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H. S. READ
AMPLIFIER CIRCUITS

Original Filed April 27, 1920

Fig. 1.

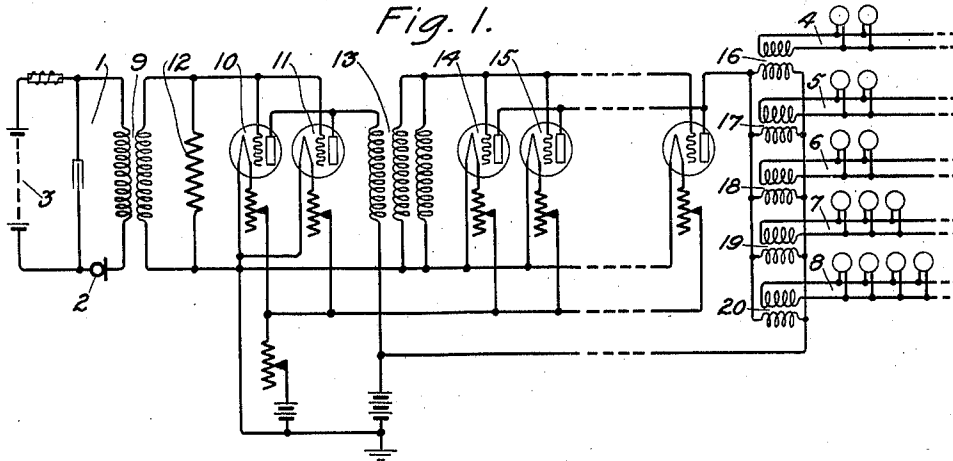
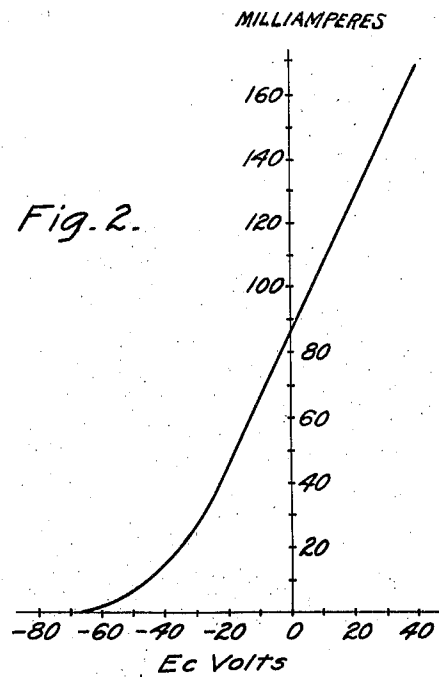


Fig. 2.



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UNITED STATES PATENT OFFICE.

HARRY S. READ, OF ITHACA, NEW YORK, ASSIGNOR TO WESTERN ELECTRIC COMPANY, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK.

AMPLIFIER CIRCUITS.

Application filed April 27, 1920, Serial No. 376,909. Renewed April 8, 1925.

To all whom it may concern:

Be it known that I, HARRY S. READ, a citizen of the United States, residing at Ithaca, in the county of Tompkins and State of New York, have invented certain new and useful Improvements in Amplifier Circuits, of which the following is a full, clear, concise, and exact description.

The invention relates to amplifying systems and has for an object to provide a system capable of amplifying the voice energy from one loud speaking transmitter to a magnitude sufficient to operate a large number, for instance, as many as 100 loud speaking receivers.

The invention makes use of vacuum tube amplifiers and provides an amplifier set that is capable of giving a very large output. In the use of the audion type amplifier, it has been common practice heretofore to maintain the grid or control electrode at all times at a negative potential with respect to the cathode, in order that none of the electrons emitted by the cathode will go to the grid. This prevents a flow of current in the grid-cathode circuit, thereby providing a high input circuit which consumes a very small amount of energy.

According to prior practice, where the grid is always maintained negative, it has been possible to work the vacuum tube amplifiers only over a very limited range, for the incoming potentials have always been maintained small enough to prevent overcoming the normal steady negative potential of the grid. This limitation is not imposed on the circuit provided according to the present invention, however, which embodies a circuit working the amplifier over a very wide range of voltages, thereby deriving from the vacuum tube amplifier an appreciably greater amount of energy.

According to this invention, the grid is not maintained normally at a negative potential with respect to the cathode, but the grid is instead at the same potential as the negative end of the cathode in the absence of electrical impulses to be repeated. In this case an electrical impulse applied to the cathode grid circuit will, at times, give the grid a potential which is positive with respect to the cathode. At such times as the grid is positive, current flows in the cathode-grid circuit and the impedance of the

cathode-grid circuit becomes much lower than at a time when the grid is negative. It is therefore evident that more energy must be supplied to the grid-cathode circuit to establish a given positive potential on the grid than an equal negative potential, and that the amount of this energy will vary with the magnitude of the potential to be established. From a slightly different viewpoint this means that the instantaneous impedance of the grid-cathode circuit varies from point to point along the applied positive voltage wave, such variations in practical amplifiers for voice frequencies being from several megohms to a few thousand ohms. It will now be clear that if the input or supply circuit have such a high impedance that the internal voltage drop due to drawing current to the grid is appreciable, a very serious distortion of the positive half wave will result. Distortion from this source approaches zero as this supply circuit is made to approach zero impedance. For high grade tone quality and articulation of repeated voice currents it has been found sufficient, in amplifiers of this type, to make the impedance of the connected line or supply circuit of the same order of impedance as the minimum impedance reached by the grid-cathode circuit during the positive half wave.

It is of course realized that with the lower impedance of the input circuit more energy will be needed to supply a given potential to the grid circuit. This can readily be compensated for by employing one or two tubes to supply the energy to the grids of many tubes in multiple each operating at or near its maximum energy output. It has been found that instead of adding more tubes in parallel in a high power amplifier having the tubes operated with the grids negative, it is by far more efficient to add this auxiliary amplifying stage for driving the grids positive.

For further details of the invention, reference may be made to the drawings in which Fig. 1 represents diagrammatically a vacuum tube amplifier system embodying the features of this invention. Fig. 2 is a curve showing the relation between the grid voltage and the plate current of a vacuum tube amplifier.

Referring in detail to Fig. 1, the circuit 1

which includes a transmitter 2 and battery 3 represents a source of impulses to be repeated and amplified. The lines 4, 5, 6, 7 and 8 may each lead to a plurality of loud speaking receivers. A total of as many as 103 receivers have been satisfactorily operated by the circuit arrangement shown. Between the incoming line 1 and the outgoing lines 4 to 8 is connected the amplifier set, which makes it possible to amplify the relatively weak impulses in the line 1 sufficiently to operate a large number of receivers. The line 1 is connected by transformer 9 to two vacuum tubes 10 and 11 in parallel.

The resistance 12 for speech amplifier design may have a value of the order of 12,000 ohms, this being such that the minimum impedance of the grid-cathode circuit will be about equal to the absolute value of the impedance of this resistance and the line transformer in parallel. The vacuum tubes 10 and 11 are coupled by means of transformer 13 to a large number, for instance, ten vacuum tubes 14, 15, etc., connected in multiple and working into the output transformers 16, 17, 18, 19 and 20. The secondary winding of transformer 13, shown with two secondary windings in parallel, has the proper turns ratio to transform the impedance of the first stage to match the minimum impedance of the the grid circuit of the multiple audions 14, 15, etc. The value of this minimum impedance will depend upon the number and the type of tubes employed, as well as the value of the impressed potential, but in the apparatus illustrated, it may be said that the impedance of these multiplied tubes will be of the order of two or three thousand ohms. It may be desirable in some cases to shunt the grids 14, 15, etc., by a resistance corresponding to 12 and its value would be determined by the same criterion. If it is necessary to employ the amplifier for purposes which admit of less distortion than the reproduction of speech for intelligible audition, the values of these resistances may of course be reduced and the transformer ratios modified accordingly.

Referring to Fig. 2, this shows the relation between the grid voltage (E_c) and the plate current (I_b milliamperes) for each of the tubes which have been employed in the circuit of Fig. 1 with good results. The curve shows that the tubes could have a range of ± 30 volts peak value, about the value -30 volts, in the grid circuit without causing the grid to become positive with respect to the filament. The corresponding plate current would be about 40 milliamperes per tube peak value. This would correspond to about 1.15 watts peak value per tube. By allowing the grid to become positive, the voltage range is increased to ± 60 volts grid voltage, about the value 0 volts, and the plate current is increased to approxi-

mately 100 milliamperes per tube, so that the power is increased to 7.1 watts peak value per tube. It is apparent that by operating the grid with positive potentials the power output in this case is multiplied practically by 6. The potential supplied by circuit 1, Fig. 1, should be such as to drive the grid to a large positive potential in the case of the tube having the characteristic illustrated in Fig. 2. This potential may be of the order of 60 volts.

Considerable advantage is to be derived from connecting (as in Fig. 1) two vacuum tube sets in tandem, each set comprising a plurality of tubes in parallel. In the above mentioned instance, where two vacuum tubes in parallel were connected in tandem to ten vacuum tubes in parallel, it was found possible to operate the one hundred and three 2500-ohm loud speaker receivers even though one amplifier in the first set and four amplifiers in the second set were removed. Thus it would be possible during operation of the circuit for one amplifier in the first set and four in the second set to become inoperative due to burning out the filament, breaking the glass envelope, etc., without rendering the circuit as a whole inoperative. This is of particular advantage when the circuit is employed as loud speaking telephone equipment for a battleship.

An application in the name of R. A. Heising, Serial No. 432,444, filed December 22, 1920, assigned to the assignee of this application, claims broadly the feature of having the impedance which faces the grid-cathode internal impedance of a vacuum tube low, in order that the impedance across the grid and cathode may not vary unduly when the grid becomes positive.

What is claimed is:

1. An incoming line adapted to supply impulses to be amplified, a vacuum tube amplifier having a cathode, an anode and a control electrode, means connecting said control electrode and said cathode to said incoming line and maintaining the steady potential between said cathode and said control electrode at such a value that said amplifier operates on only the substantially straight part of its input voltage-anode current characteristic in repeating said impulses, the impulses supplied by said line being sufficiently large to give said grid a potential which is positive with respect to the cathode, and the impedance of the line connected to said control electrode and said cathode being approximately the same as the impedance of the control electrode circuit when the control electrode is at its maximum positive potential.

2. An incoming line adapted to supply impulses to be amplified, a vacuum tube amplifier comprising a cathode, an anode and a control electrode, and means connecting

said cathode and said control electrode to said line and maintaining the steady voltage between said cathode and said control electrode at such a value that said amplifier operates on only the substantially straight part of its input voltage-anode current characteristic in repeating said impulses, the magnitude of the impulses supplied by said line being sufficient to make said grid positive at times, the control electric circuit exterior to said vacuum tube having an impedance of the order of the impedance between said control electrode and cathode when said control electrode is at a positive potential.

3. In combination, a vacuum tube amplifier having a cathode, an anode and a control electrode, an incoming line connected to said electrode for supplying alternating current impulses to said electrode, and means maintaining said cathode and said electrode at substantially the same potential in the absence of said impulses, and causing said amplifier to operate on only the substantially straight part of its input voltage-anode current characteristic in repeating said impulses, the impedance of said line connected to said electrode being approximately the same as the minimum impedance of said amplifier between said electrode and said cathode.

4. An incoming line adapted to supply impulses to be amplified, a vacuum tube amplifier, means inductively connecting said amplifier to said line, said amplifier having a control electrode, the magnitude of the impulses of said line being sufficient to make the potential of said control electrode at times positive, and means on the input side of said amplifier for reducing the distortion of the wave when said grid is positive with respect to said cathode and causing said amplifier to operate on only the substantially straight part of its input voltage-anode current characteristic in repeating said impulses.

5. The method which comprises assigning to the grid of a vacuum tube amplifier a zero steady potential during normal operation of the amplifier, energizing said amplifier with alternating current impulses, compensating for the loss occasioned by the consumption of energy in the grid circuit when said grid is at a positive potential with respect to its cathode, and approximately matching the impedance of the incoming line to that of the minimum impedance of said grid circuit.

6. The method which comprises supplying the grid circuit of a vacuum tube amplifier with alternating current impulses of value sufficiently to make the potential of said grid positive with respect to its cathode, approximately matching the impedance of the incoming line to that of an impedance value of said grid circuit when said grid is posi-

tive, and maintaining the steady potential of said grid at such a value that the amplifier operates on only the substantially straight part of its grid potential-anode current characteristic in repeating said impulses.

7. The method which comprises supplying the grid circuit of a vacuum tube amplifier with alternating current impulses of value sufficient to make the potential of said grid positive with respect to its cathode, approximately matching the impedance of said incoming line to the minimum impedance of said grid circuit and maintaining the steady potential of said grid at such a value that the amplifier operates on only the substantially straight part of its grid potential-anode current characteristic in repeating said impulses.

8. The method which comprises supplying the grid circuit of a vacuum tube amplifier with alternating current impulses of value sufficient to make the potential of said grid positive with respect to its cathode, approximately matching the impedance of the incoming line to that assumed by said grid circuit when said grid is at a positive potential, and compensating for the loss occasioned by the consumption of energy in said grid circuit due to the potential of said grid becoming positive with respect to its cathode, and maintaining the steady potential of said grid at such a value that the amplifier operates on only the substantially straight part of its grid potential-anode current characteristic in repeating said impulses.

9. The combination of a line adapted to supply alternating current impulses to be amplified, a vacuum tube amplifier connected thereto, a second vacuum tube amplifier, a coupling between said amplifiers, said coupling having an impedance substantially matching an impedance value of the grid circuit of said second mentioned amplifier under the condition that the grid of said circuit is at a positive potential, and said coupling comprising means maintaining the steady potential of said grid at such a value that the amplifier operates on only the substantially straight part of its grid potential-anode current characteristic in repeating said impulses.

10. The combination of a line for supplying electrical variations, a vacuum tube amplifier connected thereto and having means for maintaining its steady input voltage at such a value that said amplifier operates on only the substantially straight part of its input voltage-anode current characteristic in amplifying said variations, a second vacuum tube amplifier, for further amplifying said variations, said second amplifier having means for maintaining its steady input voltage at such a value that the amplifier operates on only the substantially straight part of its input voltage-

anode current characteristic in amplifying said variations, a transformer between said line and said first mentioned amplifier, a second transformer between said amplifiers, 5 the impedance of the secondary circuits of said transformers substantially matching impedance values of the grid circuits to which they are connected under the conditions that the grids of said circuits are positive. 10

11. The combination of a source of current impulses, a vacuum tube amplifier connected thereto, a substantially pure electron discharge vacuum tube amplifier having a cathode and a grid, and a coupling between said 15 amplifiers, said coupling having an impedance substantially matching the minimum grid-cathode impedance of said second mentioned amplifier, and said coupling comprising means maintaining zero normal steady 20 potential on the grid of said second amplifier and causing that amplifier to operate on only the substantially straight part of its

grid potential-anode current characteristic in repeating said impulses. 25

12. The combination of a line, a vacuum tube amplifier stage connected thereto, a second vacuum tube amplifier stage for repeating without substantial change of wave 30 form, electrical variations delivered thereto from said first mentioned amplifier stage, and a transformer between said stages, said second stage having its input electrodes, including a control electrode, at the same steady potential during normal operation of 35 the systems, and the impedance at the secondary circuit of said transformer substantially matching the impedance facing said circuit from said electrodes under the condition that said control electrode is positive. 40

In witness whereof, I hereunto subscribe my name this 20th day of April A. D., 1920.

HARRY S. READ.