July 31, 1951 I. J. P. JAMES 2,562,792

CIRCUITS FOR MODIFYING POTENTIALS

Original Filed Nov. 28, 1945

Fig. 1

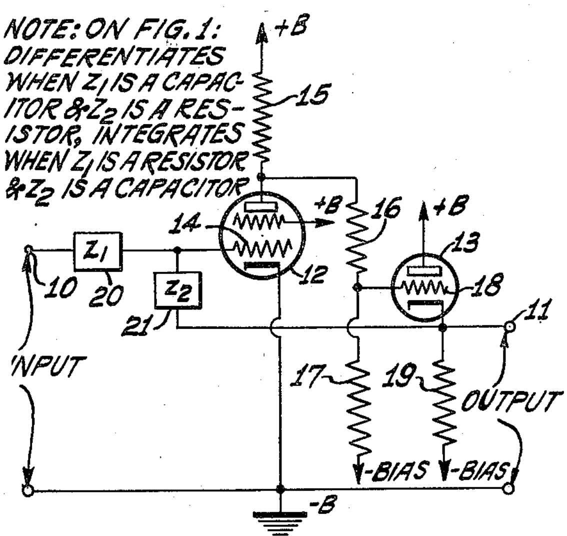
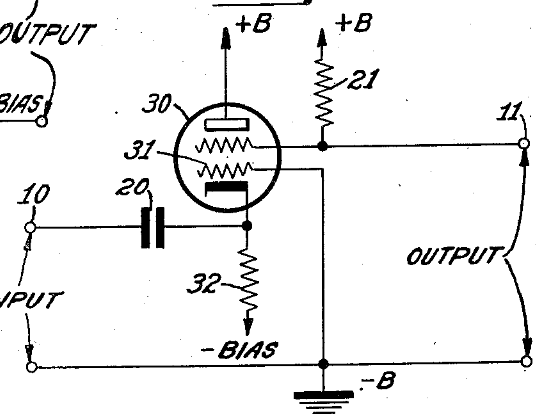



Fig. 3



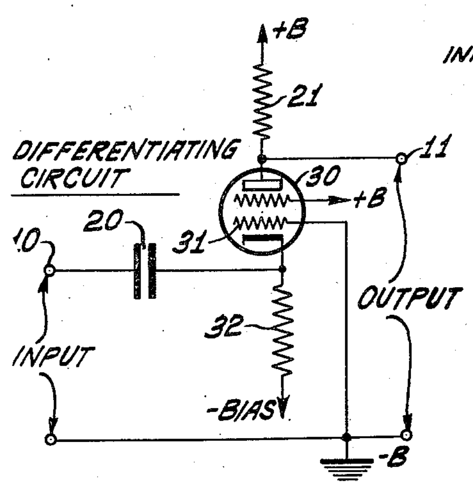




Fig. 2

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## CIRCUITS FOR MODIFYING POTENTIALS

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Original application November 28, 1945, Serial No. 631,436. Divided and this application February 11, 1949, Serial No. 75,943. In Great Britain January 12, 1944

8 Claims. (Cl. 250—27)



This application is a division of application Serial No. 631,436, filed November 28, 1945, in the names of Eric Lawrence Casling White, Ivanhoe John Penfound James, and John Edward Best, and entitled Circuits for Modifying Potentials. The claims of this application are directed to the subject matter illustrated in Figs. 2 and 3 of the drawing.

This invention relates to electric circuits for modifying electric potentials. More particularly the invention relates to circuits for deriving from a first and given potential a second potential which is mathematically related to the first potential in integral or derivative manner with respect to time. In one aspect the invention relates to the generation of electrical variations of sawtooth character.

Circuits for so modifying a given potential that the modified potential stands to the given potential in the relation of the mathematical integral or derivative with respect to time of the given potential are well known. For example, if a given potential is applied to a circuit consisting simply of a resistance and a capacity in series it is possible to derive from the circuit a modified potential which is related with accuracy to the mathematical integral or derivative of the given potential, providing that the modified potential is always small compared with the given potential, or that the frequencies of effective Fourier components of the given potential lie within a certain frequency range determined by the constants of the circuit. It is often desirable to obtain a greater amplitude of modified potential or a wider range of operating frequencies. The object of the present invention is to provide improved circuits whereby these ends may be achieved

According to the present invention, there is provided an electric circuit arrangement for modifying a given potential comprising a source of said potential, a first impedance connected effectively at one end to said source so that in operation said given potential is effectively applied to said end, a degenerative electron discharge valve amplifier arranged to provide within the effective operating frequency range of said source an impedance at a point in its circuit small compared with said first impedance, said first impedance being connected at its other end to said point whereby the current in said impedance due to said potential is determined substantially only by said given potential and said impedance, there being included in the circuit of said amplifier a second impedance



which in said effective operating frequency range is large compared with the impedance provided by said amplifier at said point and of different electrical nature from said first impedance, the arrangement being such that the whole or a fixed proportion of said current flows in said second impedance and a potential modified compared with said given potential is developed dependent substantially only on said current and said second impedance.

In order that the said invention may be clearly understood and readily carried into effect, it will now be more fully described with reference to the accompanying drawings in which:

Figures 1 to 3 illustrate some embodiments of the invention diagrammatically. In these drawings like reference numerals indicate like elements.

Figure 1, which is claimed in Serial No. 631,436, shows a circuit arrangement for modifying potentials in a predetermined manner. The source, not shown, of these potentials is connected to terminal **10** so as to develop said potentials thereat. Potentials modified in the required manner are developed at terminal **11**. Thermionic valves **12** and **13** together with their circuit connections including the coupling elements **15**, **16**, **17** and **19** constitute said thermionic amplifier aforementioned and the circuit elements **20** and **21** said first and second impedances, respectively. In said thermionic amplifier the valve **12** is arranged to develop a large gain between its anode and its control grid **14**. Potentials are developed at the anode of valve **12** by means of the anode circuit impedance **15** which may be a resistance and are transferred by means of the coupling circuit **16**, **17** to the control grid **18** of valve **13**. Impedance elements **16** and **17** may be resistances and the end of resistance **17** not connected to control grid **18** will then be connected to a point of fixed and sufficiently negative potential to bring said control grid to a proper operating potential. The anode of valve **13** is connected directly to a point of fixed positive potential while the cathode of said valve is connected by means of the large resistance **19** to a point of fixed negative potential so that potential variations occurring at said cathode are substantially identical with those applied to the control grid **18**. If it is desired that the operating range of frequencies of said amplifier should include those at which stray capacities affect the gain of the amplifier, known methods may be employed for extending the amplifier response.

It will be seen that the impedance **21** constitutes a feedback connection for the amplifier and it is arranged that the amplifier is thereby rendered highly degenerative. Impedance 21 may be of any arbitrary electrical nature, different from that of impedance 20 which is connected between the terminal 10 and control grid 14. These two impedances are so chosen that together they determine the required form of the potential developed at terminal 11 in relation to the potential applied at terminal 10. They suffice to determine the desired relationship by virtue of the high degree of degeneration present in the circuit. Since the feedback connection to the input of the amplifier, namely to the control grid 14, is of shunt character, the input impedance of the amplifier, that is, the impedance presented to impedance element 20, is reduced by the feedback at least in a certain range of frequencies to a low value. For all frequencies therefor for which the impedance of element 20 is large compared with said input impedance the current flowing in element 20 will depend only on the impedance of this impedance element and on the potential applied at the terminal 10. If $Z_1(j\omega)$ represents this impedance and U the applied potential, said current will be represented by $U/Z_1(j\omega)$. This current must necessarily flow in the impedance element 21 and, if this impedance is sufficiently large, will set up potential variations thereby large compared with those occurring at the grid 14 of the valve 12 which by reason of said low value of impedance thereat are of small magnitude. If the output potential thus set up at the cathode of valve 13 be represented by V and the impedance of impedance element 21 be represented by $Z_2(j\omega)$, V will be related to the potential U according to

$$V=-\frac{Z_2(j\omega)}{Z_1(j\omega)}U \quad (1)$$

This relation applies to all harmonic vibrations of frequency $\omega$ such that the conditions specified with regard to the magnitudes of $Z_1(j\omega)$ and $Z_2(j\omega)$ are satisfied. If U is not a harmonic vibration but may be regarded as composed of harmonic vibrations whose various frequencies are such that such conditions apply, then it is possible to write the relation between the output potential V and input potential U as

$$V=-\frac{Z_2(D)}{Z_1(D)}U \quad (2)$$

where D represents the differential operator

$$\frac{d}{dt}$$

The operator $Z_2(D)/Z_1(D)$ represents the desired predetermined relation between the potential applied to the circuit at terminal 10 and that derived at terminal 11.

Means for applying the proper biasing potential to the control grid of valve 12 have not been described but any known and suitable means may be employed. If impedance 21 is a simple resistance and impedance 20 a simple capacity, it is sufficient to bring the cathode of valve 13 to the necessary biasing potential. With this arrangement and if R is said resistance and C said capacity Equation 2 becomes

$$V=-RCDU$$

that is to say

$$V=-RC\frac{dU}{dt}$$



Thus with this arrangement V is the time derivative of U and the circuit is a differentiating circuit. If the impedance 21 is a capacity and impedance 20 is a resistance, then the relation between V and U is of the form

$$V=-\frac{1}{RCD}U$$

that is

$$V=-\frac{1}{RC}\int U\,dt$$

and the circuit is an integrating circuit. Other forms of impedance elements may be used in the circuit for impedances 20 and 21. As has been stated, however, they must always be of electrically different nature, that is to say the impedance functions $Z_1(j\omega)$ and $Z_2(j\omega)$ must be different. With such other forms the circuit can be made to modify or shape an applied potential in other ways than those just described by way of illustration.

Figure 2 shows an arrangement according to the present invention in which a different form of amplifier is employed. The amplifier comprises the amplifier valve 30 having its control grid 31 connected to ground and cathode connected to a point of fixed negative potential by means of resistance 32. The input terminal 10 is connected to the cathode of valve 30 through impedance 20 which may be a capacity as indicated while the output terminal is connected to the anode of valve 30 at which potentials are developed in response to potentials applied to terminal 10 by virtue of impedance 21 which may be a resistance connected in the anode circuit of valve 30. The impedance 32 is made sufficiently large for the circuit to be highly degenerative and to present at the cathode of valve 30 and to impedance 20 an impedance of small magnitude substantially equal to or comparable with the reciprocal of the mutual conductance of valve 30. Provided impedance 20 is large compared with the impedance presented to it at said cathode, the current in impedance 20 is determined solely by the magnitude of said impedance and the potential applied to terminal 10. This current effectively divides between the two branches formed by the impedance 32 and the valve 30. The latter branch effectively presents a very low impedance compared with that of the former and substantially the whole of the current flowing in impedance 20 is diverted into said latter branch. Of this a proportion will flow in the screen grid circuit of valve 30 but a major portion will flow in the anode circuit of the valve and thus in impedance 21. The valve 30 may be operated so that these proportions remain fixed and this being the case the relation between input and output potentials may be written

$$V=K\frac{Z_2(D)}{Z_1(D)}U \quad (3)$$

where K is the proportion of current flowing in the anode circuit, this relation holding subject to the condition that there are no frequencies effectively present in the potential U for which the impedance of impedance element 20 is not large compared with the impedance presented to it at the cathode of valve 30. As before, $Z_1(j\omega)$ and $Z_2(j\omega)$ represent the impedances of impedance elements 20 and 21 respectively at frequency $\omega$. If the valve 30 is replaced by a triode the proportion K becomes unity. The effect of a screen within the valve is still obtained in this case, since as the control grid 31 is earthed it acts as a screen between the input and output circuits of valve 30. As shown in Figure 3, if desired the impedance 21 may be inserted in the screen lead of valve 30 instead of the anode lead in which case the output terminal 11 will be connected to the screen electrode of valve 30. If necessary grid 31 may be used for mixing additional potentials to the output potentials. The circuit as shown is a differentiating circuit.

It is to be noted that in all of the above-described embodiments of the invention the source of the given potentials is assumed to be connected between the terminal 10 and a point of fixed potential which point is conveniently ground as indicated in the drawings.

What is claimed is:

1. A wave shaping circuit for changing the wave shape of a voltage applied thereto, said circuit comprising a vacuum tube having a cathode, a control grid and an output electrode, a cathode resistor connected in the cathode circuit of said tube, one end of said resistor being connected to said cathode, a first impedance unit, one end of which is connected to said cathode and the other end of which has said voltage applied thereto, said control grid being connected to a point of constant potential such as ground, a second impedance unit connected to said output electrode and through which at least a substantial portion of the tube space current flows, means for applying a positive operating potential to said output electrode, said second impedance unit being of a different electrical nature than said first impedance unit, and output terminals to which are applied the reshaped voltage appearing across said second impedance unit.

2. The invention according to claim 1 wherein said output electrode is an anode.

3. The invention according to claim 1 wherein said output electrode is a screen grid.

4. The invention according to claim 1 wherein said first impedance unit has an impedance that is large compared with the impedance presented to it at said cathode.

5. A wave shaping circuit for changing the wave shape of a voltage applied thereto, said circuit comprising a vacuum tube having a cathode, a control grid and an anode, a cathode resistor connected between said cathode and a source of negative bias, a first impedance unit, one end of which is connected to said cathode and the other end of which has said voltage applied thereto, said control grid being connected to a point of constant potential such as ground, a second impedance unit connected to said anode and through which the cathode-anode current of said tube flows, means for applying a positive operating potential to said anode, said second impedance unit being of a different electrical nature than said first impedance unit, and output terminals to which are applied the reshaped voltage appearing across said second impedance unit.

6. A wave shaping circuit for changing the wave shape of a voltage applied thereto, said circuit comprising a vacuum tube having a cathode, a control grid and an anode, a cathode resistor connected between said cathode and a source of negative bias, a first impedance unit, one end of which is connected to said cathode and the other end of which has said voltage applied thereto, said control grid being connected to a point of constant potential such as ground, a second impedance unit connected to said anode and through which a positive operating potential is applied to said anode, said second impedance unit being of a differential electrical nature than said first impedance unit, and output terminals to which are applied the reshaped voltage appearing across said second impedance unit.

7. A wave shaping circuit for changing the wave shape of a voltage applied thereto, said circuit comprising a vacuum tube having a cathode, a control grid and an anode, a cathode resistor connected between said cathode and a source of negative bias, said cathode resistor having sufficiently high impedance to make said circuit highly degenerative, a first impedance unit, one end of which is connected to said cathode and the other end of which has said voltage applied thereto, said control grid being connected to a point of constant potential such as ground, a second impedance unit connected to said anode and through which at least a substantial portion of the tube space current flows, means for applying a positive operating potential to said anode, said second impedance unit being of a different electrical nature than said first impedance unit, said first impedance unit having an impedance that is large compared with the impedance presented to it at said cathode, and output terminals to which are applied the reshaped voltage appearing across said second impedance unit.

8. A differentiating circuit for changing the wave shape of a voltage applied thereto, said circuit comprising a vacuum tube having a cathode, a control grid and an anode, a cathode resistor connected between said cathode and a source of negative bias, a capacitor, one end of which is connected to said cathode and the other end of which has said voltage applied thereto, said control grid being connected to a point of constant potential such as ground, a resistor connected to said anode and through which a positive operating potential is applied to said anode, said capacitor having an impedance that is large compared with the impedance presented to it at said cathode, and output terminals to which are applied the reshaped voltage appearing across said resistor.

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