This invention relates generally to an electronic counting or integrating network provided with a gaseous discharge device having a plurality of discharge paths and more particularly relates to such a network wherein each discharge path may be sequentially energized in response to incoming electrical impulses to count or integrate these pulses.

This network according to the invention represents an improvement over United States Patents 2,443,407 and 2,554,923 issued to N. J. Wales, Jr. In practice, it has been found that the network described in these patents is unsuitable in certain respects and particularly fails to respond properly at high counting rates. Furthermore, this network exhibits poor conduction transfer characteristics when the wave shape and duration of these impulses are not uniform.

Through the provision of new principles and techniques, the present invention overcomes these difficulties and extends the utility of this type of network.

It is an object of this invention to provide a network of the type described which has a greatly improved frequency response to incoming electrical impulses.

A further object of this invention is to provide a network of the type described which has a greatly improved stability of operation.

Another object of this invention is to provide a network of the type described which can count negatively or positively i.e., may subtract or add.

Still another object of this invention is to provide a network of the type described which requires a greatly reduced number of circuit components.

Yet another object of this invention is to provide a network of the type described which needs less precise circuit components.

Yet another object of this invention is to provide a network of the type described which uses a novel gaseous discharge device.

Still another object of this invention is to provide a network of the type described which visually indicates the results of the counting process.

These and other objects of the invention will become apparent as reference is made to the following description taken in conjunction with the accompanying drawings wherein:

Fig. 1 is a schematic diagram of an integrating or counting network in accordance with the invention;

Fig. 2 is a cross-section drawing of a gaseous discharge device used in this integrating or counting network;

Fig. 3 is another cross-section drawing of this gaseous discharge device.

In accordance with the invention, the network includes a gas filled counter tube provided with an anode electrode system and a cathode electrode system. Each system comprises a predetermined number of discharge elements or fingers, the number of these fingers being the same for both systems. Each anode finger is arranged opposite a corresponding cathode finger, thereby forming an individual conducting or discharge path therewith. In order to energize these paths, it is necessary to apply appropriate operating potentials to the fingers forming these paths through an externally coupled resistance-capacitance circuit.

When incoming electrical impulses are supplied to this circuit, these discharge paths are sequentially energized in a selected direction in accordance with these impulses, only one path being energized at a time.

Selected discharge paths may be used as index points. Thus, after a number of impulses sufficient to cause one of these selected paths to be energized in the selected energized sequence, have been applied to the circuit, the change in potential of this energized path provides an index for this number of impulses.

Referring now to Fig. 1, a plurality of equally spaced anode fingers, twenty in number, being specifically shown herein as 19a through 19t, are mounted within the tube envelope 1. These anode fingers are interconnected to form four anode sections. Thus, anode fingers 19a, 19c, 19i, 19m and 19q are connected together to form the first anode section; 19b, 19f, 19j, 19n and 19r form the second section; 19o, 19p, 19g, 19k and 19s form the third section and 19d, 19h, 19i, 19q and 19f form the fourth section. These fingers may either be connected together within the tube as herein shown, or they may be connected together externally, for example, through the use of lead-in wires terminating in the tube socket. Moreover, each anode section may be formed from one ring-like structure.

A like plurality of cathode fingers, 11a through 11t, are also mounted within the tube envelope in such a manner that each cathode finger is opposite a corresponding anode finger having the same letter designation, thereby forming 20 discharge paths. Each cathode finger is separated from its corresponding anode finger by a small distance to provide a satisfactory spacing for an arc discharge. (When such a discharge takes place, the discharge path within which the arc is produced is said to be energized.)

The cathode fingers are interconnected to form six cathode sections. Thus, cathode fingers 11c, 11e, 11m and 11q form the first cathode section; 11b, 11f, 11j, 11n and 11r form the second section; 11k, 11g and 11i form the third section; 11d, 11h, 11l and 11p form the fourth section, 11i forms the fifth section and 11s forms the sixth section.
These fifth and sixth sections are index or carry electrodes. These carry electrodes with their corresponding anode fingers form the selected discharge paths which constitute index points.

The first anode section is connected through conductor 12, diode 13, common conductor 14 and resistor 16 to the positive terminal of a battery 18. (This battery may, of course, be replaced by any suitable source of direct current.)

The second anode section is connected through conductor 17 and resistor 18 to the common conductor 14. In a similar manner, the third anode section is connected through conductor 20 and diode 21 to the common conductor 14, while the fourth anode section is connected through conductor 22 and resistor 23 to the common conductor 14. Capacitor 26 is connected between conductors 22 and 12; capacitor 27 is connected between conductors 26 and 17.

The first cathode section is connected through conductor 32, resistor 33 and common conductor 30 to the negative and grounded terminal of battery 15. The second cathode section is connected through conductor 34 and diode 33 to the common conductor 30. In a similar manner, the third cathode section is connected through conductor 36 and resistor 35 to common conductor 30, while the fourth cathode section is connected through conductor 37 and diode 33 to the common conductor 30.

The two carry electrodes are connected somewhat differently. The fifth cathode section, hereinafter called the first carry electrode, is connected to conductor 35 by way of conductor 45 and resistor 46 and is also connected by way of conductor 40 to carry terminal 61. The sixth cathode section, hereinafter called the second carry electrode, is connected by way of conductor 32 and resistor 47 to conductor 23 and is also connected by way of one terminal of the zeroing switch 59 to carry electrode 43. The other terminal of switch 59 is connected to the negative terminal of battery 61. (Battery 61, of course, may be replaced by any suitable source of direct current.)

Capacitor 44 is connected between conductors 37 and 35; capacitor 45 is connected between conductors 34 and 32.

Incoming impulses are supplied to the network by way of terminal 24 and blocking capacitor 25.

This network operates as follows. Assuming that the discharge path formed by fingers 101 and 111 has been energized by some previous operation, a discharge current flows from the positive terminal of battery 15. through resistor 16, diode 13, conductor 12, anode finger 111, cathode finger 111, diodes 45 and 33 and conductor 30 to the negative terminal battery. Capacitor 45 and diode 33 are effectively shunted across resistor 31. Capacitor 48, therefore, is charged by this discharge current to a voltage approximately equal to that produced at the junction of resistors 31 and 47. The forward resistance of diode 33 being so much smaller than that of resistance 31 should be such that the voltage appearing across this diode is relatively insignificant.

Since, for the purposes of this invention, only one discharge path may be energized at any time, the value of the positive voltage delivered by battery 15 has been chosen to exceed the extinguishing voltage (that voltage which is just insufficient to maintain an energized discharge path in an energized condition) and to fall below the ignition voltage (that voltage which is just sufficient to energize an unenergized discharge path). Hence, the voltage of battery 16 is sufficient to maintain, but not initiate, conduction through any discharge path.

It is important to understand, however, that this invention is not so limited that the battery voltage must have this chosen value. For example, the battery voltage may be chosen to exceed the ignition voltage and a source of bias voltage used to reduce the effective voltage produced across any discharge path to a value fall below the value of the ignition voltage and that of the extinguishing voltage.

Assume now that a negative impulse of sufficient amplitude to extinguish the energized discharge path through fingers 101 and 111 is applied to terminal 24. (The wave shape of this impulse should have a sharp trailing edge and may be, for example, an inverted saw tooth or may have an exponential rise toward the voltage appearing at the positive terminal of battery 15.) This impulse momentarily renders the diode 13 non-conductive, reducing the potential at anode finger 101 so that the energized conducting path therefore is deenergized.

Capacitor 45 then begins to discharge through diode 33. Since the backward resistance of this diode is much larger than its forward resistance, the capacitor discharge time is much shorter than its charging time. Consequently, a negative voltage with respect to ground (the magnitude of this negative voltage is of the order of several volts) is applied to the second cathode section, as this section is connected to the junction point between capacitor 45 and diode 33. This applied impulse has a sharp trailing edge, the voltage on common conductor 14 rises sharply positive. The voltages on the cathode fingers in the second cathode section are more negative than the voltages on the fingers of any other cathode section so that the largest potential difference across any cathode and anode section is that produced across the second cathode and anode sections. This larger potential difference establishes a preference for ignition of the second section discharge paths.

However, as is known to anyone skilled in this electronic art, when a discharge path is energized, ions are produced in the region surrounding this path, and sufficient ions remain present in the path vicinity immediately after the discharge path is deenergized to set up additional preferential conditions in this region for the re-establishment of a discharge.

The only discharge path through the second cathode and anode sections in which this further preferential condition exists is that through fingers 101 and 111. Consequently, this path is energized first, whereupon the voltage on common conductor 14 drops, because of the current flow through this newly energized path to such a value that no other discharge path through the second cathode and anode sections can be energized at this time.

The discharge current through fingers 101 and 111 charges capacitor 27. When the next successive impulse is applied to the terminal 24, the discharge path through fingers 101 and 111 is extinguished in the same manner as previously described for the discharge path through fingers 101 and 111; capacitor 27 discharges through diode 20, and the potential on the third anode section is raised relative to the potentials of the other anode sections. The largest potential difference is then across the third anode and
cathode sections. Due to the preferential ioniza-
tion condition existing about the extinguished
discharge path through fingers 10f and 11f, the
discharge path through 16k and 1lk is energized
through the same manner as previously discus-
sed.

Thus, in response to incoming impulses, the
discharge paths are successively energized in a
clockwise direction. On the tenth impulse, the
discharge path through fingers 10s and 11s is
energized. Finger 11s is the first carry electrode and is
used in this embodiment, as a tens index. When
the discharge path through fingers 10s and 11s is
energized (i.e., ten impulses have been sup-
plied to terminal 20), the current passing through
this carry electrode traverses resistor 48, thus
producing a sudden change in voltage across re-
sistor 49, which change appears at carry terminal
41. This change in voltage represents the ar-
rival of the tenth incoming pulse and may be
applied to another counter tube which would repre-
sent the next higher denominational order.
Additional counter tubes representing still higher
denominational orders could be connected in
cascade if desired.

On the twentieth pulse, the discharge path
formed by the second carry electrode 10t and its
associated anode finger 11t is energized. This
second electrode serves two purposes; i.e., that
of a twenties index and that of a discharge zero-
erizer.

As an index, the second electrode passes cur-
tent through resistor 47, producing a sudden
change in voltage thereacross which appears at
carry terminal 45. This change in voltage repre-
senting the arrival of the twentieth pulse, may
be used in the same manner as the change in
voltage at carry terminal 41.

Thus, when the discharge paths are successively
energized in a clockwise direction, the tube counts forward and indicates at any time the
number of impulses which have been previously
applied to it. Thus the tube is said to add the
number of incoming pulses.

In order to zeroize the discharge after a count
has been entered, or to start the tube after it
has been placed in the circuit, a start circuit con-
sisting of a battery 16 and a switch 50 is used in
conjunction with the second carry in-
cutrode. When the tube is to be zeroized or started,
the switch on of switch 50 (switch 60 is normally
in the position shown in Fig. 1), is momentarily
thrown to the left, thus applying a negative po-
tential onto the second electrode. This potential
is sufficient, in conjunction with the positive po-
tential applied through battery 15 and resistor
15 to anode finger 10t, to energize the discharge
path formed by fingers 10t and 11t. The result-
ing increased current flow through resistor 16 cause-
ed by this energization causes an additional
voltage drop across this resistor sufficient to de-
ergize any other conducting path in the tube
which may have been energized previously.

It will be apparent that the discharge sequence
may be reversed (the discharge paths may be
successively energized in a counter-clockwise
direction) by changing the conductor connec-
tions so that the fourth anode and cathode sections
would replace the present first section. The third
sections would replace the present second sec-
tions, the second sections would replace the pres-
ent third sections and the first sections would
replace the present fourth sections.

When this counter-clockwise sequence is used,
What is claimed is:

1. An electronic counting network responsive to applied impulses and comprising a gaseous discharge device provided with a plurality of cathode fingers and a like plurality of anode fingers, each anode finger being arranged with respect to its corresponding cathode finger to form a discharge path therewith, a source of operating potentials for said paths, and a resistance-reactance circuit connected across said paths and coupled to said source, said circuit being responsive to said applied impulses to sequentially energize said discharge paths in accordance with said impulses in a condition in which only one of said paths is rendered conductive at a time.

2. An electronic counting network as set forth in claim 1 wherein said anode fingers are spaced around a first periphery and said cathode fingers are spaced around a second and concentric periphery.

3. An electronic counting network as set forth in claim 2 wherein said anode and cathode fingers are easily spaced around their respective peripheries.

4. An electronic counting network responsive to applied impulses and comprising a gaseous discharge device provided with a plurality of cathode fingers and a like plurality of anode fingers, said anode and cathode fingers being spaced along respective concentric peripheries, each anode finger being arranged adjacent to its corresponding cathode finger to form a discharge path therewith, a source of operating potentials for said paths, and a resistance-capacitance circuit connected across said paths and coupled to said source, said circuit being responsive to said applied impulses to sequentially energize said discharge paths in a selected direction in accordance with said impulses in a condition in which only one of said paths is rendered conductive at a time.

5. An electronic counting network as set forth in claim 4 wherein said discharge paths are sequentially energized in a selected one of two given directions, said network further including switching means coupled between said circuit and said discharge paths to select said selected one direction.

6. An electronic counting network as set forth in claim 4 wherein said paths are sequentially energized in a clockwise direction.

7. An electronic counting network as set forth in claim 4 wherein said paths are sequentially energized in a counter-clockwise direction.

8. An electronic counting network responsive to applied impulses and comprising a gaseous discharge device provided with a plurality of cathode fingers and a like plurality of anode fingers, each anode finger being arranged with respect to its corresponding cathode finger to form a discharge path therewith, means connecting each of said anode fingers to selected other anode fingers to form a plurality of anode sections and means connecting selected ones of said cathode fingers to selected other cathode fingers to form a first plurality of cathode sections, said sections being connected in series; a source of operating potentials for said device, a resistance-capacitance circuit coupled between said source and said cathode and anode sections and responsive to applied impulses to sequentially energize said discharge paths in accordance with said impulses in a condition in which only one of said paths is rendered conductive at a time.

9. An electronic counting network as set forth in claim 8 wherein each of said second plurality of cathode sections constitutes a carry electrode.

10. An electronic counting network as set forth in claim 9 wherein each discharge path which is formed in conjunction with one of said second plurality of cathode sections is designated as an index point.

11. A discharge device comprising a gas-filled envelope, an anode system mounted within said envelope and constituted by a plurality of discharge fingers, and a cathode system mounted within said envelope and constituted by a like plurality of discharge fingers, each anode finger being arranged with respect to its corresponding cathode finger to form a discharge path therewith.

12. A discharge device comprising a gas-filled envelope, an anode system mounted within said envelope and constituted by a plurality of discharge fingers spaced along a first periphery, and a cathode system mounted within said envelope and constituted by a like plurality of discharge fingers spaced along a second and concentric periphery, each anode finger being arranged adjacent to its corresponding cathode finger to form a discharge path therewith.

13. A discharge device as set forth in claim 12 wherein the cathode and anode fingers are equally spaced around their respective peripheries.

14. In apparatus adapted for operation with a source of operating potential and responsive to incoming impulses, a first series circuit including in the order named a first resistance, a first set of electric valve elements and a first unidirectional conductor, a second series circuit connected across said first circuit and including in the order named a second unidirectional conductor, a second set of electric valve elements and a second resistance, said first and second sets being contained within a common envelope, and first and second capacitive members, said first member coupled between the junction of said first resistance and said first set and the junction of said second conductor and said second set, said second member coupled between the junction of said first set and said first conductor and the junction of said second set and said second resistance.

15. In apparatus adapted for operation with a source of operating potential and responsive to incoming impulses, a first series circuit including in the order named a first resistance, a first set of electric valve elements and a first unidirectional conductor, a second series circuit connected across said first circuit and including in the order named a second unidirectional conductor, a second set of electric valve elements and a second resistance, said first and second sets being contained within a common envelope, and first and second capacitive members, said first member coupled between the junction of said first resistance and said first set and the junction of said second conductor and said second set, said second member coupled between the junction of said first set and said first conductor and the junction of said second set and said second resistance.

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