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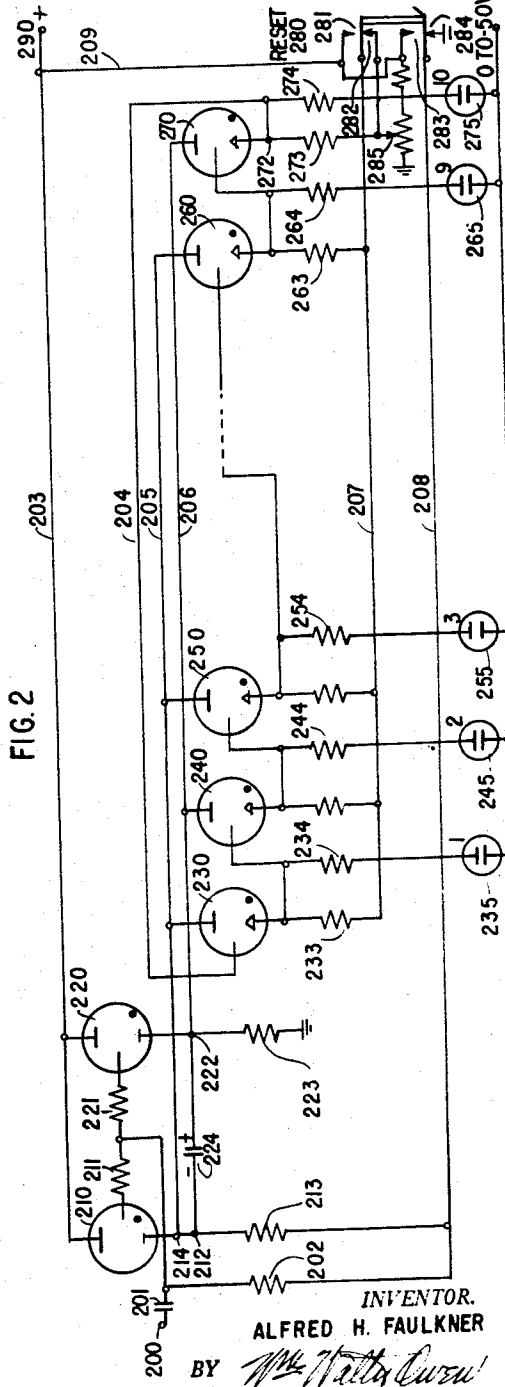
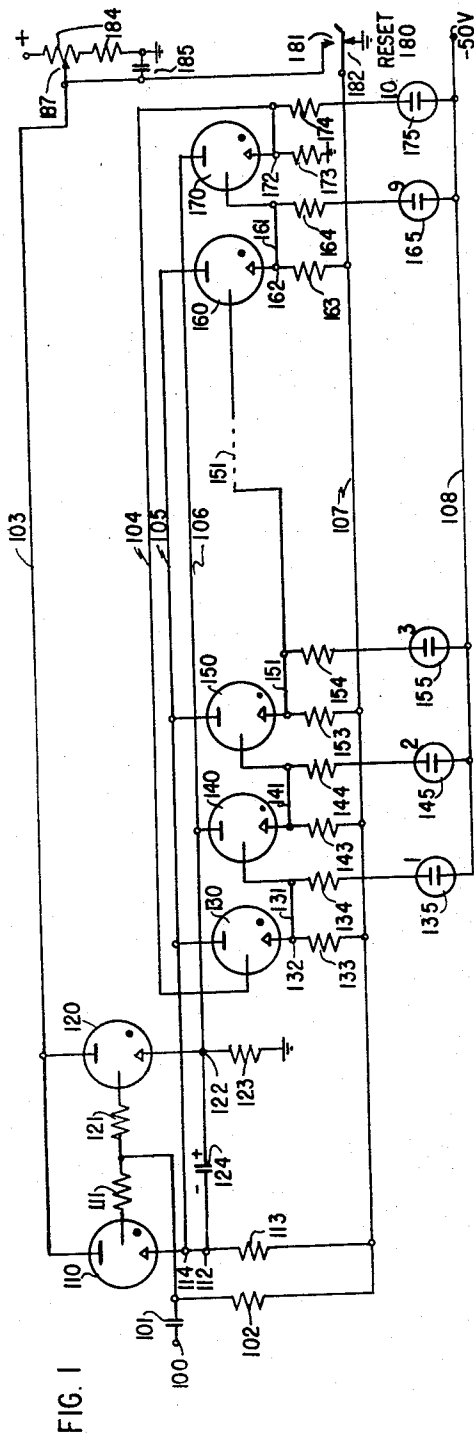
A. H. FAULKNER

2,934,677

COLD CATHODE GAS TUBE COUNTING CHAIN

Filed May 14, 1953

2 Sheets-Sheet 1



INVENTOR.
ALFRED H. FAULKNER

BY *Walter Curran*

ATTY.

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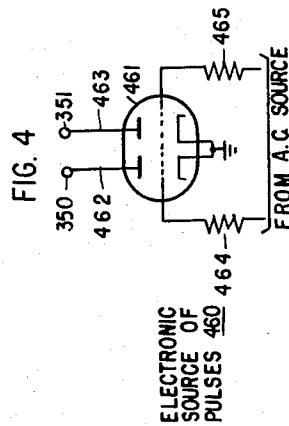
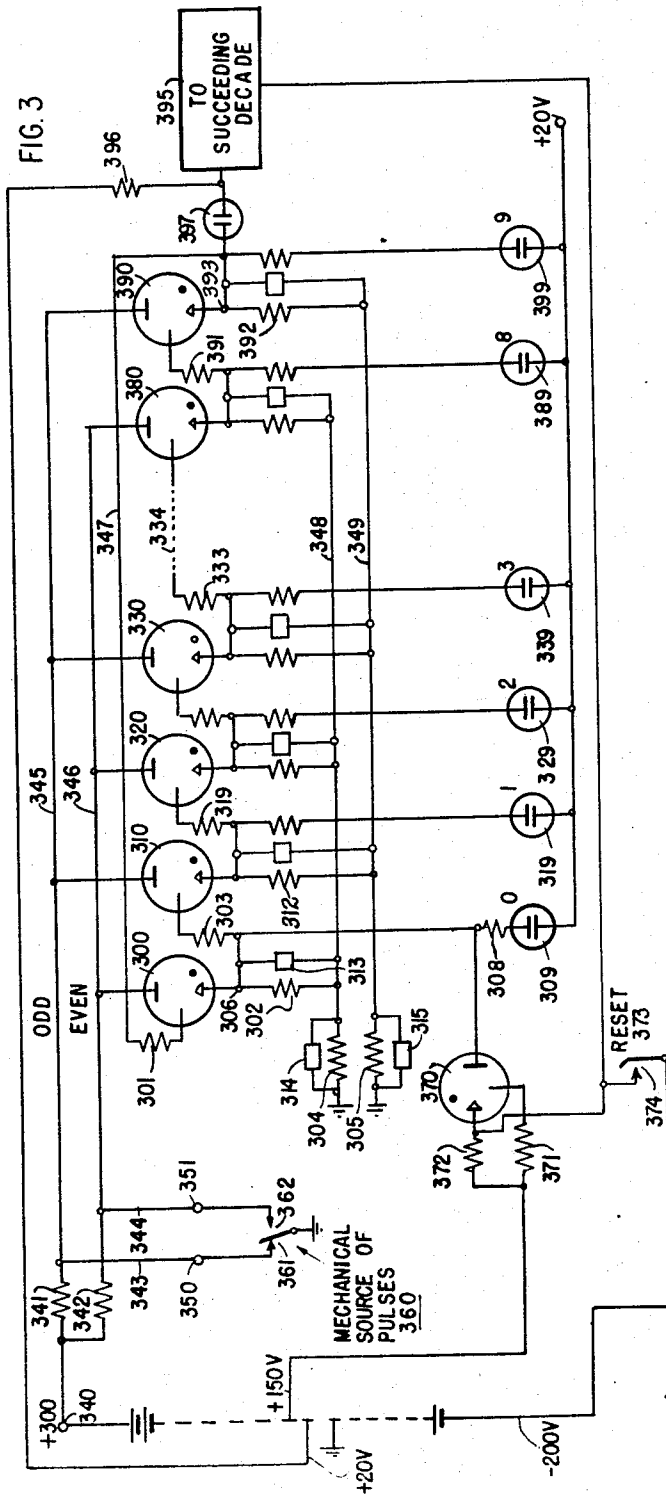
A. H. FAULKNER

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COLD CATHODE GAS TUBE COUNTING CHAIN

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2 Sheets-Sheet 2



INVENTOR.
ALFRED H. FAULKNER
BY *W. H. Hatter*

ATTY.

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COLD CATHODE GAS TUBE COUNTING CHAIN

Alfred H. Faulkner, Chicago, Ill., assignor to General Telephone Laboratories, Incorporated, a corporation of Delaware

Application May 14, 1953, Serial No. 355,053

3 Claims. (Cl. 315—84.5)

The present invention relates in general to counting chain circuits and in particular to improvements in electronic type counting chain circuits employing cold cathode gas tubes.

Up to the present time various methods have been used for coupling the tube of one stage to the tube of the succeeding stage in electronic counting chain circuits most of which have proved to be unreliable or expensive. Such counting circuits generally utilize capacitors connected between the cathodes of adjacent tubes to extinguish one tube when the succeeding tube becomes energized. Another shortcoming of the counting chain circuits used at the present time is their unreliability due to changes in operating characteristics of the counting tubes which is known as ageing. In the new circuits disclosed herein, the coupling capacitors have been dispensed with and means employed to adjust the voltages impressed across the tubes to counteract the effects of ageing.

The principal object of the invention is to provide a counting chain circuit comprising a plurality of stages, where the tube in each stage is directly connected with the preceding and succeeding stages without the use of any reactance coupling components. This results in a considerable economic saving and enables more rapid pulsing by eliminating the time constants involved in the use of reactance components or elements.

Another object is to provide means for adjusting the potential impressed across the tubes in the counting chain to overcome the deleterious effects upon operating capability due to ageing of said tubes.

Another object of the invention is to provide means for varying the counting speed of the counting chain circuits.

A further object is to provide a counting chain circuit which will remain operative throughout the life of the tubes without adjustment.

Other objects of the invention will become apparent upon a further perusal of the specification taken in conjunction with drawings and claims.

Figure 1 illustrates an embodiment of the invention disclosing a non-reactive method of coupling the stages to each other. The counting tubes 130, 140, 150—160 and 170 represent the respective stages of the counting circuit, and resistor 184 across the power supply is provided for adjusting the potential impressed across the chain circuit. A registering circuit for indicating the count utilizes neon lamps such as 135—175.

Figure 2 illustrates a modification of the invention which is similar to the embodiment shown in Fig. 1 with the exception, that the means for varying the potential impressed across the chain circuit is located in the cathode portion of the circuit, and it is arranged to provide reliable operation over a large range in supply voltage. A registering circuit for indicating the count utilizes neon lamps such as 235—275.

Figure 3 illustrates another modification of the invention employing a similar method for coupling the counting tube stages with the exception that silicon carbide discs

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are also used to achieve reliability in operation over wide supply voltage variations as an almost constant voltage drop occurs across each disc for large changes in current. The register circuit for indicating the count utilizes neon lamps such as 309.

Figure 4 shows an arrangement, such as a sharp cut-off 12A7 type tube for producing square wave pulses from A.C. source, which can be used as a source of pulses to be connected to points 350 and 351 of Fig. 3 instead of the mechanical source of pulses 360.

The disclosed subject circuits are ring type counting chains of unusually simple construction utilizing RCA type 5823 tubes. These are cold cathode gas tubes having a starter-anode to cathode breakdown voltage of around 73 volt minimum and an anode to cathode voltage drop of a minimum of 55 to 60 volts when new. As the tubes age the starter-anode to cathode breakdown voltage may rise to 105 volts and the anode to cathode voltage drop may rise to 85 volts. The counting tubes of each circuit are arranged into a group for representing odd numbers and a group for representing even numbers. As shown in Figure 1, the circuit comprises a driver stage containing therein a pair of electronic valves or driver tubes 110 and 120, the counting stage containing ten tubes of which only five tubes, such as 130, 140, 150, 160 and 170 are shown to simplify the circuit. A voltage divider network 184 is connected between positive potential and ground to provide a voltage of 182 volts at arm 187, and a register circuit made up of neon lamps 135, 145, 155—165 and 175 to indicate the count registered in the circuit, when it is at rest. The counting tubes and the neon lamps which have been omitted from the drawing belong in the space indicated by dashed lines between the tubes 150 and 160. As shown, the cathode of any counting tube is directly connected to the starter-anode of the next tube. The voltage drop across the cathode resistor for example 133, of the tube 130 when ionized, is used to bias the starter-anode of the succeeding tube 140 sufficiently positive to cause it to strike when a positive pulse is received from the cathode of tube 120 in the driver stage. Each tube in the driver stage is connected to either control the odd group or the even group respectively of counting tubes. Tube 110, controlling the odd group has its cathode connected to the anodes of tubes 130, 150 and 160. The other driver tube 120 is similarly connected to the even group of counting tubes 140—170.

A circuit using these tubes is difficult to maintain functioning properly throughout the life of the tubes without adjustment because of the increase in the starter-anode break down voltage and anode voltage drop which takes place due to the ageing of the tubes. Resistor 184 having an arm 187 for adjusting the potential derived therefrom is therefore provided to permit the voltage applied to the tubes to be increased if necessary to compensate for such variations.

A capacitor 185 provides transient A.C. voltages in the anodes of a low impedance path for tubes 110 and 120. Whenever one of the driver tubes fires, the signal voltage is impressed across the starter-anode and the plate of the same tube, which signal has a low impedance path over line 103 and the capacitor 185 to ground.

The line 151 is shown broken between the tubes 150 and 160 to indicate that in this particular section additional counting tubes and indicator lamps may be placed within the chain to any number demanded by the occasion.

The operation of the counting chain as illustrated in Fig. 1 will now be described. To prepare the circuit for operation, the reset key 180 is operated momentarily. The +182 volt potential at arm 187 is already applied to the anodes of tubes 110 and 120 over line 103. It is

now also applied through make contacts 181, over the line 107, to the starter-anodes of the tubes 110 and 120, 140, 150—160 and 170 via the resistors 102 and 111 and 121 respectively in series therewith 133, 143, 153 and 163, respectively. Only tubes 120 and 170 strike and conduct as their cathodes are connected to ground potential through resistors 123 and 173 respectively, and therefore the starter-anode to cathode breakdown voltage of 73 volts is exceeded. When the +182 volt potential is applied to lead 107 and the respective cathodes of tubes 130, 140, 150—160 through their respective cathode resistors any conductive tube among them is extinguished and similarly they are prevented from firing. The cathode resistors are between 50 and 100K ohms. Thus as the tubes 120 and 170 in firing have a voltage drop of 55 or 60 volts, a voltage drop in the neighborhood of 127 volts is provided across resistor 123 and in the neighborhood of 72 volts across resistor 173. Neon lamp 175 also conducts and becomes illuminated as a potential difference of about 60 volts across its terminals is generally sufficient to strike it. The other tubes in the counting chain such as 140, 150 and 160 do not strike at this time because the starter-anodes and cathodes of said tubes are connected to the same potential on line 107. The voltage drop of 72 volts across the cathode resistor 173, namely at the point 172 is insufficient to raise the starter-anode of tube 130 above the break down value and the tubes 130, 140, 150, and 160 remain extinguished when the reset key 180 is restored. Tubes 120 and 170 remain conductive. The path of conduction through the tube 170 can be traced from ground through the resistor 173 and also in parallel thereto from -50 v. through the neon lamp 175 and the resistor 174, through the tube 170, line 106, tube 120, line 103, through the variable tap 187 on the resistor 184 to the positive supply voltage. The starter-anode of the tube 120 conducts slightly, but the resistor 121 in series with the starter-anode is several times larger than the 50 to 100K ohm resistor 102 and for best results should be in the neighborhood of one megohm, hence the potential on the starter-anode of tube 110 is well below the breakdown value at this time.

The tubes employed in this circuit have when old a voltage drop of approximately 85 volts across each tube during the period of conduction. The voltage then present across the resistor 123 is approximately 97 volts. Similarly a voltage of approximately 97 volts exists across the capacitor 124 during the periods of conduction of the tubes or valves 110 and 120. Of course when new the potential across resistor 123 may be as high as 127 volts as before explained and charge the capacitor 124 accordingly.

The purpose of having a reset key 180 to prepare a counting circuit for operation is to insure that the chain begins counting from a fixed initial position by rendering the two tubes 120 and 170 conductive. If this were not done, a signal coming from terminal 100 over the capacitor 101 and impressed at the junction of the resistors 111 and 121 could strike either of the two tubes 110 or 120. But since tube 120 is already in the state of conduction, the only tube that is affected by the first pulse is the tube 110. Since the tube 170 is connected in tandem to the tube 120 both of these tubes form a voltage dividing network across the power supply.

Upon the receipt of the first positive pulse from the terminal 100 across the capacitor 101 and impressed upon the starter-electrode of the tube 110 via the resistor 111, tube 110 becomes ionized causing its cathode potential to increase abruptly to a value equal to the supply voltage of 182 volts minus the anode drop or approximately +127 volts. As the charge on the capacitor 124 cannot change instantly, the cathode of the tube 120 is driven positive by an amount equal to the original cathode potential of 127 volts plus the transient positive voltage of 127 volts now induced across condenser 124, thereby

causing the tube 120 to become extinguished. The voltage on the lead 106 during the transient condition may thus reach a total of 254 volts. This is well below the average minimum anode to cathode breakdown voltage of 290 volts for the tubes selected for use in this circuit. Since the anode drop of the tube 170 is nearly constant, the transient voltage across the condenser 124 is transmitted to point 172 which swings positive cause a high to a corresponding positive potential to voltage to be impressed upon the line 104 and onto the starter-anode electrode of the tube 130 with the result that the tube 130 begins to conduct as a starter-anode to cathode breakdown voltage of 73 volts is exceeded, and its anode is 127 volts positive with respect to ground potential on its cathode due to rise in potential at point 114. As it becomes conductive a potential drop of 55 volts exists across it, and its cathode swings to a value of about 72 volts which is impressed on the starter-anode of the next tube. The 72 volt potential is insufficient to cause the starter-anode to cathode circuit to breakdown and conduct, however if it does the 60 volt drop thereacross does not raise the cathode potential of that tube to a point where it affects the starter-anode to cathode circuit of the succeeding tube. Indicator lamp 135 lights up and indicates the count of one. Tube 130 remains conductive over a circuit similar to that described for tube 170 with exception that it is in series with conductive tube 110 and in parallel with resistor 117 instead of 123. As the circuit for tube 170 is opened at extinguished tube 120, it no longer conducts. The capacitor 124 is quickly discharged through the resistor 123 aiding in the extinction of the tube 170 and its associated indicator lamp 175. In the event an 85 volt potential drop exists across each of the tubes 120 and 170 the starter-anode to cathode voltage of tube 130 before the transient condition occurs is 13 volts. A 97 volt potential is then transmitted during the transient condition to the starter-anode of tube 130 to raise its total starter-anode potential to 110 volt which is sufficient to initiate conduction, and it breaks down. Tap 187 may of course be adjusted to provide a supply voltage in accordance with the potential drop across the tubes. During this time, the capacitor 124 is charged in the opposite direction so that its right plate is negatively charged.

The next positive pulse appearing at the input lead 100 causes tube 120 to strike thereby extinguishing the tube 110. As the charge on the capacitor 124 cannot change instantly, the cathode of tube 110 is driven positive thereby resulting in its extinction. At the time of the striking of tube 120, a voltage of approximately between 127 and 97 volts exists across the resistor 123, and a total transient voltage of approximately between 254 and 194 volts exists across the capacitor 124. Since point 114 is connected to point 112, the transient voltage is impressed along the line 105 across the tube 130 which is in the state of conduction as hereinbefore described. Since the anode voltage drop across the tube 130 is substantially constant, the voltage across the cathode resistor 133 is raised to a high positive value with the result that this voltage is impressed from the point 132 upon the conductor 131 onto the starter-electrode of the succeeding tube 140. This causes the tube 140 together with its associated indicator lamp 145, to become ionized so that its conduction path can be traced from ground through the break contacts 182, along the line 107, through the resistor 143, through the tube 140, along the line 106, through the tube 120, along the line 103, and through the variable tap 187 of the resistor 184 to the positive supply voltage. The indicator lamp 145, which is connected in parallel to the cathode resistor 143, similarly utilizes the path through the tube 140 as hereinbefore described. At this stage the indicator lamp 145 is illuminated thereby showing the count of two, and tube 130 is extinguished for the reasons given in conjunction with the extinguishment of tube 170.

Each succeeding input pulse advances the counting tubes

one step in a manner hereinbefore described. The initial condition of the counting chain may be restored at any time by momentarily operating the reset key 180. This effectively opens the cathode circuits of all the tubes except the tubes 120 and 170 thereby causing any ionized tubes and indicator lamps to become extinguished and to strike the tubes 120 and 170 as previously described.

Since the method of operation is the same for the succeeding tubes, the discussion of the operation will not be carried on for all of the tubes indicated in Fig. 1. It will be necessary, however, to terminate the description of the operation by showing how the counting operation is repeated in this ring type counter. Assuming that the tube 110 is conducting together with the tube 160 and indicator lamp 165 shows a count of nine, the next positive pulse (the tenth pulse) causes tube 120 to strike as already described. Ionization of tube 120 causes the tube 110 to become extinguished in the manner previously described. During this striking period, a high voltage exists between the point 112 and the ground. This high positive voltage is impressed from the point 114 across the tube 160 thereby raising the potential across its cathode resistor 163 with the result that a high positive voltage is impressed on the starter-anode of the last tube 170. Tube 170 strikes and becomes conductive in a circuit from ground through the resistor 173, through the tube 170, line 106, tube 120, line 103, and through the variable tap 187 of the resistor 184 to the positive supply voltage. Capacitor 124 discharges through the resistor 113, and the tube 160 becomes extinguished together with its indicator lamp 165. At this stage the tubes 120 and 170 are conducting; and indicator lamp 175 shows the count of ten.

The next positive pulse (the eleventh pulse) will cause the counting chain to repeat its counting operation. This pulse causes tube 110 to conduct and extinguish the tube 120. During the initial conduction of the tube 110, a high positive voltage exists between the point 122 and ground. This high positive voltage is impressed along the line 106 across the tube 170 with a resultant increase in positive voltage across the cathode resistor 173. This increase in positive voltage is applied from the point 172 along the line 104 onto the starter-electrode of the first counting tube, namely tube 130. Tube 130 strikes together with indicator lamp 135 and registers the first pulse of a new decade series of pulses. Capacitor 124 will discharge through the resistor 123 resulting in the extinction of the tube 170. Up to now, the operation of the complete cycle of counting operation has been described. The receipt of additional pulses at the terminal 100 will cause this counting chain to repeat its operation in a manner just described.

The circuit shown in Fig. 2 is a modification of the embodiment shown in Fig. 1, and it operates in substantially the same manner described for the circuit shown in Fig. 1 as with the exception of resistor 285, its circuit values and characteristics are in the same range. The ageing adjustment 285 for the counting circuit in Fig. 2 is located in the cathode circuit of the counting chain stage rather than in the plate circuit of the driver as shown in Fig. 1.

A brief description will be given for the operation entailed in the use of the counting chain shown in Fig. 2. To prepare the circuit a counting operation, the reset key 280 is momentarily operated so that the source of positive potential present at the terminal 290 is impressed on the anodes of tubes 210 and 220 and over the line 209, through the make contacts 281 and 283 in shunt, over lines 207 and 208 respectively to the cathodes of the counting tubes 230, 240, 250—and 260, and through their respective cathode resistors to the starter-anodes of the succeeding tubes in a manner already described in the circuit shown in Fig. 1, and also the starter-anode of tube 220 through resistor 202 and 221 and to the cathode and starter-anode of tube 210 through resistor 213 from

lead 208 and resistor 211 respectively. This prevents all but the afore-mentioned tubes 220 and 270 from striking because their cathodes are at the same potential as their respective starter-anodes. Tubes 220 and 270 strike as their cathodes are connected through resistors 223 and 273 in series with 285 respectively to ground. It will be noticed that although the cathode of 270 is not necessarily at ground potential, it still strikes as resistor 285 is adjusted to apply only a small biasing potential to the cathode. Thus, by varying the bias on the cathode of tube 270, a higher supply voltage may be used to initiate conduction in the tubes. Similarly lamp 275 is fired in a manner similar to 175 and a biasing potential is transmitted from point 272 to the starter-anode of tube 230. The path of conduction can be traced when key 280 is restored, from the ground through the resistor 285, and the tap, the cathode resistor 273, the tube 270, line 206 all in shunt with resistor 223, tube 220, and line 203 to the source of positive potential present in the terminal 290. Of course, some of the electron flow also takes place from ground through the cathode resistor 223, through the tube 220 and to the source of positive potential at the terminal 290. At this time the right side of the capacitor 224 is positively charged so that approximately between 127–97 volts exist across the capacitor 224 depending on the tube age as previously explained, and also on the supply voltage which may initially be of a higher value than that described for the circuit in Fig. 1 as the cathode may be biased at any desired potential through resistor 285 so that the voltage across 124 may be of both a higher maximum value and a higher minimum value.

The first positive pulse incoming at the terminal 200 and across capacitor 201 after key 281 is restored is impressed across the resistor 211 onto the starter-anode of the tube 210 causing the tube to strike. The initial flow of electrons from ground through the resistor 213 and through the tube 210 to the supply voltage causes a voltage drop of approximately between 127 and 97 volts to exist across the resistor 213 with the result that a total transient voltage of approximately between 254–194 volts exists between the point 222 and ground, namely across the capacitor 224 and the resistor 213 to ground. It may be appreciated that if the tap on resistor 285 is set to provide a voltage drop of one or two volts the aforementioned voltages are accurate, however if it is set to provide a voltage drop of between 10–100 volts, the supply voltage must be raised accordingly from the amount described in conjunction with Fig. 1 and the resultant voltages at the cathode and starter-anodes will vary correspondingly. However the description will proceed as though a similar supply voltage as that described in Fig. 1 is used and a very low voltage drop is provided across resistor 285. The increase in voltage at 222 is impressed along the line 206 across the tube 270 and its associated cathode circuit. Inasmuch as the anode drop through the tube 270 remains substantially uniform, a voltage rise is evidenced at the point 272 which in turn causes a voltage increase along the line 204 to be impressed at the starter anode of the first tube in the counting chain, namely tube 230. This causes the striking of the tube 230 causing electrons to flow from the ground through the variable resistor 285 and the variable tap, through the break contacts 282, the line 207, the cathode resistor 233, through the tube 230, line 205, through the tube 210, and the line 203 to the source of positive potential present at the terminal 290. The striking of tube 230 results in the illumination of lamp 235 thereby showing a count of one. Upon the striking of the tube 210, tube 220 became extinguished as a result of the rise in positive potential at the point 222 which rise in potential was brought about by the coupling of the capacitor 224 between the two tubes. Extinguishment of the tubes 220 and 270 results in deenergization of lamp 275.

The description of the operation of the drive stage in

conjunction with the counting chain stage of this embodiment will not be further described inasmuch as its operation is similar to that described for the counting chain circuit shown in Fig. 1. The components used herein have values in the neighborhood of those discussed in conjunction with the embodiment shown in Fig. 1.

In this modification the ageing adjustment, variable resistor 285, is connected to the cathode circuits of the counting tubes 230, 240, 250, and 260 via the contacts 282 of the reset key 280 and directly to the cathode of tube 270. This arrangement results in wider voltage tolerances and also increases the maximum counting speed of the counting chain. Wider tolerances are possible because the variable resistor 285 controls the voltage supply to all of the cathode circuits of the counting tubes and not merely the driver tubes as in the embodiment shown in Fig. 1. The full voltage supply is impressed across the tubes 210 and 220 comprising the driver stage. Because of this power supply voltage impressed across the driver tubes, reliable operation of the involved tubes is insured. The counting speed is increased due to the fact that a less complete discharge of the capacitor 224 is required to extinguish the last ionized tube in the counting ring because the cathode circuit of each counting tube, is at a somewhat positive potential with respect to the ground because of the setting of the variable tap on the resistor 285. The speed of counting can be varied within certain limits by adjustment of the tap on the resistor 285.

While a pair of cold cathode tubes, such as 110 and 120, has been employed as drivers in the circuits illustrated, it is apparent that other arrangements are possible. Tubes 110 and 120, for example, can be dispensed with and contacts employed instead to alternately connect the positive supply terminal to the capacitor 124. Another variation may entail the use of a vacuum tube in lieu of tubes 110 and 120 to obtain a faster operation. The aforementioned possibilities are similarly applicable to the counting chain circuit shown in Fig. 2.

Another modification of the present invention utilizes a circuit which is similar to that found in the two previously described arrangements in that the various stages found in the counting chain circuit are interconnected together without the use of any capacitive couplings. This circuit is the first one that has been found to remain operative throughout the life of the tubes during the normal supply voltage fluctuations encountered with an inexpensive source of supply voltage without adjustment. The circuit as shown in Fig. 3 also shows that succeeding decades such as 395 can be connected to the chain circuit for the purpose of extending the counting range. These provisions are not always required but have been shown to illustrate the manner in which this counting circuit may be applied to an electronic totalizer. As indicated in Fig. 3, one method is used for supplying pulses to be counted by this counting chain, namely a mechanical source of pulses 360. Another source of pulses can be utilized in conjunction with the illustrated counting chain by the use of an electronic source of pulses 460 as shown in Fig. 4.

Line 345 is shown as being an Odd line and the tubes connected thereto shall be classified as Odd tubes. Line 346 is indicated as an Even line and all tubes connected thereto shall be classified as Even tubes for the purpose of distinction. Thus alternate counting tubes are connected to either the Odd or the Even lines. Assuming that the driving contacts 361 are in the position indicated, none of the Odd tubes are able to strike because their anodes are connected directly to ground over the line 345, line 343 and make contacts 361. At this stage, the anodes of all the Even tubes are connected to a +300 volt potential over the line 346, resistor 342 and to the terminal 340. Any one, or more, of the Even tubes may strike as their anodes are connected to +300 volts inasmuch as the anode break down voltage of the tubes is generally less

than this value initially. As the tubes age, the anode break down voltage increases to a maximum value of 350 volts. Since none, or more than one, Even tube may strike when power is first applied, it is necessary to make some provision to insure that one and only one tube is ionized initially. The desired result may be obtained by momentarily connecting the cathode of one of the Even tubes to a -120 volt source. The selected tube is then bound to strike regardless of the condition of the remaining tubes. The striking of the selected tube will cause the potential of the Even bus to drop below ground thereby extinguishing any ionized tubes that may have been previously ionized. In the circuit shown, a momentary -120 volt potential is applied to the cathode of tube 300 through the reset tube 370 as described hereinafter.

Manual operation of the reset switch 373 closes contacts 374 to apply a -200 volt potential through said contacts 374, to the cathode of reset tube 370. The starter-anode of tube 370 is connected to the +150 volt potential through resistor 371 so that the tube strikes and remains conductive when reset key 280 is operated as the anode is connected to ground, through the resistors 302 and 304 and silicon carbide discs 313 and 314 respectively in shunt therewith. The values of resistors 302 and 304 are approximately between 50 and 100K ohms as is resistor 372 so that the anode potential of tube 370 and consequently the cathode potential of tube 300 is approximately -120 volts. Tube 300 strikes as does the neon tube 309. From the circuit path just traced, it can be visualized that a potential of approximately 500 volts is present across the two tubes and associated components causing a certain voltage to exist on the Even line 346. And this voltage present on the Even line is negative with respect to ground because of the choice of selected circuit components.

The reset tube 370 is provided for isolation when several counters must be reset by a common circuit. As shown in Fig. 3, another reset tube such as 370 also functions to control the resetting of succeeding decades such as decade 395. If only one counter is used, the -120 volt potential may be momentarily connected directly to the cathode of the tube 300 thereby preparing the counting chain for operation. With the reset key reopened 370 deionizes as point 306 swings to +120 volts. Resistors 342 or 341 should be of slightly larger value than the cathode resistors or approximately 100K ohms. The voltage drop across the cathode resistors and the anode resistors is then substantially the same, as the silicon carbide provides a substantially constant voltage drop for large variations in current.

With the tube 300 ionized and all other tubes extinguished, the starter-anode to cathode path in tube 310 is ionized at this time because the voltage present at point 306 is +120 volts which is sufficient to cause a break down between the said electrodes after which the starter-anode potential drops to around 80 volts due to the one megohm resistor 303. The voltages on the even bus 346 is of about +180 volts and is insufficient to maintain ionization of any of the other tubes connected thereto. The resistor 305 in series with 301 in the starter-anode to cathode circuit of 300 which conducts slightly at this time has a voltage drop of about 13 volts. The glow existent between electrodes of tube 310, does not transfer to the anode because it is connected to the Odd line which is presently at ground potential. Indicator lamp 309 is illuminated at this time showing that the counting chain is prepared for operation.

When the driving contacts 362 are operated to the right, ground is first removed from the Odd line and subsequently closed to the Even line. The potential on the Odd line 345 rises rapidly from 0 volts to 300 volts. If all of the tubes connected to the Odd line were in the same state, the anode to cathode path of any one of said tubes might fire at this time, but since the starter-anode

to cathode path of tube 310 is already ionized at this time, tube 310 breaks down and prevents the potential on the Odd line from rising beyond +180 volts and thereby prevent any tube connected to the Odd bus from firing. With tube 310 ionized, the anode to cathode voltage across the other tubes connected to the Odd line is 120 volts, which is far below the anode break down value. When the Even bus is closed to ground at contacts 362, tube 300 is already extinguished together with its associated indicator lamp 309. The indicator lamp 319 is illuminated at this time showing the count of one. The cathode potential of tube 310 is impressed on the starter-anode of tube 320 through the resistor 319 resulting in ionization of the starter-anode to cathode path therein. When the driving contacts 361 are operated to the left, the glow in tube 320 is transferred to the anode path; tube 310 together with its associated indicator lamp 319 is de-ionized; and the starter-anode to cathode path of 330 becomes ionized thereby preparing said succeeding tube for the next count. The count is advanced one step in like manner for each operation of the driving contacts. The preionization of each tube shortens the period of time within which the tube becomes fully conductive and thereby increases the speed with which the counting chain may be pulsed.

One application of the counting chain is as an electronic distributor such as might be used in an electronic totalizer. In such applications the chain will be driven continuously. In many cases it would be preferable to drive the chain electronically rather than by actuated contacts. Fig. 4 illustrates one method of accomplishing such operation. The tube 461 is a sharp cut off tube. The A.C. source may have a sinusoidal waveform and an amplitude sufficiently great so that a substantially square waveform is produced in the anode circuit. Since the grids are driven well into the positive region, limiting resistors 464 and 465 are employed in the grid circuits. The arrangement shown in Fig. 4 can be connected to the circuit shown in Fig. 3 by connecting the lines 462 and 463 to points 350 and 351 in place of the mechanical source of pulses 360. This arrangement has been used to drive the counting chain at any speed up to a maximum of 2000 counts per second. This speed represents the maximum obtainable over ideal conditions. In practice the speed would have to be limited to 1000 counts per second, or less, to provide an adequate margin of safety.

The neon lamp, such as 397 serves as an economical amplitude selector which prevents a cathode voltage less than a predetermined value from reaching the succeeding decade 395. The circuit arrangement in the succeeding decade 395 does not respond to the positive pulse which results when the tubes 390 and 397 becomes ionized, but does respond to the negative pulse resulting from de-ionization of tube 390. Whenever the tubes 390 and 397 are ionized, the indicator lamp 399 shows a count of nine. Whenever the tube 399 becomes extinguished, the right terminal of lamp 397 swings in a negative direction to cause the succeeding stage 395 to effect registration of a count of ten which has been counted by the previous decade.

Linear resistors may be employed in the counting circuit but it is preferred to use a combination of linear resistors and non-linear resistors commonly known as thyrite or silicon carbide disc in order to obtain the widest possible latitude in supply voltage. The following non-linear resistors are of the silicon carbide type: 313, 314 and 315. Silicon carbide discs of the same properties are connected in parallel with the cathode resistors of the other tubes of the counting chain. As is well known, the silicon carbide resistors exhibit a very high resistive characteristic at their normal operating voltage but their resistance characteristics change inversely in an exponential manner so as to present a comparatively low resistive path to current flow at high voltage levels. The use of these resistors in combination with the regular type

resistors allows a circuit to be operative with supply voltage magnitudes ranging from low to high values. The ageing of the tube alters the limits of the operating range but does not affect the reliable operation of the counting chain circuit. Thus with supply voltage varying greatly and the anode to cathode drop varying between 55 and 85 volts depending on the characteristics of the tube, the current across the circuit will vary accordingly. But as the current increases with either supply change or decreases with tube change the voltage drop across the thyrite and its parallel resistor will tend to remain almost constant as shown by some typical values below.

Voltage at 1 milli- amp.	Voltage at 1.5 milli- amp.	Voltage at 2 milli- amp.
61 62.5	66.5 68	70 72

While there has been described what is at present considered to be the preferred embodiments of the invention, it will be understood that various modifications may be made therein, and it is intended in the appended claims to cover all such modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A counting circuit comprising a pair of tubes arranged to be energized alternately on the application thereto of successive electrical pulses, a plurality of gas tubes each having an anode, cathode, and starter anode circuit and arranged in succession, alternate tubes of said plurality connected in parallel with each other, each successive tube of said plurality connected in series with a different tube of said pair, means for energizing one of said plurality of tubes and the connected tube of said pair, each tube of said plurality of tubes having its starter anode connected directly to the cathode of an individually corresponding successive one of said plurality of tubes whereby any energized tube of said plurality applies the potential at its cathode to the starter anode of the successive tube of said plurality to prepare the successive tube for energization, a pulse source connected to said pair of tubes for energizing each tube of said pair alternately in response to successive pulses applied from said source to said pair of tubes, and a reactive device connected between said pair of tubes and in common with each tube of said plurality of tubes for applying a potential to said plurality of tubes in response to the application of a pulse to said pair of tubes to thereby energize only the prepared tube of said plurality whereby successive tubes of said plurality are energized in response to successive pulses applied from said pulse source to said pair of tubes.

2. A counting circuit comprising a plurality of groups of electronic tubes, each tube of one group of tubes individually corresponding to a tube in another group of tubes and each tube in said other group of tubes individually corresponding to a tube in said one group of tubes, each tube of said one group connected in parallel with each other tube of said one group and each tube of said other group connected in parallel with each other tube of said other group, each tube having an anode, cathode and starter anode circuit, a pair of electronic valves each having an anode, cathode and starter anode circuit, said pair of valves connected in parallel, one valve of said pair individually corresponding to said one group of tubes and the other valve of said pair individually corresponding to said other group of tubes, the cathode circuit of each valve of said pair connected to the anode circuits of the tubes of its individually corresponding group of tubes, each tube in each of said groups of tubes having its cathode circuit connected directly to the starter anode of its individually corresponding tube in the other of said groups whereby the energization of a tube in any of said

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groups of tubes prepares the individually corresponding tube in the other of said groups, and a reactive means connected between the cathode circuits of said pair of valves for energizing a prepared tube in any of said groups of tubes in response to the application of an input pulse 5 to the starter anodes of said pair of valves.

3. In an arrangement such as claimed in claim 2 in which said plurality of groups of tubes comprise n tubes, a reset means comprising a source of potential, means 10 for varying the potential derived from said source, and means for connecting the potential derived from said source to the respective cathode circuit of $n-1$ of said n

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tubes whereby only a predetermined one of said n tubes is energized.

References Cited in the file of this patent

UNITED STATES PATENTS

2,303,016	Blount -----	Nov. 24, 1942
2,593,375	Williams -----	Apr. 15, 1952
2,598,764	Desch et al. -----	June 3, 1952
2,626,751	Mullarkey -----	Jan. 27, 1953
2,644,111	Desch -----	June 30, 1953