other uses will become apparent to those skilled in the art. It is preferred, therefore, that the present invention be limited not by the specific disclosure herein, but only by the appended claims.

WHAT IS CLAIMED IS:

1. A dual-rated current transformer circuit comprising:

a first current line which delivers a first current;

a second current line which delivers a second current; and

a transformer coupled to both the first and second current lines, wherein the transformer generates a current proportional to the current of each of the first and second current lines.

2. The transformer circuit of claim 1, wherein the current generated by the transformer from the first current is equal to the current generated by the transformer by the second current.

3. The transformer circuit of claim 1, further comprising a plurality of resistors communicating with the first and second current lines.

4. The transformer circuit of claim 3, wherein the plurality of resistors are arranged such that the current generated by the transformer is of a value lower than the second current.

5. The transformer circuit of claim 3, wherein the plurality of resistors are arranged such that the second current has a value equal to the current generated by the transformer.

6. The transformer circuit of claim 5, wherein the first and second current lines are separated to prevent a portion of the second current from flowing through the resistors.

7. The transformer circuit of claim 1, wherein the transformer includes a primary coil and a secondary coil.

8. The transformer circuit of claim 7, wherein the primary coil has at least one turn and the secondary coil has a plurality of turns.

9. The transformer circuit of claim 7, wherein the secondary coil of the transformer reflects a low impedance.

10. The transformer circuit of claim 7, wherein the transformer includes a portion of magnetic material wrapped about the primary and secondary coils.

11. The transformer circuit of claim 10, wherein the magnetic material is a low excitation type material.

12. The transformer circuit of claim 7, wherein the secondary coil reflects a low resistance to the primary coil and a low burden to the transformer.

13. The transformer circuit of claim 7, further comprising a second primary coil.

14. The transformer circuit of claim 13, wherein each primary coil has a single turn.

15. The transformer circuit of claim 1, wherein the first current has a value of five amperes.

16. The transformer circuit of claim 1, wherein the second current has a value of one ampere.

17. The transformer circuit of claim 1, further comprising an operational amplifier coupled to the transformer.

18. A dual-rated current transformer circuit comprising:

a first current line which delivers a first current;

a second current line which delivers a second current;

a plurality of resistors communicating with the first and second current lines; and

a transformer coupled to both the first and second current lines, wherein the plurality of resistors produce an input current to the transformer which generates a current from the transformer which is lower than the current of each of the first and second current lines.

19. The transformer circuit of claim 18, wherein the current generated by the transformer from the first current is equal to the current generated by the transformer by the second current.

20. The transformer circuit of claim 18, wherein the transformer includes a primary coil having at least one turn and a secondary coil having a plurality of turns.

21. The transformer circuit of claim 20, wherein the transformer includes a portion of magnetic material wrapped around the primary and secondary coils.

22. The transformer circuit of claim 21, wherein the magnetic material is a low excitation type material.

23. The transformer circuit of claim 20, wherein the secondary coil reflects a low resistance to the primary coil and a low burden to the transformer.

24. The transformer circuit of claim 20, further comprising a second primary coil.

25. The transformer circuit of claim 24, wherein each primary coil has a single turn.

26. The transformer circuit of claim 18, wherein the first current has a value of five amperes.

27. The transformer circuit of claim 18, wherein the second current has a value of one ampere.

28. The transformer circuit of claim 18, further comprising an operational amplifier coupled to the transformer.

AMENDED CLAIMS

[received by the International Bureau on 20 November 2000 (20.11.00); original claims 1 – 28 cancelled; new claims 29-39 added; other claims unchanged (2 pages)]

29. A dual-rated current transformer circuit comprising:

a transformer having an input line;

a first circuit in communication with said input line, said first circuit adapted to receive a first current; and

a second circuit in communication with said input line, said second circuit adapted to receive a second current that is different from said first current, wherein said first circuit and said second circuit are each adapted to provide a third current to said input line that is the same regardless of whether said first circuit or said second circuit is providing said third current.

30. The circuit of claim 29, wherein said first circuit and said second circuit share a common current return line.

31. The circuit of claim 29, wherein at least one of said first circuit and said second circuit comprise a plurality of resistors.

32 The circuit of claim 29, wherein said transformer provides a stepped down current on an output line.

33. The circuit of claim 29, wherein said transformer has a primary coil and a secondary coil, wherein said secondary coil provides a low reflected impedance to said primary coil.

34. The circuit of claim 29, wherein said transformer comprises magnetic material wrapped about a primary coil and a secondary coil.

35. The circuit of claim 34, wherein said magnetic material is a low excitation type of material.

36. The circuit of claim 29, wherein said transformer has a primary coil and a secondary coil, wherein said secondary coil reflects a low resistance to the primary coil and a low burden to the transformer.

37. The circuit of claim 29, wherein said transformer comprises a plurality of primary coils.

38. The circuit of claim 37, wherein each of said plurality of primary coils comprises a single turn.

39. The circuit of claim 29, further comprising an operational amplified coupled to said transformer.

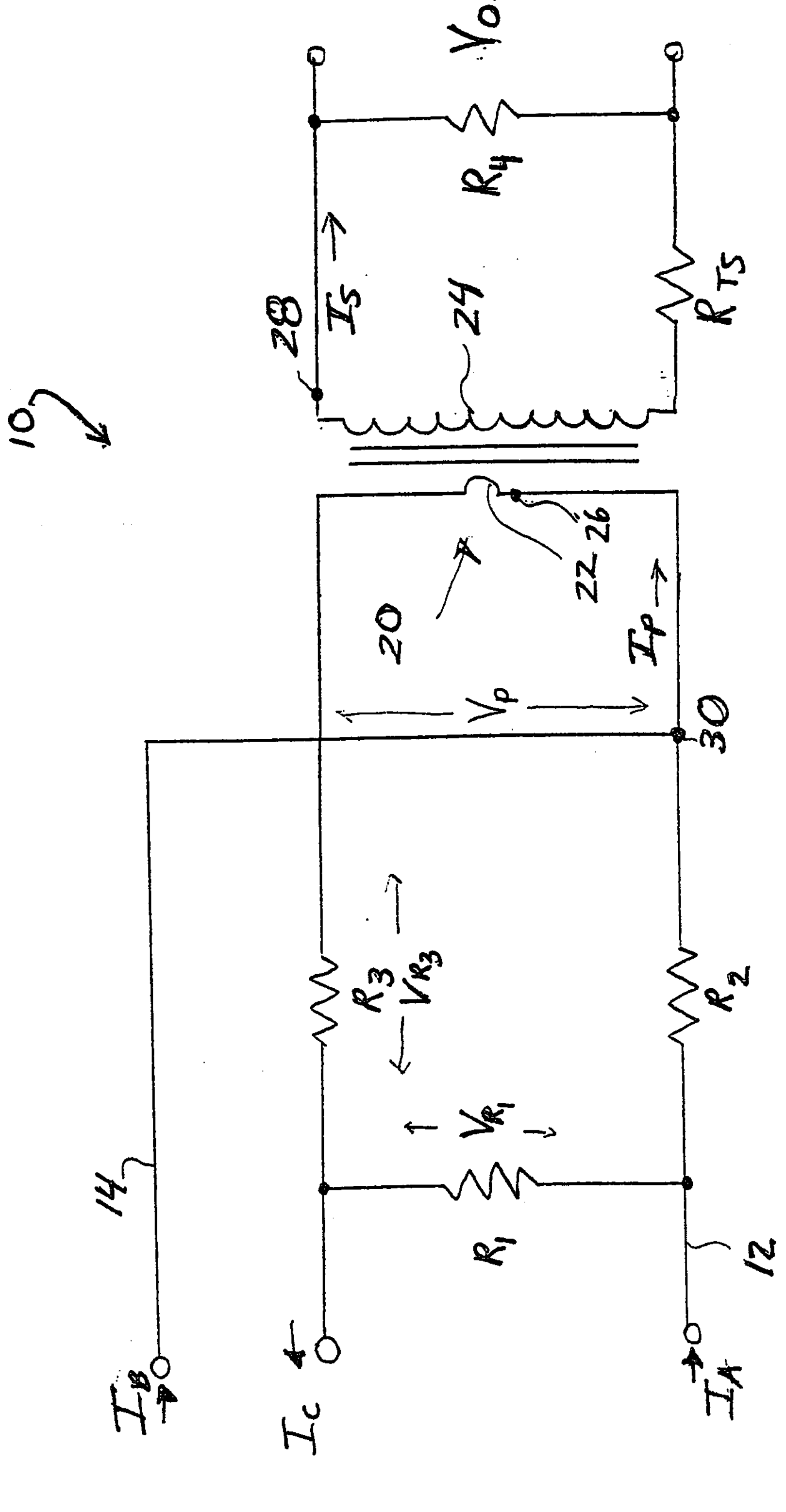

Fig. 1

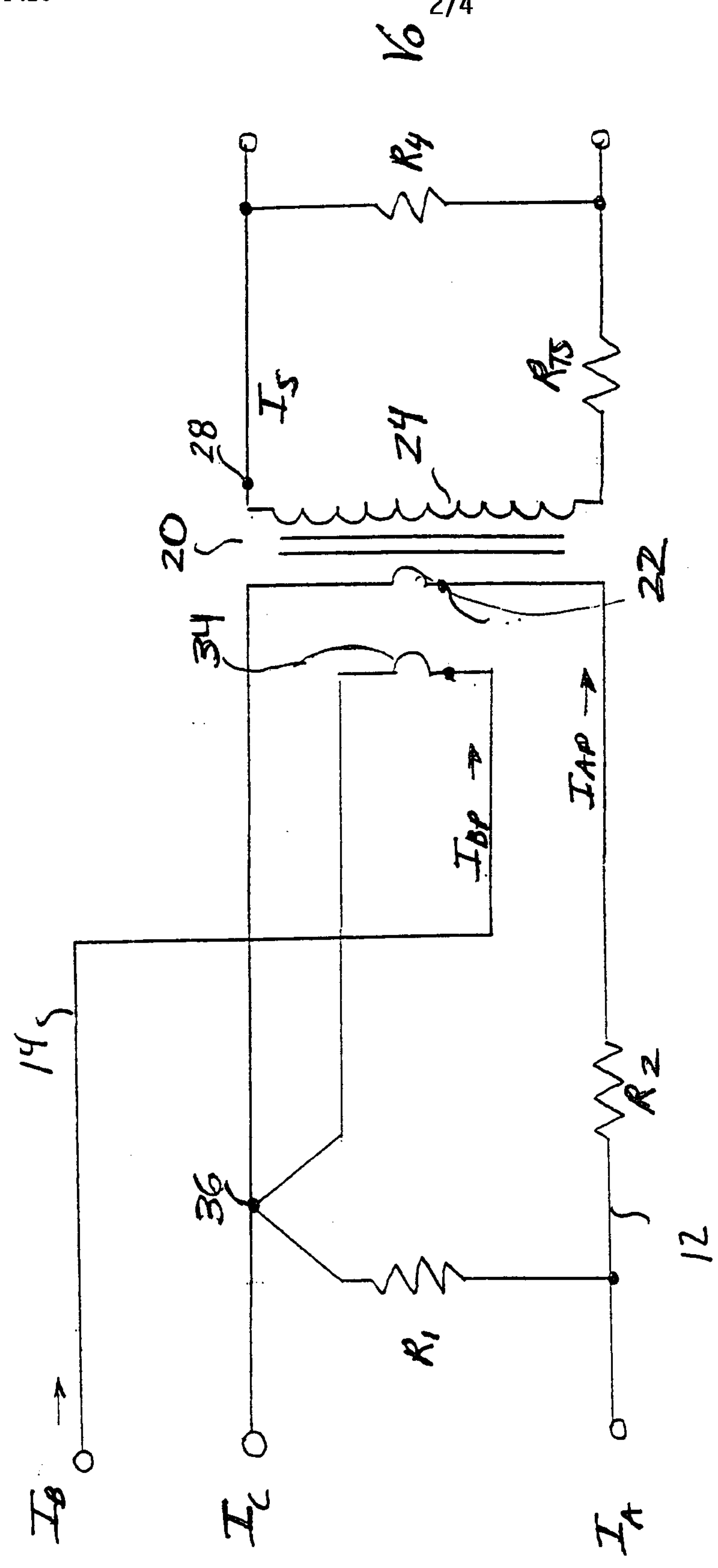

Fig. 2

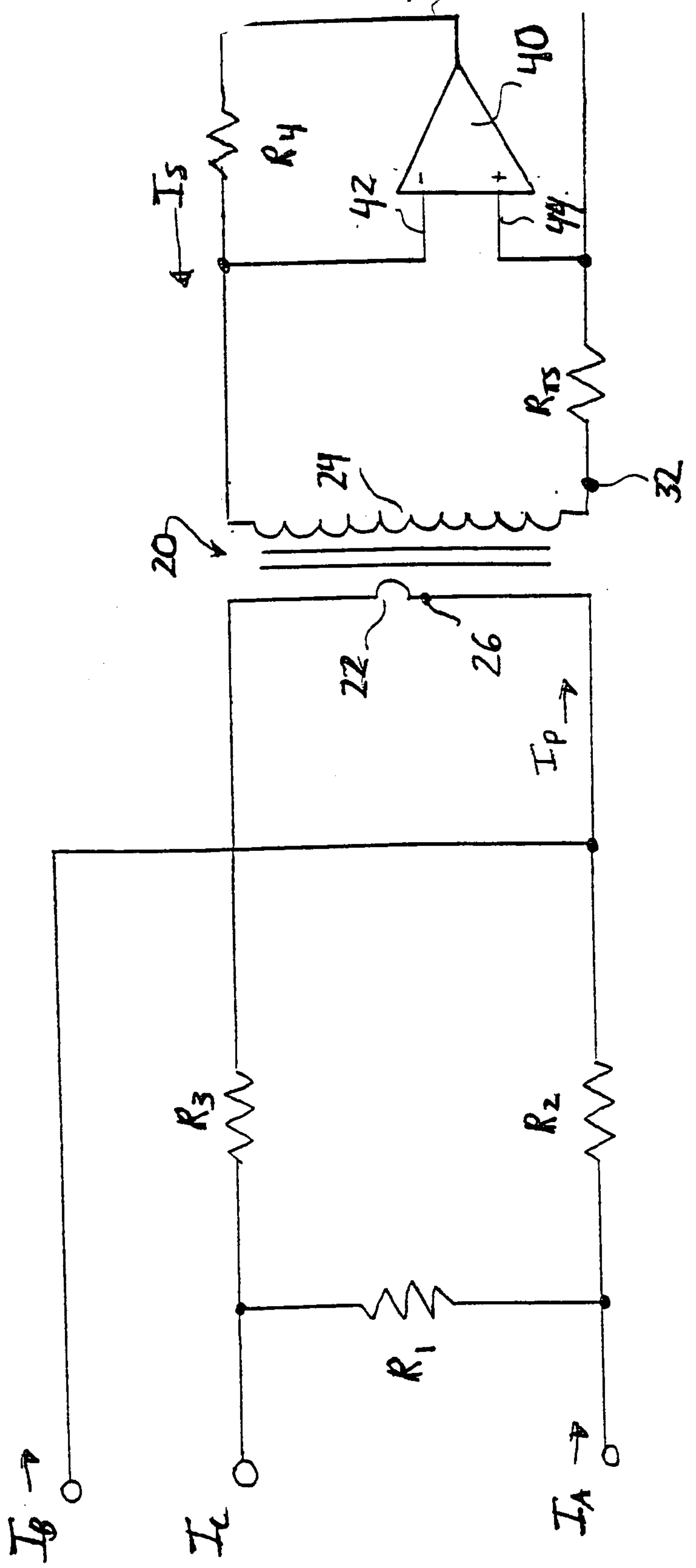

Fig. 3

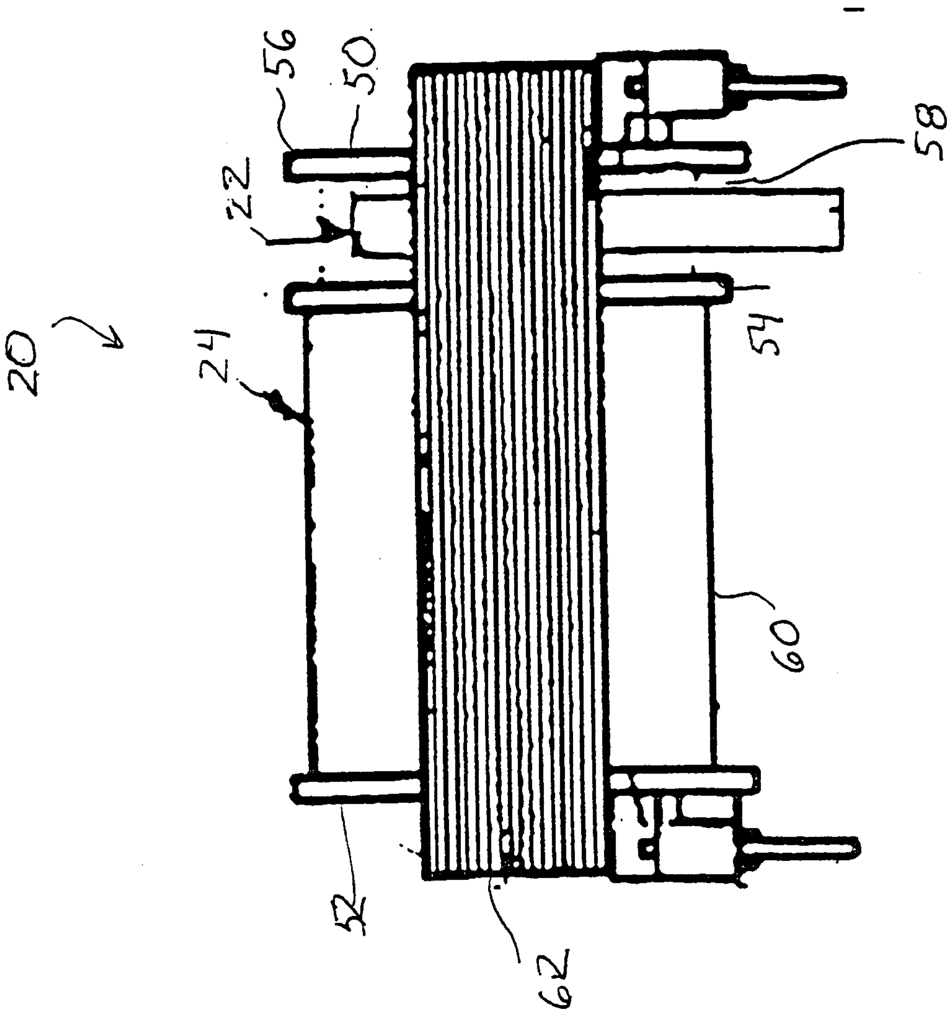

Fig. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/17809

A. CLASSIFICATION OF SUBJECT MATTER
IPC(7) : HO1F 38/00
US CL : 323/358, 355, 367, 369
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : NONE

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
USPTO APS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4,140,961 A (AKAMATSU) 20 February 1979, (20/02/79) see entire document.	1-28

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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Date of the actual completion of the international search	Date of mailing of the international search report
03 SEPTEMBER 2000	18 SEP 2000

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