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AMPLIFIER

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This invention relates to an amplifier circuit and more particularly to a circuit in which relays are employed as active elements to produce an output in the form of variable width impulses having a useful component approximately proportional to an input which is variable in magnitude and direction.

An amplifier of this type is most useful for continuous control in driving a reversible load unit such as, for example, a separately excited direct or alternating current motor.

It is therefore the object of the invention to provide an amplifier having relays as active elements thereof which is reliable in operation, simple in structure and which has a large gain with good output wattage.

The amplifier in accordance with the present invention may comprise one or more stages of vacuum tube amplification the output from the last stage of tube amplification being applied to the biasing windings of two relays in such a manner that the input signal causes the biasing of one of the relays to increase while the biasing of the other relay decreases and vice versa. The relays are each supplied with an additional operating winding. The operating windings of the two relays may be connected in series or in parallel and energized from a source of alternating or pulsating current, whereby, with no signal present and therefore no current flowing through the biasing windings of the relays, the relays operate and release in unison at a rate determined by the periodicity of the alternating or pulsating operating current.

A source of power such as a battery is connected between one contact of one relay and the corresponding contact of the other relay and two equal resistances are connected in series between the other contacts of the relays. The load circuit is connected between the junction of the resistances and the mid-cell tap of the battery so that with both relays operating and releasing in unison equal and opposite currents from the two sections of the battery are applied to the load circuit with no effect thereon.

With current of one polarity applied to the biasing windings of the relays a first one of the relays is caused to lead the other in operation so that for a short period before the other relay operates an impulse is transmitted from only one-half of the battery to the load circuit, the duration of the impulse being dependent upon the amount of the lead. Reversely, with current of the opposite polarity applied to the biasing windings the second of the relays would be caused to

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lead the operation of the first relay resulting in the transmission of an impulse from the other half of the battery in the opposite direction to the load circuit, the duration of the impulse also being dependent upon the amount of the lead.

For a clearer understanding of the invention reference may be had to the following detailed description to be read in connection with the accompanying drawing in which:

Fig. 1 is a circuit diagram illustrating the invention;

Fig. 2 shows curves illustrating the approximate values of the summation of the currents flowing through the windings of both relays when no input signal is present;

Fig. 3 shows curves illustrating the approximate values of the current flowing through the operating winding, through the biasing winding and the summation thereof for each of the relays when biasing current of one polarity is applied to the biasing windings; and

Fig. 4 shows curves illustrating the approximate values of the current flowing through the operating winding, through the biasing winding and the summation thereof for each of the relays when biasing current of the opposite polarity is applied to the biasing windings.

The load controlling relays A and B and the vibrator relay V of Fig. 1 are of the type disclosed in Patent No. 2,289,830 granted to me on July 14, 1942. It is to be understood, however, that relays of other types could be used. Each of these relays as, for example, the relay V, comprises an envelope 1 of glass or other suitable material which is either evacuated or filled with an inert gas, or hydrogen, under pressure, a pair of terminals 2 and 3 sealed through the envelope, reed armatures 4 and 5 of iron or other suitable magnetic material secured within the envelope to the inner ends of the terminals 2 and 3 with their overlapping ends normally out of engagement and an operating coil or winding 6 outside of and surrounding the envelope. When the winding 6 is sufficiently energized from a source of current, the reed armatures which lie within the field set up by the winding are attracted into engagement with each other.

Relays A and B are similar in construction to relay V except that each of these relays has two windings, relay A having an operating winding 9 and a biasing winding 10, and relay B having an operating winding 13 and a biasing winding 14.

The operating windings 9, 13 and 6 of relays A, B and V are connectable in series with the battery 15 by the switch 16. The biasing windings 10 and

14 of relays A and B are connected in series between the input terminals 17 and 18, the windings of the relays being so connected into their energizing circuits that when current is flowing through the biasing winding 10 of relay A and the biasing winding 14 of relay B in such a direction as to render windings 9 and 10 of relay A aiding, the windings 13 and 14 of relay B are energized in opposition and that when current is flowing through the biasing windings 10 and 14 in such a direction as to render windings 13 and 14 aiding, the windings 9 and 10 are energized in opposition.

To simplify the disclosure, the battery 19 and potentiometer 20 are disclosed connected between the input terminals 17 and 18 for supplying biasing potential of a desired magnitude and polarity. The potentiometer 20 is bridged around the battery 19 with the slider connected to the terminal 17 and the mid-cell tap of battery 19 connected to terminal 18. With the slider of the potentiometer 20 at the mid-tap position on the potentiometer winding, no current will flow over the circuit through the biasing windings 10 and 14 of relays A and B but if the slider is moved toward one end of the potentiometer winding current will flow in one direction through the biasing windings or if the slider is moved toward the other end of the potentiometer winding, current will flow in the other direction through the biasing windings. As previously stated, the input terminals 17 and 18 could be supplied with biasing potential in any other desired manner as, for example, from the outputs of amplifier tubes.

For creating pulsating current impulses in the operating windings 9 and 13 of relays A and B, the terminals of the winding 6 of the vibrator relay V are connected respectively to the terminals 2 and 3 so that when the winding 6 becomes fully energized and the reed armatures 4 and 5 become attracted into engagement they serve to short-circuit the winding 6 whereby impulses of current having approximately the wave form shown at *a* in Fig. 2 are transmitted through the operating windings 9 and 13 of relays A and B.

The upper contacts 7 and 11 of relays A and B are interconnected through equal resistances 21 and 22 and the lower contacts 8 and 12 of such relays are interconnected through the battery 23. The load 24 is connected between the junction point 25 of the resistances 21 and 22 and the mid-cell tap 26 of the battery 23.

It will first be assumed that the slider of potentiometer 20 is at the mid-tap position of the potentiometer winding and that therefore no biasing current flows through the biasing windings 10 and 14 of relays A and B. When the switch 16 is now closed current will flow serially through the operating windings 9 and 13 of relays A and B and through the winding 6 of relay V and relay V will become energized to cause the engagement of its reed armatures 4 and 5. Thereupon the winding 6 becomes short-circuited and the current flowing through the operating windings 9 and 13 of relays A and B increases to a value such that relay A causes its reed armatures 7 and 8 to engage and to thereby establish a circuit from the negative pole of the left section of battery 23 through the load 24, through resistance 21, over the armatures of relay A and to the positive pole of the left section of battery 23 and relay B causes its armatures 11 and 12 to engage and to thereby establish a second circuit from the negative pole of the right section of battery 23 over the armatures of relay B, through resistance 22 and through the load 24 to the positive terminal of the right section of

battery 23. It will be noted that the currents flowing through the load 24 from the two sections of battery 23 are equal and opposite. As soon as the potential stored in the winding 6 of relay B becomes dissipated over the short-circuit through the relay armatures 4 and 5, the armatures disengage and with the coil 6 again included in series with the operating windings 9 and 13 of relays A and B, the current flowing through the windings 9 and 13 decreases to a value below that required to maintain the armatures of such relays engaged and the previously traced circuits through the load 24 becomes opened. Since the relays A and B thus simultaneously attract their respective armatures into engagement and simultaneously release their armatures out of engagement, the impulses of opposite polarity which are transmitted through the load 24 on each cycle of operation of relays A and B therefore being of equal duration, no effect on the load 24 is produced.

The curve *a* shown in Fig. 2 shows the approximate shape of the current impulses transmitted through the operating windings of relays A and B under the control of the vibrator relay V, the upper curve showing the current through the operating winding of relay A and the lower curve showing the current through the operating winding of relay B. Since it has been assumed that there is no biasing current flowing through the biasing windings of relays A and B the curve also represents the summation of the currents received by both windings of each relay, these summation curves being designated *C_A* and *C_B* in Fig. 2. If it be assumed that relays A and B will each cause its associated armatures to engage when the current value rises to the value represented by the dotted line OP and will release when the current value drops to the value represented by the dotted line REL then each relay will remain energized during the periods represented by the portions O of the curve O—R and be released during the portions R. It will be noted that the length of these portions O or the length of time the relays are energized are equal for both relays and therefore no effective current is transmitted to the load as represented by curve P shown between the two portions of Fig. 2.

It will now be assumed that the slider of potentiometer 20 is now moved in a direction to apply biasing current to the biasing winding 10 of relay A which aids the pulsating current impulses applied to the operating winding 9 of this relay and to apply biasing current to the biasing winding 14 of relay B which opposes the pulsating current impulses applied to the operating windings 13 of the latter relay. Referring now to Fig. 3 the pulsating currents applied to the operating windings 9 and 13 of relays A and B are represented by the curves *a*. The biasing current applied to the biasing winding 10 of relay A is represented by the line *b+* in the upper portion of Fig. 3 and the biasing current applied to the biasing winding 14 of relay B is represented by the line *b-* in the lower portion of Fig. 3. The summation of the currents flowing through the two windings of relay A is now represented by the curve *C_A* in the upper portion of Fig. 3 and the summation of the currents flowing through the two windings of relay B is represented by the curve *C_B* in the lower portion of Fig. 3. The portions O of curve O—R in the upper portion of Fig. 3 now represent the periods during which the armatures of relay A remain engaged to apply current of one polarity to the load 24 and the portions O of curve O—R

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in the lower portion of Fig. 3 represent the periods during which the armatures of relay B remain engaged to apply current of the opposite polarity to the load 24. It is to be noted that the durations of the impulses transmitted by relay A are longer than the durations of the impulses transmitted by relay B and consequently current will flow in one direction through the load 24 under the control of relay A during such periods as relay B is not at the time energized as represented by the output curve P shown between the two portions of Fig. 3.

It will now be assumed that the slider of potentiometer 20 is now moved in a direction to apply biasing current to the biasing winding of relay A which opposes the pulsating current impulses applied to the operating winding 9 of such relay and to apply biasing current to the biasing winding 14 of relay B which aids the pulsating current impulses applied to the operating winding 13 of the latter relay. Referring now to Fig. 4 the pulsating currents applied to the operating windings 9 and 13 of relays A and B are represented by the curves a, the biasing current applied to the biasing winding 10 of relay A is represented by the line b- in the upper portion of Fig. 4 and the biasing current applied to the biasing winding 14 of relay B is represented by the line b+ in the lower portion of Fig. 4. The summation of the currents flowing through the two windings of relay A is now represented by the curve Ca in the upper portion of Fig. 4 and the summation of the currents flowing through the two windings of relay B is represented by the curve Cb in the lower portion of Fig. 4. The portions O of curve O—R in the upper portion of Fig. 4 now represent the periods during which the armatures of relay A remain engaged to apply current of one polarity to the load 24 and the portions O of curve O—R in the lower portion of Fig. 4 represent the periods during which the armatures of relay B remain engaged to apply current of the opposite polarity to the load 24. It is to be noted that the durations of the impulses transmitted by relay B are longer than the durations of the impulses transmitted by the relay A and consequently current will flow in a direction through the load opposite to that previously discussed in connection with the consideration of Fig. 3 as represented by curve P shown between the two portions of Fig. 4.

It will thus be seen that impulses of current will be applied to the load 24 in a direction which is dependent upon the direction of bias of the input current applied between the input terminals 17 and 18 and the duration of such impulses will depend upon the magnitude of the biasing current.

While the operating windings of relays A and B are disclosed as energized by pulsating current impulses generated through the action of the vibrator relay V, it will be apparent that such windings could be energized by a combination of alternating and direct current or by alternating current. As illustrated, the load 24 is represented by a box labeled "load." This load obviously could be in a device which might be designed to operate by impulses of one or the opposite polarity such as, for example, the armature circuit of a direct current motor the field of which is separately excited.

What is claimed is:

1. In an amplifier circuit, two relays, means for applying a current of periodically varying amplitude in the same phase relationship to said relays

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whereby said relays are caused to operate in phase, an input circuit for applying a biasing current in opposite phase relationship to said relays respectively, means for varying the direction of said biasing current, a source of power, a load device, and means controlled in response to the operation of said relays for applying power from said source to said load device, the application of said biasing current to said relays being effective to shift the phase relationship between the operating times of said relays whereby the direction of the impulses transmitted from said source to said load device is made dependent upon the direction of the phase shift.

2. In an amplifier circuit, two relays, means for applying a current of periodically varying amplitude in the same phase relationship to said relays whereby said relays are caused to operate in phase, an input circuit for applying a biasing current in opposite phase relationship to said relays respectively, means for varying the magnitude of the biasing current, a source of power, a load device, and means controlled in response to the operation of said relays for applying power from said source to said load device, the application of said biasing current to said relays being effective to shift the phase relationship between the operating times of said relays whereby the duration of each impulse transmitted from said source to said load device is made dependent upon the magnitude of the biasing current.

3. In an amplifier circuit, two relays, means for applying a current of periodically varying amplitude in the same phase relationship to said relays whereby said relays are caused to operate in phase, an input circuit for applying a biasing current in opposite phase relationship to said relays respectively, means for varying the direction and magnitude of said biasing current, a source of power, a load device, and means controlled in response to the operation of said relays for applying power from said source to said load device, the application of said biasing current to said relays being effective to shift the phase relationship between the operating times of said relays whereby the direction of the impulses transmitted from said source to said load device is made dependent upon the direction of the phase shift and the duration of each impulse is made dependent upon the amount of the phase shift.

4. In an amplifier circuit, two relays each having an operating and a biasing winding, means for applying a current of varying amplitude in the same phase relationship to said operating windings whereby said relays are caused to operate in phase, an input circuit for applying a biasing current in opposite phase relationship to said biasing windings respectively, means for varying the direction and magnitude of said biasing current, a source of power, a load device, and means controlled in response to the operation of said relays for applying power from said source to said load device, the energization of said biasing windings being effective to shift the phase relationship between the operating times of said relays whereby the direction of the impulses transmitted from said source to said load device is made dependent upon the direction of the phase shift and the duration of each impulse is made dependent upon the amount of the phase shift.

5. In an amplifier circuit, two relays each having an operating and a biasing winding, means including a source of current and a vibra-

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tor relay for applying a current of varying amplitude in the same phase relationship to said operating windings whereby said relays are caused to operate in phase, an input circuit for applying a biasing current in opposite phase relationship to said biasing windings respectively, means for varying the direction and magnitude of said biasing current, a source of power, a load device, and means controlled in response to the operation of said relays for applying power from said source to said load device, the energization of said biasing windings being effective to shift the phase relationship between the operating times of said relays whereby the direction of the impulses transmitted from said source to said load device is made dependent upon the direction of the phase shift and the duration of each impulse is made dependent upon the amount of the phase shift.

6. In an amplifier circuit, two relays each having an operating and a biasing winding, means including a source of current and a self-shunting vibrator relay connected in series with said operating windings for applying a current of varying amplitude in the same phase relationship to said operating windings whereby said relays are caused to operate in phase, an input

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circuit for applying a biasing current in opposite phase relationship to said biasing windings respectively, means for varying the direction and magnitude of said biasing current, a source of power, a load device, and means controlled in response to the operation of said relays for applying power from said source to said load device, the energization of said biasing windings being effective to shift the phase relationship between the operating times of said relays whereby the direction of the impulses transmitted from said source of power to said load device is made dependent upon the direction of the phase shift and the duration of each impulse is made dependent upon the amount of the phase shift.

WALTER B. ELLWOOD.

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