

Aug. 17, 1926.

B. N. SOKOLOFF

1,596,558

METHOD AND APPARATUS FOR AMPLIFYING ELECTRIC CURRENTS

Filed Sept. 29, 1922

2 Sheets-Sheet 1

Fig. 1.

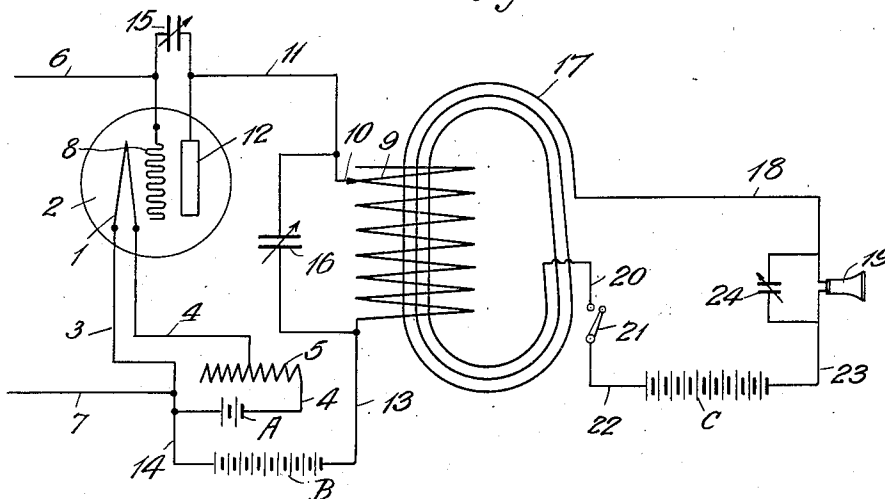


Fig. 2.

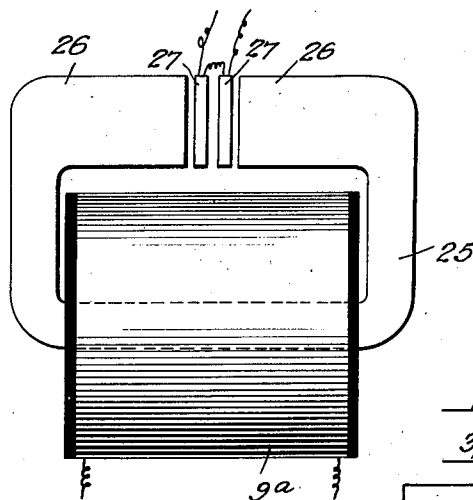


Fig. 3.

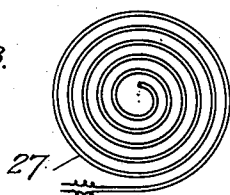
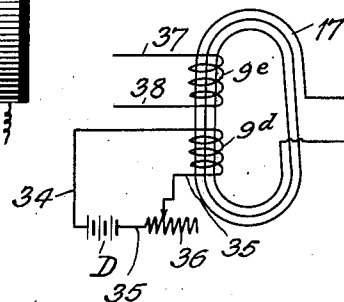


Fig. 7.



INVENTOR.
BORIS N. SOKOLOFF

BY
Shackbridge & Roset
ATTORNEYS

Aug. 17, 1926.

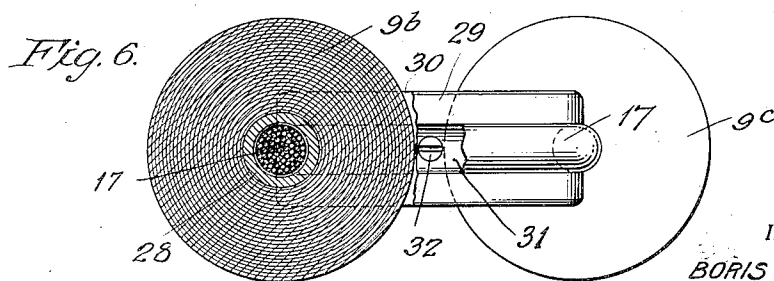
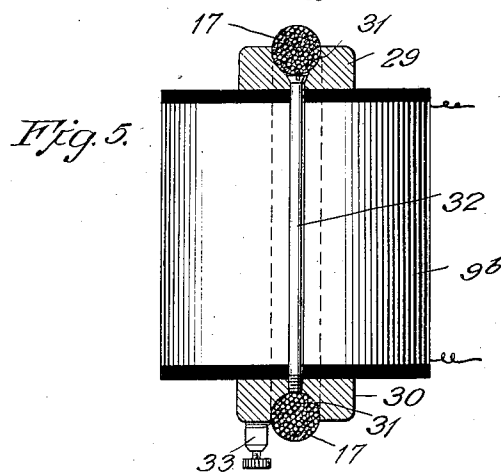
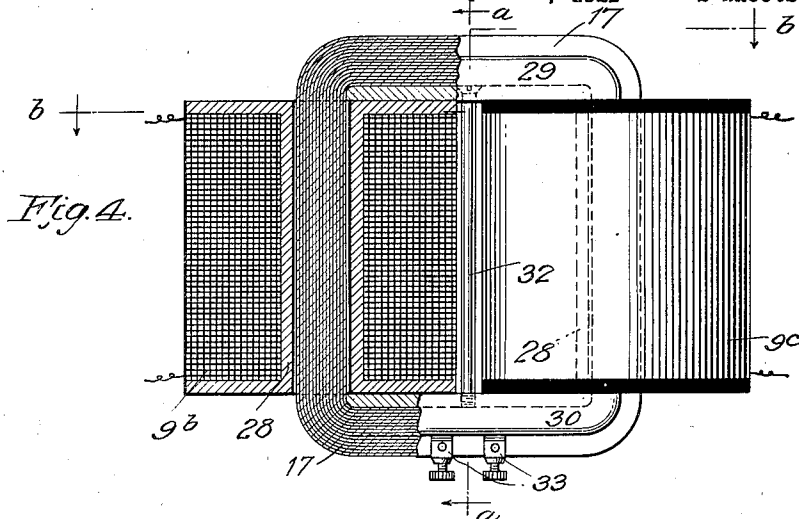
B. N. SOKOLOFF

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METHOD AND APPARATUS FOR AMPLIFYING ELECTRIC CURRENTS

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2 Sheets-Sheet 2



INVENTOR.
BORIS N. SOKOLOFF

BY
Stockbridge & Root
ATTORNEYS.

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UNITED STATES PATENT OFFICE.

BORIS N. SOKOLOFF, OF NEW YORK, N. Y.

METHOD AND APPARATUS FOR AMPLIFYING ELECTRIC CURRENTS.

Application filed September 29, 1922. Serial No. 591,347.

This invention relates to the amplification of relatively weak electric currents, and has for an object to provide an improved method and apparatus for accomplishing the amplification in a simple, effective and efficient manner. A further object is to accomplish the amplification by apparatus which is relatively simple, durable, compact, light in weight and inexpensive. Other objects and advantages will be apparent from the following description of an embodiment of the invention and the novel features will be pointed out in claim.

In the accompanying drawing:

Fig. 1 is a wiring diagram illustrating the principle of the invention;

Fig. 2 is an elevation of a portion of the apparatus which may be utilized;

Fig. 3 is an elevation of a conductor unit which may be used in the device of Figure 2;

Fig. 4 is an elevation, partly in section, of a modification of the apparatus shown in Figure 2;

Fig. 5 is a sectional elevation through the same, taken substantially along the line *a-a* of Figure 4;

Fig. 6 is a section of the same taken substantially along the line of *b-b* of Figure 4; and

Fig. 7 is a wiring diagram of a portion of the circuit and illustrating a modified apparatus.

Referring particularly to Fig. 1 the invention is illustrated in connection with an audion tube of a radio telephone and telegraph set which serves as a preliminary amplifier and rectifier of relatively weak currents to be amplified. In radio telephone and telegraph apparatus, for example, it is often necessary to have a large number of the tubes connected to one another through transformers in order to secure a current with a strength sufficient to operate a telephone receiver or loud speaker. When more than two audion tubes are connected in this manner, difficulties such as howling and other noises are encountered, which offset, to some extent, the advantages of amplification to be gained by the use of the additional audion tubes.

The filament 1 of the audion tube 2 is connected by wires 3 and 4 to opposite poles of a battery A, and the wire 4 includes therein a suitable adjustable rheostat 5.

The wires 6 and 7 carrying the weak currents to be rectified and amplified are connected respectively to the grid 8 of the audion tube and to the wire 3 connecting the A battery to the filament. One terminal of a magnetic coil 9 is connected at one end by an adjustable contact device 10 and a wire 11 to the plate 12 of the audion tube 2, and the other terminal of the coil 9 is connected by a wire 13 to one pole of a battery B. The other pole of battery B is connected by a wire 14 to the wire 3 passing between the filament and the A battery. The wires 6 and 11, leading respectively to the plate and grid of the audion tube, are connected together through a variable condenser 15, which provides an electrostatic coupling between the plate and grid circuits. With this electrostatic coupling, the advantages of a regenerative action of the audion tube are obtained, so that a greater amplification in the plate circuit will be obtained than would be possible if the regenerative connections were not utilized. It will be understood however, that the electrostatic coupling may be omitted if desired without preventing the operation of the apparatus.

I have also provided a variable condenser 16 bridged between the wires 11 and 13 leading to the terminals of the magnetic winding 9 so as to by-pass the radio frequency currents in the plate circuit of the audion tube, but it will be understood of course, that this condenser may be omitted if desired without rendering the device inoperative.

A conductor 17 is disposed in the magnetic field of the magnetic winding 9, and may form the core for the magnetic winding. One of the terminals of the conductor 17 is connected by wire 18 to a telephone receiver 19, which may be of the loud speaker type, and the other terminal of the conductor 17 is connected by a wire 20 through a switch 21 and wire 22 to a battery C. The other terminal of the battery C is connected by wire 23 to the other terminal of the telephone receiver 19. A variable condenser 24 may be bridged across the terminals of the telephone receiver 19 for the purpose of forming a by-pass for any radio frequency currents which may be found in the circuit of the conductor 17. The condenser 24 may be omitted without greatly affecting the operation of the device.

ing the operation of the device, and particularly so when the wires connected to the receiver 19 run parallel for a short distance so as to furnish the necessary capacity for by-passing the radio frequency currents. The amplified and rectified currents in the plate circuit act through the magnetic winding 9 and produce a pulsating magnetic field around the conductor 17.

The ohmic resistance of a conductor of electricity varies under the influence of a varying magnetizing force and therefore the fluctuations in the magnetic field around the conductor which are set up by the currents in the winding 9, will cause changes in the ohmic resistance of the conductor 17. When the switch 21 is closed, current from the battery C will pass through the conductor and through the telephone receiver 19. With the changes in the ohmic resistance of the conductor produced by the fluctuating magnetic field the current in the conductor 17 and through the telephone receiver 19 will pulsate in accordance with the changes in the magnetic field. The current passing through the conductor 17 and the telephone receiver may be given any desired initial strength and, therefore, will have an intensity sufficient to perform suitable work under the fluctuations produced by the varying resistance. A low resistance receiver 19 may be employed and ample energy in the circuit thereof will be available for operation of the diaphragm of the receiver so as to produce sound waves of the desired intensity. The contact 10 may be adjusted along the winding 9 so as to vary the effective number of ampere turns in the magnetizing coil, and therefore vary the intensity of the magnetic field. Among the materials which change their ohmic resistance with changes in a surrounding magnetic field are bismuth, cobalt, iron and nickel, but for a given change in the strength of the magnetic field, nickel shows the greatest change in resistance, its rate of change being about 8 times greater than that for iron or steel for the same field changes. The rate of change of the resistance for changes in the strength of the magnetic field is greatest in the highest strengths of fields, such as for example from one thousand to ten thousand c. g. s. There is also some variation in the rate of change of resistance of the material, dependent upon whether the field passes lengthwise or transversely of the conductor. The preferred material for the conductor 17 is nickel or nickel alloy because of the fact that its rate of change of resistance in a changing magnetic field is the greatest of known materials.

Referring particularly to Figures 2 and 3, one form of the magnetic winding and the conductor is shown. The winding 9^a

is placed upon a core 25 of suitable magnetic material such as iron or nickel, the poles 26 of which extend along one side of the winding 9^a and terminate in spaced relation to one another. The coil 9^a is not shown as provided with the adjustable contact 10 because for any given instrument the coil can ordinarily be given the proper number of turns and subsequent adjustment will be unnecessary. Obviously, taps can be run out from various turns of the winding at intervals therein and connected to suitable terminals over which an adjustable contact 10 may pass to vary the effective number of turns. Between the spaced poles 28, one or more conductor units 27 may be disposed so as to be within the path of the lines of force passing between the poles.

The conductor units may each comprise a double conductor extending spirally in a plane with the branches of the double conductor connected together at their inner ends so that currents induced in one branch by the varying magnetic field will be counteracted by currents induced in the other branch by said field. Any number of these conducting units may be connected either in parallel or in series with one another until the desired length of conductor 17 is obtained, but in Figure 2 these units are illustrated as connected in series with one another. In the use of this type of coil and conductor, the coil 9^a is connected in the circuit having the currents to be amplified, either directly or in the manner illustrated in Figure 1, and the conducting units are connected to the wires 18 and 20 in the manner shown in Figure 1.

In Figures 4 to 6 the conductor is disposed longitudinally in the direction of travel of the lines of force. In this embodiment of the coil and conductor, the coil A is preferably formed in two parts 9^b and 9^c having central longitudinal passages 28 through which the conductor 17 is threaded alternately so as to form a secondary coil which also forms a closed core for the coils 9^b and 9^c. In order to hold the turns of the conductor 17 together while passing between the coils 9^b and 9^c I may provide strips 29 and 30 of suitable insulating material upon the corresponding ends of the coils 9^b and 9^c so as to extend between the longitudinal passages 28. The strips 29 and 30 are each provided in its outer face with a semi-circular groove 31 in which the turns of the conductor 17 are disposed, and the two insulating strips may be clamped together and to the ends of the coils in any suitable manner such as by a screw 32 which is countersunk into one of the strips such as 29, passes between the coils and is threaded into the other insulating strip. The terminals of the conductor 17 are connected to binding posts 33 which are pro-

vided upon one of the strips such as 30. To these binding posts 33, the wires 18 and 20 of the wiring diagram of Figure 1 are to be connected. In this embodiment the conductor 17 forms a core through which the lines of force pass in a closed path and since the direction of travel of the lines of force is lengthwise of the conductor 17, no secondary currents will be induced in the conductor by the changes in the magnetic flux set up by the windings 9^b and 9^c.

As an example of apparatus which may be used, the following proportions regarding the circuits are given: In the primary circuit the two coils 9^b and 9^c may have 40,000 turns each of #36 copper wire, and with a current in the plate circuit of an audion tube of 3 milliamperes there will be 240 ampere turns. The magneto motive force $4 \pi N I$ equals 3,000. In the secondary circuit #23 B & S nickel wire, annealed, may be used with a normal resistance of approximately 30 ohms. A receiver of 1 ohm resistance may be employed and the resistance of the battery C is approximately 3 ohms. The resistance of the connections is negligible. The voltage of the battery may be 14 volts so that the permanent current in the secondary circuit will be approximately .42 amperes. With a magnetic field around the conductor ranging from one thousand to ten thousand c. g. s. the fractional increase of resistance, i. e. the increase of resistance divided by the resistance in zero field, for longitudinal magnetization in nickel wire is practically constant and amounts to approximately 1.7%.

Referring particularly to Figure 7, I have illustrated a system in which weak currents may be employed without preliminary amplification such as by the audion tube in the diagram of Figure 1. In this system a coil 9^a is employed for setting up a constant magnetic field some where between 1,000 and 10,000 c. g. s., the coil being supplied with current by wires 34 and 35 from a battery D, the wire 35 having included therein a suitable regulating rheostat 36. The circuit coil 9^c is arranged adjacent the coil 9^a and the conductor 17 is disposed in the combined magnetic field produced by these two coils 9^a and 9^c. This may be accomplished conveniently by winding the conductor 17 through the cores of the coils 9^a and 9^c so as to form a continuous magnetic core therefor. The coil 9^c is connected by wires 37 and 38 to the source of the weak currents to be amplified. In this arrange-

ment a strong magnetic field will be maintained by the coil 9^a, and the relatively weak currents passing through the coil 9^c will produce variations in the strength of the resultant magnetic field around the conductor 17, so that the change in the resistance of the conductor 17 by the changing of the field intensity will cause changes in the current passing in the conductor 17 and through the telephone receiver 19. The terminals of the conductor 17 are connected to wires 18 and 20 of the secondary circuit as illustrated in Figure 1.

It will be observed that with all of the arrangements herein described, the relatively weak electric currents will be employed to produce changes in a magnetic field around the conductor 17 of nickel, iron, or other suitable material, so as to change its ohmic resistance. A working circuit includes the conductor 17 therein so that the changes in resistance will produce corresponding changes in the current passing in the working circuit. The arrangements herein described are particularly valuable when utilized in connection with radio telephone and telegraph receiving circuits in which the relatively weak currents in the antenna circuit must be amplified considerably in order to operate suitable apparatus such as telephone receivers. It will be understood however, that the invention is applicable to all instances where relatively weak currents are to be amplified and is not to be limited to radio apparatus.

It will be obvious that various changes in the details and arrangements of parts herein described and illustrated for the purpose of explaining the nature of the invention may be made by those skilled in the art within the principle and scope of the invention.

I claim:

In electric current amplifying devices, means by which the currents to be amplified produce variations in a magnetic field, a magnetic conductor disposed in said magnetic field and having sections running in opposite directions to neutralize currents induced therein by the magnetic field, and a circuit including a source of current and the conductor whereby the current in the conductor will be varied by the changes in the ohmic resistance of the conductor which are caused by the variations in the magnetic field.

In witness whereof, I hereunto subscribe my signature.

BORIS N. SOKOLOFF.