April 18, 1950 L. J. GIACOLETTO 2,504,322

ELECTRICAL TRANSFER NETWCRK

Filed June 10, 1949

Fig. 1

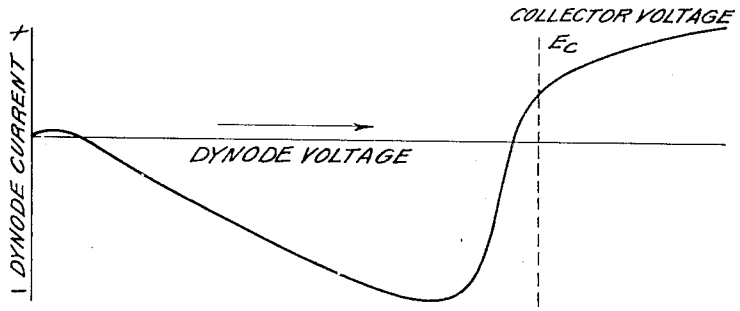


Fig. 2

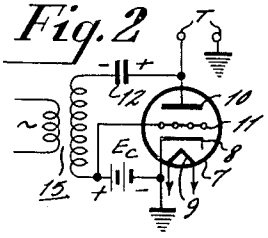


Fig. 3

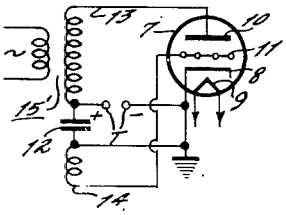


Fig. 4

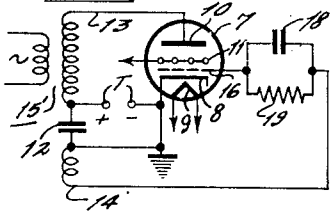


Fig. 5

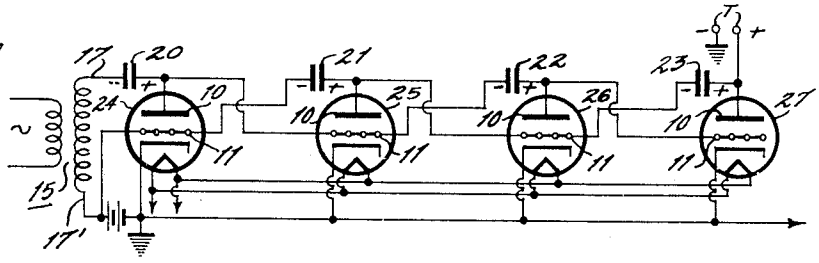
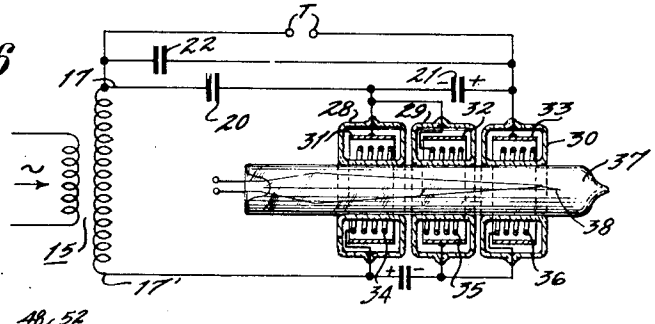


Fig. 6



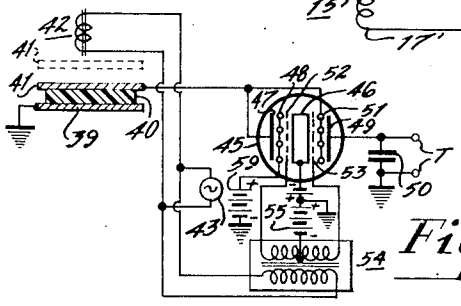


Fig. 7

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ELECTRICAL TRANSFER NETWORK

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Application June 10, 1949, Serial No. 98,302

16 Claims. (Cl. 315—201)

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This invention relates to electrical transfer networks, and is particularly concerned with transfer networks adapted for operation at high potentials.

An electrical transfer network, as that term is used herein and in the appended claims, is intended to refer to a network in which an electron stream is used to complete circuit connections between different points. In many instances, one or both of the points to be connected in a given circuit are at a high potential so that difficulties are encountered with respect to the effective insulation of elements operating at widely differing potentials.

The invention is applicable to half-wave and full-wave rectifiers, voltage-doubling-rectifying circuits, and, in general, to circuits involving a switching action. For example, an electric switching circuit may be required to connect a source terminal to a load terminal only when the potential of the source terminal exceeds a predetermined value as it varies between values above and below the potential of the load terminal. By way of further example, but not limitation, the invention is applicable to rectifying networks for converting energy from a source of varying potential into a steady direct potential for such use as may be desired.

In this connection, it may be observed that the potential variation may be referred to ground potential, in which case it is conventionally considered to be "alternating," or to any other circuit point which may or may not be at ground potential. As here considered, an "alternating" potential is one which varies in amplitude with respect to any point of reference.

A specific type of circuit to which the invention is particularly applicable is a capacitor charging and/or discharging circuit. Heretofore, it has been customary to charge a capacitor from an alternating potential source by means of a suitable rectifier, such as an electron discharge device of the thermionic diode type having an electron-emissive cathode heated by heat conduction and/or radiation from a separate heater filament. When operating at relatively high positive potentials, for example, when the circuit is being employed as a voltage doubling circuit, or as a circuit for developing accelerating potentials for kinescope tubes, the cathode of the thermionic diode is normally operated at the positive direct current potential of the supply circuit above ground, and at the same time the filament or heater is connected to a source of heating potential. This means that either the

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heater supply circuit also must be operated at the high direct current potential of the cathode, or, if the heater is operated at or near ground potential, the heater must be insulated from the cathode to withstand the full direct current output voltage.

The first expedient involves insulating the secondary winding of the filament heating transformer from the primary winding, or the use of separate batteries floating at the high potential above ground. On the other hand, when the heater is operated at or near ground potential, the insulation between heater and cathode, if sufficient to withstand the high potential difference between those electrodes, reduces the heat transfer efficiency.

It is a general object of my invention to provide an electrical transfer network in which a high voltage positive terminal of a load may be connected directly to an electron discharge electrode, which electrode is more effectively isolated from circuit elements operating at ground potentials than has heretofore been possible.

A more specific object of my invention is to provide an electrical transfer network in which a high voltage positive load terminal is connected to an electron discharge electrode which is rendered electron-emissive by bombardment with elemental energy particles from a source which is spatially removed from said electrode.

According to one modification of my invention, the electron discharge electrode is bombarded by primary electrons from a thermionic cathode.

According to another modification of the invention, the electron discharge electrode is bombarded by photons from a source relatively spatially removed from the electrode.

Other aspects of my invention relates to circuit arrangements in which the full advantages of my invention are attained.

How the foregoing and other objects are attained will appear more fully from the description which follows hereinbelow and the drawings, in which:

Figure 1 illustrates changes in dynode current with changes in dynode potential in a secondary electron emission devices;

Figure 2 illustrates a basic rectifying circuit employing a secondary emission discharge device as a uni-directional valve in accordance with the invention;

Figures 3 and 4 are modifications of the circuit of Figure 2;

Figure 5 illustrates the application of my in-

vention to voltage multiplier circuits, with rectification and switching being accomplished by means of secondary emission;

Figure 6 illustrates the application of the invention to a voltage multiplication circuit in which rectification and switching are accomplished by means of photo-emission; and

Figure 7 illustrates a circuit in which a current of varying potential is derived from a condenser whose capacity is periodically varied between maximum and minimum values by a mechanical drive arrangement and in which the condenser is charged and discharged by means of secondary electron discharge devices.

Similar reference numerals identify similar parts throughout the several figures of the drawings.

In conventional high voltage circuits of the type mentioned above, employing conventional diodes embodying thermionic cathodes, the cathode must be directly or indirectly heated from a low voltage source and in the latter case the cathode may either be insulated from the source or operated at the source potential.

In the various arrangements illustrated herein, the electrode which functions as the cathode electrode is energized by bombardment by elemental energy particles, such as electrons or photons derived from a source which is disposed at some distance from the emitting electrode. Consequently, the device may take the form of a known type of secondary-electron discharge tube, in which case the electrode which functions as a source of electrons is called a "dynode."

If a secondary-electron emitting electrode or dynode having good secondary-electron emission properties is bombarded with electrons of sufficient energy to release secondary electrons from the dynode surface, and if a second electrode maintained at fixed positive potential be provided to collect secondary-electrons emitted by the dynode, then the dynode current as a function of dynode potential is as shown in Figure 1. It will be seen that for a range of dynode voltage from slightly above zero to approximately the potential of the collector electrode, the dynode current is negative. For this range of dynode voltage, the dynode emits a larger number of secondary-electrons than the number of primary-electrons striking it, and can, therefore be considered as a cathode, and the dynode-collector operation is somewhat analogous to the cathode-anode operation of a conventional thermionic diode.

An arrangement employing a secondary-electron emission device as a rectifier is illustrated in Figure 2. The tube 7 is provided with a thermionic cathode 8 heated in the normal manner by a heater 9, which is energized by a source of low-voltage alternating current (not shown). High voltage alternating current from the secondary winding of a transformer 15 is applied to to a collector electrode 11, and to a dynode 10 in series with a capacitor 12. The collector 11 is connected to the cathode 8 through a small battery E_c, with polarity as indicated. When the potential of the dynode 10 of Figure 2 swings to a value below that of the collector 11 (but still positive with respect to the cathode 8), secondary-electrons from the dynode 10 will be collected by the collector 11, producing a D. C. voltage across the condenser 12 of such polarity that the dynode 10 will become more positive. The dynode 10 comprises material such as silver-magnesium characterized by having a large ratio S

of secondary-electrons to primary-electrons striking the dynode, and the dynode current will be (S—1) times as large as the primary or cathode current.

During the period when the dynode 10 is positive with respect to the collector 11 there will be no secondary-emission, and the primary or cathode current flow will tend to discharge the condenser 12. However, if S is much greater than 1, this discharge current will be small as compared with the charging current, and each successive cycle will increase the charge on the capacitor 12. Rectified output voltage may be derived from output terminals T and filtered as desired.

According to the invention, I may substantially eliminate the small discharge current previously mentioned by connecting the collector electrode to a point of alternating currrent potential which is 180° out of phase with the dynode and cathode potentials. For example, in the circuit shown in Figure 3, the dynode 10 and the collector 11 in the tube 7 are connected to the opposite ends 13, 14 of the split secondary winding of a power transformer 15'. An alternative placement of the capacitor 12 is also shown in Figure 3, wherein the capacitor 12 is connected in series between the two sections of the secondary winding of the transformer 15'. This arrangement places the positive D. C. output terminal at A. C. ground potential.

In the circuit of Fig. 3, when the dynode 10 is positive with respect to the cathode 8, the collector 11 will be negative with respect to the cathode. Due to the relatively close spacing between the cathode 8 and the collector 11, the latter will exert an electrostatic influence on the surface of the cathode similar to the effect of a current-control grid, and will substantially eliminate the flow of primary electrons from the cathode to the dynode. Such a connection also makes the battery E_c of Fig. 2 unnecessary, since the collector 11 will be slightly positive with respect to the cathode 8 when the dynode 10 is negative.

According to another aspect of the invention, the primary current from the cathode 8 to the dynode 10 can be substantially eliminated during the period when the dynode is positive with respect to the collector electrode by adding a control grid 16 to the tube 7, as shown in Fig. 4. In the circuit of Fig. 4, the control grid 16 is energized with a voltage which is 180° out of phase with the dynode potential. For example, the control grid 16 can be connected to a point 14, on the split secondary winding of the transformer 15', at which point the voltage will be 180° out of phase with the voltage on the dynode 10. A self-biasing network, consisting of a capacitor 18 and a resistor 19, can be connected in the grid circuit, as shown. The collector electrode 11 should be maintained at a positive potential with respect to ground, either by connecting the collector 11 to a direct current source E_c as illustrated in Fig. 2, or to a properly phased alternating current source as illustrated in Fig. 3. In either the circuit of Fig. 3 or that of Fig. 4, cathode current will flow only during the period when the dynode potential has its smallest positive value.

In the circuit of Fig. 4, the operating angle of the cathode current (i. e. the portion of the cycle during which the capacitor 12 will be discharged

due to primary electron flow from the cathode) will be particularly small, since the condenser 18 and the resistor 19 will operate as a so-called grid leak, serving to maintain the grid 16 at or below the level of cut-off except during the period when the dynode potential is at its smallest value.

If the operating angle of the cathode current is extremely small, difficulty may be experienced in getting the output voltage to build up across the condenser 12. This is because the dynode 11 will be negative with respect to the cathode 8, so that the primary electrons may not strike the dynode. This condition can be avoided by increasing the operating angle of the cathode current, either by decreasing the effective collector bias with respect to the cathode voltage, or by increasing the alternating potential on the dynode gradually as the output voltage builds up, or, alternatively, by priming the condenser 12 with a D. C. voltage.

It should be noted that, since the dynode current will be negative, the resulting load across the secondary winding of the transformer 15' will also be negative; that is, the D. C. output power will be obtained directly from the potential source for the collector electrode, and the flow of dynode current will tend to unload the secondary winding, increasing the efficiency of the driving source. For the same reason, voltage regulation of the direct current output will be improved, and will be much superior to conventional diode rectifier circuits.

According to another aspect of the invention, I may employ secondary electron emission tubes in a full-wave multiplier arrangement, as illustrated in Fig. 5. In this case, I employ a plurality of condensers 20, 21, 22 and 23, and an equal number of secondary emission discharge tubes 24, 25, 26 and 27. In the circuit of Fig. 5, the dynodes 10 in the first and third tubes 24, 26 are both connected to one end 17 of the secondary winding of the transformer 15 through the first and third capacitors 20, 22, while the collector electrodes 11 in the same tubes 24, 26 are connected to the other (grounded) end 17' of the transformer secondary winding, so that the first and third tubes 24, 26 will operate in the manner already described hereinabove. The dynodes 10 and the collector electrodes 11 in the second and fourth tubes 25, 27 are connected to the secondary winding of the transformer 15 in inverse relation with respect to the dynodes 10 and the collectors 11 in the first and third tubes 24, 26, so that the second and fourth tubes 25, 27 will operate in the same manner as do the first and third tubes 24, 26, but on opposite half-cycles of transformer voltage. While I have not illustrated in Fig. 5 any arrangement for preventing discharge of the condensers 20—23 by the primary cathode current during the time interval when the respective dynodes swing above the collector potential, it will be understood that the arrangements illustrated in Figs. 3 or 4 may be employed. Those skilled in the art will also understand that the control potentials applied to the collectors 11 (or to control grids thereof, if such are used) of the second and fourth tubes 25 and 27 must be phased 180° from the control potentials applied to the corresponding electrodes of the first and third tubes 24 and 26.

The output voltage obtainable at the dynode 10 of the fourth tube 27 will be approximately four times the voltage obtainable with a single stage, other circuit parameters being equal.

It should be noted that, since the cathodes 8 of all of the tubes 24—27 in the network of Fig. 5 are operated at the same potential, a one-envelope tube employing a common cathode may replace the individual tubes 24—27 shown in Fig. 5.

Turning now to the use of photo-emissive electrodes for transferring charges at high potentials, attention is directed to Fig. 6, in which I have illustrated a photo-electric electron discharge device in a voltage multiplier circuit similar to that shown in Fig. 5. The arrangement of Fig. 6 comprises three torroidal evacuated envelopes 28, 29, 30, containing, respectively, cylindrical photo-emissive electrodes 31, 32, 33, and collector electrodes 34, 35 and 36. Within the cylindrical space defined by the envelopes 28, 29, 30 is a light source, such as an incandescent lamp 37, preferably disposed along the axis of the envelopes, and having a filament 38 adapted to be heated to incandescence by the passage therethrough of an electric current from a suitable source (not shown).

The photo-emissive electrodes 31, 33 in the first and third tubes 28, 30 are connected to one terminal 17 of the secondary winding of a transformer 15 through capacitors 20, 22, while the collector electrodes 34, 36 in the first and third tubes 28, 30 are connected to the other terminal 17' of the transformer secondary, with a third capacitor 21 being connected between the two collectors 34, 36. The photo-emitter 32 and the collector 35 in the second tube 29 are connected to the transformer secondary inversely with respect to the connections for the first and third tubes 28, 30.

In this arrangement, photons emitted by the filament 38 will pass through the screen-like collector electrodes 34, 35, 36, and will strike the inner surfaces of the photo-emissive electrodes 31, 32, 33 with sufficient energy to dislodge electrons. When any one of the collector electrodes 34—36 is momentarily at a positive potential with respect to its associated photo-emissive electrode, a current will flow, charging the condenser in the circuit of the photo-emissive electrode, thus affording a mode of operation similar to that illustrated in Fig. 5. A D. C. voltage, having a value equal approximately to three times the peak A. C. voltage across the transformer secondary winding, will be available at the output terminals T.

As is well understood in the art, the output potential obtainable from voltage multiplier circuits of the type illustrated in Figs. 5 and 6 depends upon the value of the alternating potential across the secondary winding of the transformer 15 and the number of condensers and "rectifier" elements in the circuit. Heretofore, the output voltage obtainable in a circuit of this type was limited by the high voltage insulation problem to which reference has already been made. In both of the circuits of Figs. 5 and 6, the high voltage insulation problem is eliminated, so that the only limitation on the output voltage which can be obtained by increasing the number of condensers and rectifiers is the breakdown potential between the various parts of the apparatus.

It should also be understood that the invention is not limited to circuits in which the alternating potential is obtained from a transformer or other electromagnetic device. In Fig. 7, I have illustrated how the invention may also be used to rectify the pulsating high voltage output from an electrostatic generator of high potentials of the type illustrated and claimed in my copending application Serial No. 98,303, filed June 10, 1945.

In the circuit of Fig. 7, I have illustrated a variable condenser comprising a grounded plate 39, a dielectric layer 40, an ungrounded plate 41, an electromagnetic driving mechanism 42 for increasing and decreasing the spacing between the plates 39, 41, and a source of electrical energy, such as an alternating current generator 43, for energizing the driving mechanism 42. The operation of electrostatic generators of this type depends upon the fundamental fact that a condenser which is charged from a source of given potential while the condenser is adjusted to maximum capacity can be discharged at a much higher potenial after the capacity has been reduced, as by increasing the spacing between the plates, or by decreasing the confronting area of the plates, or both.

In this type of electrostatic generator, it is desirable to disconnect the charging source at a moment no later than the moment at which the capacity begins to decrease, and it is also desirable to eliminate the necesstiy of making and breaking contacts in an ionizable medium at the necessarily high potentials involved, to prevent arcing and related problems.

In the arrangement of Fig. 7, I accomplish the switching necessary for both the charging and discharging operations by means of secondary-electron emission devices. In Fig. 7, I have illustrated a switching tube 45 containing a thermionic cathode 46 operated slightly below ground potential, a dynode electrode 47 connected to the ungrounded condenser plate 41, and a collector electrode 48 connected to the positive terminal of a source of charging potential 59, the other terminal of which is grounded. When primary electrons from the cathode 46 strike the dynode 47, secondary electrons will be emitted by the dynode 47 and will be collected by the collector 48, so that the potential of the condenser plate 41 will be raised substantially to the potential of the positive terminal of the source 59. If the plate 41 is charged while in the position indicated by the solid outline, and then shifted to the position indicated by the dotted outline, the potential of the capacitor will rise above the potential of the collector 48, and secondary electrons will no longer flow to the collector.

At the same time, primary electrons from the cathode 46 will also be striking a second dynode 49 which is connected to an output condenser 50. The condenser plate 41 is also connected to a second collector electrode 51. As the condenser plate 41 moves away from the plate 39, the potential on the collector 51 will increase to a value above the potential on the dynode 49, and electrons will be drawn from the output circuit, increasing the potential across the condenser 50.

When the condenser plate 41 starts back toward the plate 39, the potential on the collector 51 will fall below the potential on the dynode 49, and the right-hand section of the tube will become inoperative. Until the dynode 47 falls below the potential of the collector 48, no change in the charge on the plate 41 will occur. However, before the plate 41 reaches the position indicated by the solid outline, the potential thereon will fall to the potential of the collector 48, whereupon electrons will be moved from the plate 41, and the condenser (39, 41) will resume the condition of maximum capacity and, once again, will be charged to the potential of the source 59.

Actually, of course, the primary electrons from the cathode 46 will tend to reduce the charge on the condenser plate 41 when the potential on the latter is more positive than that of the collector 48, and primary electrons will also tend to reduce the charge on the output condenser 50 during the period when the potential on the plate 41 is below the potential of the condenser 50. These losses in charge may be prevented by providing each half of the tube 45 with a grid 52, 53, which may be energized 180° out of phase with one another by voltage from a transformer 54 whose operation is synchronized with the operation of the mechanical drive 42, as by providing a connection from the generator 43 to the primary winding of the transformer 54. A bias battery 55 may be provided to insure cut-off during the critical period.

Each of the arrangements hereinabove described and illustrated is characterized by the fact that energy is transferred through an electron stream, and, hence, has all the usual advantages of electronic control. At the same time, these arrangements are not dependent upon a source of heat energy located in close physical proximity to the emitting surface to overcome the work function of the emitter. Therefore, the source of emission energy may be isolated to a high degree from the high voltage current being controlled.

Since many changes could be made in the apparatus shown and described, all within the scope and spirit of the invention, the foregoing is to be construed as illustrative, and not in a limiting sense.

What is claimed is:

1. In a circuit for transferring energy between a source of alternating potential and a load terminal, in combination, a network for connecting said load terminal to said source, said network including an electrode adapted to emit electrons upon bombardment with elemental energy particles, a second electrode for collecting electrons emitted by said first electrode, one of said electrodes being operatively connected with said terminal and the other of said electrodes being operatively connected with said source, and a source of elemental energy particles for bombarding said first electrode.

2. A circuit in accordance with claim 1 in which said collecting electrode is physically disposed in sufficient proximity to said particle source in a manner to create an electrostatic field in the region of said source, and means for establishing a predetermined potential relationship between said collecting electrode and said source.

3. A circuit in accordance with claim 1 in which said collecting electrode is disposed near said particle source, and further including a constant-potential source for maintaining said collecting electrode at a slight positive potential with respect to said particle source.

4. A circuit in accordance with claim 1 including means for returning particles emitted by said particle source to said particle source during the portion of the operating cycle of the network in which said collecting electrode is at a lower potential than said emitting electrode.

5. A circuit in accordance with claim 1 in which said collecting electrode is disposed between said particle source and said emitting electrode and in which the potential on said collecting electrode falls below the potential of said particle source when the potential of said particle source falls below the potential of said emitting electrode.

6. A circuit in accordance with claim 1 including a control electrode disposed near said

particle source, and means for varying the potential on said control electrode between values above and below the potential of said particle source, said means being arranged to bias said control electrode negatively with respect to said particle source during portions of the cycle in which said collecting electrode is at a lower potential than said emitting electrode.

7. A circuit in accordance with claim 1 in which said network includes means for limiting the period during which particles will strike said first electrode to less than a full cycle of operation of the network.

8. A circuit in accordance with claim 1 including a third electrode for controlling the flow of particles from said particles source, said third electrode being operated at a potential bearing a predetermined relationship with the potential of said potential source.

9. In a voltage supply circuit including a terminal to which power is to be delivered at a substantially fixed voltage and a source of alternating potential, in combination, a transfer network comprising a first electrode adapted to emit electrons upon bombardment by elemental energy particles, a second electrode adapted to collect electrons emitted by the first electrode, and a source of particles for bombarding said first electrode, one of said electrodes being operatively connected to said terminal and the other of said electrodes being operatively connected to said source, a control electrode interposed between said first electrode and said particle source, and means for varying the potential of said control electrode in synchronism with the variation of the potential of said potential source so as to prevent the bombardment of said first electrode during periods when said first electrode is at a positive potential with respect to said second electrode.

10. A voltage transfer network comprising a source of alternating voltage, and a capacitor and a transfer circuit serially connected across said source, said transfer circuit including a first circuit element adapted to emit electrons upon bombardment by elemental energy particles, a source of such particles, and a second circuit element for collecting electrons emitted by said first element.

11. An electrical network comprising a source of electrical energy, a first circuit element adapted to emit electrons when bombarded by elemental energy particles, a source of such particles, a second circuit element disposed to collect electrons emitted by said first element, and a capacitor, said capacitor and said circuit elements being serially connected across said source of alternating current.

12. A network in accordance with claim 11 in which said first circuit element comprises a material having a secondary-electron emission ratio greater than one.

13. A network in accordance with claim 11 in which said particle source is a thermionic electron-discharge element.

14. A network in accordance with claim 11 in which said first circuit element comprises a photo-emissive material.

15. A voltage multiplier circuit for use with a two-terminal source of alternating potential, said circuit comprising a plurality of electron discharge devices each comprising a first electrode adapted to emit electrons upon bombardment with elemental energy particles and a second electrode for collecting electrons emitted by said first electrode, a capacitor associated with each of said devices, the emitting electrode of one of said devices being connected to a first source terminal through a first capacitor, and the collector of said one device being connected to the second source terminal, and the emitting electrode of a second of said devices being serially connected to the second source terminal through a second capacitor and the collector electrode of said second device being connected to the emitting electrode of said one device, and a source of elemental energy particles for bombarding said first electrode.

16. A circuit in accordance with claim 15 in which the emitting electrode of a third one of said devices is connected to the collector electrode of said second device through a capacitor and in which the collecting electrode of said third device is connected to the emitting electrode of said second device.

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No references cited.