

May 6, 1952

W. A. GEOHEGAN

2,595,519

ELECTRONIC COUNTER

Filed April 13, 1946

4 Sheets-Sheet 1

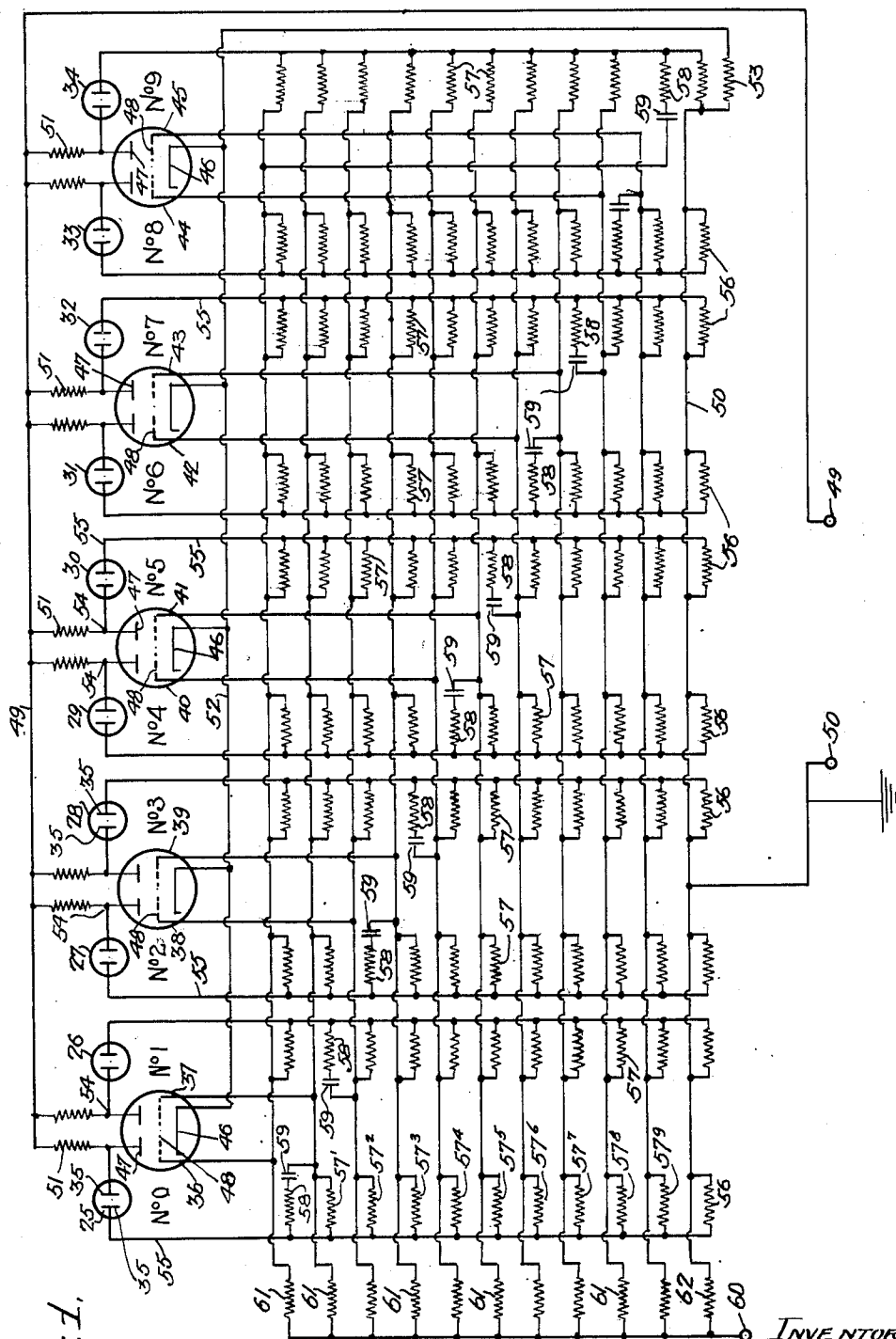


Fig. 1.

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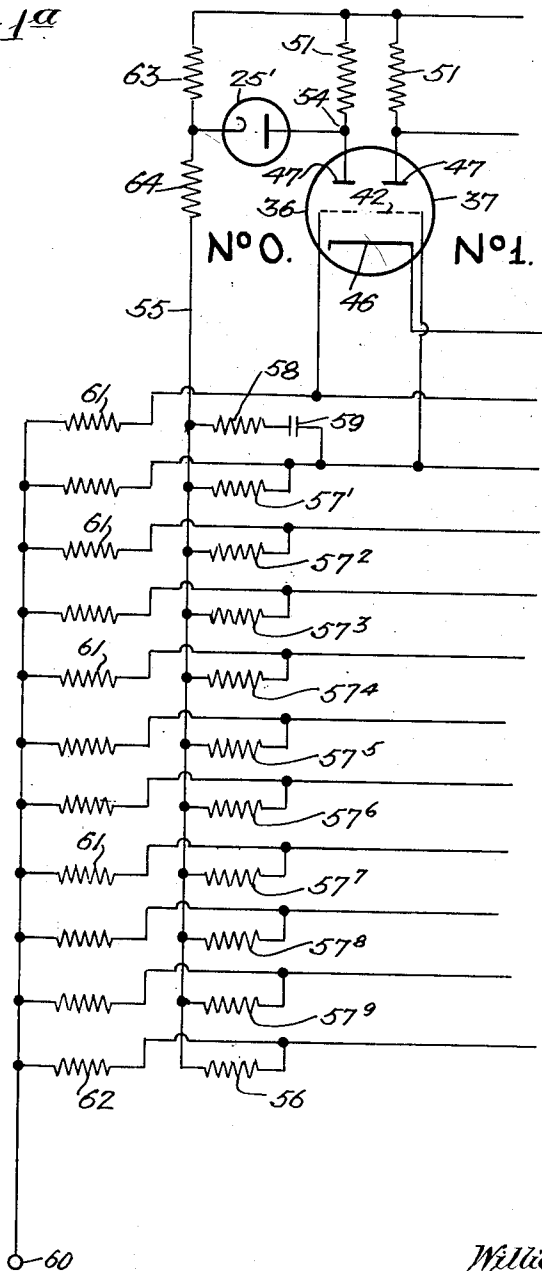
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4 Sheets-Sheet 2

Fig. 1^a



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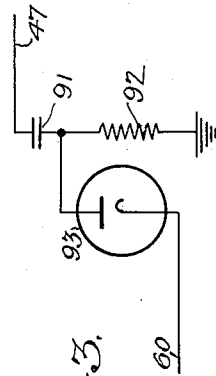
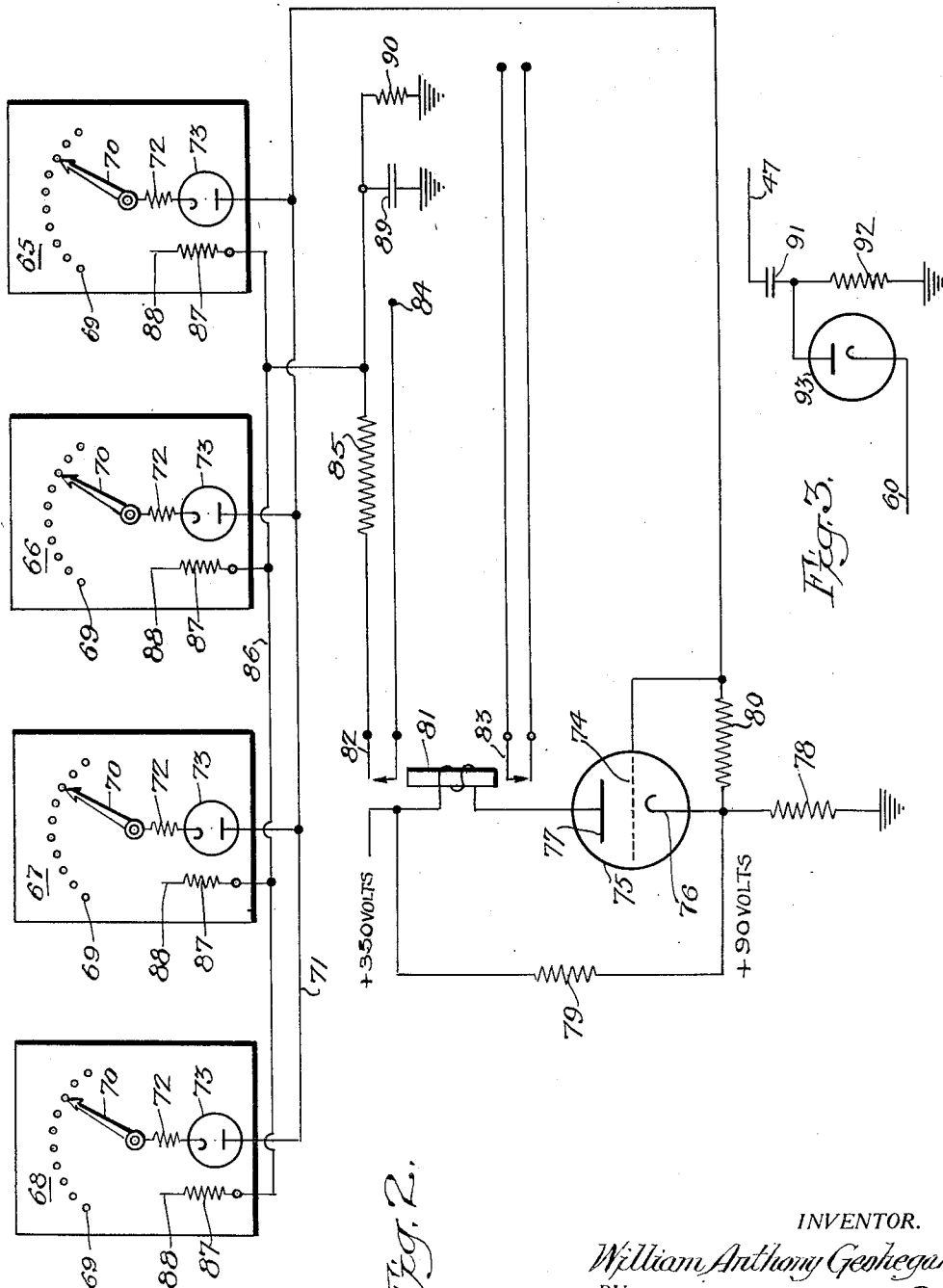
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Filed April 13, 1946

4 Sheets-Sheet 3



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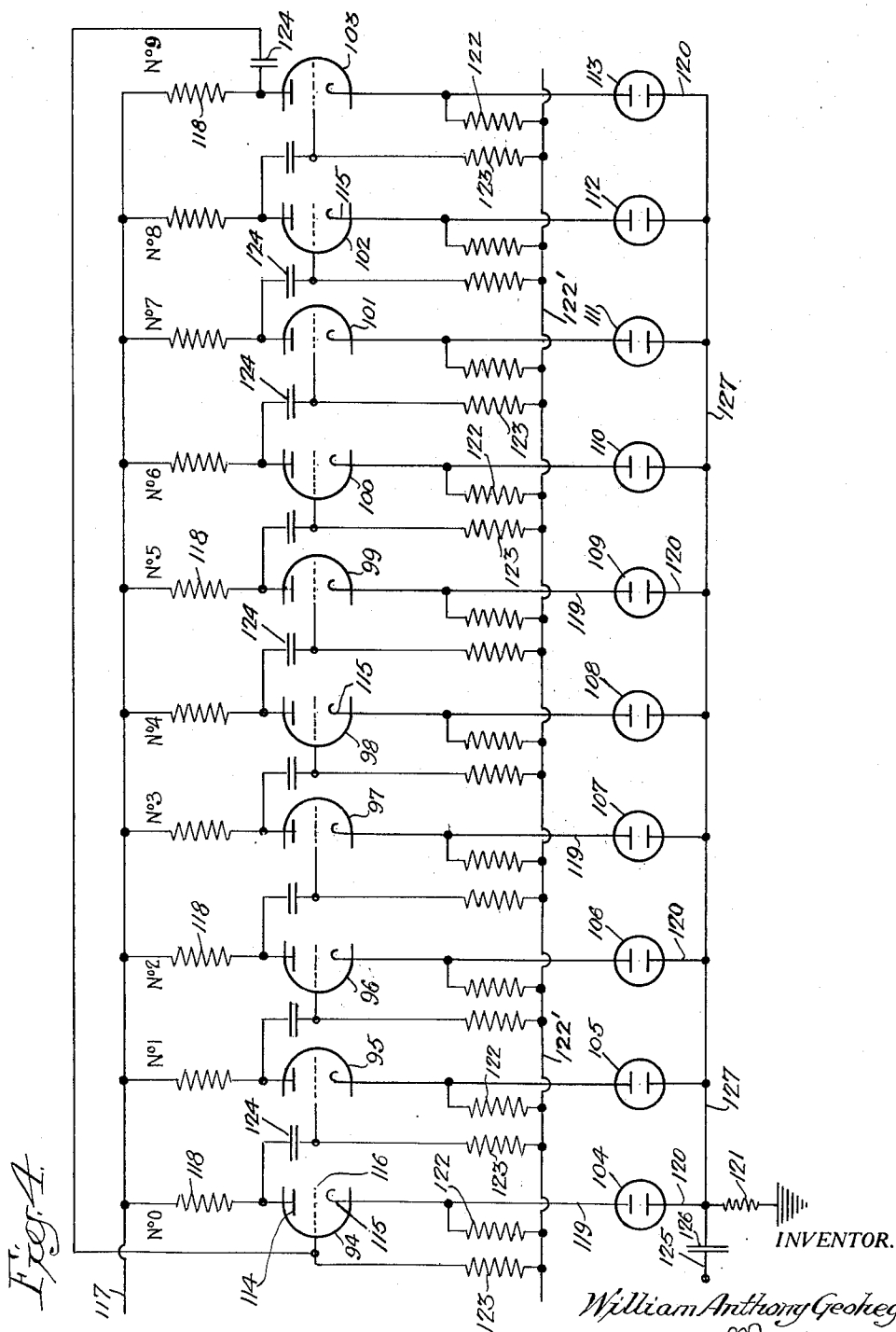
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ELECTRONIC COUNTER

Filed April 13, 1946

4 Sheets-Sheet 4



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2,595,519

ELECTRONIC COUNTER

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Application April 13, 1946, Serial No. 662,038

14 Claims. (Cl. 235—92)

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My invention relates to processes and apparatus for electronic counting.

The subject matter relating to the presettable predetermined count register, originally contained in this application, forms the subject matter of my divisional application, Serial No. 789,178, filed December 2, 1947, now abandoned, for register and process.

A purpose of my invention is to simplify, reduce the size, reduce the cost, reduce the number of electronic tubes and improve the reliability and efficiency of electronic counters.

A further purpose is to employ gas tubes, suitably gas filled glow discharge lamps such as neon or argon lamps, to function actively in an electronic counting ring, such as a decade, and not merely as indicators.

A further purpose, in an electronic counter having a counting ring, is to employ a device having a sharp voltage point at which current ceases to flow or a sharp cut-off, in each unit of the counting ring, and to utilize this device when it is conducting to prevent any other device in other units of the ring from conducting at the same time, and desirably also for rendering the device in the next unit conducting when the next impulse is received to be counted. The device having a sharp voltage point at which current ceases to flow, or a sharp cut-off, will most desirably be a gas tube such as a gas filled glow discharge lamp, but it may also be a rectifier and associated resistors as later explained. A suitable rectifier may be a vacuum tube (diode), a copper oxide rectifier, a selenium rectifier or a crystal detector. Whenever herein reference is made to such a gas tube, it is intended that any other device having a sharp voltage point at which current ceases to flow may be used.

A further purpose is to employ in an electronic counter a counting ring having a gas tube or the like in each unit, and, when any gas tube strikes, to use this striking not merely to indicate the count but to prevent any other gas tubes in the other units of the ring from striking, preferably by voltage transmitted from the gas tube which has struck through preferably substantially equal resistors to each other unit, and desirably also to transmit through the struck gas tube to the next unit of the ring the next impulse to be counted so as to strike the next gas tube.

A further purpose is to employ, in a counting ring, an amplifier having a control grid and a gas tube or the like, in each unit, to preferably indicate the count by the striking of a particular gas tube, to apply the voltage due to the current

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in the particular gas tube to each amplifier other than the one in that unit, to amplify the voltage in each other amplifier, to apply this amplified voltage to each gas tube other than the one conducting to prevent striking of any other gas tube, and upon receipt of an impulse to be counted desirably to apply that impulse to the control grid of the amplifier in the next unit in amplified and preferably inverted form with respect to any impulse applied to the control grid of any other amplifier to cause the amplifier in the next unit to gain and strike the gas tube in that unit.

A further purpose in electronic counting, using a counting ring having an amplifier with a control grid and a gas tube or the like, in each unit, is to strike one gas tube, at the same time to raise the potential of all other control grids in the ring in a positive direction and also at the same time to reduce the potential of all other gas tubes below their striking voltages, and upon receipt of the next impulse to be counted desirably to raise the potential of the next gas tube above its striking voltage.

A further purpose is to form an electronic counting ring of units operatively interconnected and each including a gas tube, the gas tube in each unit having an open circuit condition in which it is inactive and a closed circuit condition in which it conducts current to every other unit of the ring to prevent the gas tubes in such other units from striking, desirably indicates the count on the ring and desirably transmits to the next unit the impulse advancing the count.

Further purposes appear in the specification and in the claims.

In the drawings I have chosen to illustrate one main form of my invention, with variations, the main form and variations being chosen from the standpoints of convenience in illustration, satisfactory operation and clear demonstration of the principles involved.

Figure 1 is a diagrammatic illustration of the circuit of a counting ring, in the particular case a decade, in accordance with the invention.

Figure 1^a is a fragmentary circuit diagram showing a variation in Figure 1.

Figure 2 is a diagram of a circuit including several decades and a relay.

Figure 3 is a fragmentary circuit diagram showing means for passing on the impulse to the next counting ring.

Figure 4 is a circuit diagram showing a variation in the counting ring.

In the drawings like numerals refer to like parts.

The electronic counter of the present invention indicates directly the number of impulses that have been received. It also, where desired, operates any suitable device when a predetermined number of impulses has been received. When controlled by a phototube or other light-sensitive device, it may be used to count the number of objects passing a given point. It may also be used to reduce impulse frequency to any desired extent, or, in conjunction with an oscillator or other impulse generator of known frequency, it will measure time intervals. Other useful applications will be readily apparent to those skilled in the art.

By the present invention a simplification over prior art counting circuits is achieved by using gas filled glow discharge lamps (neon or argon lamps) or other devices having a sharp voltage point at which current ceases to flow or a sharp cut-off, such as other gas tubes, or rectifiers with associated resistors, such as vacuum tube rectifiers (diodes), copper oxide rectifiers, selenium rectifiers, or crystal detectors, as functional components of the counting circuit. In prior counting circuits, such neon lamps have been used merely as indicators to show the count, but the lamps did not function in connection with the operation of counting. In fact they were apt to cause error by generating unwanted impulses when they struck.

In the present invention I preferably combine the electrical characteristics of such neon lamps with the characteristics of conventional vacuum tube amplifiers in order to produce a simpler counting circuit than those of the prior art without sacrificing performance and convenience in operation or in reading. A further simplification is accomplished by using the same neon or other gas lamps as indicators and operating elements of the circuit.

The invention may be applied to any counting rings, but it is preferred to use the decade or scale of ten type, and this form has been illustrated. The ring will, however, operate with a larger or smaller number of units than ten.

The decade counter counts on the decimal system, and employs one or more decades or counting rings each of which requires ten impulses to advance it through its entire cycle and return it to its original or zero position. At the time it completes its cycle or returns to zero position, it generates an impulse which advances the succeeding decade by one step. In the preferred embodiment, a decade has ten indicators, one being energized at each unit of the count, but in some cases the decade may be "blind" or non-indicating.

Thus in the preferred form, where neon lamps are used as indicators, and are numbered "0" to "9" inclusive, where five impulses have been received, number "5" lamp in the first or units decade will be struck or lit, and number "0" lamps will be lit in all other decades. Where used herein, the term "struck" is used to indicate that the lamp lights and remains lighted until a further described change occurs in the circuit.

Again when forty impulses have been received, the units decade will have made four complete cycles, and its number "0" lamp will be struck, while the tens decade will have received one impulse for each complete cycle of the units decade, and its number "4" lamp will be struck. Thus the counter will directly read forty.

In the accompanying drawings, certain electronic tubes and impedances are illustrated, and

in several cases, to aid the user, I have given examples of tube types and impedance dimensions. It will be understood that these are stated in illustration but not in limitation, and that changes and readjustments in tube types and impedance dimensions may readily be made by those skilled in the art without departing from the spirit of the disclosure.

Figure 1 illustrates a counting ring, which in this case is a decade, consisting of ten units numbered respectively from "0" to "9" inclusive. Each unit consists of its electronic elements and associated impedances, constituting an operative unit to receive, respond to and usually indicate the counting impulse, and pass along the succeeding impulse to the next similar unit. It will be evident that this is truly a ring in the sense that not only does number "1" follow number "0," etc., but also number "0" follows number "9."

It will also be evident that auxiliary effects may occur when the ring completes a cycle, such as the actuation or advance of another counting ring, but for the moment in considering the counting ring as an entity these features are eliminated from the discussion.

It will also be understood that means may be provided for resetting the counting ring or interconnected group of counting rings to zero at any desired time, and that, as later explained, external effects may be set in motion upon attaining any particular count.

Each unit of the ring includes a device having a sharply defined voltage below which current ceases to flow, which in the preferred embodiment will be a gas tube, suitably a cold cathode gas filled glow discharge lamp, such as for ordinary purposes a small commercial neon or argon filled lamp. It will also be evident that the device having sharp cut-off may be a rectifier, with associated resistors, such as a copper oxide or selenium rectifier or a crystal detector or preferably a vacuum tube diode rectifier.

Since for best operation a gas tube will be used as a device having sharp cut-off, Figure 1 illustrates tubes of this character used for this purpose.

The individual gas tubes in the individual units are indicated at 25 to 34 inclusive, the terminals 35 of the gas tubes being suitably identical and capable of connection with either side of the tube on the high voltage side. Also employed in each unit is an individual amplifier 36 to 45, inclusive, which in the particular embodiment shown is a triode having a cathode 46, anode 47 and control grid 48. For convenience, twin triodes such as 6J6 or 7F7 are shown in which two amplifiers are placed in a single envelope, but it will be evident that this may not in all cases be necessary or desirable. It will further be evident that while I have shown triodes, other tube constructions, such as pentodes may be employed.

For convenience the cathode heater and heater circuits which will be used have been omitted from the drawing.

Energy actuation of the units is accomplished by a direct current source having its positive side above ground connected at 49 and its negative side at ground connected at 50. The lead 49 provides positive voltage connection to all units of the ring and is connected to all anodes 47 through suitable substantially equal anode load resistors 51, one in each unit of the ring. Without attempting to limit to a particular value, it may be stated that good results have been obtained using an applied voltage of approximately

350 volts and a resistance of approximately 0.24 megohm in the anode load resistors.

The cathodes 46 are connected together at 52 and connected to ground through the cathode bias resistor 53, which in the preferred embodiment of my invention may have a resistance of approximately 500 ohms.

In each unit, the device having sharp cut-off, in this case a gas tube, is connected at 54 to the anode of the amplifier of that unit, thus applying the higher voltage to the terminal of the gas tube to which this connection 54 is made. It will be noted that elsewhere this terminal will be referred to as the higher voltage terminal of the gas tube or other device having sharp cut-off.

The lower voltage terminal of each device having sharp cut-off (gas tube) is connected at 55 to ground through one of the preferably substantially equal resistors 56, which in the preferred embodiment desirably has a resistance of approximately 0.24 megohm. The lower voltage terminal of each device having sharp cut-off (gas tube) is also connected through one of the preferably substantially equal resistors 57 to the control grid of the amplifier of each other unit in the ring, but not to the amplifier of the unit containing the particular gas tube. In the number "0" unit these individual resistors are designated 57', 57², 57³, to 57ⁿ, inclusive, and it will be understood that in each other unit there will be an individual resistor between the lower voltage terminal of the gas tube or other device having sharp cut-off and the control grid of each amplifier other than the amplifier in that unit.

For best results the resistors 57 should be substantially equal and should have in the preferred embodiment a resistance of approximately 4.7 megohms.

Between the lower voltage terminal of each device having sharp cut-off and the control grid of the next amplifier in the sequence of counting, I also interpose in series connection a resistor 58, preferably having a resistance of approximately 2.2 megohms, and a capacitor 59, preferably having a capacity of approximately 100 micro-microfarads.

The impulse to be counted, which may of course be transmitted from a preceding counting ring or from a suitable impulse circuit, will be received at the terminal 60 and transmitted through individual resistors 61, suitably each having in the preferred embodiment resistances of about 4.7 megohms, to the individual control grids of the amplifiers of each unit in the ring. The input terminal 60 is also connected to ground through a resistor 62 preferably having a value of approximately .51 megohm.

It will be understood that with reasonable matching, the values of the impedances mentioned can be varied widely, and that the particular values given are stated for convenience of those who may construct the device and because the values given fit in with standard resistance sizes which are available on the market.

It will be understood that impulses of widely variant character may be counted, provided they are passed through a suitable input circuit which will convert them to nearly uniform impulses to be applied at the terminal 60. It will also be understood that as well known in the art, means may be used to amplify and shape the pulses to the most advantageous form for counting in the ring. It will also be evident that the original im-

pulses may be used to trigger impulses of the preferred character for counting. All impulses received by the counting ring will be positive and preferably of about 0.1 millisecond duration, and preferably of the order of 100 volts in amplitude. The decade will function to count such impulses with a high degree of accuracy, and at speeds as high as about 1000 per second with the particular impedance values given.

The amplifiers and gas tubes operatively interconnected as shown in Figure 1 with the impedances illustrated, form a system such that in a stable state at least one gas tube or other device having sharp cut-off will be conducting (striking or lighted in the case of the gas tube), whereas no more than one can be conducting at a given time.

If none of the devices having sharp cut-offs were conducting, all of the control grids would be at approximately zero or ground potential, all of the anodes would be regulated by the cathode bias resistor 53 to a voltage of approximately 160 volts in the example given, and all of the devices having sharp cut-off (gas tubes) would tend to become conducting (strike). When the device is first turned on, and before any impulse to be counted arrives, the conducting tube may be any one of the ten. The counting ring may then be set to zero by suitable means such as those described below (closing contacts 82 by relay 81 in Figure 2). As soon as one of these devices becomes conducting (strikes) the current flowing through it develops a positive voltage at its lower voltage terminal 55 and applies this voltage through one of the resistors 57 to the control grid of each amplifier in the other units, but not to the amplifier in its own unit. This positive voltage applied to the control grids of the other amplifiers causes all of such amplifiers to draw more current and lowers the voltage applied across each of the other devices having sharp cut-off (gas tubes) to a value below the voltage which will maintain conduction, thus preventing the gas tubes from striking where gas tubes are used. At the same time it will be evident that the potential of the control grid of the amplifier in the unit having the conducting gas tube or other device having sharp cut-off will be very slightly influenced, since there is no resistor connecting this gas tube to the control grid of its own amplifier. At equilibrium, therefore, a condition will be reached in which only one gas tube or similar device will be conducting.

Using the example shown, and assuming that the gas tube in unit number "0" has struck, typical values for the voltages of the elements under the preferred conditions would be as follows:

For the anode of amplifier number "0" about +120 volts;

For the lower voltage terminal of the gas tube of unit number "0" approximately +60 volts;

For the control grid of amplifier number "0," approximately +2 volts;

For all other control grids, approximately +6.05 volts;

For all cathodes, approximately +6 volts.

It will be understood that these and other values given are not intended to limit to the particular values, but merely to serve as examples.

Since the system is perfectly symmetrical, it will be understood that it will have ten stable states, or one corresponding to each unit in the ring, if the number of units is other than ten. In each one of these stable states one of the devices having sharp cut-off will be conducting (that is,

where gas lamps are used, one of the lamps will be lit).

Assuming that unit number "0" is operating and gas tube number "0" is lit, and that the interval since the last count has been sufficient to permit all capacitors substantially to reach equilibrium, and that a new input impulse is applied to input terminal 60, it will be evident that this impulse will be transmitted through resistors 61 to the control grids of all of the amplifiers in the ring, tending to drive all control grids in a positive direction and tending to drive all anodes in a negative direction. The anode of the amplifier (triode) number "0" is driven to a much lower voltage (possibly of the order of 35 volts), and the gas tube or other similar device in unit number "0" ceases to conduct, while the lower voltage side of this gas tube or other device drops very sharply in voltage (from approximately 60 volts to about 2 volts). The removal of this positive voltage applied through the resistors 57 from the lead 55 at the lower voltage terminal of the gas tube or similar device in unit number "0" will influence the control grids of the amplifiers of all other units of the ring, partially offsetting the positive change from the input impulse which is being counted. At the same time the lower voltage terminal of the gas tube or similar device of unit number "0" is also connected through a resistor 58 and capacitor 59 in series to the control grid of the amplifier in unit number "1," and the sharp negative change at lead 55, transmitted in this way to this control grid, more than offsets the positive change due to the input impulse, so that the net effect upon the control grid of the amplifier of unit number "1" is negative, its anode rises to a high voltage (possibly of the order of 150 volts) and causes conduction of the device having sharp cut-off (gas tube) in unit number "1."

It will thus be seen that the input impulse is amplified and inverted by the amplifier of unit number "0" in the way characteristic of vacuum tube amplifiers and that this amplified impulse is transmitted through the gas tube of unit number "0" and through the resistor 58 and capacitor 59 in series to the control grid of the amplifier in unit number "1."

For best results the time constant of the resistor 58 and capacitor 59 is long as compared with the duration of the input impulse, although operation is possible with a time constant equal to or slightly shorter than the duration of this impulse. Because of this time constant relation, the voltage transmitted in this way is effective until after the termination of the input impulse. The current flowing through the lamp or similar device in unit number "1" is then effective as previously described to hold the voltage of all other gas tubes below the striking voltage, causing the gas tube in unit number "0" to extinguish, and all other gas tubes in the remaining units to remain extinguished.

It is required for operation of the device that the interval between impulses be sufficient so that all condensers can substantially reach equilibrium condition before the arrival of the next impulse. The successive impulses then function in the same way to transfer the condition of conduction or striking from one gas tube or similar device to the next in the order of the count as predetermined by the connection between the lower voltage terminal of each gas tube and the control grid of the next amplifier through the resistance and capacitor in series. When the

sequence of operations has caused conduction of gas tube 34 in unit number "9," the next succeeding impulse to be counted will actuate unit number "0" in exactly the same manner as the count is transferred from any one of the previous units to the next unit of the ring.

It will be evident that at any position, the count in the particular decade will be indicated by the lighting of a particular gas tube, and that, where desired, if some other device having sharp cut-off be used instead of a gas tube, the particular decade may be provided with other indicating means, or with a gas tube used purely as an indicator, or where indication is not required, this function may be dispensed with.

I have indicated by a fragment of Figure 1 shown in Figure 1^a, the number "0" unit which would be employed in case a diode rectifier 25' were employed as a device having sharp cut-off, instead of the gas tube 25 as in Figure 1. In this case it would be desirable to employ additional resistors as shown, resistor 63 being interposed between the positive high voltage source and the cathode of the diode, and resistor 64 being connected between the cathode of the diode and the control grid of each other amplifier, through the resistors 57 before referred to, and also to the control grid of the next amplifier in the sequence through the resistor 58 and capacitor 59. The anode of the diode is connected directly to the anode of the triode as shown. All of the other units of the decade will be modified in the same way.

It will be understood of course that in case a diode rectifier were employed as shown, the constants of the circuit would be suitably adjusted and particularly the value of the cathode bias resistor 53 would be suitably increased, preferably to a value of the order of 4000 ohms.

It will be understood that in case some other type of device having sharp cut-off be used, as for example a copper oxide or selenium rectifier or a crystal detector, the circuit of Figure 1^a might be employed with suitable modification in the circuit constants.

It will be understood that the decade of Figure 1, or any suitable counting ring embodying the circuit of Figure 1, can be employed as a unit with similar counting rings, or with counting rings of any other suitable design, as for example those shown in the prior art. For the sake of uniformity in operation, however, it is preferred to employ successive decades or other counting rings each embodying the circuit design as shown in Figure 1, operatively connected to any suitable external circuit for actuation or influencing of external operations, when a particular count is reached. I have, however, developed a novel and preferred external circuit arrangement which is believed to give best results when used with counting rings of the type illustrated herein, namely those having a single indicator for each step of advance.

In many cases it is desirable to arrange a counting ring or series of counting rings so that an external circuit or other mechanism will operate when the number of impulses received equals a preselected total. Normally where decades are used, one corresponding to units, one to tens, one to hundreds, one to thousands, etc., a preselected unit in each decade of the system would be in operation when the preselected number is reached, and at that time it would be desirable to operate the external circuit or the like.

This result can be accomplished as shown in

Figure 2 by providing individual selector switches, one for each decade. Thus in this figure a selector switch unit 65 is provided for the units decade, a switch unit 66 for the tens decade, and a switch unit 67 for the hundreds decade and a switch unit 68 for the thousands decade. Each switch is provided with contacts 69, one of which is connected to the anode 47 of each of the amplifiers of the particular decade. By movement of the switch arm 70, it is then possible to select the particular unit of the decade which will operate the remote circuit in cooperation with other preselected units in the other decades. All of the preselector switches are connected together at 71 through resistors 72 and diodes 73, the cathodes of the diodes being connected to the resistors. The anodes of the diodes 73, connected together at 71, are connected with the control grid 74 of a vacuum tube amplifier 75 having a cathode 76 and an anode 77. The cathode 76 is grounded through a cathode bias resistor 78 and a cathode bias is further maintained by the resistor 79 which connects the cathode to the positive high voltage direct current supply (suitably at about 350 volts).

The resistors 78 and 79 maintain such a cathode bias of the amplifier 75 that it is approximately half way between the voltage of an anode of an amplifier in the counting ring when the associated gas tube of that unit is striking, and a similar amplifier when the associated gas tube is not conducting. A resistor 80 is connected between the control grid 74 and the cathode 76.

The value of the resistor 80 in relation to the resistors 72 which are in series between the selector switches and the diodes 73 will be so selected as to maintain the control grid 74 at a voltage that will cut off all current through the amplifier 75 when any one of the selector switches 65 to 68 is connected to a unit of a decade in which the gas tube or other similar device is not conducting. A suitable set of values for illustrative purposes might be as follows:

Triode 75, type 6F5;
Diode 73, one diode unit of type 6AL5;
Resistor 72, 2.2 megohms;
Resistor 80, 2. megohms;
Resistor 78, 25000 ohms;
Resistor 79, 72000 ohms.

In circuit with the anode 78 I provide a relay 81, which for convenience in illustration has been shown as a magnetic relay, but may of course be an electronic relay, or impulse generator, or other type as desired.

It will be evident that when and only when all preselector switches are in contact with units of decades which contain gas tubes or similar devices which are conducting, the amplifier 75 will be in a conducting state, passing current through the magnet coil of relay 81, and closing contacts 82 and 83. Contacts 82 close the circuit to apply a necessary voltage between terminal 84 suitably at minus 100 volts, and the control grid 48 of the amplifier in unit number "0" of each counting ring. Connection with the control grid 48 of the amplifier of unit number "0" of each of these rings is provided through a resistor 85, a common connection 86 and one of the preferably substantially equal resistors 87 to terminals 88 connected to control grids 46 in units number "0" of each counting ring by connections not shown. Intermediate between the resistor 85 and the individual resistors 87, connection to ground

is provided through capacitor 89, and a separate connection to ground is provided through resistor 90. The capacitor 89 and resistor 90 are intended to eliminate undesired impulses from vibration of the contacts of the relay. It will be evident that as soon as the terminals 82 are closed, a negative voltage will be applied to the control grid of the amplifier in unit number "0" of each counting ring, driving it in a negative direction, driving the anode of that amplifier in a positive direction and causing gas tube number "0" to strike. When gas tube number "0" strikes it functions as previously described to extinguish any other gas tubes which may be lit and prevent any other lamps from striking. Thus the counter is reset to zero, since the "0" lamp 25 is lighted.

In order to assure of adequate time for resetting, the relay 81 will desirably be of a slow release type, so that the contacts 82 will be maintained closed for a perceptible time. Interaction between the grids of amplifiers of unit number "0" of the various decades is prevented by making the values of resistors 87 high compared with the value of resistor 90. The capacitor 89 also aids in preventing such interaction.

It will be evident that the operation of an external device or closing of an external circuit as required, may be accomplished by closing the contacts 83 in the relay at the same time that the contacts 82 are operated. Thus when the preselected count is reached, recording mechanism may be actuated, alarm or indicating devices may be put in operation, or operations may be performed in connection with automatic machinery or otherwise.

It will be understood that where desired the automatic reset feature may be eliminated or the contacts 82 or a parallel set of contacts such as a push button may be closed by hand where this is advantageous.

It will be further understood that the diode 73 is not essential to operation of the circuit, and that with suitable adjustment of impedance values it could be eliminated and the switch arm 70 could be connected to the lead 71 with only resistor 72 in series, but that the inclusion of diode 73 allows a greater variation in impedance values, and permits changing the number of decades at will without altering the impedances.

It may be desirable in some cases to employ several preselection circuits as shown in Figure 2 on a single counter.

When any decade has completed its cycle, and normally at the time that unit number "9" is passing out of operation and unit number "0" is being actuated, the sharp up-swing in voltage of the anode of the amplifier in unit number "0" may be used to generate an impulse to advance the following decade by one step. A typical manner in which this may be accomplished is shown in Figure 3. The sharp up-swing in voltage of the anode 47 of the amplifier of unit number "0" when the counting transfer is from "9" to "0" is transmitted through condenser 91 across resistor 92 and to the anode of vacuum tube diode 93. It is further transmitted through the diode 93 to the input terminal 60 of the following decade.

It will be evident that the duration of this impulse will depend on the values of the resistor and condenser in Figure 3. For illustrative purpose suitable values may be as follows:

Condenser 91, 300 micro-microfarads;
Resistor 92, 2.2 megohms;
Diode 93, one diode section of type 6AL5.

It will be further evident that when the count passes from "0" to "1" a negative impulse will pass from the anode of the amplifier of unit number "0" through capacitor 91 across resistor 92 and to the anode of diode 93 but this impulse is blocked from reaching the following decade by the diode 93.

Figure 4 illustrates a modified construction of a counting ring which may be used where glow discharge lamps of fairly uniform characteristics are available. The individual units of the counting ring include amplifiers 94 to 103, inclusive, one in each unit, and desirably forming parts of twin triodes, as well as gas tubes 104 to 113, inclusive. The amplifiers have anodes 114, cathodes 115 and control grids 116. For the purpose of simplification, heaters and heater circuits which are used have been eliminated from the drawing. The amplifiers may desirably be twin triodes of type 7F7. The individual anodes are connected to the positive high voltage direct current source at 117 through desirably substantially equal anode load resistors 118. The cathodes are connected individually to the higher voltage side of the glow discharge tubes 104 to 113, at 119, the lower voltage sides of such tubes at 120 being connected together and through a common cathode bias resistor 121 to ground. The cathodes are also individually connected through desirably substantially equal resistors 122 to a common connection 122' desirably maintained at a positive voltage intermediate between the positive high voltage source at 117 and the ground potential. The control grids are connected to this same source through individual desirably substantially equal resistors 123. Each control grid is connected to the anode of the previous amplifier through one of the desirably substantially equal condensers 124.

Input of impulse to be counted is accomplished through the terminal 125 and the capacitor 126.

By way of example, suitable values of the impedances and the voltages are as follows:

Positive high voltage, approximately 200 volts;
Intermediate positive voltage, approximately 75 volts;

Resistor 118, 100,000 ohms;

Resistor 121, 15,000 ohms;

Resistor 123, 150,000 ohms;

Capacitor 124, 5,000 micro-microfarads;

Capacitor 126, 1 microfarad.

If no gas tubes are lit, all anodes will be at approximately 198 volts, all cathodes of the triodes at about 80 volts, and the lead 127 common to the low voltage terminals of the gas tubes will be at approximately zero volts. If any gas tube strikes, assuming that it burns at approximately 60 volts, it will raise the potential of lead 127 to an intermediate voltage, possibly of the order of 16 volts, and will lower the voltage across the other gas tubes by approximately 16 volts. If all gas tubes in the counting ring have burning voltages of less than the order of 60 volts and the lowest striking voltage of any gas tube in the decade is of the order of say 5 volts above the highest burning voltage of any other gas tube in the counting ring, it will then be possible for any gas tube, once it has lighted, to continue to burn and prevent all other gas tubes from striking until a new impulse is received. When any gas tube is lighted, the current flowing through that gas tube acts with its associated amplifier and its anode load resistor to lower the anode voltage of that amplifier. Accordingly, when a gas

tube strikes, a negative impulse is transmitted through the capacitor 124 of that unit to the control grid of the following amplifier. This negative impulse has little effect because the next amplifier is already nearly at cut-off. As soon, however, as the capacitor 124 has assumed the new charge, the circuit is ready to respond to a new input impulse. When the input impulse arrives at the terminal 125 it drives lead 127 positive and extinguishes the gas tube which was previously lighted. This causes a large positive impulse to be transmitted to the control grid of the next amplifier, driving its cathode far enough positive to strike the gas tube in its unit. The input impulse duration is preferably short compared with the time constant of the capacitor 124 and the resistors 118 and 123 for the particular unit connected as shown, and therefore the gas tube remains lit when the input impulse subsides, and prevents the previous gas tube in the cycle from relighting. If desired, however, the input impulse duration may be slightly longer than the said time constant.

It will be evident that the reset, coincidence and presetting circuits, and the means for passing on the impulse to the next decade, may be conveniently modified to employ this decade instead of the decade of Figure 1, where it is desired to substitute the counting ring of Figure 4.

In view of my invention and disclosure variations and modifications to meet individual whim or particular need will doubtless become evident to others skilled in the art, to obtain all or part of the benefits of my invention without copying the process and apparatus shown, and I, therefore, claim all such insofar as they fall within the reasonable spirit and scope of my claims.

Having thus described my invention, what I claim as new and desire to secure by Letters Patent is:

1. In an electronic counter, a counting ring having in each unit a device with a sharp voltage cut off at which current ceases to flow and an amplifier, means including each of the devices with a sharp voltage cut-off at which current ceases to flow when it is conducting for feeding a voltage from the amplifiers of each one of the units to each other unit for rendering the sharp cut off devices in the other units non-conducting and means including unit transfer impedance for transferring an impulse from the amplifier of one unit to the amplifier of the next unit.

2. In an electronic counter, a counting ring having in each unit an amplifier provided with an anode, a cathode and a control grid and a device having a sharp voltage cut off at which current ceases to flow, means for maintaining the cathodes of all of the amplifiers at the same potential, means including each of the devices with a sharp voltage cut off at which current ceases to flow when it is conducting for feeding a voltage from the amplifiers of each of the units to each other unit for rendering the sharp voltage cut off devices in the other units non-conducting, and means including unit transfer impedance for transferring an impulse from the amplifier of one unit to the amplifier of the next unit.

3. In an electronic counting ring, having a plurality of units operatively interconnected, an amplifier provided with an anode, a cathode and a control grid in each unit, a device having a sharp voltage point at which current ceases to flow in each unit interposed in the circuit between the output of each amplifier and the control grid of

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every other amplifier except that amplifier, means including each of the devices having a sharp voltage point at which current ceases to flow when it is conducting for feeding a voltage from the amplifiers of each one of the units to each other unit for rendering the devices having a sharp voltage point at which current ceases to flow in the other units non-conducting and means including unit transfer impedance for transferring an impulse from the amplifier of one unit to the amplifier of the next unit.

4. In an electronic counting ring, having a plurality of units operatively interconnected, an amplifier provided with an anode, a cathode and a control grid in each unit, a cathode grounding resistor through which the cathodes of all amplifiers are connected to ground, a device having a sharp cut off voltage at which current ceases to flow in each unit interposed in the circuit between the anode of each amplifier and the control grid of every other amplifier except that amplifier, means including each of the devices having a sharp cut-off voltage when it is conducting for feeding a voltage from the amplifiers of each one of the units to each other unit for rendering the devices having a sharp cut-off voltage in the other units non-conducting and means including unit transfer impedance for transferring an impulse from the amplifier of one unit to the amplifier of the next unit.

5. In an electronic counting ring, a plurality of units operatively interconnected having an amplifier provided with an anode, a cathode and a control grid in each unit, a cathode grounding resistor through which the cathodes of all amplifiers are connected to ground, a series of grid resistors for each unit, a device having a sharp cut off voltage at which current ceases to flow for each unit interposed in the circuit between the anode of each amplifier and the control grid of every other amplifier except that amplifier, one of the grid resistors being located between the device having sharp cut off and the control grid of each other amplifier, a sharp cut off device grounding resistor interposed between each device having sharp cut off on the side towards the control grids and ground, and means including unit transfer impedance for transferring an impulse from the amplifier of one unit to the amplifier of the next unit.

6. In an electronic counting ring for counting impulses from a source a plurality of units operatively interconnected having an amplifier provided with an anode, a cathode and a control grid in each unit, a cathode grounding resistor through which cathodes of all amplifiers are connected to ground, a series of grid resistors for each unit, a device having a sharp cut off voltage at which current ceases to flow in each unit interposed in the circuit between the anode of each amplifier and the control grid of every other amplifier except that amplifier, there being one of the grid resistors located between the device having sharp cut off and the control grid of each other amplifier, a sharp cut off device grounding resistor interposed between each device having sharp cut off on the side toward the control grids and ground, an impulse resistor interposed between the source of the impulse to be counted and each control grid and a unit transfer resistor and capacitor interposed in series between each sharp cut off device on the side toward the control grids and the control grid of the next unit.

7. In an electronic counting ring for counting impulses from a source, a plurality of units oper-

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atively interconnected having an amplifier provided with an anode, cathode and a control grid in each unit, a cathode grounding resistor through which the cathodes of all amplifiers are connected to ground, a series of grid resistors for each unit, a device having a sharp cut off voltage at which current ceases to flow in each unit interposed in the circuit between the anode of each amplifier and the control grid of every other amplifier except that amplifier, there being one of the grid resistors located between the device having sharp cut off and the control grid of each other amplifier, a sharp cut off device grounding resistor interposed between each device having sharp cut off on the side toward the control grids and ground, an impulse resistor interposed between the source of the impulse to be counted and each control grid and a unit transfer resistor and capacitor interposed in series between each sharp cut off device on the side toward the control grids and the control grid of the next unit, the unit transfer resistor and capacitor in series having a time constant substantially greater than the duration of the impulse to be counted.

8. In an electronic counting ring, a plurality of units operatively interconnected having an amplifier provided with an anode, a cathode and a control grid in each unit, a gas tube in each unit interposed in the circuit between the output of each amplifier and the control grid of every other amplifier except that amplifier, means including each of the gas tubes when it is conducting for feeding of voltage from the amplifiers of each one of the units to each other unit for rendering the gas tubes in the other units non-conducting and means including unit transfer impedance for transferring an impulse from the amplifier of one unit to the amplifier of the next unit.

9. In an electronic counting ring, a plurality of units operatively interconnected having an amplifier provided with an anode, a cathode and a control grid in each unit, a cathode grounding resistor through which the cathodes of all amplifiers are connected to ground, a gas tube in each unit interposed in the circuit between the anode of each amplifier and the control grid of every other amplifier except that amplifier, means including each of the gas tubes when it is conducting for feeding of voltage from the amplifiers of each one of the units to each other unit for rendering the gas tubes in the other units non-conducting and means including unit transfer impedance for transferring an impulse from the amplifier of one unit to the amplifier of the next unit.

10. In an electronic counting ring, a plurality of units operatively interconnected having an amplifier provided with an anode, a cathode and a control grid in each unit, a cathode grounding resistor through which the cathodes of all amplifiers are connected to ground, a series of grid resistors for each unit, a gas tube in each unit interposed in the circuit between the anode of each amplifier and the control grid of every other amplifier except that amplifier, there being one of the grid resistors located between the gas tube and the control grid of every other amplifier, a gas tube grounding resistor interposed between each gas tube on the side toward the control grids and ground, and means including unit transfer impedance for transferring an impulse from the amplifier of one unit to the amplifier of the next unit.

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11. In an electronic counting ring for counting impulses from a source, a plurality of units operatively interconnected having an amplifier provided with an anode, a cathode and a control grid in each unit, a cathode grounding resistor through which cathodes of all amplifiers are connected to ground, a series of grid resistors for each unit, a gas tube for each unit interposed in the circuit between the anode of each amplifier and the control grid of every other amplifier except that amplifier, there being one of the grid resistors located between the gas tube and the control grid of each other amplifier, a gas tube grounding resistor interposed between each gas tube on the side toward the control grid and ground, an impulse resistor interposed between the source of the impulse to be grounded and each control grid and a unit transfer resistance and capacitor interposed in series between each gas tube on the side toward the control grids and the control grid of the next unit.

12. In an electronic counting ring, a plurality of units operatively interconnected having an amplifier limited to a single anode, cathode and control grid in each individual unit, a gas tube in each unit interposed in the circuit between the output of each amplifier and the control grid of every other amplifier, means including each of the gas tubes when it is conducting for feeding of voltage from the amplifiers of each one of the units to each other unit for rendering the gas tubes in the other units non-conducting and means including unit transfer impedance for transferring an impulse from the amplifier of one unit to the amplifier of the next unit.

13. In an electronic counting ring, a plurality of units operatively interconnected having an amplifier limited to a single anode, cathode and control grid in each unit, a cathode grounding resistor through which the cathodes of all amplifiers are connected to ground, a gas tube in each unit interposed in the circuit between the anode of each amplifier and the control grid of every other amplifier, means including each of the gas tubes when it is conducting for feeding of voltage from the amplifiers of each one of the units to each other unit for rendering the gas tubes in the other units non-conducting and means including unit

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transfer impedance for transferring an impulse from the amplifier of one unit to the amplifier of the next unit.

14. In an electronic counting ring for counting impulses from a source, a plurality of units operatively interconnected having an amplifier limited to a single anode, cathode and control grid in each unit, a cathode grounding resistor through which the cathodes of all amplifiers are connected to ground, a series of grid resistors for each unit, a gas tube in each unit interposed in the circuit between the anode of each amplifier and the control grid of every other amplifier, there being one of the resistors located between the gas tube and the control grid of every other amplifier, a sharp cut off device grounding resistor interposed between each gas tube on the side toward the control grids and ground, an impulse resistor interposed between the source of the impulse to be counted and each control grid and a unit transfer resistor and capacitor interposed in series between each gas tube on the side toward the control grids and the control grid of the next unit.

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