April 27, 1954 F. J. RAU 2,677,099

MAGNETIC AMPLIFIER

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Fig.1.

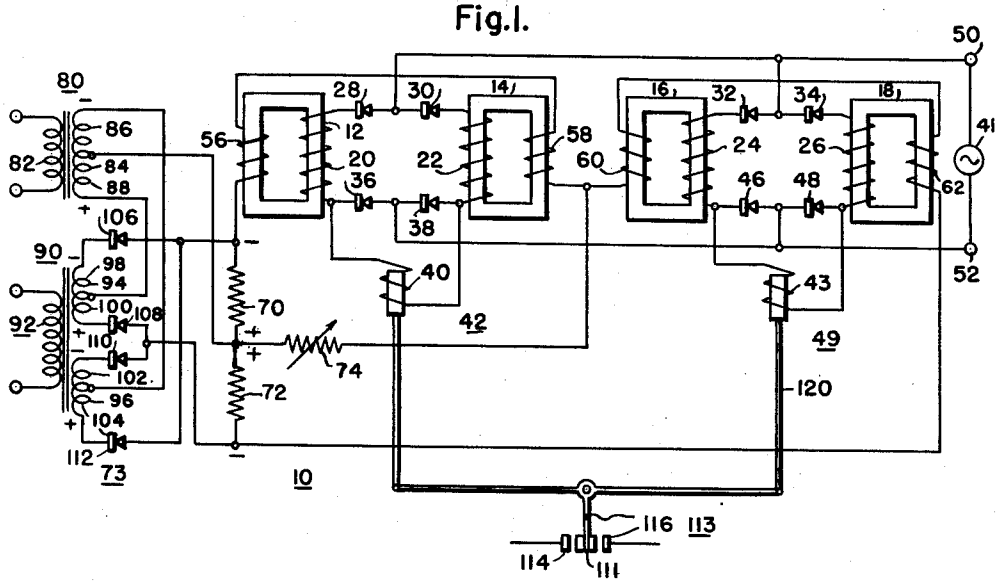
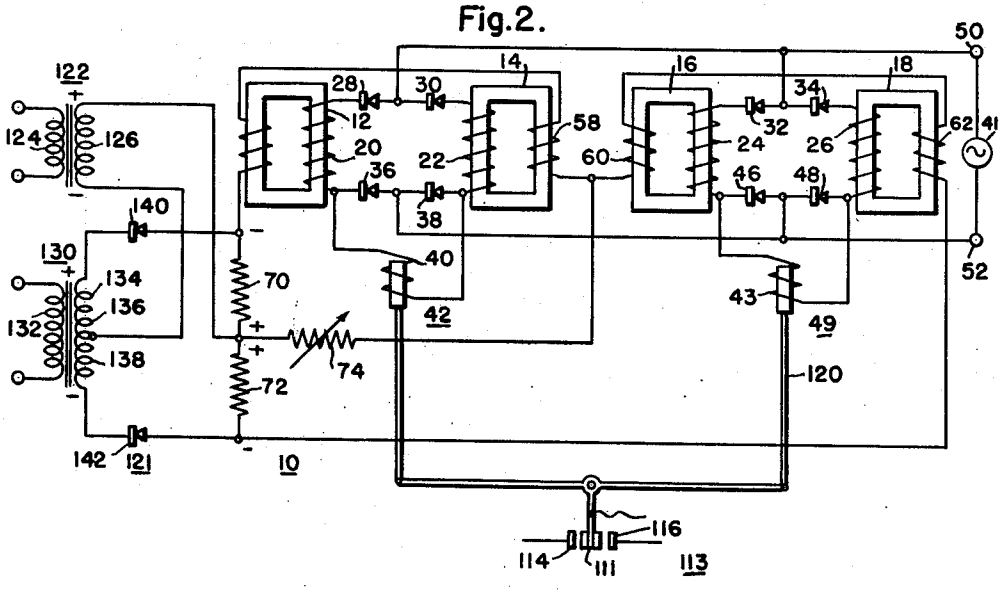


Fig.2.



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April 27, 1954 F. J. RAU 2,677,099

MAGNETIC AMPLIFIER

Filed March 29, 1952 3 Sheets-Sheet 2

Fig.3.

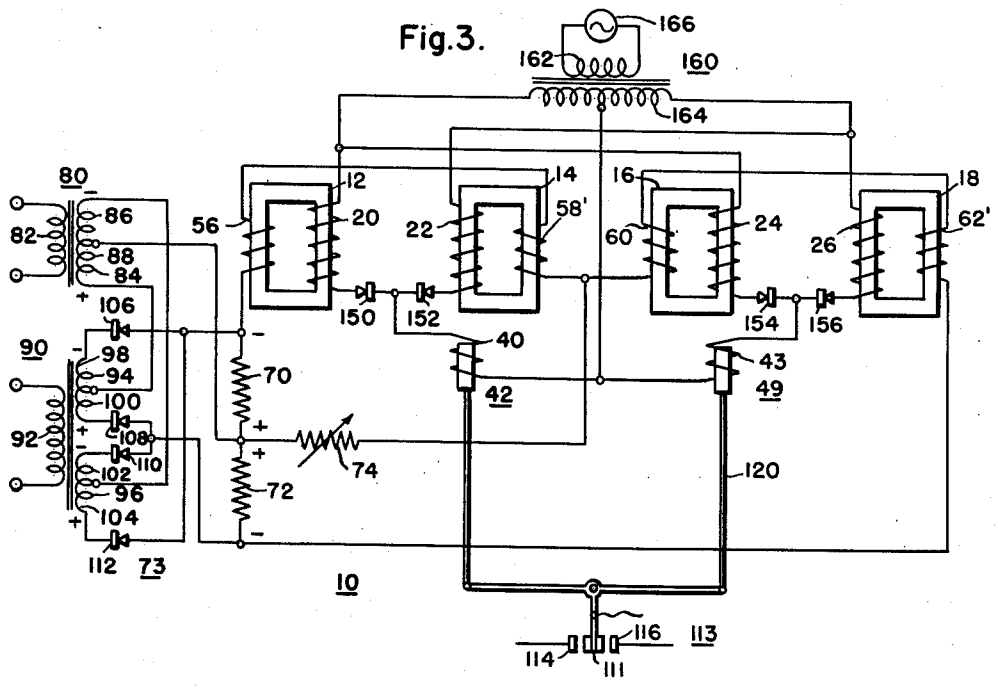
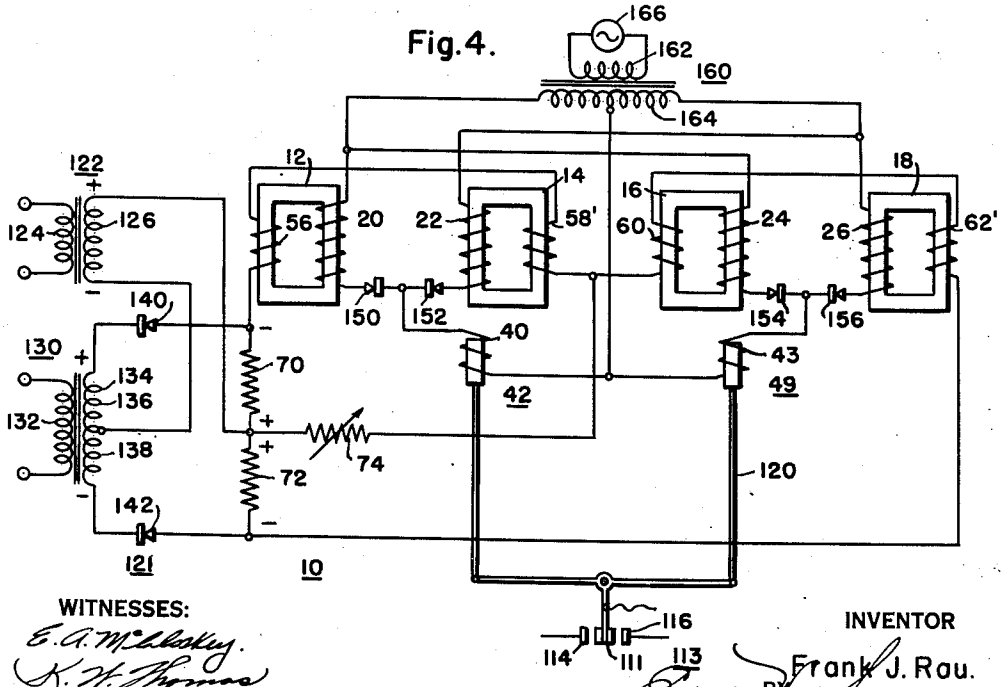


Fig.4.



WITNESSES:

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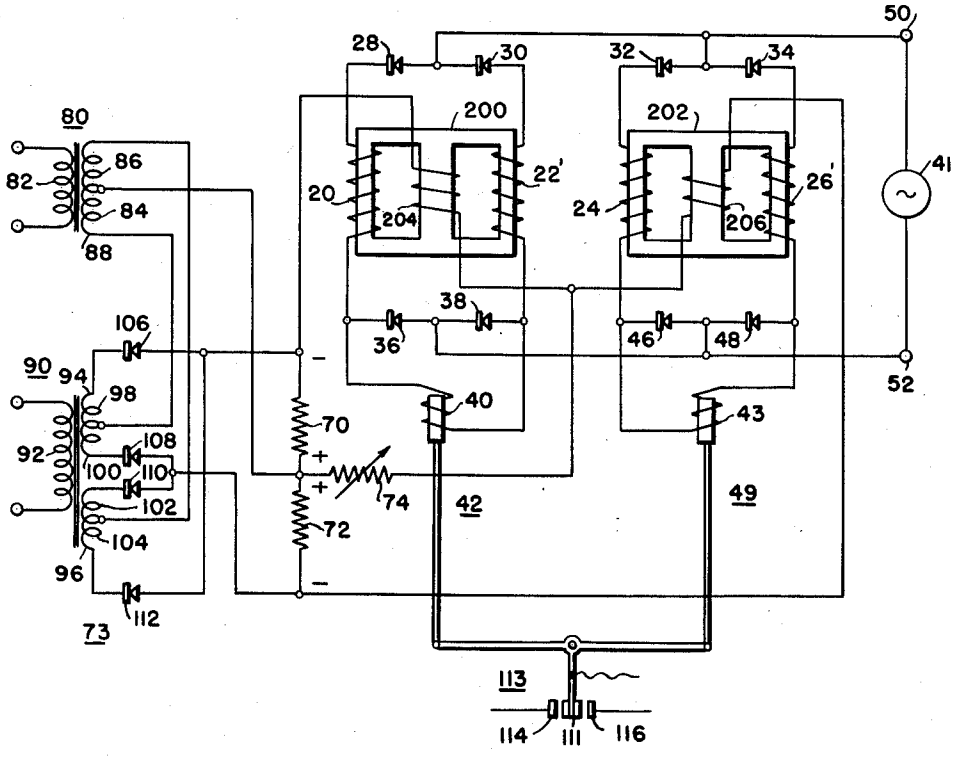
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MAGNETIC AMPLIFIER

Filed March 29, 1952 3 Sheets-Sheet 3

Fig.5.



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2,677,099

UNITED STATES PATENT OFFICE

2,677,099

MAGNETIC AMPLIFIER

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Application March 29, 1952, Serial No. 279,327

5 Claims. (Cl. 323—89)

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This invention relates to induction apparatus and in particular to magnetic amplifiers of the push-pull type.

In the past, push-pull magnetic amplifiers which receive their control signal from a phase sensitive demodulator or any other device having a similar voltage output utilize a separate biasing winding and bias voltage supply. Inasmuch as the winding operation on a magnetic amplifier represents a large percentage of the works cost, the use of a separate biasing winding and a separate control winding greatly increases the cost of manufacture. Not only does the use of these two separate windings increase the cost of manufacture, but it also increases the size of the wound core members, thus increasing the overall size and weight of the magnetic amplifier. This is a disadvantage, particularly in such fields as aircraft in which the size of the apparatus incorporated into the ship is extremely important. In addition, the use of a separate bias voltage supply increases the cost of manufacture and the overall size of the apparatus.

An object of this invention is to provide for receiving voltages from a phase sensitive demodulator or any other device having a similar voltage output and so applying them to the control winding of a push-pull magnetic amplifier that each control winding functions as both a biasing winding and a control winding.

Another object of this invention is to provide for receiving variable control signals and substantially constant reference signals from a phase sensitive demodulator and so applying the resultants of these signals, as formed by a variable and a constant signal, to the control windings of a push-pull magnetic amplifier that each control winding functions as both a biasing winding and a control winding.

A further object of this invention is to provide for receiving variable control signals and substantially constant reference signals from a phase sensitive demodulator and so applying the resultants of these signals, as formed by a variable and a constant signal to the control windings of a push-pull magnetic amplifier that the constant biasing portion of each resultant signal appearing across its associated control winding can be readily varied.

Other objects of this invention will become apparent when taken in conjunction with the accompanying drawings in which:

Figure 1 is a schematic diagram of one embodiment of the teachings of this invention;

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Fig. 2 is a schematic diagram of another embodiment of the teachings of this invention in which a different type of phase sensitive demodulator is utilized;

Fig. 3 is a schematic diagram illustrating still another embodiment of the teachings of this invention in which alternating current is applied to the reactor windings of the magnetic amplifier in a different manner;

Fig. 4 is a schematic diagram illustrating still another embodiment of the teachings of this invention, and

Fig. 5 is a schematic diagram illustrating a still further embodiment of the teachings of this invention in which a different type of core member is used in the magnetic amplifier.

Referring to Fig. 1 of the drawings, a push-pull magnetic amplifier is illustrated generally at 10 and it comprises four rectangular magnetic core members 12, 14, 16 and 18. In order to magnetize the core members 12, 14, 16 and 18, a predetermined amount, a plurality of reactor windings 20, 22, 24 and 26, respectively, are disposed in inductive relationship therewith.

For the purpose of permitting the passage of current in only one direction through the reactor windings 20, 22, 24 and 26, self-saturating rectifiers 28, 30, 32 and 34, respectively, are provided. As illustrated, the rectifiers 28 and 30 are connected in series circuit relationship, one terminal of the rectifier 28 being connected to one end of the reactor winding 20 and one terminal of the rectifier 30 being connected to one end of the reactor winding 22. In like manner, the rectifiers 32 and 34 are connected in series circuit relationship, one of the terminals of the rectifier 32 being connected to one end of the reactor winding 24 and one terminal of the rectifier 34 being connected to one end of the reactor winding 26.

In this instance, two load rectifiers 36 and 38 are connected in series circuit relationship, one terminal of the rectifier 36 being connected to the other end of the reactor winding 20 and one terminal of the rectifier 38 being connected to the other end of the reactor winding 22. The rectifiers 36 and 38 are disposed to so block the flow of current that the flow is in only one direction through a load 40, during each half cycle of an alternating current supply voltage 41. As illustrated, the load 40 comprises an energizing winding of a solenoid 42 and it is electrically connected across the series connected rectifiers 36 and 38.

In like manner, in order to block the flow of

current so that the flow is in only one direction through a load 43, during each half cycle of the alternating current supply voltage 41, load rectifiers 46 and 48 are provided. As illustrated, the rectifiers 46 and 48 are connected in series circuit relationship, one of the terminals of the rectifier 46 being connected to one end of the reactor winding 24 and one of the terminals of the rectifier 48 being connected to one end of the reactor winding 26. In this instance, the load 43 comprises an energizing winding of a solenoid 49 and it is electrically connected across the series connected rectifiers 46 and 48.

In order to supply an alternating current voltage to the reactor windings 20, 22, 24 and 26, terminals 50 and 52 and associated wiring connections are provided. As illustrated, the supply 41 is applied to the terminals 50 and 52 and the energizing circuit for the reactor winding 20 during one half cycle of the alternating current supply 41 extends from the terminal 50 through the rectifier 28, the reactor winding 20, the energizing winding 49 of the solenoid 42, and the rectifier 38, to the terminal 52. On the other hand, the energizing circuit for the reactor winding 24 during the same half cycle of the alternating current supply 41 extends from the terminal 50 through the rectifier 32, the reactor winding 24, the energizing winding 43 of the solenoid 49, and the rectifier 48, to the terminal 52. However, during the other half cycle of the alternating current supply 41, the energizing circuit for the reactor winding 22 extends from the terminal 52 through the rectifier 36, the energizing winding 49 of the solenoid 42, the reactor winding 22, and the rectifier 30, to the terminal 50. During the same half cycle of the alternating current supply 41, the energizing circuit for the reactor winding 26 extends from the terminal 52 through the rectifier 46, the energizing winding 43 of the solenoid 49, the reactor winding 26, and the rectifier 34, to the terminal 50.

For the purpose of controlling the magnetization of the core members 12, 14, 16 and 18, control windings 56, 58, 60 and 62, respectively, are disposed in inductive relationship therewith. As illustrated, the control windings 56 and 62 are electrically connected to two resistors 70 and 72, respectively, which are provided in order to receive variable control voltages and substantially constant biasing voltages from a full-wave phase sensitive demodulator 73 or any other similar voltage output device (not shown). In this instance, the impedance devices 70 and 72 are resistors which are connected in series circuit relationship.

In order to apply a portion of the voltage appearing across the resistor 70, as produced by the demodulator 73, to each of the control windings 56 and 58, the resistor 70, the control windings 56 and 58, and a variable resistance element 74 are connected in series circuit relationship. This series circuit extends from one end of the resistor 70 through the control winding 56, the control winding 58, and the variable resistance element 74, to the other end of the resistor 70. The purpose of the variable resistance element 74 will be described hereinafter.

In like manner, in order to apply a portion of the voltage across the resistor 72, as produced by the demodulator 73, to each of the control windings 60 and 62, the resistor 72, the control windings 62 and 60, and the variable resistance element 74 are connected in series circuit relationship. This series circuit extends from one end of the resistor 72 through the control winding 60, the control winding 62, and the variable resistance element 74, to the other end of the resistor 72. Thus, since the demodulator 73 is electrically connected to the resistors 70 and 72 and it produces both a variable control voltage and a substantially constant biasing voltage across each of the resistors 70 and 72, the control windings 56, 58, 60 and 62 are responsive to both a variable control voltage and a biasing voltage.

The demodulator 73, in this instance comprises a potential transformer 90, having a primary winding 92 across which is applied a substantially constant reference voltage and a secondary winding 94 which is divided into two sections 96 and 98. In this instance, a potential transformer 90 having a primary winding 92 across which is applied a variable control voltage and a secondary winding comprising the sections 94 and 96 is provided. As illustrated, the section 94 comprises an upper section 98 and a lower section 100, and the section 96 comprises an upper section 102 and a lower section 104.

In order to insure the passage of current through the sections 94 and 96 of the potential transformer 90 in a predetermined direction, rectifiers 106, 108, 110 and 112 are provided. However, for the purpose of applying the substantially constant voltage that appears across the section 96 of the transformer 90 and the variable voltage that appears across the section 104 of the transformer 92 across the resistor 70, for the polarities shown for the transformers 90 and 90, a circuit is provided which extends from one end of the resistor 70 through the rectifier 112, the section 104 of the transformer 90, and the section 96 of the transformer 80, to the other end of the resistor 70. In like manner, in order to apply the substantially constant voltage that appears across the section 98 of the transformer 90 and the variable voltage that appears across the section 102 of the transformer 90 to the resistor 72, for the given polarities as shown for the transformers 80 and 90, a circuit is provided which extends from one end of the resistor 72 through the rectifier 110, the section 102 of the transformer 90, and the section 96 of the transformer 80, to the other end of the resistor 72. However, assuming that the polarities for the transformers 80 and 90 are opposite to that shown in Fig. 1, the substantially constant voltage appearing across the section 98 of the transformer 90 and the variable control voltage appearing across the section 98 of the transformer 90, is applied to the resistor 70 by means of a circuit which extends from one end of the resistor 70 through the rectifier 106, the section 98 of the transformer 90, and the section 98 of the transformer 80, to the other end of the resistor 70. On the other hand, the substantially constant voltage appearing across the section 98 of the transformer 90 and the variable control voltage appearing across the section 100 of the transformer 90 is applied to the resistor 72 by means of a circuit which extends from one end of the resistor 72 through the rectifier 108, the section 100 of the transformer 90, and the section 98 of the transformer 80, to the other end of the resistor 72.

When the variable control voltage across the primary winding 92 of the transformer 90 is of zero magnitude and a substantially constant reference voltage is applied to the primary winding 82 of the transformer 80, the push-pull magnetic

amplifier 10 is in a balanced condition and a movable contact member 111 of a relay 113 is in the position shown in the drawings. However, when a variable control voltage is applied to the primary winding 92 of the transformer 90, the magnetic amplifier 10 becomes unbalanced so that the movable contact member 111 engages either a stationary contact member 114 or a stationary contact member 116 of the relay 113, to thus complete energizing circuits to apparatus not shown. The direction of this unbalance depends upon the polarity of the voltage across the primary winding 92 of the transformer 90 with respect to the polarity of the voltage across the primary winding 82 of the transformer 80. Still referring to Fig. 1, assuming the biasing voltage across the secondary winding 84 of the transformer 80 is of greater magnitude than the variable control voltage across the sections 94 and 96 of the transformer 90, the current flow through the control windings 56, 58, 60 and 62 will produce a flux that opposes the flux produced by the current flow through the reactor windings 20, 22, 24 and 26, respectively.

Assume for purposes of illustration that the polarity of the voltages across the windings of the transformers 80 and 90 are as shown in the drawings and that five volts appear across the sections 86 and 88 of the transformer 80 and that two volts appear across each of the sections 98, 100, 102 and 104 of the transformer 90. When this condition exists three volts will appear across the resistor 70 and seven volts will appear across the resistor 72. The seven volts appearing across the resistor 72 will affect a current flow through the variable resistance element 74, and the control windings 60 and 62, which in turn will decrease the magnetization of the core members 16 and 18, respectively. This action increases the impedance of the reactor windings 24 and 26, respectively, and thus decreases the current flow through the energizing winding 43 of solenoid 49. Under such a condition, the movable contact member 111 is brought into circuit closing position with the stationary contact member 114 of the relay 113 to thus complete an energizing circuit to apparatus not shown. The three volts appearing across the resistor 70 likewise effects an actuation of the movable contact member 111 into circuit closing position with the stationary contact member 114, since it decreases the current flow through the control windings 56 and 58 to thus increase the magnetization of the core members 12 and 14, respectively. Such action decreases the impedance of the reactor windings 20 and 22, respectively, and thus increases the current flow through the energizing winding 40 of the solenoid 42.

Assuming the polarities across the windings of the transformer 90 are opposite to that shown in the drawings and the polarities of the windings of the transformer 80 are as shown in the drawings, a larger voltage will appear across the resistor 70 than across the resistor 72. When this condition exists the larger voltage across the resistor 70 effects a decrease in the magnetization of the core members 12 and 14 to thus increase the impedance of the reactor windings 20 and 22, respectively, decreasing the current flow through the energizing winding 40 of the solenoid 42 to thereby actuate the movable contact member 111 of the relay 113 into circuit closing position with the stationary contact member 116. The smaller voltage appearing across the resistor 72 likewise effects an actuation of the movable contact member 111 into circuit closing position with the stationary contact member 116 since it effects an increase in the magnetization of the core members 16 and 18 to thus decrease the impedance of the reactor windings 24 and 26, respectively, to thereby increase the current flow through the energizing winding 43 of the solenoid 49.

In practice, the variable resistance element 74 has a much higher ohmic value than the ohmic value of the control windings 56 and 58 combined, or of the control windings 60 and 62 combined. By varying the magnitude of the resistance element 74, the magnitude of the current flow through the control windings 56, 58, 60 and 62 can be varied to thus effect different biasing potentials across each of these control windings. However, if only one biasing voltage is desired the variable resistor 74 may be replaced by a fixed resistor (not shown).

Although Fig. 1 of the drawings has been described as comprising the energizing windings 40 and 43 which actuate a pivotal member 120 to thus complete an electrical circuit through either the stationary contact members 114 or 116 to apparatus not shown, it is to be understood that other types of loads (not shown) could be connected to be responsive to the voltage across the series connected rectifiers 36 and 38 and the voltage across the series connected rectifiers 46 and 48.

It is also to be understood that the biasing voltage applied to the resistors 70 and 72 and thus to the control windings 56, 58, 60 and 62 could be reversed by changing the direction of the rectifiers 106, 108, 110, 112 in the demodulator 73 or by reversing the direction in which the control windings 56, 58, 60 and 62 are wound on their respective core members. If such a change were made, the magnetic amplifier 10 would unbalance in an opposite direction to that above-described for the same given polarities across the windings of the transformers 80 and 90.

Referring to Fig. 2 of the drawings, there is illustrated another embodiment of the teachings of this invention, and like components of Figs. 1 and 2 have been given the same reference characters. The main distinction between the apparatus of Figures 1 and 2 is that in Fig. 2, a half-wave demodulator 121 is used instead of the full-wave demodulator 73 shown in Fig. 1.

As illustrated, the demodulator 121 is electrically connected to the resistors 70 and 72 of Fig. 2. In this instance the demodulator 121 comprises a potential transformer 122 having a primary winding 124 across which is applied a substantially constant biasing voltage and a secondary winding 126. The demodulator 121 likewise comprises a potential transformer 130 having a primary winding 132 across which is applied a variable control voltage and a secondary winding 134 comprising sections 136 and 138.

The energizing circuit for applying the substantially constant biasing voltage appearing across the secondary winding 126 of the transformer 122 and the variable control voltage appearing across the section 136 of the transformer 130 to the resistor 70 extends from one end of the resistor 70 through a rectifier 140, the section 136 of the transformer 130, and the secondary winding 126 of the transformer 122, to the other end of the resistor 70. On the other hand, the circuit for applying the substantially constant biasing voltage appearing across the secondary winding 126 of the transformer 122 and the variable control voltage appearing across the

section 138 of the transformer 130 to the resistor 72 extends from one end of the resistor 72 through a rectifier 142, the section 138 of the transformer 130, and the secondary winding 126 of the transformer 122, to the other end of the resistor 72.

Since the demodulator 121 is only a half-wave demodulator, no voltages will appear across the resistors 70 and 72 during the half cycle when the polarities of the windings of the transformers 122 and 130 are opposite to those polarities shown in Fig. 2 of the drawing. Also, since the remainder of the apparatus shown in Fig. 2 of the drawing is identical to the corresponding apparatus of Fig. 1, its description and operation is considered unnecessary.

Referring to Fig. 3 of the drawings, there is illustrated another embodiment of the teachings of this invention. Like components of Figs. 1 and 3 have been given the same reference characters. The main distinction between the apparatus of Figs. 1 and 3 is in the manner of applying the alternating supply voltage to the reactor windings 20, 22, 24 and 26. In addition, control windings 58' and 62' are used in place of the control windings 58 and 62, respectively, of Fig. 1 since the control windings 58' and 62' are wound oppositely from the control windings 58 and 62, respectively. This is necessary since the current flow through the reactor windings 22 and 26 of Fig. 1 is in a direction opposite to the current flow through the reactor windings 22 and 26, respectively, of Fig. 3.

In order to permit the flow of current in only one direction through the reactor windings 20, 22, 24 and 26, self-saturating rectifiers 150, 152, 154 and 156, respectively, are provided. As illustrated, the rectifiers 150 and 152 are connected in series circuit relationship and are oppositely poled in the series circuit, one terminal of the rectifier 150 being connected to one end of the reactor winding 20, and one terminal of the rectifier 152 being connected to one end of the reactor winding 22. In like manner, the rectifiers 154 and 156 are connected in series circuit relationship and are oppositely poled in the series circuit, one terminal of the rectifier 154 being connected to one end of the reactor winding 24 and one terminal of the rectifier 156 being connected to one end of the reactor winding 26.

In order to supply energy to the reactor windings 20, 22, 24 and 26 of Fig. 3, a transformer 160 having a primary winding 162 and a center-tapped secondary winding 164 is provided. As illustrated, an energizing circuit for the reactor winding 26 during one half cycle of an alternating current supply 166 extends from one end of the secondary winding 164 of the transformer 160 through the reactor winding 26, the rectifier 156, and the energizing winding 43 of the solenoid 49 to the center-tap of the secondary winding 164. During the same half cycle of the alternating current supply 166, an energizing circuit for the reactor winding 22 extends from the same end of the secondary winding 164 through the reactor winding 22, the rectifier 152 and the energizing winding 40 of the solenoid 42 to the center-tap of the secondary winding 164. On the other hand, during the other half cycle of alternating current supply 166, an energizing circuit for the reactor winding 24 extends from one end of the secondary winding 164 through the reactor winding 24, the rectifier 154, and the energizing winding 43 of the solenoid 49, to the center tap of the secondary winding 164. During the same half cycle of the alternating current supply 166, an energizing circuit for the reactor winding 20 extends from one end of the secondary winding 164 through the reactor winding 20, the rectifier 150, and the energizing winding 40 of the solenoid 42, to the center tap of the secondary winding 164.

Since the operation of the apparatus of Fig. 3 is substantially identical to the operation of the apparatus of Fig. 1, a description of such operation is considered unnecessary.

Referring to Fig. 4 of the drawings, there is illustrated still another embodiment of the teachings of this invention, in which like components of Figs. 2, 3 and 4 have been given the same reference characters. The main distinction between the apparatus shown in Figs. 3 and 4 is that in the apparatus of Fig. 4, the half-wave demodulator 121 of Fig. 2 is substituted for the full-wave demodulator 73 of Fig. 3.

Since the operation of the apparatus of Fig. 4 is substantially identical to the operation of the apparatus of Fig. 2, a description of such operation is considered unnecessary.

Referring to Fig. 5 of the drawings, there is illustrated a still further embodiment of the teachings of this invention, in which like components of Figs. 1 and 5 have been given the same reference characters. The main distinction between the apparatus shown in Figs. 1 and 5 is that in the apparatus of Fig. 5, two three-legged magnetic core members 200 and 202 are substituted for the four rectangular core members 12, 14, 16 and 18 of Fig. 1. Such an interchangeability in push-pull magnetic amplifiers between rectangular and three-legged core members is well known in the art. In addition, the reactor windings 22 and 26 of Fig. 1 are replaced in Fig. 5 by reactor windings 22' and 26' and they are wound oppositely from the windings 22 and 26 of Fig. 1.

When utilizing the three-legged core members 200 and 202 of Fig. 5, it is only necessary to provide two control windings 204 and 206, one disposed in inductive relationship with each of the core members 200 and 202, respectively. Such being the case, in order to apply the variable control voltage and the biasing voltage appearing across the resistor 70 to the control winding 204, the resistor 70, the variable resistance element 74, and the control winding 204 are connected in series circuit relationship. Thus, the control winding 204 is responsive to both the variable control voltage and the biasing voltage. In order to apply the variable control voltage and the biasing voltage appearing across the resistor 72 to the control winding 206, the resistor 72, the variable resistance element 74, and the control winding 206 are connected in series circuit relationship.

As illustrated, the control winding 204 is disposed on the middle leg of the core member 200 and the current flow therethrough produces a flux in the core member 200 that opposes the flux produced in the core member 200 by the current flow through the reactor windings 20 and 22', provided the polarity of the voltages across the resistors 70 and 72 are as shown in the drawing. The control winding 206 is also so disposed on the middle leg of the core member 202 that the current flow therethrough produces a flux in the core member 202 that opposes the flux produced in the core member by the current flow through the reactor windings 24 and 26'. Of course, it is to be understood

that if the rectifiers 106, 108, 110 and 112 of the demodulator 73 were reversed in direction, the current flow through the control windings 204 and 206 would be in an opposite direction and thus the flux produced by the current flow through the control winding 204 would be additive to the flux produced by the current flow through the reactor windings 20 and 22', and the flux produced by the current flow through the control winding 206 would likewise be additive to the flux produced by the current flow through the reactor windings 24 and 26'.

Since the operation of the apparatus of Fig. 5 is substantially identical to the operation of the apparatus of Fig. 1, a description of such operation is considered unnecessary.

It is to be understood that two three-legged core members, could also be substituted for the core members 12, 14, 16 and 18 of Figs. 2, 3 and 4.

Although the invention has been described with reference to certain specific embodiments thereof, numerous modifications falling within the spirit and scope of the invention are possible.

I claim as my invention:

1. In a push-pull magnetic amplifier, the combination comprising, a plurality of magnetic core members, a reactor winding disposed in inductive relationship with each of the magnetic core members, a rectifier in series circuit relationship with each of the reactor windings so as to permit passage of current in only one direction therethrough, means for applying an alternating current voltage to each of the series connected reactor windings and rectifiers, a control winding disposed in inductive relationship with each of the magnetic core members, two resistors connected in series circuit relationship, electrical apparatus electrically connected to the resistors for producing both a substantially constant biasing voltage and a variable control voltage across each of the resistors, a resistance element, circuit means for connecting one of said two resistors, the resistance element, and one of the control windings in series circuit relationship, another circuit means for connecting the other of said two resistors, the resistance element, and another of the control windings in series circuit relationship so that each control winding functions as both a biasing winding and a control winding, and means responsive to the current flow through the reactor windings and actuated in response to the variable control voltage across each of said two resistors to perform a predetermined operation.

2. In a push-pull magnetic amplifier, the combination comprising, a plurality of magnetic core members, a reactor winding disposed in inductive relationship with each of the magnetic core members, a rectifier in series circuit relationship with each of the reactor windings so as to permit passage of current in only one direction therethrough, means for applying an alternating current voltage to each of the series connected reactor windings and rectifiers, a control winding disposed in inductive relationship with each of the magnetic core members, two resistors connected in series circuit relationship, a phase sensitive demodulator electrically connected to the two resistors so that both a substantially constant biasing voltage and a variable control voltage appear across each of the two resistors, a variable resistance element, circuit means for connecting one of the two resistors, the variable resistance element, and one of the control windings in series circuit relationship, another circuit means for connecting the other of said two resistors, the variable resistance element, and another of the control windings in series circuit relationship so that each control winding functions as both a biasing winding and a control winding, and so that the magnitude of the voltage across each of the control windings can be varied by means of the variable resistance element, and means responsive to the current flow through the reactor windings and actuated in response to the variable control voltage across each of the two resistors to permit a predetermined operation.

3. In a push-pull magnetic amplifier, the combination comprising, four magnetic core members, a reactor winding disposed in inductive relationship with each of the magnetic core members, a rectifier connected in series circuit relationship with each of the reactor windings for permitting current to flow in only one direction therethrough, means for applying an alternating current voltage to each of the series connected reactor windings and rectifiers, a control winding disposed in inductive relationship with each of the core members, two resistors connected in series circuit relationship, a phase sensitive demodulator electrically connected to the two resistors so that both a substantially constant biasing voltage and a variable control voltage appear across each of the two resistors, a resistance element, circuit means for connecting one of the two resistors, the resistance element, and two of the control windings in series circuit relationship, another circuit means for electrically connecting the other of said two resistors, the resistance element, and the other two control windings in series circuit relationship so that each control winding functions as both a biasing winding and a control winding, and means responsive to the current flow through the reactor windings and actuated in response to the variable control voltage across each of said two resistors to perform a predetermined operation.

4. In a push-pull magnetic amplifier, the combination comprising, two three-legged magnetic core members, two reactor windings disposed in inductive relationship with each of the core members, a rectifier connected in series circuit relationship with each of the reactor windings for permitting current to flow in only one direction therethrough, means for applying an alternating current voltage to each of the series connected reactor windings and rectifiers, a control winding disposed in inductive relationship with each of the core members, two resistors connected in series circuit relationship, a phase sensitive demodulator electrically connected to the two resistors so that both a substantially constant biasing voltage and a variable control voltage appear across each of the two resistors, a resistance element, circuit means for electrically connecting one of the two resistors, the resistance element, and one of the control windings in series circuit relationship, another circuit means for connecting the other of said two resistors, the resistance element, and the other control winding in series circuit relationship so that each control winding functions as both a control winding and a biasing winding, and means responsive to the current flow through the reactor windings and actuated in response to the variable control voltage across each of said two resistors to perform a predetermined operation.

5. In a push-pull magnetic amplifier, the combination comprising, four magnetic core members, a reactor winding disposed in inductive relationship with each of the magnetic core mem-

bers, a rectifier connected in series circuit relationship with each of the reactor windings for permitting current to flow in only one direction therethrough, means for applying an alternating current voltage to each of the series connected reactor windings and rectifiers, a control winding disposed in inductive relationship with each of the core members, two resistors connected in series circuit relationship, electrical apparatus electrically connected to the two resistors for producing both a substantially constant biasing voltage and a variable control voltage across each of the two resistors, a variable resistance element, circuit means for electrically connecting one of the two resistors, the variable resistance element, and two of the control windings in series circuit

relationship, another circuit means for electrically connecting the other of said two resistors, the variable resistance element, and the other two control windings in series circuit relationship so that each control winding functions as both a biasing winding and a control winding, and so that the magnitude of the voltage across each of the control windings can be varied by means of the variable resistance element, and means responsive to the current flow through the reactor windings and actuated in response to the variable control voltage across each of said two resistors to perform a predetermined operation.

No references cited.