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# HALF-WAVE BRIDGE MAGNETIC AMPLIFIER

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FIG. 1.

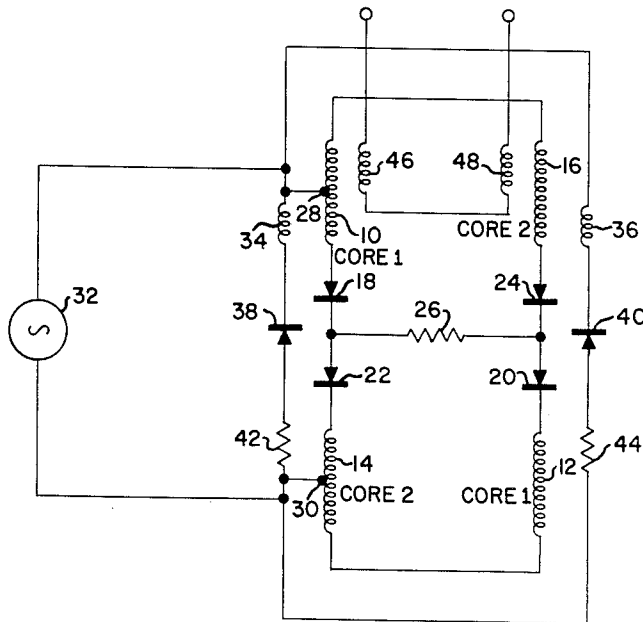
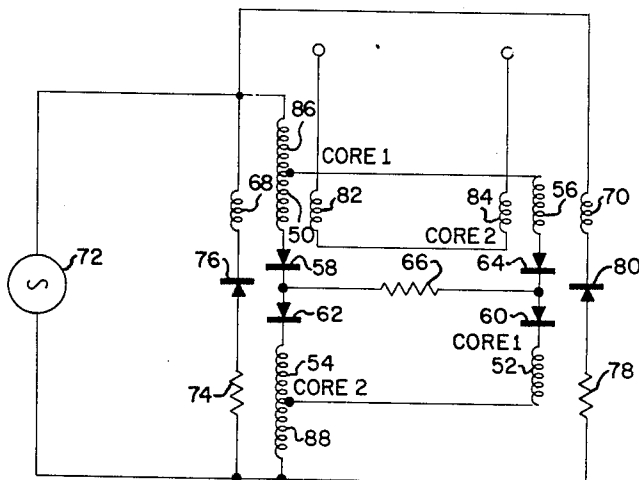


FIG. 2.



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1

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## HALF-WAVE BRIDGE MAGNETIC AMPLIFIER

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8 Claims. (Cl. 323—89)

(Granted under Title 35, U. S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

This invention relates to magnetic amplifiers, and more particularly pertains to the half-wave bridge magnetic amplifier.

When utilizing the half-wave bridge magnetic amplifier, it is sometimes necessary to provide output voltages on the load that are in the order of the supply voltage or higher. However, the conventional half-wave bridge can only supply an output voltage of approximately half the source voltage applied across the bridge.

Heretofore, it has been known to provide a separate transformer to step up the source voltage to the desired level, or, alternatively, the output of the bridge may be transformer coupled to the load. The latter expedient employing transformation of the load is undesirable because of the D. C. pulse character of the output. It has also been proposed to utilize a transformer having a center tapped secondary as two legs of the bridge circuit, to thereby provide the higher voltages necessary. However, each of the above mentioned expedients possess the common disadvantage that in order to achieve the higher voltages necessary for certain applications, a separate transformer must be provided, adding considerable bulk and weight to the unit.

The present invention provides the higher voltage necessary for certain applications of the half-wave bridge magnetic amplifier by transformation directly on the bridge reactors.

An important object of this invention is to provide a half-wave bridge magnetic amplifier which will produce a higher output voltage from a given power supply source than can be achieved by the direct operation of the bridge from the power supply source, without the necessity of utilizing an external transformer.

Another object of this invention is to provide a half-wave bridge type magnetic amplifier in which transformation of the power supply voltage is achieved on the reactor cores whereby any desired output voltage can be obtained from a given power supply voltage.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

Fig. 1 is a schematic diagram of a half-wave bridge magnetic amplifier employing step-up transformation of the power supply voltage on the reactor cores; and

Fig. 2 is a schematic diagram of a half-wave bridge type magnetic amplifier employing step-down transformation of the power supply voltage on the reactor cores.

The half-wave bridge type magnetic amplifier has an inherent rapid speed of response desirable in magnetic amplifiers for servo mechanisms and other control devices. However, the bridge circuit operating directly

2

across the power supply voltage cannot produce an output voltage much more than about 50% of the line voltage r. m. s.

The output voltage of a half-wave bridge magnetic amplifier is a series of unidirectional pulses with a peak level somewhat lower than line voltage, the amplitude of the voltage pulses being determined by the relation of the internal impedance of the amplifier to the load impedance.

In accordance with the present invention, higher load voltages can be obtained without the use of additional components such as transformers, by the use of transformation directly on the reactor cores.

Referring now more specifically to Fig. 1 of the drawings, there is illustrated a half-wave bridge type magnetic amplifier comprising a pair of cores respectively designated core 1 and core 2. Controlled windings 10 and 12 may advantageously be wound on a common core such as core 1, and controlled windings 14 and 16 may advantageously be wound on a common core such as core 2. Unidirectional impedance elements 18, 20, 22 and 24 are respectively connected in series circuit with controlled windings 10, 12, 14 and 16, each of which series circuits forms one leg of a bridge circuit. More specifically, a branch circuit comprising controlled winding 10 and unidirectional impedance 18 connected in series with controlled winding 16 and unidirectional impedance 24 is connected across the load 26, and a second branch circuit comprising controlled winding 14 and unidirectional impedance 22 connected in series with controlled winding 12 and unidirectional impedance 20 is also connected across the load 26. In accordance with the present invention, auto-transformation of the power supply voltage on the saturable reactor cores may advantageously be employed. For this purpose, a pair of controlled windings, one in each of the branch circuits, and which controlled windings form a pair of adjacent legs of the bridge circuit, are each provided with taps 28 and 30 at points intermediate ends thereof. An A. C. potential from the supply source 32 is applied across the taps 28 and 30, the unidirectional impedance elements 18-24 being so phased that current flows through all of the controlled windings only during one half cycle of the power supply voltage, hereinafter referred to as the conducting half cycle of the bridge.

As is conventional in half-wave bridge type circuitry, a pair of reference windings 34 and 36 are provided on the cores 1 and 2 respectively, which reference windings are connected in series with unidirectional impedance elements 38 and 40 and resistors 42 and 44, respectively across the power supply source 32, whereby half-wave reference currents are supplied to the cores 1 and 2. The rectifiers 38 and 40 are phased so that the reference current flows through the respective reference windings 34 and 36 during the nonconducting or control half-cycle of the half-wave bridge so as to thereby establish the reference flux level in the cores 1 and 2 during the nonconducting half-cycle of the bridge. Control windings 46 and 48 are also provided on the cores 1 and 2 respectively and are wound so as to differentially vary the firing angles of the cores in response to the application of the control signal thereto.

In operation, the cores 1 and 2 are referenced to fire at some predetermined firing angle by the reference circuit, as is conventional. On the conducting or saturating half cycle, auto-transformation occurs before the cores reach saturation. After saturation, there is no more transformation, but quiescent current flows down the sides of the bridge. Under both conditions, however, the bridge remains balanced and the resultant current flowing through the load 26 is zero. With a control sig-

3

nal, control flux is established in the cores 1 and 2 during the nonconducting half cycle of the bridge, which control flux aids the reference flux in one core and opposes the reference flux in the other core, whereby the cores fire at different points on the conducting half cycle of the bridge. Again before saturation of either core, the auto-transformation of the power supply voltage takes place in both cores, and the bridge remains balanced.

However, one core fires ahead of the other core under control signal conditions, whereby the bridge becomes unbalanced, and current flows through the load 26 in a direction dependent upon the sense of the bridge unbalance. After one of the cores, such as core 1 saturates and before the other core saturates, the impedance of the diagonally opposite windings such as 10 and 12 on the saturated core is reduced to very nearly zero. The load 26 is then effectively in series circuit with the saturated impedance of that portion of the controlled winding 10 between the tap 28 and the unidirectional impedance 18, the forward impedance of the rectifier 18, the forward impedance of rectifier 20 and the saturated impedance of the winding 12, which series circuit is connected across the power supply voltage as stepped up due to auto-transformation in the winding 14. Winding 16 contributes little due to the direction of the rectifier 24 except that the polarity of voltage is such as to oppose current by-passing the load through that winding. After core 2 saturates, the bridge is rebalanced.

In order to prevent current flow through the bridge on the non-conducting half cycle thereof, the rectifiers 18 and 22 in those legs of the bridge circuit having the tapped controlled windings 10 and 14 must be positioned between the tap 28 and tap 30 on the controlled windings, in order to be effective.

When it is desired to supply an output voltage to a load of a lower value of that of the power supply voltage, the half-wave bridge circuit may be connected to achieve step-down transformation on the reactor cores. As in the preceding embodiment, auto-transformation may conveniently be employed. More specifically, the controlled windings 50 and 52 on core 1, and the controlled windings 54 and 56 on core 2 are connected in series with unidirectional impedance elements 58, 60, 62 and 64 respectively and are interconnected to form a bridge circuit, the windings on core 1 forming one pair of diagonal legs of the bridge and the windings on core 2 forming the other pair of diagonal legs.

Unidirectional impedance element 58, controlled winding 50, controlled winding 56 and unidirectional impedance element 64 are series connected with each other, and constitute one branch circuit which is connected in parallel with the load 66. Unidirectional impedance element 62, controlled winding 54, controlled winding 52 and unidirectional impedance 60 are series connected with each other, and form a second branch circuit in parallel with load 66. As in the preceding embodiment, the proper operating flux level in the cores 1 and 2 is established by reference windings 68 and 70 on cores 1 and 2 respectively. Reference winding 68 is energized by the power supply source 72 through resistor 74 and unidirectional impedance 76, reference winding 70 being energized from the power supply source through resistor 78 and unidirectional impedance 80. Control windings 82 and 84 are provided on the cores 1 and 2 respectively, and are arranged so as to differentially vary the flux level in the cores during the flux setting half-cycle, in response to the application of a control signal thereto.

In accordance with the present invention, the reactor cores of the bridge circuit are utilized to transform the power supply voltage to gain the desired output voltage. For this purpose, transformer windings 86 and 88 may advantageously be provided on cores 1 and 2 respectively, and are connected in series aiding with the controlled windings such as 50 and 54 which constitute one pair of

4

adjacent legs of the bridge circuit, and which lie in separate branch circuits. For proper operation, each transformer winding must be wound on the same core with the series connected controlled winding. Thus, before either of the cores saturate, the transformer winding and the series connected controlled winding functions as the primary of an auto-transformer, the controlled winding functioning as a secondary thereof to thereby apply a reduced voltage to the bridge circuit.

As in the preceding embodiment, before either of the cores saturate, auto-transformation takes place. However, since the bridge is balanced no current flows through the load 66. After one of the cores such as core 1 saturates, the impedance of the controlled windings on the saturated core is reduced to substantially zero, and consequently the transformed power supply voltage is placed across the load. Core 2 continues to function as an auto-transformer until saturation, at which time the bridge is again balanced.

The present invention thus utilizes the saturable reactor cores in a half-wave bridge circuit to auto-transform the power supply voltage to the desired level so as to thereby obtain the proper output voltage. The saturable reactor core may be utilized to step-up the power supply voltage or step-down power supply voltage, depending upon the desired load voltage and the available power supply voltage. This is achieved without the use of an external transformer, or other additional components, and without the sacrifice of the inherent one cycle speed of response of the half-wave bridge magnetic amplifier.

For proper operation, the number of turns at the controlled winding on each leg of the bridge circuit should be equal. Thus in the case of the step-up auto-transformer, it is merely necessary to provide tapped controlled windings in a pair of adjacent legs of the bridge and apply the power supply voltage to the taps to achieve the step-up auto-transformation of the voltage. When utilizing the reactor cores to step-down the power supply voltage, it is necessary to provide an additional winding on each of the cores which is connected in series aiding with the controlled windings which lie in an adjacent pair of legs of the bridge, the power supply voltage being applied across the added windings and the series connected controlled windings, to thereby achieve the step-down auto-transformation of the power supply voltage. In either embodiment, it is advantageous to position the rectifiers in the bridge circuit so that current cannot flow on the reverse half cycle of the power supply voltage. In this manner, "loading" of the control windings during the control half-cycle of the bridge by the controlled windings, is obviated.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed as new and desired to be secured by Letters Patent of the United States is:

1. A magnetic amplifier comprising a plurality of cores of saturable magnetic material, four controlled windings on said cores arranged to form a bridge circuit, a source of A. C. potential, means connecting said source to one pair of controlled windings in adjacent legs of the bridge, said means and said one pair of controlled windings with their respective cores being interconnectingly arranged to form an autotransformer for transforming the voltage from said source and for applying the transformed voltage across one pair of diagonally opposite corners of the bridge, unidirectional impedance elements in said bridge circuit whereby current flows through said controlled windings only during one half cycle of the A. C. potential, a load impedance connected across the other pair of diagonally opposite corners of the bridge, a reference winding on each of said cores for establishing the reference flux level in said cores, said reference windings being connected

across said source in parallel circuit relation, and means including control windings on said cores for differentially varying the impedances of the controlled winding in adjacent legs of the bridge.

2. A magnetic amplifier comprising a plurality of cores of saturable magnetic material, four controlled windings on said cores arranged to form a bridge circuit, a source of A. C. potential coupled to said bridge, autotransformer means including one pair of controlled windings in adjacent legs of the bridge and the cores on which said pair of controlled windings are wound for transforming the voltage from said source and for applying the transformed voltage to the bridge, a load impedance connected to said bridge, unidirectional impedance elements in series with each of said controlled windings and so arranged that the cores are each driven to saturation during one half cycle of the A. C. potential, a reference winding on each of said cores for establishing the reference flux level in said cores, said reference windings being connected across said source in parallel circuit relation, and control windings on said cores for differentially varying the firing angles of the cores on which the controlled windings in adjacent legs of the bridge are wound.

3. A magnetic amplifier comprising a plurality of saturable reactor cores, four controlled windings wound on said cores, a bridge circuit including one of said controlled windings in each of the legs thereof, a source of A. C. potential, means connecting the A. C. source to one pair of controlled windings in adjacent legs of the bridge to form an autotransformer therewith whereby the A. C. potential from said source is transformed on the cores on which said pair of controlled windings are wound and the transformed voltage is applied to the bridge, unidirectional impedance elements in each of the legs of the bridge arranged so that the cores are driven to saturation only during one-half cycle of said A. C. potential, a reference winding on each of said cores for establishing the reference flux level in said cores, said reference windings being connected across said source in parallel circuit relation, and control windings on said cores arranged so as to advance the firing angle of the core on which one pair of diagonally opposite controlled windings are wound and retard the firing angle of the core on which the other pair of controlled windings are wound.

4. A magnetic amplifier comprising a plurality of saturable reactor cores, four controlled windings wound on said cores, a bridge circuit including one of said controlled windings in each of the legs thereof, a tap intermediate the ends of each of a pair of said controlled windings in adjacent legs of the bridge to adapt said pair of controlled windings for autotransformer operation when energized from a potential source, a load impedance connected to a point between the tapped pair of controlled windings and to a point between the other pair of controlled windings, means connecting a source of A. C. potential to the taps on said controlled windings whereby said controlled windings function as autotransformers for transforming the voltage from said source and for applying the transformed voltage to said bridge, unidirectional impedance elements in each of the legs of said bridge arranged so that current flows through each of said controlled windings only during one half-cycle of the A. C. potential, a reference winding on each of said cores for establishing a reference flux level in said cores, and control windings on said cores for differentially varying the firing angles of the cores on which the controlled windings in adjacent legs of the bridge are wound.

5. A magnetic amplifier comprising a plurality of saturable reactor cores, four controlled windings wound on said cores, each of said windings having an equal number of predetermined turns on said cores, a closed bridge circuit including one of said controlled windings in each of the legs thereof, each of the controlled windings in one pair of adjacent legs of the bridge having one end of an

auxiliary winding connected thereto and wound on the same core therewith to constitute a pair of extended windings each of which has a total number of turns exceeding said number of predetermined turns, said pair of extended windings forming an autotransformer when energized from a potential source, a source of A. C. potential, means connecting said source of A. C. potential to the other ends of said auxiliary windings whereby said extended windings function as an autotransformer for transforming the voltage from said source and for applying the transformed voltage to said bridge, unidirectional impedance elements in each of the legs of said bridge whereby current flows through the controlled windings of the bridge only during one half-cycle of the supply voltage, a reference winding on each of said cores for establishing the reference flux level in said cores, said reference windings being connected across said source in parallel circuit relation, means including control windings on said cores for advancing the firing angle of the core on which the controlled windings in one pair of diagonally opposite legs of the bridge are wound and for retarding the firing angle of the core on which the other controlled windings are wound, and a load impedance connected to said bridge.

6. A magnetic amplifier comprising, a pair of saturable reactor cores, a source of energizing potential having two output terminals, a first circuit connected across said output terminals including a first reference winding wound on one of said cores, a second circuit connected across said output terminals including a second reference winding wound on the other of said cores, a third circuit connected across said output terminals including at least a portion of a first controlled winding wound on said one core and at least a portion of a second controlled winding wound on said other core, a fourth circuit connected across said output terminals including a third controlled winding wound on said one core and a fourth controlled winding wound on said other core, said first, second, third and fourth controlled windings being interconnected to form a bridge circuit having four junction points of interconnection, means for effecting the connection between said source and said third circuit, said means and said first and second controlled windings with their respective cores forming an autotransformer for transforming the voltage from said source and for applying the transformed voltage to said bridge, and a load impedance connected across one pair of diagonally opposite junctions of said bridge.

7. A magnetic amplifier according to claim 6, wherein said means comprise a tap intermediate the ends of said first controlled winding to which one of said two terminals is connected and a tap intermediate the ends of said second controlled winding to which the other of said two terminals is connected, whereby the autotransformer formed is a step-up autotransformer.

8. A magnetic amplifier according to claim 6, wherein said means comprise a first auxiliary winding having one end connected to one junction of the other diagonally opposite junctions of said bridge and the other end connected to one of said two terminals, and a second auxiliary winding having one end connected to the other junction of said other diagonally opposite junctions and the other end connected to the other of said two terminals, whereby the autotransformer formed is a step-down autotransformer.

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