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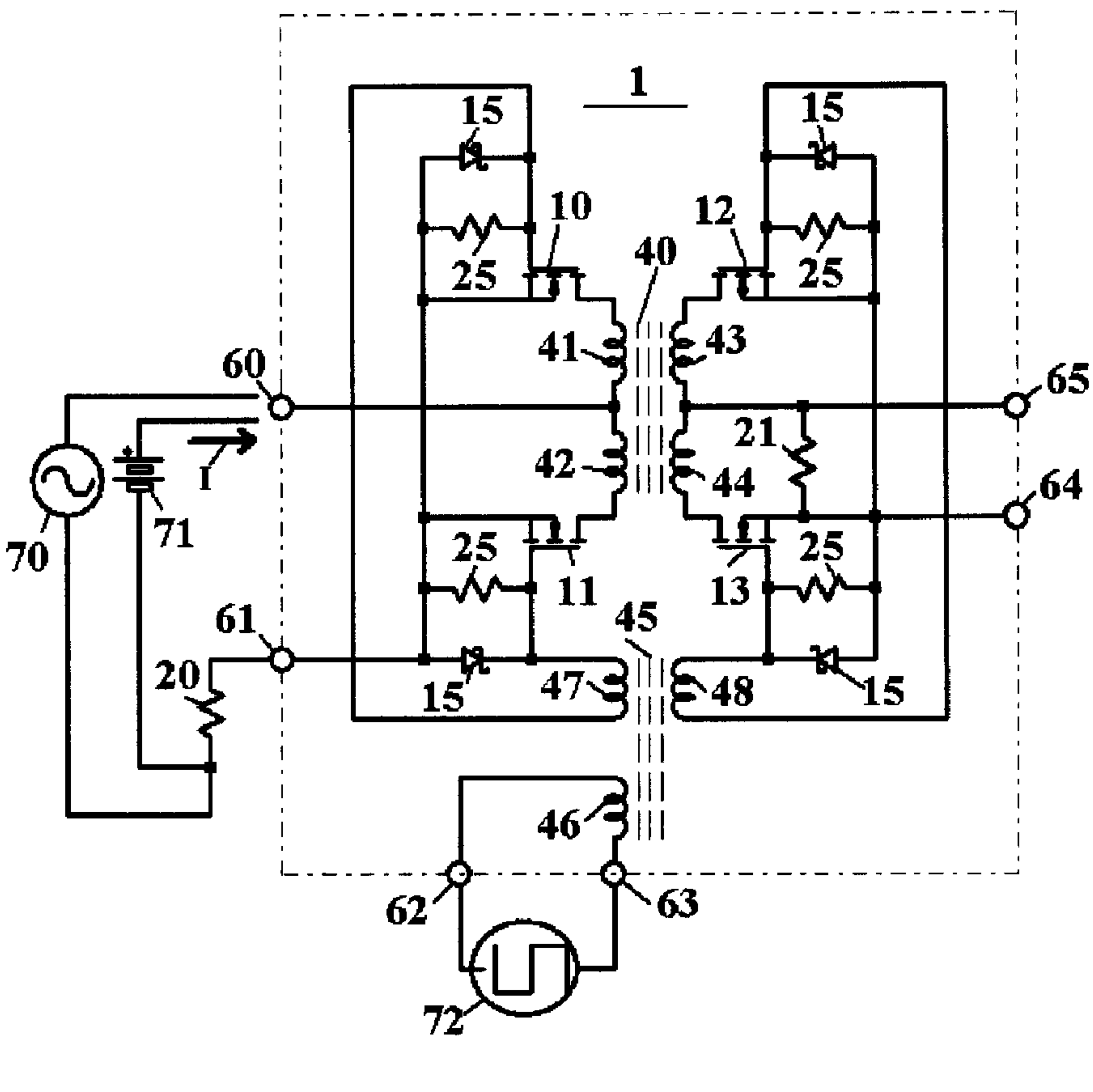
(71) Demandeur/Applicant:
MORONG, WILLIAM H., US

(72) Inventeur/Inventor:
MORONG, WILLIAM H., US

(54) Titre : TRANSFORMATEUR DE COURANT A COURANT CONTINU
(54) Title: DIRECT-CURRENT CURRENT TRANSFORMER



(57) Abrégé/Abstract:
The present invention provides a direct-current current transformer, or DCCT, yielding bandwidth from DC to several MHz. The DCCT according to this invention is a simple, open-loop, device in which flux densities occur at very low levels, avoiding difficulties occasioned by core saturation.

Abstract of the Invention:

The present invention provides a direct-current current transformer, or DCCT, yielding bandwidth from DC to several MHz. The DCCT according to this invention is a simple, open-loop, device in which flux densities occur at very low levels, avoiding difficulties occasioned by core saturation.

Title of the Invention:

DIRECT-CURRENT CURRENT TRANSFORMER

Technical Field of the Invention:

The present invention relates to galvanically isolated measurement of direct current.

Background of the Invention:

The AC current transformer has been well-known for many decades, and is used where substantially alternating currents are to be measured. Current transformers are often used when galvanic isolation is required between the circuit being measured and apparatus responsive to current in the measured circuit. However, when direct current flows in the circuit being measured, the AC current transformer is, by itself, unable to transform any DC portion of its input current to responsive apparatus. Moreover, if sufficient direct current flows in a current transformer, core saturation is likely, preventing transformation of either alternating or direct current.

The measurement of DC currents without galvanic isolation is well-known, and is not relevant to this invention. This invention is one form of a type of apparatus known as direct-current current transformers, or DCCT's. Many prior art DCCT's supplement an AC current transformer to provide DC response. One common method is exemplified by the AC/DC current probe of U.S. Patent No. 7,309,980, wherein a Hall-effect transducer provides low frequency transformation. Such devices have proven useful, but are subject to thermal drift, and to stray magnetic fields and, may require de-gaussing. Another method is alternately to saturate and de-saturate a current transformer core to convert the DC flux therein into a transformable AC signal. This method is exemplified by the current probe of U.S. Patent No. 6,885,183, which also exemplifies another much-used method, to wit, that of using a DC feedback winding to cancel the DC flux in the transformer core. Generally, the methods using DC feedback are either complex or have bandwidth limited to a few KHz. Numerous other methods, some very complex, have been employed to provide a direct-current current transformer, or DCCT.

Objects of the present invention:

A first object of the present invention is to provide current-transformer apparatus capable of transforming both alternating and direct input currents, or a mixture of both, to output a signal responsive thereto. A further object of this invention is to provide such apparatus that is simple, and which provides bandwidth to several MHz. Yet another object of the present invention is to provide a DCCT that is substantially insensitive to stray magnetic fields and, which does not require degaussing.

Brief summary of the present invention:

According to this invention, an input current passing through a primary winding of a current transformer is commutated by a first switch to generate AC primary flux in the transformer at a chopping frequency. This flux cuts a secondary winding of the current transformer which is in circuit with a well-known current transformer burden, or load. As occurs with well-known current transformers with well-chosen burdens, magnetic flux of the primary winding is substantially canceled by that of the secondary winding, producing little net flux in the transformer core and little voltage across the burden. The burden of this invention may be a simple resistor, or may comprise other apparatus such as a well known low input-impedance amplifier.

According to this invention, a second switch may be interposed in circuit with the secondary winding and with the burden to commutate its current into the burden, thereby restoring to the burden current any low-frequency or DC components representing low frequency or DC components of the current flowing through the input terminals.

Other well-known means of rectifying the output of the burden may be applied to practice this invention.

The output of this DCCT may be taken as either a voltage, as a current, or as an optical signal to practice this invention.

Brief description of the drawing:

Fig. 1 is a schematic diagram of a preferred embodiment of the present invention.

Detailed description of the drawing:

Fig. 1 is a schematic diagram of a preferred embodiment of the present invention. A current I, in this case generated by an AC voltage source 70, or a DC voltage source 71, flows through input terminals 60 and 61 of the inventive DC current transformer(DCCT)1, and through a load 20, in circuit both one or more the aforesaid voltage sources and the input terminals. A first switch comprising MOSFET's 10 and 11, steers the input terminal current through either an upper, 41, or a lower, 42, winding of a current transformer 40 responsive to the state of a chopping signal from a drive generator 72. The chopping signal is applied to DCCT 1 through drive terminals 62 and 63. In circuit with drive terminals is the primary winding 46 of a drive transformer 45, a secondary winding 47 of which provides both galvanic isolation and bipolar drive to the first switch comprising MOSFET's 10 and 11. Resistors 25 assure that MOSFET's 10 and 11 remain in an OFF state unless driven ON by generator 72. Diodes 15 limit negative voltage excursions of the gates of MOSFET's 10 and 11 relative to their sources, and assure that the drive signal is maximally applied to the gate of the MOSFET being enhanced. In this embodiment, a well-known center-tapped winding and two MOSFET's are arranged in push-pull to commutate input current into transformer 40. Obviously, four MOSFET's forming a well-known bridge can be connected in circuit with a non-center-tapped winding to obtain commutation according to this invention. Even with a DC input, the flux in the core of transformer 40 is AC, responsive to the AC drive from generator 72. The generator 72 signal, is preferably a 100KHz square wave derived from a digital divider to assure substantially 50% duty cycle, avoiding significant DC flux in the core of transformer 40. Since MOSFET's 10 and 11 of this embodiment are enhancement devices, there exist minuscule times during chopping cycle transitions when both MOSFET's are OFF. This time is adequate to allow short voltage transients to occur which reset any flux in the core of transformer 40. To reduce stray inductance, MOSFET's 10 and 11 may be "DIRECT-FET"s such as International Rectifier type IRF6711. Gate drives of +5V produce good enhancement, with larger voltages achieving minimum voltage between input terminals 60 and 61, at the expense of increased switching noise in the inventive DCCT 1.

In this embodiment, transformer 40 is wound on a toroidal ferrite core, Magnetics Inc. type J40603, with a center-tapped primary winding 41 and 42 of two single turns, and a center-tapped secondary winding 43 and 44 of 10 turns, bifilar-wound.

Moving across current transformer 40 to its secondary side we find a circuit comprising two MOSFET's 12 and 13 in circuit with upper, 43, and lower, 44, secondary windings, and with a burden resistor 21. Two more resistors 25, two more diodes 15, and another secondary winding 48 of drive transformer 45 operate analogously to their counterparts on the primary side of transformer 40 to toggle MOSFET's 12 and 13 responsive to the AC drive from generator 72, commutating in synchrony with the commutation occurring in the primary circuit thereof the secondary current of transformer 40. However, instead of flowing through external terminals commutated transformer 40 secondary current flows largely through a burden resistor 21, which preferably has a value of 100 milli-ohms.

As occurs in a well-known AC current transformer, the ampere-turns of transformer 40 primary and secondary windings cancel. Since transformer 40 secondary windings 43 and 44 have ten times as many turns as its primary windings 41 and 42, their currents must be 1/10th of the input current. As in an ordinary AC current transformer, the output of DCCT 1, the voltage across the burden, is proportional to input current. As with an ordinary current transformer, the 100 milli-ohms of burden 21 is reflected in the primary circuit as an imaginary 1 milli-ohm shunt resistor in the primary circuit. The turns-ratio of transformer 40 amplifies the output of that imaginary shunt resistor by 10, yielding 100mV for 10 amperes of primary current, as in an ordinary AC current transformer. The salient difference between this embodiment of the present invention and an ordinary AC current transformer is that, because of the interposed commutating switch, the inventive DCCT 1 input current can be DC, producing a substantially DC output across burden resistor 21, to be presented at DCCT 1 output terminals 64 and 65.

Since the currents in MOSFET's 12 and 13 are smaller than in their counterparts 10 and 11, electrically smaller MOSFET's such as Fairchild Semiconductor type NDS355AN suffice for them.

It should be understood that with a correctly chosen burden 21 and well chosen MOSFET's, the voltages occurring between MOSFET drains and sources are, in this embodiment of the present invention, significantly less than one silicon PN diode-drop of about 600mV.

It is commonly understood that because of the connection of their body diodes to their source terminals, most MOSFET's unilaterally block current flow. What is less widely understood, however, is that below one diode-drop the same MOSFET's bilaterally block in their OFF state. Thus, in this embodiment with its low drain to source voltages, such usually unipolar blocking MOSFET's suffice for bipolar operation, that is operation with both DC and AC inputs and outputs.

It should be understood that either N-channel MOSFET's, P-channel MOSFET's, or combinations of both may be applied to practice this invention, as may NPN and PNP BJT's, or combinations of the above.

It should also be understood that the burden resistor, 21 of this embodiment is but a convenient component with which to practice this invention. Well-known circuits having low input impedance and providing a current-responsive output may replace burden resistor 21 to practice this invention. This invention may also be practiced by placing burden resistor 21 directly in circuit with a secondary winding of transformer 40, and converting the resulting AC voltage across burden resistor 21 to DC using well-known rectifier circuits, synchronous or asynchronous, to replace the commutation at the secondary winding of transformer 40. This invention may also be practiced by omitting any rectification or commutation of transformer 40 secondary current and taking an AC output.

It should, moreover, be understood that this invention can be practiced using a burden driving well-known analog to digital conversion (ADC) circuitry having a digital output which may be communicated to other apparatus either through output terminals, or through a well-known optoelectronic link without electrically conductive terminals. The use of digital signal processing to rectify an ADC output is well-known, providing yet another way to rectify the burden output of this invention within the scope thereof.

Exemplary Application of the present invention:

The inventive DCCT has many applications, of which one would be galvanically isolated measurement of the current flowing in a DC motor where it might be inconvenient or unsafe to refer the measurement apparatus to local ground or earth without galvanic isolation.

What is claimed is:

1. A DCCT having an input terminals and output terminals, also comprising;

a current transformer having,
a primary winding,
a secondary winding and,
a core,

a chopping frequency signal and,

a commutating switch responsive to the chopping frequency signal connected in circuit with the DCCT input terminals and with the current transformer primary winding.

2. The DCCT of claim 1 wherein the commutating switch comprises MOSFET's.

3. The DCCT of claim 1 wherein the commutating switch comprises BJT's.

4. The DCCT of claim 1 wherein the commutating switch comprises two switches acting in push-pull.

5. The DCCT of claim 1 wherein the commutating switch comprises more than two switches arranged in a bridge.

6. The DCCT of claim 1, further comprising a commutating switch in circuit with the current transformer secondary winding.

7. The DCCT of claim 1, further comprising a burden to load the

secondary winding of the current transformer.

8. The DCCT of claim 7, wherein the burden is a resistor.

9. The DCCT of claim 7, wherein the burden signal is processed by an active electronic circuit.

10. The DCCT of claim 7, further comprising a rectifier.

11. The DCCT of claim 10, wherein the rectifier is synchronous with the chopping frequency.

12. The DCCT of claim 10, wherein the rectifier is asynchronous with the chopping frequency.

13. In a DCCT comprising input terminals and a current transformer having a core and a primary winding,

the method of interposing a commutating switch in circuit with the input terminals and a primary winding of the current transformer to prevent saturation of the transformer core thereof by low frequency or direct primary current.

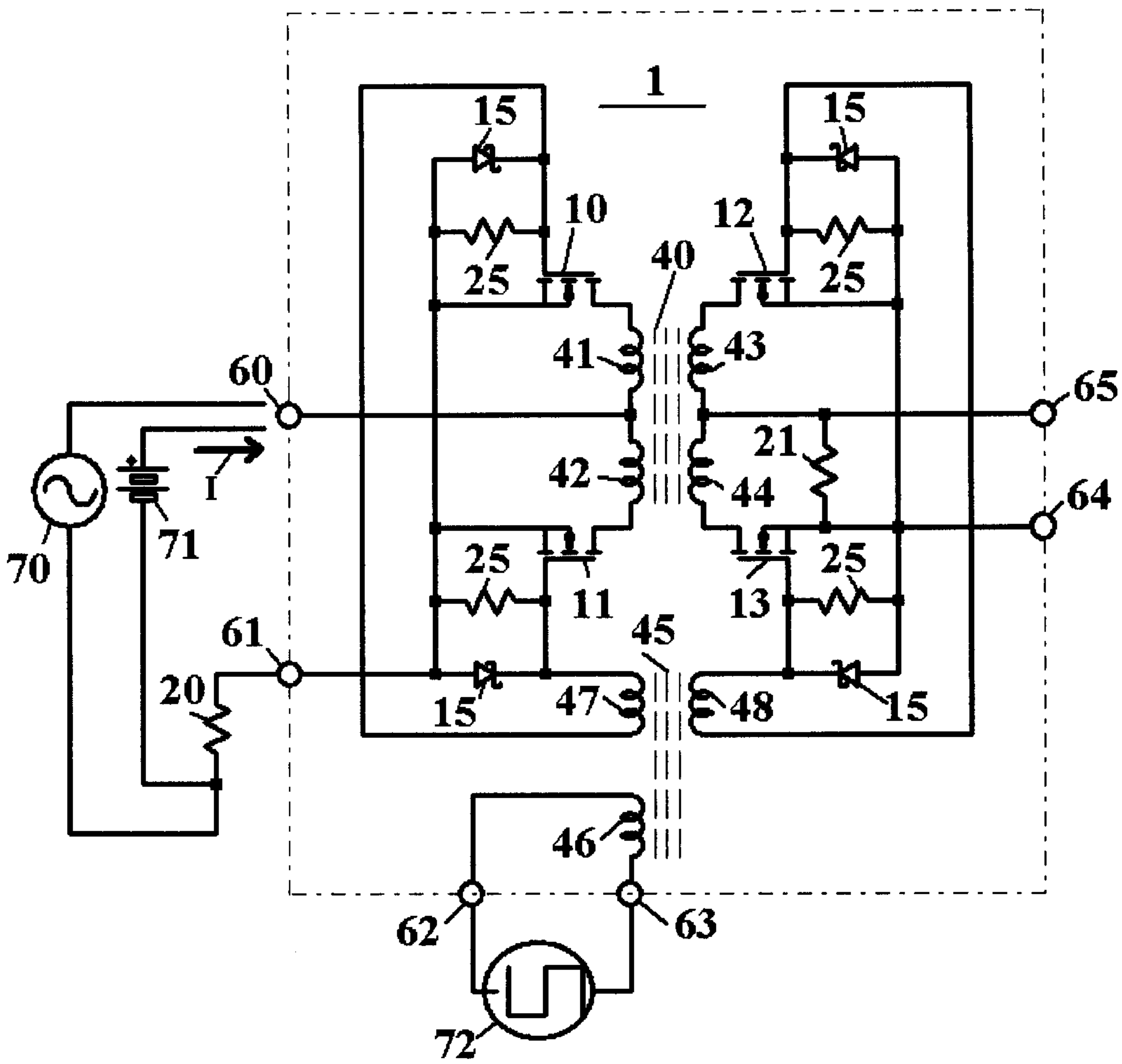

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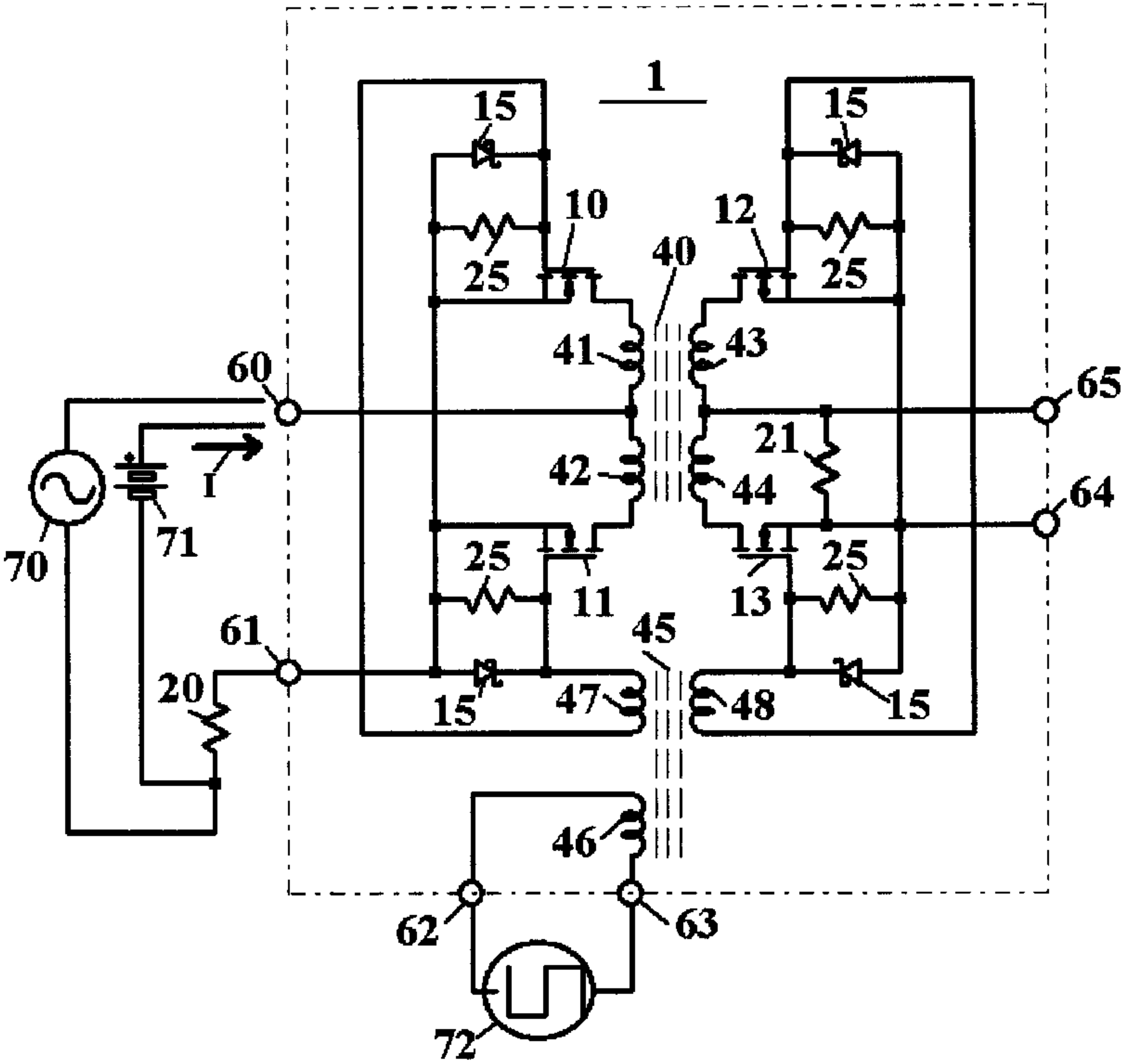
Fig.1



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