PULSE-COUNTING SYSTEMS

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Fig. 1.

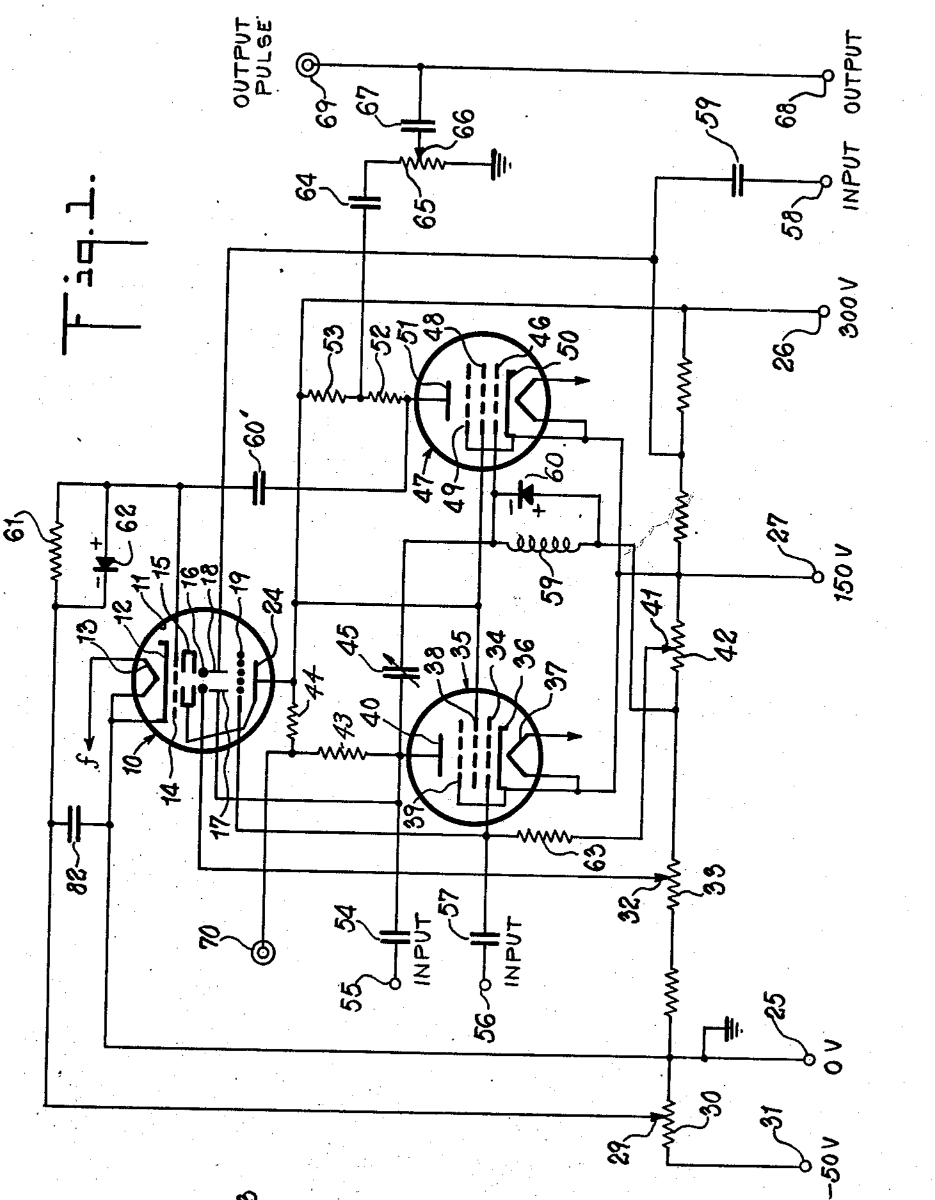
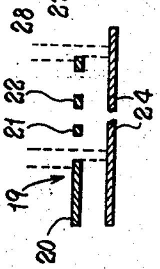


Fig. 1A



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PULSE-COUNTING SYSTEMS

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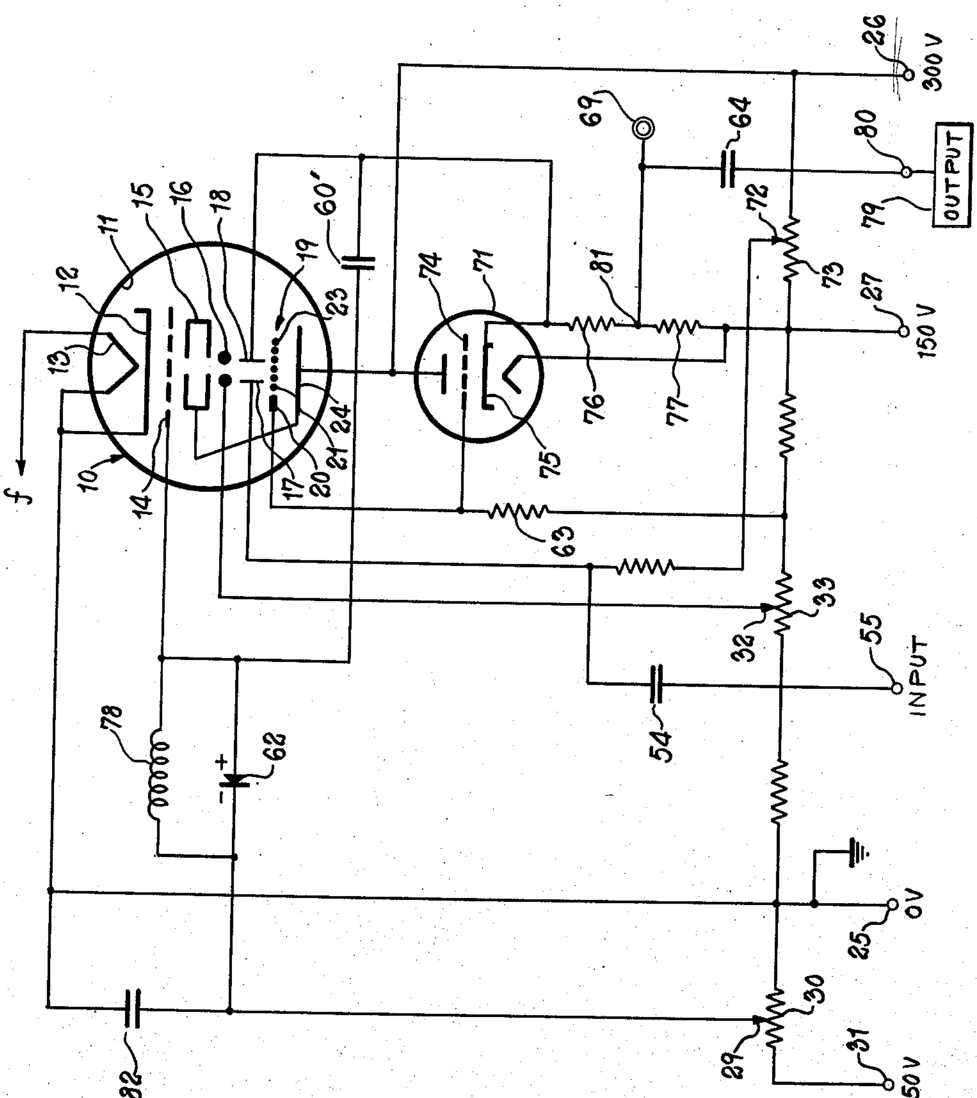

Fig. 2.

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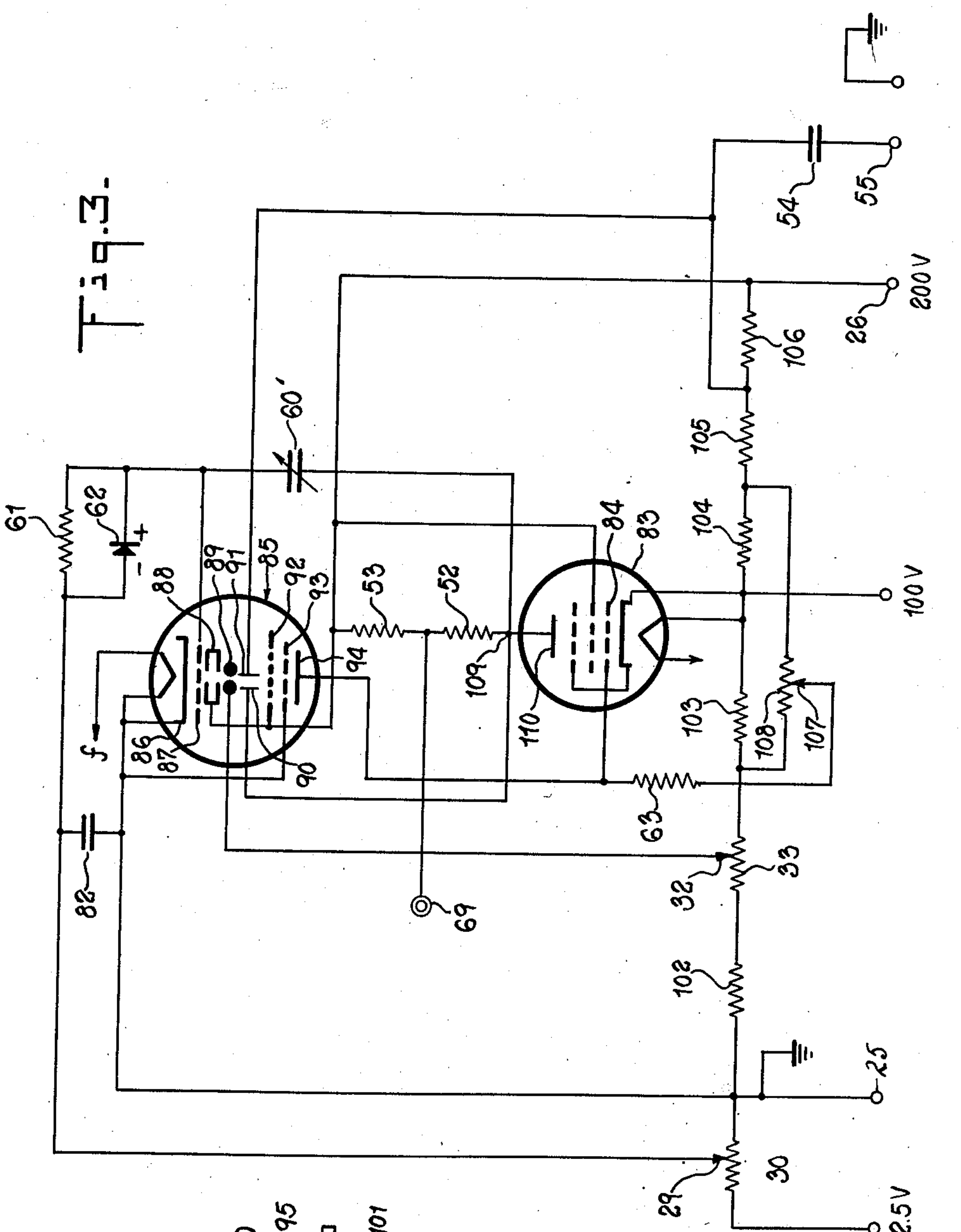
Fig.3.



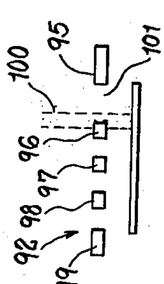


Fig.3A

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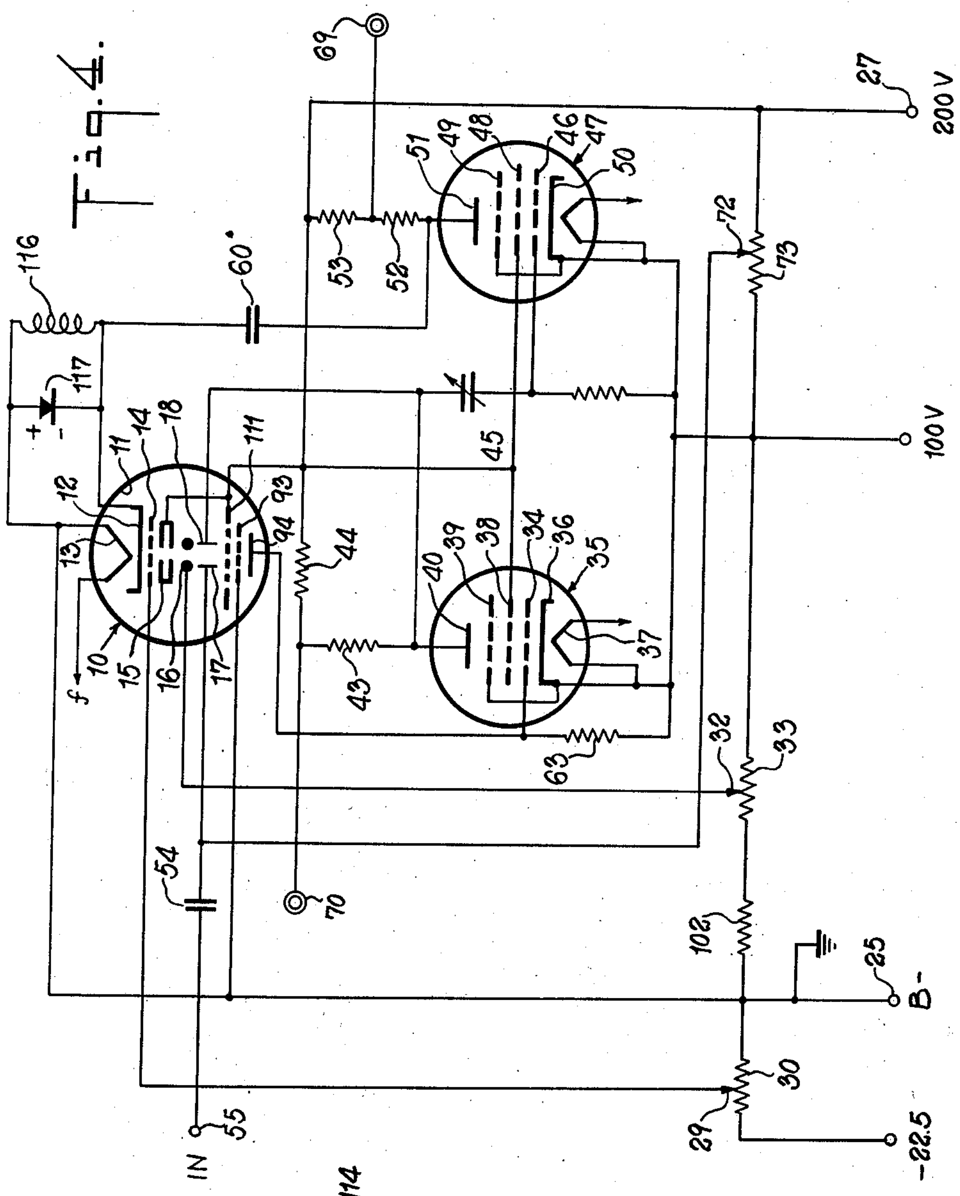

Fig. 4.

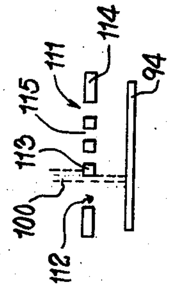

Fig. 4A

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PULSE-COUNTING SYSTEMS

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Application July 5, 1952, Serial No. 297,276

9 Claims. (Cl. 315—8.5)

This invention relates to pulse-counting systems and more especially to such systems using counters of the cathode-ray tube kind.

A principal object of the invention is to provide improved arrangements for computing or totalizing a series of received pulses whether received in regular time sequence or in random sequence.

Another object is to provide pulse-totalizing or computing tube arrangements which are capable of counting or totalizing pulses at a very high rate.

A feature of the invention relates to a pulse-counting or totalizing system employing a deflectable cathode-ray beam and a minimum number of associated controlling electron tubes.

Another feature relates to a novel organization, arrangement and relative location and interconnection of parts which cooperate to provide an improved and simplified pulse-counting system.

Other features and advantages not particularly enumerated, will be apparent after a consideration of the following detailed descriptions and the appended claims.

In the drawing,

Fig. 1 shows in schematic form one embodiment of the invention.

Fig. 1A is an enlarged diagrammatic view of part of the cathode-ray tube of Fig. 1.

Figs. 2, 3 and 4 are respective modified embodiments of the invention.

Fig. 3A is an enlarged diagrammatic view of certain of the electrodes of Fig. 3.

Fig. 4A is an enlarged diagrammatic view of certain of the electrodes of Fig. 4.

Referring to Fig. 1, the numeral **10** represents schematically any well-known form of cathode-ray tube, comprising the usual evacuated enclosing envelope **11**. An electron-emitting cathode **12**, with its heater element **13** is used for developing a beam of electrons. The intensity of that beam is controlled by the usual control grid **14**, and the electrons in the beam are accelerated and focussed, for example by the anodes **15** and **16**. A pair of beam deflector plates **17**, **18**, control the lateral deflection of the beam in the well-known manner. A beam holding grid **19** is interposed in the path of the focussed beam. This grid consists of a series of parallel spaced wires **20**, **21**, **22**, **23**, etc. While the drawing shows six such wires, it will be understood that a greater or less number may be employed depending upon the number of pulses to be totalized, all the wires being electrically connected to form a unitary grid structure.

In accordance with one feature of the invention, the first grid wire **20** is much wider than the remaining grid wires. Furthermore, the cathode-ray beam is focussed so that its cross-sectional width at the plane where it strikes the holding grid, is no greater than the distance between grid wires as shown schematically in Fig. 1A. In the embodiment of Fig. 1, the holding grid wires are designed to act as efficient emitters of secondary electrons when struck by the primary electrons in the beam. For this purpose, they may be made of any metal which is an efficient secondary emitter or they may be coated with secondary emission material as is well-known in the art. Mounted adjacent the holding grid **19** on the side of that grid remote from the cathode, is a metal plate or collector electrode **24** for collecting the secondary electrons released by the holding grid wires.

A source of direct current voltage, for example 300 volts, is connected across terminals **25**, **26**, and across which terminals a suitable voltage divider resistance string is connected. This divider may have the terminal **25** connected to a common ground return as indicated. The normal intensity of the cathode-ray beam **28** is adjusted by the slider **29** on the voltage divider resistor **30** which may be connected between ground and a negative terminal **31** of the direct current power supply, for example —50 volts. The focussing of the cathode-ray beam is controlled by a slider **32** coacting with the associated voltage divider resistor **33**, this slider being connected to the focussing electrode **16**.

The holding grid **19** is connected to the control grid **34** of a multi-grid electron tube **35**, which for example may be of the pentode type having the electron-emitting cathode **36** with its heater **37**; first control grid **34**; shield grid **38**, suppressor grid **39**; and the output plate or anode **40**. The potential of grid **34** will therefore be a function of the potential of the holding grid **19**. The potential of control grid **34** can also be adjusted by means of the slider **41** cooperating with divider resistor **42**. The plate **40** of tube **35** receives its direct current voltage by being connected through resistors **43**, **44**, to terminal **26**. In the well-known manner, the suppressor grid **39** is connected directly to the cathode **36**. The plate **40** of tube **35** is coupled through an adjustable condenser **45** to the first control grid **46** of another multi-grid tube **47** which may be similar to tube **35**. The shield grid **48** is connected directly to the shield grid **38**. The suppressor grid **49** is returned directly to the cathode **50**, and the plate or output anode **51** is connected to the 300 volt D. C. terminal **26** through the resistors **52**, **53**.

The deflector plate **17** is connected through a coupling condenser **54** to a signal input terminal **55** so that the polarity of the signal voltages, which may be negative pulses, on plate **17**, is the same as the phase of the negative signal pulses applied at terminal **55**. In the event that the input pulses are positive, a separate input terminal **56** is coupled through condenser **57** to the control grid **34**. By reason of the polarity inversion action of tube **35**, the polarity of the corresponding pulses at plate **40** becomes negative. An additional or main input circuit terminal **58** upon which positive signal pulses can be impressed, is coupled through condenser **59** directly to the deflector plate **18**.

The control grid **46** is returned to its cathode through the inductance coil **59** which is shunted by the rectifying diode **60** polarized as shown. The inductance **59** cooperates with the condenser **45** to provide a pulse decay control circuit for purposes to be described hereinbelow. The plate or anode **51** of tube **47** is coupled through condenser **60'** to the beam intensity control grid **14**, so that the intensity of that beam is a function of the potential of plate **51**. The control grid **14** is connected to the slider **29** through a suitable resistance **61** and parallel rectifying diode **62** polarized as indicated and a purpose of which will be described hereinbelow.

For purposes of explaining the operation of the system, it will be assumed that the pulses to be counted or totalized are positive pulses applied to terminal **58**. When no signal pulses are being received, the various potentials are adjusted so that the cathode-ray beam **28** strikes the right-hand edge of the first or wide grid wire **20** as indicated in Fig. 1A, wherein it is shown that one-half the beam width is intercepted by the wire **20** and the other half of the beam width proceeds unobstructed to the collector **24**. Under these conditions, the grid wire **20** emits sufficient secondary electrons to impart a predetermined positive potential to wire **20**. The circuit parameters are so designed that this potential is slightly more positive than the potential at the slider **41** so that the electron current flows from wire **20** through resistor **63**, thence to slider **41**. The slider **41** is set at such a point so as to bias the control grid **34** to near or below plate current cut-off. Since the anode **40** is connected directly to the deflector plate **17**, the potential at slider **41** would tend to move the cathode-ray beam **28** to the left-hand edge of grid wire **20**. However, the above-noted electron current flowing through resistor **63** will adjust itself, and therefore will adjust the voltage on control grid **34** to the desired value so that the voltage of anode **40** is at such a value as to hold the beam **28** on the right-hand edge of grid wire **20** as indicated in Fig. 1A At the same time, the bias on control grid **46** is below plate current cut-off for tube **47**. The above are the normal or zero pulse-count conditions of the circuit.

When the first positive pulse is applied at terminal **58**, and thence to deflector plate **18**, this will cause the cathode-ray beam to swing rapidly to the right so that it is intercepted by the #1 grid wire **21**. The beam **28** cannot move beyond the right-hand edge of wire **21** because of the automatic adjustment of the potential of plate **17** similar to that described above in connection with the automatic adjustment of the beam with respect to the right-hand edge of wire **20**. When the #1 positive pulse disappears, the beam will settle back to its partial intercept position at the right-hand edge of wire **21**, because under that condition the secondary emission from the wire **21** will make the grid sufficiently positive so as to correspondingly control the potential at grid **34**, and therefore the potential of anode **40** and plate **17**. Under this condition just sufficient current will flow to hold the beam **28** on the right-hand side of the #1 grid wire **21**. The receipt of subsequent positive pulses applied to terminal **58** and therefore to plate **18**, will step the beam over intervening grid wires depending upon the number of pulses which are applied. In each case at the cessation of the last pulse, the beam will find itself automatically stabilized at the right-hand edge of the corresponding grid wire where it is held. For example, if nine wires **23** plus a zero wire **20** are used, the system is arranged to count or totalize ten pulses, and at the end of the #9 pulse the beam **28** will find itself stabilized on the right-hand edge of the #9 wire **23**. The tenth pulse restores the beam to the zero level condition as is the usual practice for decade counters.

The invention, of course, is not limited to the totalization of ten pulses but may be used to totalize any other number, for example "n" pulses, in which event, of course, there are "$n-1$" grid wires **23**. Upon the receipt of the nth pulses, the beam will be deflected to the right so that it completely clears the last or nth grid wire **23**. Thus, the beam will not strike the holding grid at all for a short time. During this short interval, the positive voltage previously set up on the holding grid **19** will decrease quite rapidly because of its relatively high magnitude. This decay of the holding grid voltage will appear at the anode **40** as a positive voltage swing since it represents a decrease in the positive potential at grid **34**. In other words, the tube **35** acts as an amplifier for this decaying voltage. The positive swing at plate **40** representing this amplified decay voltage is also applied through condenser **45** to the control grid **46** where it is further amplified in tube **47**. However, at plate **51**, the voltage swing is reversed in polarity with respect to the voltage swing at anode **40** so that a corresponding negative voltage swing is applied through condenser **60'** to control grid **14**.

Thus during this decay action, the intensity of the beam **28** is likewise reduced rapidly because of the two stages of amplification provided by the tubes **35** and **47**. Consequently, when the beam starts to reverse its movement, and when it strikes the last or nth grid wire **23**, instead of being held on that wire as it would ordinarily be held during the totalizing action as described above, it is prevented from being held so that it continues its reverse motion towards the left. In other words, as the beam moves towards the left, it first strikes the wire **23** but because of the reduction in beam intensity at this stage, the said wire is incapable of holding the beam and a second increment of decay will take place. This second increment in the decay voltage will also appear to the anode **51** as an additional voltage swing so that the decay action becomes cumulative. This additional decaying increment results in further decrease in the intensity of the beam **28**, so that when the beam moves to the left and strikes the next grid wire **22**, a third decay increment will appear. This decaying condition, or what is the same thing, this increase in the negative swing at anode **51** will build up as the beam successively passes each grid wire in moving to the left so that when the beam finally reaches the zero wire **20**, the negative voltage at anode **51** is sufficient to completely blank off the beam. The primary elements which determine the flyback pulse are inductance **59** and capacitance **45**. This combination would tend to oscillate as a damped oscillator if the shunting crystal device **60** were not provided. With the proper proportioning of the elements **45** and **59**, the negative decay pulse applied to grid **14**, which is usually large enough to cut the beam off early in the decaying process, is made to last until the decaying process is completed. After this interval the grid **14** reassumes its normal potential whereby the beam is again turned on awaiting the receipt of the next series of pulses to be totalized.

The above-noted decay voltage is developed across the inductance **59** and its duration is controlled by the value of that inductance and by the condenser **45** and the input capacitance of tube **47**. The crystal diode **60** is used to prevent a negative swing of the oscillating voltage in the combination **59, 45**. Thus, the fly-back voltage is amplified in tube **47**. The crystal diode **62** is provided so as to limit any positive swing in the potential that may reach control grid **14**.

From the foregoing, it will be seen that the beam can be stepped to the right and held in registry with any grid wire in accordance with the number of received pulses, and while the beam is moving to the right, each grid wire acts as a holding element. On the other hand, when the final pulse has been received, the beam automatically starts to move to the left towards the zero grid wire and during this motion each grid wire is prevented from acting as a holding element, which would ordinarily impede the beam returning to its zero position.

Fig. 2 shows another embodiment similar to that of Fig. 1 except that only one auxiliary tube is required which may be a simple triode **71**. The elements and connections in Fig. 2 which function the same as the corresponding elements of Fig. 1, bear the same designation numerals. The normal bias on the beam intensity control grid **14** is provided by slider **29**; while the focussing of the beam is controlled by slider **32**. By adjusting an additional slider **72** on resistor **73**, the bias on deflector plate **17** can be adjusted so that when no negative pulses are applied to input terminal **55**, the cathode-ray beam is partially intercepted by the right-hand edge of the zero grid wire **20** (see Fig. 1A). Normally, that is, if the grid wire **20** were not a secondary emitter the adjustment of slider **72** would cause the beam to be completely intercepted by grid wire **20**. However, because of the secondary emission from wire **20**, when struck by the beam, the flow of secondary electron current through resistor **63** decreases the negative potential on control grid **74** resulting in an increase in plate current through tube **71** and therefore resulting in a positive potential at cathode 75. Cathode 75 is connected directly to deflector plate 18, which causes the beam to move to the right-hand edge of grid wire 20. The balance between the voltage on slider 72 and the voltage at plate 18 will be adjusted automatically by the current through resistor 63 to such a value that the beam is held at the right-hand edge of wire 20 as described above in connection with Fig. 1A. This is the zero pulse count or normal position of the beam. The first negative pulse applied to deflector 17 through condenser 54 will shift the beam towards the right over the #1 grid wire 21 of the holding grid 19. As this first pulse decreases in magnitude the current through resistor 63 will increase because of the flow of secondary electrons from grid wire 21 to collector 24. Similar to the action in the zero count position the current through resistor 63, by increasing, will change the voltage on grid 74 and therefore on cathode 75 and on deflector 18. This current will automatically adjust itself to a value such that the beam is held on the right-hand edge of wire 21, so as to be only partially intercepted thereby. This is a stable condition and the beam will remain partially intercepted at the right-hand edge of wire 21 until receipt of the next pulse. Succeeding negative pulses applied to deflector 17 will pulse the beam successively over each of the remaining grid wires. As each pulse decays, the current through resistor 63 will increase sufficiently to hold the beam in the new stable position after each pulse.

Finally the beam will rest on the last grid wire 23 so that when it is pulsed to the right by the next pulse it will encounter no grid wire and will move automatically back towards the left as this final pulse disappears. During the time that the beam is off the last grid wire 23, the voltage on grid 74 will decay because there is no current from the holding grid 19. This decay in voltage is coupled directly to deflector 18 from the cathode 75 and through condenser 60′ to the beam intensity control grid 14. Since this voltage decay is in a negative direction it will decrease the beam current. This decrease in the beam current will likewise decrease the ability of the beam to hold itself on the last grid wire 23 as the beam is moving back to normal. Since the beam current is no longer large enough to hold the beam on the wire 23, it will continue to move towards the next adjacent grid wire in the left-hand direction. This second increment of decay is also coupled to the control grid 14 and will further decrease the magnitude of the beam current. The beam will then move towards the next adjacent grid wire in the left-hand direction. This process continues until the beam is entirely cut-off. The beam will remain cut-off until the decay process is complete, at which time the voltage-drops across resistors 63, 76 and 77 are returned to zero or to a very low value. The duration of the negative voltage applied to grid 14 is controlled largely by the values of condenser 60′ and the inductance 78 and is normally adjusted so that it will disappear shortly after the decay of voltage on the grid 74 has disappeared. The beam will then come back on to normal intensity, and current will flow again through resistance 63 and the beam will return itself to its zero pulse condition where it is partially intercepted by the right-hand edge of grid wire 20. The system has now completed a cycle and is ready for the next input pulse.

In Fig. 2, the resistors 76, 77, form a voltage divider and a load in the cathode circuit of tube 71. The output measuring, indicating or recording device 79 may be connected to output terminal 80 and through condenser 64 to the point 81. A suitable output jack 69 may also be connected to point 81 to monitor the operation of the system. A crystal diode 62 is connected across inductance 78 between the cathode 12 and the grid 14 to provide a high impedance to negative pulses and a low impedance to positive pulses as in Fig. 1. The large negative pulse, described above as occurring during the decay of the voltage at cathode 75, is present at almost full magnitude on the grid 14; while the positive steps appearing at cathode 75 are greatly attenuated at grid 14 because of the short-circuiting effect of diode 62. A suitable by-pass condenser 82 is provided between the diode 62 and the cathode 13. Without this condenser the resistor 30 would form an undesired part of the load between the cathode and control grid of tube 11.

Fig. 3 is a modification of Fig. 2, likewise using a single control tube 83 whose control grid 84, instead of being controlled by secondary electron current from the cathode-ray tube is controlled by the primary electron current from the cathode-ray beam. The cathode-ray tube 85 has the electron gun cathode 86, beam intensity control grid 87, accelerating anode 88, beam focussing electrode 89, deflector plates 90, 91, beam holding grid 92, secondary electron suppressor grid 93, and output anode 94. The holding grid 92 as shown in enlarged section in Fig. 3A, comprises a zero pulse grid wire 95, #1 grid wire 96, #2 grid wire 97, #3 grid wire 98, etc., and a final grid wire 99. The spacings between the adjacent wires 96, 97, 98 and 99 are equal to each other. The cathode-ray beam 100 is focussed so that its cross section at the holding grid is slightly less than the spacing between the grid wires 96, 97, 98, 99. However, the spacing 101 between the zero grid wire 95 and the #1 grid wire 96 is very much greater than the beam cross-section and much greater than the spacings between the remaining wires. In this embodiment, the holding grid 92, suppressor grid 93, and anode 94, cooperate to provide the current output for holding the beam at its successive pulsed portions. The grid 92 permits the beam to pass to anode 94 or prevents its passing depending upon where the beam is with respect to the grid wires. The large aperture 101 is the zero pulse aperture. The suppressor 93 which is at cathode potential will prevent any secondary electrons released from anode 94 from reaching grid 92. The voltages on 92 and 94 are such that the undesirable flow would be from 94 to 92.

The voltage divider comprised of resistors 30, 33 and 102—106, connected to the direct current power supply terminals 25, 26, supplies the usual direct current bias voltage to the various tube electrodes. Slider 29 applies the desired normal beam intensity control bias to grid 87. Slider 32 adjusts the beam focus by being connected to focus electrode 89. Slider 107 and resistor 108 control the normal bias on grid 84 and therefore the normal potential at point 109 and at deflector plate 90. The voltage divider constituted of resistors 105, 106, furnishes a reference voltage for the deflectors 90, 91.

The various voltages are adjusted so that with very small beam current the beam strikes the grid 92 somewhere in the aperture 101. This beam current can be increased for the normal or zero pulse position by moving slider 29 to the right. The primary beam electrons will therefore strike the anode 94 and flow through the resistor 63. This primary beam current will make the voltage at grid 84 more negative and the voltage at point 109 more positive. This positive potential at point 109 will move the beam to the left-hand edge of the zero aperture 101 until it is partially intercepted by the #1 grid wire 96 (see Fig. 3A). This is the zero pulse stable position.

The first negative pulse applied to terminal 55 and thence through condenser 54 to deflector 91, will pulse the beam into the second grid aperture between wires 96, 97. While the beam is between these two wires an increased current flows through the resistor 63 and the beam is automatically moved to the left-hand edge of the second grid aperture until it is partially intercepted by wire 97. It is automatically held at this position until the next negative pulse, and a similar stepping and holding action occurs for each successive negative pulse.

After the beam has reached the last aperture, it is automatically returned to the zero aperture by the next negative pulse. The manner in which this return is effected is as follows. Upon receipt of this next pulse, the beam is moved from the left-hand edge of the last aperture onto grid wire 99, which is of greater width than the smaller grid wires 96, 97, 98, etc. Therefore, the beam is completely intercepted by this last wire and the current and voltage across resistor 63 will decay towards zero. This is a positive voltage change, which is amplified and inverted by tube 83. The resultant negative voltage change on the anode 110 of tube 83, will appear at deflector plate 90 and on the control grid 87. Because of this negative voltage the intensity of the current in beam 100 will be decreased causing the beam to move towards the right until it enters the aperture between wires 98 and 99 and it is partially intercepted by the wire 98. This gives a second increment of negative voltage to the grid 84, which in turn results in a further decrease in the intensity of beam 100. This action is cumulative as the beam moves towards the right and a large negative voltage is soon built up on the control grid 87 sufficient to reduce the beam current to zero or to a very low value. With no beam current the grid plate voltages will fall rapidly to the normal or zero pulse condition.

Since the voltage on slider 107 is more positive than the zero level value of the voltage of control grid 84, the voltage on that grid will tend to position the beam in the zero aperture 101. The above-noted fall in the grid and plate voltage is interrupted by the cathode ray beam, as it will come on again as the beam passes the left-hand edge of the zero aperture 101. The "off" time of the beam is determined by the values of condenser 60′ and resistance 61. With proper choice of these values the negative pulse pulse on grid 87 will last just long enough to cut off the beam during the entire decay of the voltages on grid 84 and plate 110. The slider contact 107 is adjusted so that with zero beam current, the beam would pass through the large aperture 101. The beam then comes back on and restores itself to the left-hand edge of aperture 101 (see Fig. 3A) by establishing a voltage across resistance 63. An output jack 69 can be connected between the resistors 52 and 53 to monitor the operation of the circuit.

Fig. 4 shows a modification of Fig. 1, wherein similar parts are designated by the same numerals. The main difference is that in the embodiment of Fig. 4, the holding of the cathode-ray beam in its pulsed positions is controlled by the primary electrons in the cathode-ray beam, whereas in the embodiment of Fig. 1 the beam is held in its pulsed position under control of secondary electrons from the holding grid 19.

In Fig. 4 the cathode-ray tube 10 is provided with a holding grid 111 which functions similar to the holding grid 92 of Fig. 3. This holding grid is associated with a suppressor grid 93 and an output anode 94. The input pulses to be counted are negative pulses applied to the deflector plate 17 through condenser 54, from input terminal 55. Resistances 30, 102, 33 and 73 connected across the direct current power supply terminals 25, 27, form a voltage divider to supply the required direct current voltages to the various tube electrodes. The bias on the cathode-ray tube control grid 14 is controlled by slider 29. The focussing of the beam is controlled by slider 32 and the centering of the beam is controlled by the slider 72.

At the zero pulse count the bias on control grid 34 of tube 35, is at or near zero volts and the plate voltage at plate 40 is very low. The bias on control grid 46 of tube 47 is also at or near zero. By means of the slider 72 the cathode-ray beam is held as shown in Fig. 4A at the right-hand edge of the zero aperture 112, so that the beam is partially intercepted by the #1 grid wire 113. This is the zero pulse count position of the beam. The centering control 72 is set so that with zero bias on grid 34, the beam will strike somewhere in the zero aperture 112. However, a slight electron flow through this aperture to the holding anode 94 will place a slightly negative voltage on the grid 34. This will make the anode

40 more positive and also will make more positive the deflector plate 18. This positive potential will move the beam to the right across the zero aperture 112 until it assumes the zero pulse position as shown in Fig. 4A. The primary beam current from the anode 94 flowing through resistor 63 will decrease to a value where the beam will become stabilized at its zero pulse position.

Negative input pulses to be counted and applied to terminal 55 will pulse the beam to the right and into succeeding apertures in the grid 111. The stabilized holding action for the beam at each grid wire is similar to that above described. In other words, the beam is first moved into the next aperture by the corresponding pulse to be counted and as this pulse disappears the current through resistor 63 will increase and hold the beam to the right-hand edge of the aperture. The next pulse will then move the beam into the succeeding aperture where it is again held by a still further increase in current through resistor 63.

After the beam has been moved into the last aperture the receipt of any succeeding pulses will cause it to be completely intercepted by the last grid wire 114, thus cutting off completely the flow of primary electron current to the anode 94. The primary electron current through resistor 63 will therefore cease. During the short interval when the current through resistor 63 has ceased, the voltage across 63 will decrease. This decrease in voltage is in a positive direction on the grid 34 and therefore in a negative direction on the anode 40 and in a positive direction on the anode 51. It will be observed that the anode 40 is coupled to the control grid 46 through the condenser 45 as described above in connection with Fig. 1. Since condenser 60′ connects the anode 51 to the cathode 12, the above-noted positive swing at anode 51 will decrease the current in the cathode-ray beam to such an extent that the said beam is no longer able to pass enough current through resistor 63 to hold at the last aperture.

As the beam returns towards the left from the last aperture and towards the next preceding aperture 115, still greater positive voltage is applied to the cathode 12. This will further decrease the current in the cathode-ray beam and the beam will no longer be able to hold at the aperture 115. From this third decrease of voltage across resistor 63, there will be a third drop in the beam current. This decaying process will continue and will be cumulative until the beam current becomes zero or nearly zero. It will remain at the zero or near-zero value until the positive half cycle across inductance 116 has disappeared. The inductance 116 and the shunt crystal diode 117 perform functions similar to the elements 59 and 60 of Fig. 1. This positive half cycle is adjusted so that it is longer than the time required for the voltage across resistor 63 to drop to zero. Thereafter the cathode-ray beam will increase to its normal intensity and will automatically readjust itself to its stabilized zero pulse count position shown in Fig. 4A. The device has thus gone through a complete counting cycle of "n" pulses, being understood of course that there are "n" apertures in the grid 111.

The resistors 43 and 44 form a voltage divider to which the output jack 70 is connected for monitoring the voltage on anode 40 and also to form a plate load for tube 35. Similarly resistances 52 and 53 form a voltage divider to which the output jack 69 for monitoring the voltage at anode 51 and for forming a plate load for tube 47. The length of time that the beam current is cut-off is determined by the values of condenser 60′ and inductance 116. The crystal diode 117 is polarized so that it clamps out the negative swing of voltage across inductance 116.

While certain embodiments have been described herein, it will be understood that various changes and modifications may be made therein without departing from the spirit and scope of the invention.

What is claimed is:

1. A pulse-counting system comprising in combination, a cathode-ray tube having means to develop a cathode-ray beam, means to control the intensity of the beam, means to deflect the beam, a holding grid having a series of grid elements for holding the beam in successive deflected positions away from a normal position and under control of received pulses to be counted, and means effective when the beam has been deflected beyond the last grid element to restore the beam to a normal position while simultaneously nullifying the holding action of said holding grid, the last-mentioned means including circuit arrangements for progressively and increasingly reducing the beam intensity as it moves backwardly across said grid elements toward said normal position.

2. A pulse-counting system comprising in combination, a cathode-ray tube having means to develop a focussed cathode-ray beam, means to control the intensity of the beam, means to step the beam away from a normal position to any one of a series of successive selected stopping positions in accordance with a corresponding number of pulses to be counted, a holding grid having a series of grid elements one for each of said stopping positions to hold the beam at such position even after the cessation of pulses, and means effective when the beam has been deflected beyond the last grid element for automatically restoring it to a normal position while simultaneously nullifying the holding action of said grid, the last-mentioned means including circuit arrangements for progressively and increasingly reducing the beam intensity as it moves backwardly across said grid elements to said normal position.

3. A pulse-counting system according to claim 2, in which means are provided for automatically restoring the beam to a normal intensity a predetermined interval after it has reached said normal position.

4. A pulse-counting system comprising in combination, a cathode-ray tube having means to develop a focussed cathode-ray beam, deflecting means to step the beam to any one of a series of successive predetermined stopping positions in accordance with a corresponding number of pulses to be counted, a holding grid having a series of grid elements one for each of said stopping positions, each of said elements being a secondary electron emitter, a collector electrode for said secondary electrons, a grid-controlled electron tube having its control grid connected to said holding grid and having an output electrode coupled to said intensity control means, said output electrode also being connected to the beam-deflecting means, and means effective when the beam has been deflected beyond the last grid element for gradually and increasingly varying the bias on said control grid to automatically restore the beam to a normal undeflected position while simultaneously nullifying the holding action of said grid during said restoration.

5. A pulse-counting system comprising in combination, a cathode-ray tube having means to develop a focussed cathode-ray beam, a pair of beam deflector elements to step the beam away from a normal position to any one of a series of successive selected stopping positions in accordance with a corresponding number of pulses to be counted, a beam-holding grid having a series of grid elements one for each of said stopping positions, a grid-controlled electron tube, a source of direct current for biassing said control grid, a connection from said control grid to said holding grid, means to adjust said biassing potential to produce a resultant bias at said control grid and thereby to apply predetermined bias to one of said deflector plates for holding the beam in partial intercepting relation with the first of said series of grid elements to constitute said normal position, means to apply the first pulse to be counted to one of said deflector elements to step the beam to the second grid element in said series and to hold the beam in partial intercepting relation with said second grid element, and means effective when the beam has been stepped beyond the last grid element for automatically changing the relative bias on said deflector plate to restore the beam to its normal intercepting position with said first grid element, the last-mentioned means including circuit arrangements for progressively and increasingly reducing the beam intensity as the beam is being so restored to normal.

6. A pulse-counting system according to claim 1, in which said holding grid comprises a series of spaced grid wires which are efficient emitters of secondary electrons when struck by said beam, circuit arrangements for normally biassing the beam in the absence of received pulses to a position where it partially intercepts the first grid wire, the last-mentioned circuit arrangements including a grid-controlled tube whose control grid is biassed under control of the holding grid potential, and whose output is coupled to the beam intensity control means.

7. A pulse-counting system comprising a cathode-ray tube, having means to develop a focussed electron beam, beam-deflecting means upon which pulses to be counted are impressed for correspondingly stepping the beam in a forward or pulse-counting direction, a holding grid having a series of spaced grid wires for holding the beam at any grid wire determined by the number of pulses impressed on said beam stepping means, and means effective when the beam has been stepped beyond the last grid element for changing the potential applied to said deflector means and to start the beam moving backward over said grid wires, and other circuit arrangements for preventing the beam being held at the succeeding grid wires during its backward movement while simultaneously gradually and increasingly reducing the beam intensity until the beam reaches its normal position.

8. A pulse-counting system according to claim 7, in which the said means for changing the potential applied to said deflector means for starting the backward movement of the beam includes a first grid-controlled amplifier tube whose control grid is connected to said holding grid and whose anode is connected to said beam stepping means, and said circuit arrangements include another grid-controlled amplifier tube whose control grid is coupled to the anode of the first amplifier tube and whose anode is coupled to a beam intensity control grid of said cathode-ray tube.

9. A pulse-counting system according to claim 8, in which said intensity control grid is returned to the cathode of the cathode-ray tube through an asymmetric conducting device which is biassed to form substantially a short circuit for positive voltage changes at said intensity control grid, and said anode of said second tube is returned to ground through a condenser-resistor combination to automatically restore the bias on the intensity control grid to restore the beam to its normal intensity after it has been moved backward to its normal position in registry with the first grid wire.

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