

May 19, 1959

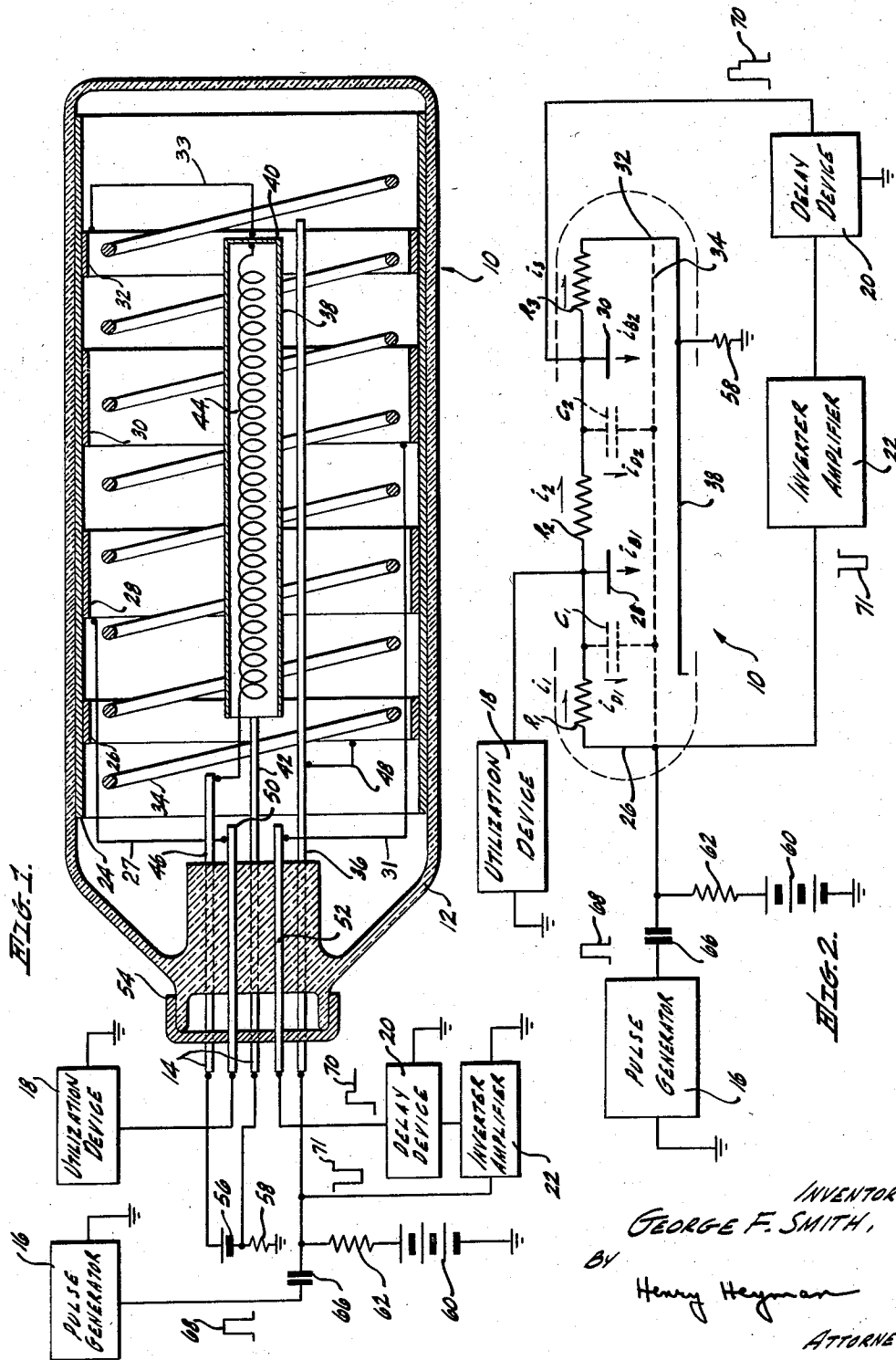
G. F. SMITH

2,887,610

ELECTRON DISCHARGE DEVICE

Filed Jan. 12, 1955

3 Sheets-Sheet 1





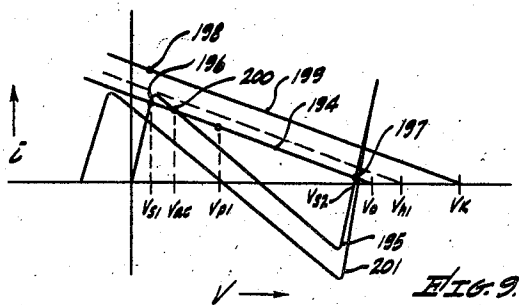
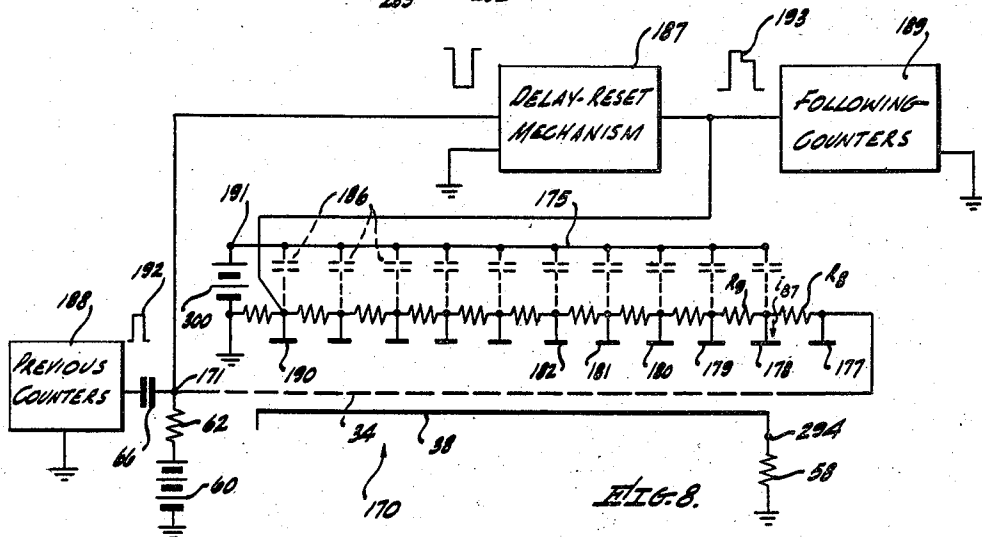
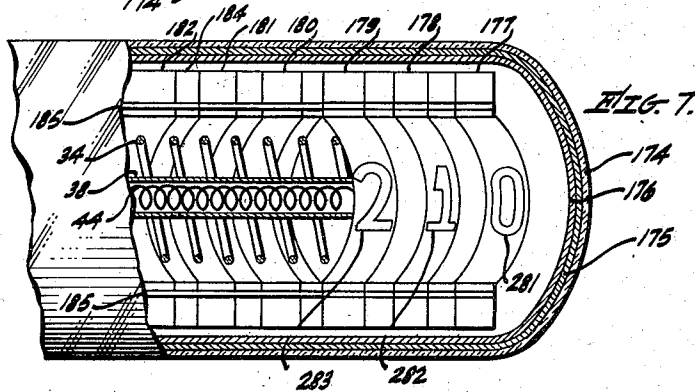
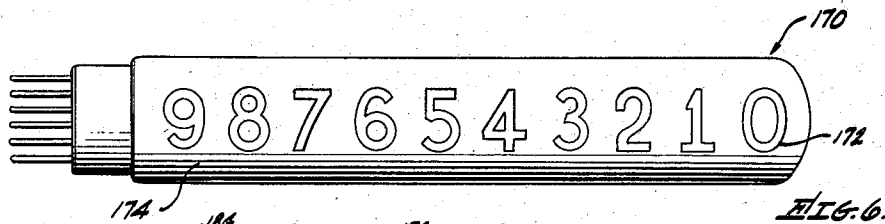
May 19, 1959

G. F. SMITH  
ELECTRON DISCHARGE DEVICE

2,887,610

Filed Jan. 12, 1955

3 Sheets-Sheet 3



INVENTOR.  
GEORGE F. SMITH,  
BY  
Henry Heyman  
ATTORNEY.

1

2,887,610

## ELECTRON DISCHARGE DEVICE

George F. Smith, Los Angeles, Calif., assignor to Hughes Aircraft Company, Culver City, Calif., a corporation of Delaware

Application January 12, 1955, Serial No. 481,308

10 Claims. (Cl. 315-8.5)

This invention relates to electron tubes and more particularly to a secondary emission counter tube suitable for use in a digital computer.

Many types of counters used in digital computers are bulky and expensive. They generally require a considerable amount of power. This is particularly true of bi-stable multivibrators and other digital type counters in which vacuum tubes are employed. Transistor multivibrators and other transistor counters are useful in reducing both the size of and power consumption of digital computers; however, an extremely large number of circuit connections must be made in order to construct computers in which either vacuum tubes or transistors are employed. Furthermore, the counting modulus of vacuum tube or transistor digital counters cannot be easily increased to, for example, decade counters which have numerous other practical applications. In such cases, the cost of construction of computer is sizably increased not only by the number of circuit connections but also by the precision with which the circuit elements must be connected and by the number of circuit elements necessarily employed in these digital counters. When transistors are employed, their relatively small size also increases the difficulty of making numerous accurate circuit connections.

It is therefore an object of the invention to provide a secondary emission counter tube having a simple mechanical construction.

It is another object of the invention to provide a digital computer counter tube which requires little external circuitry to provide for any desired counting modulus.

In accordance with the invention, a plurality of metallic anodes is positioned within an evacuated envelope and a resistive element is provided between each pair of adjacent anodes. A wire grid is then disposed adjacent the anodes to act as a collector electrode and a single cathode is disposed within the envelope on the side of the collector electrode opposite the anodes to provide a source of electrons. Pulses are then impressed between the collector electrode and a point of reference potential to change the potential of each of the anodes from very near the potential of the cathode to very near the potential of the collector electrode or vice versa. The potentials of the anodes are thus sequentially raised or lowered, whereby the tube may have a counting modulus equal to the number of anodes, e.g. ten in a decade counter which may be found to be of particular utility due to the decimal system of numbers which is widely used.

The novel features which are believed to be characteristic of the invention, both as to its organization and method of operation, together with further objects and advantages thereof, will be better understood from the following description considered in connection with the accompanying drawings in which several embodiments of the invention are illustrated by way of example. It is to be expressly understood, however, that the drawings are for the purpose of illustration and description only, and

2

are not intended as a definition of the limits of the invention.

Fig. 1 is a sectional view of one embodiment of the counter tube of the invention shown with associated circuitry;

Fig. 2 is an equivalent circuit diagram of the tube of Fig. 1 with associated circuitry;

Figs. 3, 4, and 5 are graphs showing voltage-current curves characteristic of the operation of the embodiment of the invention illustrated in Fig. 2;

Fig. 6 is a plan view of another embodiment of the counter tube of the invention;

Fig. 7 is a broken-away section of the tube of Fig. 6;

Fig. 8 is an equivalent circuit diagram of the tube of Figs. 6 and 7 shown with associated circuitry; and

Fig. 9 is a graph of voltage-current curves characteristic of the operation of the counter tube shown in Fig. 8.

Referring to Fig. 1, a secondary emission counter tube 10 is shown having an evacuated envelope 12. The counter tube 10 has a plurality of pin connectors 14 connected, respectively, to a pulse generator 16, a utilization device 18, a delay device 20, and an inverter amplifier 22.

A resistive cylinder 24 is disposed inside of and contiguous to the envelope 12 of the counter tube 10. The resistive cylinder 24 may consist of a material such as stannous chloride which may be applied to the envelope 12. According to techniques well known in the art, the resistivity of such a cylinder of stannous chloride may be varied over a wide range, and therefore can be used as a resistive layer or as a conductive layer.

On the internal surface of the resistive cylinder 24, four relatively short metallic cylinders 26, 28, 30, and 32 are shown. The cylinders 26, 28, 30, and 32 may readily be disposed on the internal surface of the resistive cylinder 24. This very fact contributes substantially to the particular utility of the counter tube 10 because the cylinders 28 and 30 are secondary emissive and act as first and second anodes respectively. By the use of this type of construction internal and external metal-to-metal connectors may thus be avoided. The cylinders 26, 28, 30, and 32 may be easily manufactured by brushing a liquid suspension of silver or aluminum particles onto the resistive cylinder 24. The conductive cylinders 26, 28, 30, and 32 may also be conveniently evaporated onto the resistive cylinder 24 by masking off appropriate areas of the resistive cylinder 24 and evaporating a metal such as aluminum onto the internal surface of the resistive cylinder 24.

Disposed within the resistive cylinder 24 and spaced from the conductive cylinders 26, 28, 30, and 32 is a helical metallic grid 34 which serves as a collector electrode. The collector 34 is positioned within envelope 12 by being attached to three axial pins 36, only one being a pin connector, while the other two pins are not shown in Fig. 1.

In the geometric center of the envelope 12, a cylindrical cathode 38 is shown having a cover 40 enclosing its right end. The cathode 38 is mechanically supported by means of three supporting pins 42, one being a pin connector as shown in Fig. 1, while the other two are not illustrated. The cathode 38 is provided with coiled filament 44, one end of which is connected to a pin connector 46, and the other end of which is connected to the enclosing cover 40 of cathode 38.

The metallic cylinder 32 serves both as a connector and as an anode. To this end, the enclosing cover 40 of cathode 38 is directly connected to the metallic cylinder 32 by lead 33. Likewise, the metallic cylinder 26 serves both as an anode and as a connector. The metallic cylinder 26 is accordingly connected to the collector 34 by means of a connection 48 to the pin connector 36. The first anode 28 and the second anode 30 are respec-

tively connected to separate pin connectors 50 and 52 by leads 27 and 31. The axial pin connectors 46, 50, 42, 52, and 36 are maintained in appropriate alignment by means of dielectric cup 54 which is disposed on the left end of the envelope 12 whereby the axial pin connectors may project through the cup.

The filament 44 is supplied with direct current by means of a filament source of potential 56, which is connected between pin connectors 46 and 42 connected respectively to filament 44 and cathode 38. The cathode 38 is connected to ground through a resistor 58 which has a terminal connected to the pin connector 42. The collector 34 is maintained at a potential positive with respect to the cathode 38 by means of a collector source of potential 60 which has a positive terminal connected to the pin connector 36 through a resistor 62.

The pulse generator 16 is connected through a blocking capacitor 66 to the pin connector 36 to apply pulses to the collector 34 which are positive with respect to ground. With a voltage pulse indicated by 68, the counter tube 10 may be employed to count positively or negatively, i.e., the anodes 28 and 30 may be initially maintained near the potential of the cathode 38 or near the potential of the collector 34 and pulsed successively either in the positive or negative direction depending on the polarity of the applied pulses. Because the pulse generator 64 produces a positive pulse 68, the counter tube 10 is arranged to count positively in the embodiment shown in Fig. 1. The counter tube 10 may also be made to count either positively or negatively simply by maintaining the collector 34 at a constant direct-current potential and by pulsing the cathode 38 in a negative or positive direction, respectively. A reset mechanism is employed which comprises a delay device 20 and an inverter amplifier 22 which are serially connected between the anode 30 through the pin connector 52 and the collector 34 through the pin connector 36. After a second of the pulses 68 is received or impressed upon the collector 34, the anode 30 will rise in potential, thereby impressing a pulse shown at 70 on the delay device 20 through the pin connector 52. The pulse is delayed by delay device 20, amplified and inverted by inverter amplifier 22, which may be initially biased below cut-off, and impressed on the pin connector 36 as a negative pulse 71. The potential of both anodes 28 and 30 then may again be reduced to the potential of cathode 38 by the negative pulse 71 impressed upon the collector 34. Resetting may also be accomplished by pulsing the cathode 38 in a positive direction rather than by pulsing the collector 34 in a negative direction.

The utilization device 18 is connected to the pin connector 50 in order to indicate the existing stable state of the anode 28. As will be more fully explained hereinafter the anode 30 does not indicate the number of counted pulses, but only serves to reset the counter tube 10. The counter tube 10 thus has only two stable states, i.e. when the anode 28 is negative and when it is positive. Negative and positive in this context mean that the anode 28 is at substantially the same potential as that of the cathode 38 and that it is at substantially the same potential as that of the collector 34, respectively.

An equivalent circuit diagram of the counter tube 10 and suitable associated circuitry is shown in Fig. 2 including pulse generator 16, blocking capacitor 66, resistors 62 and 58, potential source 60, collector 34, cathode 38, anodes 28 and 30, utilization device 18, delay device 20, and inverter amplifier 22.  $R_1$  indicates the resistance between the anode 28 and conductive cylinder 26;  $R_2$  indicates the resistance between the anodes 28 and 30; and  $R_3$  indicates the resistance between anode 30 and conductive cylinder 32.  $R_1$ ,  $R_2$  and  $R_3$  are, in fact, provided by resistive cylinder 24. Capacitors  $C_1$  and  $C_2$  are intended to show the interelectrode capacitance between the anodes 28 and 30 and collector electrode 34, respectively.

In the operation of the device, a conduction current,  $i_1$ ,

may flow through the resistor  $R_1$ ; a displacement current,  $i_{D1}$ , may flow through the capacitor  $C_1$ ; a resistive current,  $i_2$ , may flow through the resistor  $R_2$ ; a displacement current,  $i_{D2}$ , may flow through the capacitor  $C_2$ ; and an electron beam current,  $i_{B1}$ , may flow to or from the anode 28. A beam current,  $i_{B2}$ , may likewise flow to or from the anode 30, and a resistive current,  $i_3$ , may flow through the resistor  $R_3$ .

The counter tube 10 is set for counting when both the anodes 28 and 30 are near the potential of cathode 38. The true static load characteristics of the counter tube 10 will be better understood with reference to the graph of Fig. 3 which illustrates a secondary-emission voltage-current curve 130, which the metal, used for the anodes 28 and 30, may have. The curve 130 is thus the inverse of a secondary-emission-ratio curve. The curve 130 then is the current  $i_{B1}$  plotted as a function of  $V_1$ ,  $V_1$  being the potential of anode 28. The curve 130 is likewise the same for  $i_{B2}$  plotted as a function of  $V_2$ ,  $V_2$  being the potential of the anode 30. All potentials are taken relative to the cathode 38, hence  $i_3$  and  $i_{B2}$  may be plotted as a function of  $V_1$ . The mechanics of the plot of  $i_3$  plus  $i_{B2}$  versus  $V_1$  involves determining the magnitude of  $i_3$  plus  $i_{B2}$  at the particular voltage  $V_1 = V_0$ . The fact that  $i_3$  plus  $i_{B2}$  plotted as a function of  $V_1$  is linear and passes through the origin can be easily proven algebraically.  $i_3$  plus  $i_{B2}$  at  $V_1 = V_0$  is found graphically by solving the equation

$$i_3 + i_{B2} = \frac{V_2}{R} + f(V_2)$$

simultaneously with

$$i_2]_{V_1=V_0} = \frac{V_0 - V_2}{R}$$

where  $f(V_2)$  is the function illustrated by the curve 130. For the sake of clarity, the resistances of the resistors  $R_1$ ,  $R_2$ ,  $R_3$ , are all assumed to be equal to  $R$ . In Fig. 3, the sum of  $i_3$ ,  $i_{B2}$  and  $i_{B1}$  is plotted as a function of  $V_1$ , assuming  $i_{D2}$  to be equal to zero. This is indicated by curve 132. In the plot of curve 132, it is also assumed that  $V_2$  is near the potential of the cathode 38.  $i_1$  is plotted as a function of  $V_1$  resulting in the line 134. This is the load line of  $R_1$  which passes through the collector potential  $V_0$  and has a slope equal to

$$-\frac{1}{R}$$

The intersections 136, 138, and 140 of curves 134 and 132 indicate the stable and unstable potentials of anode 28. Thus the beam current must be sufficiently high to produce three intersections or the anodes will have only one stable state for a given resistance and collector voltage.

At a given abscissa in Fig. 3, if the ordinate of the load line 134 is larger than that of curve 132, the rate of change of the potential of anode 28 with respect to time will therefore be positive. For example, where the load line 134 intersects the curve 132 at the point 136, the potential of the anode 28 is  $V_{1u}$ . If the potential of anode 28 is less than  $V_{1u}$ , a displacement current will cause the potential of anode 28 to rise to the point 136. The load line 134 intersects curve 132 at two other points 138 and 140 where the potential of the anode 28 is  $V_{1c}$  and  $V_{1m}$ , respectively. When the potential of the anode 28 is larger than  $V_{1u}$ , and smaller than  $V_{1c}$ , the rate of change of the potential of the anode 28 will then be negative, and the potential of the anode 28 will be driven toward the point 136 by secondary emission current. When the potential of the anode 28 is larger than  $V_{1c}$  and smaller than  $V_{1m}$ , the rate of change  $V_1$  with respect to time is then positive and the potential of anode 28 will rise to the point 140 where  $V_1 = V_{1m}$ . When the potential of anode 28 is larger than  $V_{1m}$ , the ordinate of curve 132 is larger than that of the load line 134, whereby the rate of change of  $V_1$  with respect to time is negative and the potential of anode 28 is driven back toward the potential  $V_{1m}$ .

5

The potential of the anode 30 when the potential of anode 28 is equal to  $V_{1u}$  may be determined by first drawing the load line of the resistor  $R_2$ , which is equal to  $i_2$  plotted as a function of  $V_2$ . This is indicated by the curve 142. The sum of  $i_3$  plus  $i_{B2}$  is then plotted as a function of  $V_2$ . This is indicated by the curve 144. The load line 142 therefore intersects curve 144 at a point 146, which indicates the potential of the anode 30 where  $V_2$  equals  $V_{2uu}$ .

The minimum voltage pulse amplitude of pulse generator 16 must be about equal to or somewhat greater than  $V_{1cc}$  minus  $V_{1u}$ , where  $V_{1cc}$  is the critical voltage of the anode 28 when the collector voltage is equal to  $V_0$  plus  $V_{1cc}$  minus  $V_{1u}$ . There is no limit on the maximum voltage pulse amplitude; however, for a given pulse amplitude, the pulse width should be small enough to keep the potential of anode 30 below its critical potential after the collector 34 is returned to  $V_0$ . The critical potential of anode 30 is shown as  $V_{2c}$  at a point 158 in Fig. 4 which is a graph of the static load characteristic of anode 30.

If the amplitude of the pulse 63 is larger than  $V_{1cc}$  minus  $V_{1u}$ , the interelectrode capacitance  $C_1$  between collector 34 and anode 28 will cause the anode voltage  $V_1$  to increase from  $V_{1u}$  to a voltage which may be  $V_p$  which is at a point 150 on a dynamic load line 148 of resistor  $R_1$ . Since at the point 150  $i_1$  will be larger than the sum of  $i_3$ ,  $i_{B2}$ , and  $i_{B1}$ , the potential of the anode 28 will then rise to  $V_{1m}$  if after the collector 34 has been returned to the quiescent value  $V_0$ , the potential of anode 28 is larger than  $V_{1c}$ .

The voltage pulse width should thus be large enough to permit the anode 28 to rise to a potential greater than  $V_{1c}$  after the collector 34 has been returned to  $V_0$ . The minimum pulse amplitude for the anode 30 is shown as  $V_{2cc}$  at a point 157 in Fig. 4. If the pulse amplitude for pulsing anode 28 is greater than  $V_{1cc} - V_{1u}$  and less than  $V_{2cc} - V_{2u}$ , the pulse width may be as large as desired although not less than the minimum pulse width. When the voltage pulse raising the potential of anode 28 is larger than  $V_{2cc}$ , the pulse width should then again be small enough to keep the potential of anode 30 below  $V_{2c}$  when the collector 34 is returned to  $V_0$ .

As stated previously, the counter tube 10 may be used to count negatively. This may be accomplished by applying pulses to the anode 28 to lower its voltage from a potential  $V_{1m}$  to a potential below  $V_{1c}$ , while  $V_2$  is near the potential of the cathode 38.

The stable and critical potentials of the anode 30 when the anode 28 is near the potential of the collector 34 are shown in Fig. 4 where the sum of  $i_3$  and  $i_{B2}$  is plotted as a function of  $V_2$  as indicated by a curve 152, and  $i_1$  minus  $i_{B1}$  is plotted as a function of  $V_2$  as indicated by the voltage-current characteristic 154.  $i_1$  minus  $i_{B1}$  may be found graphically from the curve 130 of Fig. 3, assuming  $i_{D1}$  to be equal to zero and assuming  $V_1$  to be near the potential of the collector 34. The lower stable potential of anode 30 is therefore  $V_{2u}$  shown at the point 156 where the curves 152 and 154 intersect. The critical potential of anode 30 is shown to be  $V_{2c}$  at the intersection of the curves 152 and 154 at point 158. The relatively high stable potential of the anode 30 is shown at the potential  $V_{2m}$  where the point 160 indicates the intersection of the curves 152 and 154.

When the anode 30 is at the potential  $V_{2m}$ , the potential of anode 28 may be found by drawing a load line 162 of  $R_2$ . Curve 162 and a curve 164 of  $i_1$  minus  $i_{B1}$  plotted as a function of  $V_1$  then intersect at a point 166 which gives the potential of anode 28 at  $V_{1m}$ . The pulsing of the anode 30 is analogous to the pulsing of the anode 28.

It was stated previously that the cathode 38 could be pulsed negatively in order to count positively instead of pulsing the collector positively. The operation of the counter tube 10 when this is done is then shown in Fig.

6

5 where  $V_2$  is assumed to be near the potential of the cathode 38, and the curves 132 and 134 are shown to a smaller scale. When the cathode 38 is pulsed negatively, the characteristic curve 132 then assumes a different position, shown by curve 168. Since the potential of the anode 28 remains at  $V_{1u}$  the ordinate of the curve 134 is then larger than the curve 168, and the potential of the anode 28 increases to the potential  $V_{1m}$  from the point 136 on the curve 134 through the point 138 to the point 140.

The invention may be conveniently practiced with numerous different embodiments, another of which is shown in Fig. 6. An elongated counter tube 170 is there illustrated with ten illuminated areas 172 on an evacuated envelope 174; the illuminated areas may have the shape of the numbers from 0 to 9, as shown. The counter tube 170 is employed to visually indicate its state by the illumination of a given number. It is to be understood, however, that all numbers smaller than the given number will also generally be illuminated. Further, zero will generally be illuminated all of the time the tube 170 is in operation. The counter tube 170, a decade counter, may be employed with other such counter tubes to accomplish such functions as frequency measurement. A broken-away section of one end of a counter tube 170 is shown in Fig. 7 comprising the evacuated envelope 174 on the internal surface of which is coated a conductive layer 175 such as stannous chloride, and a fluorescent layer 176 such as luminescent phosphor. Stannous chloride layer 175 is maintained at a potential about 1000 volts positive with respect to the cathode 38 in order to set the potential of phosphor layer 176 at about 1000 volts. The phosphor layer 176 may, however, be maintained at about this potential by numerous other methods, viz., by interposing a relatively high potential grid between the anodes and phosphor layer 176 or by coating the internal surface of the phosphor layer 176 with an aluminum layer and maintaining the aluminum layer at a relatively high potential.

Inside of the envelope 174 and spaced from the phosphor coating 176 are ten anodes of which anodes 177, 178, 179, 180, 181, and 182 are visible. On one side of the anodes 177, 178, and 179, numbers 0, 1, and 2, indicated by 281, 282, and 283, are silhouetted by the metallic sheets forming the anodes whereby electrons may pass through the apertures forming the numerals indicated by 181, 182, and 183 and be converted into light by the luminescent phosphor particles 176. For this reason the anode 177 is always maintained at the potential of the collector 34 shown inside the anodes at the center of the envelope 174. The cathode 38 is illustrated inside collector 34 inside of which the filament 44 is positioned. Electrons are prevented from illuminating the phosphor particles 176 by a plurality of dielectric strips 184 which are disposed between adjacent anodes. The strips 184 and the anodes are all mounted on two dielectric rods 185 which may consist of a material known as sauerisen cement impregnated with graphite. Resistance is thus provided between the anodes to form an equivalent circuit, which is illustrated in Fig. 8.

Tube 170 in Fig. 8 is shown with circuitry necessary for its proper function in a chain of decade counters. It can be seen from Fig. 8 that the anode 177 is a connector anode because it only has one stable state corresponding to the potential of collector 34, to which it is directly connected. A plurality of capacitors 186 is shown connected to each of the anodes, the capacitors 186 representing a substantially greater capacitance between the anodes and the stannous chloride layer 175 than that existing between the anodes and the collector 34. Also shown in Fig. 8 are the resistor 62, the potential source 60, the resistor 58, a delay-reset mechanism 187 and blocks 188 and 189 indicating previous and subsequent or following counter stages. Blocking capacitor 66 is shown between the counters 188 and

collector electrode 34. The delay-reset mechanism 187 is connected between an extra anode 190 and through a terminal 171 to the collector electrode 34. The anode 190 is called an extra anode because it is not employed to indicate the state of the counter tube 170 in exhibiting a numeral on the luminescent phosphor coating 176, but it is only employed to reset the counter tube 170. The following counters 189 derive their input pulses 193 from the rise in potential of the extra anode 190.

The sides of the capacitors 186 not connected to the anodes are mutually joined to a terminal 191, which is maintained at a potential positive with respect to ground, for example, at a potential 1000 volts positive with respect to ground, by a source of potential 300. The terminal 191 need not be connected to potential source 300, but may be connected to any other constant potential. The terminal 191 may also be connected to the collector 34. In this case the tube operates in exactly the same way as does the counter tube 10 of Fig. 1. In the counter tube 170 of Fig. 8 with the terminal 191 being connected to some fixed potential source to count positive, a positive pulse 192 may either be impressed upon collector electrode 34, or upon the terminal 191 or alternatively a negative pulse may be impressed upon the cathode 38. Conversely to count negatively, a negative pulse may be impressed upon the collector 34 or on the terminal 191, or a positive pulse may be impressed upon the cathode 38 at a terminal 294.

When the counter tube 170 is employed to count positively, in the initial state all of the anodes including the extra anode 190 are near the potential of cathode 38. If  $R_8$  is the resistance between the collector 34 and the anode 178 and  $R_9$  is the resistance between the adjacent anodes 178 and 179, then the load line of the resistance  $R_8$  is illustrated in Fig. 9 by the line 194. The sum of the currents,  $i_9$ , through the resistor  $R_9$ , and  $i_{B7}$  to the anode 178 may be illustrated by the curve 195. The stable points of the anode 190 are then points 196 and 197 at potentials  $V_{s1}$  and  $V_{s2}$  and the critical potential  $V_{ac}$  is shown at points 200.

When the terminal 191 is connected to ground or to a point of some fixed potential, the pulse widths of the pulses which the counter tube 170 counts may be critical when the pulse amplitudes are either above or below the critical potential of the second succeeding anode to be pulsed. When positive pulses are applied to the collector, the voltage of anode 178 will instantaneously remain unchanged, but because of a displacement current, the current through the resistor  $R_8$  will rise to the point 198 on a curve 199, which is the load line of the resistor  $R_8$  when the pulse amplitude is equal to  $V_k$  minus  $V_0$ . It is thus important not to have the pulse width too great because all of the anodes will rise to their relatively high potential state if the collector 34 is not returned to the quiescent value  $V_0$  before the anode having the next highest potential passes its respective critical potential  $V_{cc}$ . For example, before anode 179 passes above its critical potential when a pulse is impressed on anode 178 to raise its potential toward  $V_{s2}$ , the collector 34 should be returned to  $V_0$ .

When the terminal 191 is maintained at ground or at some fixed potential, and the potential of cathode 38 is lowered negatively, the curve 195 will assume the form of curve 201. The ordinate of the curve 194 is then greater than curve 201 and the anode 178 will rise to the potential  $V_{s2}$ . For the counter tube 170 to count negatively, the operation is analogous in that  $V_{ac}$  is still the critical potential for the anode 178, and the potential of anode 178 must be lowered from  $V_{s2}$  to a potential less than  $V_{ac}$  before the collector 34 is again returned to the quiescent value  $V_0$ .

A counter tube of any desired modulus may thus be constructed in a most facile manner and supernumerary circuit connections necessary for transistor and vacuum

tube multivibrators may be avoided by the use of plural anodes.

What is claimed is:

1. A secondary emission counter tube comprising an evacuated envelope, a thermionic cathode disposed within said envelope; a plurality of anodes disposed successively adjacent one another at least one of said anodes being capable of emitting secondary electrons; a collector electrode disposed between said cathode and said anodes; and means providing resistance between two adjacent anodes, between one of said anodes and said cathode, and between another one of said anodes and said collector electrode.

2. A secondary emission counter tube comprising an evacuated envelope, a thermionic cathode disposed within said envelope; a plurality of anodes disposed successively adjacent one another; at least one of said anodes being capable of emitting secondary electrons; a collector electrode disposed between said cathode and said anodes; means providing resistance between two adjacent anodes, between one of said anodes and a first point having a predetermined reference potential, and between another one of said anodes and a second point having a potential positive with respect to said reference potential, said reference potential being approximately equal to the potential of said cathode; each of said anodes being capacitively connected to said collector electrode.

3. A secondary emission counter tube circuit comprising an evacuated envelope, a thermionic cathode disposed within said envelope; a plurality of anodes disposed successively adjacent one another; at least one of said anodes being capable of emitting secondary electrons; a collector electrode disposed between said cathode and said anodes; means providing resistance between two adjacent anodes, between one of said anodes and said cathode, and between another one of said anodes and said collector electrode; each of said anodes capacitively connected to said collector electrode; and means for maintaining said collector electrode at a substantially fixed potential with respect to the potential of said cathode.

4. The invention as defined in claim 3, wherein said collector electrode is connected to said cathode.

5. A secondary emission counter tube circuit comprising an evacuated envelope, a thermionic cathode disposed within said envelope; a plurality of anodes disposed successively adjacent one another; at least one of said anodes being capable of emitting secondary electrons; a collector electrode disposed between said cathode and said anodes; means providing resistance between two adjacent anodes, between one of said anodes and said cathode, and between another one of said anodes and said collector electrode; means for maintaining said collector electrode at a potential positive with respect to that of said cathode; and means for applying a voltage pulse between said collector electrode and said cathode, whereby the potentials of said anodes are sequentially changed.

6. A secondary emission counter tube circuit comprising an evacuated envelope, an elongated cylindrical cathode disposed at the center of said envelope, a conductive cylindrical grid disposed about and spaced from said cathode to provide a collector electrode, a resistive coating disposed on the internal surface of said envelope, a plurality of annular metallic strips capable of emitting secondary electrons disposed on the internal surface of said resistive coating and spaced from one another, means for maintaining one of said annular metallic strips at substantially the same potential as that of said cathode, means for maintaining another one of said annular metallic strips at the same potential as that of said collector electrode, and means for maintaining said collector electrode at a potential positive with respect to the potential of said cathode.

7. A secondary emission counter tube circuit comprising an evacuated envelope, an elongated cylindrical

thermionic cathode disposed at the center of said envelope, a cylindrical grid-type collector electrode disposed concentrically about said cathode, a plurality of annular metallic strips capable of emitting secondary electrons disposed about said collector electrode and axially spaced from each other, said strips being connected to at least one resistive rod, said rod projecting axially parallel to and outside of said collector electrode, means for maintaining one of said annular metallic strips at the same potential as that of said cathode, and means for maintaining another one of said annular metallic strips and said collector electrode at a potential positive with respect to that of said cathode.

8. The invention as defined in claim 7, wherein a luminescent dielectric coating is disposed on the internal surface of said envelope, and said annular metallic strips are provided with apertures forming predetermined characters, whereby the stable state of said counter tube at any time may be determined by observing the characters illuminated on said dielectric coated surface of said envelope.

9. A secondary emission counter tube circuit comprising an evacuated envelope, a thermionic cathode disposed within said envelope, a plurality of anodes at least one of which is capable of emitting secondary electrons disposed successively adjacent one another; a collector electrode disposed between said cathode and said anodes; means providing resistance between two adjacent anodes, between one of said anodes and said cathode, and between another one of said anodes and a point of potential positive with respect to that of said cathode; a first terminal junction connected to said collector electrode; a second terminal junction; each of said anodes being capacitively connected to said second terminal junction; means for maintaining said collector electrode at a quiescent potential positive with respect to that of said cathode; and

means for applying a voltage pulse between said cathode and one of said terminal junctions.

10. A secondary emission counter tube circuit comprising an evacuated envelope, an elongated cylindrical thermionic cathode disposed at the center of said envelope, a cylindrical grid-type collector electrode disposed concentrically about said cathode, a plurality of annular metallic strips capable of emitting secondary electrons disposed about said collector electrode and axially spaced from each other, said strips being connected to at least one resistive rod, said rod projecting axially parallel to and outside of said collector electrode, means for maintaining one of said annular metallic strips at the same potential as that of said cathode, means for maintaining another one of said annular metallic strips and said collector electrode at a potential positive with respect to that of said cathode, a conductive coating disposed on the internal surface of said envelope, the capacitance between said collector electrode and said anodes being substantially different than the capacitance from said anodes to said conductive coating, and a luminescent dielectric coating disposed on said conductive coating, said annular metallic strips being provided with apertures forming predetermined characters, whereby the stable state of said counter tube at any time may be determined by observing the characters illuminated on said dielectric coated surface of said conductive coating.

#### References Cited in the file of this patent

##### UNITED STATES PATENTS

|           |                   |               |
|-----------|-------------------|---------------|
| 1,987,136 | Sukumlyn          | Jan. 8, 1935  |
| 2,090,001 | Hamacher          | Aug. 17, 1937 |
| 2,141,838 | Farnsworth        | Dec. 27, 1938 |
| 2,640,169 | Nevin             | May 26, 1953  |
| 2,645,741 | Westervelt et al. | July 14, 1953 |
| 2,728,815 | Kalfaian          | Dec. 27, 1955 |