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GASEOUS DISCHARGE DEVICE

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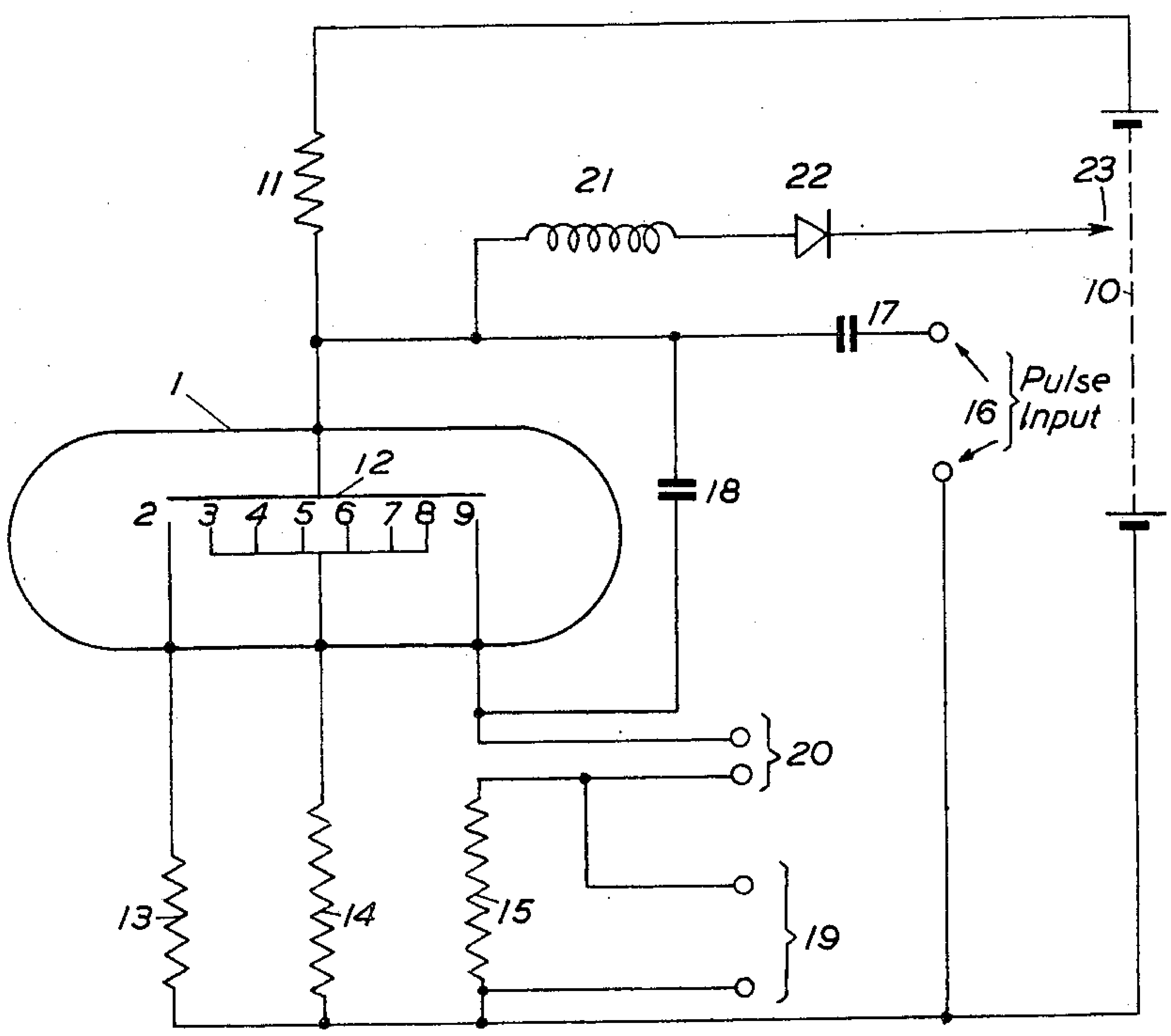

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GASEOUS DISCHARGE DEVICE

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This invention relates to the use of cold cathode gaseous discharge tubes having a plurality of discharge gaps such as tubes of the type described in copending application No. 763,655, filed July 25, 1947, entitled "Improvements in or Relating to Gaseous Discharge Tubes" and application No. 763,656, filed July 25, 1947, entitled "Improvements in or Relating to Gaseous Discharge Tubes."

In these specifications there are described cold cathode gaseous discharge tubes having a number of discharge gaps which fire in succession in a predetermined order, on the application of pulses of electrical energy to the said gaps in common, due to ionisation of an unfired gap caused by the discharge in an adjoining fired gap.

A first pulse applied to the tube will fire only a predetermined gap called the starting gap and measures to ensure this include the closer spacing of the electrodes of the starting gap, a bias potential applied to the starting gap only or the provision of a permanently discharging gap called a pilot gap adjoining the starting gap causing the ionisation of the starting gap.

After a sequence of discharges of the gaps of the tube, and when the last gap (in the predetermined order) has fired, all discharges are extinguished and the tube is allowed to deionise before the commencement of another firing cycle.

If it is required to operate such a tube from a continuous sequence of regularly spaced pulses, a limit is set to the permissible frequency of pulse repetition by the need for a time interval between pulses, long enough to allow the gaps to become de-ionised.

If gaps remained ionised there would be no guarantee that the starting gap would fire first, or in preference to the others, in a second or subsequent cycle of pulses now that the predetermined firing order would be maintained.

To enable higher pulse rates to be used, measures to reduce de-ionising time may be taken and a way of doing this is by the use of special gas atmospheres in the tube. Alternatively, it may be arranged to ensure that one or more pulses succeeding that which fires the last gap, are prevented from firing any gap in the tube, so that a time longer than the interpulse interval is allowed, for de-ionisation of the gas in the gaps. Methods of doing this are described in application No. 777,815, filed October 3, 1947, entitled "Improvements in or Relating to Gaseous Discharge Devices," while (inter alia) the reduction of the inter-electrode voltage so that

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pulses do not reach the level necessary to cause firing, for the duration of such one or more pulses, or the use of two or more tubes operating alternately, are outlined.

It is possible to apply a constant inter-electrode potential to the gaps of the tube, insufficient by itself to initiate a discharge in the gaps but sufficient to maintain a discharge once initiated. With such a potential applied, gaps once fired, will continue to discharge and at the end of a cycle all will be discharging and must be extinguished before the commencement of the next operating cycle of the tube. There are various ways of doing this, one of which is used in an embodiment of the invention to be described later.

If no such constant discharge-maintaining potential is applied, discharges will collapse between pulses during the firing cycle of the tube and the interval between pulses must not be so long that the ionisation can fall below the level necessary to secure sequential firing. This involves the use of pulse rates such that the tube has not time to become de-ionised between consecutive pulses at the end of the firing cycle after extinguishment of the discharges and measures such as those described in application No. 777,815, filed October 3, 1947, entitled "Improvements in or Relating to Gaseous Discharge Devices" become essential.

In the subsequent description in relation to tubes of the types so far described, the expression "the said gaps" includes only those gaps of a tube which are arranged to fire in sequence and excludes a pilot gap.

Furthermore, in references to "de-ionisation of the said gaps" it is to be understood that a starting gap, maintained in a permanently ionised state by the presence of an adjacent discharging pilot gap, is not included in this de-ionisation.

In application No. 763,656, filed July 25, 1947, entitled "Improvements in or Relating to Gaseous Discharge Tubes" a phenomenon, occurring in multigap tubes of this type, and called the "memory effect," is described.

This effect consists of a rise in the voltage required to fire a gap which follows an extinguished discharge in that gap, when certain electrode materials and gases are used in the construction thereof.

If tubes possessing this feature are supplied with pulses to their gaps in common, and with no constant discharge-maintaining potential, a gap, once fired, will ionise the adjacent unfired gap and extinguish at the end of the pulse which fired it. The next pulse will fire the ionised adjacent unfired gap but will not re-fire the extinguished gap owing to the said rise in its critical firing voltage, it being arranged that the pulse amplitude is below such critical voltage.

This "memory effect" persists long enough to ensure that gaps once fired, will not again fire during the firing cycle of the tube, but when all gaps have fired and all possess the "memory effect," the first gap to recover will be that which has been extinguished for the longest time, i. e., the starting gap, and this alone will fire on the first pulse of the next cycle. A corresponding decay of the memory effect will pass down the gaps of the tube in the predetermined firing order, in advance of the firing sequence so that all in turn are ready to fire from successive pulses.

A small bias may be applied to the starting gap to make quite sure that the sequence starts with that gap in cycles after the first. This bias must not be such as to leave the starting gap permanently discharging, however.

It is proposed to use tubes of the type described in the role of pulse responsive devices such as frequency dividers, counters and the like.

According to one of its features, therefore, the invention consists of a device responsive to recurrent pulses of electrical energy comprising a cold cathode gaseous discharge tube having three or more discharge gaps which, in response to pulses applied to all the said gaps in common, are adapted to fire in predetermined order by reason of the discharge in a fired gap causing ionisation and consequent priming of the adjacent unfired gap, and which is adapted to perform a plurality of cycles of discharge of the gaps, each consisting in firing all the said gaps in succession and extinguishing and the recovery of said gaps to a condition permitting their subsequent firing in the said predetermined order, prior to the commencement of the succeeding cycle.

According to another of its features, the invention consists of a device responsive to recurrent pulses of electrical energy comprising a cold cathode gaseous discharge tube having three or more discharge gaps which, in response to pulses applied to all the said gaps in common, are adapted to fire in predetermined order by reason of the discharge in a fired gap causing ionisation and consequent priming of the adjacent unfired gap, and which is adapted to give a signal at a predetermined point in a complete cycle of operation consisting in firing all the said gaps in succession and extinguishing and the recovery of the said gaps to a condition permitting their subsequent firing in the said predetermined order.

An embodiment of the invention will now be described in relation to the accompanying drawing which is a circuit diagram of the embodiment.

In the drawing, a cold cathode gaseous discharge tube **1** has a starting gap **2** and other gaps **3**, **4**, **5**, **6**, **7**, **8** and **9**. A source of potential represented by battery **10**, is applied across all the gaps in common, through an impedance **11** to an anode **12** common to all gaps, and through an impedance **13** to the cathode of the starting gap **2**, through an impedance **14** to the cathodes of gaps **3** to **8**, and through an impedance **15** to the cathode of gap **9**.

In the drawing, the gap **2** is shorter than the rest and with this arrangement, separate impedances in the cathodes of gaps **2** and **3** to **8**, are not essential.

If the separate bias were to be applied to a gap **2** of the same size as the rest, however, the separate connection would be necessary and the bias arrangements could take the place of impedance **13**.

Pulses are applied to terminals **16** and reach the anode through feed condenser **17**.

The gaps fire in succession in the manner described, the battery being insufficient to fire the gaps except in the presence of a pulse which also has to be aided by ionisation from an adjacent discharging gap except in the case of the starting gap **2** where it is otherwise aided (i. e., by the shortness of the gap).

On the firing of the last gap **9**, condenser **18**, connected between the anode and cathode of that gap, and normally maintained in a state of charge somewhat above that potential of battery **10**, discharges across the gap and thus lowers the anode potential below that required to maintain the discharges in the gaps, which are thus extinguished. The cathode of gap **9** may have a larger area than the other cathodes, so that this gap passes a larger current than the others so as to enhance the discharging surge of condenser **18**. The increased voltage drop across the common impedance **11** also assists in producing the necessary fall of the inter-electrode voltage.

The recovery of the inter-electrode voltage to that of battery **10** proceeds at a rate determined by the time constant of **18** combined with the various impedances through which the charging current must pass. (Principally **11**, in practice, as this will be high in relation to **15**, in parallel with any circuit connected to terminals **19**, or in series with any circuit connected to terminals **20**.)

An output circuit can be connected in parallel at **19**, or in series at **20**, as convenient. In the former case **20** would have to be short circuited, in the latter case the circuit connected to **20** would have to present a continuous conducting path. If the said time constant is something less than the interval between consecutive pulses, the next pulse after that which fired gap **9**, will fire gap **2** again and start a new firing cycle.

It may be, however, that a longer time constant will be chosen, when one or more pulses following the one which fired gap **9** will not be able to fire any gaps of the tube. Application No. 777,815, filed October 3, 1947, entitled "Improvements in or Relating to Gaseous Discharge Devices" describes a way of exploiting this so as to enable a pulse recurrence frequency to be used such that the interval between pulses is too short to permit de-ionisation of the said gaps.

To maintain a steady voltage despite the different number of gaps firing at different times, choke **21** and rectifier **22** in series are connected between anode **12** and a tapping **23** on battery **10**. The tapping is chosen so that, as the voltage at the anode tends to drop as more gaps fire, the rectifier just becomes biased to non-conduction at the inception of the discharge in **9**, and so that cut-off is complete in time to prevent the voltage drop due to the discharge in **9** being affected. When fewer gaps are discharging, the anode voltage is higher and the rectifier is conducting, putting the anode into communication with the lower voltage of the tapping point **23**. The effect is to stabilise the anode voltage at a potential in the vicinity of that of point **23**, up to the point of the discharge in **9**.

There is a tendency, when increasing the area of the cathode of gap **9** to defeat one's object by creating a considerably higher general level of ionisation in the tube and in extreme cases, this may lower the critical firing voltage of the said gaps to a point at which they are able to refire during the pulse which fires 9, despite the drop of anode voltage.

Generally speaking, the larger the number of gaps in the tube, the larger the area of the last gap cathode must be to produce the requisite voltage drop.

Difficulty may therefore be experienced in increasing the number of gaps beyond a certain point when the circuit of the drawing is used.

It may therefore be desirable to resort to other means of extinguishing the discharges such as a circuit external to the tube, triggered by the discharge in the last gap, which disconnects the battery or applies an opposing potential.

Alternatively, either pulses or battery or both may be transferred to another similar tube or tubes in turn, each tube completing a firing cycle of its said gaps whilst the others lie dormant and the first tube recommencing when the last has completed its cycle.

Such an arrangement has obvious advantages where a long counting cycle is required in a counter or a large divisor is required in a frequency divider.

Signals can be taken from all or any of the tubes in such a multi-tube arrangement.

To use tubes connected in the ways above described, in the role of counters, one pulse is delivered by a circuit connected as for instance to terminals 19 or 20 in the drawing, though it is of course possible to have all or any of the gaps led out of the tube separately and to extract a signal from the tube on the discharge of any one or more chosen gaps.

The same applies to the use of the arrangements in a frequency divider role, and the division frequency may be taken from or derived from the discharge from the chosen gap or gaps.

When the expedients resorted to in application No. 777,815, filed October 3, 1947, entitled "Improvements in or Relating to Gaseous Discharge Devices" are used, and a pulse or pulses different in number from the gaps of a tube are prevented from affecting the tube. Such pulses must be added to the radix of the count, in a counter or the divisor in a frequency divider. Furthermore, in the former case, since the first train of pulses applied to the tube will produce an output pulse after a number of pulses equal to the number of gaps fired, there will be a phase displacement which will not be corrected when, in subsequent cycles, the circuit produces an output once for every $n+x$ pulses where n is the number of gaps in the tube and x is the number of pulses, after the firing of the last gap, which are unable to cause discharges in the tubes. In many applications, however, this phase displacement will be unimportant or can be corrected or allowed for.

In using tubes having the "memory effect" as described in application No. 763,656, filed July 25, 1947, entitled "Improvements in or Relating to Gaseous Discharge Tubes" a much simpler circuit arrangement is possible.

There is no longer any need for a constant maintaining potential and, since, discharges are extinguished between pulses, it is unnecessary to provide other means for extinguishing discharges between operating cycles of the tube. Furthermore, the memory effect ensures the sequential firing of the gaps in the predetermined order even though substantial ionisation is still present at the commencement of the second and later cycles of operation. It is also unnecessary to have voltage stabilisation arrangements such as 21 and 22 since only one gap at a time is discharging.

It is an advantage when using tubes with the memory effect, to have a high resistance in the common pulse feed circuit to the gaps so that, once a gap has discharged there is a voltage drop through this common resistance, reducing the inter-electrode voltage across all gaps to a value in the vicinity of the maximum voltage necessary to maintain a discharge.

When one gap fires, therefore, the voltage drop lessens the risk of another gap firing from the same pulse. This enables the tube to be operated with closer margins of preference in favour of the required gap firing rather than another gap. For instance, in a tube having a large number of gaps, the difference of memory effect between the second and third gaps may not be great since the difference in their firing times may be small in relation to the operating cycle time. A small difference is however sufficient to ensure that the second gap fires before the third and once the second gap has fired the voltage drop in the common resistance prevents the firing of the third gap.

When using tubes of the type described in counting roles, several counting stages can be used, by having several tubes, the output pulses of one tube being used as the operating pulses of another. This greatly increases the permissible counting radix in comparison with that possible with a single tube and has the advantage that each tube can deliver its own output to a recording circuit as well as providing operating pulses for a successor.

An instance of such an arrangement would be a combination of tubes each having a counting cycle of ten pulses.

The output circuit of the first tube would record tens, the second, hundreds, and the third, thousands, and so on. Alternatively, tubes with different pulse cycles could be used, an instance being an arrangement of a twelve-pulse, and a twenty-pulse tube working together, the first being supplied with pulses representing pence, and delivering output pulses representing shillings, and the second tube delivering output pulses representing pounds.

A similar arrangement used as a frequency divider could provide, simultaneously, more than one divided frequency output.

Second and subsequent tubes in such a train would have progressively slower operation rates and tubes and circuits suitable for such rates would have to be chosen for each link in the chain.

In the case of frequency dividers, where pulses are required, of a reduced repetition frequency, these pulses may be obtained directly from the output circuit from the tube, one means being the inclusion of a transformer in series with the connection to the gap chosen for the recording of the tubes output.

Where the pulse shape is not suitable, however, or where other waveforms (a sine wave for instance) are required, wave shaping circuits must be added or the output pulse may be used to trigger or synchronise a separate pulse generator or oscillator.

What is claimed is:

1. A pulse responsive system comprising an electrostatically operated cold cathode gas discharge tube having three or more discharge gaps

arranged adjacent each other so that firing of one gap produces ionization migration to the next gap thereby priming that next gap for sequential firing in a predetermined succession, means for applying to said gaps in common incoming pulses of a predetermined time interval spacing, utilization means coupled to a selected of said gaps for producing a response upon the firing of said selected gap, and gap extinguishing means coupled to and responsive to the firing of the ultimate of said gaps, said extinguishing means having a predetermined time cycle with respect to the time interval between said pulses, whereby the operating cycle of said tube may be made dependent upon the number of said gaps and said operating time cycle.

2. A pulse responsive system as claimed in claim 1, wherein said tube further comprises an electrode array, said array having a common anode and a plurality of spaced cathodes, said anode defining a series of spaced sequential discharge gaps with said cathodes, a source of discharge maintaining potential connected between said anode and said cathodes, discharge load impedance means serially disposed between said electrode array and said source.

3. A pulse responsive system as claimed in claim 1, wherein said gap extinguishing means comprises a capacitor in shunt with said ultimate gap.

4. A pulse responsive system as claimed in claim 1, wherein said tube comprises an electrode array, said array having a common anode and a plurality of spaced cathodes, said anode defining a series of spaced, sequential discharge gaps with said cathodes, a source of discharge-maintaining potential connected between said

anode and said cathodes, discharge load impedance means serially disposed between said electrode array and said source, and said gap extinguishing means comprises a capacitor in shunt with said ultimate gap, said capacitor together with said discharge load impedance means has a time constant value less than the time interval between said pulses.

5. A pulse responsive system as claimed in claim 4, wherein said capacitor together with said discharge load impedance means has a time constant value greater than the time interval between said pulses.

6. A pulse responsive system as claimed in claim 4, further comprising anode voltage stabilizing means disposed between said anode and said source.

7. A pulse responsive system as claimed in claim 4, wherein said discharge-maintaining potential source is of a value insufficient to initiate a discharge across any of said gaps whether ionised or not, but which is of sufficient value to maintain a discharge once initiated.

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