April 8, 1947. E. LIDOW 2,418,516

AMPLIFIER

Filed June 6, 1944 2 Sheets-Sheet 1

Fig. 4.

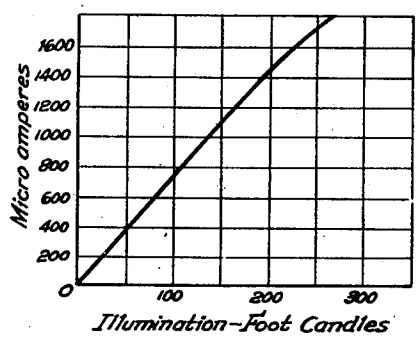
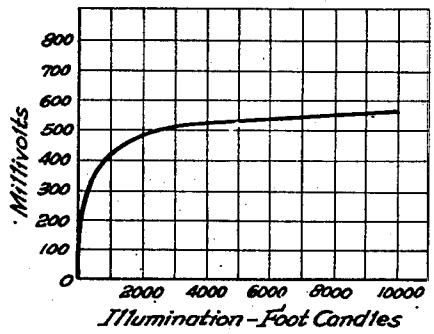



Fig. 3.



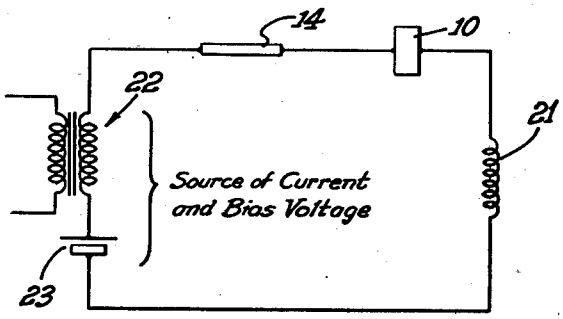




Fig. 5.

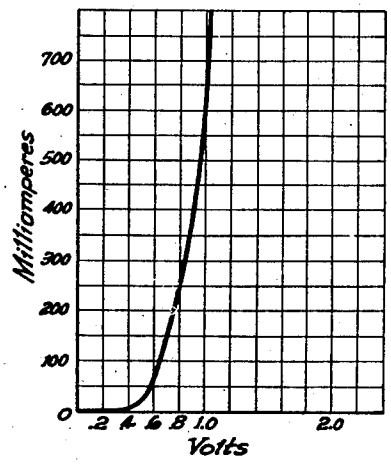



Fig. 1.

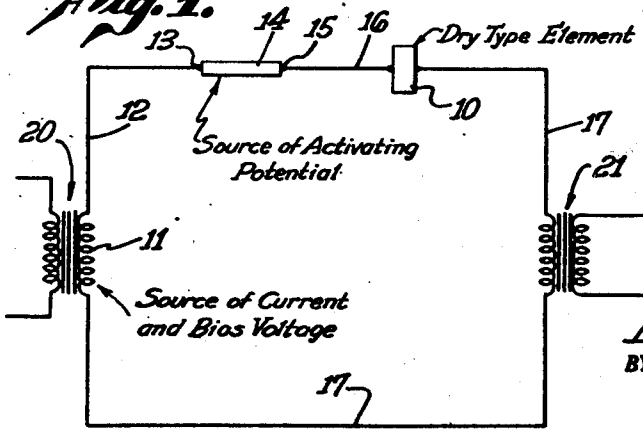



Fig. 2.

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April 8, 1947. E. LIDOW 2,418,516

AMPLIFIER

Filed June 6, 1944 2 Sheets-Sheet 2

Fig. 6.

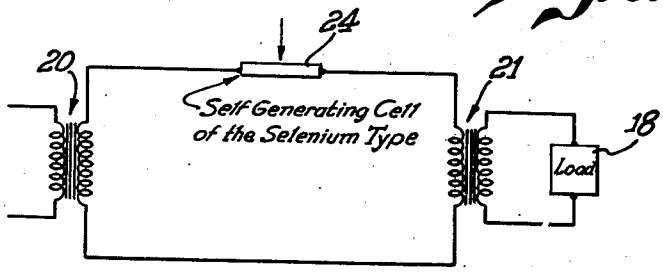



Fig. 9.

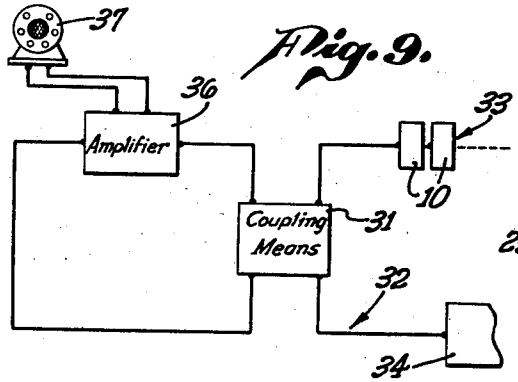
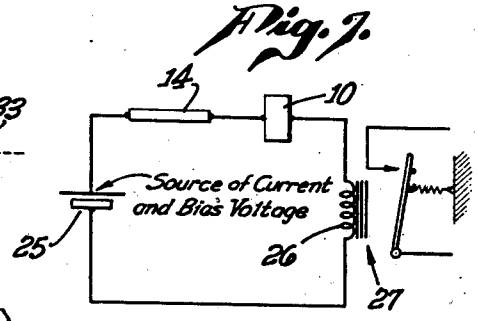



Fig. 7.



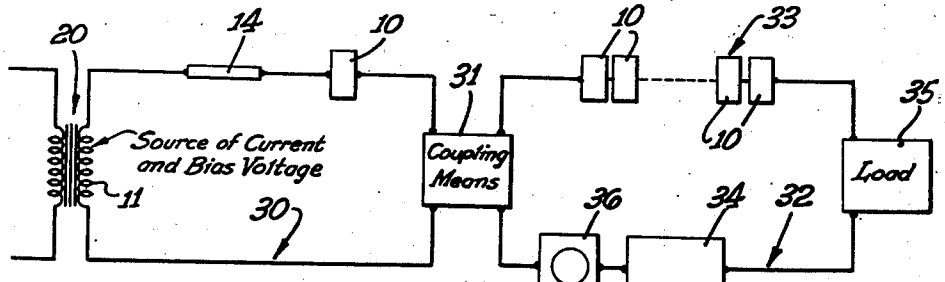




Fig. 8.

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# UNITED STATES PATENT OFFICE

2,418,516

## AMPLIFIER

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Application June 6, 1944, Serial No. 538,967

2 Claims. (Cl. 250—41.5)

1

This invention relates to electric amplifiers.

It is an object of this invention to provide an amplifier having a simple electrical circuit and utilizing elements of great mechanical strength and durability, substantially unlimited life, and small size.

It is known to utilize the characteristic curve of various types of electrical devices to obtain amplification of an applied current, such for example are amplifiers utilizing thermionic tubes, or saturating reactors. However, amplifiers of either of these types require considerable associated apparatus. Thus, a thermionic tube amplifier requires a source of high potential as well as large heating currents, while a saturating reactor requires a heavy winding and a substantial current supply to obtain the necessary saturation of the cores. It is thus another object of this invention to provide an amplifier which is light, compact and requires only a small amount of associated apparatus.

Amplification of the output of devices having a low internal resistance presents difficulties due to the necessity of using an amplifying circuit also having a low resistance. This renders the use of conventional circuits employing thermionic tubes difficult. Photo-electric cells of the self generating type are examples of such devices, and the field of their application has been restricted due to the difficulty of amplifying their output.

Thus, it is another object of this invention to provide an amplifier circuit having a low resistance, and which is particularly adapted for amplifying the output of devices having a low internal resistance.

It is another object of this invention to provide an amplifier which does not require any tubes or saturating reactors.

It is another object of this invention to provide an amplifier in which the elements producing amplification are current conductors having non-linear voltage-current characteristics and coupling means.

It is another object of this invention to provide an improved and simplified amplifier capable of amplifying direct current.

It is another object of this invention to provide an amplifier wherein a self-generating photo-electric cell serves to provide the element having a curved voltage-current characteristic as well as

2

to produce the activating potential for such element.

It is another object of this invention to provide an amplifier capable of a large current output.

It is another object of this invention to provide an amplifier which is unaffected by temperature changes, and thus has a substantially constant output throughout a wide range of temperatures.

It is still another object of this invention to provide an amplifier which is capable of being constructed of very small size and light weight, so as to be readily portable.

It is a still further object of this invention to provide an amplifier particularly adapted for use with so-called hearing aids, utilized by persons with impaired hearing faculties.

This invention possesses many other advantages and has other objects which may be made more easily apparent from a consideration of several embodiments of the invention. For this purpose there are shown a number of forms in the drawings accompanying and forming part of the present specification. These forms will now be described in detail, illustrating the general principles of the invention; but it is to be understood that this detailed description is not to be taken in a limiting sense, since the scope of the invention is best defined by the appended claims.

In the drawings,

Figure 1 is a diagram showing the circuit of one form of amplifier incorporating the invention;

Figure 2 is a typical characteristic curve of a dry type element suitable for use in the amplifier circuit of Figure 1;

Figures 3 and 4 are respectively the voltage and current output curves of a self-generating photo-electric cell;

Figures 5 and 6 are diagrams showing modified forms of amplifier circuits;

Figure 7 is a circuit diagram of a direct current amplifier incorporating the invention;

Figure 8 is a diagram showing a pair of amplifier circuits coupled in cascade for greater amplification; and

Figure 9 is a modified form of cascade circuit.

Amplifiers in accordance with this invention contemplate the use in an appropriate circuit, of an element having as an inherent characteristic, a high resistance and corresponding low current value up to a definite voltage, and a low

resistance and large current value above such voltage. Such an element may or may not have a backward resistance in excess of the forward resistance for a given voltage. Such elements are meant to include all structures known in the prior art and used as rectifiers, as well as non-linear resistors with a voltage-current characteristic wherein

$$\frac{di}{dv}$$

varies with the value of $v$, in which $i$ is current passed by the resistor, and $v$ is voltage of the applied current.

Such an amplifier includes a source of current having a potential approximating the definite voltage above mentioned, but not in excess thereof and arranged to be effective across the element, a source of activating potential arranged to be applied additionally across the element to trigger it or cause it to pass current, and an output circuit or load in which this passing current is utilized. It is obvious that in such an arrangement, the current acting on the load is a function of the activating potential, and the circuit can accordingly be used to amplify desired signals. Thus, for example the source of activating potential can be a self-generating photo-electric cell, or it can be a microphone of appropriate type. Or such source can be, if desired, a conventional circuit utilizing thermionic tubes operating as a pre-amplifier.

Referring to Figure 1 of the drawings, an element of the type just discussed is indicated at 10. For example, such an element may comprise a selenium coated plate, and the curve of Figure 2, is the forward resistance curve of such an element as determined by actual measurement. Thus, referring to Figure 2, it will be seen that for an applied voltage of about four-tenths of a volt, the element will pass practically no current, while for a voltage of 0.75 volt the element will pass over 250 milliamperes, and at one volt it will pass about 600 milliamperes. Such a curve may be considered typical, but the particular values depend on the specifications to which the element is made. Other dry type elements may be used instead of a selenium coated plate. For example, a plate coated with copper oxide or cuprous oxide may be used.

Elements of this class have a low resistance of the order of 20 ohms per cm.$^2$ of surface, and an important advantage of utilizing them in the manner set forth is that for this reason, the amplifier has a low overall resistance making it possible to utilize the amplifier with generators of minute currents which have a low internal resistance, as for example microphones, self-generating photo-electric cells, and the like. Thus, a self-generating photo-electric cell may be used to supply the activating voltage for the amplifier.

Figures 3 and 4 show curves respectively illustrating the typical voltage and current output of a selenium type photo-electric cell under different intensities of illumination. An inspection of these figures will show that for a relative'y small illumination, for example 100 foot candles, the cell will put out about 0.2 of a volt and about 800 microamperes, a relatively large current, showing that the internal resistance of the cell is low. Such a voltage is sufficient to operate a conventional amplifier using thermionic tubes, but the resistance of a circuit incorporating such tubes is high, so that when such a cell is coupled in the circuit for purposes of amplifying its output, the output of the cell drops to practically zero due to the low internal resistance of the cell. Thus, the cell will not operate the amplifier. However, by applying such voltage to a suitably biased dry type element in a circuit having a low overall resistance, good results are obtained. Thus, if an element having a non-linear characteristic as illustrated in Figure 2 is connected to a source of current and biased to about 0.4 volt, substantially no current will pass, but if a small additional voltage is applied, substantial current will flow.



In the circuit of Figure 1, a source of energy of suitable voltage to bias the element 10 to the bend or critical point of its characteristic curve is indicated by 11 and is connected by lead 12 to one terminal 13 of a device 14 for supplying the activating or trigger voltage to the circuit. Such a device may be a photo-electric cell of the self-generating type, or other appropriate source of current. The other terminal 15 of the device 14 is connected by lead 16 to one side of the element 10. The other side of the element 10 is connected to source 11 by a return lead 17 which is appropriately coupled to the output circuit or load 18.

The operation of the circuit should be obvious from the previous discussion. Voltage from source 11 biases the dry type element 10 to the bend in its curve, and the additional activating voltage impressed on the element 10 by the device 14 causes the element to pass current from the source 11 to the load 18 in accordance with the potential received from the device 14. As shown in Figure 1, a pulsating or alternating current provides the operating current and the biasing voltage for the element being supplied by one winding 11 of an appropriate transformer 20, the other winding of which is connected to a source of current (not shown). Due to the fact that the current passed by the element is pulsating, the load 18 may be connected to the amplifier by an output transformer 21, one winding of which is interposed in lead 17 of the amplifier circuit. However, the amplifier is not limited to pulsating current, but will function effectively with direct current, as will be presently discussed.

It may be desirable to provide a source of current having a potential less than the biasing voltage, and to provide a source of additional potential cooperating therewith to furnish the biasing voltage. Thus, in Figure 5 an amplifier circuit is shown which is identical with the circuit of Figure 1, except that a source of energy 22, which may be alternating or pulsating current, is provided and a separate source of additional potential 23 is provided which is interposed in the circuit between the element 10 and source 22. Since the latter source 23 is not called upon to furnish any substantial amount of current, it may be a battery. It is to be understood that the combined potentials of the current source 22 and the potential source 23 are such as to reach the critical point of the curve of the element 10, so that the element will be activated to pass current by the additional voltage received from the device 14. Such a circuit has the important advantage of utilizing the energy received from source 22 in a more efficient manner than the circuit of Figure 1.

In some types of self-generating photo-electric cells, such as those with a selenium coated element, the element has a non-linear characteristic similar to that discussed for a selenium coated plate as well as the ability to serve as a source of activating current when illuminated. Thus,

it is possible to replace the element 10 and the device 14 of Figure 1 with such a cell as indicated by 24, in Figure 6, the source of current and biasing voltage 20, and the output transformer 21 being arranged as in Figure 1. The operation of this amplifier is substantially the same as that of the form of Figure 1. The voltage from the source 11 is such as to reach the bend of the characteristic curve of the selenium element in cell 24. When this cell is illuminated, additional voltage is generated across this element, which combined with the biasing voltage from source 11, causes the cell to transmit current from the source 11 to the output transformer 21, and in accordance with the amount of illumination applied to the cell.

Figure 7 shows a circuit similar to Figure 1 but arranged for direct current amplification. Thus, the current may be supplied by any desired source of direct current, such as a battery 25, arranged to supply a suitable voltage to the element 10. The current passed by the element 10 in response to activation by the device 14 may serve to energize the coil 26 of a relay 27 for controlling a power circuit. Such an arrangement has important advantages, since it avoids the necessity of using a special sensitive relay capable of operation by the minute output of photo-electric cell, and without the need of an elaborate amplifier. As pointed out in connection with Figure 6, the element 10 and the device 14 may be replaced by a self-generating photo-electric cell. This arrangement would have great utility where it is desired to control substantial sources of power by a light ray.

Another import use of the circuit of Figure 7 is in the amplification of currents of audio frequency. Thus, by utilizing a microphone for the device 14 which is capable of impressing additional voltage on the element 10, and providing earphones or a speaker in place of relay 27, an audio amplifier is provided. Such an amplifier, due to the possibility of making it of small size and light weight, would be very useful in hearing aids.

A plurality of amplifier circuits of the type of Figures 1, 5 or 6 can be arranged in cascade, if it is desired to obtain greater amplification than is possible with a single circuit. Thus, in Figure 8 a circuit 30 is shown which may be substantially identical with the circuit of Figure 1, including an element 10, an activating device 14, a source of pulsating energy and biasing voltage 11, and output coupling means 31. This means 31 may be a transformer, or it may be of some other type of coupling, as capacitative coupling.

The coupling means 31 serves to couple circuit 30 with a second amplifier circuit 32. Circuit 32 includes a stack 33 comprising a plurality of dry type elements 10 connected in series, the number of elements in stack 33 being chosen in accordance with the output desired and the characteristics of the coupling 31. Such a stack of elements 10 has a composite non-linear characteristic, similar to that for a single element as shown in Figure 2, with the bend or critical point at a voltage corresponding to the critical voltage of a single element multiplied by the number of elements in the stack.

Circuit 32 includes a source of electrical energy 34, of appropriate voltage to bias stack 33 to its critical point. Thus, additional voltage impressed on circuit 32 from circuit 30 in response to activation of the circuit 30 by device 14, will cause current to flow in circuit 32 for use in the output



circuit 35. With circuits arranged in this manner, a large current can be readily built up and controlled by a self-generating photo-electric cell, microphone, or other device capable of producing but a minute current.

The source of energy 34 may supply either direct or alternating current. If both circuits 30 and 32 are supplied with alternating or pulsating current, phasing means indicated at 36 for maintaining the currents in phase may be provided in either circuit if necessary, such means being well known.

As previously mentioned, the source of activating potential 14 in any of the amplifier circuits, may be a conventional amplifier employing thermionic tubes. Or as shown in Figure 9, an amplifier 36 of any preferred type serving for example to amplify impulses received from a source, as microphone 37, may be connected to an amplifier circuit such as circuit 32 of Figure 8 employing a stack 33 of the elements 10, by coupling means 31. The circuit amplifies the output from amplifier 36 in an obvious manner.

An amplifier in accordance with the instant invention has important advantages. Thus, as compared with a saturated reactor of similar current handling capacity, such an amplifier is very much lighter in weight. For example, a saturated current reactor of 10 ampere capacity weighs about four pounds, while a suitable element of similar capacity is obtainable which weighs less than two ounces. Further, dry type elements capable of outputs of 1000 amperes are readily obtainable, making such amplifiers especially suitable for a large kilowatt output.

Another feature of importance, particularly with regard to such an amplifier employing selenium coated plates, is that selenium has a negative temperature characteristic, the resistance of a selenium plate decreasing with increased temperature. The associated elements in the amplifier consist mainly of copper wire, relays and the like having positive temperature characteristics. Thus, under changing temperatures, the resistance of the plate or element changes in such a way as to at least partly offset the changes in resistance of the remainder of the circuit, so that the overall resistance of the circuit is substantially constant. This provides an amplifier which is to a large degree independent of temperature changes, an important advantage in applications in equipment, such as aircraft, operating over a wide range of temperature.

I claim:

1. In an electric amplifier, a dry type element having a curved characteristic and capable of passing substantial current only above a predetermined voltage, means coupled to said element for applying a current to said element of substantially said predetermined voltage, a current generator responsive to energy received in the form of wave motion, means coupling said generator and said element for applying current from said generator to said element whereby the voltage across said element is increased sufficiently to cause the element to pass current, and means in circuit with said element in which the current acts.

2. In an amplifier, a dry type element capable of passing substantial current only above a definite voltage and in accordance with the magnitude of said voltage, a source of direct current coupled to said element and having a voltage substantially that at which said element passes current, means responsive to energy received as wave

motion for generating an activating current, means coupling said generating means and said element for impressing said activating current on said element whereby said element passes current in accordance with the received energy, and means in circuit with said element for converting said passed current into wave motion.

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