Dec. 17, 1940. N. E. LINDENBLAD 2,224,915

AMPLIFIER

Original Filed Feb. 1, 1935 3 Sheets-Sheet 1

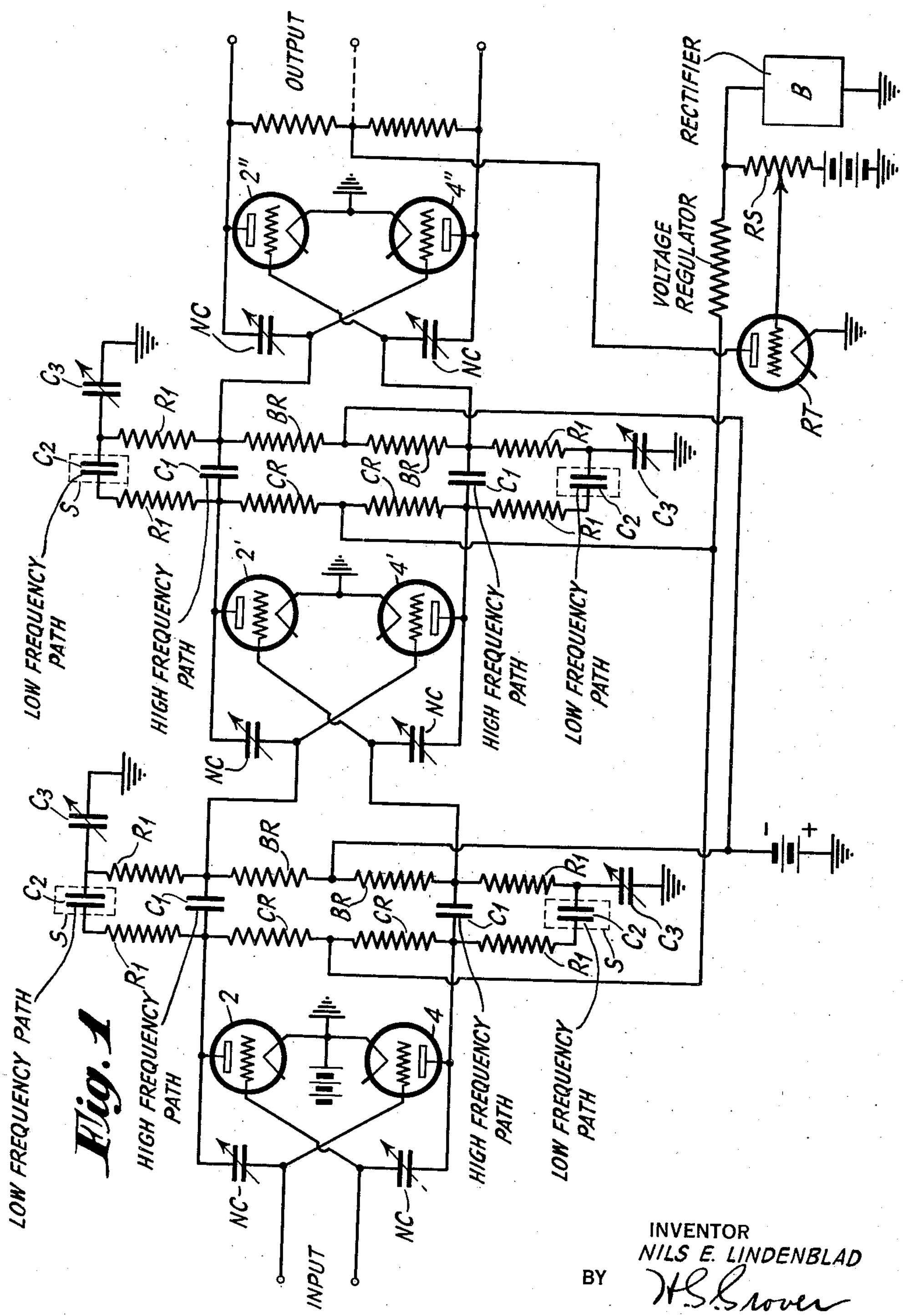

Fig. 1

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Fig. 2

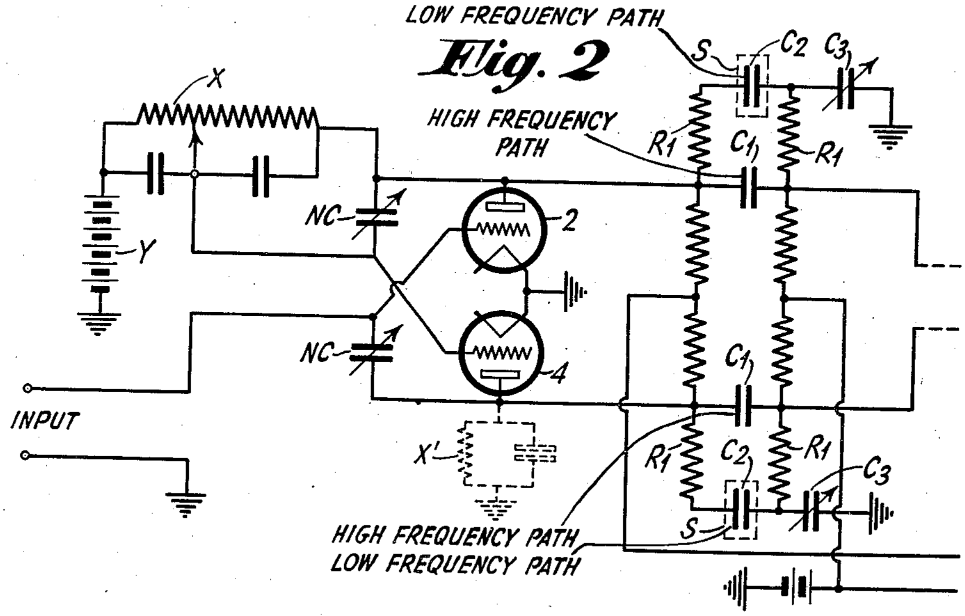

Fig. 3

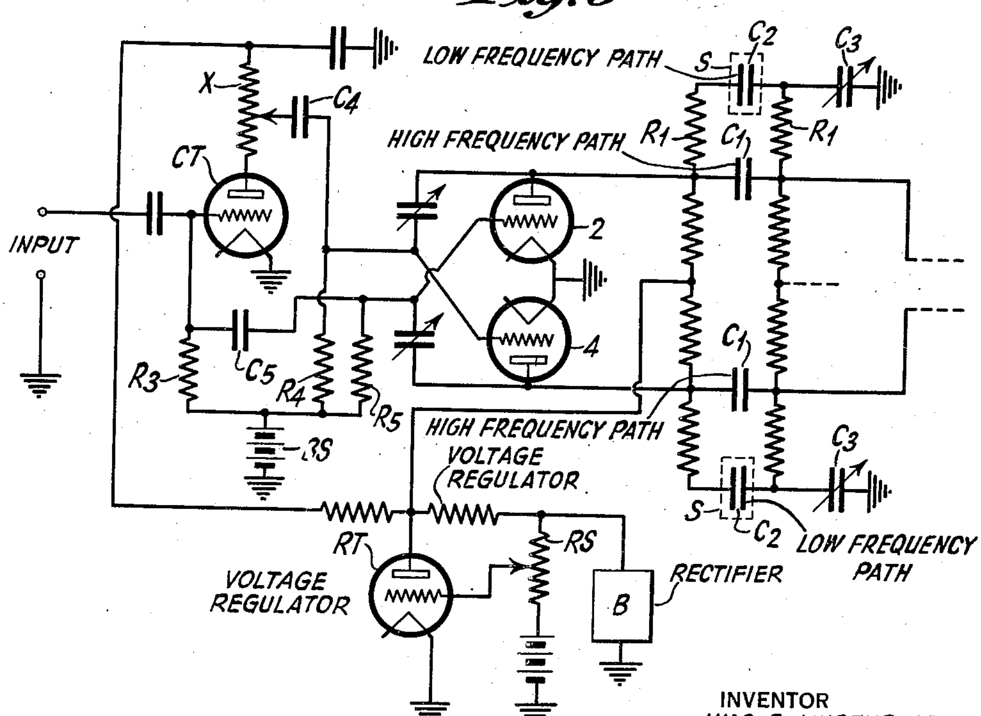

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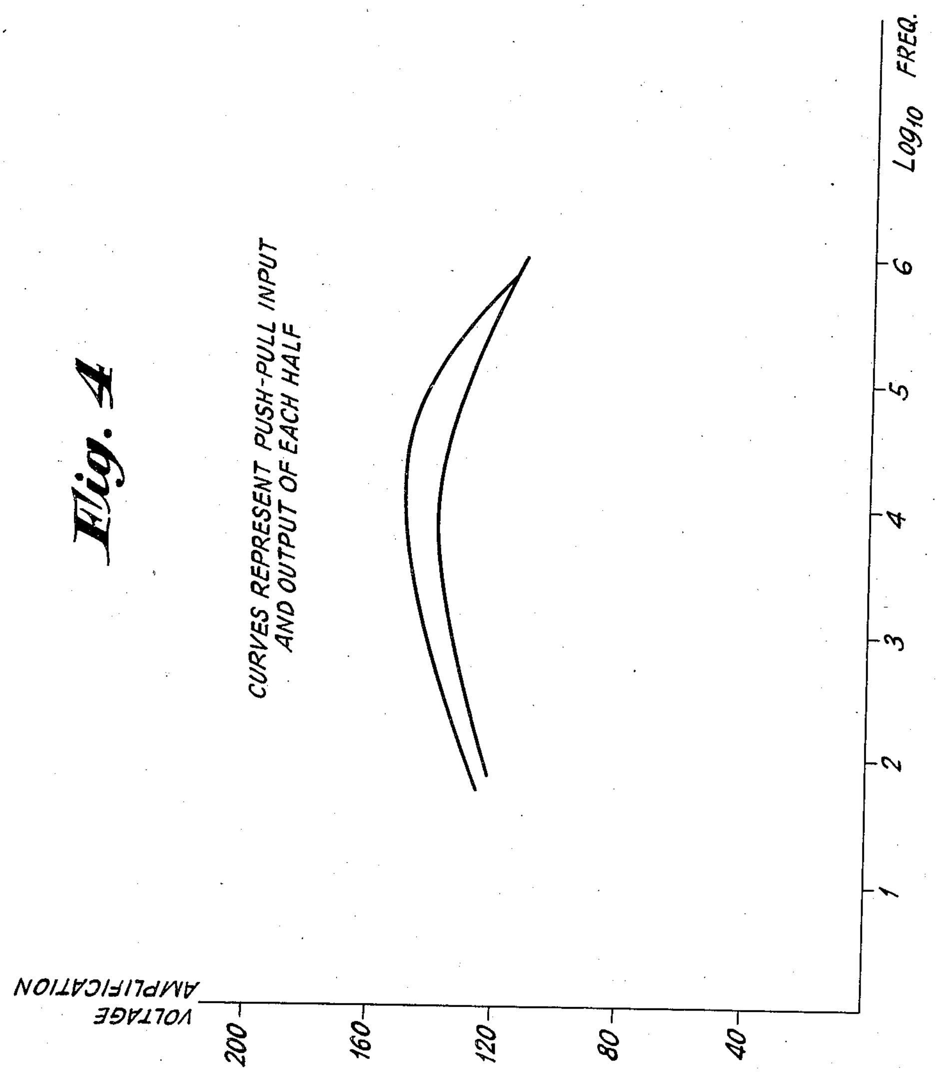
Fig. 4



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UNITED STATES PATENT OFFICE

2,224,915

AMPLIFIER

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Original application February 1, 1935, Serial No. 4,474. Divided and this application July 17, 1937, Serial No. 154,152

6 Claims. (Cl. 179—171)

My application Serial #4,474 filed February 1, 1935, now U. S. Patent No. 2,131,566, granted September 27, 1938, relates to amplifier of the thermionic type and is in particular concerned with an amplifier of flat characteristics over an extremely wide frequency range such as for example 20 to 1,000,000 cycles. The amplifier of the said invention makes use of thermionic tubes now in commercial use, although certain characteristics of said tubes, such as limited electron emission and large inter-electrode capacity, work against the operation of said tubes effectively in known circuits over a frequency band of less width than the frequency band involved in this invention. By my novel circuit, a frequency band of extreme width is successfully amplified, and all of the frequencies in said band are amplified, substantially the same amount.

In working on this problem, it at once became clear that transformer coupling between the stages must be excluded at least for the time being, because of the limited frequency range which can be passed by transformer coupling means. I next investigated the possibilities of capacity-resistance coupling. Moreover, it was found desirable to use such coupling in conjunction with push-pull type of amplifier circuits due to their symmetry and the ease with which neutralizing may be accomplished in such circuits. Having decided on these points, the task left was to determine such coupling constants which would result in a flat amplifying characteristic between 20 to 1,000,000 cycles. It became apparent that a condenser with a high coupling capacity and having the necessary insulation to separate the plate voltage in one stage from the grid voltage in the next stage is of necessity a condenser of appreciable physical dimensions. A condenser of such dimensions has an appreciable stray capacity, while this stray capacity has only a small shunting effect at 20 cycles, its shunting effect at 1 megacycle has a paralyzing influence on the efforts to obtain the desired flat characteristic. On the other hand, if a condenser of smaller physical dimensions be used, it cannot be given enough capacity to carry through the lower frequencies. It also became clear that a compromise could hardly be obtained and that instead of a compromise, some kind of combination of the two condensers had to be worked out in order to obtain the desired result. The solution that was finally arrived at was to combine one small and one large capacity as components in a network or impedance trap of such a characteristic that practically only one of the two capacities are in function at each extreme end of the frequency band. Both capacities are to varied extents operative at frequencies intermediate the extreme ranges. The amplifier described above has been claimed in my United States application #4,474 filed February 1, 1935, now U. S. Patent No. 2,131,566, granted September 27, 1938, of which application the present is a division.

As indicated above, the amplifier of the present invention is, for reasons also pointed out above, of the push-pull type. The input energy supplied to the amplifier may be supplied from a push-pull source and may be fed in the usual manner to the control grids of the first stage. In many cases, it is necessary to connect the amplifier of the present invention to a single-ended stage. Several novel means for adapting the push-pull wide frequency band amplifier described above to connection with a single-ended source have been disclosed in this application.

The nature of my invention and the manner in which the same as carried out will be understood from the following detailed description thereof and therefor when read in connection with the drawings throughout which like characters indicate like parts insofar as possible and in which:

Figure 1 illustrates a thermionic amplifier of the push-pull type comprising several stages interconnected by the novel network of the present invention. In Figure 1, the input is assumed to be taken from a push-pull source, while the output circuit of the final stage is arranged to feed either a push-pull utilization circuit or a single-ended circuit.

Figures 2 and 3 illustrate amplifiers of the nature illustrated in Figure 1. In Figures 2 and 3, however, a novel means is included for feeding the push-pull amplifier from the output of a single tube or single-ended stage.

Figure 4 is a curve illustrating the characteristics of the amplifier of the present invention.

In Figure 1, I have shown a cascaded amplifier of the push-pull type, comprising pairs of electron discharge tubes 2, 4, 2′, 4′, etc., connected in cascade by way of resistance and capacity networks, as shown. The input of the first stage may be connected to a full wave source. The anode-to-control grid capacity of each stage is as shown neutralized by a capacity NC. The output of the push-pull amplifier may be connected to a push-pull ultilization circuit by means of leads represented by the solid lines or to a single-ended input by means of one of the said leads and a lead represented by the dotted line.

As will be seen by an inspection of Figure 1, the small capacities C_1 are directly connected between the anodes of the tubes **2**, **4** and the control grids of the tubes **4'**, **2'**, respectively, whereas the large capacities C_2 are as shown connected in parallel to the capacity C_1 by way of link resistors R_1. The succeeding stages are as shown connected in a similar manner.

During operation at the high frequency end of the band the small capacities C_1 have a low reactance and therefore the coupling current prefers passage through these capacities rather than going through capacitors C_2 by way of link resistors R_1. This is, however, not a point of importance. The important fact is that at this high frequency, the stray capacity of the large condenser C_2 is in series with the resistors R_1, and the effect of this stray capacity on the swing of the grids is reduced. At the very lowest frequencies, the reactance of condensers C_1 is very high and the coupling current is forced through condensers C_2 by way of the resistors R_1. This might seem inefficient to force the coupling current through a resistance, but it must be remembered that the tube reactance being extremely high at these frequencies results in a very high grid impedance, since the grids are biased to carry no electron current. The fact that the load from the grids is negligible at the low frequencies therefore makes the fact insignificant that they are fed through resistors R_1. By actual measurements of the characteristics of this circuit, it was found that it was not necessary to take too great precautions in keeping the stray capacities of condensers C_2 down by providing very spacious shields S around the said capacities. The spacing of the shields was made smaller and this is desirable as it results in smaller dimensions of the amplifier as a whole. The stray capacities of these condensers not only can be made larger, but it was found advisable and necessary to do so. To increase the stray capacities of the condensers C_2, I provide as shown, an additional condenser C_3 which is preferably variable. This condenser, which is small in capacity relative to condenser C_2, may be connected on either side of C_2 between C_2 and ground. In this manner, a fine regulation of the stray capacity may be accomplished. Another reason for the need of the variable capacity C_3 is that at the intermediate frequencies of about 100,000 cycles, the amplifier without the use of said capacities gives somewhat higher amplification due to an optimum impedance condition of my simple network without a correct stray capacity of condenser C_2. With this condition corrected by means of adjusting the stray capacity, the variation in amplification throughout the whole band between 20 cycles and 1 megacycle was at one time brought below two decibels (1.25:1).

In operation, it is desirable to have a well regulated or steady direct current source B supplying plate current to this type of amplifier. Preferably, however, a separate voltage regulator tube RT and the resistor system RS may be connected as shown with the source B. A similar arrangement has been described in detail in my United States Patent #2,052,576 dated September 1, 1936. The source B may be a direct current machine or may represent the output of a rectifier connected with a source of alternating current. Grid biasing potentials for the tubes **2'**, **4'** and **2''**, **4''** may be supplied from sources connected as shown with the control grids of these tubes. Grid biasing potentials for tubes **2** and **4** may be supplied by the source connected with the cathodes of **2** and **4** by way of a lead (not shown) connected to a point on the input circuit.

In practice, it is desirable that terminal circuits be arranged so that this amplifier, which as shown in Figure 1 is assumed to be supplied from a push-pull stage, may be connected also to single ended circuits in such a way that the push-pull stages receive balanced input. An arrangement for accomplishing this has been shown in Figure 2.

Assume that the signal is to be supplied from the output of a single ended stage between the control grids of one of the tubes **2**, **4** and ground as shown by way of the leads marked Input; the signal on the grid of tube **2** modulates or controls the voltage on the plate of tube **2** and this control or variation is opposite in phase to the controlling potentials applied to the grid. This voltage variation or modulation appears across the resistor X connected as shown by way of source Y between the plate of tube **2** and ground. Voltage variations or modulations are supplied from the resistance or potentiometer X by way of a movable point and a lead to the control grid of tube **4**. By moving the point on the potentiometer X to the proper position, voltages of an amplitude equal to the amplitude of the voltages on the grid of tube **2** and of a phase opposite in phase to the voltages on the grid of tube **2** may be applied to the grid of tube **4** so that we have a true push-pull input. The source Y provides a counterelectromotive force to insure correct direct current voltage on the grid of tube **4**. Condensers proportional, in reactance, to the resistance on each side of the tapping point may be connected with the resisance X as shown. These condensers, if used, must be very small. An additional circuit containing a resistor X' may be added to the plate of tube **4** to complete the balance.

Another arrangement for adapting a single ended input to my push-pull amplifier has been shown in Figure 3. In Figure 3, a converter tube CT may have its control grid and cathode connected as shown to any source of alternating current potential to be amplified. A capacity may be included in this connection. The input line and the control grid of tube CT are also connected as shown by way of a coupling and direct current blocking condenser C_5 to the control grid of one of the tubes in the first push-pull stage, as for example tube **2**. The grid of the other tube, as for example tube **4**, in the first push-pull stage is supplied by potentials from a potentiometer resistance X connected in series between the plate and the anode source B. The variations of the voltage across this potentiometer will then be of opposite phase with respect to the voltage variations applied to the grid of this same converter tube CT. By adjusting the tap connected between the control grid of tube **4** and potentiometer resistance X by way of coupling and direct current blocking condenser C_4, a voltage for the grid of tube **4** may be obtained which is equal to the voltage applied to the grid of tube **2** and of a proper phase relative to said voltage to insure balanced push-pull input for the push-pull stage **2**, **4**. The point at which the condenser C_4 is connected to X depends upon the amplification of the tub CT.

Biasing potentials to the control grids of tubes CT, **4**, and **2** respectively from the source BS are supplied through the resistances R_3, R_4, and R_5. The regulator tube RT may be connected with the plate potential source B by way of a resistance system RS, as shown.

The push-pull amplifier of Figures 2 and 3 and the networks interconnecting the stages thereof are as shown in Figure 1.

The characteristics of a push-pull amplifier the cascaded stages of which are interconnected by the network of my invention have been illustrated by the curves in Figure 4, wherein frequency is plotted as abscissae against voltage amplification as ordinates. As can be seen, the amplifier has a flat characteristic over an extremely wide frequency range.

I claim:

1. In a system for transferring potentials from two terminals, one of which is at fixed potential and the other of which varies in potential relative to said one terminal to two other terminals, both of which vary in potential relative to said one terminal at fixed potential, an electron discharge tube having a control grid, a cathode, and an anode, a connection between the cathode of said tube and said point of fixed potential, a condenser connected between said other terminal, the potential of which varies, and the control grid of said tube, a condenser connecting one of said two other terminals and said control grid, an impedance and a source of potential connecting the anode of said tube to the cathode of said tube, a movable point on said impedance, and a condenser coupling the other of said two other terminals to said movable point.

2. In a system for transferring potentials from two terminals one of which is at fixed potential and the other of which varies in potential relative to said one terminal to three other terminals, one of which is of fixed potential and the other two of which are of potentials which vary relative to said one, an electron discharge tube having an anode, a cathode, and a control grid, a connection between the cathode of said tube and said latter point of fixed potential, a condenser coupling said other terminal of said two terminals to the control grid of said tube, a condenser coupling said grid to one of the other two of said three terminals, an impedance connecting the anode of said tube to the cathode of said tube and a condenser coupling an adjustable point on said impedance to the other of the other two of said three terminals.

3. Means for impressing oscillations from a single ended stage on the control grids of a pair of thermionic tubes in push-pull fashion in like amounts comprising, a coupling between the control grid of said single ended stage and the control grid of one of said tubes of said pair of thermionic tubes, a resistance connected to the anode of said single ended stage, and means coupling a point on said resistance to the control grid of the other tube in said pair of thermionic tubes.

4. In a system for transferring potentials which cover a wide frequency range from two leads, one of which is at fixed potential and the other of which varies in potential relative to said one to three terminals, one of which is of fixed potential and the other two of which are of potentials which vary relative to said one, a plurality of electron discharge tubes each having an anode, a cathode, and a control grid, a connection between the cathode of two of said tubes and said fixed point, a condenser coupling said other of said two leads to the control grid of one of said two tubes, a connection between the control grid of a third tube and said other of said two leads, an impedance connecting the anode of said third tube to the cathode of said third tube, a condenser coupling an adjustable point on said impedance to the control grid of the other of said two tubes, and connections between the anodes of said two tubes and said other two terminals.

5. A system as recited in claim 4 wherein each of said last connections include a plurality of parallel paths each responsive to potentials of a different frequency range, the several paths being responsive to a wide frequency range.

6. Means for impressing oscillations from a single ended amplifier stage including a thermionic discharge tube having at least a control grid and anode on the control grids of a pair of thermionic tubes each having at least a control grid and an anode in push-pull fashion in like amounts comprising, a condenser coupling control grid of one of said tubes of said pair of thermionic tubes to the control grid of said single-ended stage, a resistance connected to the anode of said single ended stage, and capacitive means coupling a point on said resistance to the control grid of the other tube in said pair of thermionic tubes.

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