July 3, 1956 E. T. HOOPER, JR 2,753,517

COMBINATION CONTROL AND REFERENCE CIRCUIT FOR A MAGNETIC AMPLIFIER

Filed March 27, 1953

FIG. 1.

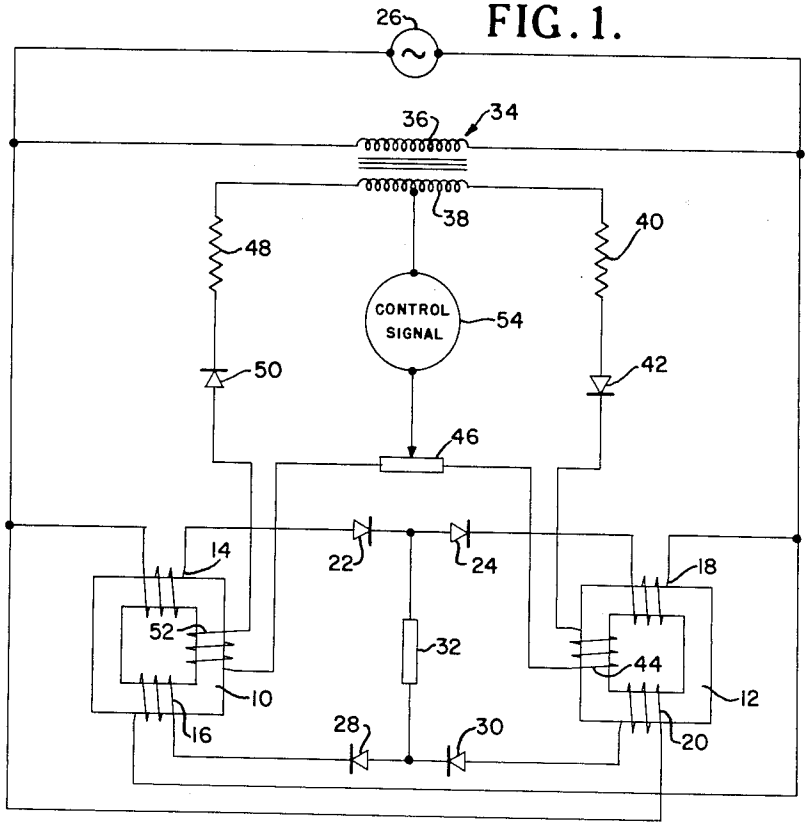
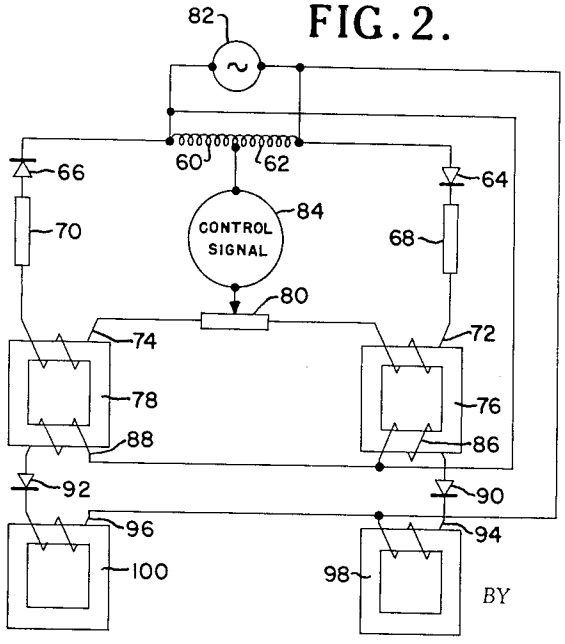


FIG. 2.



INVENTOR
EDWARD T. HOOPER, JR.

BY

R. M. Hicks

ATTORNEYS

United States Patent Office 2,753,517 Patented July 3, 1956

2,753,517

COMBINATION CONTROL AND REFERENCE CIRCUIT FOR A MAGNETIC AMPLIFIER

Edward T. Hooper, Jr., Hyattsville, Md., assignor to the United States of America as represented by the Secretary of the Navy

Application March 27, 1953, Serial No. 345,271

7 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 a combination bias and control circuit therefor.

In magnetic amplifiers, the reactance of the cores and hence the current flow through the controlled windings thereon is varied by the passage of a control current through the control winding on the core. The proper operating flux level in the cores is established by bias circuits, which bias circuits commonly utilize separate bias windings on the cores which are energized from the power supply source.

In half-wave self-saturating magnetic amplifiers it is desirable to utilize half-wave currents for both biasing and control. The present invention is a continuation-in-part of the copending application of Edward T. Hooper, Serial No. 335,619, filed February 6, 1953, for Full-Wave Magnetic Amplifier. The control circuit provides a half-wave reference voltage from an A. C. supply source, and a half-wave control voltage from an A. C. control source, both control and reference voltages being placed on the saturable reactor core in a single winding.

An important object of this invention is to provide a circuit for applying half-wave control and reference voltages in a single winding on the reactor core.

Another object of this invention is to provide a circuit for providing a half-wave reference from an A. C. supply source and a half-wave control voltage from an A. C. control source and for applying the control and reference voltages to a single winding on the reactor.

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 the combination reference and control circuit applied to the bridge type half-wave magnetic amplifier; and

Fig. 2 is a schematic diagram of a modified form of combination bias and control circuit having a second amplifier stage connected in cascade therewith.

Reference is now made more specifically to Fig. 1 of the drawings wherein there is illustrated a half-wave bridge type magnetic amplifier having a combination bias and control circuit applied thereto. The amplifier includes a pair of cores **10** and **12** of saturable magnetic material. The core **10** has split load windings **14** and **16** thereon, the core **12** having split load windings **18** and **20** wound therein. Load windings **14** and **18** are connected in series circuit with rectifiers **22** and **24** across the A. C. supply source **26** and constitute one pair of adjacent legs of a bridge circuit, the load windings **16** and **20** being connected in series circuit with rectifiers **28** and **30** across the supply source **26** and forming the other pair of adjacent legs of the bridge circuit. The load **32** is connected

to a point between the rectifiers **22** and **24**, and to a point between the rectifiers **28** and **30**.

The circuit thus far described is conventional, and forms no part of this invention. In operation, during one-half cycle of the A. C. power supply voltage **26**, current flows through winding **14**, rectifier **22**, and in one direction through load **32**, through rectifier **28**, and winding **16**, the load current also flowing during the same half cycle through winding **20**, rectifier **30**, through load **32** in the opposite direction, through rectifier **24** and winding **18**. The parameters of the circuit are adjusted so that when the reactances of the cores **10** and **12** are equal, the load currents flowing through the load windings on each of the cores are equal, and consequently the resultant current flowing through the load **32** is zero. However, when the reactances of the cores are varied differentially, a resultant load current flows through load **32** in a direction dependent upon the sense of the unbalance of the cores.

The combination bias and control circuit includes a transformer **34**, the primary **36** of which is connected across the A. C. power supply source **26**. The transformer **34** has a center-tapped secondary **38**, which center-tapped secondary constitutes one pair of adjacent legs of the control bridge circuit. The third leg of the control bridge circuit includes resistor **40**, rectifier **42**, and control winding **44** on the core **12**. The fourth leg of the bridge includes resistor **48**, rectifier **50**, and control winding **52** on the core **10**. A balancing potentiometer **46** may be provided to facilitate equalizing the current flow through the control windings **44** and **52** under zero control signal conditions. The control signal source **54** is connected between the tap on the secondary **38** and the tap on the potentiometer **46**. Rectifiers **42** and **50** are polarized so that current flows through the control windings **44** and **52** during the non-conducting half cycle of the half-wave bridge circuit comprising windings **14**, **16**, **18** and **20** previously described. Resistors **40** and **48** and potentiometer **46** are adjusted so that the half-wave currents flowing through windings **44** and **52** preset the desired operating flux level in the cores **10** and **12**. When a control signal from the control source **54** is applied, the combination reference and control circuit bridge is unbalanced causing an increase in current flow through one of the control windings and a decrease in current flow through the other control winding. These combined actions take place on the half-cycle when the load windings on the cores **10** and **12** are non-conducting, whereby the flux levels of the respective cores are preset to the proper value determined by the control signal to thereby determine the firing angle of the cores on the succeeding half-cycle.

As is deemed apparent, the combination control and reference bridge circuit provides a half-wave reference current from the A. C. power supply source, and in addition effects half-wave control from an A. C. control source.

In the embodiment illustrated in Fig. 2 of the drawings, the combination control and reference circuit includes a center-tapped impedance having legs **60** and **62**, which impedance may be the inductance illustrated or, alternatively, may comprise a capacitive or resistive impedance. The legs **60** and **62** of the center-tapped inductance form one pair of adjacent legs of a bridge circuit, rectifiers **64** and **66**, resistors **68** and **70**, windings **72** and **74** on saturable reactor cores **76** and **78** respectively and the potentiometer **80** forming the other pair of adjacent legs of the bridge circuit. Potential from the A. C. power supply source **82** is applied across the legs **60** and **62** of the center-tapped inductance, and the rectifiers **64** and **66** are phased so as to allow current flow through the control windings **72** and **74** of the bridge only in one

direction. This permits a constant half-wave reference voltage to be applied to the control windings, which voltage is adjusted to the proper value by the resistors 68 and 70. The control signal from the source 84 is applied between the tap on the center-tapped impedance and the tap on the potentiometer 80, the potentiometer being provided to permit balancing of the bridge circuit under zero control signal conditions. When the bridge is balanced, the same reference voltage appears on both control windings 72 and 74. The application of a control signal, however, unbalances the bridge circuit, raising the voltage on one control winding and lowering the voltage on the other.

Load windings 86 and 88 on cores 76 and 78 respectively are connected in a bridge circuit, and form one pair of adjacent legs thereof. The remaining pair of legs of the bridge are formed by rectifiers 90 and 92 and the control windings 94 and 96 on the cores 98 and 100, which last mentioned pair of cores constitute a portion of a second stage of the magnetic amplifier. Load windings 86 and 88 are energized, as from the supply source 82 and the rectifiers 90 and 92 are phased so that load current flows through the load windings during the half-cycle of the power supply voltage succeeding that half-cycle during which reference flux is established in the cores 76 and 78. The second stage load circuit [not illustrated] may be of any desired type such as the half-wave bridge type illustrated in connection with Fig. 1 of the drawings.

From the foregoing it is deemed apparent that the combination bias and control circuit supplies both a half-wave reference voltage and a half-wave control voltage to a single control winding on each of the reactors. The half-wave reference potential may be supplied from an A. C. power supply source and the control voltage supplied by either an A. C. or a D. C. control source.

The voltages induced in the control windings on each of the cores are additive and only under zero control signal conditions will there be no induced current flow through the control signal source. With a control signal, an unbalance occurs and a small induced current flows through the control source. This is true of all two-core control systems, but in the instant case the induced current does not flow on the half-cycle during which control is being formed, and no error results.

It is deemed apparent that the A. C. control signal source and the A. C. supply source may be interchanged in the control bridge circuit provided one of the rectifiers in the control bridge circuit is reversed so that the reference or bias current only flows during one half-cycle of the A. C. supply voltage. However, the bridge circuit including power windings 14, 16, 18 and 20 must be energized from a power supply source. Thus, the power supply voltage as from source 26 may be applied between the tap on transformer secondary winding 38 and the tap on potentiometer 46, in which case the control voltage from source 54 would be applied across transformer primary winding 36. However, one of the rectifiers such as 42 must be reversed so that the reference or bias current flows during one half-cycle of the power supply voltage.

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 is:

1. In a half-wave self-saturating type magnetic amplifier including a pair of saturable reactor cores each having controlled winding means energized from an A. C. source on the same alternate half-cycles of said source, a combined bridge type bias and control circuit including a control winding for each of said cores interconnected to be included in one pair of adjacent legs of the bridge, impedance elements serially interconnected with said control winding to form the other pair of adjacent legs of the bridge, circuit means for applying said A. C. source across one pair of diagonally opposite terminals of the bridge, unidirectional impedance elements in said bridge circuit for passing current from said source in one direction only through the bridge so that half wave current flows through the control windings only during the other alternate half-cycles of said source, and means for applying a control signal across the other pair of diagonally opposite terminals of the bridge to thereby differentially vary the half-cycle current flow through the control windings.

2. In a half-wave magnetic amplifier, a pair of cores of magnetic material having definite saturation characteristics, a control winding on each of said cores, a control signal source, means connecting said control windings to said control source in separate parallel branch circuits, an impedance element in each of said branch circuits, supply voltage means for applying an A. C. potential across said impedance elements, and unidirectional impedance elements in each of said branch circuits connected so that current from said supply voltage means flows in the same direction through said branch circuits only during the same alternate half-cycles of the supply voltage means.

3. The combination of claim 2 including means in each of said branch circuits for adjusting the magnitude of the half-wave currents flowing therethrough.

4. A bridge circuit energized from a biasing source and a control signal source for functioning simultaneously as a bias circuit and a control circuit for a magnetic amplifier having a plurality of saturable core reactors with power windings wound thereon, said bridge circuit being defined by a closed series loop including control windings for presetting the flux levels in predetermined ones of said reactors in a manner correlative to the current flowing through said control windings as a consequence of application thereto of a biasing voltage and a control voltage from said biasing source and said control signal source, respectively, and unidirectional conductive means for permitting current flow through said series loop in one direction only.

5. The bridge circuit of claim 4, wherein said bridge has two pairs of diagonally opposite terminals, and further including circuit connections for connecting said control signal source across one of said pairs of diagonally opposite terminals, and circuit means for applying biasing voltage from said biasing source across the other pair of diagonally opposite terminals.

6. A bridge circuit according to claim 5 to serve as a common bias and control circuit for a half-wave magnetic amplifier having a pair of saturable core reactors with power windings arranged to be energized only on the same alternate half-cycles from an A. C. source, wherein said unidirectional conductive means are so poled that said current flow through said series loop occurs only during the nonconductive half-cycles of said power windings.

7. A half-wave magnetic amplifier having a common bias and control circuit comprising, in combination, a source of alternating current; a pair of saturable core reactors; load windings on said reactors connected across said source through rectifier means arranged to pass current through said load windings only during the same alternate half-cycles of said source; a control winding on each of said cores and serially interconnected to define a first common terminal at the junction thereof; a pair of impedances serially interconnected to define a second common terminal at the junction thereof; a first unilateral conductive device electrically interposed between one of said control windings and one of said impedances and serially connected to the unconnected terminals of said one control winding and said one impedance, and a second unilateral conductive device electrically interposed between the other of said control windings and the other of said impedances and serially connected to the unconnected terminals of said other control

winding and said other impedance to thereby form a closed series loop including said pairs of control windings and impedances, and said first and second unilateral conductive devices; a control signal source connected across said first and second common terminals; and circuit means for applying an alternating current from said alternating current source across said pair of impedances, said unilateral conductive devices being poled so as to pass current from said alternating current source in one

direction through said series loop only during the non-conductive half-cycles of said load windings.

References Cited in the file of this patent

UNITED STATES PATENTS

2,632,145	Sikorra	Mar. 17, 1953
2,677,099	Rau	Apr. 27, 1954
2,704,823	Storm	Mar. 22, 1955