

March 17, 1942.

M. G. CROSBY

2,276,565

LIMITING AMPLIFIER

Filed May 23, 1939

2 Sheets-Sheet 1

Fig. 1

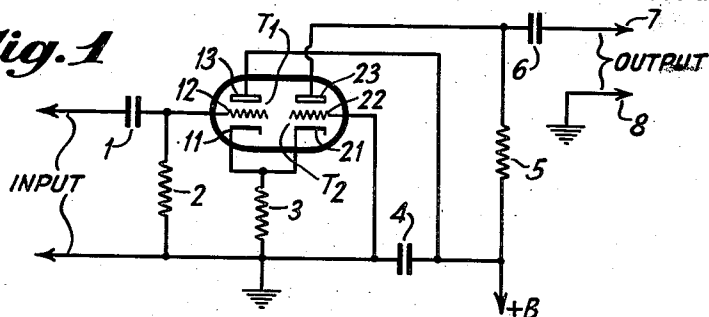


Fig. 2

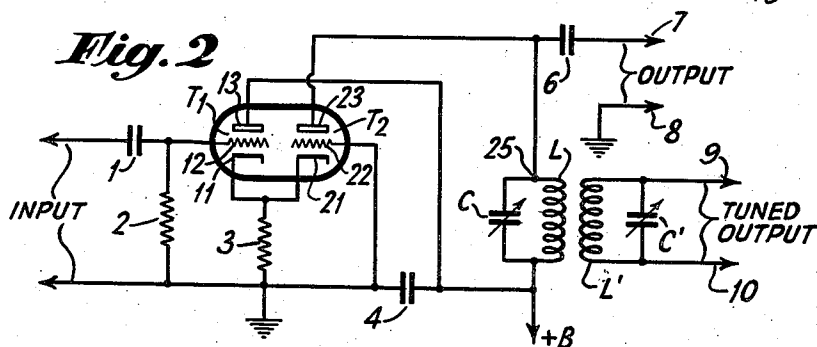


Fig. 4

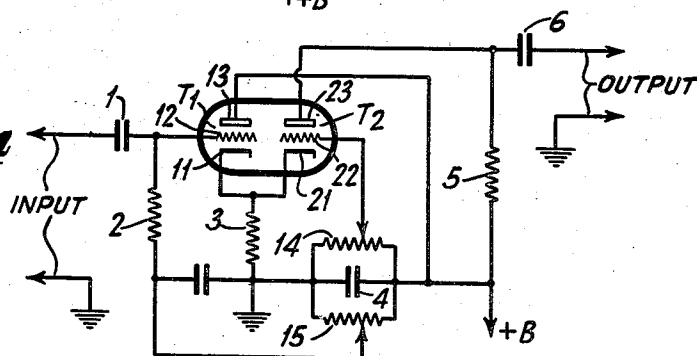
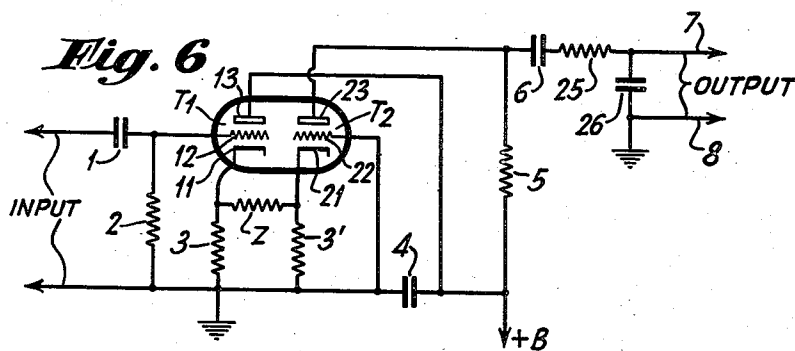


Fig. 6



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2 Sheets-Sheet 2

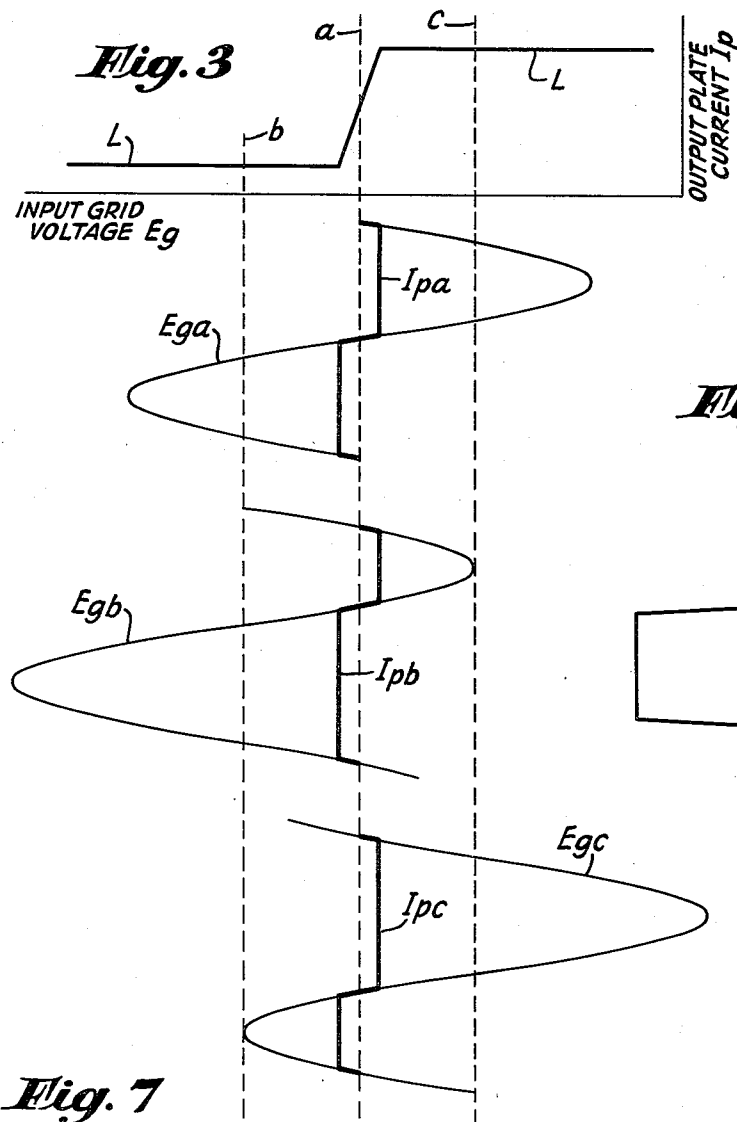


Fig. 5

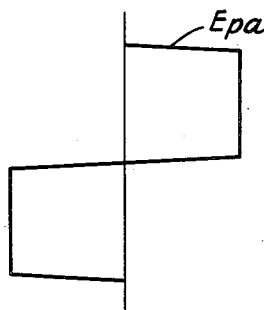
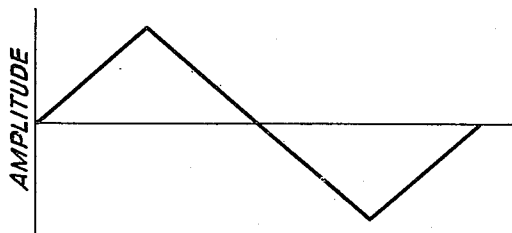


Fig. 7



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2,276,565

LIMITING AMPLIFIER

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Application May 23, 1939, Serial No. 275,151

13 Claims. (Cl. 178-44)

The present invention relates to amplifiers and, more particularly, to limiting amplifiers in which both positive and negative half cycles of the input wave are limited to a predetermined amplitude.

As far as I am aware, limiters disclosed in the prior art have been either of the negative grid cascaded direct current amplifier type or of the type which utilizes an overloaded tube with lowered element voltages. Limiters of the first mentioned type which utilize cascaded direct current amplifiers are ordinarily directly coupled by means of bucking batteries. Thus the plate of the first stage of amplification is connected directly to the grid of the second stage through a bucking battery which keeps the plate voltage from being effective on the grid of the second stage. These bucking batteries are bulky and inconvenient from the standpoint of replacement. Furthermore, the majority of the batteries used in this type of limiter are at a high potential relative to ground. The second mentioned type of limiter which utilizes an overloaded tube depends upon negative grid cut-off to limit one-half cycle of the wave and upon a lowered element voltage for the limiting of the other half cycle. This arrangement, as far as I am aware, usually results in a dissymmetry which produces a limiter which is not "flat." A limiter which is not "flat" is one whose output does not remain constant after the limiting point is reached but rises or lowers. Another disadvantage which usually accompanies limiters heretofore known in the art is the fact that the input grid draws current and places a load on the input circuit above a certain input level.

An object of the present invention is to provide a limiter which is free from the heretofore mentioned disadvantages.

Another object of the present invention is the provision of a negative grid cut-off limiter which will accurately limit both positive and negative half cycles of the input wave.

Still another object is the provision of a limiter which has stable characteristics.

A further object of the present invention is the provision of a limiter which places no load on the input circuit.

Still a further object of the present invention is the provision of a cathode drive coupling limiting amplifier which does not require batteries at a high potential above ground and which has the input characteristics of a class A amplifier regardless of the signal level applied to the input.

Further objects and advantages will appear from the following detailed description taken in connection with the accompanying drawings and appended claims.

In accordance with an embodiment of my invention, I provide a pair of negative grid limiting amplifiers which are coupled together by a cathode drive coupling. In this way the first tube is effective for a negative grid limiting of the negative half cycles of the input signal, while the second tube, due to phase reversal of its grid-cathode voltage with respect to the grid-cathode voltage of the first tube, is effective for a negative grid limiting of the positive half cycles of the input wave.

Reference will now be had, for a more complete understanding of the invention, to the following detailed description, which is accompanied by drawings, in which Figure 1 shows one specific embodiment of the invention; Figure 2 shows a modification of Figure 1 utilizing a tuned output circuit; Figure 3 is a series of curves explanatory of the operation of the circuits shown in Figures 1 and 2; Figure 4 shows a further modification of the invention; Figure 5 is a voltage output curve showing the characteristic form of output wave from a limiter embodied in my invention; Figure 6 shows an embodiment of the invention with an alternative form of output circuit and a cathode coupling circuit, and Figure 7 is a curve showing the resultant form of output from the circuit of Figure 6.

In Figure 1 I have shown a pair of thermionic discharge tubes or electron discharge structures T₁ and T₂. These tubes are entirely separate as far as their electron streams are concerned but have been shown as enclosed within the same glass bulb. While a double triode type of amplifier tube has been shown, it is within the scope of my invention to use entirely separate triode tubes if desired. It should be further understood that I intend by the use of the term "tube" to mean a structure including a cathode electrode and an anode electrode within an evacuated space and means for causing, influencing or otherwise controlling an electron stream between said electrodes regardless of whether the evacuated space is common to more than one electrode assembly or how it is maintained in an evacuated condition. Tube T₁ comprises a triode type of amplifier tube having a cathode 11, a grid 12 and a plate 13, while tube T₂ has similar elements 21, 22 and 23. The input to my limiting amplifier is conventional in construction embodying a grid resistor 2 and a cou-

pling condenser 1, the grid resistor 2 being connected between grid 12 and ground. Between cathodes 11 and 21, which are connected together, and ground is connected a cathode coupling resistor 3. The plate 13 of tube T₁ is directly connected to a source of plate potential B+. The grid 22 of tube T₂ is connected directly to ground while the plate 23 of tube T₂ is connected through resistance 5 to the source of plate potential B+. A by-pass or decoupling condenser 4 is connected from ground to the common connection of the two plate circuits to the source of plate potential. Plate 23 of tube T₂ is coupled to any desired utilization circuit through condenser 6 by means of terminals 7, 8. While I have in this description referred to certain connections as being made to ground, it is to be clearly understood that an actual ground connection may not be necessary, the ground connection being merely a reference point of zero signal potential.

In the circuit shown in Figure 1 when the grid 12 of tube T₁ is made positive increased cathode current is drawn through resistance 3 so that the cathodes 11 and 21 of both tubes are made more positive with respect to ground. Making the cathode 21 of tube T₂ more positive with respect to ground is equivalent to making the grid 22 more negative. Thus a positive change on the grid 12 of tube T₁ effects a resultant negative change on the grid 22 of tube T₂. This phase reversal causes tube T₂ to effect the negative grid limiting for the positive half cycles of the input wave while tube T₁ effects it for the negative half cycles. Thus, when grid 12 of tube T₁ is swung negative, negative grid cut-off limits the change in cathode current caused by the input wave. When the grid of tube T₁ is swung positive, grid 22 of tube T₂ is effectively swung negative until negative cut-off is reached for tube T₂.

In Figure 2 I have shown a circuit which operates in substantially the same manner as that shown in Figure 1, with the exception that a tuned output circuit 25 has been provided in the plate circuit of tube T₂ instead of the resistance 5. The tuned circuit 25 which is composed of inductance L and a capacity C, either or both of which may be variable, may be coupled to output terminals 9, 10 by means of a coil L' in inductive relationship with coil L. Coil L' may, likewise, be tuned to the desired resonant frequency by means of condenser C'. If a tuned output circuit is not desired an impedance coupled output may be obtained at terminals 7, 8, which are coupled to the plate circuit by means of condenser 6, as heretofore described with reference to Figure 1.

In Figure 3 I have shown a curve L, L with the input grid voltage E_g as abscissae and the output plate current I_p as ordinates. This curve shows the static characteristic of my limiting amplifier. Below curve L, L I have shown sinusoidal input voltages E_{ga}, E_{gb} and E_{gc}, and output currents I_{pa}, I_{pb} and I_{pc} referred to the static characteristic of curve L, L above. With no permanent bias on either grid 12 or 22 of my limiting amplifier, the amplifier operates at point a of the curve. As long as the input voltage E_{ga} does not exceed the straight portion of the static characteristic the plate current I_{pa} follows substantially the same form as the input voltage. However, after the input grid voltage swings beyond either knee of the characteristic curve no further change takes place in

the output plate current and thus a substantially flat topped current wave is obtained. If a negative bias is placed on grid 12 of tube T₁ the amplifier operates about point b of the static characteristic curve and the resultant output circuit is shown by curve I_{pb}. As will be seen by an inspection of the curve the positive half cycles are limited much higher on the input wave E_{gb} giving very much shorter corresponding output half cycles. This is shown in the upper right portion of the plate current curve I_{pb}. Similarly, the alternative negative half cycles are cut off at a much lower value giving correspondingly longer output half cycles, as shown in the lower left portion of the plate current curve I_{pb}. The negative bias on grid 12 of tube T₁ may be applied by means of a bias battery or merely by making the grid 22 of tube T₂ more positive. In a similar manner, if a negative bias is applied to grid 22 of tube T₂ or a positive bias on grid 12 of tube T₁, my limiting amplifier will operate about the point C on the static characteristic curve. The resultant plate current will then follow the form shown in curve I. The plate current curve I_{pc}, it will be seen, is a mirror image of the curve just previously described. By means of the differential bias just described it will be seen that square wave forms are obtainable with variable length mark and space, as desired.

The circuit shown in Figure 4 is particularly adapted to the production of waves of variable mark and space, such as those shown by curves I_{pb} and I_{pc} in Figure 3. This circuit differs from those previously described in the inclusion of potentiometers 14 and 15 between the grid returns of the two grid circuits and ground. With this circuit in order to obtain a wave form such as shown by curve I_{pb} in Figure 3, the variable arm of potentiometer 14 is adjusted to the ground or low potential end of the potentiometer so that no bias voltage is applied to grid 22 of tube T₂. The arm of potentiometer 15 is adjusted to provide a finite positive bias voltage to grid 12 of tube T₁. This positive voltage on grid 12 causes its cathode current to increase. The increase of current through resistance 3, thereby makes cathode voltage of both tubes more positive. The resultant effect is to make the grid 22 of tube T₂ more negative so that it is closer to its cut-off voltages. Similarly, by reversing the relative positions of the arms of potentiometers 14 and 15 so that a positive voltage is applied to grid 22, the grid 12 of tube T₁ will become more negative and a wave form which is the mirror image of that previously obtained will appear in the output.

I have found that by varying the value of the cathode resistor 3 the degree of amplification may be varied, as well as the input at which grid current is drawn. For instance, higher values of cathode resistor 3 produce lower degrees of amplification and increase the value of input voltage at which grid current is drawn. Since grid current flow produces dissymmetry in the limiting action of the amplifier higher values of cathode resistor are more desirable for high degrees of limiting. The over-all gain of the amplifier is reduced by higher values of cathode resistor due to the greater percentage of inverse feedback present on tube T₂. The percentage of inverse feedback on tube T₁ remains constant at 100 percent, regardless of the value of the cathode resistor.

In Figure 5 I have shown the output voltage

wave form resulting from the current I_{pa} flowing through resistor 5 of Figures 1 and 4. It will be seen that the wave form of the voltage wave is the same as that of the current wave but the relative amplitude is much higher. Similar output voltage waves are obtained for the currents I_{pb} and I_{pc} shown in Figure 3.

If a different type of output network such as shown in Figure 6 is utilized a triangular output wave form may be obtained. The output circuit shown in Figure 6 includes a resistor 25 and a condenser 26 connected in series between condenser 6 and ground, and the square topped wave ordinarily obtained by my limiter applied thereacross. The final output is then taken from terminals 7 and 8 across condenser 26. The resultant triangular wave is shown in Figure 7. A further modification of the circuit is shown in the cathode coupling arrangement in Figure 6. Instead of a single coupling resistor 3, as shown in the previous figures, each cathode is separately connected to ground by resistances 3 and 3'. The cathodes are coupled together by an impedance Z which may be a condenser, a resistor or an inductance. By varying the value of the coupling impedance and its character the wave form of the output wave may be varied somewhat or, in case unsymmetrical limiting is obtained by proper adjustment for the desired amplitudes of input and output, the output wave form may be made perfectly symmetrical.

While I have particularly described and shown several embodiments of my invention, it is to be clearly understood that my invention is not to be limited to these embodiments but that modifications within the scope of the invention may be made.

What I claim as my invention and desire to have secured by Letters Patent is:

1. A limiting amplifier comprising a pair of thermionic discharge tubes each having an anode, a grid and a cathode, said cathodes being so coupled together that a variation in the discharge current of one of said tubes varies the discharge current of the other of said tubes, means for applying a signal to the grid of one of said tubes sufficient to swing said grid beyond cut-off and an output circuit coupled to the anode of the other of said tubes, the remaining grid and plate being maintained at a zero signal potential.

2. A limiting amplifier comprising a pair of thermionic discharge systems each having an anode, a grid and a cathode, means for so coupling said cathodes together that a variation in the discharge current of one of said systems thereby influences the discharge current of the other of said systems, means for applying a signal to the grid of one of said systems sufficient to swing said grid beyond cut-off and an output circuit coupled to the anode of the other of said systems and means for independently and adjustably biasing the grids of each of said systems, the remaining anode and grid being maintained at zero signal potential.

3. A limiting amplifier comprising a pair of thermionic discharge systems each having an anode, a grid and a cathode, an input circuit coupled from the grid of one of said systems to a point of zero reference potential, an output impedance connected from the anode of the other of said systems to a source of anode potential and a common impedance connected between said cathodes and said point of zero potential, the input to said amplifier being sufficient to swing said grids beyond cut-off, the re-

maining grid and plate being maintained at zero signal potential.

4. A limiting amplifier comprising a pair of thermionic discharge tubes each having an anode, a grid and a cathode, an input circuit coupled from the grid of one of said tubes to ground, an output impedance connected from the anode of the other of said tubes to a source of anode potential and a common impedance connected between said cathodes and ground, the remaining one of said grids being connected to ground and the remaining one of said anodes being connected to said source the input to said amplifier being sufficient to swing said grids beyond cut-off.

5. A limiting amplifier comprising a pair of thermionic discharge tubes each having an anode, a grid and a cathode, an input circuit coupled from the grid of one of said tubes to ground, an anode impedance connected from the anode of the other of said tubes to a source of anode potential, a common impedance connected between said cathodes and ground, the remaining one of said grids being connected to ground and the remaining one of said anodes being connected to said source, a wave shaping circuit coupled to said anode impedance and an output circuit coupled to said wave shaping circuit.

6. A limiting amplifier comprising a pair of thermionic discharge tubes each having an anode, a grid and a cathode, an input circuit coupled to the grid of one of said tubes, a tuned output impedance connected from the anode of the other of said tubes to a source of anode potential, a common impedance connected between said cathodes and ground for coupling said cathodes together, the remaining one of said grids being connected to ground and the remaining one of said anodes being connected to the said source, the input to said amplifier being sufficient to swing said grids beyond cut-off.

7. A limiting amplifier comprising a pair of thermionic discharge tubes each having an anode, a grid and a cathode, an input circuit coupled between the grid of one of said tubes and a point of zero reference potential an anode potential connection, a pair of resistances connected between said point and said anode potential connection, variable taps on each of said resistances, one of said taps being connected to each of said grids, an output impedance connected from the anode of one of said tubes to said anode potential connection, the remaining one of said anodes being connected directly to said anode potential connection and means for so coupling said cathodes together that a variation in the discharge current of one of said tubes thereby influences the discharge current of the other of said tubes the input to said amplifier being sufficient to swing said grids beyond cut-off.

8. A limiting amplifier comprising a pair of thermionic discharge systems each having an anode, a grid and a cathode, an input circuit coupled between the grid of one of said systems and a point of zero reference potential, an anode potential connection, a pair of resistances connected between said point and said connection, variable taps on each of said resistances, one of said taps being connected to each of said grids, an output impedance connected from the anode of the other of said systems to said anode potential connection, the remaining one of said anodes being connected directly to said anode potential connection and means for so coupling said

cathodes together that a variation in the discharge current of one of said systems thereby influences the discharge current of the other of said systems comprising a common connection from said cathodes to said point of zero reference potential, the input to said amplifier being sufficient to swing said grids beyond cut-off.

9. A limiting amplifier comprising a pair of thermionic discharge systems each having an anode, a grid and a cathode, an input circuit coupled between the grid of one of said systems and ground, an anode impedance connected from the anode of the other of said systems to a source of anode potential, a connection from the anode of the first of said systems to said source of anode potential, an impedance connecting each of said cathodes to ground and means for so coupling said cathodes together that a variation in the discharge current of one of said systems thereby influences the discharge current of the other of said systems, the remaining one of said grids being connected to ground, the input to said amplifier being sufficient to swing said grids beyond cut-off, a wave shaping circuit coupled to said anode impedance and an output circuit coupled to said wave shaping circuit.

10. A limiting amplifier comprising a pair of thermionic discharge systems each having an anode, a grid and a cathode, means for so coupling the cathodes of said systems together that a variation in the discharge current of one of said systems thereby influences the discharge current of the other of said systems, means for applying a signal to the grid of one of said systems of sufficient amplitude to drive said grid beyond cut-off and an output circuit coupled to the anode of the other of said systems and means for independently and adjustably biasing the grids of each of said systems, the remaining anode and grid being maintained at zero signal potential.

11. An amplifier comprising a pair of thermionic discharge systems each having an anode,

a grid and a cathode, an input circuit coupled from the grid of one of said systems to ground, the input to said amplifier being sufficient to swing said grids beyond cut-off, an output impedance connected from the anode of the other of said systems to a source of anode potential and a common impedance connected between said cathodes and ground whereby said systems are so coupled together that a variation in the discharge current of one of said systems thereby influences the discharge current of the other of said systems, the remaining grid and anode being maintained at zero signal potential.

12. An amplifier comprising a pair of thermionic discharge tubes each having an anode, a grid and a cathode, an input circuit coupled from the grid of one of said tubes to ground, the input to said amplifier being sufficient to swing said grids beyond cut-off, an output impedance connected from the anode of the other of said tubes to a source of anode potential and a common impedance connected between said cathodes and ground, the remaining one of said grids being connected to ground and the remaining one of said anodes being connected to said source.

13. An amplifier comprising a pair of thermionic discharge systems each having an anode, a grid and a cathode, an input circuit coupled between the grid of one of said systems and ground, the input to said amplifier being sufficient to swing said grid beyond cut-off, a tuned output impedance connected from the anode of the other of said systems to a source of anode potential, a common impedance connected between said cathodes and ground for so coupling said cathodes together that a variation in the discharge current of one of said systems thereby influences the discharge current of the other of said systems, the remaining one of said grids being connected to ground and the remaining one of said anodes being connected to the said source.

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