Nov. 4, 1952 W. H. T. HOLDEN 2,616,627

COUNTER CIRCUIT

Filed Oct. 6, 1948 3 Sheets-Sheet 1

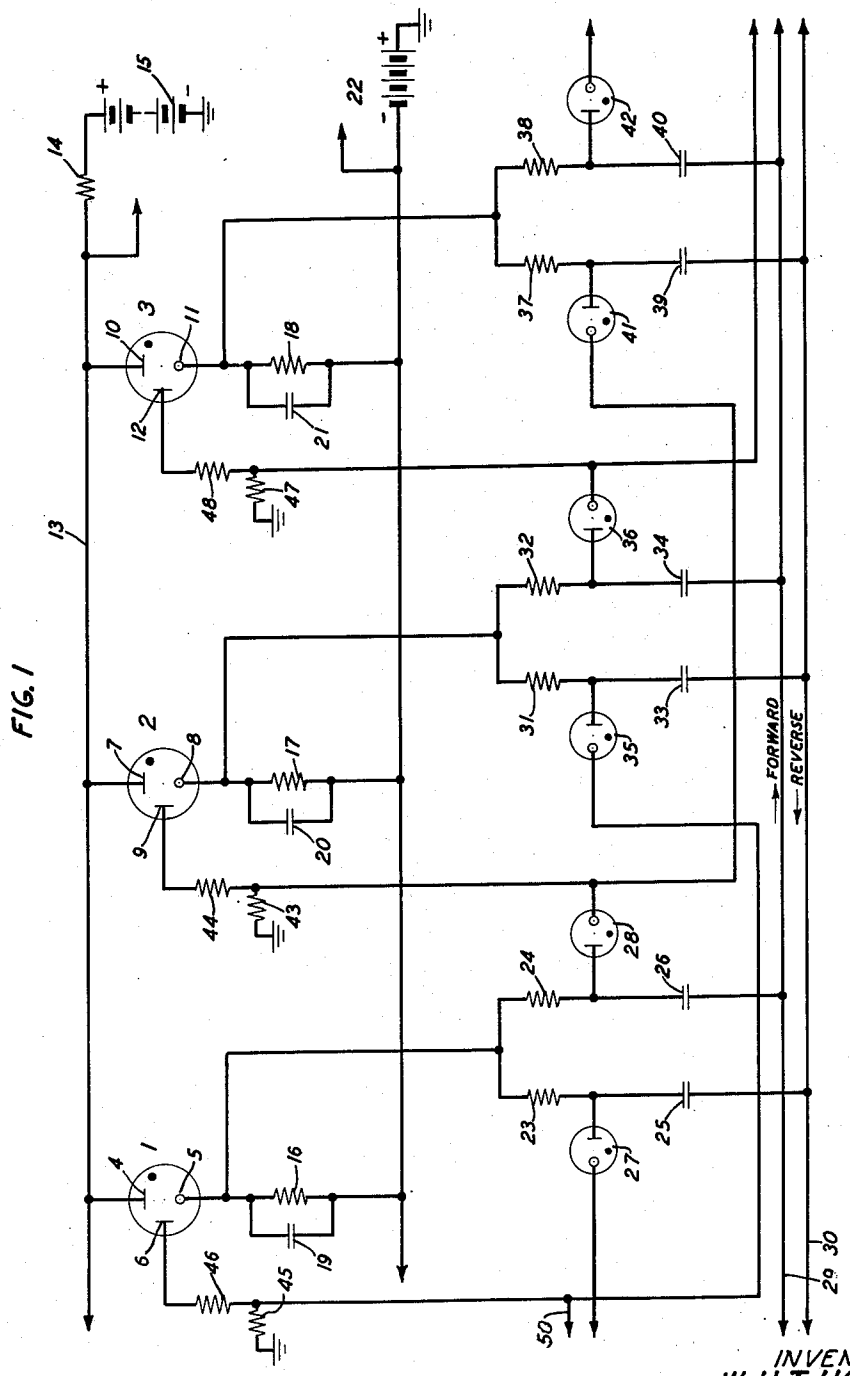


FIG. 1

INVENTOR
W. H. T. HOLDEN
BY
J. W. Schmied
ATTORNEY

Nov. 4, 1952 W. H. T. HOLDEN 2,616,627

COUNTER CIRCUIT

Filed Oct. 6, 1948 3 Sheets-Sheet 2

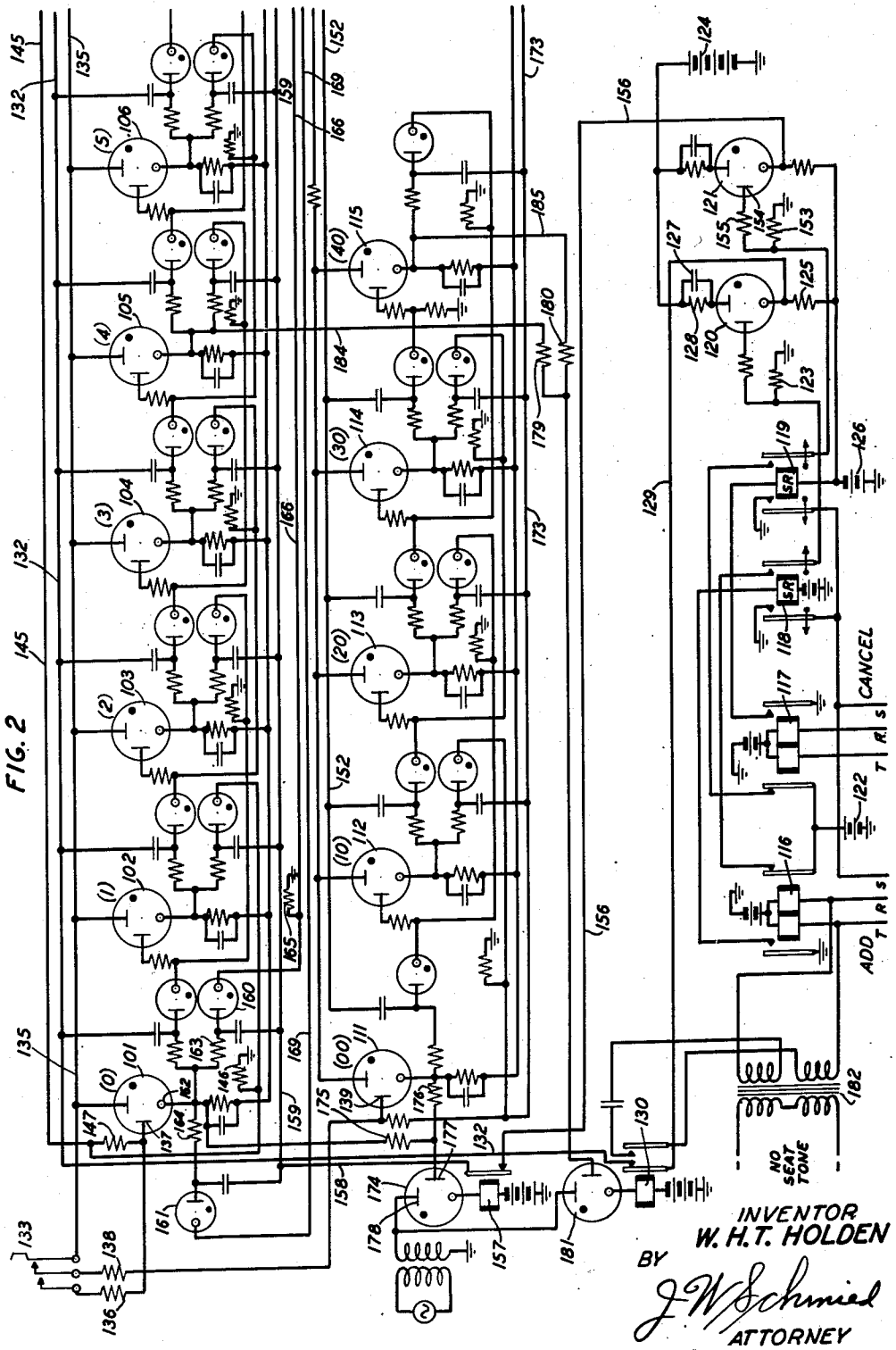


FIG. 2

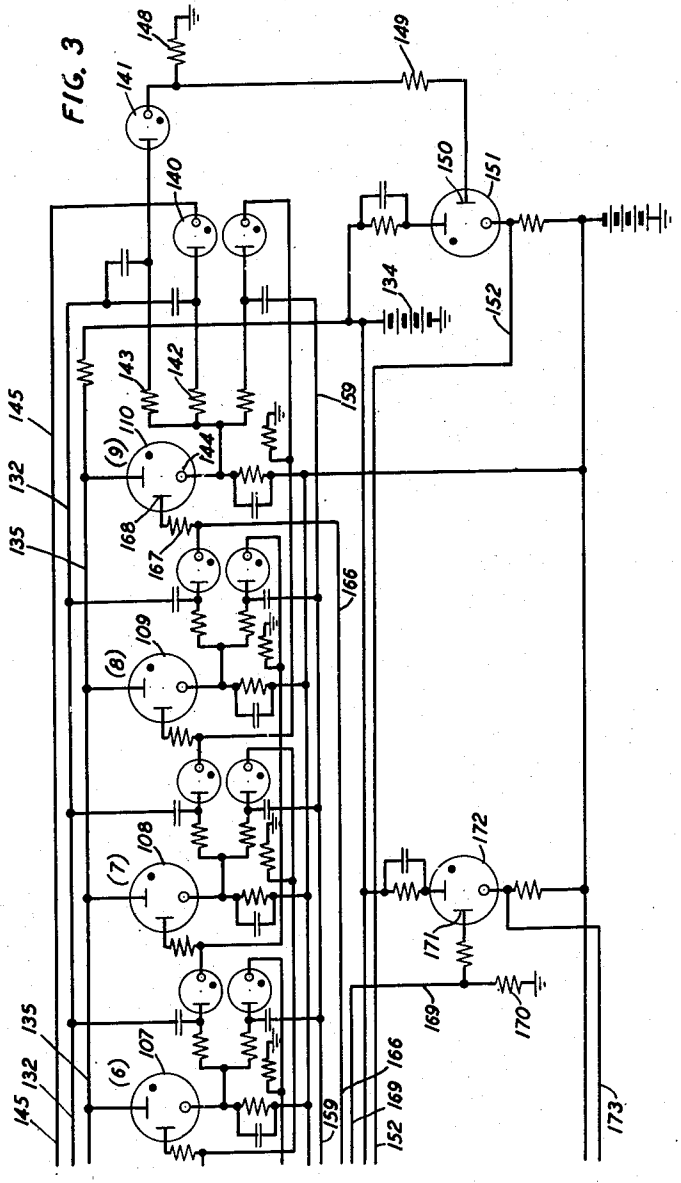
INVENTOR
W. H. T. HOLDEN
BY
J. W. Schmied
ATTORNEY

Nov. 4, 1952 W. H. T. HOLDEN 2,616,627

COUNTER CIRCUIT

Filed Oct. 6, 1948 3 Sheets-Sheet 3

FIG. 3



INVENTOR
W. H. T. HOLDEN

BY J. W. Schmied

ATTORNEY

Patented Nov. 4, 1952 2,616,627

UNITED STATES PATENT OFFICE

2,616,627

COUNTER CIRCUIT

William H. T. Holden, Woodside, N. Y., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application October 6, 1948, Serial No. 53,079

18 Claims. (Cl. 235—92)

1

This invention relates to electronic counting circuits and more particularly to tube counting chains in which pulses on one of two input leads cause the tubes to fire sequentially in one direction while pulses on the other input lead cause the tubes to fire sequentially in the opposite direction, thus providing add-subtract or two-way operation.

An object of this invention is to furnish an electron tube counting circuit capable of being stepped in either direction.

Another object of the invention is to render the operation of a counting chain non-critical with regard to the magnitude of the supply voltages or the critical voltages of the tubes therein.

Another object of this invention is to provide means operable from a remote point over telephone circuits which will register the number of seats sold or canceled in railroad trains or passenger aircraft and which will automatically indicate the present available space.

These objects have been accomplished, in a preferred embodiment of the invention, by connecting the cathode of each tube in the chain to the starter anode of the immediately preceding tube through a pulse-gate gas diode and by similarly connecting the cathode of each tube to the starter anode of the next following tube through a gas diode. With one tube in the chain conducting, a diode in the next preceding stage and a diode in the next succeeding stage have priming potentials impressed across them. Application of a pulse to the forward input lead will render the diode associated with the next succeeding stage conductive and the next tube in the forward direction will be fired. Application of a pulse to the reverse pulse lead will result in the rendering of the next preceding tube conductive in a similar fashion. Means may be provided to extinguish those tubes which were conductive prior to the receipt of the pulse.

The invention may be more clearly understood from the following detailed description made in reference to the accompanying drawings in which:

Fig. 1 illustrates a portion of a bidirectional counting chain constructed in accordance with the invention; and

Figs. 2 and 3 illustrate an application of the

2

bidirectional counting circuit of Fig. 1 to the problem of automatically recording the number of seats sold in transport aircraft.

Referring now to Fig. 1, reference character 1 indicates a cold-cathode glow-discharge tube of the well-known three-element type having a main anode 4, a main cathode 5, and a starter anode 6. The adjacent tube 2 in the forward direction has similar elements, as does tube 3, designated respectively 7, 8, 9 and 10, 11 and 12. The main anodes of these tubes, and of other tubes not shown, are multipled and connected by lead 13 to commutating impedance 14, which may be a resistor, as shown, or an inductor. The other side of impedance 14 is connected to the positive pole of battery 15, the negative pole of which is grounded, while the cathodes of tubes 1, 2 and 3 are connected through cathode resistors 16, 17 and 18, by-passed by capacitors 19, 20 and 21, to negative battery 22 the positive pole of which is grounded.

From the cathode of tube 1, resistors 23 and 24 are connected to capacitors 25 and 26, respectively, and also to the anode terminals of cold-cathode diodes 27 and 28, respectively. The other electrode of capacitor 26 is connected to the forward pulse wire 29 and the other electrode of capacitor 25 is connected to reverse pulse wire 30. Tube 2 is similarly provided with resistors 31 and 32, capacitors 33 and 34, and diodes 35 and 36. Tube 3 has similarly connected resistors 37 and 38, capacitors 39 and 40, and diodes 41 and 42. The cathodes of diodes 28 and 41 are connected together, are connected to ground through resistor 43, and are connected to the starter anode 9 of tube 2 through resistor 44. Similarly the cathode of diode 35 is connected through resistor 45 to ground, through resistor 46 to starter anode 6 of tube 1, and through lead 50 to the cathode of the associated diode in the next stage in the reverse direction. The remaining diodes throughout the chain are similarly connected. The arrows projecting from each side of Fig. 1 represent connections to preceding and succeeding stages.

In the following discussion of the operation of the circuit of Fig. 1, and throughout this specification, it is to be understood that the suggested voltages are but exemplary and that other potentials may be applied to achieve optimum

operating results in view of the parameters of the circuits. While the values of the voltages from the batteries 15 and 22 are not critical, they must meet certain requirements imposed by the characteristics of the tubes. For instance, the sum of the voltages of batteries 15 and 22 should be less than the main-anode breakdown voltage of the triodes, and greater than the sustaining voltage of the triodes, both by suitable margins. In addition, the effective voltage of negative battery 22 must be slightly less than the minimum sustaining voltage of the shown diodes or triodes. It will be assumed hereinafter, for purposes of explanation, that batteries 15 and 22 are 130 volts and 50 volts, respectively.

In general, with any one tube in the chain conducting, application of a pulse of approximately 70 volts amplitude over forward pulse wire 29 will result in the next tube in the forward direction in the chain becoming conducting, while the application of a similar pulse over the reverse pulse lead 30 will result in the adjacent tube in the reverse direction becoming conducting. Simultaneous pulses on both leads 29 and 30 could cause operation of one or the other of these tubes, but not both. These pulses are preferably exponential in shape, and should be of suitable duration and amplitude to meet the functional requirements of the circuit. The pulses may be derived from a variety of circuits, one of which will be described in further detail in connection with Figs. 2 and 3.

Presume now that tube 2, which has been depicted as a cold-cathode type, is conducting and has been conducting for a sufficient period so that capacitors 33 and 34 have had time to become fully charged. When the circuits are in this condition, the cathode of conducting tube 2 will be at a voltage of 55 to 65 volts positive relative to ground, while the cathodes of the remaining, non-conducting tubes will be at 50 volts negative relative to ground. Therefore, the anodes of diodes 35 and 36 will be at 50 volts positive and the anodes of the remaining diodes will be at 50 volts negative relative to ground.

Considering now forward pulsing, when a pulse is received over forward pulse input lead 29, the anode of diode 36 rises to 125–135 volts positive relative to ground, causing diode 36 to become conducting. Since the drop in a typical diode, when conducting, is in the range of 55–75 volts, from 50 to 80 volts positive appears across resistor 47. Since the cathode of tube 3 is at 50 volts negative relative to ground, a net voltage of 100 to 130 volts is thus applied between starter anode 12 and cathode 11 of tube 3, and tube 3 thereby becomes conducting. The pulses applied to the diodes 28 and 42, and other diodes (not shown) having their anodes connected to forward pulse lead 29, only carried their anodes from 50 volts negative to 25 volts positive relative to ground and, therefore, no other diode is rendered conductive. Since such diodes typically have anode breakdown voltages in the range of 65 to 90 volts, it is apparent that there is no need for close margins in the critical voltages of the tube or in the supply voltages.

In order that the firing of a tube in the chain may render previously conducting tubes non-conducting, an impedance is placed in the common anode wire 13, and is herein depicted as a resistor 14, although other forms of impedance may be used. When tube 3 becomes conductive, the initial current flow therethrough is limited only by impedance 14 and thus the voltage on the common anode wire 13 is lowered to approximately 20 volts positive relative to ground. Since cathode 8 of tube 2 is held at 55–65 volts positive relative to ground until capacitor 20 can discharge through resistor 17, tube 2 will become non-conducting.

After tube 3 has become conductive, capacitor 21 will charge through resistor 18, and, when steady conditions are reached, voltages will be distributed as described before except that tube 3 will be conducting instead of tube 2.

It will be noted that with properly selected pulse durations, the time constant of the resistor-capacitor networks 23—25, 24—26, 31—33, 32—34, 37—39 and 38—40 is such that only one tube will become conducting on one pulse.

In reverse pulsing, or causing the next preceding tube in a chain to become conductive, the above considerations apply. With tube 2 conducting and with the resulting "priming" potential across associated diodes 35 and 36, receipt of a pulse over reverse pulse input lead 30 will render diode 35 conductive, thus developing an output voltage across resistor 45 and rendering tube 1 conductive. Tube 2 will then be rendered non-conductive as previously discussed.

It may, then, be seen that receipt of impulses on the forward pulse lead 29 will cause the tubes in the chain to become successively conductive in a forward or right-hand direction, while receipt of pulses on the reverse pulse lead 30 will result in the tubes in the chain becoming successively conductive in a reverse or left-hand direction.

It is to be understood that the voltage-responsive switching means, illustrated herein as gas diodes, are not essential to the functioning of the circuit since by a proper selection of circuit parameters the chain would operate bidirectionally without the diodes being present. However, in the absence of such switching means, the operation of the circuit is marginal, i. e., the biasing voltage of the tube in the preceding or succeeding stage and the voltage of the pulse must each be less than the breakdown voltage of the tube to be fired, while the combination of these voltages must exceed the breakdown voltage so as to render the tube conductive. Adjustment for such marginal operation is difficult and a possibility of circuit malfunctioning is present. The difficulty in marginal operation arises from supply voltage variations and from the problem of pulse amplitude control. As has been stated, the pulses are preferably exponential in shape, rising suddenly to full value and dropping exponentially. In a marginally operated circuit, in order that the pulses may be of sufficient amplitude and duration, the leading spike may necessarily be of such amplitude that the tubes will be rendered conductive from the pulse alone. The presence of a voltage-responsive switching means, such as gas diodes, renders the operate margins so wide that no rigid voltage-regulation requirements are imposed. It has been found, in the preferred embodiment, that at a pulsing speed of 20 pulses per second, and a pulse width at 35 volts of 2 to 3 milliseconds is satisfactory, although other pulse amplitudes and durations may be utilized.

Referring now to Figs. 2 and 3, a circuit is shown for a remotely controlled register for recording sales of space in passenger aircraft. It is well known that a major problem in passenger procurement is the expense and difficulty of securing adequate control of sales of space in aircraft. Unless all sales are handled through a central bureau, multiple sales of the same space

may be made. But if such a central bureau is used, delays in making reservations and sales are unavoidable and in many cases teletype messages must be exchanged between sales desk and central bureau before space can be sold. Although the present invention relates primarily to the registering equipment in the central bureau, it is proposed that in a nationwide leased-wire private branch exchange, two numbers be assigned to each flight during the period in which reservations or sales may be made. A ticket seller, upon receiving a request for space or the cancellation of space in a particular flight, will dial the proper number into a telephone set connected to a step-by-step network or other switching system. These assignment numbers are terminated in special connectors which differ from standard connectors primarily in that no ringing is provided, and if the called terminal is idle, the circuits are extended through to the circuits of Figs. 2 and 3. If the called terminal is busy, busy signal is returned. It will be observed that two appearances are provided, designated "add" or "cancel." The same appearance on the special connector contains the sleeve lead common to both, but the tip and ring leads are at first terminated in an additional digit-responsive switch which enables one or the other appearance to be cut through after a single steering digit is dialed in. These circuits, embodying no novelty over the step-by-step circuits well known in the prior art, have been omitted, as their makeup will be obvious to any one skilled in step-by-step switching systems.

Let it now be assumed that the circuit of Fig. 2 has been reached over the "add" input. Relay 116 will operate from the closure at the calling station, and will in turn operate slow-release relay 118, which grounds the sleeve lead S. Relay 116 will release once for each dial pulse, but relay 118 will remain operated through these momentary interruptions. When relay 118 is operated and relay 116 is released, a path is established from +130-volt battery 122, back contact of relay 116, front contact of relay 118, resistor 123, and ground. Thus a potential is placed upon the starter anode of tube 120. The anode of tube 120 is connected to battery 124 through a parallel connected resistance-capacitance network, while the cathode is connected through resistor 125 to negative 50-volt battery 126. The starter gap breaks down and main anode transfer takes place rendering tube 120 conductive. Due to the presence of capacitor 127 in the anode circuit, current is initially limited only by the cathode resistor 125 and a pulse of about 100 volts peak amplitude appears across resistor 125. As capacitor 127 in the anode circuit charges, the current flow is reduced and the drop in cathode resistor 125 falls exponentially to a low value. Tube 120 is preferably of the argon-filled type. Since resistor 128 in parallel with the anode capacitor 127 is high in value, the resultant current when capacitor 127 is charged is very small. Under these conditions, main anode conduction is unstable and the discharge will cease and tube 120 deionize as soon as voltage is removed from the starter anode. Hence, tube 120 sends out a pulse over lead 129 through the back contact of relay 130 to lead 132 which is the forward pulse lead for the upper counting chain of ten tubes. The number registered in the counting chain is thus increased by one for each interruption of the dial at the ticket seller's telephone.

When a register is to be set up to take reservations, zero units tube 101 and zero tens tube 111 are operated through the momentary closure of switch 133 which connects positive battery 134 (Fig. 3) through common anode wire 135, through resistor 136 to starter anode 137 of zero units tube 101 and through resistor 138 to starter anode 139 of zero tens tube 111.

The units counting chain comprising tubes 101 to 110 is a ten-tube closed ring identical with that shown in part in Fig. 1, and consequently, the discussion of the internal operation will not be repeated. Upon the receipt of the ninth "add" pulse over the forward pulse input lead 132, and the consequent rendering of the nine units tube 110 conducting, the circuit must be prepared so that upon receipt of the next "add" pulse, zero units tube 101 will again be fired and also so that a ten may be carried into the tens register comprising tubes 111 to 115. These functions are accomplished by means of gas diodes 140 and 141 (Fig. 3). The anodes of these diodes are connected through resistors 142 and 143, respectively, to cathode 144 of tube 110 so that when tube 110 is conducting they receive a priming potential. The next "add" pulse over forward pulse lead 132 renders diode 140 conductive and current is conducted over lead 145 through resistor 146 to ground. The potential drop across the resistor 146 applied to starter anode 137 of zero units tube 101 through resistor 147 fires tube 101, and tube 110 is extinguished as hereinbefore described. Thus the units registration is converted to zero. The tens register is shown with five stages and comprises a circuit which operates in the same fashion as that described in Fig. 1. With the nine units tube 110 conducting and diode 141 thereby primed, receipt of an "add' pulse will render diode 141 conductive, passing current through resistor 148 to ground, thereby applying a potential through resistor 149 to starter anode 150 of pulse repeater 151. The firing of pulse repeater 151 will pass a pulse over the "add" or forward pulse input lead 152 of the tens register and tube 112 will be fired. Thus with the nine units tube conducting, receipt of an "add" pulse will both fire the zero units tube 101 and "carry" into the tens register.

If, however, reservations are to be canceled, the ticket seller or cancellation clerk will dial the code for the particular flight, and on finding the equipment idle so that access is obtained from the step-by-step switch train, will dial the "cancel" code with the additional digit-responsive switch and will be connected to relay 117 which will then operate. Relay 117 in operating closes a circuit through its front contact to operate slow release relay 119, and sets up a pulsing path to tube 121 from battery 122, back contact of relay 117, front contact of relay 119 and resistor 153 to ground. Receipt of a pulse, now indicating a cancellation, will render tube 121 conducting through the application of a potential to starter anode 154 through resistor 155. The output circuit of tube 121 is identical with the previously described output circuit of tube 120 except that tube 121 pulses out over lead 156 through the back contacts of relay 157, over lead 158 to reverse pulse input lead 159 in the units register. By dialing in the number of spaces released or canceled, the units register is stepped in the opposite direction as explained in reference to Fig. 1

With the zero units tube conducting, receipt of a "canel" must both step the units register from zero to nine and perform negative "carry," that is, subtract ten in tens register. These functions

are accomplished by diodes 160 and 161 the anodes of both which are connected to cathode 162 of tube 101 through resistors 163 and 164, respectively, so that both diodes are primed. A pulse on the units register reverse pulse lead 159 will render diode 160 conducting and current will be passed through resistor 165 to ground and a potential will be impressed over lead 166, through resistor 167, and on starter anode 168 of nine units tube 110. Simultaneously, receipt of the "cancel" pulse over wire 159 will render diode 161 conducting, current will pass over lead 169 through resistor 170 to ground, thus placing a potential on starter anode 171 of pulse repeater 172. Tube 172, in operating, will pass a pulse over the tens register reverse pulse lead 173 thus subtracting ten in the tens register. It will be observed that the tens register is an open chain instead of a closed ring.

In the event that tube zero in both the units and tens register is operated, provision may be made to prevent effective "cancel" pulses from entering the registers. In order that this may be accomplished, tube 174, having an alternating current supply, is arranged to operate when tubes 101 and 111 are both operated. Equal shimming resistors 175 and 176 are connected between the cathodes of tubes 101 and 111, respectively, and the starter anode 177 of tube 174. When tubes 101 and 111 are both operated, tube 174 will be rendered conductive and relay 157 will be operated to open the "cancel" pulse lead 156 at the back contact of relay 157. At such time as either tube 101 or 111 is extinguished, the potential at the starter anode 177 of tube 174 will drop and tube 174 will be extinguished when anode 178 thereof becomes negative.

Similar provision may be made to disable the "add" circuit and to provide a "no seat" tone when all seats are reserved. Assuming now that the aircraft has forty-four saleable seats for passengers. When forty-four sales have been registered, tube 105 in the units ring and 115 in the tens chain are operated, and the joint operation of these tubes via leads 184 and 185 and resistances 179 and 180 will operate tube 181. This tube has an alternating current anode supply so as to be self-releasing if tube 105 or 115 is rendered non-conductive by a "cancel" or backward stepping operation. Tube 181 operates relay 130 which opens the circuit from tube 120 via conductor 129 to the "add" pulse lead 132, preventing further stepping, and also applies a distinctive "no seat" tone from a source not shown through transformer 182 to the "add" input, advising the ticket seller that no space is available. It is apparent that leads 184 and 185 may be selectively associated with any two tubes, that the tens register may be extended, and that a hundreds register may be added if necessary.

Many other features may be added to this basic circuit. For example voice frequency signaling channels can be provided to set up teletype records of each sale using some identifying mark or code and recording name, address, telephone number of purchaser, and the serial number read off from the register chain by checking tubes operated on a cathode voltage basis. Many other features controllable from this basic circuit will be apparent to one skilled in the art.

While these circuits have been described on the basis of cold cathode tubes, it is obvious that by suitable readjustments of voltages and bias supplies, negative or positive grid-hit cathode thyratrons could be used.

The drawings and descriptions thereof are but illustrative of one embodiment of the invention and are not to be interpreted in a limiting sense.

What is claimed is:

1. An impulse-counting circuit comprising a plurality of electronic devices, each having an anode, a cathode and a control element, two pulse-input leads, and circuit means connecting the cathode of each of said devices to the control element of the next adjacent ones of said devices, said circuit means including voltage-responsive switching means responsive to pulses on one of said leads to render said devices successively conducting in one direction and responsive to pulses on the other of said leads to render said devices successively conducting in the other direction.

2. An impulse-counting circuit comprising a plurality of electronic devices, each having an anode, a cathode and a control element, two pulse-input leads, and circuit means connecting the cathode of each of said devices to the control element of the next adjacent ones of said devices, said circuit means including voltage-responsive switching means responsive to pulses on one of said leads to render said devices successively conducting in one direction and responsive to pulses on the other of said leads to render said devices successively conducting in the other direction, said means comprising gas-filled diodes.

3. An impulse-counting chain comprising a plurality of gaseous-discharge tubes each having an anode, a cathode, and a control element, two pulse-input leads, circuit means connecting the cathode of each of said tubes to the control element of the next succeeding one of said tubes and to one of said pulse-input leads, and circuit means connecting the cathode of each of said tubes to the control element of the next preceding one of said tubes and to the other of said pulse-input leads.

4. An impulse-counting chain comprising a plurality of gaseous discharge tubes each having an anode, a cathode, and a control element, two pulse-input leads, circuit means connecting the cathode of each of said tubes to the control element of the next succeeding one of said tubes and to one of said pulse-input leads, and circuit means connecting the cathode of each of said tubes to the control element of the next preceding one of said tubes and to the other of said pulse-input leads, each of said circuit means including voltage-responsive switching means.

5. An impulse-counting chain comprising a plurality of gaseous-discharge tubes each having an anode, a cathode, and a control element, two pulse-input leads, circuit means connecting the cathode of each of said tubes and to one of said pulse-input leads, and circuit means connecting the cathode of each of said tubes to the control element of the next preceding one of said tubes and to the other of said pulse-input leads, each of said circuit means including voltage-responsive switching means comprising a gas diode.

6. An impulse-counting chain comprising a plurality of gaseous-discharge tubes each having an anode, a cathode, and a discharge-control element, a common source of anode potential for said tubes and an extinguishing impedance in series with said source, a source of cathode potential for said tubes, a resistance-capacitance network in series with each of said cathodes and said source of cathode potential, a pulse generator, two pulse-input leads, circuit means connecting the cathode of each of said tubes to the con-

trol element of the next succeeding one of said tubes and to one of said pulse-input leads, circuit means connecting the cathode of each of said tubes to the control element of the next preceding one of said tubes and to the other of said pulse-input leads, each of said circuit means including a resistor and a gas diode.

7. Two impulse-counting chains each comprising a plurality of electronic devices each having an anode, a cathode, and a control element, two pulse-input leads, and circuit means connecting the cathode of each of said devices to the control element of the next succeeding one of said devices, said circuit means including voltage-responsive switching means responsive to pulses on one of said leads to render said devices successively conducting in one direction and responsive to pulses on the other of said leads to render said devices successively conducting in the other direction, and voltage-responsive switching means interconnecting said two counting chains.

8. In combination, a first and a second impulse-counting chain each comprising a plurality of electronic devices each having an anode, a cathode and a control element, two pulse-input leads, circuit means connecting the cathode of each of said devices to the control element of the next adjacent ones of said devices, said circuit means including voltage-responsive switching means responsive to pulses on one of said leads to render said devices successively conducting in one direction and responsive to pulses on the other of said leads to render said devices successively conducting in the other direction; and voltage-responsive switching means connecting said first impulse-counting chain to each of said pulse-input leads of said second impulse-counting chain.

9. In combination, a first and a second impulse-counting chain each comprising a plurality of gaseous-discharge tubes each having an anode, a cathode, and a control element, two pulse-input leads, circuit means connecting the cathode of each of said tubes to the control element of the next succeeding one of said tubes and to one of said pulse-input leads, circuit means connecting the cathode of each of said tubes to the control element of the next preceding one of said tubes and to the other of said pulse-input leads, each of said circuit means including voltage-responsive switching means, and voltage-responsive switching means connecting the cathode of the initial tube in said first chain to one of said pulse-input leads in said second chain and voltage-responsive switching means connecting the final tube in said first chain to the other of said pulse-input leads in said second chain.

10. In a bidirectional pulse register, two pulse-input circuits, a units register bidirectional counting ring having two pulse-input leads connected to said pulse-input circuits, a tens register bidirectional counting chain having two pulse-input leads, voltage-responsive switching means connecting the initial element of said units register to one of said pulse-input leads in said tens register, and voltage-responsive switching means connecting the final element of said units register to the other of said pulse-input leads in said tens register.

11. A bidirectional impulse-counting circuit comprising a plurality of stages interconnected by voltage-responsive switching means, two pulse-input leads associated with said switching means, and means associated with one of said stages disabling one of said pulse-input leads when said one stage is operated.

12. A bidirectional impulse-counting circuit comprising a plurality of stages interconnected by voltage-responsive switching means, two pulse-input leads associated with said switching means, means associated with the initial one of said stages disabling one of said pulse-input leads when said initial stage is operated, and means associated with another of said stages disabling the other of said pulse-input leads when said other stage is operated.

13. In a bidirectional pulse register, two pulse-input circuits, a units register bidirectional counting ring having a plurality of stages and two pulse-input leads connected to said pulse-input circuits, a tens register bidirectional counting chain having a plurality of stages and two pulse-input leads, voltage-responsive switching means connecting the initial element of said units register to one of said pulse-input leads in said tens register, a voltage-responsive switching means connecting the final element of said units register to the other of said pulse-input leads in said tens register, and means associated with one of the stages in each of said registers disabling one of said pulse-input circuits when said associated stages are operating.

14. In a bidirectional pulse register, two pulse-input circuits, a units register bidirectional counting ring having a plurality of stages and two pulse-input leads connected to said pulse-input circuits, a tens register bidirectional counting chain having a plurality of stages and two pulse-input leads, voltage-responsive switching means connecting the initial element of said units register to one of said pulse-input leads in said tens register, voltage-responsive switching means connecting the final element of said units register to the other of said pulse-input leads in said tens register, means associated with the initial one of said stages in each of said registers disabling one of said pulse-input circuits when said initial stages are both operating, and means associated with another of said stages in each of said registers disabling the other if said pulse-input circuits when said other stages are both operating.

15. An impulse-counting chain comprising a plurality of electron-discharge devices each having an anode, a cathode and a control element, switching means controlled by said devices connecting the cathode of each of said devices to the control element of the next adjacent one of said devices, a pulse source, and a control connection including said switching means connecting said pulse source to the control elements of all of said devices.

16. An impulse-counting chain comprising a plurality of electron-discharge devices each having an anode, a cathode and a control element, switching means controlled by said devices responsive to a critical voltage for connecting the cathode of each of said devices to the control element of the next adjacent one of said devices, a pulse source, and a control connection including said switching means connecting said pulse source to the control elements of all of said devices.

17. An impulse-counting chain comprising a plurality of electron-discharge devices each having an anode, a cathode and a control element, switching means comprising a gas-filled diode connecting the cathode of each of said devices to the control element of the next adjacent one of said devices, a pulse source, and a connection including said switching means connecting said pulse source to the control elements of said devices.

18. In an impulse-counting chain, a first and a second electron discharge device each having an anode, a cathode and a control element, a connection comprising a gas-filled diode connecting the cathode of said first device to the control element of said second device, a pulse source, and a connection comprising said gas-filled diode connecting said pulse source to the control element of said second device.

WILLIAM H. T. HOLDEN.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,308,778	Prince	Jan. 19, 1943
2,373,134	Massonneau	Apr. 10, 1945

Number	Name	Date
2,402,372	Compton	June 18, 1946
2,404,106	Snyder	July 16, 1946
2,405,096	Mumma	July 30, 1946
2,408,086	Meacham	Sept. 24, 1946
2,421,005	Bray	May 27, 1947
2,428,990	Rajchman	Oct. 14, 1947
2,442,428	Mumma	June 1, 1948
2,462,275	Morton	Feb. 22, 1949
2,516,146	Prugh	June 16, 1950

OTHER REFERENCES

"Decade Counting Circuits," V. H. Regener; Review of Scientific Instruments, May 1946; volume 17, number 5, pages 185–189.

"Reversible Decade Counting Circuit," V. H. Regener; Review of Scientific Instruments, Oct. 1946; volume 17, number 10, pages 375–376.