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(54) Title: AC POWER CONDITIONING CIRCUIT

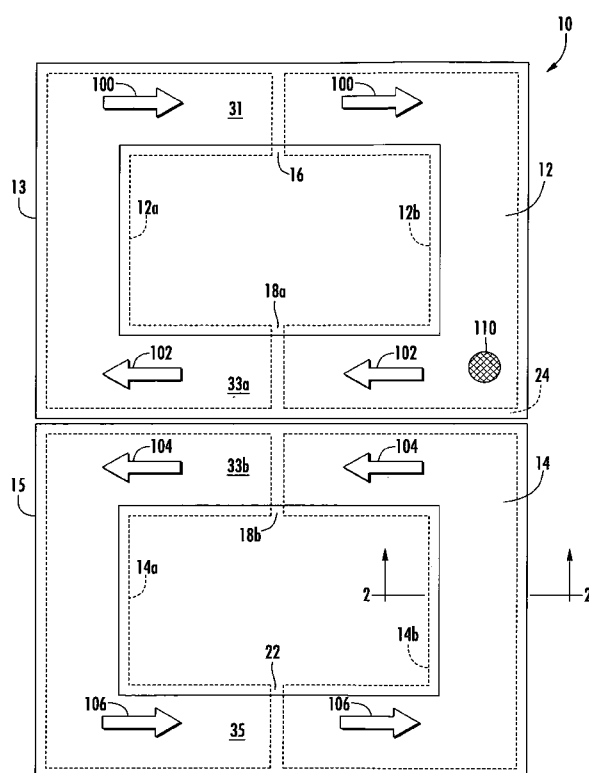


FIG. 1

(57) Abstract: A multi-coil choke for an AC power conditioner includes a magnetic core having first, second and third parallel legs. A first coil wrapped around the first leg terminates in first and second leads at respective ends. A second coil wrapped around the second leg terminates in first and second leads at respective ends. A third coil wrapped around the third leg terminates in first and second leads at respective ends. A fourth coil is formed from a proximal portion of the second lead of said first coil. The fourth coil is wrapped around a distal portion of the second lead of the third coil. A fifth coil is formed from a proximal portion of the second lead of the third coil. The fifth coil is wrapped around a distal portion of the second lead of the first coil. AC power conditioners using one or more such chokes are also disclosed.



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AC POWER CONDITIONING CIRCUIT

BACKGROUND OF THE INVENTION

- [0001] The present invention relates to the distribution of AC power, and more particularly to apparatus for conditioning the power delivered and reducing energy usage.
- [0002] Transient surges are common on all power systems. Lightning, generator switching, and major power line shorts are examples of externally generated surges. Transients up to twice the applied voltage are common and up to 50 times the applied voltage have been observed.
- [0003] More common and more frequent are transient surges caused by inductive load devices such as motors, transformers, relay coil and fluorescent light ballasts. These are known as internally generated surges.
- [0004] Various transient voltage surge suppressors are well known in the art. U.S. Pat. Nos. 4,152,743; 4,259,705; 4,584,622; 4,587,588; 4,739,436; 4,760,485; 4,777,555; 4,802,055; 4,845,580; 4,866,560; 4,870,528; 4,870,534; and 4,901,183 illustrate various transient voltage suppression systems, surge suppressors, and filters for use in the distribution of electrical power. These patents disclose circuits that use devices such as capacitors and varistors between power lines together with chokes in series with the power lines to filter AC power. None of these references discloses or suggests the provision of inductors across power lines or across a power line and the neutral line of a power source. These patents also fail to disclose apparatus for substantially reducing energy consumption.
- [0005] Commonly assigned U.S. Patent 5,105,327, incorporated herein by reference, discloses a power conditioner for AC power lines that has a choke and capacitor coupled in series across the power lines. The choke comprises a coil terminating in a line, with

the line looped back through the coil. The power lines are thereby balanced to provide greater operating efficiency. Capacitors and transient suppressors are used for transient suppression and power factor correction.

- [0006] Any load that requires a magnetic field to operate, for example motors, transformers, fluorescent lamp ballasts, solenoids, and the like will cause the phase relationship between voltage and current supplied by the utility to change. Such phase shifting reduces the efficiency of the load, resulting in increased power consumption.
- [0007] The phase angle between voltage and current is called power factor. Inductive circuits have a lagging power factor because the current lags the voltage. Capacitive circuits have a leading power factor because the current leads the voltage. It is desirable to make the angle between voltage and current approach zero. When voltage and current are in phase, the power factor is unity and the most efficient utilization of the power distribution system is obtained.
- [0008] It would be advantageous to provide apparatus for conditioning AC power to eliminate transients and surges and reduce the energy consumed by inductive and capacitive loads in a manner that improves upon the operation and efficiency of prior art devices, including the devices disclosed in U.S. Patent 5,105,327. The present invention provides multi-coil chokes and power conditioner apparatus that can be implemented to achieve these and other advantages.

SUMMARY OF THE INVENTION

- [0009] In accordance with the invention, a multi-coil choke is provided. The choke includes a magnetic core having a first leg, a second leg and a third leg. The three legs are substantially parallel to each other. A first coil is wrapped around the first leg. The first coil terminates in a first lead at a first end thereof and a second lead at a second end thereof. A second coil is wrapped around the second leg of the core and terminates in a first lead at a first end thereof and a second lead at a second end thereof. A third coil is wrapped around the third leg and terminates in a first lead at a first end thereof and a second lead at a second end thereof. A fourth coil is formed from a proximal portion of the second lead of the first coil. The fourth coil is wrapped around a distal portion of the second lead of the third coil. A fifth coil is formed from a proximal portion of the second lead of the third coil. The fifth coil is wrapped around a distal portion of the second lead of the first coil.
- [0010] In a preferred embodiment, the distal portion of the second lead of said of said first coil passes through said third coil before passing through said fifth coil. Likewise, the distal portion of the second lead of said third coil passes through said first coil before passing through said fourth coil.
- [0011] The magnetic core can be formed from two rectangular closed cores placed side-by-side with adjacent sides forming the second leg. The first and third legs can each include a gap. The second leg can include substantially aligned gaps in the adjacent sides of the rectangular closed cores. The gaps can be centrally located along their respective legs. An additional gap can be provided along the length of the adjacent sides of the rectangular closed cores. Moreover, each of the rectangular closed cores can be contained within an insulating cover.
- [0012] A multi-coil choke in accordance with a preferred embodiment of the invention has its first coil wrapped in one of a clockwise and counterclockwise direction, with the second and third coils being wrapped in the other of the clockwise and

counterclockwise direction. More particularly, the first coil can be wrapped in a counterclockwise direction with the second and third coils wrapped in a clockwise direction. The fourth coil is wrapped in the same direction as the first coil, e.g., counterclockwise. The fifth coil is wrapped in the same direction as the third coil, e.g., clockwise.

- [0013] A power conditioner for AC power lines in accordance with the invention includes a multi-coil choke and at least one capacitor. Means are provided for coupling the choke and at least one capacitor in series across an AC power source. The choke comprises a magnetic core having a first leg, a second leg and a third leg. The legs of the core are substantially parallel to each other. A first coil is wrapped around the first leg. The first coil terminates in a first lead at a first end thereof and a second lead at a second end thereof. A second coil is wrapped around the second leg. The second coil terminates in a first lead at a first end thereof and a second lead at a second end thereof. A third coil is wrapped around the third leg and terminates in a first lead at a first end thereof and a second lead at a second end thereof. A fourth coil is formed from a proximal portion of the second lead of the first coil. The fourth coil is wrapped around a distal portion of the second lead of the third coil. A fifth coil is formed from a proximal portion of the second lead of the third coil. The fifth coil is wrapped around a distal portion of the second lead of the first coil.
- [0014] The power conditioner can have a plurality of the multi-coil chokes, each coupled in series with at least one capacitor across a respective AC power source. In such an embodiment, the coupling means are adapted to couple each of the multi-coil chokes with the first and fourth coils in series with at least one capacitor across a respective AC power source, the second coil in series with at least one capacitor across a respective AC power source, and the third and fifth coils in series with at least one capacitor across a respective AC power source.
- [0015] In an embodiment with a single multi-coil choke, the coupling means can be adapted to couple the first and fourth coils in series with at least one capacitor across a respective AC power source, the second coil in series with at least one capacitor across

a respective AC power source; and the third and fifth coils in series with at least one capacitor across a respective AC power source.

[0016] The magnetic core can be formed from two rectangular closed cores placed side-by-side with adjacent sides forming the second leg. Each of the first and third legs can include a gap. The second leg can include substantially aligned gaps in the adjacent sides of the rectangular closed cores. The gaps in the first, second and third legs can be centrally located along their respective legs. An additional gap can reside along the length of the adjacent sides of the rectangular closed cores. This additional gap can result, e.g., from the provision of an insulating cover on each of the rectangular closed cores.

BRIEF DESCRIPTION OF THE DRAWINGS

- [0017] Referring now to the figures, wherein like elements are numbered alike:
- [0018] FIG. 1 is a diagram showing a magnetic core structure on which a choke in accordance with the invention can be wound.
- [0019] FIG. 2 is a cross-sectional view of a portion of the core.
- [0020] FIG. 3 is an enlarged view of the core with windings thereon to form a multi-coil choke in accordance with the invention.
- [0021] FIG. 4 is a schematic diagram of a single phase power conditioner using one choke in accordance with the invention.
- [0022] FIG. 5 is a schematic diagram of a three-phase power conditioner using one choke in accordance with the invention.
- [0023] FIG. 6 is a schematic diagram of a three-phase power conditioner using two chokes in accordance with the invention.
- [0024] FIG. 7 is a schematic diagram of a three-phase three-line power conditioner using three chokes in accordance with the invention.
- [0025] FIG. 8 is a schematic diagram of a three-phase three-line with neutral power conditioner using three chokes in accordance with the invention.

DETAILED DESCRIPTION OF THE INVENTION

- [0026] A power conditioner for alternating current in accordance with the invention uses a unique multi-coil choke. Referring to Figure 1, a magnetic core structure 10 is shown that can be used to fabricate a choke in accordance with the invention. The choke can be fabricated, for example, using two side by side cores 12 and 14. Such cores can comprise, for example, "Snap-together Torroid Choke" cores available from Radio Shack under Catalog No. 273-104. These cores include a ferrite core with a plastic outer cover. In particular, cover 13 (shown in a solid line) is illustrated surrounding core sections 12a, 12b (shown in dashed lines) and cover 15 (shown in a solid line) is shown surrounding core sections 14a, 14b (shown in dashed lines).
- [0027] Each of the cores 12 and 14 is constructed from two C-shaped ferrite core components 12a, 12b and 14a, 14b respectively that, when assembled side by side within the plastic outer covers 13, 15 respectively, form gaps where the top and bottom ends of each "C" meet. These gaps can be seen at reference numerals 16 and 18a in the core 12. Similar gaps 18b and 22 are shown in the core 14. When the two cores 12 and 14 are placed side by side as shown in Figure 1, an additional gap 24 is formed along the adjacent sides of the cores. It is noted that the gap 24 comprises the space between the actual ferrite cores (i.e., between the dashed lines) which is mostly dictated by the thickness of the walls of the plastic cover portions 13, 15 that reside within the gap.
- [0028] The core structure shown in Figure 1 results in three legs around which wire coils are wound in accordance with the invention. These are a top leg 31, middle leg 33a, 33b and bottom leg 35. As can be seen, the top leg 31 is part of core 12, the bottom leg 35 is part of core 14, and the middle leg 33a, 33b comprises portions of both cores 12 and 14. A dot 110 (e.g., paint) can be placed, for example, on the lower right corner of core 12 to assist a person in maintaining the core structure in a proper orientation when winding coils on the legs. This is important, as proper operation of the choke will depend on the directions in which the various coils are wound.

- [0029] When the coils are properly wound in accordance with the invention, as will be explained below, the magnetic field created when the choke is energized will be oriented in the directions shown by arrows 100, 102, 104 and 106. In particular, the field in the first leg 31 will be oriented from left to right as designated by arrows 100. The field in the second leg 33a, 33b will be oriented from right to left as designated by arrows 102, 104. The field in the third leg 35 will be oriented from left to right as designated by arrows 106. It should be appreciated that the coils can also be wrapped such that the magnetic fields will be oriented in directions opposite to those shown in the example of Figure 1.
- [0030] Figure 2 is a cross section of the core taken along the line 2-2 shown in Figure 1. In particular, Figure 2 illustrates the ferrite core 14b inside of plastic cover 15. The cover 15 acts as an insulating jacket for the core. It is noted that the cover 15 covers three sides of the core 14b, with the side 14c of the ferrite core being exposed.
- [0031] Figure 3 is an enlarged, detailed view of a choke in accordance with the invention that has been wound on the core structure 10 of Figure 1. The choke has five coils, three of which (first coil 30, second coil 32 and third coil 34) are wound around respective legs 31, 33a,b and 35 of the core. A fourth coil 36 is wound around a lead portion of the third coil. The fifth coil 38 is wound around a lead portion of the first coil. The choke is adapted for use in various embodiments of AC power conditioners, also referred to as "shunt efficiency" systems. Examples of such power conditioners are provided in Figures 4-8.
- [0032] In the choke embodiment illustrated in Figure 3, first coil 30 is wrapped around first leg 31 of core 12. Second coil 32 is wrapped around a second leg, which consists of leg 33a of core 12 and adjacent leg 33b of core 14. Third coil 34 is wrapped around a third leg 35 of core 14. As indicated, the gaps 16 and 22 are centered along first leg 31 and third leg 35, respectively. Similarly, gaps 18a and 18b (together referred to as gap 18) are generally aligned in a centered position along second leg 33a, 33b. As can be seen in Figure 1, the three legs 31, 33a,b and 35 are substantially parallel to each other.

- [0033] The direction in which the first, second and third coils are wrapped around their respective legs is important to the operation of the multi-coil choke and, more particularly, to power conditioners fabricated from the choke. In particular, the first coil 30 is wrapped in one direction (e.g., counterclockwise) and the second and third coils 32, 34 are wrapped in the opposite direction (e.g., clockwise). It should be appreciated that these directions can be reversed, as long as the relationships between the coils is maintained.
- [0034] Although the number of turns present in each coil can vary depending on the requirements of the circuit in which the choke is used, typically each of coils 30, 32 and 34 will have 4-6 turns of, e.g., 12 AWG insulated stranded copper wire. In the illustrated embodiment, each of the first, second and third coils 30, 32 and 34 has five turns, with the first coil wrapped around leg 31 in a counterclockwise direction and the second and third coils wrapped around leg 33a, 33b and 35, respectively, in a clockwise direction. Also in the illustrated embodiment, fourth and fifth coils 36 and 38, respectively, have seven turns.
- [0035] Fourth coil 36 extends from the first coil 30 and fifth coil 38 extends from the third coil 34. As can be seen in the figures, first coil 30 has a first lead 40 and a second lead 41. The fourth coil 36 is formed from a portion of second lead 41 that is proximal to first coil 30. Likewise, third coil 34 has a first lead 44 and a second lead 45. The fifth coil 38 is formed from a portion of second lead 45 that is proximal to the third coil 34.
- [0036] The fourth coil 36 is wrapped around a portion 45' of the second lead 45 of the third coil 34 that is distal to the third coil 34. Similarly, the fifth coil 38 is wrapped around a portion 41' of the second lead 41 of first coil 30 that is distal to the first coil 30. On its way to the fourth coil 36, the second lead 45 of the third coil passes through the first coil 30 as shown at 45''. This occurs after formation of the fifth coil 38 in the second lead 45. As a result of this structure, the distal portion of the second lead 45 of the third coil 34 passes through the first coil 30 before passing through the fourth coil 36.

- [0037] In the same manner, on its way to the fifth coil 38, the second lead 41 of the first coil passes through the third coil 34 as shown at 41''. This occurs after the formation of the fourth coil 36 in the second lead 41 of coil 30. As a result, the distal portion of the second lead 41 of the first coil 30 passes through the third coil 34 before passing through the fifth coil 38.
- [0038] The unique choke shown in Figure 3 can be used in any of a variety of different power conditioner implementations. These include, for example, 120/240 volt single phase residential/recreational units, as well as 208, 240, 480 and 600 volt three phase commercial/industrial units (for three, four, and five wire applications). Various such embodiments are shown in Figures 4-8. It is noted that for clarity in the drawings, the air gaps 16, 18, 22 and 24 of the chokes, which are shown in the enlarged views of Figures 1 and 3, are not illustrated in Figures 4-8. However, each of the chokes in Figures 4-8 has these air gaps.
- [0039] Figure 4 is a schematic diagram of an example single phase 120 volt power conditioner implementation. In this embodiment, the first lead 40 of the first coil 30 is connected to the line 50 (L1) of an AC power source to be conditioned. The second lead 41 of the first coil 30 is connected at its free end to the neutral 52 (N) of the AC power source via a capacitor 54. Similarly, the first lead 44 of the third coil 34 is connected to the line 50 (L1) of the AC power source, and the second lead 45 is connected at its free end to neutral 52 through a capacitor 56. Second coil 32 is coupled between line 50 and neutral 52 as well. In particular, line 42 of second coil 32 is coupled to line 50 (L1) and line 43 of the second coil 32 is coupled to neutral 52 (N) via capacitor 58.
- [0040] The embodiment of Figure 4 includes various additional components. A lamp 60 (e.g., LED or incandescent) is connected between line 50 and neutral 52 via a current limiting resistor 62. Transient suppression is provided by a varistor (e.g., MOV) 64 coupled between L1 and neutral. A bleed resistor 66 is coupled in parallel with varistor 64 to bleed off stored charges, thereby reducing the possibility of electrical shock to an electrician working with the unit after power has been turned off.

- [0041] Figure 5 is a schematic diagram of an example 240 volt recreational unit (e.g., for watercraft) having line 50 (L1), line 53 (L2) and neutral 52 (N). As with the embodiment of Figure 4, a single choke 10 is used with the first, second and third coils 30, 32, 34 coupled as shown. Additional components in this implementation include lamp 61 and series resistor 63, varistor 65 with parallel bleed resistor 67, and varistor 68.
- [0042] Figure 6 shows an example 240 volt three phase power conditioner implementation using the multi-coil chokes 10 of the present invention. In this embodiment, two identical chokes 10a and 10b are used. These chokes are the same as choke 10 illustrated in Figure 3. The first, second and third coils 30, 32 and 34 of each choke are coupled to lines L1, L2 and N of the AC power source as shown. Additional components in this implementation include capacitors 70, 72 and 74.
- [0043] Figure 7 shows a three phase embodiment suitable, e.g., for a 480 volt power conditioner installed on an AC source having three hot lines 50 (L1), 53 (L2) and 55 (L3). Three chokes 10a, 10b and 10c are provided, each having the same configuration of the choke 10 shown in Figure 3. The first, second and third coils 30, 32 and 34 of each choke are coupled to lines L1, L2 and L3 of the power source as shown. Additional components in this implementation include lamp 80 and series resistor 81, and capacitors 83, 84 and 85. An additional bleed resistor 69 is also provided across varistor 68.
- [0044] Figure 8 is a schematic diagram of an example power conditioner used for, e.g., a 208 volt or 480 volt 3 phase Y configured AC power source. Such a power source has three hot lines and a neutral. These are shown in Figure 8 as line 50 (L1), line 53 (L2), line 55 (L3) and neutral 52 (N). Three chokes 10a, 10b and 10c are provided, each having the same configuration of the choke 10 shown in Figure 3. The first, second and third coils 30, 32 and 34 of each choke are coupled to lines L1, L2 L3 and N of the power source as shown. Additional components in this implementation include varistor 85 and resistor 86.

- [0045] The multi-coil choke of the present invention provides power conditioners with improved transient and surge protection as well as substantial energy savings over prior art power conditioners, including significant improvements over the power conditioners disclosed in US Patent 5,105,327. Transient and surge protection is provided by the various capacitors and transient suppressors. As shown in the drawings, capacitors are provided across power lines. Transient suppressors, such as metal oxide varistor ("MOV") devices can be placed at various points throughout the circuit. An MOV can be placed across incoming power lines. An MOV can be coupled from incoming lines to neutral. MOVs can be placed between neutral and ground. Bleed resistors across the transient suppressors take down the charge held by the circuit to protect against electrical shock when the unit is disconnected from the AC power source.
- [0046] The values of the various components shown will depend upon the AC power source to be conditioned and the loads to be protected by the power conditioners. Typically, the capacitors will be between 25-100 microfarads and will have a voltage limit that is suitable for the maximum voltage to be applied to the power conditioner. The bleed down resistors placed across the varistors will be on the order of 30K Ω to 100K Ω or more with a typical power rating of 2 watts. The MOV devices used for the transient suppressors will typically be selected to have a rating of about 40,000 joules each.
- [0047] Power conditioners using the multi-coil chokes disclosed herein are frequency independent, so that they can work on both 60 Hz line current found in North America as well as on 50 Hz current used elsewhere in the world. Power conditioners manufactured using the inventive chokes are vastly improved over prior art devices due to various factors, including the three leg core design, the provision of five coils in each choke with the winding configuration taught herein, and the four separate air gaps provided in the core. These air gaps are shown most clearly in Figure 1 as gaps 16, 18 (18a and 18b), 22 and 24. Tests have shown that energy savings are about double the savings provided by prior art devices of the type shown in US Patent 5,105,327, with faster surge suppression and the ability to handle larger surges. The improvements in

surge suppression are achieved, at least in part, due to the multiple air gaps provided in the chokes which prevent the chokes from saturating. Better filtering is also provided by power conditioners using the chokes of the present invention.

[0048] The components of the power conditioner can be provided in a module that is connected to a user's power lines at the service panel. Alternatively, the module can be connected to the user's power lines at a load. A plurality of such modules can be provided throughout a commercial establishment or residence. For example, one module can be installed at each fluorescent light fixture in an office building or on each separate line feeding such lighting fixtures. Connections to the module are made at taps on the power lines. There is no need to cut the power lines when installing the module, since none of the components are placed in series with any of the lines.

[0049] While the present invention has been described with reference to various example embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiments disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims.

What is claimed is:

1. A multi-coil choke comprising:

a magnetic core having a first leg, a second leg and a third leg, said legs being substantially parallel to each other;

a first coil wrapped around said first leg and terminating in a first lead at a first end thereof and a second lead at a second end thereof;

a second coil wrapped around said second leg and terminating in a first lead at a first end thereof and a second lead at a second end thereof;

a third coil wrapped around said third leg and terminating in a first lead at a first end thereof and a second lead at a second end thereof;

a fourth coil formed from a proximal portion of the second lead of said first coil, said fourth coil being wrapped around a distal portion of the second lead of said third coil; and

a fifth coil formed from a proximal portion of the second lead of said third coil, said fifth coil being wrapped around a distal portion of the second lead of said first coil.

2. A multi-coil choke in accordance with claim 1 wherein:

the distal portion of the second lead of said of said first coil passes through said third coil before passing through said fifth coil; and

the distal portion of the second lead of said third coil passes through said first coil before passing through said fourth coil.

3. A multi-coil choke in accordance with claim 1 wherein said magnetic core is formed from two rectangular closed cores placed side-by-side with adjacent sides forming said second leg.

4. A multi-coil choke in accordance with claim 3 wherein:

said first leg includes a gap;

said second leg includes substantially aligned gaps in the adjacent sides of said rectangular closed cores; and

said third leg includes a gap.

5. A multi-coil choke in accordance with claim 4 comprising an additional gap along the length of the adjacent sides of said rectangular closed cores.
6. A multi-coil choke in accordance with claim 4 wherein said gaps are centrally located along their respective legs.
7. A multi-coil choke in accordance with claim 3 wherein each of said rectangular closed cores is contained within an insulating cover.
8. A multi-coil choke in accordance with claim 1 wherein said first coil is wrapped in one of a clockwise and counterclockwise direction, and said second and third coils are wrapped in the other of said clockwise and counterclockwise direction.
9. A multi-coil choke in accordance with claim 8 wherein said fourth coil is wrapped in the same direction as said first coil and said fifth coil is wrapped in the same direction as said third coil.
10. A multi-coil choke in accordance with claim 1 wherein said first and fourth coils are wrapped in a counterclockwise direction, and said second, third and fifth coils are wrapped in a clockwise direction.
11. A power conditioner for AC power lines comprising:
 - a multi-coil choke;
 - at least one capacitor; and
 - means for coupling said choke and at least one capacitor in series across an AC power source;wherein said choke comprises:
 - a magnetic core having a first leg, a second leg and a third leg, said legs being substantially parallel to each other;

a first coil wrapped around said first leg and terminating in a first lead at a first end thereof and a second lead at a second end thereof;

a second coil wrapped around said second leg and terminating in a first lead at a first end thereof and a second lead at a second end thereof;

a third coil wrapped around said third leg and terminating in a first lead at a first end thereof and a second lead at a second end thereof;

a fourth coil formed from a proximal portion of the second lead of said first coil, said fourth coil being wrapped around a distal portion of the second lead of said third coil; and

a fifth coil formed from a proximal portion of the second lead of said third coil, said fifth coil being wrapped around a distal portion of the second lead of said first coil.

12. A power conditioner in accordance with claim 11 wherein:

the distal portion of the second lead of said of said first coil passes through said third coil before passing through said fifth coil; and

the distal portion of the second lead of said third coil passes through said first coil before passing through said fourth coil.

13. A power conditioner in accordance with claim 11 comprising a plurality of said multi-coil chokes, each coupled in series with at least one capacitor across a respective AC power source.

14. A power conditioner in accordance with claim 13 wherein said means for coupling are adapted to couple each of said multi-coil chokes with:

said first and fourth coils in series with at least one capacitor across a respective AC power source;

said second coil in series with at least one capacitor across a respective AC power source; and

said third and fifth coils in series with at least one capacitor across a respective AC power source.

15. A power conditioner in accordance with claim 11, wherein said means for coupling are adapted to couple:

said first and fourth coils in series with at least one capacitor across a respective AC power source;

said second coil in series with at least one capacitor across a respective AC power source; and

said third and fifth coils in series with at least one capacitor across a respective AC power source.

16. A power conditioner in accordance with claim 11 wherein said magnetic core is formed from two rectangular closed cores placed side-by-side with adjacent sides forming said second leg.

17. A power conditioner in accordance with claim 16 wherein:

said first leg includes a gap;

said second leg includes substantially aligned gaps in the adjacent sides of said rectangular closed cores; and

said third leg includes a gap.

18. A power conditioner in accordance with claim 17 comprising an additional gap along the length of the adjacent sides of said rectangular closed cores.

19. A power conditioner in accordance with claim 17 wherein said gaps are centrally located along their respective legs.

20. A power conditioner in accordance with claim 16 wherein each of said rectangular closed cores is contained within an insulating cover.

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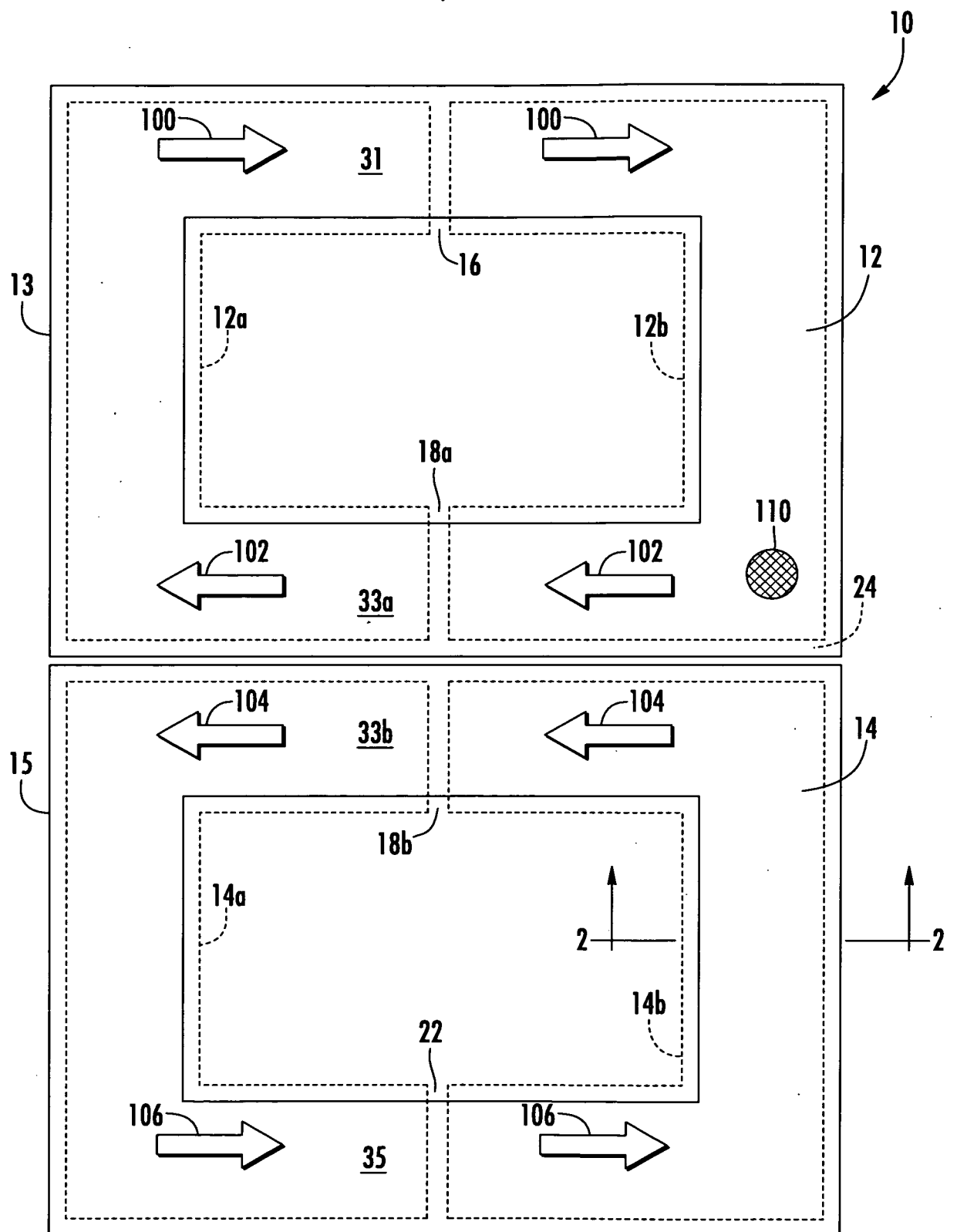


FIG. 1

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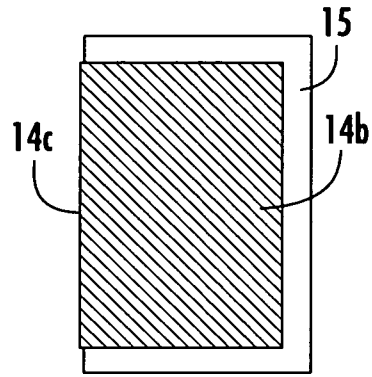


FIG. 2

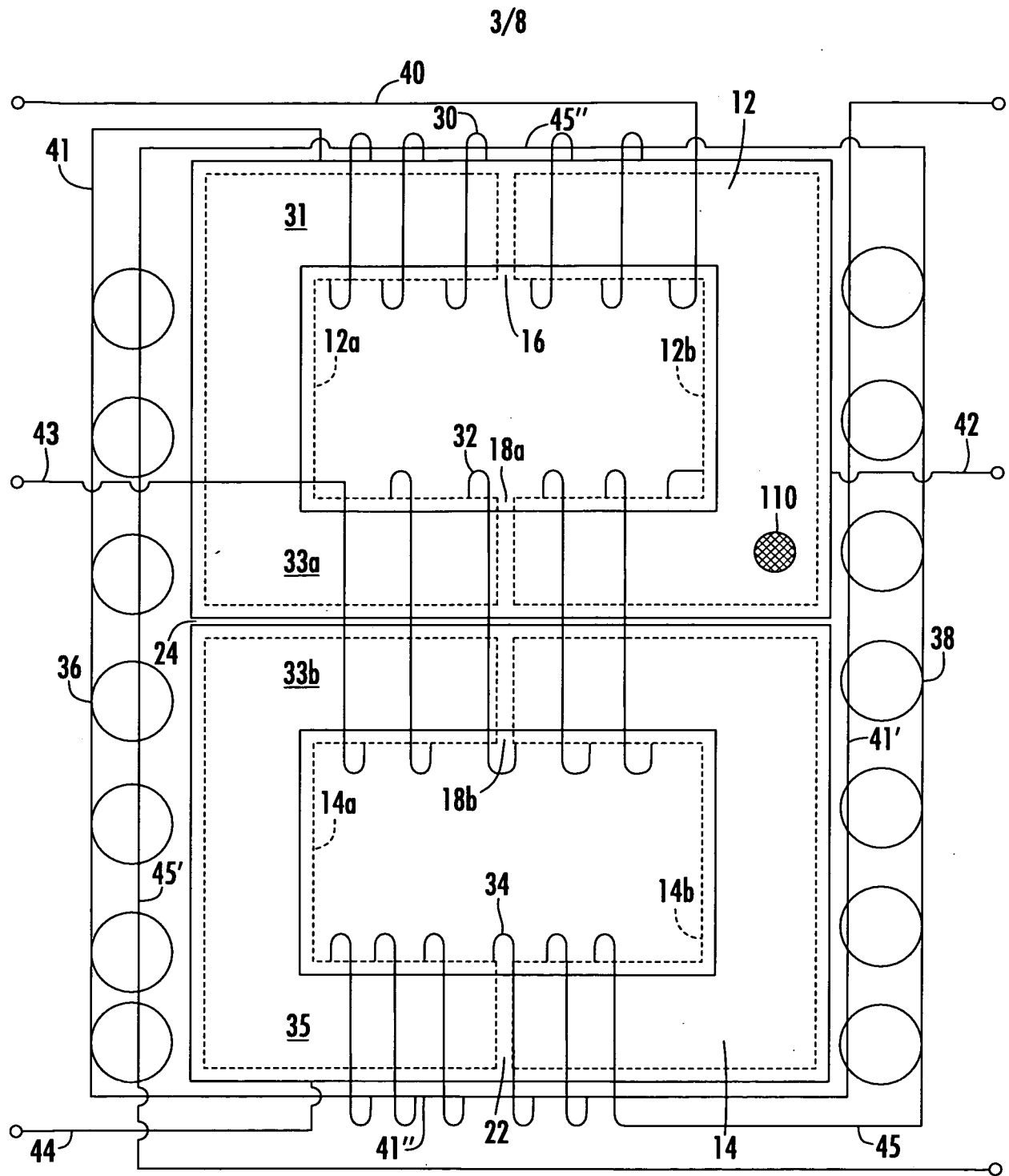


FIG. 3

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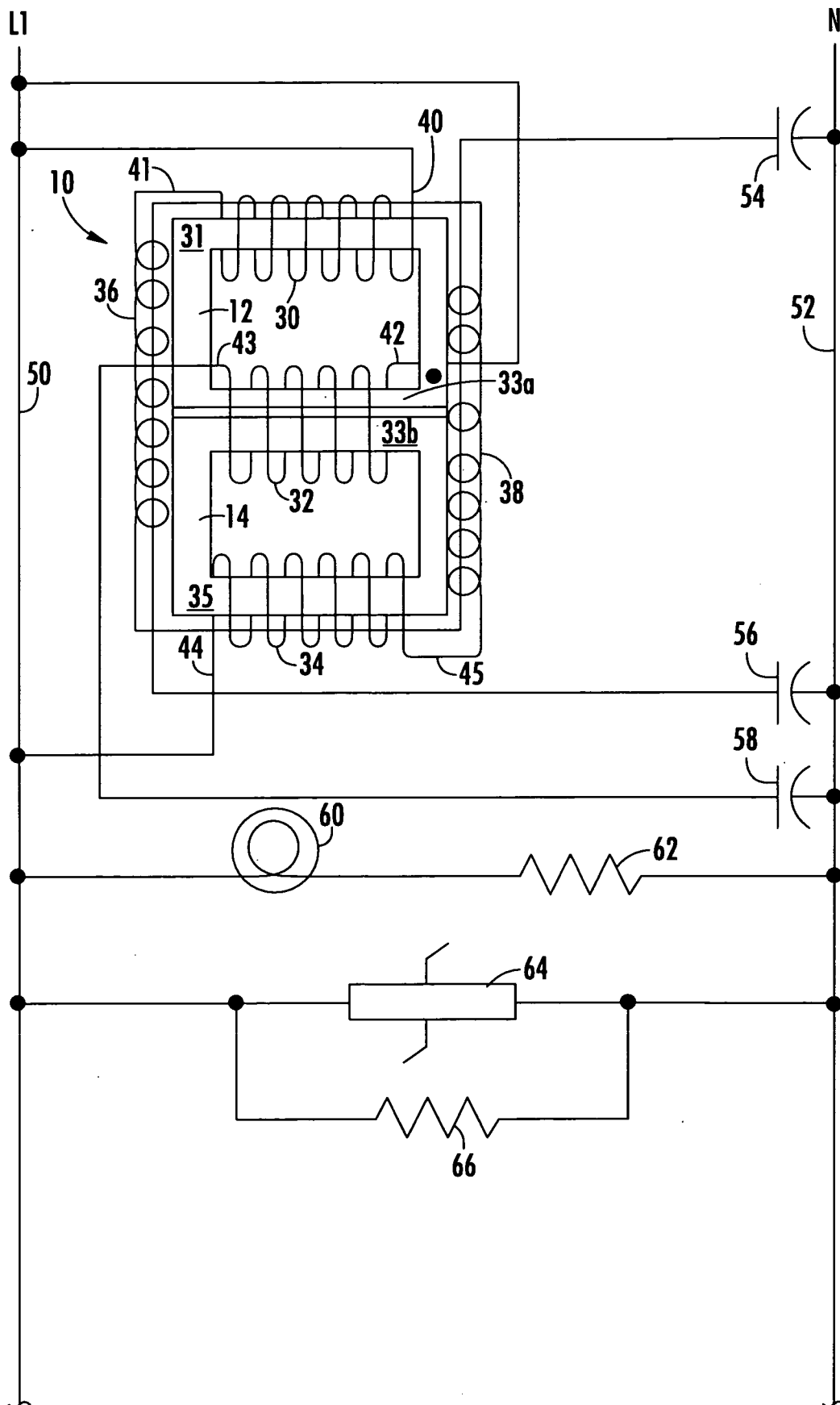


FIG. 4

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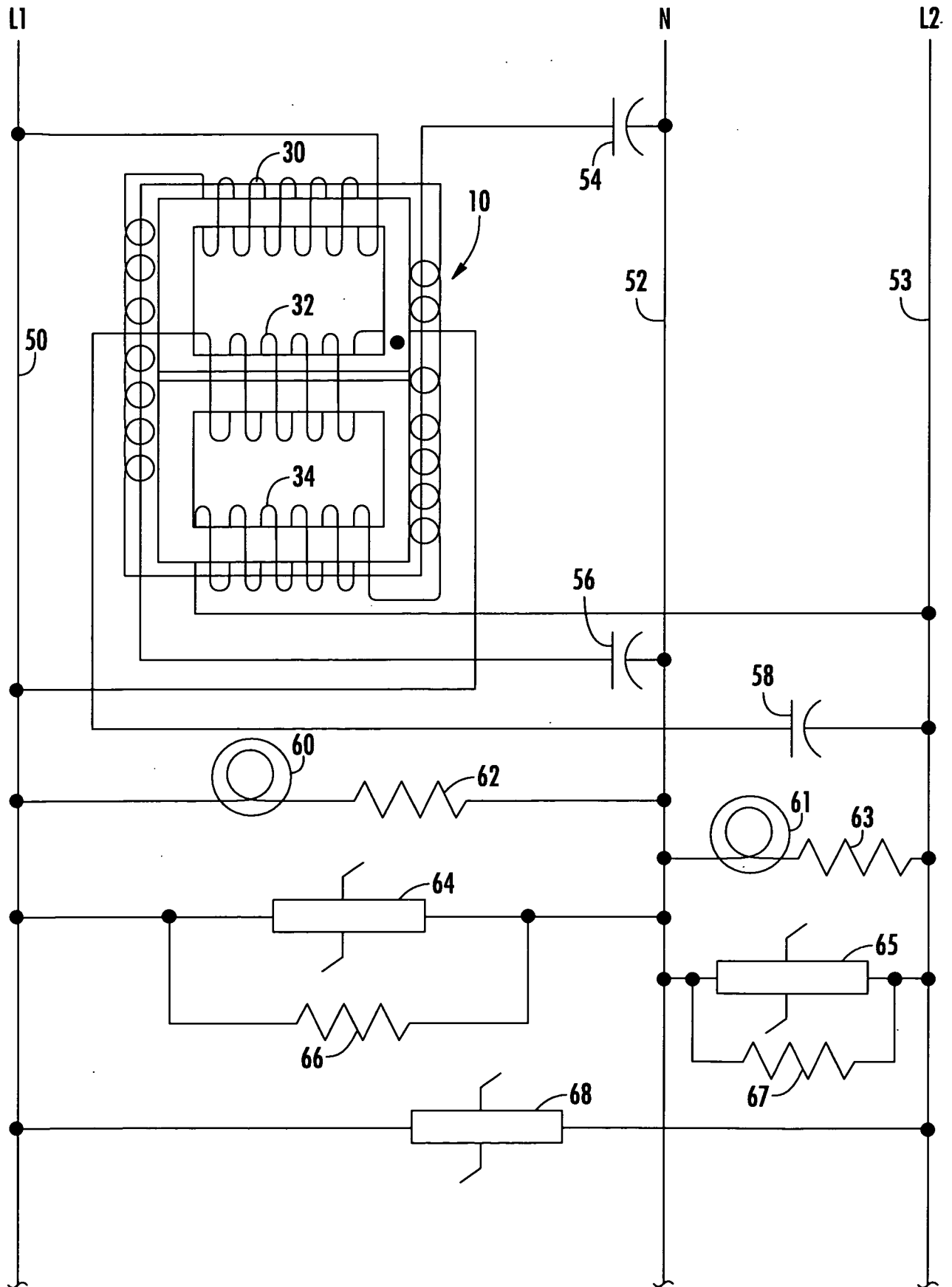


FIG. 5

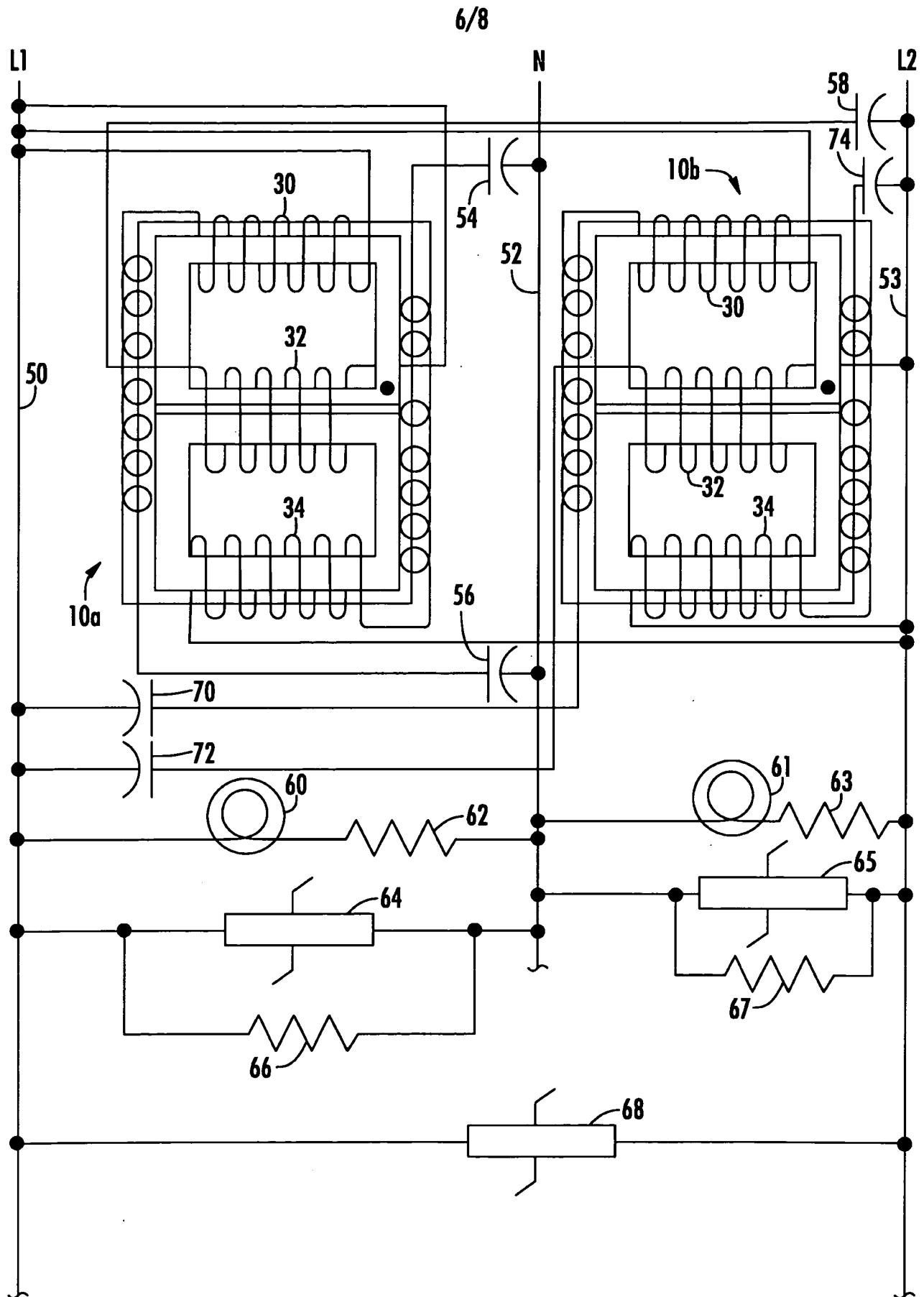
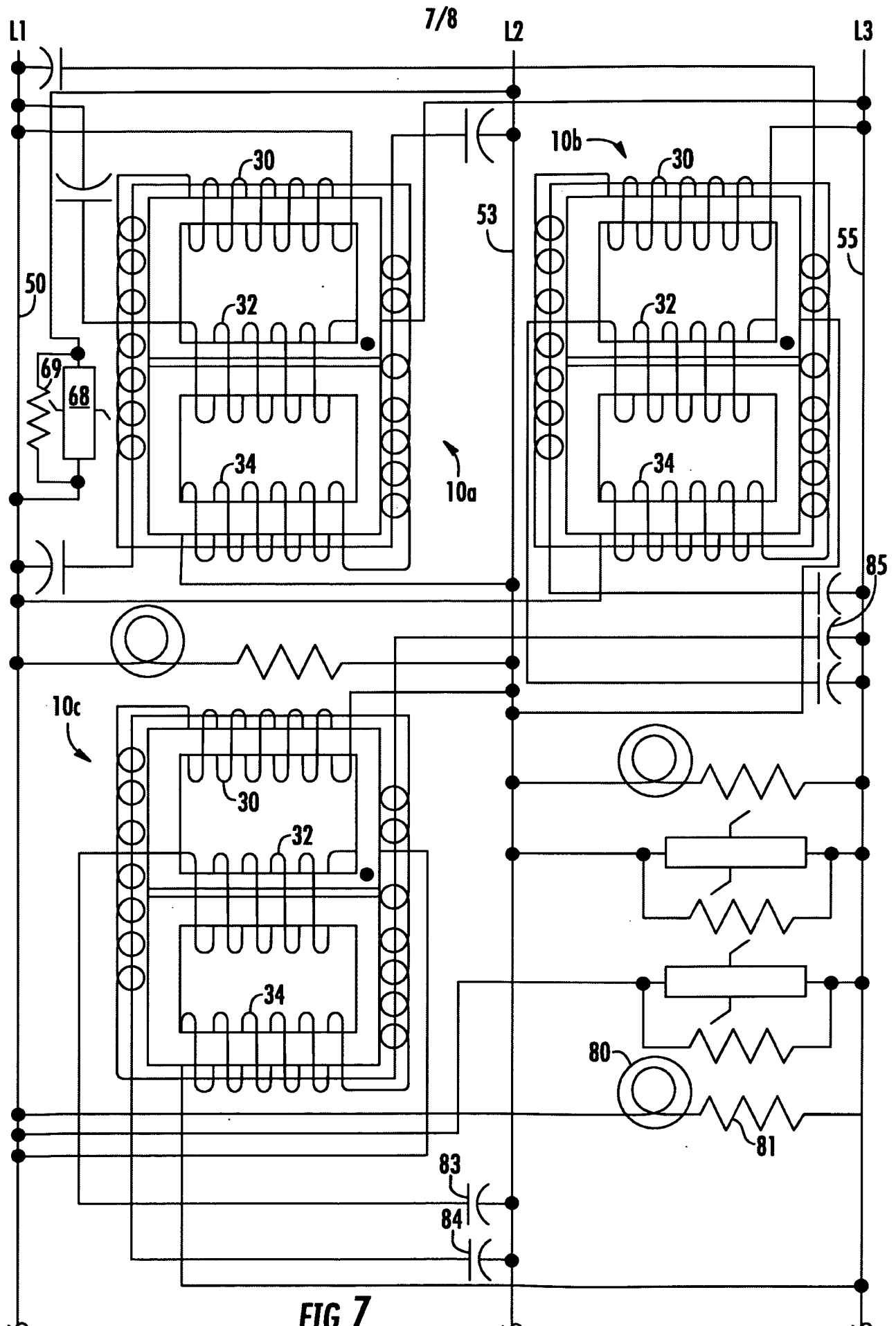


FIG. 6



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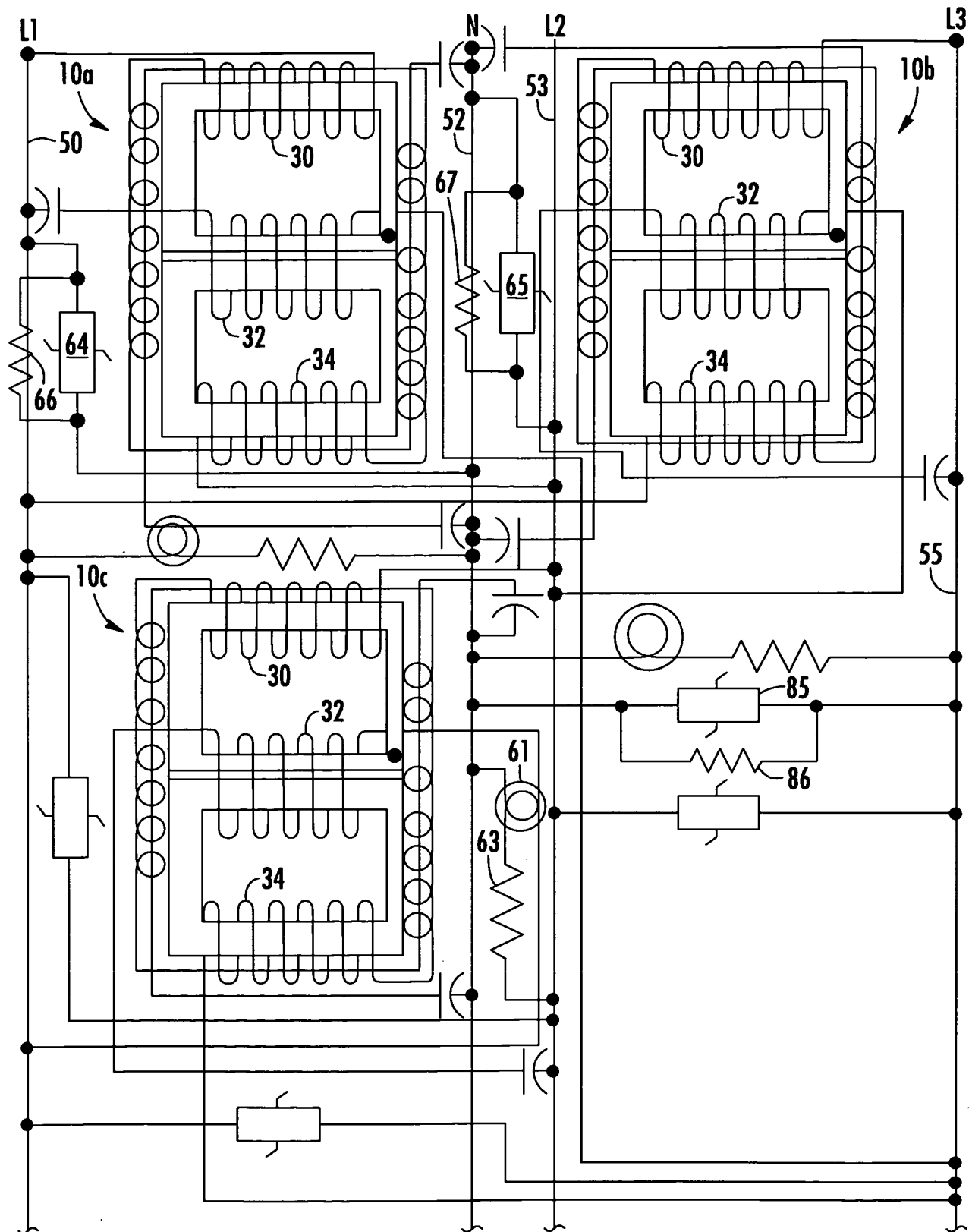


FIG. 8

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2011/001251

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - H01F 27/28 (2011.01)

USPC - 336/170

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)

IPC(8) - H01F 17/06, 27/28, 38/20 (2011.01)

USPC - 336/170, 178, 180, 184

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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

MicroPatent, Google Patents, Google Scholar

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,422,620 A (BITTERLI) 06 June 1995 (06.06.1995) entire document	1-20
Y	US 5,105,327 A (WOHLFORTH) 14 April 1992 (14.04.1992) entire document	1-20
Y	US 6,512,438 B1 (YOSHIMORI et al) 28 January 2003 (28.01.2003) entire document	7, 20
Y	US 1,647,928 A (OWEN) 01 November 1927 (01.11.1927) entire document	8-10
A	US 7,142,081 B1 (SHUDAREK) 28 November 2006 (28.11.2006) entire document	1-20
A	US 3,247,449 A (MEDLAR) 19 April 1966 (19.04.1966) entire document	1-20

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Date of the actual completion of the international search

03 November 2011

Date of mailing of the international search report

16 NOV 2011

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