

Dec. 22, 1953

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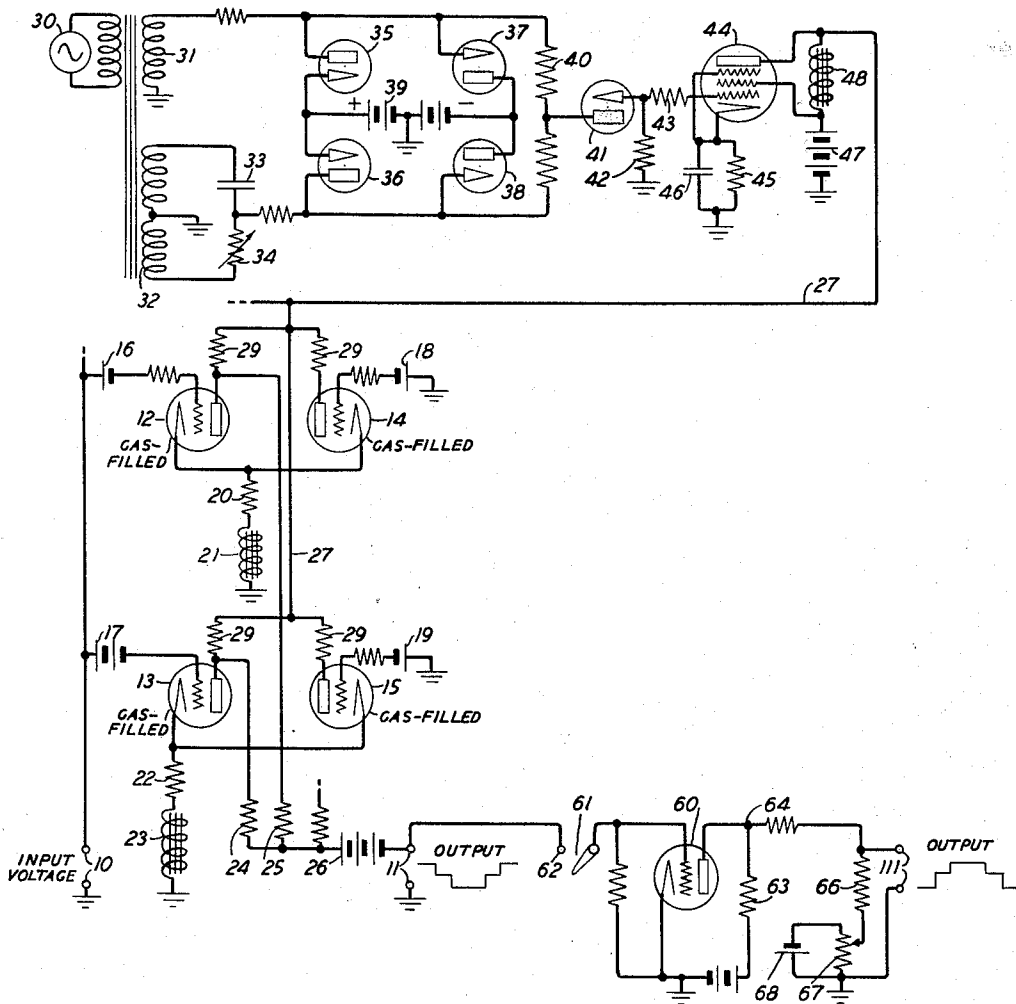
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ELECTRICAL WAVE TRANSFORMING SYSTEM

Filed Aug. 19, 1941

3 Sheets-Sheet 1

FIG. 1



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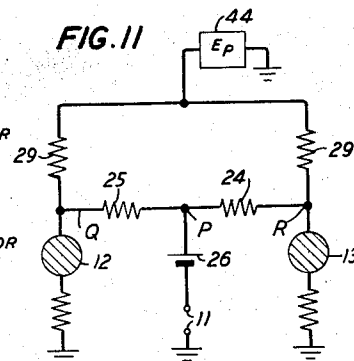
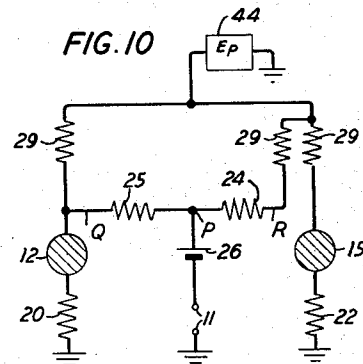
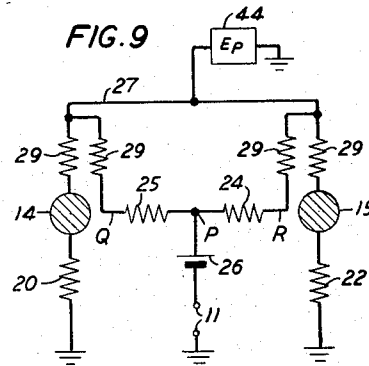
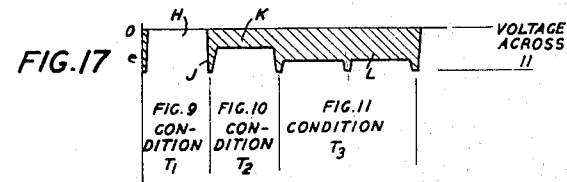
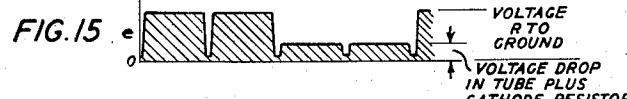
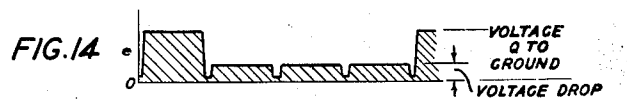
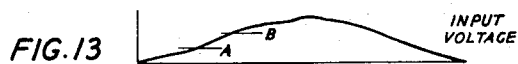
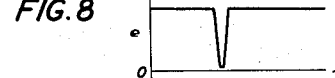
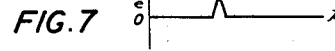
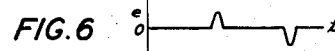
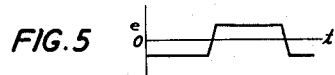
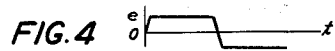
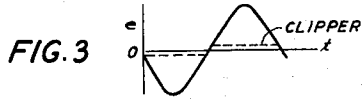
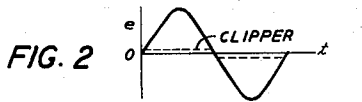
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ELECTRICAL WAVE TRANSFORMING SYSTEM

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3 Sheets-Sheet 2



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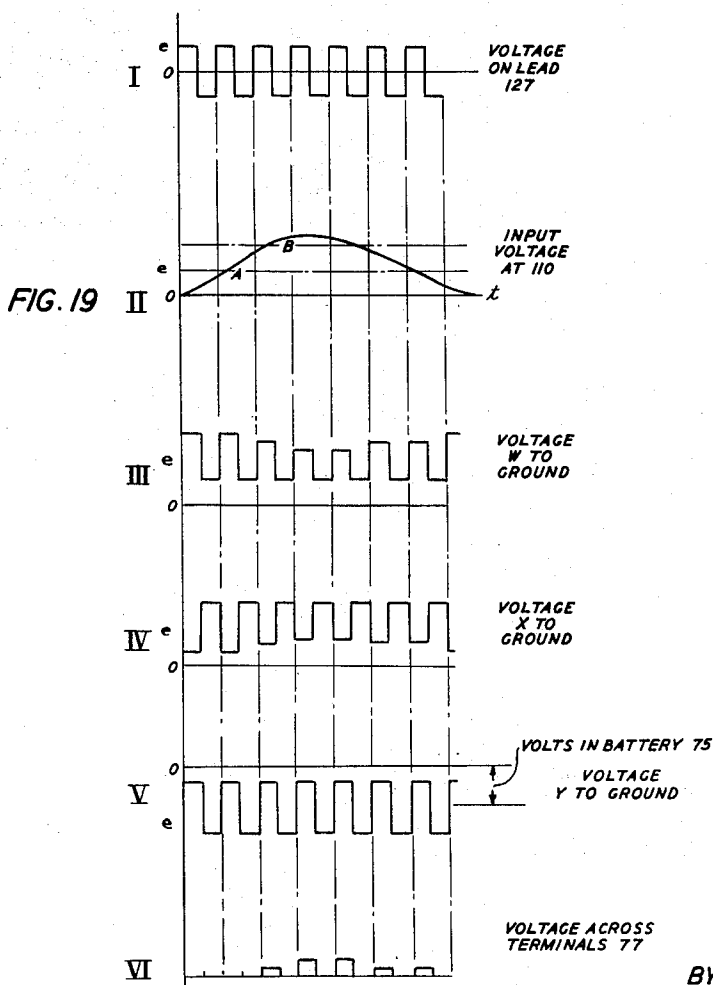
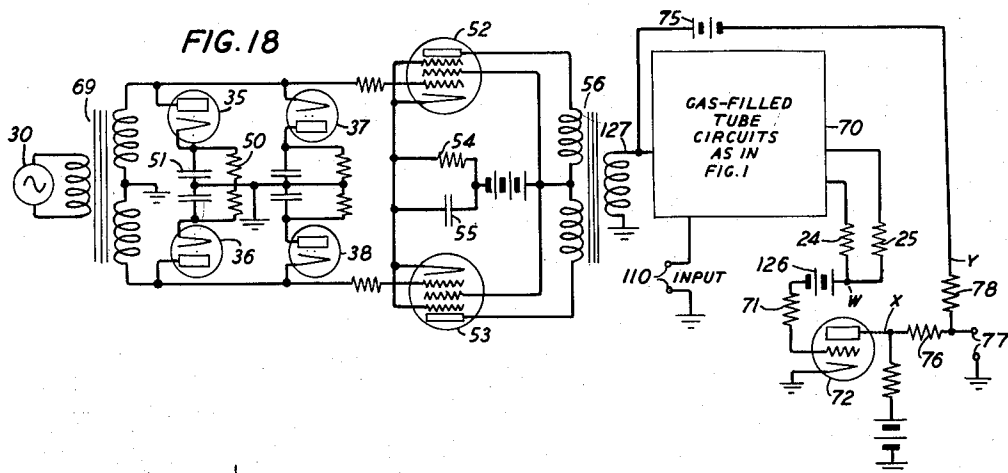
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ELECTRICAL WAVE TRANSFORMING SYSTEM

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3 Sheets-Sheet 3



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ELECTRICAL WAVE TRANSFORMING
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9 Claims. (Cl. 250-27)

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The present invention relates to electrical wave translation; to change a gradually varying amplitude wave into a wave whose amplitude is varied abruptly in steps.

An object of the invention is to effect this type of wave translation with accuracy and without substantial time delay.

In the specific embodiment of the invention to be disclosed in this application, trigger tubes, such as gas-filled tubes, are used to connect into the circuit resistances in different combinations, these resistances operating similarly to a potentiometer to apply to the output terminals different voltages in steps in response to rising or falling voltage at the input.

This specific disclosure represents the best form that the present applicant has thus far devised for accomplishing this object but it is realized that the circuit may be widely varied by substitution of equivalent or nearly equivalent means at various points and no attempt is made to illustrate such alternative constructions. The claims to be found at the end of this specification are not to be construed as limited to the particular form or forms disclosed.

The nature of the invention and its various features and objects will appear more fully as the description proceeds.

In the attached drawings, forming a part of this specification,

Fig. 1 is a schematic diagram of one over-all circuit for accomplishing the object of the invention;

Figs. 2 to 3 and 12 to 17 show graphs to be referred to in the description of the operation of the circuit of Fig. 1;

Figs. 9, 10 and 11 are simplified impedance or voltage diagrams illustrating different circuit conditions for the system of Fig. 1;

Fig. 18 is a schematic diagram of a system using an alternative type of energizing voltage for a voltage-dividing circuit of the type shown in Fig. 1; and

Fig. 19 shows graphs to be referred to in the description of the operation of the circuit of Fig. 18.

While the invention is of general application; one use to which it may be put is the subdivision of gradually varying voltage or current waves into stepped waves in certain systems for analyzing or synthesizing speech waves. One such system is disclosed in an article entitled "The carrier nature of speech" by Homer Dudley, published in Bell System Technical Journal for October 1949; volume 19, pages 945 to 951. Fig. 10

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of that publication shows an oscillogram of speech-defining signals of low frequency (0 to 25 cycles) obtained by analysis of spoken words. These speech defining currents exhibit gradually rising and falling amplitude and the invention may be used to translate such currents into currents having generally similar wave form but rising and falling in a series of abrupt steps instead of by smooth gradations. The voltage developed by the flow of these speech defining signals through resistances may be stepped up if necessary by vacuum tube amplifiers to the proper levels to fit the characteristics of the trigger tubes employed in the embodiment of the invention disclosed herein.

Referring to Fig. 1, the input voltage is applied to the terminals 19 and the output voltage of stepped characteristic may be taken off at terminals 11 or at terminals 111. A plurality of gas-filled tubes 12, 13, 14 and 15 are connected, in a manner to be described, between the input and output terminals. Opposing voltage sources 16 and 17 of graduated value are inserted between the ungrounded input terminal 19 and the grid of the respective tubes 12, 13. Bias voltages 18 and 19, all having the same value, are connected to the grids of the tubes 14 and 15. The cathodes of tubes 12, 14, are connected together and through a resistance 20 and inductance 21 to ground. A similar resistance and inductance is shown at 22, 23 for the cathodes of the tubes 13 and 15. Each anode is connected through an individual resistance 29 to a lead 27 leading to the anode of the pentode 44. The anodes of the left-hand tubes 13, 12 are connected through individual resistances 24 and 25 to the ungrounded output terminal 11. In one embodiment the resistances 29 had a value of 30,000 ohms, resistances 20 and 22 each had a value of 10,000 ohms and the resistances 24 and 25 each had a value of 250,000 ohms, these values being by way of example and not critical.

At the upper portion of the figure there is shown an impulsing circuit for controlling the operation of the gas-filled tubes 12, 13, 14 and 15. In this circuit there is an oscillator 30 generating sine wave voltage, at some suitable frequency such as 50 cycles. The output of the oscillator is coupled through a transformer to two secondary windings 31 and 32, which lead in turn to a clipper circuit consisting of four diodes 35, 36, 37 and 38 shunted across the circuit as shown. Winding 32 is connected across a phase splitting circuit comprising capacity 33 and resistance 34, and winding 32 is center-tapped to

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ground. Battery 39 having its center point grounded is connected to the diodes in such polarity as to oppose the current flow in response to driving voltages developed in windings 31 and 32.

The operation of this part of the circuit for producing controlling pulses is indicated by certain of the curves given in Figs. 2 to 3. The sine wave curves in Figs. 2 and 3 show the voltages applied to the clipper circuit. The voltage of Fig. 3 is displaced in phase with respect to that in Fig. 2 by means of the phasing elements 33, 34. The action of the diodes in limiting the amplitude of the wave applied to the output resistor 40 is shown by the dotted horizontal lines, indicating that most of the voltage wave is suppressed. Figs. 4 and 5 show with an enlarged ordinate scale the shape of the current wave transmitted to the output resistor 40 from the respective pairs of diodes.

The resistance 40 is center-tapped and is coupled through a rectifier diode 41 and resistances 42 and 43 to the grid of the pentode 44. The result of the addition of the voltages given in the curves of Figs. 4 and 5 in the resistance 42 is shown by the short positive and negative pulses of Fig. 6. Only the positive pulses, shown in Fig. 7, are transmitted through the rectifier 41. The resulting voltage wave in the output of pentode 44 is indicated in Fig. 8 comprising a constant portion with very abrupt depressions resulting from the amplification of the impulses of the type shown in Fig. 7.

The operation of the gas-filled tubes and their associated resistances in producing a stepped output voltage will now be described with the aid of the simplified diagrams of Figs. 9, 10 and 11 and the graphs given in Figs. 12 to 17. It will be assumed that a gradually varying input voltage such as indicated in Fig. 13 is applied to terminals 10. Fig. 12 shows the character of the voltage wave that is applied to the gas-filled tubes from conductor 27. The curves in these figures are somewhat idealized but serve to illustrate the principles of operation.

If the voltage wave at terminals 10 is too small to produce the smallest voltage that is desired across the output terminals 11, that is, an input voltage less than the value A in Fig. 13, such input wave fails to overcome the opposing voltage 16 (which is smaller than 17) and fails to initiate discharge in tube 12 when the anode of the latter is driven positive by the voltage applied over lead 27. Voltages impressed on the grids of the tubes 14 and 15 from the batteries 18 and 19 are such as to permit the tubes 14 and 15 to become ionized and the interconnections between the tubes of each pair are such that only one tube of a pair can be ionized at the same time. Tubes 14 and 15 will become ionized in the event that the opposite tube of the pair is not previously ionized. Under the conditions assumed, therefore, when lead 27 applies positive voltage to the anodes of tubes 14 and 15, both of these tubes are ionized and the resulting circuit condition corresponds to that shown in diagram in Fig. 9. It is seen from this diagram that the resistances 24 and 25 are connected, in series with individual resistances 29, to lead 27 so that in the absence of current flow through these resistances the voltage at Q and at R and at P is equal to the positive voltage existing in lead 27 as indicated in Figs. 14 and 15 in time period T₁. It is assumed in the present disclosure that the voltage of battery 26 is just sufficient to reduce the ter-

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minal voltage 11 to zero under these conditions. This is indicated at H, Fig. 17.

The brief interruption of the voltage in lead 27 at the end of the time interval T₁ deionizes the tubes 14 and 15 and immediately thereafter the full voltage of lead 27 is reapplied to the plates of all of the gas-filled tubes. This brief interruption causes a momentary voltage to be applied to terminals 11 from the battery 26 as indicated at J. This is of such short duration that it may readily be suppressed by a low-pass filter, if desired.

It will next be assumed that the input voltage impressed at terminals 10 is in excess of the value A (Fig. 13) but less than value B. In the present case the input voltage is sufficient to overcome the opposing voltage 16 in the input circuit of tube 12 and that tube ionizes before tube 14 has ionized. The resulting current flow through resistance 29 and inductance 21 to ground causes a counter-electromotive force to be developed, raising the potential of both cathodes of tubes 12 and 14 to such voltage that the anode-cathode voltage appearing across tube 14 is insufficient to permit that tube to ionize with the grid bias applied from 18. Tube 15, however, ionizes as in the previous case, since the input voltage is assumed less than value B and tube 13 is not, therefore, ionized.

The diagram representing this circuit condition is given in Fig. 10. It is noted from Fig. 10 that the potential of the point P is approximately the potential of the mid-point of the resistance 29 that is in series with the plate of tube 15. This is true because the high resistances 23 and 24 produce at the point P a potential which is midway between the potentials at Q and R, that is, the potential of the plate of tube 12 and the approximate potential of the conductor 27, resistances 24 and 25 being, as stated, very large compared with resistances 29. This potential P is indicated in Fig. 16 in the time interval T₂. The voltage of battery 26 when subtracted from this potential gives the value K in Fig. 17. At the end of the period T₂ the interruption of the voltage applied over conductor 27 again deionizes the gas-filled tubes.

Let it next be assumed that the input voltage has risen to a value greater than that indicated at B, Fig. 13. This is sufficient to overcome the opposing bias voltages of both sources 16 and 17 in the input circuits of tubes 12 and 13. Both of these tubes, therefore, ionize and prevent ionization of tubes 14 and 15 because of the potential developed across the cathode lead impedances 20, 21 and 22, 23.

The diagram corresponding to this condition is shown in Fig. 11. The potential dividing resistors 24 and 25 are both connected to the anodes of tubes 12 and 13 so that the points Q, R and P now are at the same voltage, corresponding to the voltage of conductor 27 minus the potential drop through either resistance 29 associated with tube 12 or 13. This corresponds to the lowest voltage indicated in Fig. 16. When the voltage of the battery 26 is subtracted from this voltage the voltage L, Fig. 17, is obtained which is the voltage applied to the terminals 11.

In effecting the lock-out between the two tubes of a pair as mentioned above, the inductance 21 or 23 develops an initial or transient lock-out voltage and the resistance 20 or 22 provides lock-out during the remainder of the cycle. The time constant of the circuit depends upon the relative proportioning of the reactance and resistance and

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may in a practical case be as small as a few microseconds. Lock-out is used to assure that once a set of output conditions is established at the beginning of a cycle these conditions will not change until the plate voltage in lead 27 has been reduced and reapplied irrespective of what happens to the grid voltage during the cycle.

If the input voltage remains above the value B, Fig. 13, for the duration of several voltage impulses in lead 27, the gas-filled tubes are deionized momentarily at the end of each such impulse but the persistence of the input voltage causes the tubes 12 and 13 to be ionized again and maintain the voltage conditions as represented in the time period T₃, Fig. 17.

For descending values of the input voltage wave, Fig. 13, the same action takes place as for rising voltages. That is, as long as the input voltage remains above the value B, tubes 12 and 13 are ionized during each impulse time, Fig. 12; when the voltage drops to a value between B and A, tubes 12 and 15 are ionized during each impulse time and when the voltage drops below the value A, tubes 14 and 15 are ionized throughout each impulse time.

Fig. 1 indicates dotted connections which may lead to still further pairs of gas-filled tubes corresponding to 13, 15 and 12, 14. For each such additional pair of gas-filled tubes there is an additional resistance corresponding to 24, 25. Three pairs of tubes will give an output voltage wave having three stepped values in addition to zero, four pairs of tubes will give four steps, etc. For example, referring to Fig. 10 in which, as explained, the potential dividing resistors 24 and 25 give a potential at point P corresponding substantially to the midpotential existing in resistor 29 associated with tube 15, if an additional tube like 12 were also ionized at this time, corresponding to an input voltage intermediate between A and B, the potential of the point P would correspond approximately to a point in resistance 29 associated with tube 15 one third the distance along that resistance, measured from the plate of tube 15. The reason for this is that there would then be three potential dividing resistors, and the potential produced at point P would be the same as if the third resistor were in parallel with 25. Similarly, with four pairs of tubes the potential existing across one of the resistors 29 would be effectively divided into one, two, three or four parts, depending upon the particular tubes ionized in any given case to provide for a total of four steps of values besides the zero value.

The voltage produced at terminals 11 will be stepped as indicated by the wave form shown adjacent these terminals in Fig. 1 and its phase will be opposite to that of the input wave because of the action of the circuit as above described. For some purposes the wave as it appears at terminals 11 may be suitable. If, however, it is desired to turn over the phase of this voltage wave, switch 61 is closed on contact 62 and terminals 11 are used as the output terminals. In this way the triode 60 is used to give the phase reversal.

The design of this vacuum tube stage may be varied to suit conditions. It is illustrated as a direct current circuit, with the grid suitably biased from battery 26. Plate voltage is supplied through resistor 63, which may also be inductive. The normal voltage that would be applied to terminals 11 from across coupling resistor 66 when the applied input voltage is zero may be canceled by the counter-potential taken from potentiometer resistance 67 across a small battery 68.

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When the voltage at terminals 11 has the value H (Fig. 17) the slider on resistance 67 is adjusted to give zero voltage at terminals 11. When the voltage at terminals 11 has some other value such as K or L, the grid of tube 60 is made more negative by this amount, increasing the internal resistance of the tube 60 which makes the potential at point 64 more positive, and therefore the potential of the upper terminal 11 more positive.

Fig. 18 shows an embodiment in which square waves are applied to the gas-filled tubes instead of waves with only very short interruption times as previously described. These square waves are produced from sine waves generated at 30 and transmitted through transformer 69 to a clipper circuit consisting of diodes 35, 36, 37 and 38 to the control grids of two pentodes 52 and 53. The diodes 35, etc., are self-biased by cathode resistors 50 each provided with the usual shunting capacity 51. These diodes cause flat topped waves to be applied to the grids of pentodes 52 and 53. The pentodes are self-biased by cathode resistor 54 shunted by capacity 55. Output transformer 56 is designed to pass square top waves to the required degree of approximation. The waves applied to conductor 127 have the general form shown in Fig. 19, graph I, consisting of both positive and negative portions.

One advantage of using waves of this form is that transformers may be used for distributing such waves to points at which they are to be used and they may be transmitted at any suitable voltage and transformed at the place where they are used.

The apparatus in the box 70 may comprise the gas-filled tubes 12, 13, 14, 15 and associated resistances, inductances and grid biasing batteries as shown in Fig. 1. The input terminals are in this case indicated at 110. The potential dividing resistances 24 and 25 connect through a source of opposing voltage 126 and series resistor 71 to the grid of a phase reversing amplifier 72.

The operation of this type of embodiment will be described in connection with the graphs given on Fig. 19. Assuming an input voltage at 110 of the general form shown in graph II, Fig. 19, it is noted that the first positive impulse and the beginning of the second positive impulse (counting from the left) occur before the input voltage rises above the value A. This corresponds to the circuit condition indicated in Fig. 9 so that the voltage at W (Fig. 18) is as shown in Fig. 19, graph III at the corresponding times.

At the start of the third positive impulse of the wave of graph I the input voltage is intermediate between values A and B. This corresponds to the circuit condition of Fig. 10 and gives an intermediate value of voltage at W as shown in graph III, the third impulse.

The fourth positive impulse, Fig. 19, graph I, occurs at a time when the input voltage exceeds the value B. This corresponds to the circuit condition of Fig. 11 and gives a minimum value of voltage at W.

This wave in graph III is reversed in phase by the tube 72 so that the voltage appearing from x ground is as indicated in graph IV. Some of the original voltage from lead 127 is taken around through biasing battery 75 and resistor 78 to the ungrounded output terminal 77 and is combined with the output wave in tube 72 arriving at this same point through resistor 76. The voltage taken from lead 127 and displaced in the negative direction by the voltage of battery 75 is indicated by graph V. The result of algebraic

addition of the voltages represented in graphs IV and V is shown in graph VI, this being the voltage appearing across the output terminals 17.

What is claimed is:

1. In combination, circuit means for converting gradually varying voltage into a voltage varying abruptly in steps comprising a plurality of trigger tubes, a source of interrupted output voltage of constant peak value for the tubes, graduated voltage sources connected to the input terminals of said tubes opposite in sign to said gradually varying voltage, means to apply the gradually varying voltage to the input terminals of said tubes in common whereby certain of the tubes are triggered at a time depending upon the instantaneous value of the applied input voltage, output terminals between which said stepped voltage is to be produced, resistances connected in parallel between one of said output terminals and said source, said trigger tubes having output terminals connected to points in the individual resistances and means including the tubes that are triggered at any one time for individually producing a potential drop in the corresponding resistance between said source of interrupted voltage and said output terminals.

2. In combination, circuit means for converting a gradually varying voltage into a stepped voltage comprising trigger tubes in interlocking circuit relation in pairs, graduated voltage sources connected severally to the first tube of each pair, means to apply the gradually varying voltage to said first tube of each pair in opposition to said graduated voltage sources to trigger on certain of said tubes depending upon the instantaneous voltage of said applied wave, output terminals, a source of output voltage supply for said tubes, and means including resistances connected between output electrodes of said tubes and said output terminals for producing abruptly changing voltages at said output terminals in response to the triggering on of said tubes under control of the gradual variations in said applied voltage.

3. In a circuit for translating a gradually changing input voltage to an abruptly changing output voltage, a plurality of trigger tubes having graduated triggering characteristics whereby they are triggered selectively by input voltages of different value, means to apply said input voltage to said tubes in common to cause certain of them to be triggered at a time depending upon the input voltage applied, a source of output voltage, output terminals, and resistances individual to said tubes connected in parallel from said source of output voltage to said output terminals, said trigger tubes having output circuits effectively including a small portion only of the corresponding output resistance whereby when said tubes are triggered abrupt reductions in voltage occur between said source of output voltage and said output terminals depending upon the number of tubes triggered at a time.

4. In combination, a plurality of pairs of gas-filled tubes, a pulsing circuit connected to the anodes of all of said tubes, means for causing one tube of each pair to break down on each positive pulse from said pulsing circuit, a source of gradually varying input voltage connected to the grid of one tube of each pair, graduated negative bias sources connected to said grids for causing said last-mentioned tubes to be ionized selectively according as the input voltage exceeds the bias on one or more of said last-mentioned tubes, interlocking connections between the tubes of each pair for preventing both tubes from ion-

izing during any one pulse, output terminals, resistances connected between said pulsing circuit and said output terminals to provide a voltage at said output terminals of a magnitude determined by the potential drop through certain of said resistances, and connections from points on said resistances to said tubes to enable the output terminal voltage to be varied in steps depending upon which tubes of said pairs of tubes are ionized during each impulse.

5. In combination, a source of voltage, output terminals, a plurality of resistances adapted when effectively connected in different combinations to said source and said terminals to apply different fractional parts of the voltage of said source to said terminals, a source of incoming waves of gradually varying amplitude, a plurality of trigger tubes having input electrodes connected in common to said source of input waves, means to initiate discharge in different ones of said tubes in response to input wave variations dependent upon the instantaneous amplitude of said waves and means causing said tubes when triggered to increase the potential drop through portions of said resistances between said source of voltage and said output terminals to apply to said terminals abruptly changing voltage in steps in response to rising and falling voltage of said input waves.

6. In combination, a circuit having a pair of input terminals and a pair of output terminals, a source of slowly varying voltage connected to said input terminals, a source of waves of flat-top wave form connected in circuit with said output terminals, resistances effectively included between said latter source and output terminals for reducing in steps the voltage applied to said output terminals when current is caused to flow through said resistances, a trigger tube connected to each resistance and adapted when broken down to produce current flow through the corresponding resistance and means controlled by the instantaneous input voltage for determining the number of trigger tubes that are broken down at a time.

7. In combination, a circuit having input terminals and output terminals, a source of flat-topped voltage waves connected to said output terminals, a set of trigger tubes connected in shunt relation to said source and to said output terminals through individual resistances and means for initiating discharge through said tubes during positive periods of said voltage waves to control the maximum voltage applied from said source to said output terminals, a second set of trigger tubes connected in shunt relation to said source and said output terminals through individual resistances, means to initiate discharge in a variable number of said second set of tubes by application of voltage of different value to said input terminals, a source of variable voltage connected to said input terminals, means controlled by tubes in said second set, when energized, to prevent discharge in corresponding tubes of said first set and means controlled by energized tubes of said second set for reducing the voltage applied from said first source to said output terminals, in steps depending upon the number of tubes in the second set that are energized.

8. In combination, a source of voltage, output terminals, and means for applying various fractional amounts of said voltage to said terminals in abrupt steps under control of a gradually varying voltage, comprising resistances connected, in parallel with each other, in series between one

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terminal of said source and one output terminal, a connection from the opposite terminal of said source to the other output terminal, each resistance consisting of a small portion adjacent said source in series with a large portion adjacent said one output terminal, a trigger tube for each resistance having its discharge terminals connected from a point in the resistance between said portions across to said connection, a control terminal for each trigger tube, means to apply the gradually varying voltage to the control terminals of all of said trigger tubes in common, and graduated bias voltages for said trigger tubes for causing different numbers of said tubes to be triggered at a time depending upon the instantaneous amplitude of said varying voltage.

9. A circuit for converting a gradually varying current wave into a stepped wave, said circuit having input terminals for application of said gradually varying wave and output terminals across which the stepped wave is to be produced, a group of trigger tubes having control electrodes in circuit with said input terminals and having output electrodes including anodes, a source of regularly recurring positive voltage pulses, means to apply said pulses to the anodes of all of said tubes in parallel to render said anodes positive so as to cause current to flow through said tubes under control of the applied input voltage wave,

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means to apply blocking potential to the input electrodes of said tubes to prevent breakdown except at the beginning of each of said pulses, means to remove said blocking potential between pulses and to place said tubes under control of said gradually varying wave for an instant at the beginning of each pulse, means to cause a varying number of said tubes to break down depending upon the instantaneous amplitude of said varying wave, means to cause the tubes that thus break down to remain in conducting condition throughout the ensuing pulse period and to maintain the other tubes of the group non-conducting during such pulse period, and parallel connections from the output electrodes of said tubes to said output terminals, including individual resistors in the conductors from the output electrodes of said tubes.

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