Aug. 7, 1956 D. S. RIDLER ET AL 2,758,250

GASEOUS DISCHARGE TUBE COUNTING CHAINS

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FIG. 1.

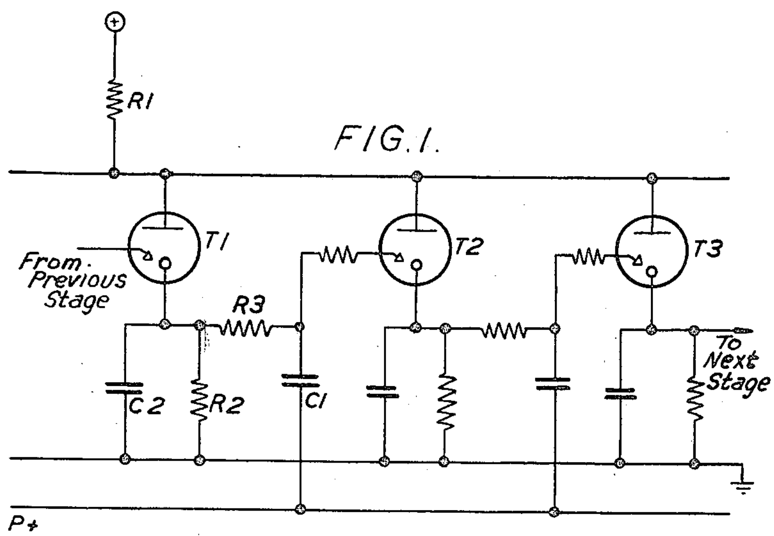

FIG. 2.

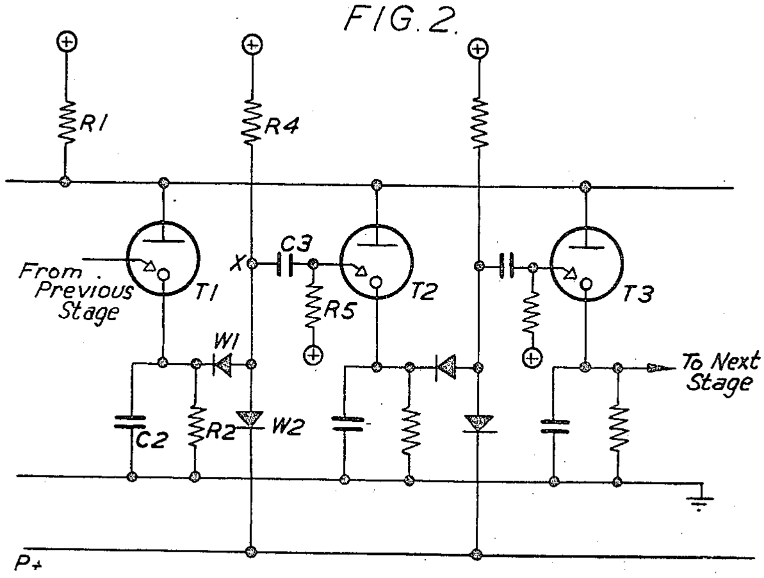

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FIG. 3.

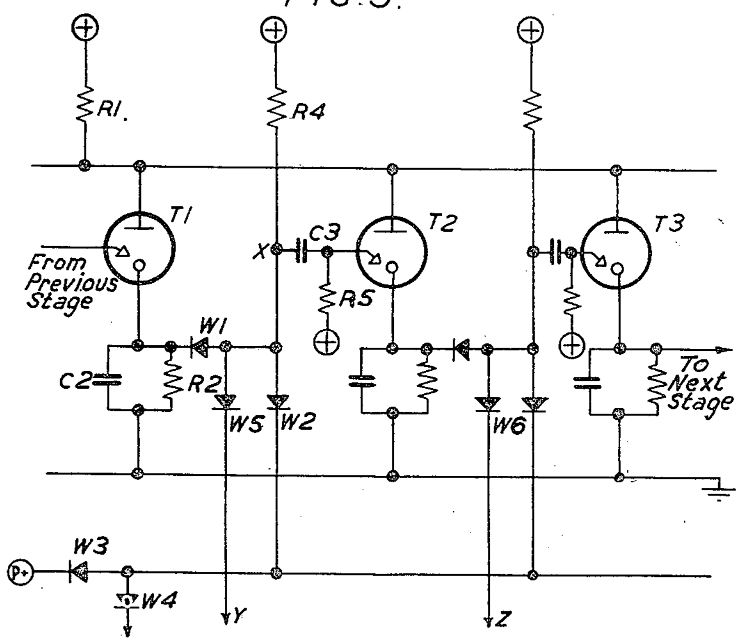

FIG. 4.

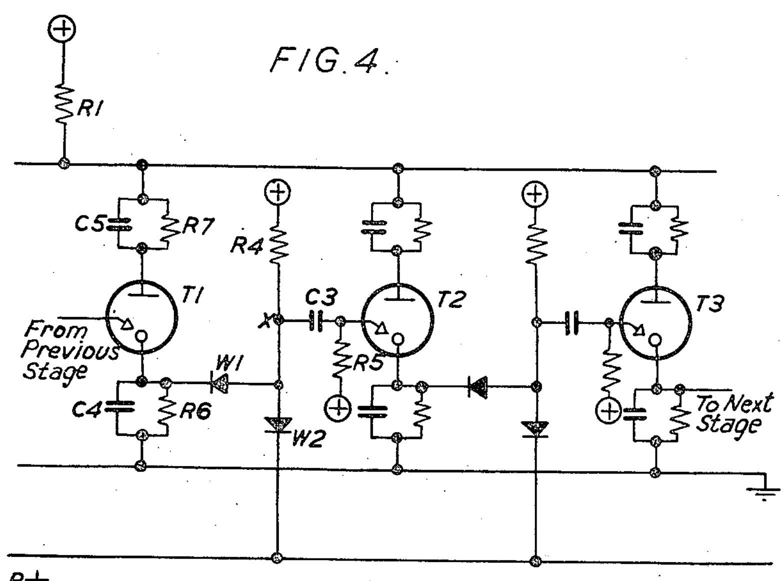

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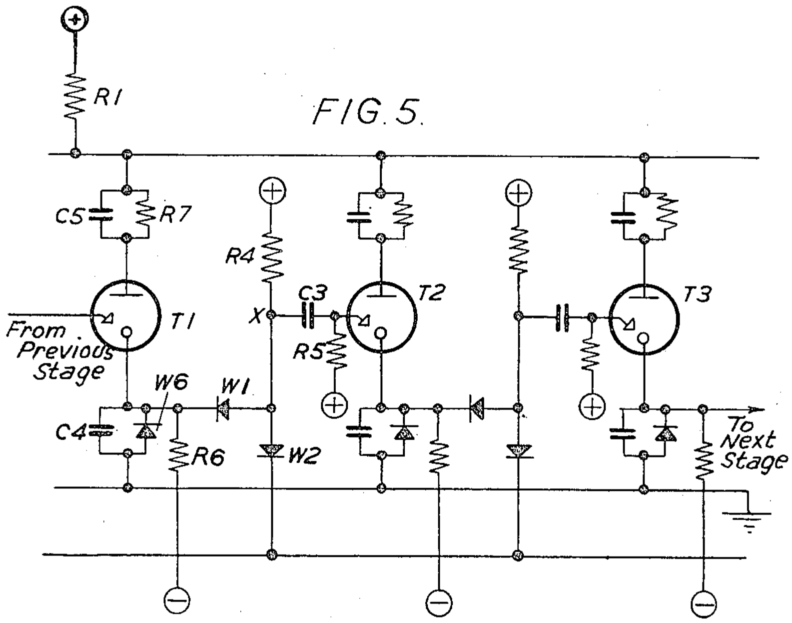
FIG. 5.



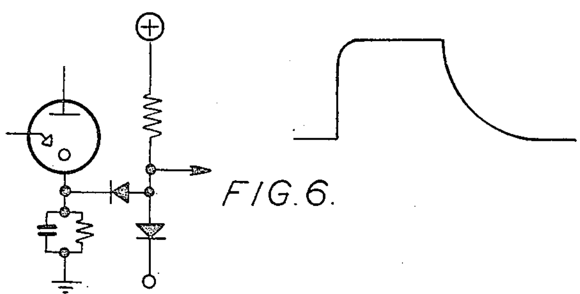


FIG. 6.

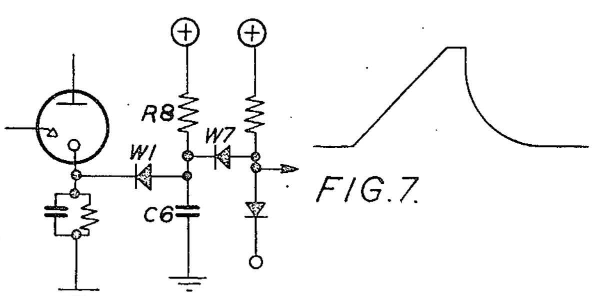


FIG. 7.

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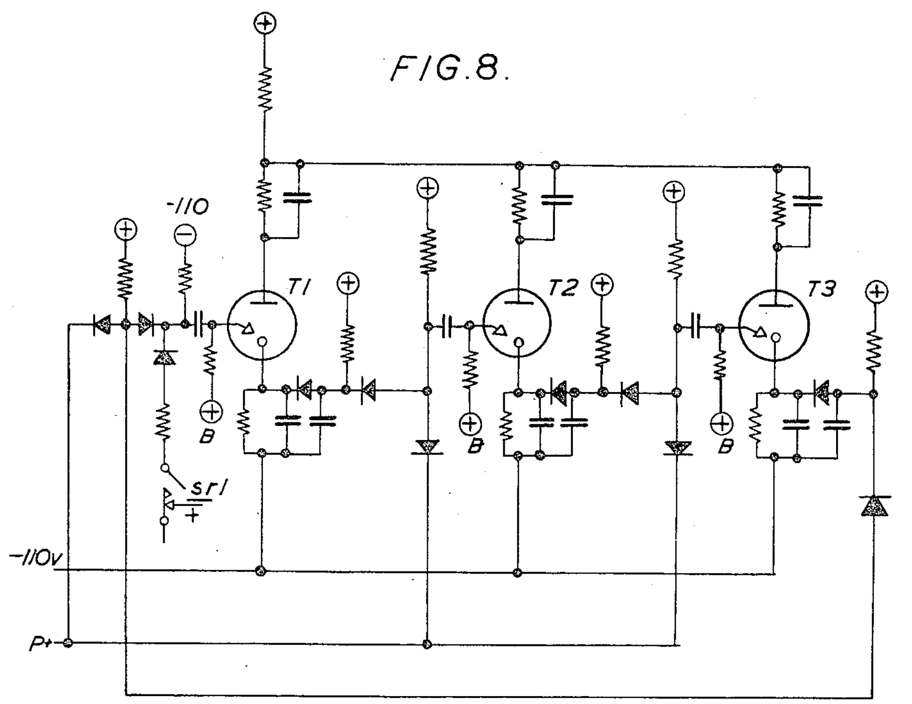
FIG. 8.



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GASEOUS DISCHARGE TUBE COUNTING CHAINS

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15 Claims. (Cl. 315—84.5)

The invention relates to gaseous discharge tube counting chains.

The main feature of the present invention comprises a gaseous discharge tube counting chain of the type which is responsive to pulses received over a common supply lead which comprises a coincidence gate circuit between the tubes of each pair of consecutive tubes in the chain, each gate circuit interconnecting the cathode of the first tube of a pair, the trigger electrode of the second tube of the pair, and the common pulse lead in such a way that the second tube of a pair fires when coincidence occurs between the discharge of the first tube of the pair and a pulse on said common supply lead, and that a pulse is only applied to the second tube of a pair when the first tube is discharging.

The invention will now be described with reference to the accompanying drawings in which:

Fig. 1 is a known form of counting chain;

Fig. 2 is one embodiment of the present invention;

Figs. 3, 4 and 5 are other embodiments of the invention;

Fig. 6 illustrates the output waveform of a tube of the counting chain of Fig. 4;

Fig. 7 illustrates the output waveform of a tube of a preferred embodiment of the invention; and

Fig. 8 is a complete divide-by-three counting chain embodying the preferred embodiment of the invention.

The known circuit of Fig. 1 embodies the pulse-plus-bias method of triggering the next tube in the chain, and the deionising pulse which extinguishes the previously fired tube is generated across a common anode load R1. Assuming that tube T1 is initially conducting, there will be a positive bias potential developed across R2 in its cathode circuit. This potential charges C1 through R3. The positive pulses which step the chain are applied over the connection marked P+. The positive pulses are of such an amplitude that the next positive pulse, together with the bias potential on C1 from the cathode of T1 fires tube T2. Firing of this tube causes a negative-going impulse to be generated on the anode line of the chain, and this impulse is of such a value as to extinguish the previously-firing tube T1. This is achieved by correct choice of the values of R1, R2 and C2. The time constant K of this deionisation or extinguishing pulse is given by

$$K=C2\left[\frac{R1.R2}{R1+R2}\right]$$

The value of K must obviously be greater than the minimum deionisation time of the tube.

The time required for C1 to charge (and discharge when T1 extinguishes) limits the speed of operation of such a counting chain.

Fig. 2 has been evolved to overcome this disadvantage. In this circuit the inter-tube coupling circuit includes a rectifier gate circuit. The stepping pulses are applied over the lead P+, and when a pulse is not actually being applied, this lead is connected to earth potential. These pulses are applied, as usual in such chains, to the trigger circuits of all the tubes in common. It will be assumed that tube T1 is discharging, so that its cathode bears a positive potential. Connected between the cathode of T1 and the trigger electrode of T2 is a rectifier W1. The side of W1 not connected to the cathode of T1 is connected over W2 to the stepping pulse source, over R4 to the high tension positive source and over C3 to the trigger of T2. Also connected to the trigger of T2 over resistance R5 is a source of bias potential having a value insufficient alone to cause T2 to discharge. In the absence of a pulse on the P+ lead, the potential at point X is fairly low as the high tension voltage produces a current through R4 and W2 in series and the forward resistance of W2 is small compared with the resistance of R4. Therefore X is at or near earth potential. Rectifier W1 is blocked by the positive potential on the cathode of T1.

On the next pulse, a fairly high positive potential is applied to the P+ lead, so that rectifier W2 is blocked to such an extent that substantially the full P+ potential appears as a pulse at X. This pulse is fed in the usual manner through C3 to the trigger of T2, which therefore fires. T1 is extinguished by the negative going impulse due to the increased current flow in R1. Interconnection between other tubes is similar. Since one time constant charging circuit has been eliminated in the inter-tube coupling, such a circuit is capable of operation at a much higher speed than previously known circuits.

The circuit of Fig. 3 is the same as that of Fig. 2 in general operation. However, the stepping pulses are supplied to the circuit via an additional gate circuit formed by W3 and W4. The circuit cannot start unless W4 is blocked at the same time as the P+ pulse matures to block W3 (both W3 and W4 are connected to earth in the absence of positive potential). Also connected to point Y and Z and at corresponding points in the chain are rectifiers W5, W6 . . . etc. If T1 is discharging, T2 cannot fire on the next P+ pulse unless W5 is blocked by a positive potential applied to point Y (which also goes to earth in the absence of positive). Similarly, when T2 is discharging, T3 cannot fire on the next P+ pulse unless W6 is blocked by positive potential at Z. Such connections therefore permit the chain to be stopped in any required position.

A limiting factor in counting chain operation is the time necessary to deionise the tubes on extinguishing. This time can be reduced if the working anode potential be raised. The optimum condition would therefore be a circuit in which anode loads were low and cathode loads high. However, it is often required that the positive cathode output of a tube be used to control a large number of gate circuits. In such a case a low output (cathode circuit) impedance is desirable. These requirements are effectively combined in Fig. 4. In this figure, R1 is the normal common anode resistance via which the extinguishing pulse is developed. The cathode time constant circuit is now split into two portions, C4—R6 and C5—R7. C4 and R6 remain in the cathode circuit to provide a low output impedance, and the other "half" of the time constant C5—R7 is inserted in the anode circuit between the tube anode and the common anode line. When T1 is not discharging, the voltage on its anode will be the voltage on the common anode line.

If T1 is discharging, its anode current flows through R1 and R7 in series, and its anode voltage falls to, or to a voltage very near to, the voltage which it falls to in a circuit such as that of Fig. 3. Therefore the voltage on the common anode line is higher than it would be in the absence of R7. R1 and R7 are preferably so proportioned that this gives a voltage on the common anode line some 20 volts above that on the anode of the discharging tube.

When the next tube, T2 in the present case, fires, the usual extinguishing pulse is produced across R1. The result of the time constant circuit R7—C5 in this case is merely to slightly lengthen the extinguishing impulse.

The frequency limit of the circuit of Fig. 4 is set by the need for the voltage across the cathode circuit of a tube to fall to a few percent of its maximum value when that tube is extinguished. This time can be reduced by use of the circuit of Fig. 5. In this circuit the cathode load resistors, e. g. R6 are returned to a negative potential while an additional rectifier W6 is connected across each cathode condenser C4. This rectifier prevents the cathode voltage from falling below earth potential since the rectifier W6 is connected to earth as shown. Current flow through T1 then passes through resistor R6, since rectifier W6 is non-conducting for current in that direction, and C4 charges quickly. When T1 is extinguished C4 discharges, not towards earth, but towards the negative potential to which R6 is returned. Therefore the initial stage of the discharge is quicker than if it was towards earth. However, the effect of W6 is to "catch" the cathode potential of T1 at earth. Thus the return of this cathode potential to earth is accelerated, so that the circuit may be operated at a higher frequency.

Fig. 6 shows the cathode circuit of a tube of a chain of the Fig. 4 type and its cathode pulse output. The form of this pulse is due to low anode loads used at high speeds. Assuming that the P+ pulse repetition frequency is 5 kc./s., it is normal to allow three time constants of decay in one cycle of P+, i. e. in 200 microseconds. The rise time constant is about one fifth of the decay time constant and so is approximately 13 microseconds. If the maximum cathode output is 70 volts, then at 15 microseconds the cathode voltage will have reached about 50 volts which might be sufficient to operate any gates controlled by this cathode prematurely. To avoid this the cathode circuit shown in Fig. 7 may be used. In this circuit an additional rectifier W7 and an integrating circuit C6—R8 are inserted in the inter-tube coupling. When the cathode of the tube goes positive, W1 is blocked therefrom and current flows from the H. T. source through R8 to charge C6. As C6 is charging towards a relatively high voltage it charges in a substantially linear manner, as shown in Fig. 7, until it has charged to the voltage on the tube cathode. W1 then "catches" it at this voltage, in which condition C6 remains until the next P+ pulse arrives, when the next tube is triggered.

Such a "slow-rising" pulse output enables a higher frequency of operation, 20 kc./s. for example, to be attained without the risk of two tubes firing to the same received pulse.

Fig. 8 is a "divide-by three" circuit using the circuit of Fig. 4 modified according to Fig. 7. The cathodes of the tubes are returned to −110 volts and the anodes to +220 volts. The bias potential in this, as in all the other circuits is a potential considerably below full H. T. potential. To start the circuit, tube T1 is fired by a momentary positive pulse applied to its trigger during the bunching time of contacts *sr*1 of a start relay (not shown).

While the principles of the invention have been described above in connection with specific embodiments, and particular modifications theerof, it is to be clearly understood that this description is made only by way of example and not as a limitation on the scope of the invention.

What we claim is:

1. A gaseous discharge tube counting chain of the type which is responsive to pulses received over a common supply lead which comprises a coincidence gate circuit between the tubes of each pair of consecutive tubes in the chain, a normally ineffective source of potential connected to each gate circuit, each gate circuit interconnecting the cathode of the first tube of a pair, the trigger electrode of the second tube of the pair, and the common pulse lead in such a way that said source of potential becomes effective to fire the second tube of a pair when coincidence occurs between discharge of the first tube of the pair and a pulse on said common supply lead, and that a pulse is effective to fire the second tube of a pair only when the first tube is discharging.

2. A counting chain, as claimed in claim 1, wherein said gate circuit comprises a first rectifier connected between the trigger electrode circuit of said second tube and the cathode circuit of said first tube, said rectifier being so connected as to offer a lower resistance to current flowing away from said second tube circuit than to current flowing towards said second tube circuit, and a second rectifier connected between the trigger electrode circuit of said second tube and the common supply lead, said second rectifier being so connected as to offer a lower resistance to current flowing towards said supply lead than to current flowing away from said supply lead whereby the coincidence of a positive potential on the cathode of said first tube and a positive supply pulse on said common lead causes said second tube to fire.

3. A counting chain, as claimed in claim 2, wherein said gate circuit further comprises means for stopping operation of said counting chain at any desired position.

4. A counting chain, as claimed in claim 3, wherein said stopping means comprises a third rectifier connected between the trigger electrode circuit of the second tube and a control point, said third rectifier being so connected as to offer a lower resistance to current flowing towards said control point than to current flowing away from said control point, whereby said second tube is unable to fire unless there is also a positive potential at said control point, whereby operation of said counting chain may be stopped at any desired position.

5. A counting chain, as claimed in claim 2, further comprising a separate independent time constant circuit connected in the anode circuit of each tube.

6. A counting chain, as claimed in claim 1, further comprising a cathode time constant circuit for each tube of the chain which comprises a second source of potential, a capacitance connected between said cathode and said second source of potential, and a rectifier connected in parallel with said capacitance in such a manner that the cathode of the tube can not fall below the potential of said second source, a third source of potential more negative than the potential of said second source, a resistor, and a connection from said cathode over said resistor to said third source of potential, whereby said condenser charges rapidly when the tube is fired and discharges rapidly to said second potential source when the tube is extinguished.

7. A counting chain, as claimed in claim 1, further comprising an integrating circuit connected between the cathode circuit of one tube in the chain and the trigger electrode of the next tube in the chain.

8. A counting chain, as claimed in claim 7, and in which said integrating circuit comprises a capacitance, a charging circuit over which said capacitance can be charged and a rectifier connected between said capacitance and the cathode of the first named tube, said rectifier being so connected that the capacitance cannot be charged unless said first named tube is discharging.

9. A gaseous discharge tube counting chain comprising a plurality of tubes, a common supply lead over which pulses of positive potential are supplied, a separate resistance capacitance time constant circuit in the cathode circuit of each said tube, a rectifier coincidence gate network between the tubes of each pair of consecutive tubes in the chain, a normally ineffective source of potential connected to each gate network, each said gate network interconnecting the cathode circuit of the first tube of a pair, the trigger electrode of the second tube of the pair and the common supply lead in such a way that said

source of potential becomes effective to fire the second tube of the pair in response to the coincidence of said first tube discharging and the receipt of a pulse of positive potential on said common supply lead, and common extinguisher means coupled to said tubes whereby the first tube of the pair is extinguished when the second tube of the pair is fired.

10. A gaseous discharge tube counting chain comprising a plurality of tubes, a common supply lead over which pulses of positive potential are supplied, a separate resistance-capacitance time-constant circuit in the anode circuit of each tube, a separate resistance-capacitance time constant circuit in the cathode circuit of each said tube, and a rectifier coincidence gate network between the tubes of each pair of consecutive tubes in the chain, a normally ineffective source of potential connected to each gate network, each said gate network interconnecting the cathode circuit of the first tube of a pair, the trigger electrode circuit of the second tube of the pair and the common supply lead in such a way that said source of potential becomes effective to fire the second tube of the pair in response to the coincidence of said first tube discharging and the receipt of a pulse of positive potential on said common supply lead, and common extinguishing means coupled to each of said tubes whereby the first tube of the pair is extinguished when the second tube of the pair is fired.

11. A gaseous discharge tube counting chain comprising a plurality of tubes, a common supply lead over which pulses of positive potential are supplied, a separate time constant in the cathode circuit of each of said tubes which comprises a first source of potential, a capacitance in shunt with a rectifier connected between the cathode of the tube and said first source of potential, a resistor, a second source of potential more negative than the potential of said first source, and a connection from said cathode over said resistor to said second source of potential, a rectifier coincidence gate network between the tubes of each pair of consecutive tubes in the chain, a normally ineffective third source of potential connected to each gate network, each said gate network interconnecting the cathode circuit of the first tube of a pair, the trigger electrode circuit of the second tube of the pair, and the common supply lead in such a way that said third source of potential becomes effective to fire the second tube of the pair in response to the coincidence of said first tube discharging and the receipt of a positive pulse on said common supply lead, and common extinguishing means coupled to said tubes, whereby the first tube of the pair is extinguished when the second tube of the pair is fired.

12. A gaseous discharge tube counting chain comprising a plurality of tubes, a common supply lead over which pulses of positive potential are supplied, a separate resistance-capacitance time constant circuit in the cathode circuit of each said tube, a rectifier, a capacitance charging circuit connected to said time constant circuit and to the cathode circuit of each of said tubes over said rectifier, said rectifier being so connected that the capacitance forming part of said charging circuit can only charge when said rectifier is blocked by a potential condition on the cathode of said tube due to that tube discharging, a rectifier coincidence gate network between the tubes of each pair of consecutive tubes in the chain, a normally ineffective source of potential connected to each gate circuit, each said gate circuit interconnecting the capacitance charging circuit of the first tube of a pair, the trigger electrode of the second tube of that pair and the common supply lead in such a way that said source of potential becomes effective to fire the second tube of the pair in response to the coincidence of said capacitance being sub-

stantially fully charged as a result of said first tube discharging and the receipt of a positive pulse on said common lead, and common extinguishing means coupled to said tubes, whereby the first tube of the pair is extinguished when the second tube of the pair is fired.

13. A gaseous discharge tube counting chain comprising a plurality of tubes, a common supply lead over which pulses of positive potential are supplied, a separate resistance-capacitance time constant circuit connected in the anode circuit of each tube, a resistance-capacitance time constant circuit connected in the cathode circuit of each said tube, a rectifier for each tube, a capacitance charging circuit connected to the cathode circuit of each of said tubes over said rectifier, said rectifier being so connected that the capacitance forming part of said charging circuit can only charge when said rectifier is blocked by a potential condition on the cathode of the tube due to that tube discharging, a rectifier coincidence gate network between the tubes of each pair of consecutive tubes in the chain, a normally ineffective source of potential connected to each gate circuit, each said gate circuit interconnecting the capacitance charging circuit of the first tube of a pair, the trigger electrode circuit of the second tube of the pair and the common supply lead in such a way that said source of potential becomes effective to fire the second tube of the pair in response to the coincidence of said capacitance being substantially fully charged as a result of said first tube discharging and the receipt of a positive pulse on said common lead, and common extinguishing means coupled to said tubes, whereby the first tube of the pair is extinguished when the second tube of the pair is fired.

14. A gaseous discharge tube counting chain as claimed in claim 9 and further comprising separate means coupled to said gate networks for stopping operation of said counting chain at any desired position.

15. A gaseous discharge tube counting circuit comprising a plurality of gaseous discharge tubes each having an anode, a cathode, and a trigger electrode, a coincidence gate circuit connected between the tubes of each pair of consecutive tubes, each of said gate circuits comprising a resistor, and a pair of inputs and an output connected to one end of said resistor, a source of potential connected to the other end of said resistor, a rectifier connected in each input, said rectifiers being poled so as to offer a lower resistance to current flowing from said source of potential through said resistor and said rectifiers than to current flowing in the other direction, a common input pulse lead, means for connecting one of the rectifiers of each gate circuit to said common input pulse lead, means for connecting the other rectifier of each gate circuit to the cathode of the first of the pair of tubes associated with said gate circuit, means for coupling the output of each gate circuit to the trigger electrode of the second of the pair of tubes associated with said gate circuit, whereby both rectifiers of a gate circuit are blocked when a pulse appears on said common input pulse lead coincident with the operation of the first tube of the pair associated with said gate circuit and the potential of said source will then appear on the output of said gate circuit to fire the second tube of said pair.

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