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MIXING CIRCUIT

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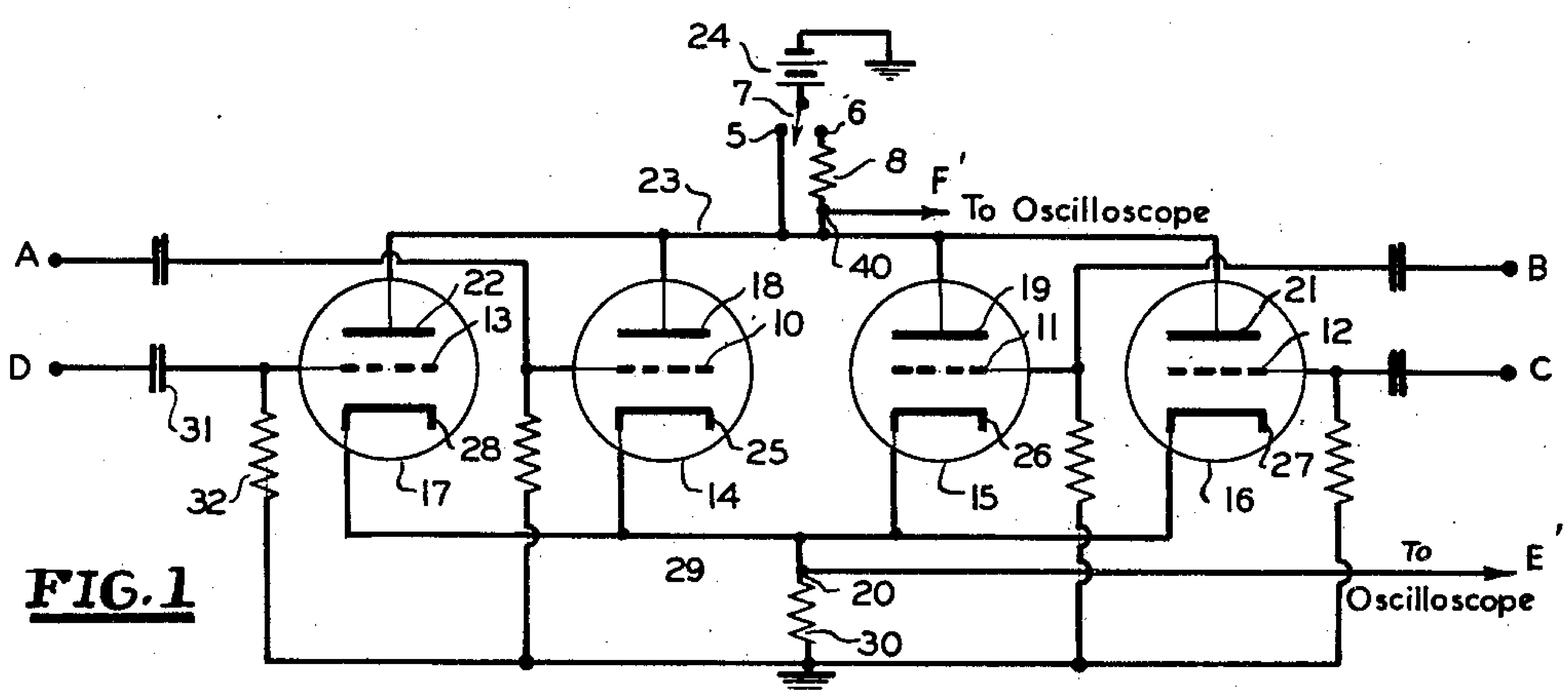

FIG. 1

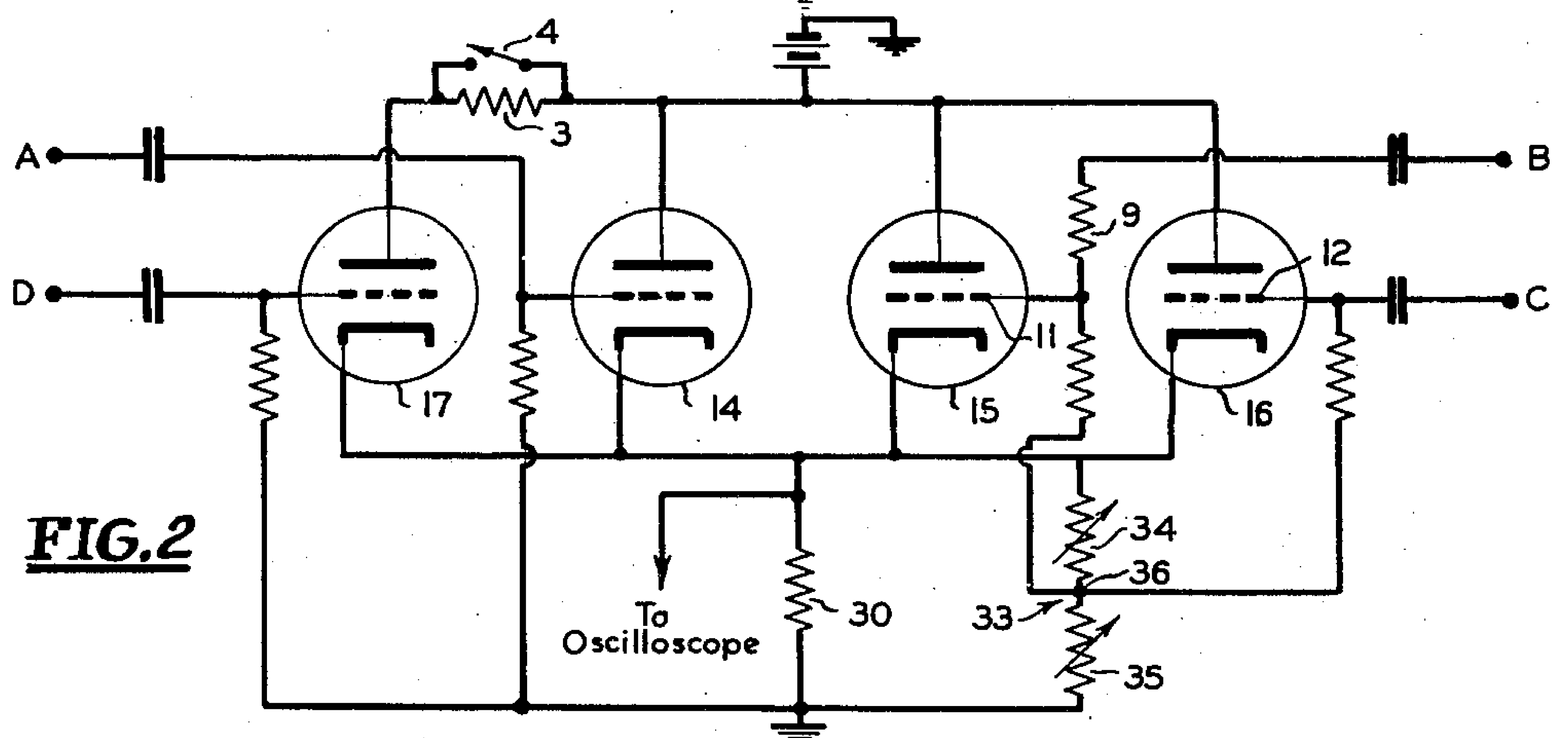

FIG. 2

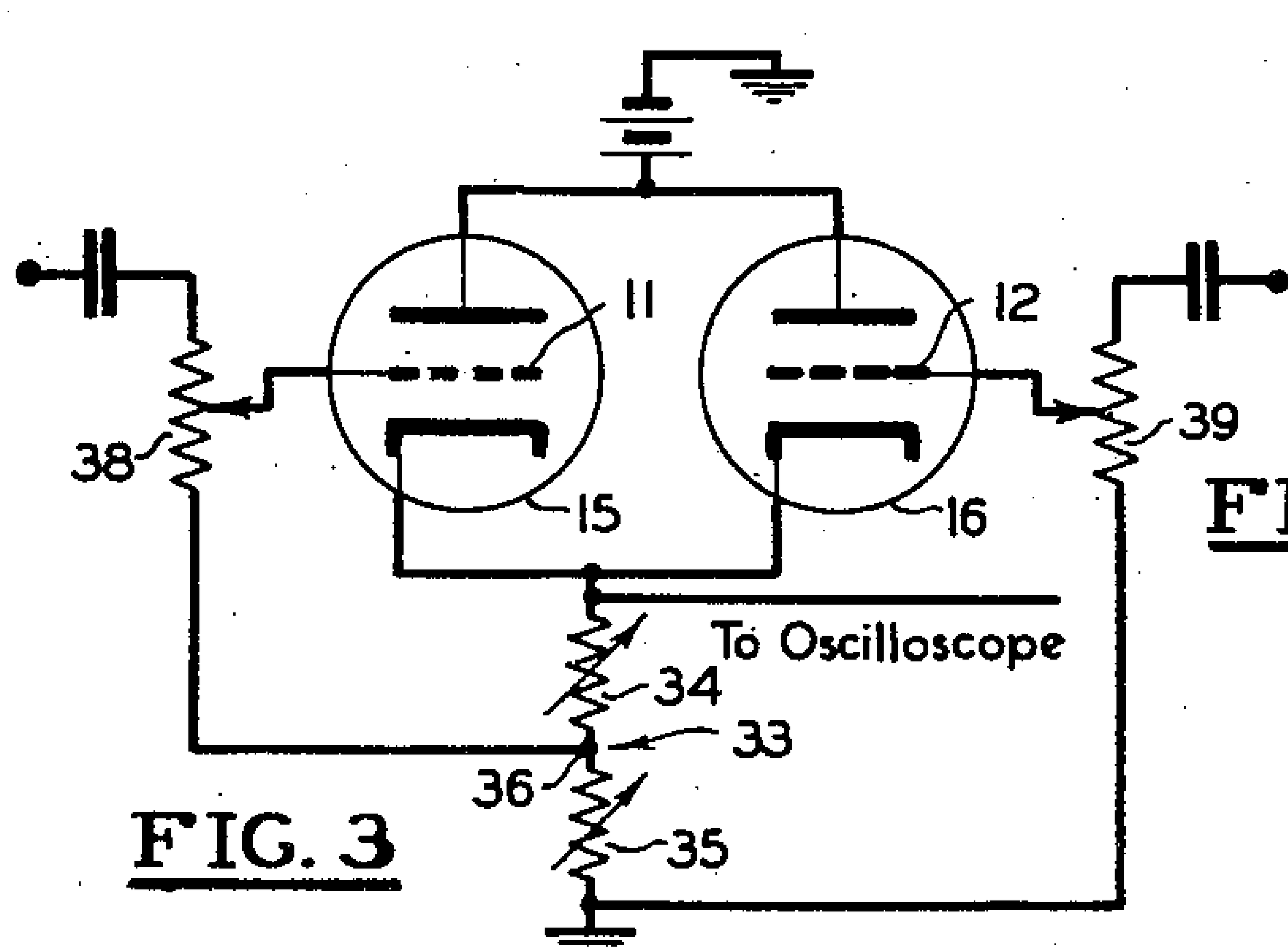

FIG. 3

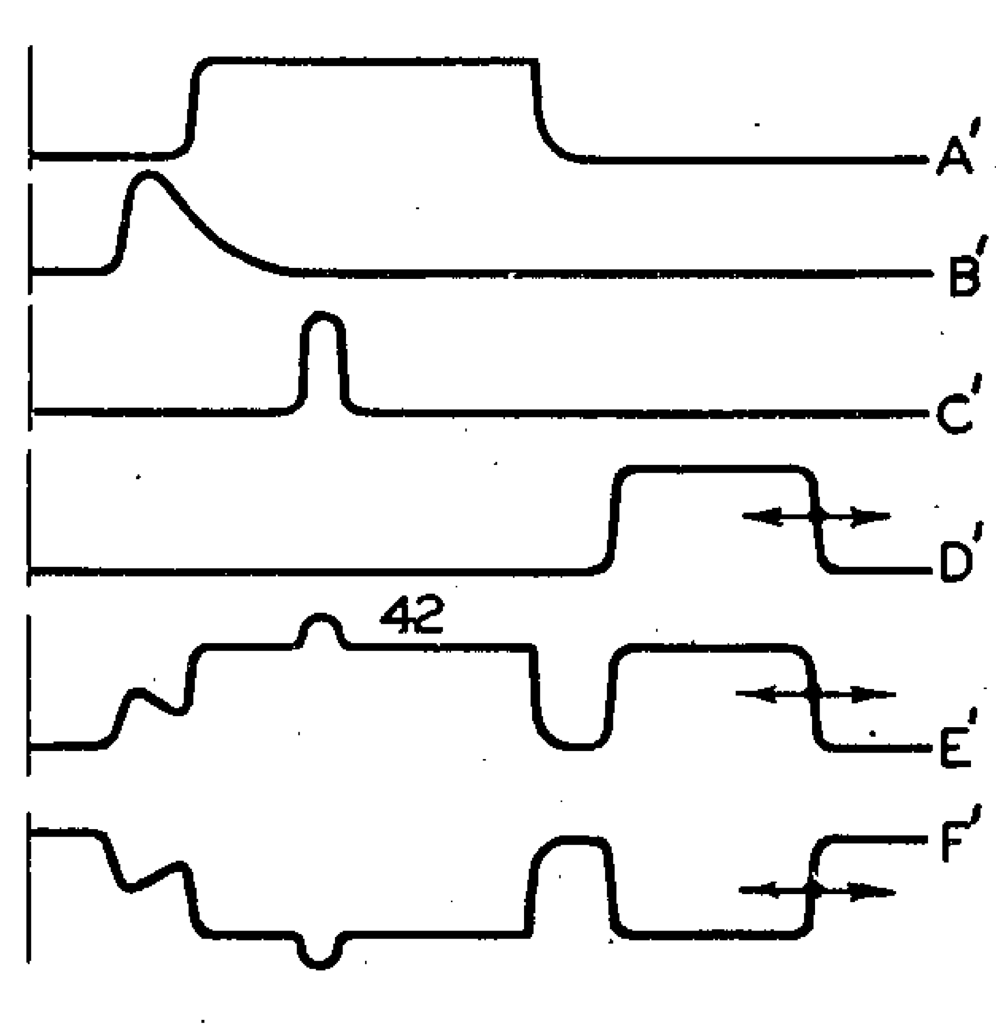

FIG. 4

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MIXING CIRCUIT

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My invention relates to mixing circuits in general and more particularly to non-linear mixers.

In linear or current source types of mixers the amplitudes of the various energy waves are additive, and the output wave form of these circuits is the algebraic sum of the inputs. For example, if a square wave is "mixed" with a pulse or narrow gate in such a circuit, the flat top of the resultant output square wave will be distorted in amplitude to the extent of the amplitude of the pulse or gate.

In some applications it is desirable that the signals shall be combined non-linearly; that is, in the example taken above, the flat top of the square wave shall be distorted by the pulse only to the extent that the latter's amplitude exceeds a voltage in the vicinity of that of the square wave.

In other applications, it is necessary to vary the datum of one component of the output or mixed wave without affecting the amplitude of another component. Thus, if two signals are to be mixed for application to the grid of a cathode ray oscilloscope, one of which is a square wave and the other a pulse, it may be desirable to set the pulse height or spot for a certain brilliance and variably set the brilliance of the background noise represented by the square wave. This cannot be accomplished in a linear mixer, since the pulse height would be increased with an increased setting of the square wave, the grid of the cathode ray tube would be driven positive, the spot would be excessively bright, and defocusing would result.

Accordingly, it is an object of my invention to provide a non-linear mixing circuit.

It is also an object of my invention to provide a mixing circuit in which only a portion of one signal is mixed with another.

I also wish to provide, as one of the objects of my invention, a mixing circuit which gives a closer approach to a relay type of operation than do prior art circuits.

As another object of my invention, I wish to provide a mixing circuit having a plurality of electronic discharge devices arranged to receive the signals to be mixed, the electron discharge devices being connected together through a common cathode and common anode resistor across either of which the output of the circuit may be taken.

Another purpose of my invention is to provide a mixing circuit in which a plurality of non-linear mixing elements are so connected that the amplitude of a signal produced by one of them will not be distorted, as a component of the output, by signals of appreciably lesser amplitude produced by the other elements.

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A still further object of my invention is to provide a mixing circuit having a plurality of electronic discharge devices arranged to receive the signals to be mixed, the devices being tied together through a common cathode resistor across which the output voltage is developed.

Still another purpose of my invention is to provide a mixing circuit in which a selected portion of one signal may be mixed with one or a group of other signals.

Yet another purpose of my invention is to provide a mixing circuit in which the datum of one signal taken as a reference may be variably controlled to selectively determine a portion of another signal to be mixed with it.

A still further object of my invention is to provide a mixing circuit in which a plurality of thermionic elements are tied together through a common cathode resistor, said elements having connected in their anode and control circuits certain parameters for supplying various biasing voltages to the respective elements.

These and other objects will become apparent as the description proceeds.

In carrying out my invention in a preferred embodiment thereof, I provide a number of non-linear mixing elements, such as electronic valves or vacuum tubes, the number of which is determined by the number of signals to be mixed. The control electrode of each element is connected to receive one of the signal voltages, and the anode electrodes of all the elements are tied together and connected to a positive energy source, directly or through a common anode resistor. The cathodes of all of the elements are likewise tied together and connected to ground through a common cathode resistor. The output is taken across either the common cathode or common anode resistor, depending upon the desired polarity of the output signal.

When thus connected, the circuit is primarily controlled by the signal of greatest amplitude, and such a signal, reproduced as a component in the output wave, is not distorted by any other of the signals received by the other tube elements so long as their respective amplitudes remain appreciably smaller. When the tube receiving such a signal becomes conducting under the influence of a sufficiently large signal, all of the other mixing elements in the circuit are automatically biased to cut-off and remain so until their grids are driven sufficiently positive by their respective incoming signals to render the respective mixing elements conducting, and to this extent only is the signal so received additive to the signal received by the element previously conducting.

In one of the modifications of my invention, I connect a voltage divider across the common cathode resistor of the circuit to which is connected the control electrode of one or more of the mixing elements. The other tubes of the circuit, whose cathodes are grounded through the common load resistor, are thus biased to cut-off when no signals are being received, thereby causing the heights of the components in the output wave attributable to the signals received by the conducting elements to be increased with respect to those produced by the cut-off biased elements. By making the arms of the voltage divider adjustable, or by placing a series resistor in one or more of the anode leads, it is possible to control the relative heights of the various wave components.

In another embodiment of my invention, I provide the common cathode resistor of the circuit with a tap point to which one or more of the control electrodes of the various mixing elements are connected, the control electrodes of the other elements being grounded. Under such an arrangement, the elements having grounded control electrodes are biased to cut-off and portions only of the signals received by them are mixed into the common output impedance. Here again the portoin of the signals mixed may be varied by making the component resistances forming the cathode resistor variable.

A more comprehensive understanding of my invention will be afforded from the following detailed description when taken together with the accompanying drawing, in which,

Fig. 1 is a schematic circuit diagram of an embodiment of my invention;

Figs. 2 and 3 are circuit diagrams showing modified forms of my invention; while

Fig. 4 depicts graphically, representative wave forms which may be combined in the circuits shown in Figs. 1 and 2, and the resultant wave form output, illustrative of their operation.

Like reference numerals have been used throughout in the drawing to designate like parts.

In the embodiment illustrated in Fig. 1, I provide a plurality of input terminals A, B, C and D, upon which are impressed the signals to be mixed. These terminals are respectively connected to grids **10**, **11**, **12** and **13** of electronic discharge devices **14**, **15**, **16** and **17**, which may take the form of triodes. Anodes **18**, **19**, **21** and **22** of these devices are tied together by a common bus **23** and are connected to positive energy source **24**, directly or through a common anode resistor **8**, depending upon the position of the arm of a two-way switch **7**. In like manner, cathodes **25**, **26**, **27** and **28** are tied together by a bus **29** and connected to ground through a common cathode resistor **30**. The grid circuit of each element is provided with a coupling condenser and biasing resistor such as the capacitor **31** and resistor **32** connected in the grid circuit of element **17**.

In the embodiment of my invention shown in Fig. 2, the elements **14**, **15**, **16** and **17** are connected as illustrated in Fig. 1 with the following exceptions. A series resistor **3**, having a shorting switch **4** in parallel therewith, is connected in the anode lead of the tube **17**. Across the cathode resistor **30**, a voltage divider **33** is connected, comprising variable resistors **34** and **35** having a tap point **36**. Grids **11** and **12** of elements **15** and **16**, respectively, are connected through grid resistors to the tap point **36** of voltage divider **33** rather than to ground, as illustrated in Fig. 1. Also, a series resistor **9** is placed in the input connection to grid **11** of element **15**. Common anode resistor **8** and switch **7** are omitted, although they may be used in this or any other embodiment of my invention, as desired.

In the form illustrated in Fig. 3, I show a circuit of two elements only, such as elements **15** and **16** of the circuit illustrated in Fig. 2, with the voltage divider **33** of that circuit connected as the common resistor. To the tap point **36** I connect the control grid **11** of element **15** through a potentiometer **38**. Grid **12** of element **16** is connected to ground through a potentiometer **39** rather than to tap point **36** through a resistor as illustrated in Fig. 2.

In operation four signals, such as those illustrated as A′, B′, C′, and D′ in Fig. 4, are respectively impressed upon the terminals A, B, C, and D of the circuit illustrated in Fig. 1, and the output of the circuit is selectively taken from the connecting point **20** across resistor **30**, or from point **40** across resistor **8**, for delivery to any load such as an oscilloscope. Within this circuit the various wave forms are combined in a novel manner which will now be described, to give an output such as that shown.

Of the signal voltages impressed upon the input terminals of the circuit, that one which is predominantly the greatest in amplitude is controlling and remains so until the amplitude of one of the signals received by the other elements exceeds the cut-off value of that element. Thus, for the signals illustrated, the positive rise of signal B′ drives grid **11** of element **15** positive, thereby carrying all the cathodes positive and so biasing elements **14**, **16** and **17** as to reduce or cut-off anode current therethrough.

Shortly after signal B′ begins to fall, grid **10** of element **14** receives signal A′ which is greater in amplitude than the corresponding time point of B′ and tube **14** is driven above cut-off and becomes conducting. As the potential of its cathode **25** goes up element **15** is biased to cut-off as are elements **16** and **17**, and tube **14** takes control.

In sequence, signal C′ gives control to element **16** and signal D′ to element **17** as their respective amplitudes exceed that of the signal on the then conducting element, and a signal E′ or F′ is produced as the output, depending on the point from which it is taken.

If taken from point **20**, across resistor **30**, E′ represents the output, and F′, if taken from point **40**, across resistor **8**. For selecting the polarity of the output, switch **7** is provided. When it is desired to take the signal from point **20**, switch **7** is closed to contact **5** and resistor **8** is cut out of the circuit. When closed to contact **6**, switch **7** causes resistor **8** to become operative in the circuit, and a signal such as F′ may be taken from point **40**.

Control of the relative heights of the components of the output waves is effected by adjusting the variable resistors **34** and **35** of voltage divider **33**, or, with regard to signal D′, by opening or closing shorting switch **4**. Under the last-mentioned control operation, series resistor **3** is selectively placed in or out of the circuit. Either of these methods of control results in a change in bias on the various tubes; these methods may be used separately or conjunctively.

The advantages of this circuit are thus made clear, since it is apparent that any variations in signals B′, C′ and D′, during the period in which signal A' is flat-topped, do not appear as components of the output wave, such as they would in a linear mixer, so long as they are appreciably smaller in amplitude. Also, if a pulse such as C' is to be added above the flat-top of signal A', it is necessary only to consider the shape of C' in the region at the peak of the pulse. Further, that component 42 of the output wave, attributable to signal C', is not a function of the magnitude of signal A' but is independent therefrom, provided signal C' exceeds signal A' by an appreciable margin. Hence, the pulse height of C' and the square wave height of A' may be determined by separate controls and each one varied without affecting the other.

In addition, the above described circuit provides a closer approach to a relay type of operation than does conventional plate current mixing. For example, when tube 14 is conducting, its equivalent variational impedance as a generator working into the common load is very low compared to the load impedance, being approximately equal to the reciprocal of the sum of tube transconductance and tube plate conductance, each of which is a function of the current through the tube.

These conductances are zero when the tube is cut off and increase rapidly when grid 10 is brought to a potential sufficient to make the element conducting. As the current through the tube increases the voltage across resistor 30 increases and for the above described sequence of operation, the current through triode 15 decreases. This in turn reduces the impedance of tube 15 as a generator working into the common load 30, until the continuance of this sequence causes tube 15 to be cut off entirely. The time required for this switching operation, which is a function of the non-linearity of the generator impedance is comparatively short, and, depending upon the amplification factor of the elements used, approaches that of relay action.

In the embodiment of my invention illustrated in Fig. 2, grids 11 and 12 of elements 15 and 16 are connected through grid resistors to a voltage divider across the cathode resistor 30. Thus, when no signals are being received by the circuit, elements 14 and 17 are biased beyond cut-off at the start. Consequently, and if the signals of Fig. 4 be taken as examples, a larger voltage of signals A' and D', respectively, will be required to drive tubes 14 and 17 above cut-off and hence the component of the output wave attributable to them will be smaller. In effect this increases the height of the output component 42 due to C' with respect to the components due to A' and D'.

A series resistor 9 is placed in the grid circuit of element 15 to limit the output voltage to the value which results when grid 11 begins to draw current. The flow of current through resistor 9 produces a voltage drop which tends to prevent further voltage rise of grid 11 and cathode 26 beyond this point.

Fig. 3 illustrates a third modification of my invention, embodying a novel mode of operation in which one of the mixing elements 16 is biased to cut-off to control the height of the output component due to the signal received by it. In this embodiment, series cathode resistors 34 and 35 serve to fix an intermediate voltage tap 36 and also function as the entire cathode to ground resistor.

Thus, with reference to Fig. 3, when no signal is being received by either of the grids 11 or 12, element 16 is cut off, due to the bias provided by the voltage drop across resistors 34 and 35. Assuming the pulse C' of Fig. 4 is applied to grid 12 and the square wave A' to grid 11, then only that portion of C' above cut-off will be mixed into the common output impedance. By varying resistors 34 and 35 the height of component 42 attributable to pulse C' with respect to A' may be varied.

It will be apparent to one skilled in the art, that many modifications of my invention are possible through various combinations of the control arrangements described above, and that unlimited possibilities are available for increasing the number of signals to be mixed by increasing the number of mixing elements in the circuit.

Accordingly, it is intended that all matter contained in the above description or shown in the accompanying drawing shall be interpreted as illustrative and not in a limiting sense, and that the spirit and scope of my invention shall be regarded as of such breadth as is defined by the appended claims.

What is claimed is:

1. In a mixing circuit comprising a plurality of electronic discharge devices each having anode, cathode, and control electrodes, a common cathode resistor for all of said electronic discharge devices having a tap, means for connecting the control electrode of at least one of said devices to said tap, means for connecting the control electrode of the remainder of said devices to ground, and means for taking the output of said circuit across said common cathode resistor.

2. An electronic mixing circuit comprising first and second electronic discharge devices each having anode, cathode, and control electrodes, third and fourth electronic discharge devices having similar electrodes, means for connecting said anodes of said first, second, third and fourth electronic discharge devices to a positive source, means for connecting said cathode electrodes of said electronic discharge devices to ground through a common cathode resistor comprising a voltage divider, means for connecting the control electrodes of said first and second electronic discharge devices to ground, and means for connecting the control electrodes of said third and fourth electronic discharge devices to said voltage divider.

3. A combined mixing and gating circuit for receiving a plurality of input signals and providing an output voltage wherein the component corresponding to one of said input signals is dependent upon the strength of another of said input signals, comprising a plurality of electronic discharge elements having anode, cathode and grid electrodes, means for impressing one of a plurality of signals upon each of said grid electrodes with respect to ground, common supply means for maintaining at least two of said anode electrodes at the same potential with respect to ground, and means for degeneratively intercoupling said electronic discharge elements, said last named means comprising a high-impedance common cathode load for said elements in circuit between their cathodes and ground, at least one of said electronic discharge elements being conditioned to develop across said common cathode load, in response to its grid electrode input signal, a high voltage for biasing another of said electronic discharge elements to a substantially unresponsive condition.

4. A combined mixing and gating circuit for receiving a plurality of input signals and providing a composite output voltage wherein the component corresponding to one of said input signals is dependent upon the strength of another of said input signals, comprising a plurality of electronic discharge elements having anode, cathode and grid electrodes, input circuit means for impressing upon each of said grid electrodes one of a plurality of input signals, connecting means between the anode electrodes of at least two of said tubes for maintaining them at common potential, and means for degeneratively intercoupling said electronic discharge elements, said last named means comprising a high-impedance common cathode load for said electronic discharge elements, said load being included in the input circuit of one of said electronic discharge elements, another of said electronic discharge

elements being conditioned to develop across said common cathode load, in response to its grid electrode input signal, a high voltage for biasing said one electronic discharge element to a substantially unresponsive condition.

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