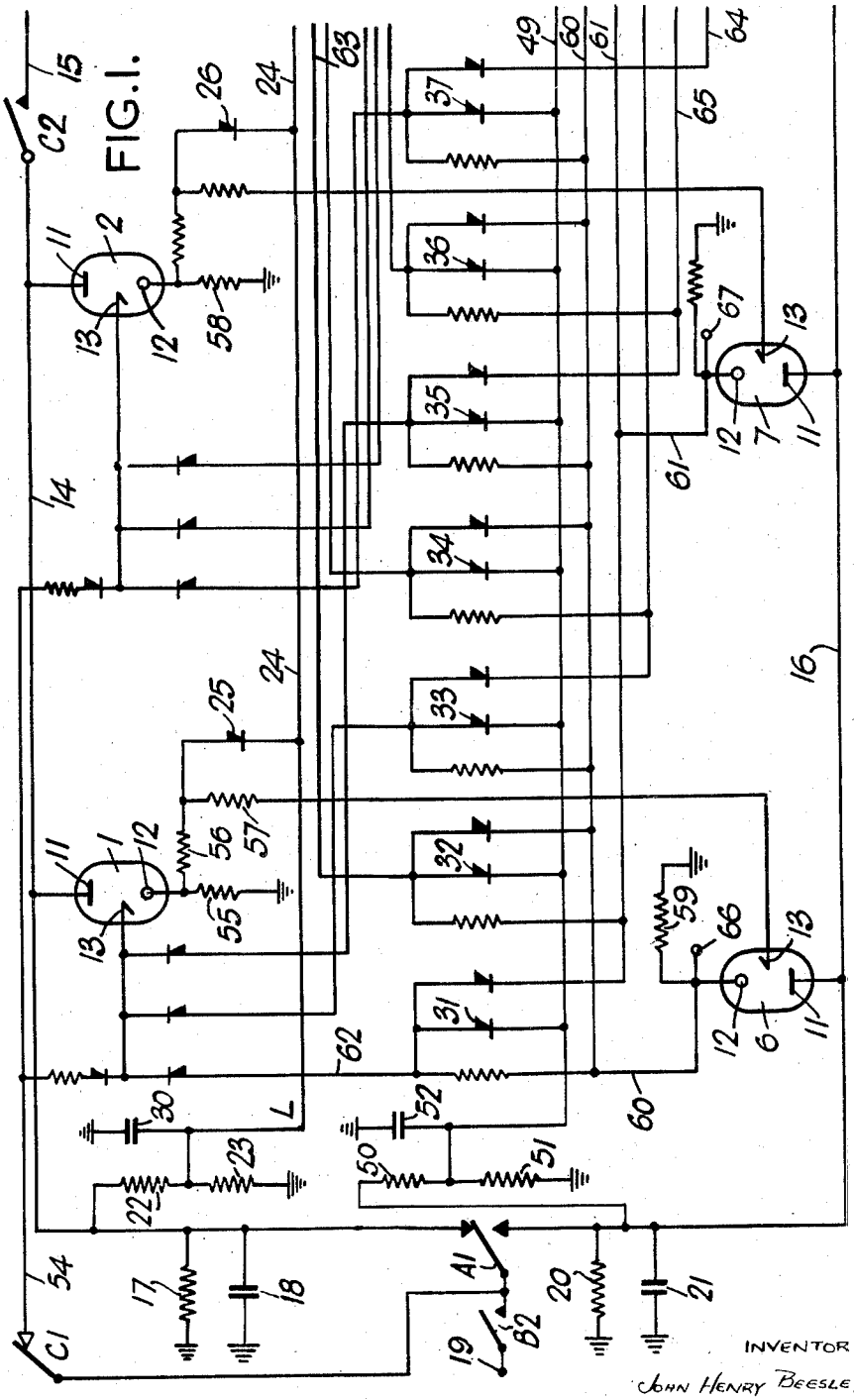
Dec. 24, 1957 J. H. BEESLEY 2,817,481

ELECTRICAL PULSE COUNTING CIRCUITS

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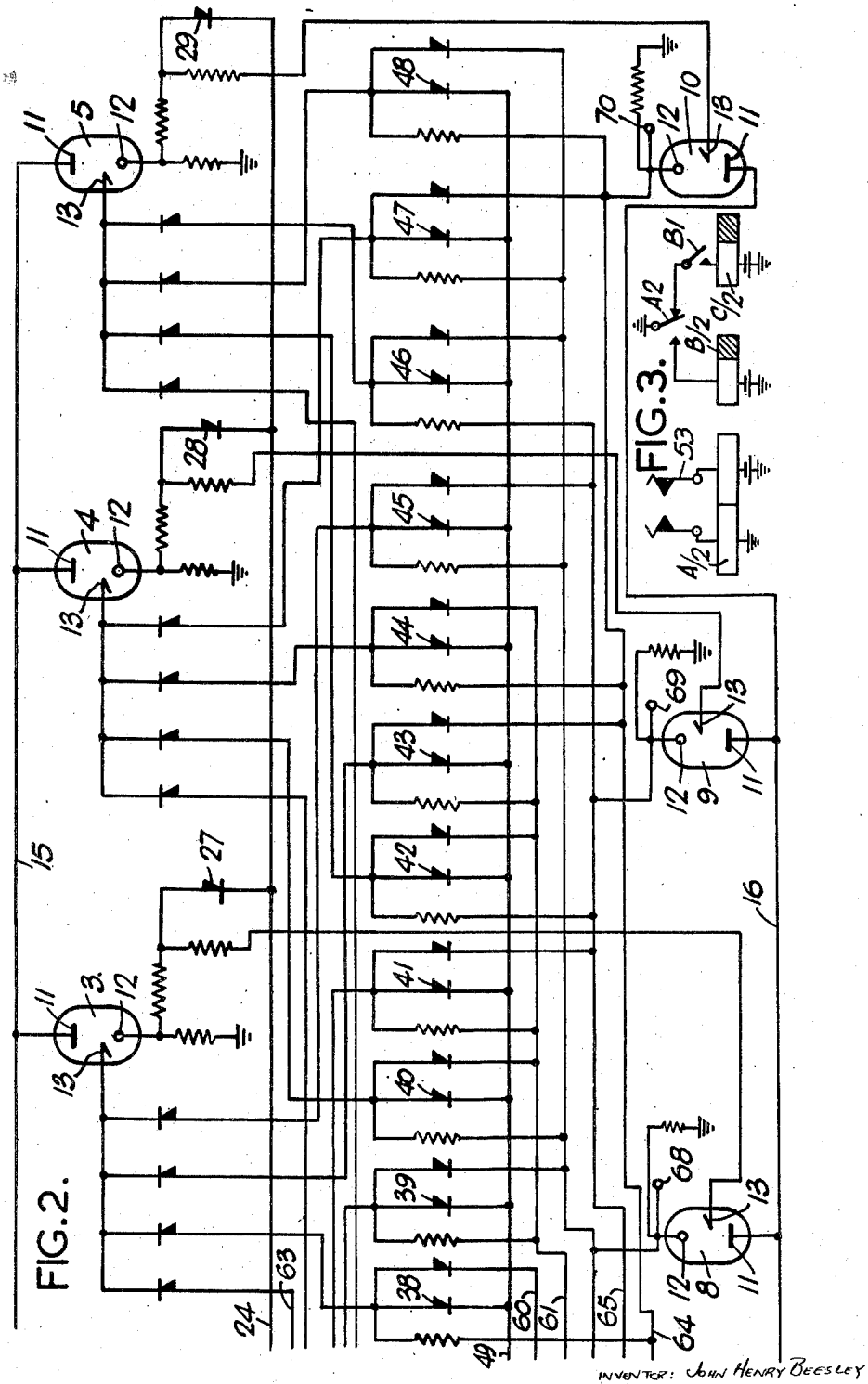
FIG. 1.



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ELECTRICAL PULSE COUNTING CIRCUITS

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ELECTRICAL PULSE COUNTING CIRCUITS

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12 Claims. (Cl. 235—92)

The present invention relates to electrical pulse counting circuits. The invention is more particularly concerned with counting circuits employing electrical bi-stable devices to register the number of pulses counted.

It is an object of the present invention to provide improved counting circuits in which the number of pulses counted is represented in the form of a code.

It is another object of the invention to provide such counting circuits in which the bi-stable devices are cold cathode gas discharge tubes.

According to the present invention an electrical pulse counting circuit comprises two groups of bi-stable devices, each pulse being arranged to operate one or more devices in the first group and thereafter to operate one or more devices in the second group as determined by the operated devices in the first group, the operated device or devices in the second group thereafter biasing the device or each of the devices in the first group to be operated by the next pulse received.

According to a feature of the present invention an electrical pulse counting circuit comprises a plurality of gas discharge tubes which are arranged in two groups, each tube having an anode and a cathode forming a main discharge gap and a trigger electrode forming an auxiliary discharge gap with the cathode, means for applying a first voltage signal or signals across the auxiliary discharge gap of one or more tubes in the first group, means whereby on the arrival of a pulse to be counted a second voltage signal is applied across the main discharge of at least those tubes in the first group to which said first voltage signal is applied, said first and second voltage signals being of such amplitudes that a discharge is initiated across the main discharge gap of the tube or each of the tubes having both said voltage signals applied, said first voltage signal being thereafter discontinued, means for deriving a third voltage signal from the main gap discharge current of the conducting tube or such signals from each of the conducting tubes in the first group, means for applying the third voltage signal or each of the third voltage signals across the auxiliary discharge gap of a tube or each of a combination of tubes in the second group as determined by the conducting tube or tubes in the first group, means operable on the termination of the pulse to be counted to apply a fourth voltage signal across the main discharge gap of at least the tube or each of the combination of tubes in the second group to which said third voltage signal is applied so as to initiate a discharge across the main gap of this tube or each of these tubes, said second voltage signal being thereafter discontinued, means for deriving a fifth voltage signal from the main gap discharge current of the conducting tube or such signals from each of

the combination of conducting tubes in the second group, and means for applying the fifth voltage signal or each of the fifth voltage signals across the auxiliary discharge gap of the tube or each of the tubes in the first group as determined by the conducting tube or tubes of the second group, the fifth voltage signal or signals constituting the said first voltage signal or signals of the next sequence of operation upon arrival of the next pulse to be counted and the arrangement being such that the tube or combination of tubes in the second group that are conducting after the arrival of any particular pulse characterises the number of pulses counted.

One example of an electrical pulse counting circuit in accordance with the present invention will now be described with reference to the three figures of the accompanying diagrammatic drawings in which—

Figures 1 and 2 are complementary illustrations of a counting circuit employing cold cathode gas discharge triodes which is suitable for counting pulse trains having up to ten pulses and

Figure 3 shows an arrangement of three electro-magnetic relays, the associated contacts of which fulfill certain switching functions in the counting circuit of Figures 1 and 2.

Referring now to Figures 1 and 2, the pulse counting circuit comprises two groups of cold cathode gas discharge triodes, there being five triodes in each group. Each of the triodes **1** to **5** in the first group and the triodes **6** to **10** in the second group has an anode **11** and a cathode **12** forming a main discharge gap, and a trigger electrode **13** forming an auxiliary discharge gap with its cathode **12**. The anodes **11** of the triodes **1** and **2** are connected together over a common lead **14** and the anodes **11** of the triodes **3**, **4** and **5** are connected together over a common lead **15**. The relay make-contacts C2 act to connect the lead **14** to the lead **15** on the associated electro-magnetic relay C of Figure 3 operating. The lead **14** is also connected to one fixed contact of the relay change-over contacts A1, the other fixed contact of A1 being connected to the lead **16** which is common to the anodes of the triodes **6** to **10**. The change-over contact of the relay contacts A1 is connected to one side of the relay make-contacts B2 the other side of which is connected to a terminal **19**. A suitable source of positive HT potential is arranged to be connected between the terminal **19** and earth, the amplitude of this potential being alone insufficient to initiate a discharge when applied across the main gap of any one of the triodes **1** to **10**, but sufficient to cause transference of a discharge which exists across the auxiliary gap of any one of these triodes to its main discharge gap and to thereafter maintain this main gap discharge.

A resistor **17** and capacitor **18** are each connected between the lead **14** and earth. The function of this parallel resistance-capacitance combination is to maintain the potential on the leads **14** and **15** above the main gap discharge maintaining value of the triodes **1** to **5** for a short time after the HT potential is removed from these leads. A similar parallel resistance-capacitance combination comprising the resistor **20** and the capacitor **21** fulfils the corresponding function for lead **16**.

Each of the rectifiers **25** to **29** is connected to the lead **24** so as to be conductive to conventional current flow towards this lead. The lead **24** is connected to the junction of the two resistors **22** and **23**. These resistors **22** and **23** are connected in series between the lead **14** and earth

and the arrangement is such that on the HT potential being applied to the lead 14 the lead 24 attains a positive potential which biasses the rectifiers 25 to 29. The capacitor 30 which is connected between the lead 24 and earth acts to maintain the bias potential on the lead 24 for a short time after the removal of the HT potential from the lead 14. In a similar manner to that described above, the presence of HT potential on the lead 16 results in a positive potential being applied to the lead 49. This potential biasses the rectifiers 31 to 48 and is derived from the junction of resistors 50 and 51. The capacitor 52 fulfils a similar function for the lead 49 to that described above in connection with capacitor 30.

Referring now to Figure 3, a source of current pulses is represented by impulsing springs 53, which may be the impulsing springs of a telephone subscriber's instrument in an automatic telephone system. These springs 53 are closed when it is required to make use of the counting circuit and are thereafter opened momentarily for each pulse to be counted. The electromagnetic relays B and C are both of the slow release type.

The manner of operation of the circuit shown in Figures 1, 2 and 3 is as follows:

When the counting circuit is taken into use the impulsing springs 53 close, thereby completing an energising circuit for the relay A.

On relay A operating, the contacts A1 connect the fixed contact of B2 to the lead 16 and so prepare a circuit to connect the positive HT potential that is supplied to the terminal 19 to the anodes 11 of the triodes 6 to 10 of the second group upon the subsequent operation of the relay B. The contacts A2 complete an energising circuit for the relay B.

On the relay B operating the contacts B1 close but have no function at this stage. The contacts B2 close and complete a circuit from the terminal 19 to the lead 16. These contacts B2 also complete a circuit for applying the HT potential to the lead 54 over the relay break contacts C1. The triodes 1 and 2 each have their trigger electrodes 13 connected to the lead 54 over a resistor and a suitably polarised rectifier. A positive potential is thus applied between the trigger electrodes 13 of each of these triodes and earth and is of sufficient amplitude to initiate a discharge across their auxiliary discharge gaps.

On the impulsing springs 53 opening for the first pulse, the energising circuit of the relay A is broken.

On the relay A releasing, the contacts A1 restore and HT potential is applied to the lead 14 and hence to the anodes 11 of the triodes 1 and 2. The discharge existing across the auxiliary gap of each of the triodes 1 and 2 consequently transfers to its main discharge gap. On the contacts A2 restoring the energising circuit of the relay B is broken but this relay remains operated throughout the subsequent pulse train due to its slow release properties. The contacts A2 also complete an energising circuit for the relay C.

On the relay C operating, the contacts C1 open and disconnect HT potential from the lead 54 thereby removing the source of positive potential for the trigger electrodes 13 of the triodes 1 and 2. The main gap discharge in each of these triodes is however maintained by the HT potential on its anode. The contacts C2 close and connect HT potential to the lead 15.

The HT potential on the lead 14 charges the capacitor 18 ready for the subsequent reoperation of the relay A. The potential of the lead 24 rises so that a positive bias is applied to the rectifiers 25 to 29.

The main gap discharge current of the triode 1 results in a positive voltage being developed across the resistor 55 which is in series with its main discharge gap. This voltage is applied by way of a current limiting resistor 56 to a gating circuit comprising a resistor 57 and a rectifier 25. As a result of the positive bias on the lead 24, the rectifier 25 is non-conductive to the voltage across the resistor 55. This voltage is therefore applied over the resistors 56 and 57 to the trigger electrode 13 of the triode 6 and is of sufficient amplitude to initiate a discharge across the auxiliary gap of this triode. In a similar manner the voltage across the resistor 58 which is in series with the main discharge gap of the triode 2, is applied to the trigger electrode 13 of the triode 7 and is of sufficient amplitude to initiate a discharge across the auxiliary gap of this triode.

The termination of the first pulse in the train is marked by the closure of the impulsing springs 53 with the consequent reoperation of the relay A.

On the relay operating, the contacts A1 switch the HT potential from the lead 14 to the lead 16. The contacts A2 complete an energising circuit for the relay B and break the energising circuit for the relay C which holds operated throughout the subsequent pulse train by virtue of its slow release properties. The application of HT potential to the lead 16 results in the auxiliary discharge in each of the triode 6 and 7 being transferred to its main discharge gap. The capacitor 18 discharges through resistor 17, the gas triodes 1 and 2 being extinguished when the voltage of lead 14 falls below the main gap discharge maintaining value for these triodes. A slow rate of discharge is necessary for the capacitor 18 in order that the main gap discharge in each of the triodes 1 and 2 and hence the auxiliary gap discharge in each of the triodes 6 and 7 shall be maintained at least until the said tranference has taken place. The capacitor 30 also discharges slowly in order that the positive bias on each of the rectifiers 25 and 26 shall be maintained throughout this transference.

The HT potential on the lead 16 charges the capacitor 21 ready for the subsequent release of the relay A in response to the next pulse of the train, and the potential of the lead 49 rises so that a positive bias is applied to each of the rectifiers 31 to 48.

The main gap discharge current of the triode 6 results in a positive voltage being developed across the resistor 59 which is in series with its main discharge gap. This voltage is applied to the lead 60 which is common to eight similar gating circuits. Each of these gating circuits, of which there are eighteen in the circuit shown, comprises a resistor and two rectifiers. Both of the rectifiers must be biassed to a non-conducting condition if an output voltage signal is to be obtained over their associated resistor. The rectifiers 31 to 48 each constitute one of the gate rectifiers, the rectifiers 31 to 38 being associated one with each of the eight gates under consideration. In a similar manner the main gap discharge current of the triode 7 results in a positive voltage signal being applied to the lead 61. This lead 61 is also common to eight of said gating circuits of which the rectifiers 31 and 32 and the rectifiers 39 to 44 are associated one with each. It will thus be seen that it is only in the gating circuits containing the rectifiers 31 and 32 that the circuit conditions required for an output voltage prevail. These output voltages are applied over the leads 62 and 63 to the trigger electrodes 13 of the triodes 1 and 3 respectively, and are of sufficient amplitude to initiate a discharge across the auxiliary discharge gap of each of these triodes.

On the relay A releasing in response to the next pulse of the train, the contacts A1 switch the HT from the lead 16 to the leads 14 and 15 so that the triodes 1 and 3 strike, whereafter the gas triodes 6 and 7 are extinguished due to the discharge of capacitor 21 through resistor 20. The striking of the gas triodes 1 and 3 causes a discharge to be initiated across the auxiliary gap of each of the triodes 6 and 8 in a similar manner to that described above in connection with the gas triodes 6 and 7. Subsequent re-operation of the relay A results in the triodes 6 and 8 striking and the triodes 1 and 4 being there-

after predisposed by the initiation of a discharge across their auxiliary gaps. The count thus proceeds in accordance with the following table:

Pulse No.	GROUP 1		GROUP 2	
	Triodes predisposed	Triodes struck	Triodes predisposed	Triodes struck
0	1 and 2			
1 incidence		1 and 2	6 and 7	
1 termination	1 and 3			6 and 7.
2 incidence		1 and 3	6 and 8	
2 termination	1 and 4			6 and 8.
3 incidence		1 and 4	6 and 9	
3 termination	1 and 5			6 and 9.
4 incidence		1 and 5	6 and 10	
4 termination	2 and 3			6 and 10.
5 incidence		2 and 3	7 and 8	
5 termination	2 and 4			7 and 8.
6 incidence		2 and 4	7 and 9	
6 termination	2 and 5			7 and 9.
7 incidence		2 and 5	7 and 10	
7 termination	3 and 4			7 and 10.
8 incidence		3 and 4	8 and 9	
8 termination	3 and 5			8 and 9.
9 incidence		3 and 5	8 and 10	
9 termination	4 and 5			8 and 10.
10 incidence		4 and 5	9 and 10	
10 termination				9 and 10.

From the above table it will be seen that a different pair of triodes of the second group are struck across their main gaps for each pulse in the train. The number of pulses counted is thus represented in code form by the struck triodes in the second group, and hence by the positive potentials existing on two of the terminals **66** to **70** which are associated one with each cathode **12** of the triodes **6** to **10** respectively.

On the termination of the last pulse of a train, the relay A operates and the contacts A1 switch the HT potential to the lead **16** thereby causing the two- pre-disposed triodes of the second group to strike across their main gaps. The contacts A2 complete an energising circuit of the relay B and break the energising circuit of relay C. After a short interval determined by its slow release properties the relay C restores. On the relay C restoring the contacts C1 close and apply the positive HT potential to the lead **54**. A discharge is consequently initiated across the auxiliary gap of each of the triodes **1** and **2** ready for the commencement of a further pulse train. The contacts C2 open and so prevent the triodes **3**, **4** or **5** from striking across their main gaps should the relay A restore, as, for example, in response to the first pulse of the next train. This arrangement is necessary since one or more of these triodes **3**, **4** or **5** will usually be predisposed by the conducting triodes in the second group.

Release of the counting circuit at this stage results in the impulsing springs **53** opening. The relay A consequently releases and the contacts A2 switch the HT potential from the lead **16** to the lead **14**. This causes the struck triode in the second group to be extinguished and may result in the pre-disposed triodes **1** and **2** of the first group striking, but this is of no consequenc. The contacts A2 break the energising circuit of the relay B which restores after a short interval determined by its slow release properties. On the relay B restoring the contacts B1 open thereby breaking the energising circuit of the relay C. The contacts B2 disconnect the HT potential from the counting circuit so that all main gap and auxiliary gap discharges are extinguished.

A particular application of the present invention lies in the field of automatic telephony where it may be used to count the number of pulses in each of a series of pulse trains, the pulse trains being each representative of a digit dialled by a subscriber for the purpose of routing a call through an automatic telephone exchange.

In the counting circuit described above the registration of a tenth impulse by the striking of the triodes **9** and **10** does not result in two further triodes in the first group

such as triodes **1** and **2**, being pre-disposed ready for the arrival of the next pulse, that is, the circuit does not operate in a cyclic manner. The circuit may however be readily modified to operate in such a cyclic manner and one method of performing such modifications is to provide two additional gating circuits of the kind incorporating two rectifiers and a resistor. One of the two rectifiers in each of these gating circuits is connected to the common lead **49**. The remaining rectifier of one circuit and one end of the resistor of the other circuit are then connected to the lead **64** and the other two elements similarly connected to the lead **65**. An output lead is then taken from the junction of the three elements of each gating circuit to the trigger electrodes **13** of the triodes **1** and **2** respectively.

Although in the embodiment described above, cold cathode gas discharge tubes are employed as the bi-stable devices, it should be understood that any suitable device having two stable states may be employed. Thus in an alternative arrangement, electro-magnetic relays are employed as the bi-stable devices, the relay contacts being employed to provide the necessary signal gating facilities between the two groups. Again, each device may comprise one or more thermionic valves or transistors, in which case the gating circuits are preferably composed of an assembly of rectifiers and resistors.

I claim:

1. An electrical pulse counting circuit comprising a plurality of bi-stable devices that are arranged in two groups, each said device having an "on" condition in which it is operated and an "off" condition in which it is non-operated, means to bias a particular combination comprising a predetermined number of the said devices of a first group prior to the commencement of a counting operation, means responsive to the first pulse to be counted to operate said combination of devices, means responsive to the operation of each combination comprising said predetermined number of the said devices in the first group to bias a different combination comprising a predetermined number of said devices in the second group, means responsive to the termination of a pulse to operate the combination of devices in the second group that are then biased and means responsive to the operation of the combination of devices in the second group to bias the combination of devices of the first group to be operated by the next pulse to be counted, the combination of said devices in the second group that are "on" after the termination of any pulse characterising the number of pulses counted.

2. An electrical pulse counting circuit according to claim 1 in which the said bi-stable devices are cold cathode gas discharge tubes of the kind each having an anode, a cathode and a trigger electrode.

3. An electrical pulse counting circuit comprising a plurality of gas discharge tubes which are arranged in two groups, each gas discharge tube having an anode and a cathode forming a main discharge gap and a trigger electrode forming an auxiliary discharge gap with the cathode, means to initiate auxiliary gap discharge in a particular combination comprising a predetermined number of the gas discharge tubes in a first group prior to the commencement of a counting operation, means responsive to the first pulse to be counted to strike the said combination of gas discharge tubes across their main gaps, means responsive to the said striking of each combination comprising said predetermined number of the gas discharge tubes in the first group to initiate auxiliary gap discharges in a different combination comprising a predetermined number of the gas discharge tubes in the second group, means responsive to the termination of a pulse to strike across their main gaps the combination of gas discharge tubes in the second group that then have auxiliary gap discharge and means responsive to said striking of the combination of gas tubes of the second group to initiate auxiliary gap discharges in the combina-

tion of gas discharge tubes of the first group to be struck across their main discharge by the next pulse to be counted, the combination of said gas tubes in the second group that are struck after the termination of any pulse characterising the number of pulses counted.

4. An electrical pulse counting circuit according to claim 3 in which the gas discharge tubes are cold cathode gas discharge triodes.

5. An electrical pulse counting circuit according to claim 3 in which each of the gas discharge tubes has individual resistance means connected to its cathode and in series with its main gap to derive from the main gap discharge current a control voltage of value sufficient to initiate an auxiliary gap discharge in any of the gas discharge tubes when applied across its auxiliary gap.

6. An electrical pulse counting circuit according to claim 3 in which the gas discharge tubes in the first group all have their anodes connected to a first common lead during a counting operation and the gas discharge tubes in the second group have their anodes connected to a second common lead and in which there is provided means that responds to each pulse to be counted to switch the circuit power supply from the second common lead to the first common lead, each said common lead having individual delay means connected thereto to maintain the voltage of that common lead above the main gap discharge maintaining value for a short interval upon the switching of the circuit power supply to the other said common lead.

7. An electrical pulse counting circuit according to claim 3 in which the number of gas discharge tubes in the first group is the same as the number of gas discharge tubes in the second group.

8. An electrical pulse counting circuit according to claim 3 in which each gas discharge tube has individual resistance means to derive a control voltage from its main gap discharge current, which control voltage applied to the trigger electrode of any of the said gas tubes is of sufficient value to initiate an auxiliary gas discharge and in which there are provided a plurality of coincidence signal gating circuits, each said gating circuit having an output and a plurality of inputs and acting upon the coincidence of control voltages on all its inputs to gate to its output a voltage of the same value, a common point, connections from the common point to one of the inputs of each said gating circuit, bias means to derive from the circuit power supply a bias voltage of value at least equal to the said control voltage and to maintain the bias voltage at said value for a short interval upon the disconnection from said bias means of the circuit power supply, a connection from the bias means to the common point to apply said bias voltage to the common point, connections from the gas discharge tubes in the second group to the remaining inputs of said gating circuits to apply the said control voltages to said remaining inputs, each said combination of the gas discharge tubes in the second group being thus connected to all the remaining inputs of a different combination of the said gating circuits, each said gating circuit occurring in only one such combination, and connections from the outputs of the said gating circuits in each combination to the trigger electrodes of a different combination of the gas tubes in the first group.

9. An electrical pulse counting circuit according to claim 3 in which each of the gas discharge tubes has individual resistance means to derive a control voltage from its main gap discharge current, which control voltage applied to the trigger electrode of any of the said gas tubes is of sufficient value to initiate an auxiliary gap discharge and in which there are provided a plurality of coincidence signal gating circuits, each said gating circuit having an output connected to the trigger electrode of a different one of the gas tubes in the second group and two inputs and acting upon the coincidence of control voltages on both its inputs to gate to its output a voltage of the same value, a common point, connections from the common point to a first input of each said gating circuit, bias means to derive from the circuit power supply a bias voltage of value at least equal to said control voltage and to maintain the bias voltage at the said value for a short interval upon the disconnection from said bias means of the circuit power supply, a connection from the bias means to the common point to apply said bias voltage to the common point and connections from the gas tubes of the first group to the second inputs of said gating circuits to apply said control voltages to said second inputs, each said gas tube of the first group being thus connected to the second input of a different one of said gating circuits.

10. An electrical pulse counting circuit according to claim 3 which is adapted to count trains of pulses, the number of pulses in each train having a predetermined maximum value and in which the second group comprises "N" gas discharge tubes, there being "X" of these tubes in each said combination and the total number of different ways of selecting "X" from "N" being not less than the said maximum value.

11. An electrical pulse counting circuit comprising a plurality of gas discharge tubes which are arranged in two groups, each gas discharge tube having an anode and a cathode forming a main discharge gap and a trigger electrode forming an auxiliary discharge gap with the cathode, a plurality of resistance means equal in number to the said gas tubes, each resistance means being connected to the cathode and in series with the main gap of a different one of said gas tubes to derive from the main gap discharge current of its gas discharge tube a control voltage at the cathode of that gas tube which control voltage, applied to the trigger electrode of any one of said gas tubes, is of value sufficient to initiate an auxiliary gap discharge, a first common lead to which the anodes of a particular combination comprising a predetermined number of the gas tubes in the first group are connected, a second common lead to which the anodes of the gas tubes in the second group are connected, means which responds to each pulse to be counted to switch the circuit power supply from the second lead to the first common lead, delay means individual to each said common lead, each said delay means acting to maintain the voltage of its common lead above the main gap discharge maintaining value for a short interval upon the switching of the circuit power supply to the other common lead, means to apply control voltages to the trigger electrodes of the said particular combination of the gas tubes in the first group prior to the commencement of a counting operation, means which responds to the first pulse of a counting operation to connect the anodes of all the gas tubes in the first group to the first common lead and which continues responded throughout the counting operation, first selective switching means to apply the control voltages derived upon the striking across their main gaps of each combination of gas tubes in the first group comprising said predetermined number to the trigger electrodes of a different combination comprising a predetermined number of gas tubes in the second group, the switching of said power supply to the second common lead upon the termination of a pulse resulting in the striking across their main gaps of the combination of gas tubes in the second group then having auxiliary gas discharges, and second selective switching means to apply the control voltages derived upon the said striking of the combination of gas tubes in the second group to the trigger electrodes of the combination of gas tubes in the first group to be struck across their main gaps upon the said switching of the circuit power supply to the first common lead in response to the next pulse to be counted, the

combination of said gas tubes in the second group that are struck after the termination of any pulse to be counted characterising the number of pulses counted.

12. An electrical pulse counting circuit according to claim 11 in which the gas discharge tubes are cold cathode gas discharge triodes.

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