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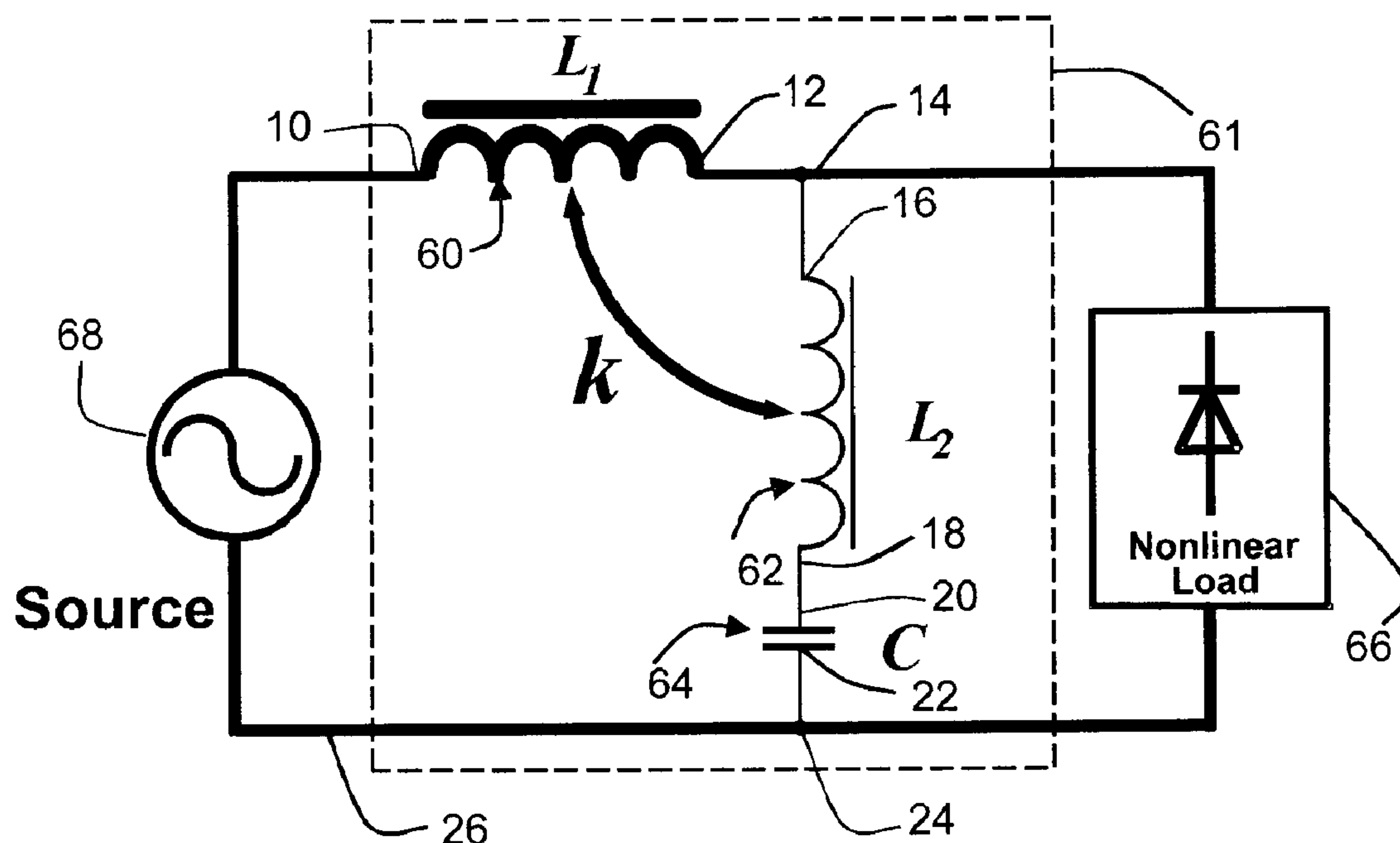
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(54) Titre : FILTRE A HARMONIQUES

(54) Title: DEVICE FOR FILTERING HARMONICS



(57) Abrégé/Abstract:

A power device is provided for filtering or dampening harmonics and optimizing the power factor in power distributions systems. A device for a 3-phase power system comprises series inductors able to communicate between an AC power source and a non-linear load. Connected in parallel to the series inductors, at the junction with the non-linear load, are shunt inductors used to trap harmonic currents. Power factor correction capacitors are connected to the ends of the shunt inductors. The series inductor and shunt inductor are used to form a coaxial reactor assembly, which further comprises a reactor core. The coaxial reactor assembly is formed by winding a first inductor around the core and then winding a separate second inductor around the perimeter of the first inductor. In another embodiment, the device includes a third inductor to achieve better dampening and power factor performance.



1 ABSTRACT

2 A power device is provided for filtering or dampening harmonics and optimizing the
3 power factor in power distributions systems. A device for a 3-phase power system comprises
4 series inductors able to communicate between an AC power source and a non-linear load.
5 Connected in parallel to the series inductors, at the junction with the non-linear load, are shunt
6 inductors used to trap harmonic currents. Power factor correction capacitors are connected to
7 the ends of the shunt inductors. The series inductor and shunt inductor are used to form a
8 coaxial reactor assembly, which further comprises a reactor core. The coaxial reactor assembly
9 is formed by winding a first inductor around the core and then winding a separate second
10 inductor around the perimeter of the first inductor. In another embodiment, the device includes
11 a third inductor to achieve better dampening and power factor performance.

1 **DEVICE FOR FILTERING HARMONICS**

2 **FIELD OF THE INVENTION**

3 **[0001]** The present invention relates generally to devices for dampening harmonics.

4 **BACKGROUND OF THE INVENTION**

5 **[0002]** Electric power is often provided in the form of alternating currents and voltages. In
6 North America, for example, the electric power may typically be provided at a frequency of 60
7 Hz. When the electric power interacts with various electronic devices, current and voltage
8 distortions may occur. The distorted power may affect the operation of many electronic devices.
9 In one example, a building's power distribution system may be connected to various electronic
10 devices comprising, for example, computers, electronic ballasts, printers, fax machines, HVAC
11 equipment, and uninterruptible power supplies. These devices, or non-linear loads, may cause
12 the quality of the building's power supply to degrade.

13 **[0003]** Harmonics cause distortion in sinusoidal power waveforms. These distortions are
14 referred to as "harmonic distortion" and are caused by various factors. By way of background, a
15 harmonic of a wave, in this case a power signal, is an integer multiple of the fundamental
16 frequency. As mentioned above, the fundamental frequency, or frequency at which electric
17 power is generated, in North America is 60 Hz. In European countries, the fundamental
18 frequency may be 50 Hz, while an aircraft system may generate power at a fundamental
19 frequency of 400 Hz. It is appreciated that the fundamental frequency in a power system may
20 vary. The superposition of a harmonic current and a current operating at the fundamental
21 frequency may generate a distorted current and/or voltage signal, also referred to as harmonic
22 distortion.

23 **[0004]** Typically, harmonic distortion provides undesirable voltage and current waveforms to
24 electronic devices. It is appreciated that many electronic devices are designed for power input
25 in the form of an undistorted sine wave. Therefore, a distorted power input may cause a variety
26 of problems for electronic devices, including overheating, increased power consumption,
27 reduced power factor, malfunction or failure, erratic operation of breakers and relays, and
28 pronounced magnetic fields near transformers and switch gears. As described herein, filtering
29 or dampening the harmonics refers to the reduction of harmonic distortion.

1 **[0005]** It has been shown that harmonics may be dampened by using various approaches,
2 including without limitation, active and passive filters. Active filters may use additional energy to
3 dampen the harmonics, and in some cases may rely on the principle of wave cancellation.
4 Active filters generally require costly electronic components, which may have relatively short life
5 expectancies. Furthermore, due to limited capability of electronic components, active filters are
6 typically not suitable for larger current loads.

7 **[0006]** Passive harmonic mitigation generally utilizes the flow of current to trap or pull the
8 harmonics within a device, thereby preventing the propagation of the harmonics throughout the
9 system. By way of background, passive harmonic filters for dampening or filtering harmonics
10 generally comprise reactors and capacitors. A reactor may comprise at least one inductor and
11 may be used to absorb sudden changes in current. Advantages of passive systems over active
12 ones include lower costs, simplified structure, utility across larger current and voltage ranges,
13 and increased robustness.

14 **[0007]** In addition to the above considerations, power factor is also of interest in the field of
15 harmonic filtration or mitigation devices. It is appreciated that the power factor is the ratio
16 between the power used (i.e. Active or Real power) and power supplied (i.e. Apparent power) to
17 a device. In ideal circumstances, the power factor would be 1.

18 **[0008]** An example of a passive filter is provided to U.S. patent number 6,127,743 (the '743
19 patent) which discloses a harmonic mitigation device comprising two oppositely wound
20 inductors arranged in series. These oppositely wound inductors are further electrically
21 connected in series between an AC source and non-linear load. A third inductor is connected in
22 parallel between the junction of the two series inductors. A capacitor is connected in series to
23 the third inductor. The '743 patent teaches that the inductors are stacked vertically along the
24 length of a common reactor core.

25 **[0009]** In U.S. patent number 6,844,794 (the '794 patent), a harmonic filter is described
26 using two inductors. The '794 patent shows that one of the inductors that is electrically
27 connected in series to the non-linear load may be removed, while mitigating the effects of the
28 harmonics. In the '794 patent, an embodiment is described with two separate reactors.

29 **[0010]** There exists a need for a device for dampening harmonics that overcomes at least
30 one of the drawbacks associated with the prior devices.

1 SUMMARY OF THE INVENTION

2 **[0011]** In one aspect, the invention provides a harmonic filter device for a single-phase
3 power system comprising at least one series inductor, which, when in use, is electrically
4 connected between an AC power source and a non-linear load. Connected in parallel to the
5 series inductor, at the junction with the non-linear load, is a shunt inductor that is used to trap
6 harmonic currents. A power factor correction capacitor is connected to the end of the shunt
7 inductor. The series and shunt inductors are used to form a coaxial reactor assembly, which
8 further comprises a reactor core. The coaxial reactor assembly is formed by winding a first
9 inductor around the reactor core and then winding a separate second inductor around the
10 perimeter of the first inductor. In an embodiment, the ampacity of the wire used to form the
11 shunt inductor may be different from the ampacity of the series inductor wire. Ampacity is
12 defined herein as the capacity to carry current.

13 **[0012]** In another aspect of the invention, three coaxial reactor assemblies may be used to
14 form a harmonics filter for three-phase power systems.

15 **[0013]** In another aspect of the invention, a device for dampening harmonics is provided.
16 The device is electrically connectable to at least one power source and at least one non-linear
17 load. The device comprises a first inductor comprising a first end being connectable to the at
18 least one power source and a second end being electrically connectable to the at least one non-
19 linear load. There is also a second inductor comprising a first end electrically connected to the
20 first or the second end of the first inductor and a second end electrically connected to at least
21 one capacitor. The first and second inductors are in a coaxial arrangement comprising two
22 layers wound around a core. The layers comprise an inner layer adjacent to the core, the inner
23 layer comprising one of the inductors. The layers also comprise an outer layer provided over
24 the inner layer, the outer layer comprising the other of the inductors.

25 **[0014]** In another aspect of the invention, the first end of the first inductor is a start of
26 winding and the second end of the second inductor is another start of winding.

27 **[0015]** In another aspect of the invention, the first end of the first inductor is a start of
28 winding and the first end of the second inductor is another start of winding.

29 **[0016]** In another aspect of the invention, the inner layer comprises the first inductor and the
30 outer layer comprises the second inductor.

1 **[0017]** In another aspect of the invention, the inner layer comprises the second inductor and
2 the outer layer comprises the first inductor.

3 **[0018]** In another aspect of the invention, the second inductor comprises a wire with a
4 smaller cross-sectional area than the first inductor.

5 **[0019]** In another aspect of the invention, the first end of the second inductor is connected
6 to the second end of the first inductor.

7 **[0020]** In another aspect of the invention, a three-phase power distribution system is
8 provided comprising three phase assemblies, wherein each phase assembly comprises the
9 device for dampening harmonic distortions.

10 **[0021]** In another aspect of the invention, a device for dampening harmonics is provided.
11 The device is electrically connectable to at least one power source and at least one non-linear
12 load. The device comprises a first inductor and a second inductor, each comprising a first end
13 and a second end. The first end of the first inductor is electrically connectable to the at least
14 one power source. The second end of the first inductor is electrically connected to the first end
15 of the second inductor. The second end of the second inductor is electrically connectable to the
16 at least one non-linear load. The second end of the first inductor and the first end of said
17 second inductor are both electrically connected to at least one capacitor. The first and second
18 inductors are in a coaxial arrangement comprising two layers wound around a core. The layers
19 comprise an inner layer adjacent to the core, the inner layer comprising one of the inductors.
20 The layers also comprise an outer layer provided over the inner layer, whereby the outer layer
21 comprises the other of the inductors.

22 **[0022]** In another aspect of the invention, a device is provided for dampening harmonics.
23 The device is electrically connectable to at least one power source and at least one non-linear
24 load. The device comprises a first inductor, a second inductor and a third inductor, each
25 comprising a first end and a second end. The first end of the first inductor is electrically
26 connectable to the at least one power source and the second end of the first inductor is
27 electrically connected to the first end of the third inductor. The second end of the third inductor
28 is electrically connectable to the at least one non-linear load. The first end of the second
29 inductor is electrically connected to the first or the second end of the first inductor. The second
30 end of the second inductor is electrically connected to at least one capacitor. Two of said
31 inductors are in a coaxial arrangement comprising two layers wound around a first core. The

1 layers comprise an inner layer adjacent to the first core, the inner layer comprising one of the
2 inductors. An outer layer is provided over the inner layer, the outer layer comprising the other of
3 the inductors.

4 **[0023]** In another aspect of the invention, the remaining one of the three inductors is
5 coaxially provided as a third layer over the outer layer.

6 **[0024]** In another aspect of the invention, the inner and outer layers cover a first section of
7 the first core and wherein the remaining one of the three inductors is wound over a second
8 section of the first core and separated from the inner and outer layers.

9 **[0025]** In another aspect of the invention, the remaining one of the three inductors is wound
10 around a second core.

11 **BRIEF DESCRIPTION OF THE DRAWINGS**

12 **[0026]** Embodiments of the invention will now be described with reference to the appended
13 drawings wherein:

14 **[0027]** Figure 1 is an electrical schematic of a harmonic filter device for only one phase
15 according to one aspect of the invention.

16 **[0028]** Figure 2a is a cross-sectional view of a coaxial reactor assembly according to one
17 aspect of the invention.

18 **[0029]** Figure 2b is a top view of the coaxial reactor assembly as shown in Figure 2a.

19 **[0030]** Figure 3a is an electrical schematic of an embodiment of a harmonic filter device
20 showing only one phase.

21 **[0031]** Figure 3b is an electrical schematic of another embodiment similar to Figure 3a
22 showing only one phase.

23 **[0032]** Figure 4a is an electrical schematic of an embodiment of a harmonic filter device
24 showing only one phase.

25 **[0033]** Figure 4b is an electrical schematic of another embodiment similar to Figure 4a
26 showing only one phase.

1 **[0034]** Figure 5 is an electrical schematic of another embodiment of a harmonic filter device
2 showing only one phase.

3 **[0035]** Figure 6 is an electrical schematic of a harmonic filter device for three phases,
4 according to one aspect of the invention.

5 **[0036]** Figure 7 is an electrical schematic of a harmonic filter device for three phases,
6 according to another aspect of the invention.

7 **[0037]** Figure 8 is a voltage and current waveform from the data of Example 1.

8 **[0038]** Figure 9 is a voltage and current waveform from the data of Example 2.

9 **[0039]** Figure 10 is an electrical schematic of another embodiment of a harmonic filter
10 device with three inductors for only one phase according to one aspect of the invention.

11 **[0040]** Figure 11a is an electrical schematic of an embodiment of a harmonic filter device
12 with three inductors showing only one phase.

13 **[0041]** Figure 11b is an electrical schematic of another embodiment similar to Figure 11a
14 showing only one phase.

15 **[0042]** Figure 12a is an electrical schematic of an embodiment of a harmonic filter device
16 with three inductors showing only one phase.

17 **[0043]** Figure 12b is an electrical schematic of another embodiment similar to Figure 12a
18 showing only one phase.

19 **[0044]** Figure 13a is an electrical schematic of an embodiment of a harmonic filter device
20 with three inductors showing only one phase.

21 **[0045]** Figure 13b is an electrical schematic of another embodiment similar to Figure 13a
22 showing only one phase.

23 **[0046]** Figure 14 is an electrical schematic of another embodiment of a harmonic filter
24 device with three inductors coaxially wound around a single core showing only one phase.

25 **[0047]** Figure 15a is a cross-sectional view of a coaxial reactor assembly with three
26 inductors according to one aspect of the invention.

1 **[0048]** Figure 15b is a top view of the coaxial reactor assembly as shown in Figure 15a.

2 **[0049]** Figure 16 is a cross-sectional view of another embodiment of a coaxial reactor
3 assembly with three inductors according to one aspect of the invention.

4 **[0050]** Figure 17 is an electrical schematic of a harmonic filter device for three phases,
5 according to one aspect of the invention.

6 **[0051]** Figure 18 is an electrical schematic of a harmonic filter device for three phases,
7 according to another aspect of the invention.

8 **DETAILED DESCRIPTION OF THE INVENTION**

9 **[0052]** It will be appreciated that for simplicity and clarity of illustration, the figures contained
10 herein will include reference numerals that may be repeated to indicate corresponding or
11 analogous elements. The present description is intended to be directed to a person skilled in
12 the art of harmonic filters. The description is not to be considered as limiting the scope of the
13 invention described herein.

14 **[0053]** The present invention provides, in one aspect, a passive filter device for filtering or
15 dampening harmonics, thereby reducing the total harmonic distortion. Filtering is known in the
16 art to mean dampening or reducing harmonics. As used herein, the terms filtering, dampening
17 or reducing harmonics may be used interchangeably. In another aspect, the device of the
18 invention further provides an ameliorated power factor. In yet another aspect, the device may
19 be used to limit a current's rate of rise when a power system or electronic device is powered on.
20 It is appreciated that the device of the present invention may alternatively be referred to as a
21 harmonic mitigation device or a harmonics filter device.

22 **[0054]** The device for dampening or filtering harmonics may be applied to non-linear loads.
23 It is appreciated that non-linear loads refer to devices that operate using voltage and current,
24 wherein the voltage and current have a non-linear relationship. In one example, the harmonic
25 filter may be used in high power applications including, for example, power distribution systems
26 of office buildings or factories. It is appreciated that the harmonic filter's components may be
27 sized to be suitable for various applications.

28 **[0055]** Figure 1 shows an embodiment of one phase 61 of a three-phase harmonic filter in
29 isolation from the other two phases. The one phase 61 comprises at least two inductors,

1 namely a "series" inductor 60 and a "shunt" inductor 62, and at least one capacitor 64. The
2 terms "series" and "shunt" will be discussed below. For the purposes of this description,
3 reference will be made to one series inductor, one shunt inductor and one capacitor. However,
4 it will be understood that more than one of each component may be used in the invention in
5 accordance with the description provided herein. In this embodiment, a power source 68, the
6 series inductor 60, and a non-linear load 66 are arranged in series to allow the current from the
7 power source 68 to flow to the non-linear load 66. Specifically, a first end 10 of the series
8 inductor 60 is electrically connected to the power source 68 and a second end 12 of the series
9 inductor 60 is electrically connected to the non-linear load 66. In effect, the series inductor 60 is
10 arranged in series between the power source 68 and non-linear load 66.

11 **[0056]** Continuing with Figure 1, the shunt inductor 62 is electrically connected in parallel
12 with the series inductor 60 to direct harmonic currents towards itself and the capacitor 64. The
13 shunt inductor 62 comprises a first end 16 and a second end 18. The first end 16 of the shunt
14 inductor 62 is electrically connected at a first electrical junction 14 located between the series
15 inductor 60 and the non-linear load 66.

16 **[0057]** A first end 20 of the capacitor 64 is electrically connected to the second end 18 of the
17 shunt inductor 62. The capacitor's 64 opposite second end 22 is electrically connected at a
18 second electrical junction 24, which is located on an electrical connection 26 extending directly
19 between the non-linear load 66 and the power source 68.

20 **[0058]** The capacitor 64 may comprise a single capacitor component or a number of
21 capacitors arranged to form a capacitor bank. It will be understood that the purpose of the
22 capacitor is (i) to create, together with the shunt inductor, a low impedance path in order to trap
23 the harmonics and (ii) to improve the system power factor, and any capacitance means to that
24 end are encompassed by the scope of this invention.

25 **[0059]** It is appreciated that, in general, an inductor's first end may be a start of the winding
26 and the second end may be a finish of the winding. Conversely, an inductor's first end may be a
27 finish of the winding and the second end may be a start of the winding. By way of background,
28 according to the dot convention as known to those skilled in the art of inductors, the start of a
29 winding, hereon referred to as a start point, is indicated by a dot. The opposite end, or finish, of
30 the winding is hereon referred to as a finish point. The polarity of an inductor is indicated by the
31 positioning the start point on either one of the inductor's two ends.

1 **[0060]** In one aspect of the invention, the series inductor 60 and shunt inductor 62 are
2 generally cylindrical and are arranged in a coaxial configuration to increase the mutual coupling
3 there-between. Such coupling may be represented by a coupling factor k .

4 **[0061]** In one embodiment, the mutual coupling is generated by placing the inductors 60, 62
5 around a shared reactor core. By way of background, an inductor may comprise a copper wire
6 that is wound in a helical configuration. In some cases, the inductor may be wound around a
7 metal core.

8 **[0062]** Figures 2a and 2b show a reactor assembly comprising a single reactor core 72 and
9 two wound inductors 60, 62. More generally, in one aspect of the invention, a core 72 and at
10 least two inductors are provided in a layered coaxial arrangement around the core 72. In one
11 embodiment, the series inductor 60 is wound around the reactor core 72 first, thereby forming
12 an inner layer that is coaxially arranged around the core 72. The shunt inductor 62 is then
13 wound around the outer perimeter of the series inductor 60, such that the series inductor 60 and
14 the shunt inductor 62 are coaxial with one another. The shunt inductor 62 forms an outer layer
15 that is coaxially arranged around the core 72. In another embodiment, the shunt inductor 62
16 may be wound first around the core 72, followed by the series inductor 64 around the outer
17 perimeter of the shunt inductor 62. It is appreciated that having layered inductors or coaxial
18 inductors along the length of the reactor core 72, may be also referred to as a coaxial reactor
19 assembly. It is also appreciated that the layered coaxial arrangement comprises at least two
20 layers, for example, an inner layer and an outer layer. Although not shown, the inductors 60, 62
21 are coated with an insulation to electrically insulate the inductors 60, 62 from one another and to
22 electrically insulate the wires within each inductor 60, 62. It is further appreciated that the close
23 proximity and increased adjacent surface area between the series 60 and shunt 62 inductor in a
24 coaxial configuration increases the coupling factor k .

25 **[0063]** The coaxial reactor assembly may include further variations, such as the direction in
26 which the wires are wound (i.e. clockwise or counter clockwise) and the position of the start
27 point. As will be understood by a person skilled in the art, different winding configurations may
28 affect the mutual or electromagnetic coupling between the inductors. In a preferred
29 embodiment of the coaxial reactor assembly, the inductors 60, 62 may be wound starting from
30 different ends of the reactor core 72. Specifically, one inductor may be wound around a core 72
31 from the bottom-up, while the other inductor may be wound from the top-down. This
32 configuration allows for a positive mutual inductance between the two inductors 60, 62. In

1 another embodiment, both inductors 60, 62 may be wound around the core 72 starting from the
2 same end. This configuration establishes a negative mutual inductance between the two
3 inductors 60, 62. It is appreciated that the start points may be placed in various configurations
4 to achieve different polarities and coupling effects. It will also be understood that various
5 configurations that allow for two separate inductors to be wound in a coaxial arrangement are
6 encompassed within the scope of the invention.

7 **[0064]** Figures 3 through 5 represent various topologies for only one phase, for example, of
8 a three-phase or single-phase harmonic filter. Figure 3a and 3b show a similar topology to that
9 of Figure 1. More particularly, in Figure 3a, the start point 80 on the series inductor 60 is
10 electrically connected to the finish point of the shunt inductor 62 at a junction 14, whereby the
11 junction 14 is also electrically connected to the load. The finish point of the series inductor 60 is
12 electrically connected to the source. The start point 82 of the shunt inductor 62 is electrically
13 connected to a capacitor. In another embodiment shown in Figure 3b, the start point 80 of the
14 series inductor 60 is electrically connected at the junction 14 to the start point 82 of the shunt
15 inductor 62. Other configurations for the start and finish points on the inductors are
16 encompassed within the scope of this invention.

17 **[0065]** Figures 4a and 4b show a different topology wherein the shunt inductor 62 is
18 connected at a junction 40 in electrical connection with the source and the series inductor 60. In
19 one particular embodiment shown in Figure 4a, the start point 80 of the series inductor 60 is
20 electrically connected at junction 40, which is also in electrical connection with the source and
21 the start point 82 of the shunt inductor 62. The finish point of the series inductor 60 is
22 electrically connected to the load, and the finish point of the shunt inductor 62 is electrically
23 connected to a capacitor. By contrast, in Figure 4b, the start point 80 of the series inductor 60 is
24 electrically connected to the source and junction 40, whereby the finish point of the shunt
25 inductor 62 is also electrically connected to the junction 40. Further, the start point 82 of the
26 shunt inductor 62 is electrically connected to a capacitor. Other configurations for the start and
27 finish points on the inductors are encompassed within the scope of this invention.

28 **[0066]** Figure 5 shows another embodiment wherein a first inductor 60 and a second
29 inductor 84 are both in series between the source and the load. Specifically, the first inductor
30 60 is electrically connected in series to the source; the second inductor 84 is electrically
31 connected in series to the first inductor 60; and the load is electrically connected in series to the
32 second inductor 84. An electrical junction 50 is positioned between the two inductors 60, 84, to

1 which a capacitor is connected in parallel. In the embodiment according to Figure 5, the start
2 points 80, 82 of each inductor 60, 64 are electrically connected to one another. Other
3 configurations for the start and finish points on the inductors are encompassed within the scope
4 of this invention.

5 **[0067]** It is appreciated that various topologies for the two inductors are encompassed by
6 the scope of this invention and may be applied to three-phase power systems. It is further
7 appreciated that all of the above inductor pairs, whether in series or parallel to one another, are
8 used to form a coaxial reactor assembly. For example, inductors 60 and 84 in Figure 5 are both
9 wound coaxially around a common reactor core.

10 **[0068]** Various types of core configurations may also apply to the coaxial reactor assembly.
11 The core 72 may be formed of iron, silicon steel, and/or ferrite material. In a preferred
12 embodiment, the core 72 is comprised of grain oriented electromagnetic steel. The core 72 may
13 also comprise various geometrical configurations including for example, a bobbin and a toroid.
14 The core 72 may further comprise several smaller cores. The purpose of the reactor core is to
15 (i) fix the inductance values of the series (60) and shunt (62) inductors and (ii) increase their
16 mutual coupling, and any means to that end are encompassed by the scope of this invention.

17 **[0069]** It is appreciated that two separate inductors 60, 62 arranged coaxially provide
18 several advantages. It is recognized that the coaxial configuration increases the mutual
19 coupling between the two inductors 60, 62, which may be used advantageously to increase
20 power efficiency in the harmonic filter as discussed in further detail below. Furthermore, the two
21 separate windings 60, 62 allows for each inductor to have a different cross-sectional area to
22 accommodate for the different current loads, thereby increasing the harmonics filtering
23 performance.

24 **[0070]** Additional advantages include reduced space requirements of the harmonic device,
25 wherein the coaxial reactor assembly requires a single reactor core, as opposed to two cores, to
26 interact with two separate inductors. Space requirements are further reduced since the coaxial
27 arrangement, or layering of the inductors around a single core, facilitates the use of a reactor
28 core having a shorter length. It is appreciated that the use of a single reactor core having a
29 shorter length also reduces the amount of core material and thereby, the associated costs.

30 **[0071]** The following is an explanation of how various aspects of the aforementioned device
31 operates and is not intended to limit the scope of the invention.

1 **[0072]** As will be known to those skilled in the art, the reactance of the shunt inductor 62
2 may be equated to that of the capacitor 64. From this equality, it is understood that the
3 capacitance C of the capacitor 64 is inversely related to the inductance and mutual inductance
4 of the shunt inductor 62. In effect, the capacitance C is inversely related to the coupling factor
5 k , whereby the coupling factor k is used to determine the mutual inductance. In one example
6 where the relative position of the winding starts allow for an inverse relationship, such as in
7 Figure 3a, a larger coupling factor k may result in a lower capacitance value C . For clarity, a
8 capacitor with a smaller capacitance may be herein referred to as a smaller capacitor.

9 **[0073]** It is therefore recognized that the coaxial inductor arrangement provides a larger
10 coupling factor k and therefore reduces the capacitance requirement in the circuit of the
11 invention. As a result, a smaller capacitor 64 may be used to achieve a desired power factor
12 and harmonic dampening performance. The coupling factor k may be increased by the close
13 proximity in the coaxial reactor assembly. This configuration, shown in Figure 3a for example,
14 allows for the coupling factor k to achieve values above 0.95. For tight coupling, the coupling
15 factor k may reach 0.99.

16 **[0074]** Several advantages are realized by allowing the use of a smaller capacitor.
17 Typically, more electric charge accumulates in a large capacitor and therefore, may incur larger
18 energy loss, for example in the form of heat. By contrast, a lower amount of electric charge
19 accumulates in a smaller capacitor and thereby, provides the advantage of decreasing energy
20 loss. As a result, the coaxial reactor assembly facilitates the use of a smaller capacitor in the
21 harmonics filter device of the invention to achieve the desired harmonic and power reductions in
22 high-power applications, while advantageously increasing energy efficiency.

23 **[0075]** Another advantage of a smaller capacitor is the decreased cost of the component,
24 thereby reducing the cost to manufacture the harmonics filter device 61. Moreover, capacitors
25 having lower capacitance values are generally smaller in size. It is recognized that a smaller
26 capacitor 64 achieved in the invention reduces the size of the harmonics filter device 61 and
27 thus, facilitates installation of the device 61 in environments with constrained space.

28 **[0076]** Yet another advantage of a smaller capacitor is the reduced risk of injury to a person,
29 such as a technician, servicing a harmonics filter device 61. The harmonics filter device 61
30 significantly reduces the capacitor size and, therefore, the amount of stored electric charge. A
31 lower stored charge reduces the risk of inadvertently electrocuting a technician.

1 **[0077]** In addition to increasing the coupling factor, the coaxial reactor assembly of the
2 invention increases the power factor and power efficiency of the harmonic filter device 61.
3 Generally, the shunt inductor 62 acts as a harmonic current trap and directs harmonic current
4 towards the capacitor 64. The harmonic current passing through the shunt inductor 62 is
5 generally lower than the main power current being transmitted between the power source 68
6 and the load 66. Therefore, the ampacity of the shunt inductor is different from the ampacity of
7 the series inductor. Various characteristics of the shunt inductor 62, such as the resistance of
8 the inductor's wire, are preferably selected to allow for harmonic currents to be trapped, while
9 reducing the amount of source or fundamental current from also becoming trapped by the shunt
10 inductor 62. It is understood that the trapping of source current by the shunt inductor 62 may
11 lead to a decrease in the power output to the load 66.

12 **[0078]** Separate inductors, namely the wires used to form the series inductor 60 and shunt
13 inductor 62, are preferably made of different cross-sectional area windings suited for the
14 currents passing through them. Specifically, the shunt inductor 62 may comprise a wire with a
15 smaller cross-sectional area than the series inductor 60. The embodiment of the coaxial reactor
16 assembly shown in Figure 2a illustrates the shunt inductor 62 having a smaller cross-sectional
17 area than the series inductor 60. This accommodates for the smaller harmonic current flowing
18 through the shunt inductor 62, while advantageously increasing the power factor and power
19 efficiency of the harmonic filter device 61.

20 **[0079]** It is recognized that additional characteristics of an inductor wire may affect the flow
21 of current, including without limitation the conductive material and the number of strands in the
22 wire. In a preferred embodiment, the purpose of the shunt inductor 62 is to trap harmonic
23 currents and, in another aspect, to reduce the amount of source or fundamental current drawn
24 into itself; any means to that end are encompassed by the scope of the invention.

25 **[0080]** In yet another embodiment, the inductors 60, 62 may comprise multi-stranded wires
26 twisted together, also referred to as Litz wire, to reduce the "skin effect". By way of background,
27 in AC systems, the skin effect is the tendency for the electric current to flow at the outer portion
28 of a conductor, thereby increasing the effective resistance of the conductor with the increase of
29 frequency. Other types of conductors suitable for conducting electricity and being wound
30 around a core are equally applicable for forming an inductor.

1 **[0081]** Referring now to Figure 6, an embodiment of the invention is shown of a harmonics
2 filter 180 configured for a three-phase power system. It will be understood that the three-phase
3 harmonic filter device 180 comprises three coaxial reactor assemblies and three capacitors,
4 wherein the capacitors are electrically connected in various configurations as discussed below.
5 Therefore, the three-phase harmonics filter device 180 comprises three coaxial reactor
6 assemblies.

7 **[0082]** The voltage V_{ab} is the line voltage between input lines A 184 and B 186, and the
8 current i_A is the line current flowing through input line A 184. In this embodiment, the capacitors
9 202, 204, 206 for each phase are arranged in a "delta" connection, as known in the art. It is
10 appreciated that other capacitor arrangements suitable for three-phases, for example the "wye"
11 or "star" arrangement, are equally applicable. The delta arrangement may be preferable in
12 applications where the source voltage is below 480V. For higher source voltages, the star
13 arrangement may be preferable. An example of a star arrangement is shown in Figure 7.

14 **[0083]** Returning to Figure 6, the three-phase harmonic filter device 180 comprises three
15 power source lines 184, 186, 188. Along each line 184, 186, 188 is an inductor 190, 192, 194,
16 respectively, that is electrically connected in series between the source terminal and the non-
17 linear load 182. Electrically connected in parallel to each series inductor 190, 192, 194 is a
18 corresponding shunt inductor 196, 198, 200, respectively. As shown in Figure 6, the capacitors
19 are connected in a delta arrangement, that is: (a) capacitor 202 is electrically connected to the
20 ends of the shunt inductors 196 and 198; (b) capacitor 206 is electrically connected to the ends
21 of the shunt inductors 198 and 200; and (c) capacitor 204 is electrically connected to the ends of
22 the shunt inductors 196 and 200.

23 **[0084]** Two examples, namely Example 1 and Example 2, of a circuit comprising a power
24 source and a non-linear load will be discussed below without limitation to the scope of the
25 invention.

26 **[0085]** In Example 1, a first circuit comprises a three-phase power source in direct electrical
27 connection to a non-linear load. In this example, the harmonic filter of this invention is not
28 connected to the circuit. The power source operates at a frequency of 60 Hz and has three
29 connection lines A, B and C. Referring now to Figure 8, the 60 Hz waveforms are shown of the
30 input line voltage V_{AB} measured across lines A and B, and the line current i_A measured through
31 line A. Specifically, the voltage waveform 220 shows the line voltage V_{AB} , from which a voltage

1 Total Harmonic Distortion (THD_V) is measured to be 6.8%. Similarly, the current waveform 222
2 shows the line current i_A , from which a current Total Harmonic Distortion (THD_i) is measured to
3 be 66.8%. It can be further seen from the current waveform 222 that each cycle has multiple
4 peaks, as opposed to a desired sinusoidal waveform. Further, the current waveform 222 and
5 voltage waveform 220 are not linearly related. The results shown in this example provide a
6 baseline for comparison with the use of the harmonic filter device of the invention.

7 **[0086]** In Example 2, a second circuit comprises a three-phase power source, a three-phase
8 harmonic filter device 180 and a non-linear load, wherein a specific embodiment of the harmonic
9 filter device 180 is electrically connected in series there-between the power source and load.
10 For the purpose of comparing the second circuit to the first circuit, it is understood that the
11 power source and non-linear load in Example 2 are identical in form and operation to the power
12 source and non-linear load in Example 1. The inclusion of the harmonic filter device 180, using
13 the "delta" capacitor configuration shown in Figure 6, reduces the THD. It is noted that the
14 second circuit comprises a configuration according to Figure 3a, wherein the start point of each
15 series inductor is connected to the finish point of a corresponding shunt inductor.

16 **[0087]** Continuing with Example 2, the waveform 224 of the voltage V_{AB} and the waveform
17 226 of the current i_A is shown in Figure 9. It can be seen that voltage waveform 224 and current
18 waveform 226 have a sinusoidal form as a result of using the harmonic filter device 180 in the
19 circuit. Specifically, in the embodiment according to Example 2, a THD_V of 1.3% and a THD_i of
20 4.8% are achieved. The dominant harmonics, namely the 5th, 7th, 11th and 13th harmonics, are
21 practically attenuated.

22 **[0088]** Turning to Figure 10, in another aspect of the invention, a one phase harmonic filter
23 238 is provided comprising a first inductor 60 and a second inductor 62 that are magnetically
24 coupled and wound around a core 72, and a third inductor 230 that is wound around another,
25 i.e. separate core. The one phase harmonic filter 238 also comprises a capacitor 64. This is
26 similar to the embodiment described in Figure 1, however, it contains the addition of a third
27 inductor 230.

28 **[0089]** In particular, the first inductor 60 comprises a first end 10 and a second end 12. The
29 second inductor 62 also comprises a first end 16 and a second end 18. Either one of the first
30 inductor 60 or the second inductor 62 is wound around the core 72 and the other of the first

1 inductor 60 and the second inductor 62 is wound there-around. The inductors 60, 62 and the
2 core 72 form a coaxial assembly 236.

3 **[0090]** Located on a separate core is the third inductor 230, which also comprises a first end
4 232 and a second end 234. The first inductor 60 is electrically connected in series between the
5 power source 68 and the third inductor 230. The first end 10 of the first inductor 60 is
6 electrically connected to the power source 68, and the second end 12 of the first inductor 60 is
7 electrically connected to the first end 232 of the third inductor 230, at junction 14. The second
8 end 234 of the third inductor 230 is electrically connected to the non-linear load 66. The second
9 inductor 62 is electrically connected to the first inductor 60 and the third inductor 230 at junction
10 14. The first end 16 of the second inductor 62 is electrically connected to junction 14 and the
11 second end 18 is electrically connected in series to a first end 20 of the capacitor 64. A second
12 end 22 of the capacitor 64 is connected at another electrical junction 24 connecting the power
13 source 68 and the non-linear load 66.

14 **[0091]** Although not shown, in another embodiment of the invention, it is appreciated that
15 the first end 16 of the second inductor 62 is electrically connected to the first end 10 of the first
16 inductor 60, instead of the second end 12 as shown in Figure 10.

17 **[0092]** A person skilled in the art of electronics will appreciate that the above-described one
18 phase harmonic filter 238 may be also applied to a three-phase harmonic filter, whereby each
19 phase comprises three inductors.

20 **[0093]** The presence of the third inductor 230 provides several advantages including further
21 suppressing the major harmonics (e.g. 5th, 7th, 11th and 13th harmonics) generated by non-linear
22 loads such as, for example, variable speed drives. In particular, in an experiment of a three-
23 phase harmonic filter, whereby each phase comprised three inductors as described in Figure
24 10, a 60 Hz waveform was applied to the filter and a THD_i of less than 4.5% and a THD_v of less
25 than 1.2% were achieved.

26 **[0094]** It is also recognized that the third inductor 230 improved the power factor. The third
27 inductor 230 also increased the voltage consistency, such that the voltage generated by the
28 power source 68 is approximately the same voltage outputted by the harmonics filter to the non-
29 linear load 66. The presence of the third inductor 230 also allows for a capacitor 64 with a
30 smaller or lower capacitance value.

1 **[0095]** Figures 11 through 13 represent various topologies for only one phase, for example,
2 of a three-phase or single-phase harmonic filter. Figure 11a and 11b show a similar topology to
3 that of Figure 10. More particularly, in Figure 11a, the start point 80 on the first inductor 60 is
4 electrically connected to the finish point of the second inductor 62 at a junction 14, whereby the
5 junction 14 is also electrically connected to one end of the third inductor 230. The other end of
6 the third inductor 230 is electrically connected to the load. The finish point of the first inductor
7 60 is electrically connected to the source. The start point 82 of the second inductor 62 is
8 electrically connected to a capacitor. In another embodiment shown in Figure 11b, the start
9 point 80 of the first inductor 60 is electrically connected at the junction 14 to the start point 82 of
10 the second inductor 62. Other configurations for the start and finish points on the inductors are
11 encompassed within the scope of this invention.

12 **[0096]** Figures 12a and 12b show a different topology wherein one end of the third inductor
13 230 is electrically connected to the source and the other end of the third inductor 230 is
14 electrically connected at a junction 235. The first inductor 60 is electrically connected between
15 the junction 235 and the load. In one particular embodiment shown in Figure 12a, the start point
16 80 of the first inductor 60 is electrically connected at junction 235, which is also in electrical
17 connection with the third inductor 230 and the finish point of the second inductor 62. The finish
18 point of the first inductor 60 is electrically connected to the load, and the start point 82 of the
19 second inductor 62 is electrically connected to a capacitor. By contrast, in Figure 12b, the start
20 point 82 of the second inductor 62 is electrically connected to the third inductor 230 at junction
21 235, whereby the finish point of the second inductor 62 is electrically connected to the capacitor.
22 Other configurations for the start and finish points on the inductors are encompassed within the
23 scope of this invention.

24 **[0097]** Figures 13a and 13b show a different topology wherein the power source, the first
25 inductor 60, the second inductor 62 and the load are electrically connected in series with one
26 another. One end of the first inductor 60 is electrically connected to the source and another end
27 is electrically connected to a junction 237. One end of the second inductor 62 is electrically
28 connected to the junction 237 and the other end is electrically connected to the load. The third
29 inductor 230 is electrically connected in parallel to the first and second inductors 60, 62. One
30 end of the third inductor 230 is electrically connected to the junction 237 and the other end is
31 electrically connected to a capacitor. In one particular embodiment shown in Figure 13a, the
32 start point 80 of the first inductor 60 is electrically connected at junction 237, which is also in
33 electrical connection with the third inductor 230 and the start point 82 of the second inductor 62.

1 The finish point of the first inductor 60 is electrically connected to the power source, and the
2 finish point 82 of the second inductor 62 is electrically connected to the load. By contrast, in
3 Figure 13b, the start point 82 of the second inductor 62 is electrically connected to the load and
4 the finish point of the second inductor 62 is electrically connected to the junction 237. Other
5 configurations for the start and finish points on the inductors are encompassed within the scope
6 of this invention.

7 **[0098]** In the embodiments shown in Figures 11 through 13, there are at least two layers of
8 inductors in a layered coaxial arrangement around the core 72. The arrangement has an inner
9 and outer layer which comprises various combinations, including any one of the following: the
10 first 60 and the second 62 inductors, respectively; the second 62 and the first 60 inductors,
11 respectively; the second 62 and the third 230 inductors, respectively; the third 230 and the
12 second 62 inductors, respectively; the first 60 and the third 230 inductors, respectively; or, the
13 third 230 and the first 60 inductors, respectively.

14 **[0099]** It is appreciated that various topologies for the three inductors are encompassed by
15 the scope of this invention and may be applied to three-phase power systems. It is further
16 appreciated that all of the above inductor pairs comprising the first inductor 60 and second
17 inductor 62, whether in series or parallel to one another, are used to form a coaxial reactor
18 assembly.

19 **[00100]** Figure 14 shows another embodiment of the invention of only one phase, for
20 example, of a three-phase or single-phase harmonic filter comprising a first inductor 60, a
21 second inductor 62 and a third inductor 230 wound coaxially around a common core 72.
22 Winding all three inductors 60, 62, 230 coaxially around the same core 72 magnetically couples
23 the three inductors. Thus, three layers of inductors are coaxially formed around the core 72. In
24 particular, a coupling factor k_{12} is generated between the first inductor 60 and second inductor
25 62. Another coupling factor k_{23} is generated between the second inductor 62 and the third
26 inductor 230. Another coupling factor k_{13} is generated between the third inductor 230 and the
27 first inductor 60. The coupling factors are generated because the inductors 60, 62, 230 share a
28 common core 72, and are increased because they are wound coaxially around the core 72.

29 **[00101]** As discussed above, magnetically coupling the inductors on a common core 72
30 provides several advantages. These include increasing the power efficiency, reducing the

1 capacitance value, reducing the number of cores and reducing the overall size of the harmonic
2 filter.

3 **[00102]** Figures 15a and 15b show a single reactor assembly comprising a single reactor
4 core 72 and three coaxially wound inductors 60, 62, 230. The inductors form a layered coaxial
5 arrangement around the core 72. Thus, another outer layer is formed comprising, for example,
6 the third inductor 230. Each of the inductors 60, 62, 230 are coated with an insulation to
7 electrically insulate the inductors 60, 62, 230 from one another and to electrically insulate the
8 wires within each inductor 60, 62, 230. In one embodiment, the first inductor 60 is wound
9 around the reactor core 72 first. The second inductor 62 is then wound around the outer
10 perimeter of the first inductor 60, such that the first inductor 60 and the second inductor 62 are
11 coaxial with one another. Then the third inductor 230 is wound around the outer perimeter of
12 the second inductor 62, such that all three inductors 60, 62, 230 are coaxial with one another.
13 In another embodiment, not shown, the second inductor 62 may be wound first around the core
14 72, the third inductor 230 may be wound around the outer perimeter of the second inductor 62,
15 and the first inductor 60 may be wound around the outer perimeter of the third inductor 230. It is
16 appreciated that there are different configurations for winding the three inductors 60, 62, 230
17 coaxially around the core 72 and any such configuration to that end is encompassed by the
18 scope of the invention. The cross-sectional area and/or materials of the wire or wires in each of
19 the inductors 60, 62, 230 may also be different. It is also appreciated that having layered
20 inductors or coaxial inductors along the length of the reactor core 72, may be also referred to as
21 a coaxial reactor assembly.

22 **[00103]** Referring now to Figure 16, another embodiment of a layered coaxial arrangement
23 around a core 72 is provided. Two of the three inductors are provided in a layered arrangement
24 and the remaining inductor is wound around the same core in a non-layered arrangement. In
25 other words, the inner and outer layers cover a first section of the core and the remaining one of
26 the three inductors is wound over a second section of the core and separated from the inner
27 and outer layers. The inner layer is formed from one inductor adjacent to the core 72. An outer
28 layer is provided over the inner layer, whereby the another layer is formed from another of the
29 inductors. The remaining inductor is wound around the same core 72, either above or below the
30 layered arrangement of the other two inductors. In the embodiment shown in Figure 16, the
31 inner layer comprises the first inductor 60 and the outer layer comprises the second inductor 62.
32 The third inductor is located adjacent to the layered arrangement, also wound around the same
33 core 72.

1 **[00104]** By having two of the inductors in a layered arrangement and another inductor in a
2 non-layered arrangement, but still wound on the same core 72, all three inductors are
3 magnetically coupled. The inductor that is not in a layered arrangement will have a lower
4 coupling factor to the other inductors, compared with the inductors that are in a layered
5 arrangement. For example, in the embodiment described in regards to Figure 16, the coupling
6 factor k_{13} will be lower than the coupling factor k_{12} , since the first and second inductors 60, 62
7 are in a layered arrangement and the third inductor 230 is not in a layered arrangement. It is
8 appreciated that the coupling factors can thus be adjusted depending on the position of an
9 inductor relative to another inductor. Various arrangements combining layered and non-layered
10 inductors that are magnetically coupled by a common core and have two or more inductors in a
11 layered arrangement are encompassed by the scope of the invention.

12 **[00105]** Figure 17 shows an embodiment of the invention of a three-phase harmonic filter
13 250, whereby each phase comprises three inductors. The embodiment shown herein is similar
14 to the embodiment described with respect to Figure 7, with the difference of each phase having
15 a third inductor. In particular, for a first phase, a first inductor 190 and a third inductor 238 are
16 electrically connected in series between the power source line 184 and the non-linear load 182.
17 For a second phase, a first inductor 192 and a third inductor 240 are electrically connected in
18 series between the power source line 186 and the non-linear load 182. For a third phase, a first
19 inductor 194 and a third inductor 242 are electrically connected in series between the power
20 source line 186 and the non-linear load 182. Each of the second inductors 196, 198 and 200
21 are electrically connected to each of the first inductors 190, 192 and 194, respectively. The
22 capacitors 202, 204, 206 are connected in a delta configuration. Other configurations, such as
23 the wye or the star configuration are equally applicable. It can also be seen by the straight bars
24 along the first and second inductors, that in the first phase, the first inductor 190 and the second
25 inductor 196 share a first single core; in the second phase, the first inductor 192 and the second
26 inductor 198 share a second single core; and, in the third phase, the first inductor 194 and the
27 second inductor 200 share a third single core. The third inductors 238, 240, 242 in each phase
28 have a separate core.

29 **[00106]** However, it is readily understood that all three inductors in each phase may also
30 share a single core. Referring now to Figure 18, another embodiment of a three-phase
31 harmonic filter 252 is provided. Although similar to the embodiment described with respect to
32 Figure 16, the embodiment in Figure 17 comprises, for the first phase, three inductors share the
33 first core. For the second phase, all three inductors share the second core. For the third

1 phase, all three inductors share the third core. The capacitors are also shown in a star
2 configuration. It is appreciated that the three inductors in each phase may all be in a layered
3 coaxial arrangement. Alternatively, two of the inductors are in a layered coaxial arrangement,
4 while the remaining inductor is in a non-layered arrangement.

5 **[00107]** Although the invention has been described with reference to certain specific
6 embodiments, various modifications thereof will be apparent to those skilled in the art without
7 departing from the purpose and scope of the invention as outlined in the claims appended
8 hereto. Any examples provided herein are included solely for the purpose of illustrating the
9 invention and are not intended to limit the invention in any way. Any drawings provided herein
10 are solely for the purpose of illustrating various aspects of the invention and are not intended to
11 be drawn to scale or to limit the invention in any way.

WE CLAIM:

1. A device for dampening harmonics, the device being electrically connectable to at least one power source and at least one non-linear load, the device comprising:
 - a first inductor comprising a first end being connectable to said at least one power source and a second end being electrically connectable to said at least one non-linear load;
 - a second inductor comprising a first end electrically connected to said first or said second end of said first inductor and a second end electrically connected to at least one capacitor; and,
 - wherein said first and second inductors are in a coaxial arrangement comprising two layers wound around a core, said layers comprising:
 - an inner layer adjacent to said core, said inner layer comprising one of said inductors, and
 - an outer layer provided over said inner layer, said outer layer comprising the other of said inductors.
2. The device of claim 1, wherein said first end of said first inductor is a start of winding and said second end of said second inductor is another start of winding.
3. The device of claim 1, wherein said first end of said first inductor is a start of winding and said first end of said second inductor is another start of winding.
4. The device of any one of claims 1 to 3, wherein said inner layer comprises said first inductor and said outer layer comprises said second inductor.
5. The device of any one of claims 1 to 3, wherein said inner layer comprises said second inductor and said outer layer comprises said first inductor.
6. The device of any one of claims 1 to 5, wherein said second inductor comprises a wire with a smaller cross-sectional area than said first inductor.
7. The device of any one of claims 1 to 6, wherein said first end of said second inductor is connected to said second end of said first inductor.

8. A three-phase power distribution system comprising three phase assemblies, wherein each phase assembly comprises the device according to any one of claims 1 to 7.
9. A device for dampening harmonics, the device being electrically connectable to at least one power source and at least one non-linear load, the device comprising:
a first inductor and a second inductor, each comprising a first end and a second end, wherein:
said first end of said first inductor being electrically connectable to said at least one power source;
said second end of said first inductor is electrically connected to said first end of said second inductor;
said second end of said second inductor being electrically connectable to said at least one non-linear load;
and said second end of said first inductor and said first end of said second inductor both electrically connected to at least one capacitor; and,
wherein said first and second inductors are in a coaxial arrangement comprising two layers wound around a core, said layers comprising:
an inner layer adjacent to said core, said inner layer comprising one of said inductors, and
an outer layer provided over said inner layer, said outer layer comprising the other of said inductors.
10. The device of claim 9, wherein said second end of said first inductor is a start of winding and said first end of said second inductor is a start of winding.
11. The device of any one of claims 9 and 10, wherein said inner layer comprises said first inductor and said outer layer comprises said second inductor.
12. The device of any one of claims 9 and 10, wherein said inner layer comprises said second inductor and said outer layer comprises said first inductor.
13. The device of any one of claims 9 to 12, wherein said second inductor comprises a wire with a smaller cross-sectional area than said first inductor.

14. A three-phase power distribution system comprising three phase assemblies, wherein each phase assembly comprises the device according to any one of claims 9 to 13.
15. A device for dampening harmonics, the device being electrically connectable to at least one power source and at least one non-linear load, the device comprising:
- a first inductor, a second inductor and a third inductor, each comprising a first end and a second end;
 - said first end of said first inductor being electrically connectable to said at least one power source and said second end of said first inductor electrically connected to said first end of said third inductor;
 - said second end of said third inductor being electrically connectable to said at least one non-linear load;
 - said first end of said second inductor electrically connected to said first or said second end of said first inductor;
 - said second end of said second inductor electrically connected to at least one capacitor; and,
 - wherein two of said inductors are in a coaxial arrangement comprising two layers wound around a first core, said layers comprising:
 - an inner layer adjacent to said core, said inner layer comprising one of said inductors, and
 - an outer layer provided over said inner layer, said outer layer comprising the other of said inductors.
16. The device of claim 15, wherein the remaining one of said three inductors is coaxially provided as a third layer over said outer layer.
17. The device of claim 15, wherein the inner and outer layers cover a first section of the first core and wherein the remaining one of said three inductors is wound over a second section of the first core and separated from the inner and outer layers.
18. The device of claim 15, wherein the remaining one of said three inductors is wound around a second core.

19. The device of claim 18, wherein said first and second inductors are wound around the first core, and said first end of said first inductor is a start of winding and said second end of said second inductor is another start of winding.
20. The device of claim 18, wherein said first and second inductors are wound around the first core, and said first end of said first inductor is a start of winding and said first end of said second inductor is another start of winding.
21. The device of claim 18, wherein said inner layer comprises said first inductor and said outer layer comprises said second inductor.
22. The device of claim 18, wherein said inner layer comprises said second inductor and said outer layer comprises said first inductor.
23. The device of any one of claims 15 to 22, wherein said first end of said second inductor is connected to said second end of said first inductor.
24. A three-phase power distribution system comprising three phase assemblies, wherein each phase assembly comprises the device according to any one of claims 15 to 23.

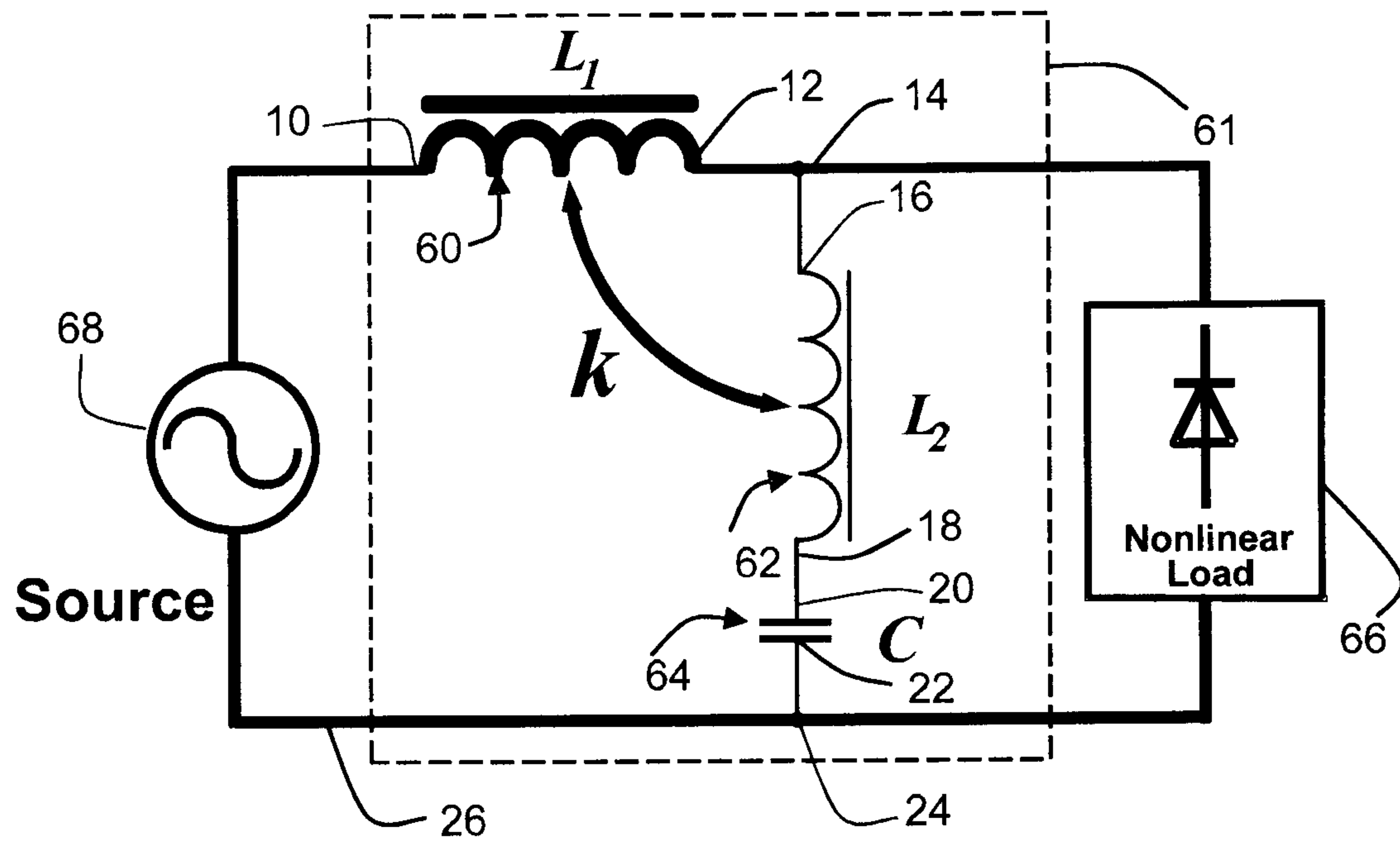


Figure 1

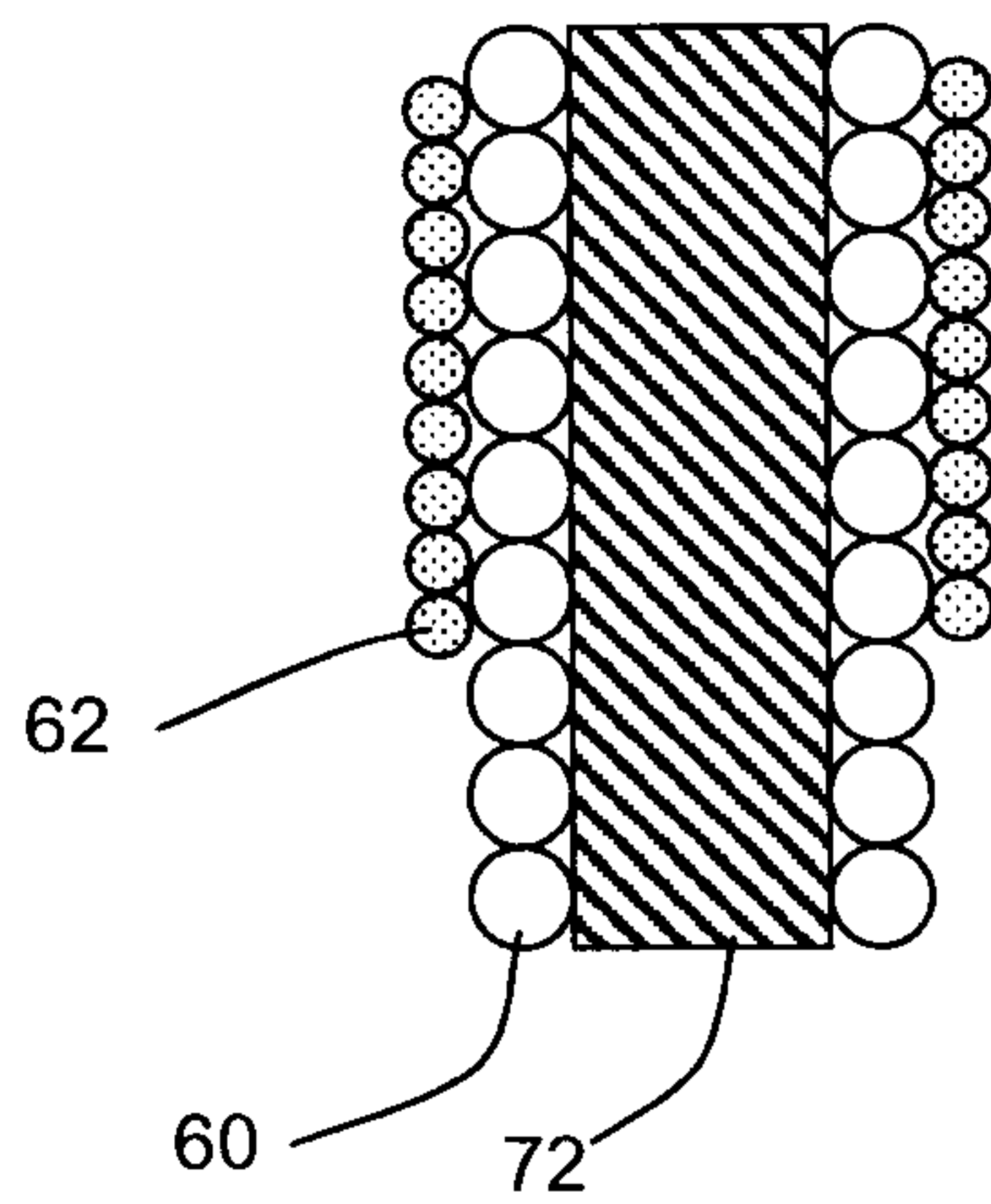


Figure 2a

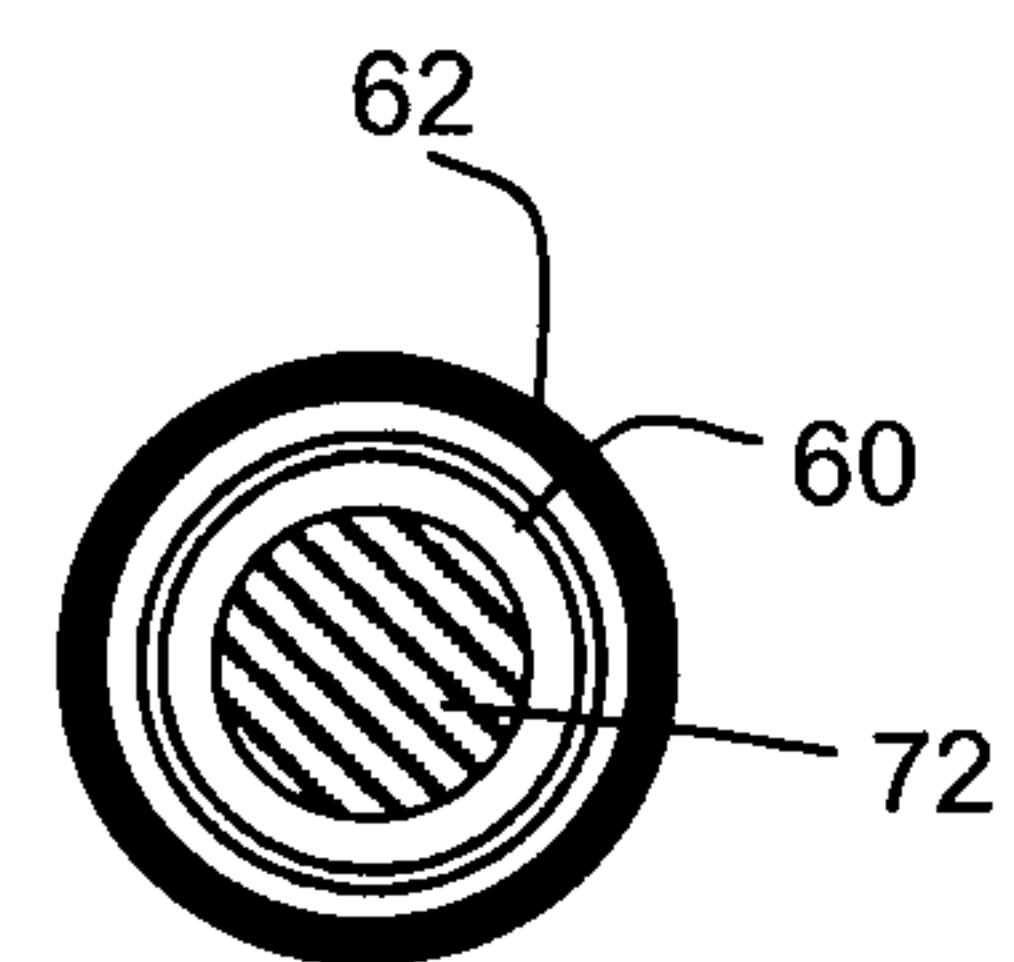


Figure 2b

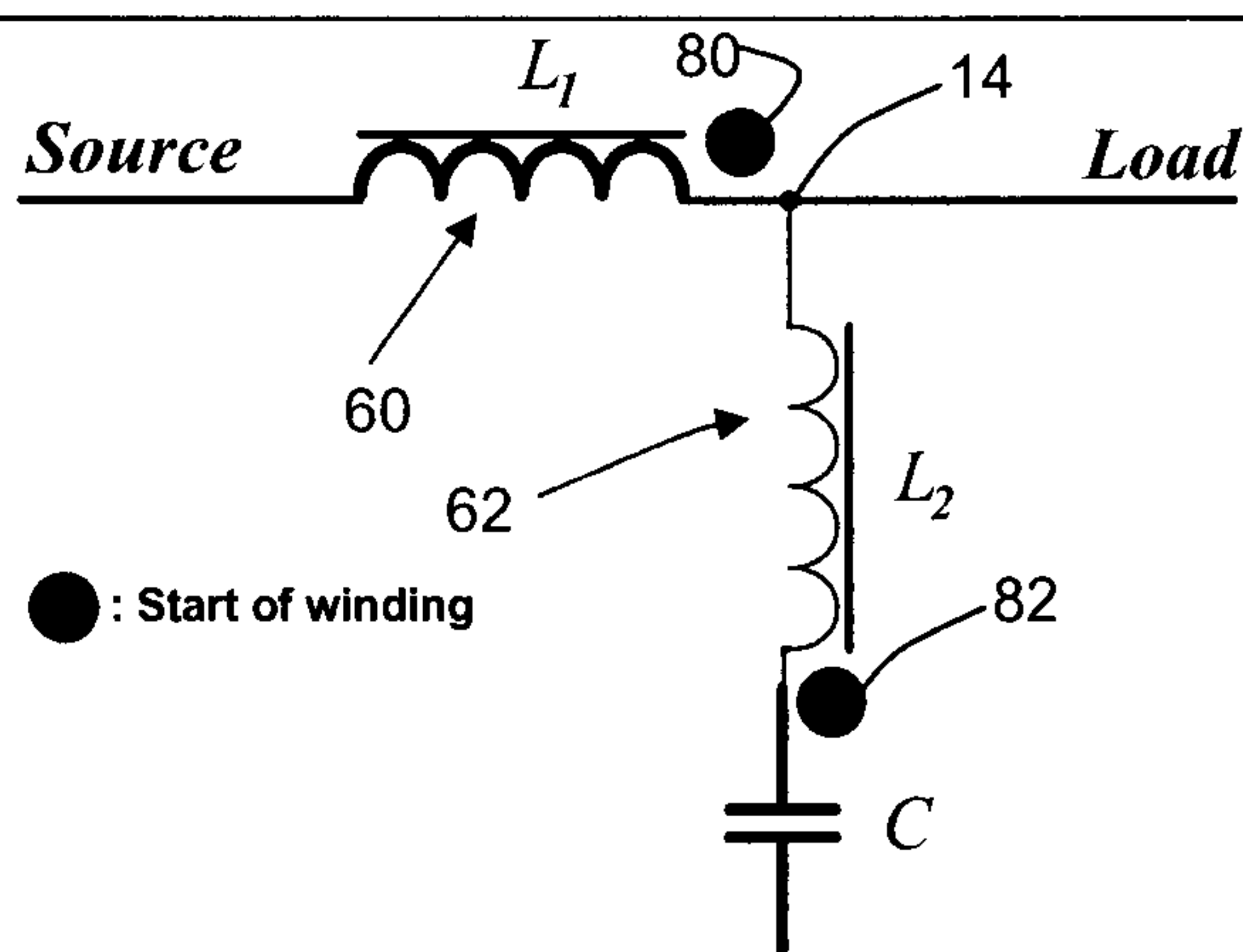


Figure 3a

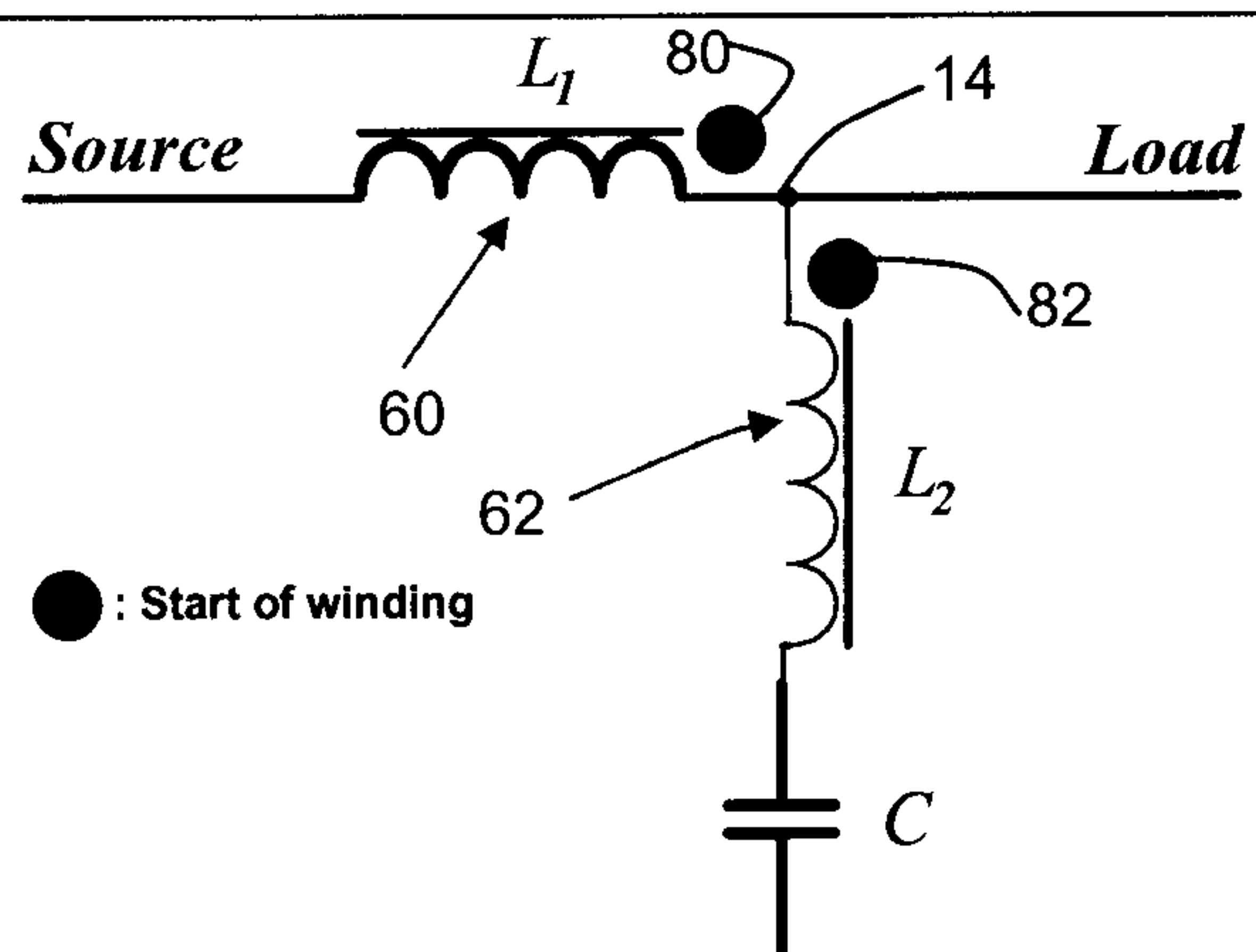


Figure 3b

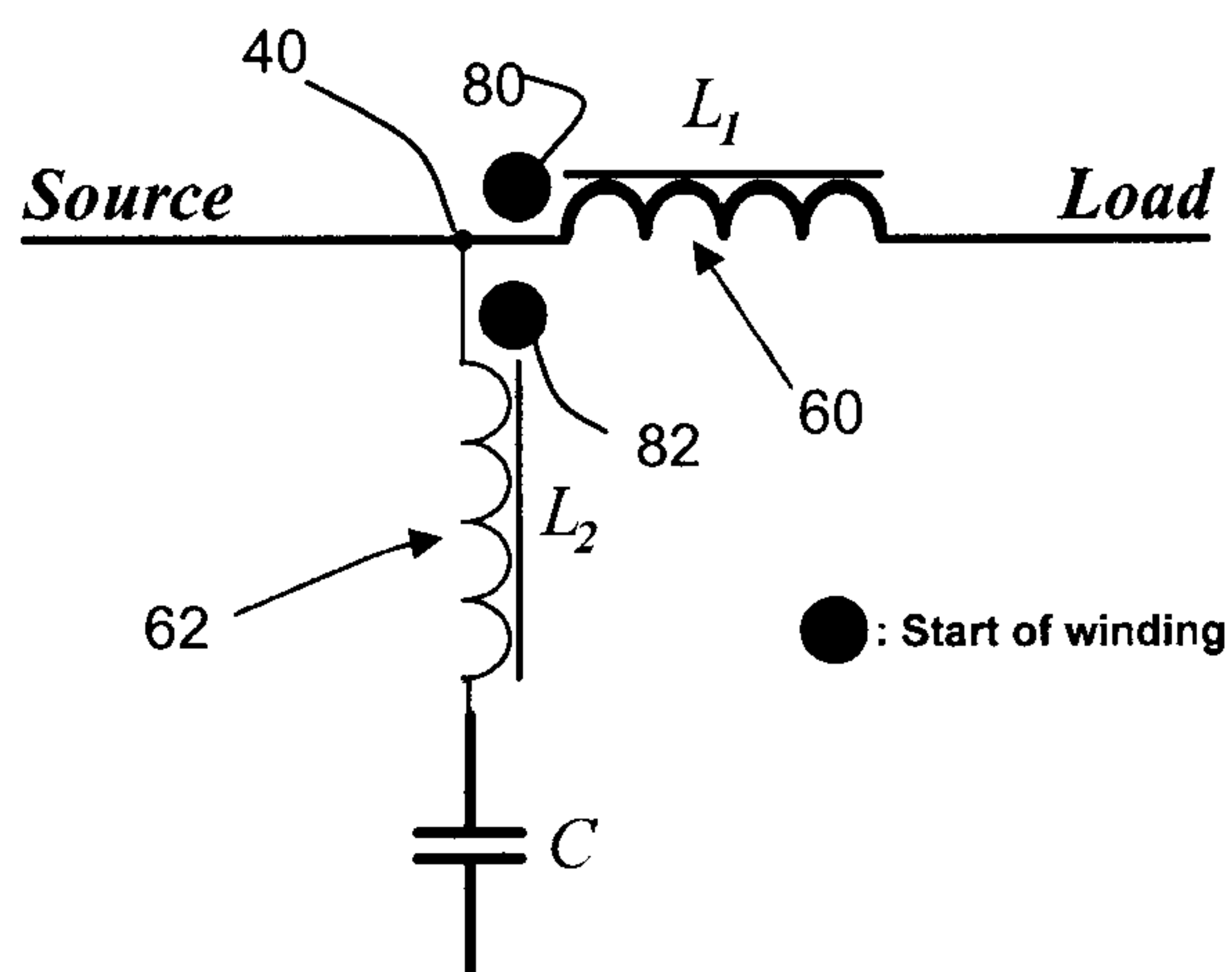


Figure 4a

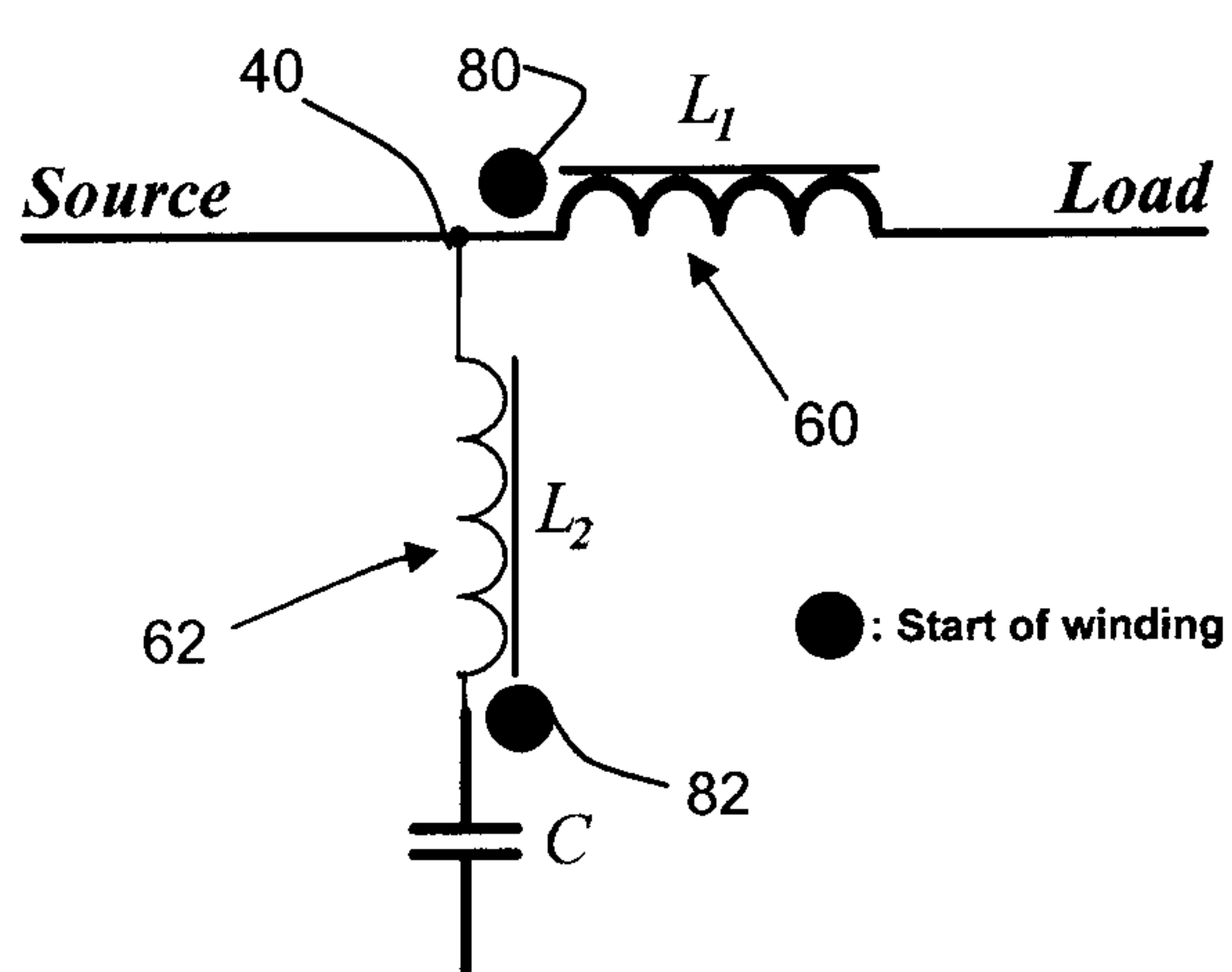


Figure 4b

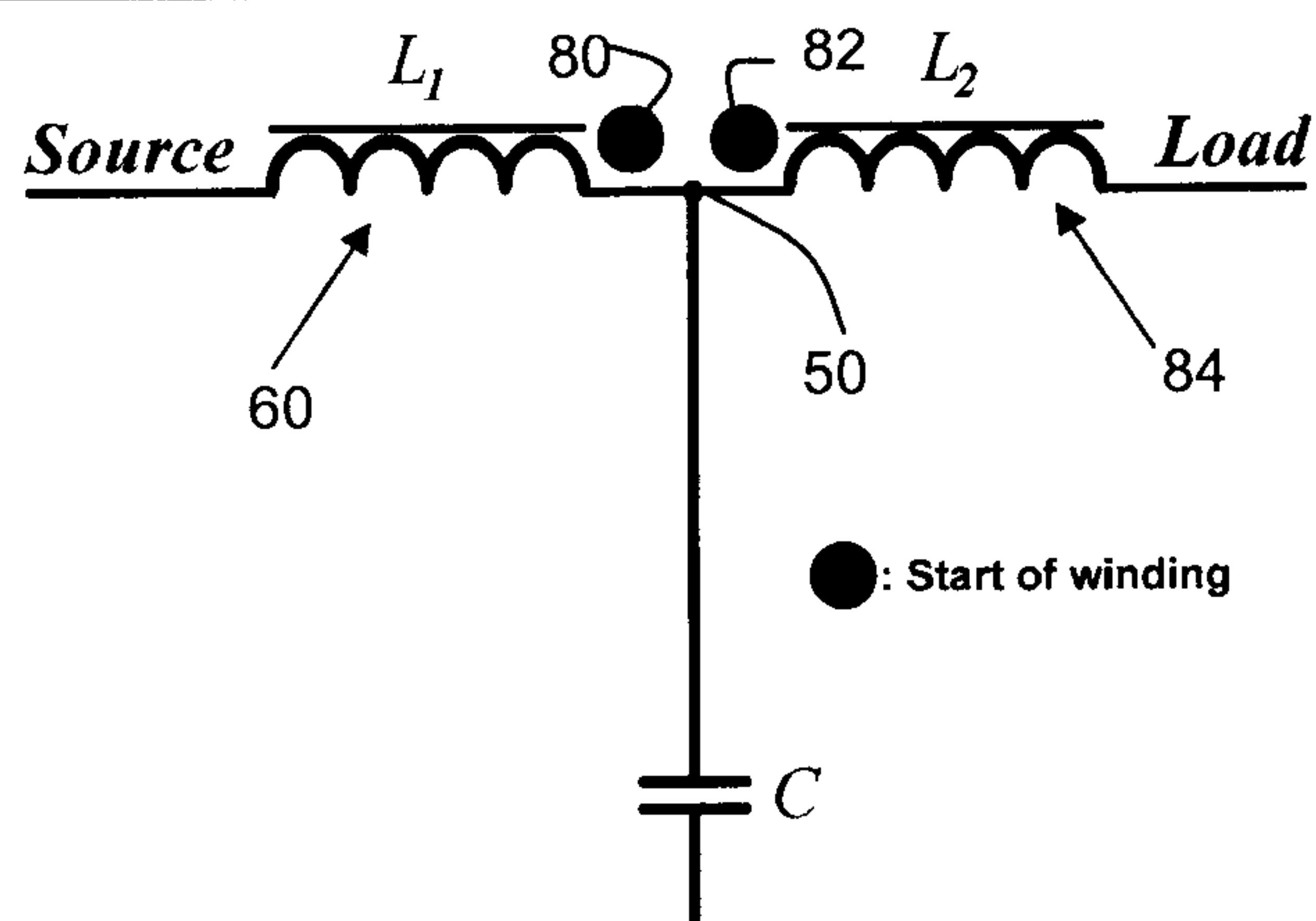


Figure 5

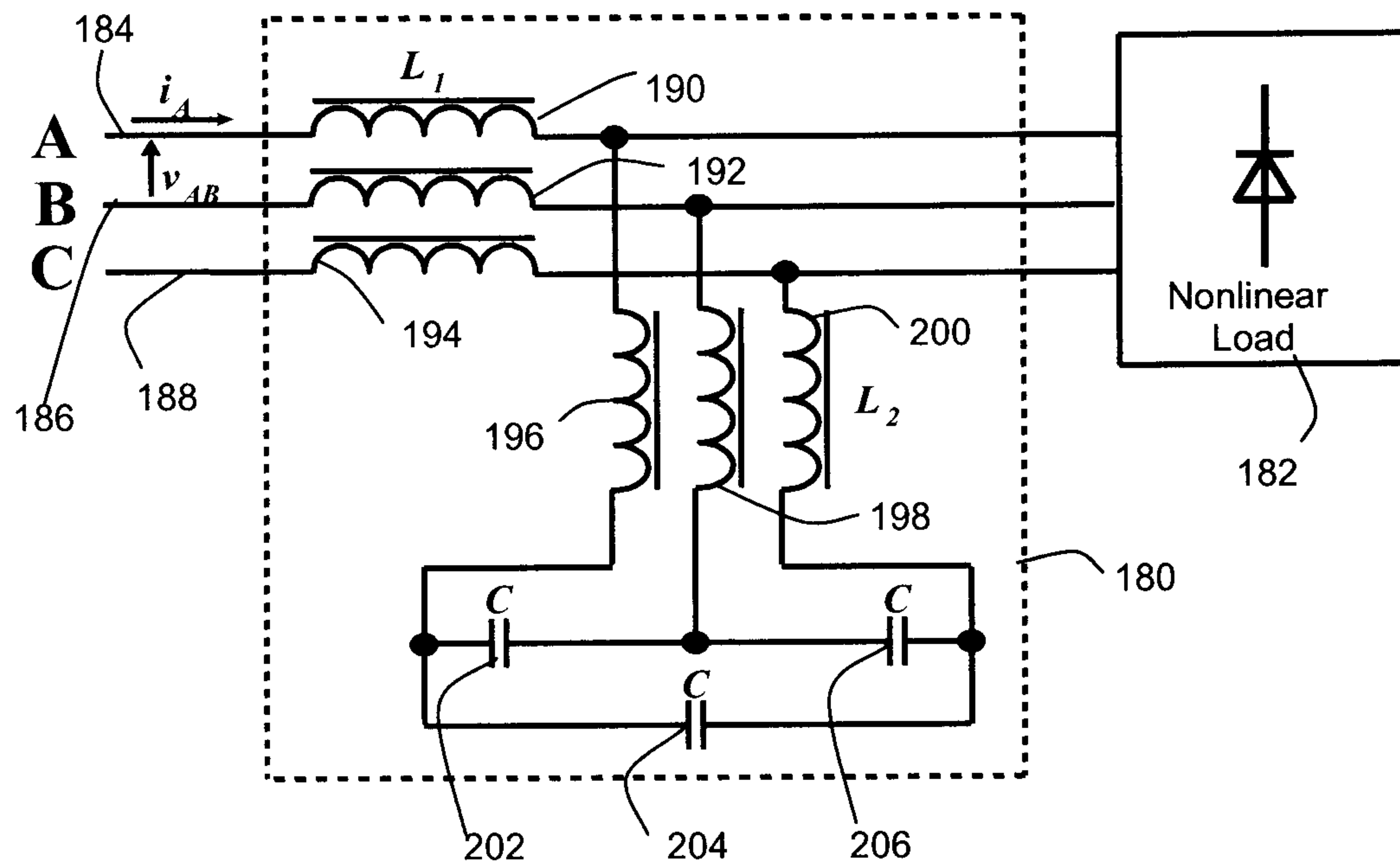


Figure 6

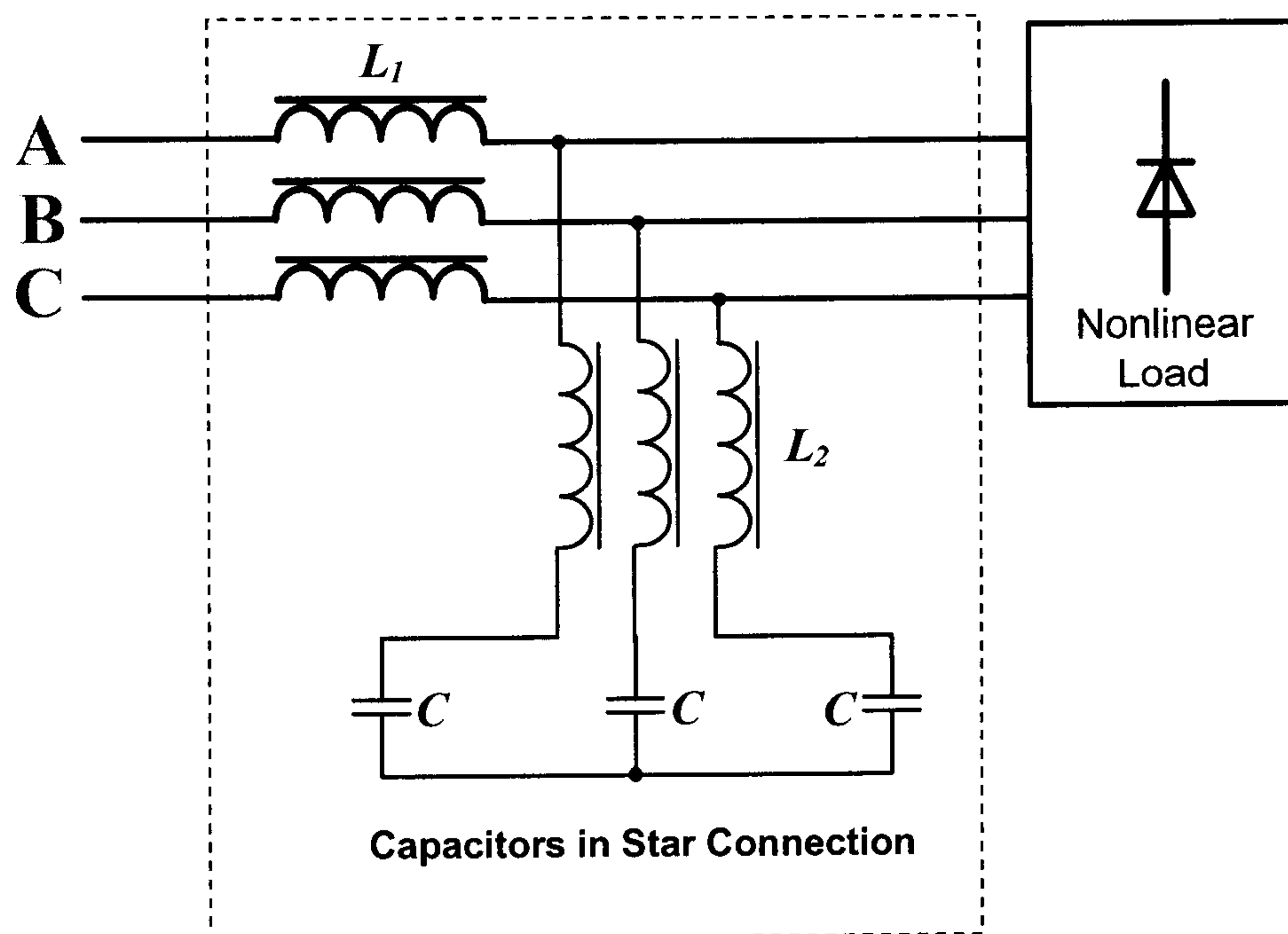


Figure 7

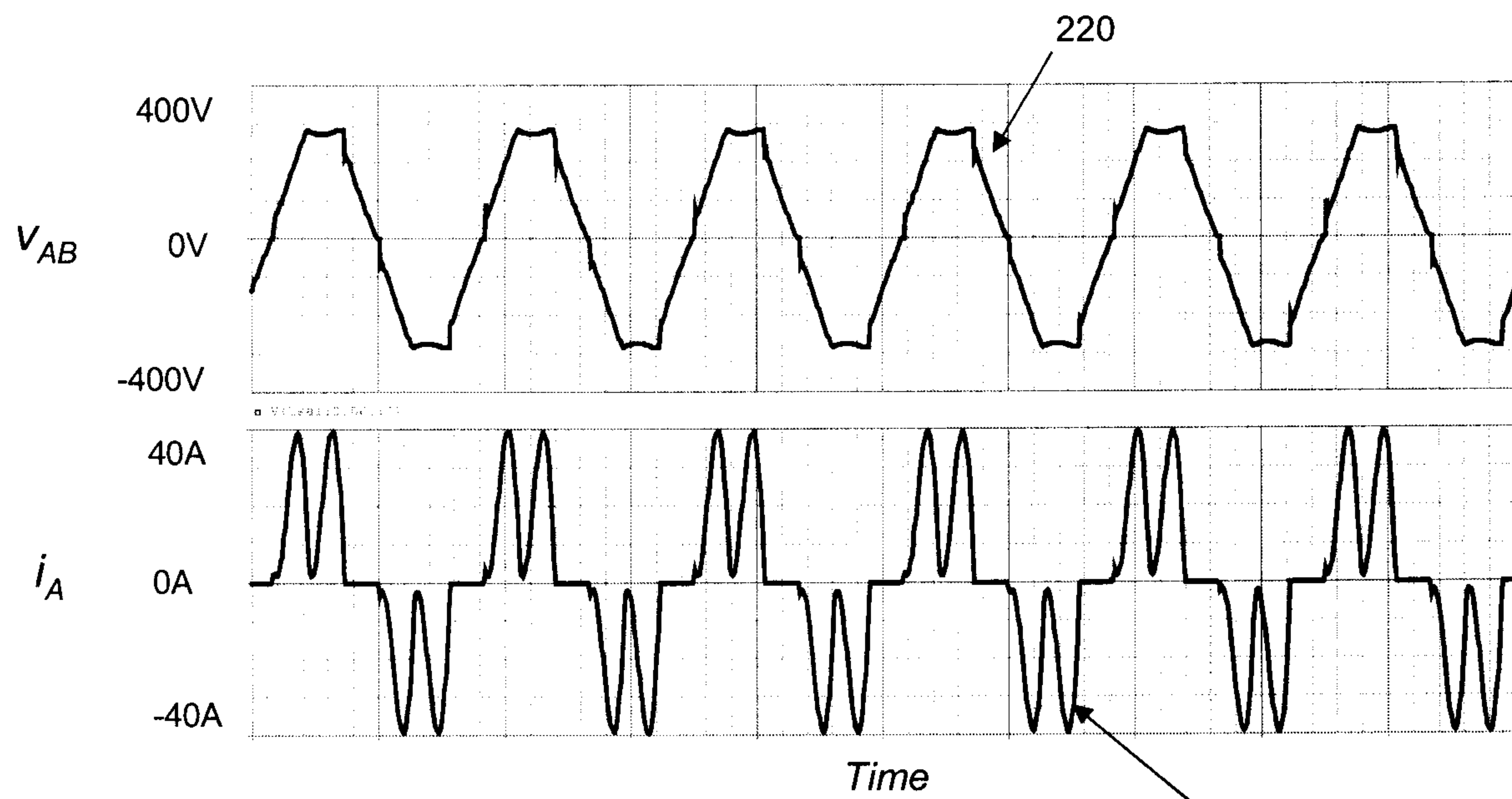


Figure 8

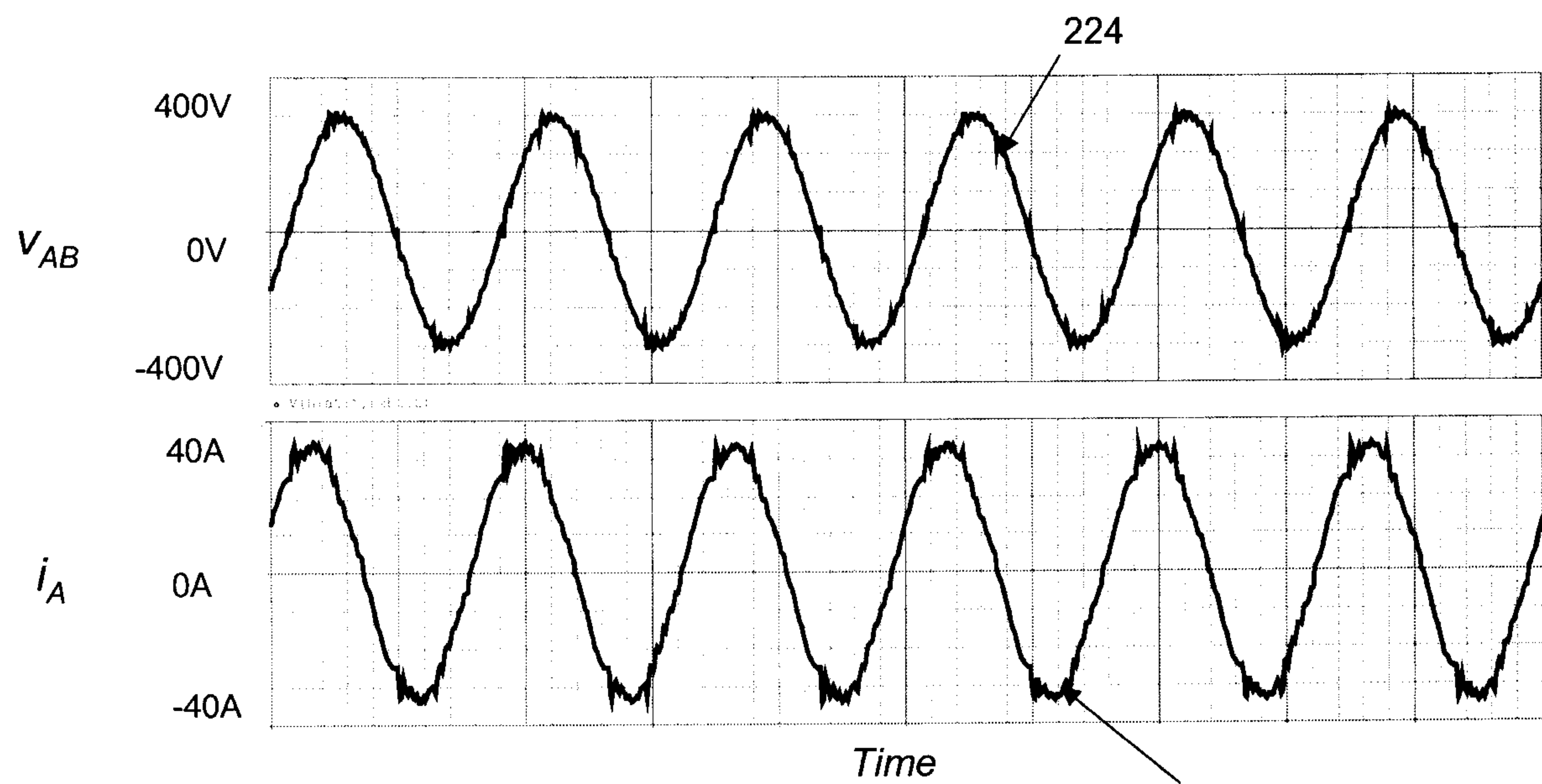


Figure 9

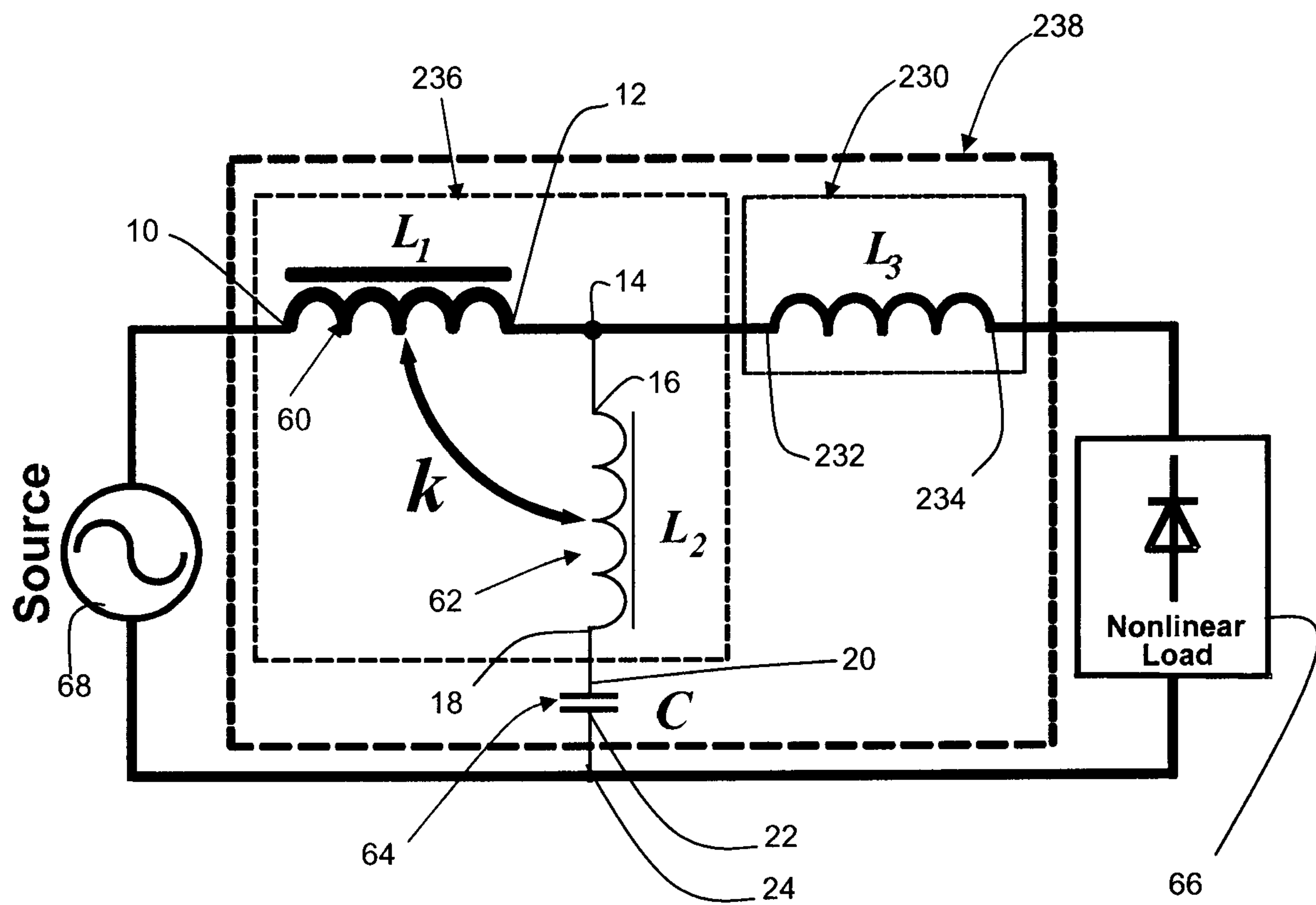


Figure 10

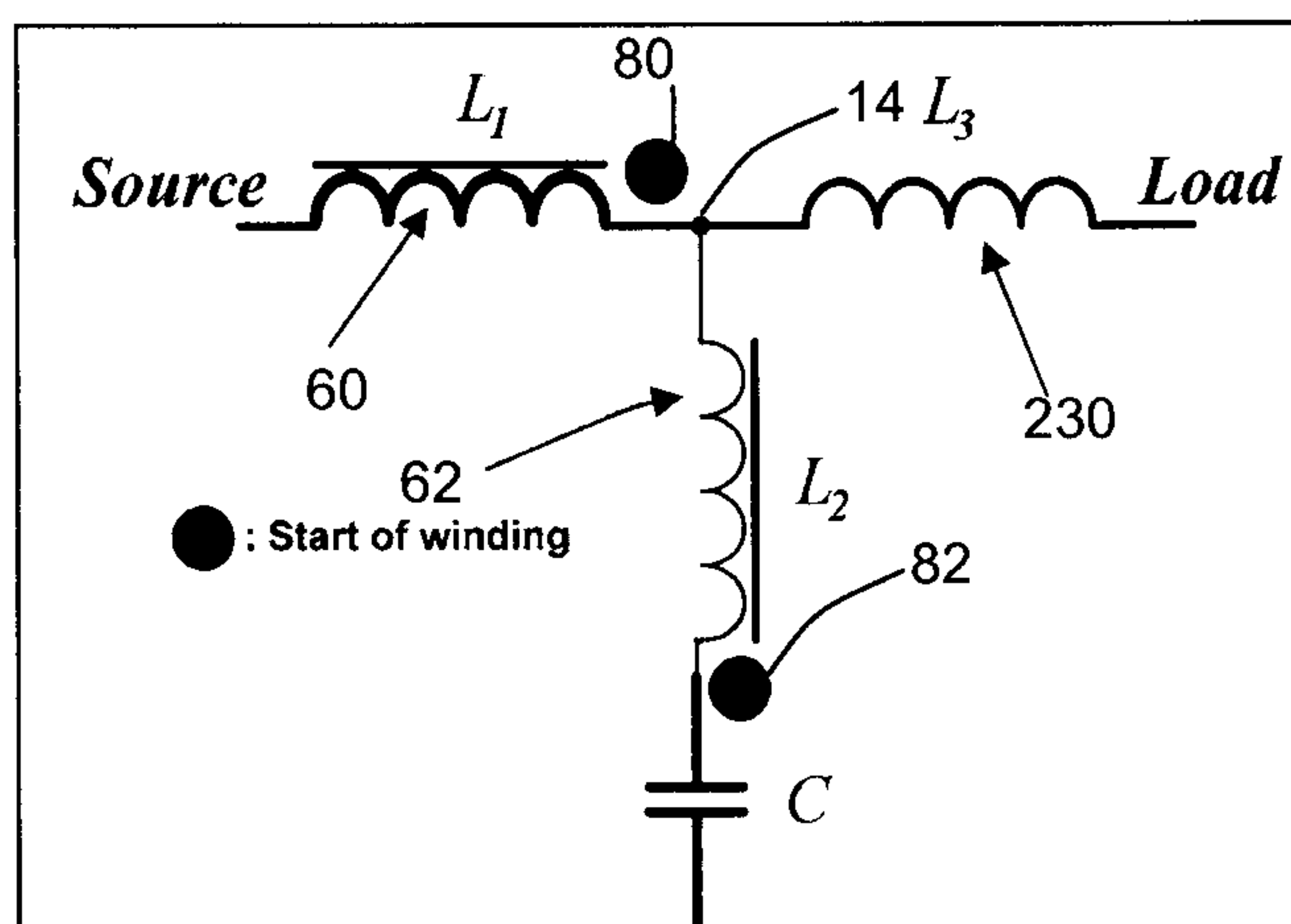


Figure 11a

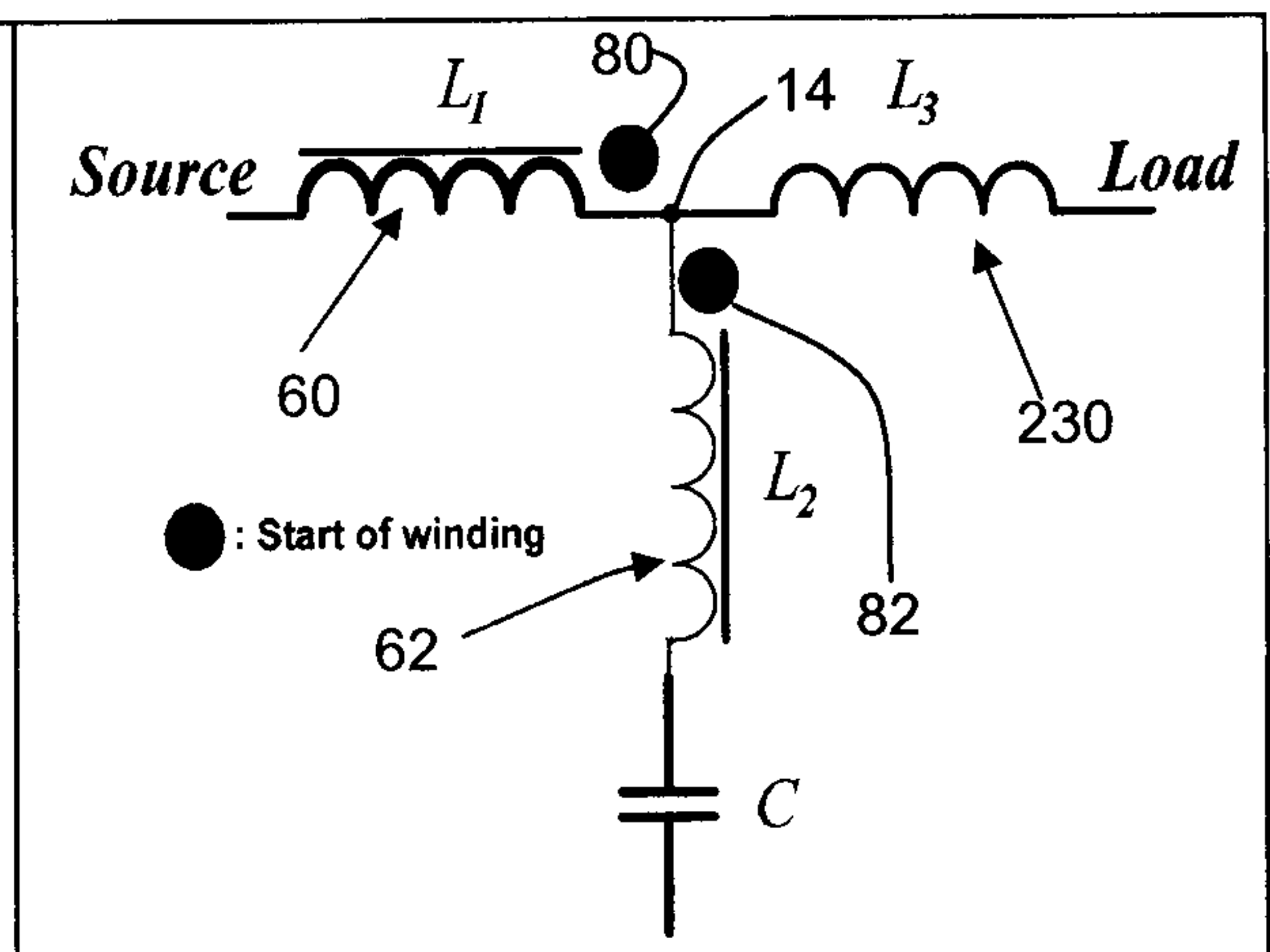


Figure 11b

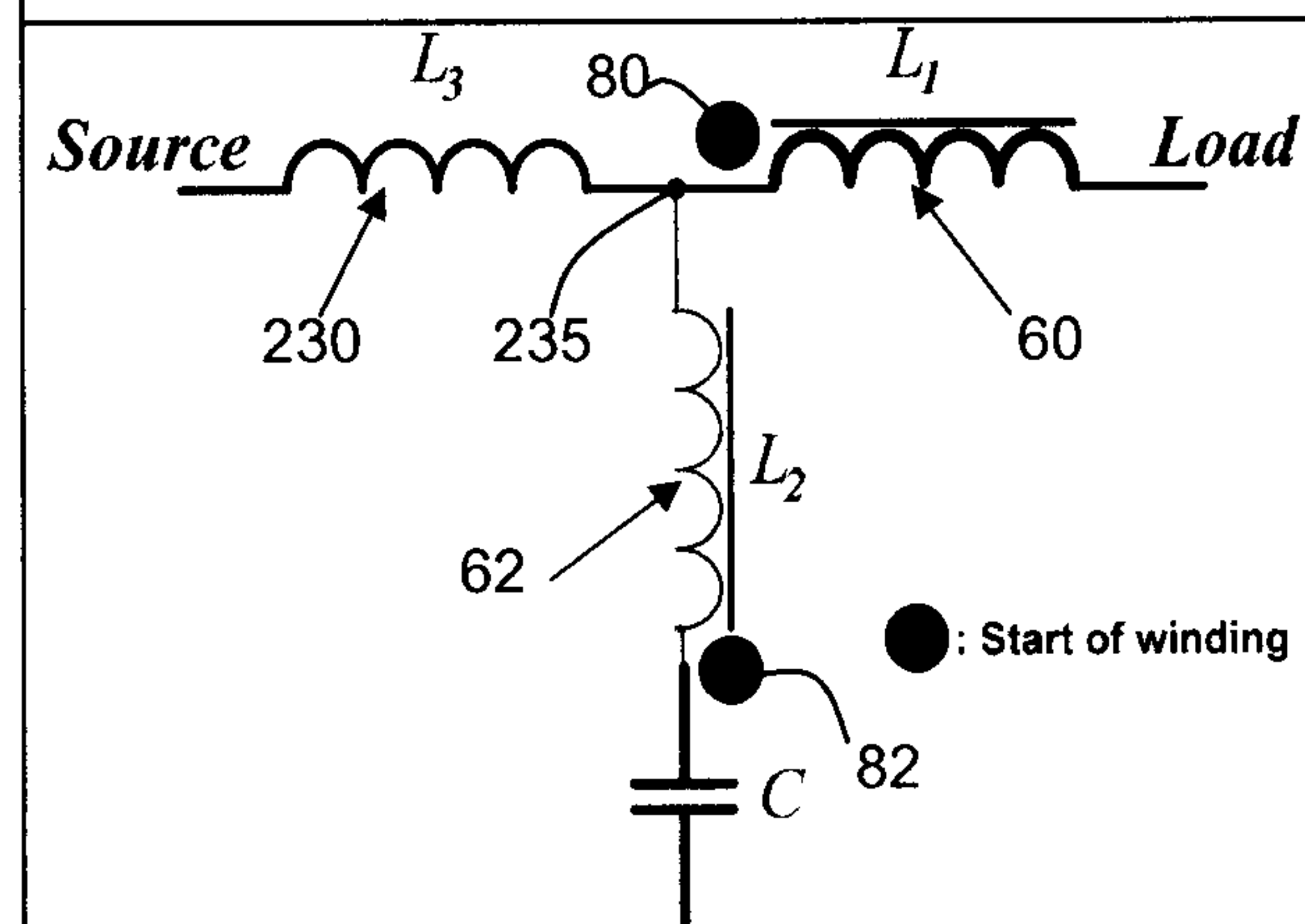


Figure 12a

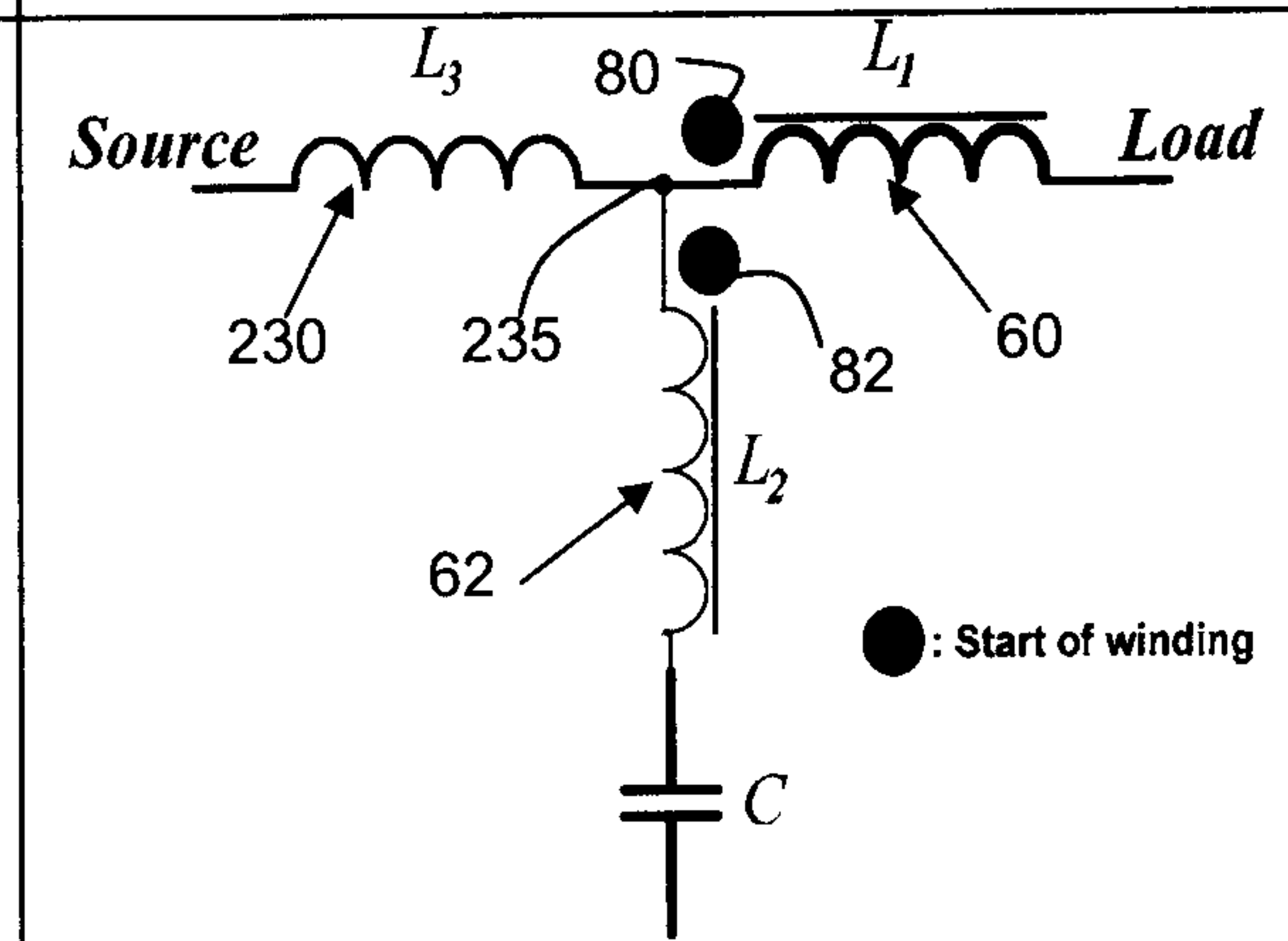


Figure 12b

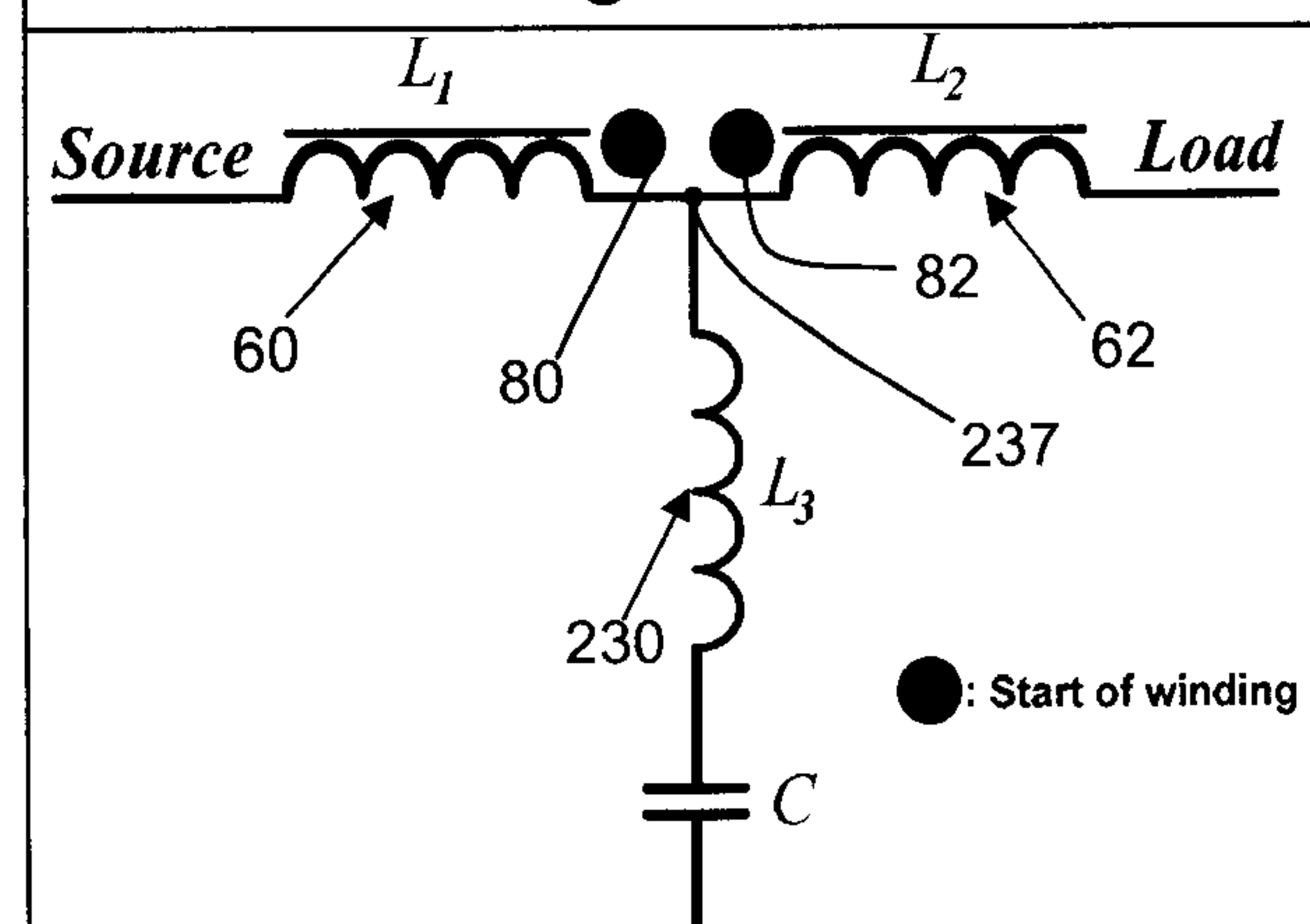


Figure 13a

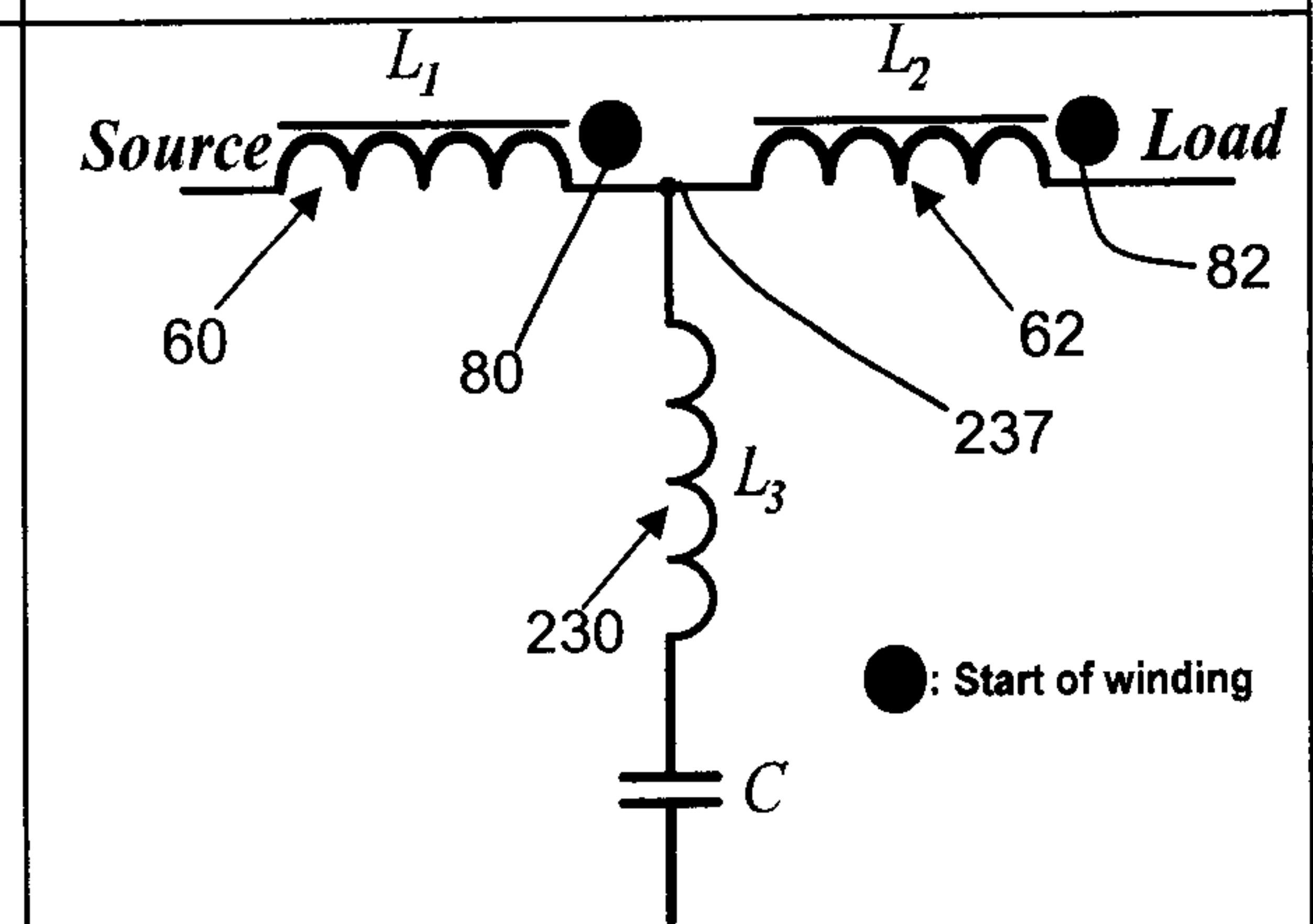


Figure 13b

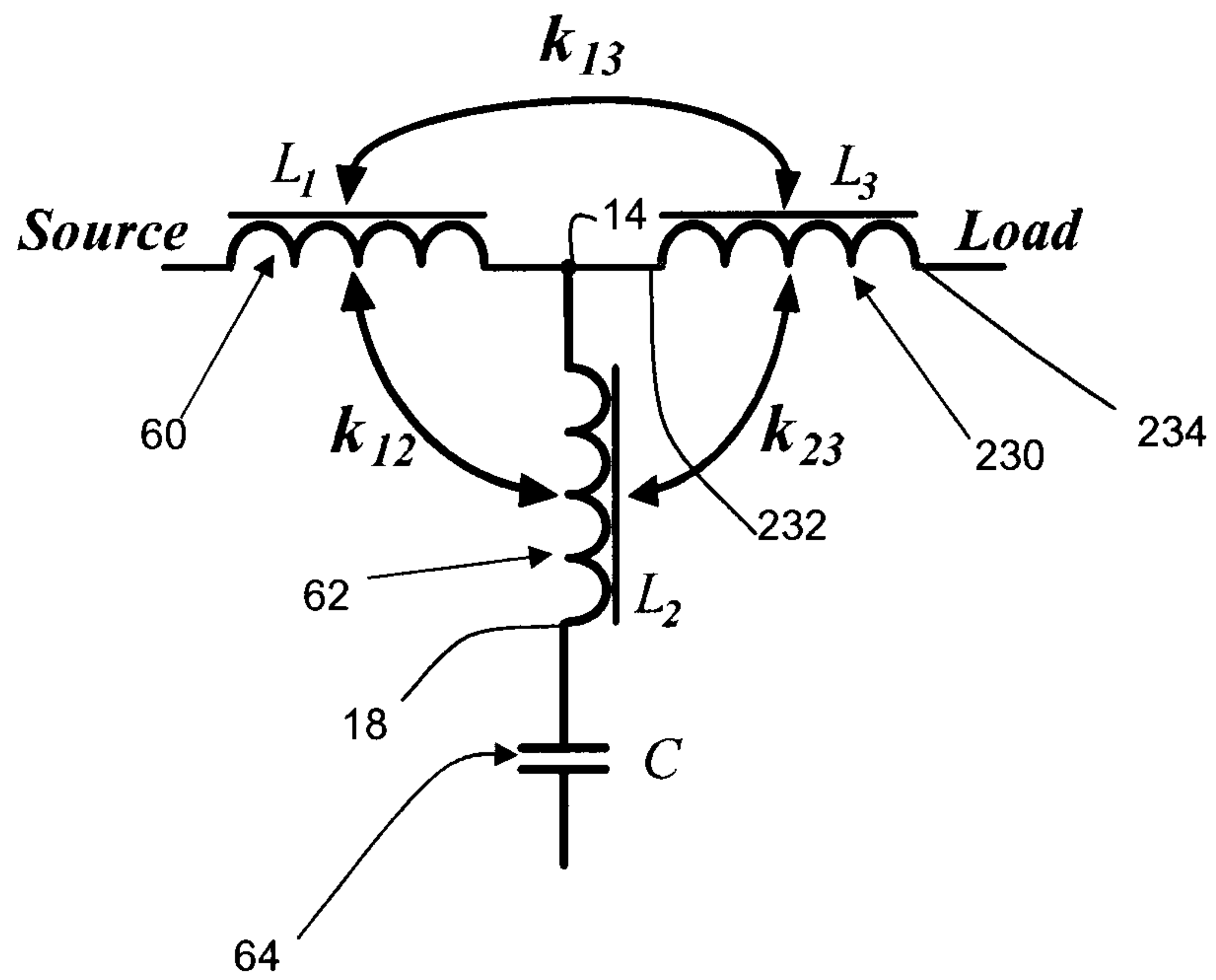


Figure 14

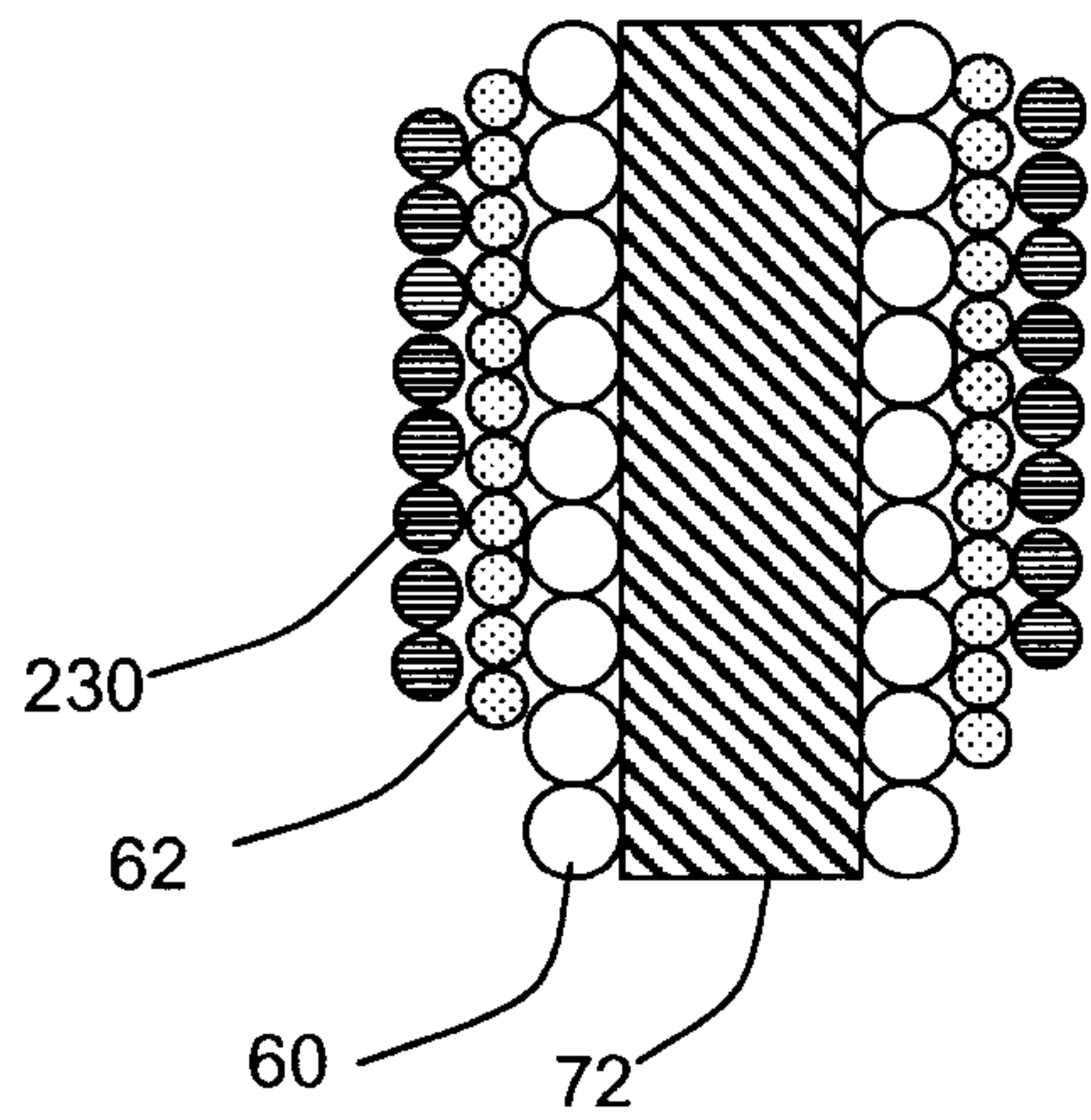


Figure 15a

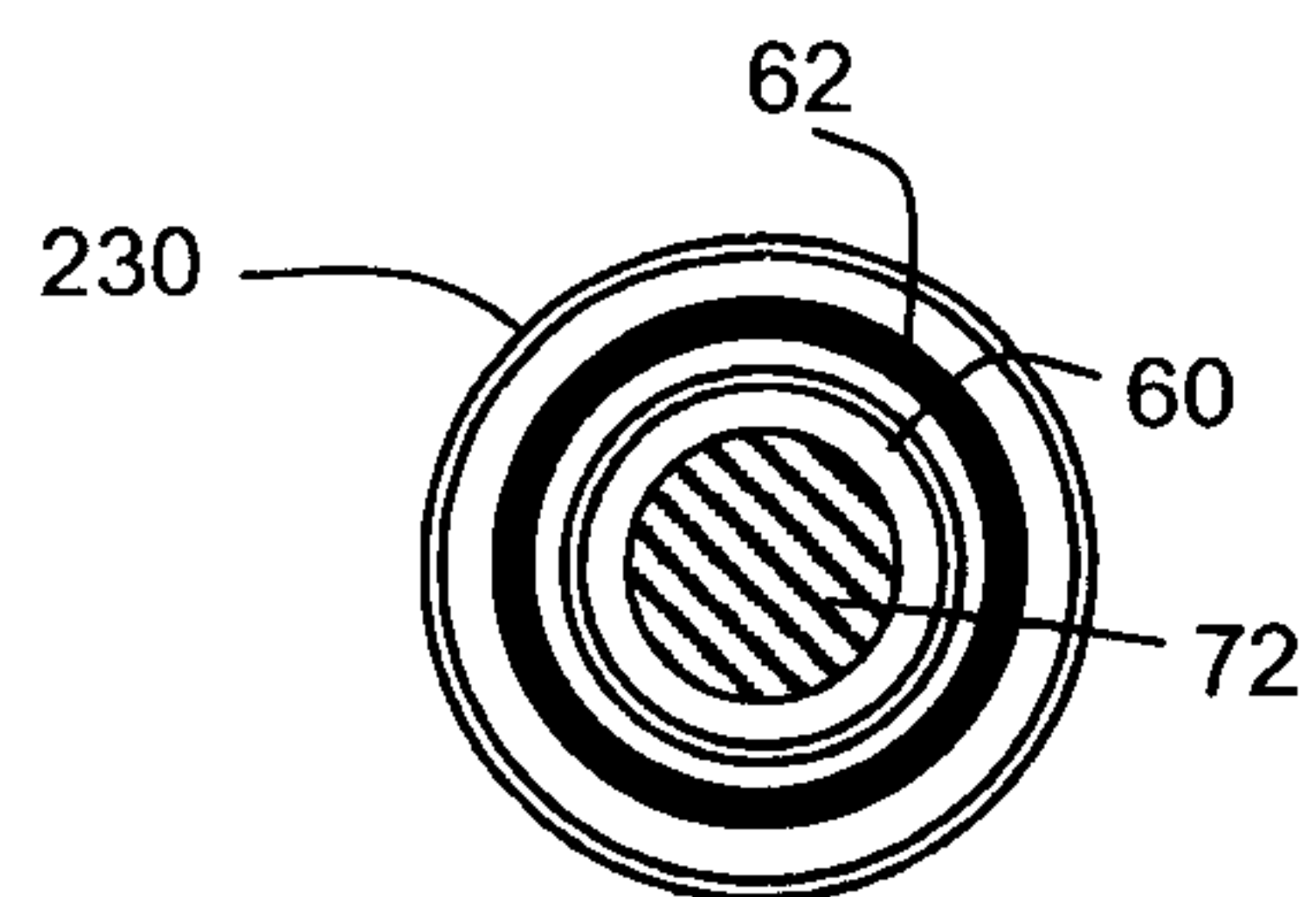


Figure 15b

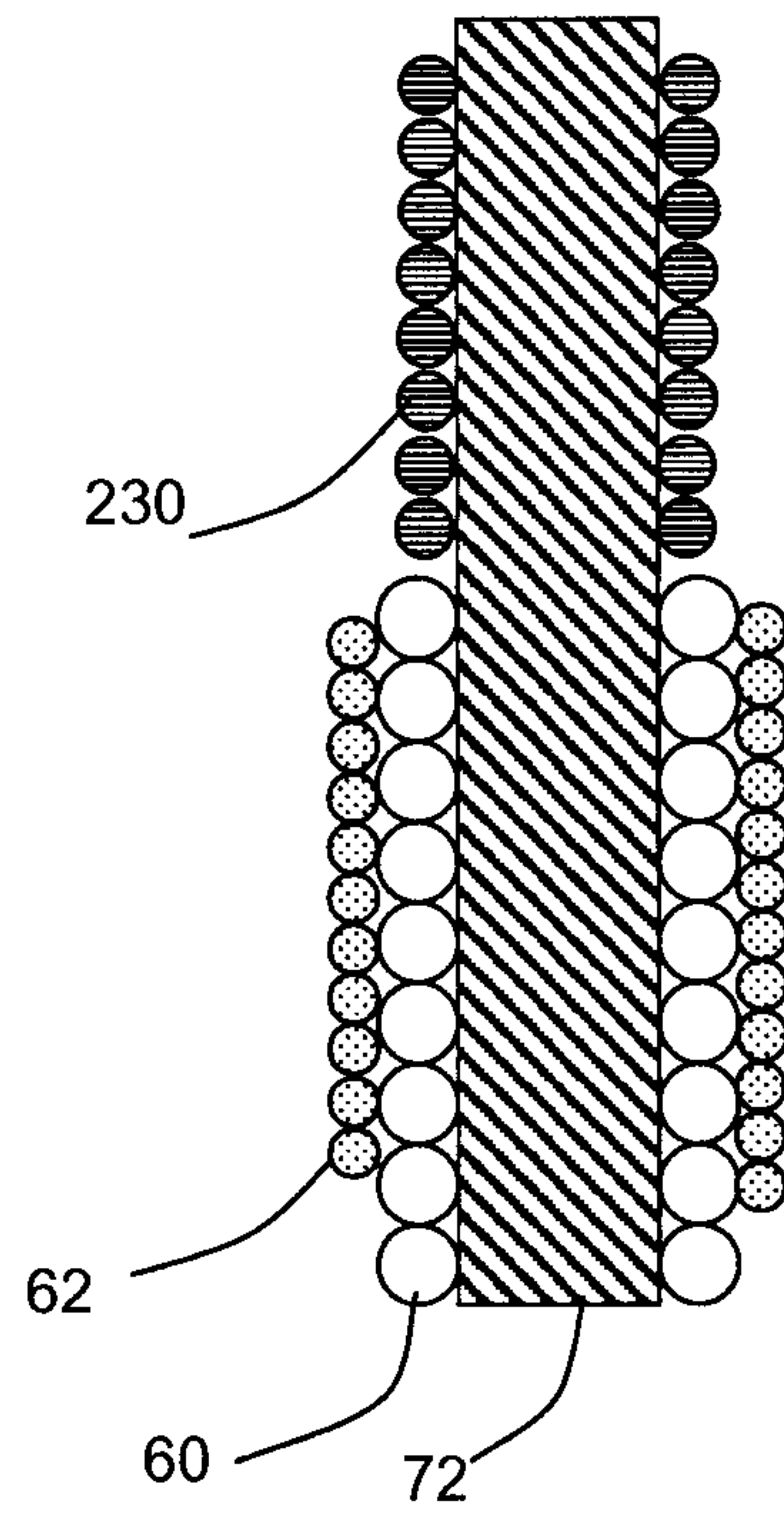


Figure 16

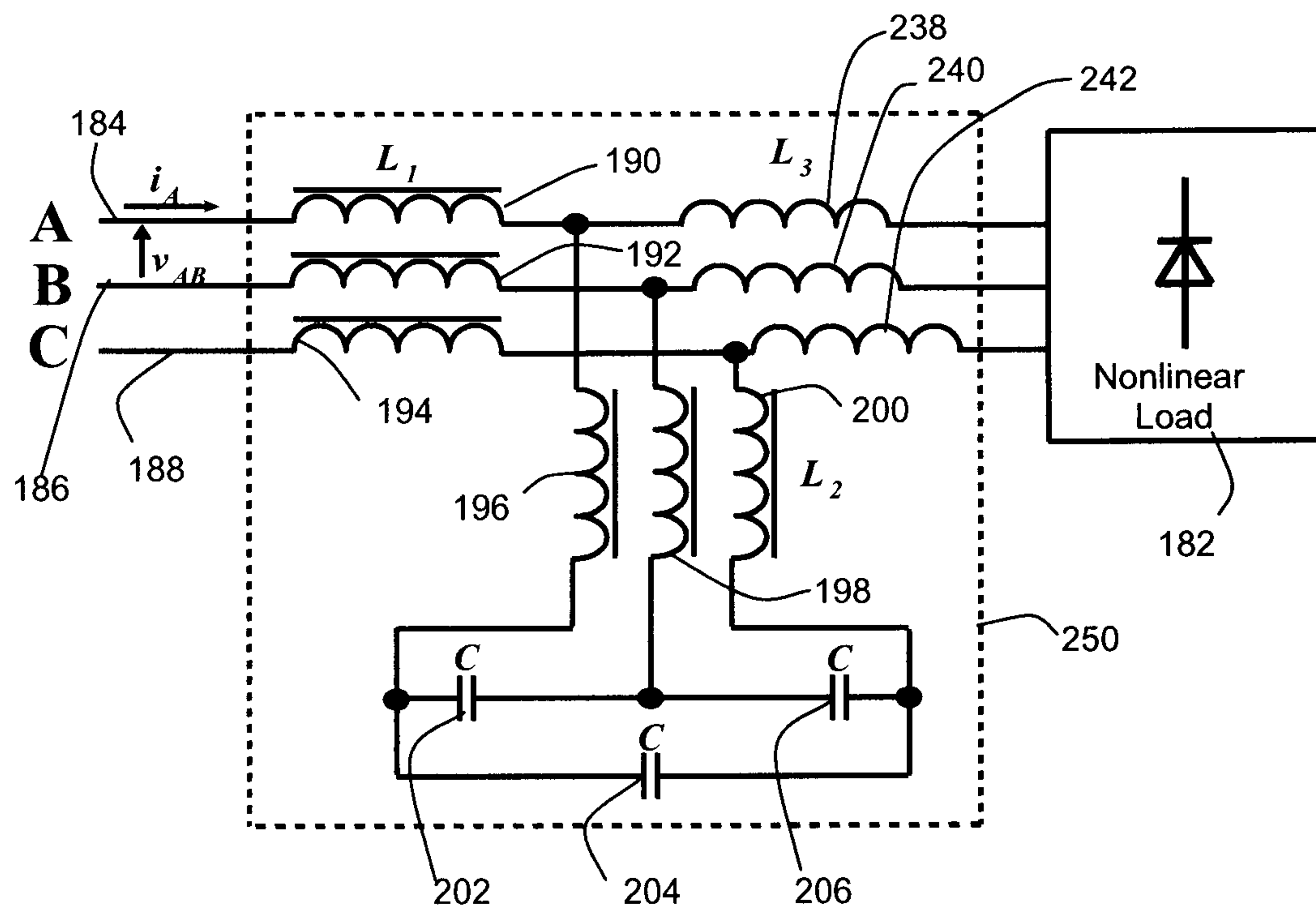


Figure 17

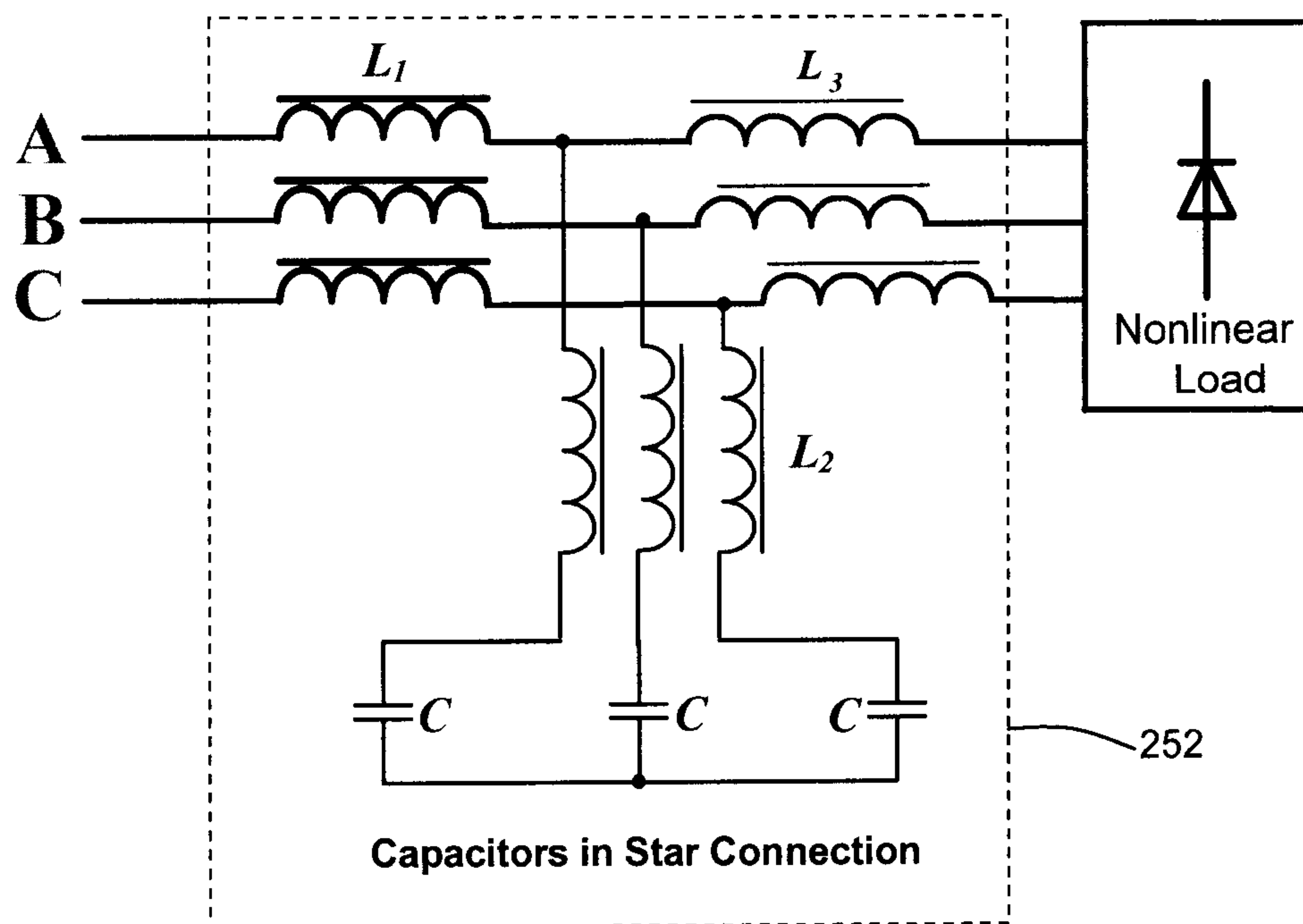


Figure 18

