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E. M. BOARDMAN

2,108,642

MAGNETIC DEVICE

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FIG. 1

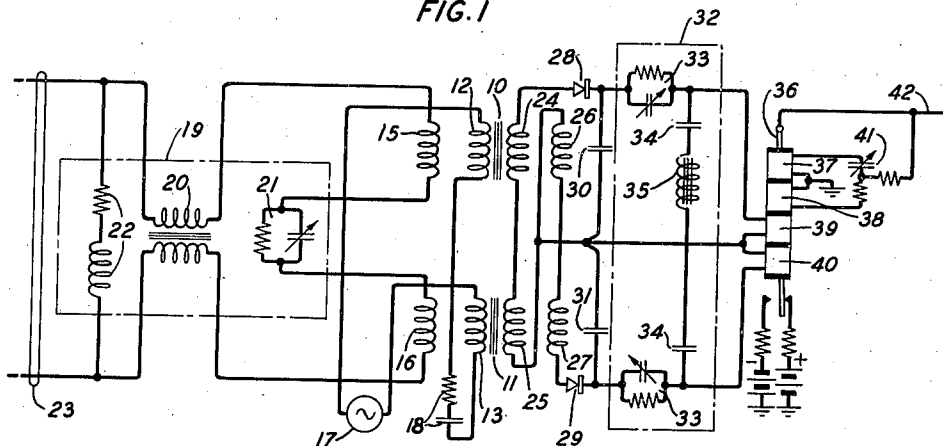


FIG. 2

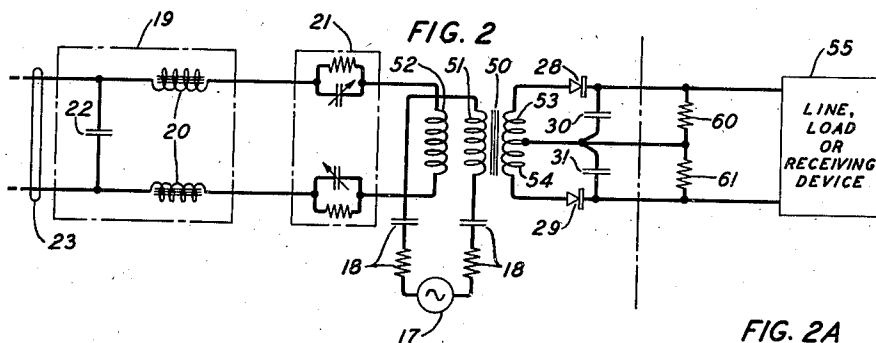


FIG. 2A

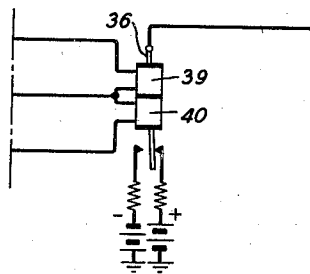


FIG. 3A

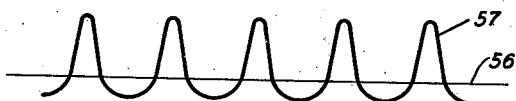
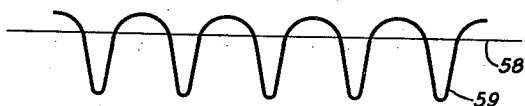


FIG. 3B



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MAGNETIC DEVICE

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9 Claims. (Cl. 178-70)

This invention relates to magnetic devices and more particularly to magnetic amplifiers for amplifying electrical impulses.

The usual magnetic amplifier circuits are not responsive to both positive and negative current impulses, or else they cannot differentiate between these two kinds of impulses. In case it is desired or necessary to repeat either two or three-element signals comprising both positive and negative current impulses, or positive, negative and zero current impulses it has been necessary in the past to either provide two magnetic amplifiers and modulating systems therefor, one to repeat the positive current impulses and the other to repeat the negative current impulses; or to bias an amplifier so that positive impulses will increase the output while negative impulses will decrease the output of the amplifier. The double amplifier is both bulky and expensive while the use of a bias necessitates a balancing circuit to balance out the normal steady output of the amplifier in case it is desired to transmit both positive and negative signal impulses from the amplifier. These balancing arrangements tend to make the amplifier unstable and introduce distortion into the signals.

It is the object of this invention to provide an improved magnetic amplifier of simplified construction employing only a single magnetic modulating system having one or two saturable magnetic coils for repeating either two or three-element signals employing both positive and negative current impulses which minimizes the undesirable features pointed out above.

It has been discovered that the wave shape of the output current of magnetic modulators when an input is applied is unsymmetrical. During one-half of the cycle the output rises to a much higher value than during the other half of the cycle of the output current so that if a half-wave rectifier or demodulator is connected in the output circuit in a direction to pass the peak current, a considerably greater output is obtained than if the demodulator is connected in the reverse direction. It has further been discovered that the polarity of this peak is dependent upon the polarity of the impulse applied to the input circuit of the magnetic amplifier.

In accordance with this invention two sets of output windings are provided on a single magnetic modulating system of either a single or pair of modulating cores. Half-wave rectifiers or demodulators are connected to these output windings so that one of them will pass peaks due to

positive impulses applied to the input circuit and the other so that it will pass the peaks due to negative impulses applied to the input circuit. These windings and demodulators are then connected to an output circuit in such a way as to transmit or apply the respective positive and negative impulses to the output circuit.

While the claims appended hereto define the scope of this invention, the foregoing objects and features as well as other objects and features of this invention may be more readily understood from the following description when read with reference to the accompanying drawing in which:

Fig. 1 illustrates a preferred embodiment of this invention employing a single modulating system comprising two magnetic cores for repeating and amplifying telegraph signal impulses of both positive and negative polarity;

Figs. 2 and 2A show a simplified magnetic amplifier for repeating both positive and negative signal impulses employing a single magnetic core; and

Figs. 3A and 3B illustrate curves of the voltages which are applied to the output rectifiers by the output windings of the saturable cores during the time that positive and negative signal impulses respectively are received by the amplifier.

The magnetic amplifier shown in Fig. 1 comprises a single modulating system consisting of two saturable cores 10 and 11. Each core is provided with power windings 12 and 13, respectively, which are connected through network 18 to a source of alternating current 17 the frequency of which is considerably higher than that of any component of the input signal. Network 18 is provided to reduce the impedance of the power circuit and to control the current flowing therethrough. In addition, in the embodiment of this invention shown in Fig. 1 in which the modulating system comprises two saturable cores, the power windings 12 and 13 are so proportioned with respect to cores 10 and 11 and source 17 that the cores are saturated during a portion of each half cycle of the alternating current from source 17.

Cores 10 and 11 are provided with input windings 15 and 16. These windings are so connected that when there is no input signal potential applied to them or when there is no input current flowing through them the potential induced in winding 15 by core 10 and winding 12 is opposed by an equal and opposite potential induced in winding 16 by core 11 and winding 13.

An input potential applied to these windings

or an input current flowing through them, however disturbs the magnetization of cores 10 and 11 so that a harmonic or multiple voltage appears in the input circuit in a manner similar to the manner that the same voltage appears in the output circuits to be described hereinafter.

Frequency discriminating network 19 is connected in the input circuit to prevent currents due to this voltage from disturbing the input circuit and line 23 and also to prevent changes of the impedance of the line 23 to this harmonic voltage or current from affecting or disturbing the operation of the amplifier. Consequently, frequency discriminating network 19 comprising elements 20, 21 and 22 may include low-pass filters, band pass filters, band suppression filters, or high suppression as well as equalizing elements and networks.

In addition to being attenuated telegraph signal impulses are distorted in form by the transmission line over which they are transmitted. The signal impulses are further distorted by the input circuit of the magnetic amplifier. In order to secure the required sensitivity for the amplifier it is necessary to provide a large number of turns in the input windings. This increases the inductance of the winding and also the time constant of the input circuit so the amplifier does not respond as much to short impulses as it does to long impulses.

The frequency discriminating network 21 may include equalizing elements, sections, or networks for improving the shape of the telegraph signal impulses as well as for increasing or equalizing the response of the amplifier to short signal impulses.

The cores 10 and 11 are provided with two sets of output windings. Windings 24 and 25 of cores 10 and 11 provide one set of output windings and windings 26 and 27 of cores 10 and 11 provide the second set of output windings. Each set of output windings is connected through a half wave copper oxide rectifier or other suitable demodulating devices 28 and 29, respectively, to windings 39 and 40 of relay 36, a second frequency discriminating network including equalizing network 32 comprising elements 33, 34 and 35 is connected in this circuit to further improve the wave form of the signal impulses transmitted to relay 36. As shown in Fig. 1, relay 36 is provided with a vibrating circuit and winding comprising a condenser 41 and windings 37 and 38 which operate in the usual manner and need not be further described here.

Normally when no signal impulses or signal impulses of zero polarity are received over line 23, the potentials induced in windings 24 and 26 are opposed by equal and opposite potentials induced in windings 25 and 27, respectively, so that there is no resultant potential and thus no current flowing in either of the output circuits of linking cores 10 and 11. However, when a current impulse, assume for example, a positive impulse, is received from line 23, the current of this impulse will flow through the input windings 15 and 16. This current flowing through these windings alters the magnetization of the cores 10 and 11 so that the potentials induced in windings 24 and 26 are no longer opposed by exactly equal and opposite potentials induced in windings 25 and 27, respectively. Instead, a harmonic potential, which in the preferred embodiment is preponderantly the second harmonic of source 17, that is, a potential of twice the frequency of source 17, is induced in both output circuits and

causes a voltage of the corresponding frequency to be applied to the respective demodulators 28 and 29 and their associated circuit.

However, the wave shape of the voltage appearing in these output circuits is not symmetrical. Fig. 3A illustrates the wave shape of the potential induced in the output windings on cores 10 and 11 during the time a positive impulse or positive current therefrom is flowing through the input windings 15 and 16. In Fig. 3A line 56 represents the zero potential line. When a positive impulse is received the wave form of the potential in the output windings is illustrated by the curve 57. It is to be noted that the potential of positive half cycles is much higher than the potential of the negative half cycles.

One rectifier or demodulator 28 is connected to the output circuit comprising windings 24, 25 in such a manner that it will pass these high positive peaks while the rectifier or demodulator 29 is connected oppositely to the output circuit comprising windings 26 and 27, that is, it is connected so that it passes the low potential negative peaks, but does not pass the high potential positive peaks. These rectifier elements have non-linear characteristics similar to copper oxide rectifiers in which the impedance in the forward or conducting direction falls or decreases rapidly as the potential applied to them increases. Consequently the current flowing through the demodulator 28 during the time the high potential positive peaks are applied to it in response to a positive impulse received over line 23 is much greater than the current flowing through demodulator or rectifier 29 due to the low potential half cycles applied to it during this time. The current flowing through these rectifiers or demodulators passes through windings 39 and 40 of relay 36. Since the current flowing through winding 39 is much greater, it overpowers the current flowing through winding 40 and also the current flowing through the bias winding 38 of the vibrating circuit and causes the relay to move to the positive contact, as shown in Fig. 1.

The demodulated or output current flowing through devices 28 and 29 also flows through the output windings 24, 25, 26, and 27. The demodulated current flowing through windings 24 and 25 is in a direction to aid the magnetic effect of the positive input current while the demodulated output current flowing through windings 26 and 27 is in the direction to oppose the magnetic effect of the positive current flowing in the input windings. However, since the current flowing through windings 24 and 25 and device 28 greatly exceeds the current flowing through the windings 26 and 27 and device 29, the net effect is that the demodulated output current flowing through the output windings tends to aid the input positive current flowing in the input circuit and thus causes a regenerative feedback action which increases the output of the amplifier.

During the reception of a negative signal impulse from line 23, the negative current of which flows through the input windings 15 and 16 of cores 10 and 11, respectively, the wave shape of the second harmonic voltage of source 17 induced in the output windings 24, 25 and 26, 27 is shown by curve 59 of Fig. 3B where line 58 is the zero axis or zero potential line. Under this condition the operation of the demodulators or rectifiers 28 and 29 is reversed. The current flowing through rectifier or demodulator 29 due to the high potential and negative half cycles applied

to it is much greater than the current flowing through the rectifier or demodulator 28 due to the low potential positive half cycles flowing through it. Under these conditions the current flowing through winding 40 from demodulator 29 is much greater than the current flowing through winding 39 and consequently overpowers this winding and also the current flowing through the bias winding 38 of the vibrating circuit of relay 36. This causes relay 36 to move to the opposite contacts to connect negative potential to line 42.

Under these conditions both the current flowing in the input circuit and the net demodulated current flowing in the output circuits, which current also flows through the output windings, are reversed. Consequently the demodulated current flowing in the output windings again increases the gain or output of the amplifier.

Thus, the amplifier shown in Fig. 1 is capable of receiving and amplifying and retransmitting impulses of both positive and negative polarity. While the windings on cores 10 and 11 have been described as individual windings it is to be understood that various windings such as 15 and 16, 24 and 25, 26 and 27, may be combined into a single winding providing they interlink each of the cores so that the respective circuits will have voltages induced in them in the same manner as the cores induce voltages in the circuits described in Fig. 1.

It is also possible to provide other output circuits for this amplifier. For example, the output circuit shown in Fig. 2 to be described hereinafter, may be provided for retransmitting the signal impulses to another telegraph line, load or other receiving apparatus. The output circuit may be connected to the input circuit of a similar amplifier thus forming a multi-stage magnetic amplifier.

The amplifier shown in Fig. 1 is also applicable to amplifying three-element signals, that is, signals of positive, negative and zero polarity. In this case it will be necessary to provide a three-element relay or responsive device connected to the output circuit of the amplifier. Under these conditions the responsive device will be held on its positive contact by a greater current flow in the output circuit through demodulator 28 in response to the reception of a positive impulse from line 23 and it will be held on its negative contact in response to a negative impulse received from line 23 which causes the greatest current to flow through the demodulating device 29. During the time no impulses are received no current or equal currents will be transmitted to the current responsive device corresponding to relay 36 which will, consequently, assume a zero and neutral position.

It is to be also understood that the vibrator windings 37 and 38 and condenser 41 are not essential to the correct operation of Fig. 1, but merely serve to improve the operation of the circuit.

The following values for the various elements of a typical amplifier have been found satisfactory for receiving telegraph signals over composited Morse metallic telegraph lines over 200 miles long; element 22, 3500 ohms resistance and 16 henries inductance; element 20, 4 henries inductance total; element 21, 2000 ohms resistance and 5 microfarads; modulator cores 10 and 11 comprise 20 turns of a tape of an alloy comprising 3.8% molybdenum, 78.5% nickel, and the balance chiefly iron $\frac{1}{4}$ inch wide, 0.003 inch

thick, and having an average diameter of $1\frac{1}{8}$ inches; input windings 15 and 16 are each provided with 2100 turns; power windings 12 and 13 with 450 turns each; output windings 24, 25, 26, and 27 with 400 turns each; network 18, a resistance of 300 ohms and a capacity of 0.016 microfarad; condensers 30 and 31 a capacity of 0.5 microfarad each; each demodulator 28 and 29 comprises 8 copper oxide rectifier discs $\frac{3}{4}$ inch in diameter connected in series; source 17, a voltage of 34 volts at 2160 cycles per second; elements 33, a resistance of 3000 ohms and a capacity of 8 microfarads; elements 34 and 35 were not required for this particular amplifier and were not provided; and relay 36 was a polarized telegraph relay having windings 39 and 40 of 3800 turns and 370 ohms resistance each, and windings 37 and 38 of 800 turns each; the resistances in the vibrator circuit were 10,000 ohms each and the condenser had a capacity of 0.5 microfarad; and 130 volt positive and 130 volt negative batteries were connected to the contacts of relay 36.

The embodiment of this invention shown in Fig. 2 employs only a single saturable core 50 in combination with other circuit elements to amplify both positive and negative electrical impulses or current. Core 50 is provided with a power supply winding 51 which is connected through networks 18 and to a source of alternating current 17. Networks 18 are provided to reduce the impedance of the power supply source 17 and to control the current to a suitable value. Winding 51 is so designed with relation to core 50 and source 17 that the current from source 17 flowing through winding 50 does not normally saturate core 50 unless current is also flowing through the input winding 52. Core 50 is provided with an input winding 52 which is connected to line 23 through a frequency discriminating network including equalizer 21 and a low-pass filter network 19. It is to be understood that this frequency discriminating network may assume any suitable form and include any of the elements described with reference to the frequency discriminating network of Fig. 1.

While the input circuits of both the amplifiers shown in Figs. 1 and 2 have been shown connected to a telegraph line through a frequency discriminating and equalizing network it is to be understood that these input windings may be connected directly to the line 23 or may receive input power from any other source which it is desired to amplify. For example, the input circuit may be connected to bridge circuits or to any other indicating instrument which furnishes only a small amount of power which it is desired to amplify. The frequency discriminating network 21 shown in Fig. 2 tends to improve the wave shape of the received signals, to counteract the effect of the high inductance of the input winding, and correct for the distortion due to the line and compositing networks. The low-pass filter 19 prevents current induced in winding 52 by the alternating current supply 17 from flowing in line 23, and prevents changes in impedance of line 23 to this current from affecting the operation of the amplifier. Core 50 is provided with two output windings 53 and 54. These may be a single winding as shown in Fig. 2 with a center tap between them. Each one of these windings is connected through a single wave rectifier or demodulator 28 and 29 to an output or load circuit. Condensers 30 and 31 are provided to increase the output by by-pass-

ing the alternating current component thereof. These rectifiers are connected through resistances 60 and 61 the center tap of which is connected to the center point of condensers 30 and 31 and the center tap of windings 53 and 54. The rectifiers are also connected to load or line circuit 55. Load 55 may be any suitable receiving device, load, input circuit of another amplifier, telegraph line, meter, etc.

During the time no current flows through the input winding 52 of core 50 equal and opposite potentials having the same frequency as the frequency of source 17 are induced in the windings 53 and 54. These equal and opposite potentials cause equal currents to flow through the rectifying or demodulating devices 28 and 29. The rectified current from these devices, which is substantially equal, flows through resistances 60 and 61, respectively, which are also substantially equal. Since these currents flow through these resistances in opposite directions, that is, from each outside to the common terminal and then back to the common terminal of windings 53 and 54, they produce substantially equal and opposite potential drops across the resistances 60 and 61 so that there is no potential across the outer wires which are connected to the line or load 55. As pointed out previously a potential having the same frequency as source 17 is also induced in the input winding 52. However, the low pass filter 19 prevents this potential from performing any useful or detrimental function. When an input current flows through the input winding 52 it will tend to alter the magnetization of core 50 so that it will tend to become saturated during a portion of one-half cycle of the alternating current from source 17, but will not be saturated during the other half cycle. Under these conditions the voltages induced in windings 53 and 54 will again become distorted similar to that shown in Figs. 3A or 3B. In this case again the voltages will be of the same frequency as source 17 and not a harmonic thereof as in the case of Fig. 1.

Assume for example that a positive impulse or positive current is applied to the input winding 52. This will cause the wave shape of the voltage introduced in output windings 53 and 54 to assume a shape such as shown in Fig. 3A. Assume further that the positive half cycles which are the high potential half cycles as shown in Fig. 3A are applied to the rectifier or demodulator 28 in such a manner that this rectifier passes these positive half cycles while demodulator or rectifier 29 is connected so that it passes the low potential negative half cycles shown in Fig. 3A. Under these conditions, as in Fig. 1, considerably greater current flows through rectifier 28 due to the fact that these unilateral rectifiers or demodulators have considerably less impedance when the applied voltage in the conducting direction is increased. This causes the current through resistance 60 to exceed the current through resistance 61 and therefore the voltage drop across resistance 60 exceeds the voltage drop across resistance 61. This applies a corresponding voltage drop which equals the difference of these two voltages across the outside line or leads to the load line or receiving device 55. In case a negative impulse or negative current is applied to the input winding 52, the reverse condition applies. The output is distorted as shown in Fig. 3B so that the high voltage half cycles are applied to demodulator or rectifier 29 and the low voltage half cycles are applied to

rectifier 28. Under these conditions the greater voltage drop is across the resistance 61 and since this voltage drop is in the opposite direction to the voltage drop across resistance 60, the total voltage across these two is now of the opposite polarity. Thus a negative impulse is repeated to the line or load 55.

The demodulated current flowing in the output circuit also flows in the output windings 53 and 54 and, as described with reference to Fig. 1, tends to increase the gain and output of the amplifier arrangement shown in Fig. 2 when both positive and negative impulses are applied to the input circuit.

It is to be noted that with an output circuit of the type shown in Fig. 2 the amplifier is capable of receiving both positive, negative and zero signal impulses and transmitting the corresponding impulses in amplified form to line or load 55. The load circuit in Fig. 2 might be applied equally well to the amplifier shown in Fig. 1. All that is necessary is that the three wires to the right of the dot-dash line of Fig. 2 be connected to the three wires from the equalizing network 32 of Fig. 1. In this case the amplifier shown in Fig. 1 will amplify and transmit signal impulses of a positive negative and zero polarity.

Fig. 2A shows an alternative output circuit which may be connected to the amplifiers shown in either Figs. 1 or 2. When this circuit is connected to the circuit shown in Fig. 2 the relay will be energized so as to close its armature to the positive contact in response to a positive signal impulse received over line 23. The positive impulse received over line 23 causes the current flowing through the element 28 to greatly exceed the current flowing through element 29 so that the current flowing through winding 39 of relay 36 of Fig. 2A will greatly exceed the current flowing through winding 40 thereof and cause the relay armature to move to the positive contacts. Similarly when a negative impulse is received from line 23 it causes a considerably greater current to flow through element 29 than flows through element 28. Consequently a greater current flows through winding 40 than flows through winding 39. This will cause the relay armature to move it to the negative contact. Consequently the relay operates in response to the signal impulses received over line 23.

It is to be understood that there is an actual gain in signal strength when the signal impulses are transmitted through the amplifiers shown in Figs. 1 and 2. For example, with suitable constants for the various equalizing networks it is possible to secure a gain of 15 decibels over a considerable frequency range for telegraph signals. If it is desired the equalizing networks may be so arranged that a considerable greater gain of over 20 decibels may be obtained for certain frequencies.

What is claimed is:

1. A magnetic amplifying device comprising a single modulating system, a power supply circuit for said system, an input circuit for said system, two sets of output circuits for said system, a unilateral non-linear conducting device connected to each of said output circuits, in opposite directions, so that one of said conducting devices passes current during one-half cycle of one polarity of the output current and the other of said devices passes current during the other half cycle of the opposite polarity and an energy utilizing circuit connected to said output circuits in opposite directions.

2. A magnetic amplifying device comprising a single magnetic modulating system comprising a single core of saturable material, a power supply winding on said core, an input winding on said core, two sets of output windings wound on said core, a unilateral non-linear conducting device connected to each of said output windings in opposite directions and a load circuit including said output windings and unilateral conducting devices connected in opposite directions.

3. A magnetic amplifying device employing a single magnetic modulating system comprising a pair of saturable magnetic cores, power windings wound on said cores, a source of alternating current power connected to said windings, said alternating current being of sufficient magnitude to saturate both of said cores during a portion of each half cycle of said alternating current, two sets of output circuits including output windings wound on said cores, an input circuit including input windings wound on said cores, a non-linear unilateral conducting device connected to each set of said output windings in opposite directions and an output circuit to which said sets of windings and the respective non-linear unilateral conducting devices are connected oppositely.

4. A magnetic amplifying device, for amplifying positive and negative electrical impulses comprising a single magnetic modulating system, a power supply circuit interlinking said modulating system, an input circuit interlinking said system, two sets of output circuits interlinking said system, a unilateral conducting device connected to each of said output circuits in opposite directions whereby one of said output circuits responds more than the other of said output circuits to input signal impulses of positive polarity and the other of said output circuits responds more to input signal impulses of negative polarity than said first-mentioned output circuit, and a load circuit connected to said output circuits whereby said load circuit receives positive signal impulses in response to received positive signal impulses and receives negative signal impulses in response to negative signal impulses received by said magnetic amplifying device.

5. A magnetic amplifying device for amplifying signal impulses of positive, negative and zero polarity employing a single modulating system comprising a pair of saturable magnetic cores, power windings interlinking said cores, a source of alternating current power of sufficient magnitude to saturate said cores during a portion of each half cycle of the current from said power source connected to said power windings, an input circuit interlinking said cores, frequency discriminating networks connected to said input circuit, two output circuits interlinking said cores, a non-linear unilateral conducting device connected to each of said sets of output circuits, said unilateral conducting devices being connected to pass opposite half cycles of the power induced in said output windings, and an energy utilizing circuit so connected to one of said output circuits as to receive positive signal impulses therefrom in response to a positive signal impulse applied to said input circuit and so connected to the other of said output circuits as to receive negative signal impulses therefrom in response to received negative signal impulses whereby signal

impulses of positive, negative, and zero polarity are received in said energy utilizing circuit in response to the reception of similar impulses in said input circuit.

6. An amplifying system comprising in combination a single magnetic modulating system, power supply windings interlinking said system, an input circuit interlinking said system, two output circuits interlinking said system, a unilateral conducting device connected to each of said output circuits to pass opposite half cycles of current induced in said output circuits and a two position responsive device connected to said output circuits whereby said device will assume one position in response to signal impulses of one polarity applied to said input circuit and will assume the other of said positions in response to signal impulses of the opposite polarity applied to said input circuit.

7. An amplifying system comprising in combination a single magnetic modulating system, power supply windings interlinking said system, an input circuit interlinking said system, two output circuits interlinking said system, a unilateral conducting device connected to each of said output circuits in a manner to pass opposite half cycles of current induced in said output circuits and to cause said opposite half cycles to flow in said output circuit interlinkages to increase the output of said device, and an energy utilizing circuit connected to said output circuits oppositely whereby one of said output circuits transmits positive impulses to said energy utilizing circuit and the other of said output circuits transmits negative impulses to said energy utilizing circuit.

8. An amplifying system comprising in combination a single magnetic modulating system, power supply windings interlinking said modulating system for normally energizing all the elements of said modulating system to substantially the same magnitude during each half cycle of the alternating power supply, an input circuit interlinking said system, two output circuits interlinking said system, a unilateral conducting device connected to each of said output circuits to pass opposite half cycles of current induced in said output circuit and a load circuit oppositely connected to said unilateral conducting devices whereby an amplified positive current flows in said load circuit in response to a positive current flowing in said input circuit and an amplified negative current flows in said output circuit in response to a negative current flowing in said input circuit.

9. An amplifying system comprising in combination a single magnetic modulating system, power windings interlinking said system, an input circuit interlinking said system, an output circuit interlinking said system, a load circuit, an operative connection between said output circuit and said load circuit including two non-linear unilateral conduction devices connected oppositely to said output circuit whereby an amplified positive current flows in said output circuit in response to a positive current flowing in said input circuit and an amplified negative current flows in said output circuit in response to a negative current flowing in said input circuit.

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