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ADDING AND SUBTRACTING DRIVE CIRCUIT FOR COUNTING TUBES

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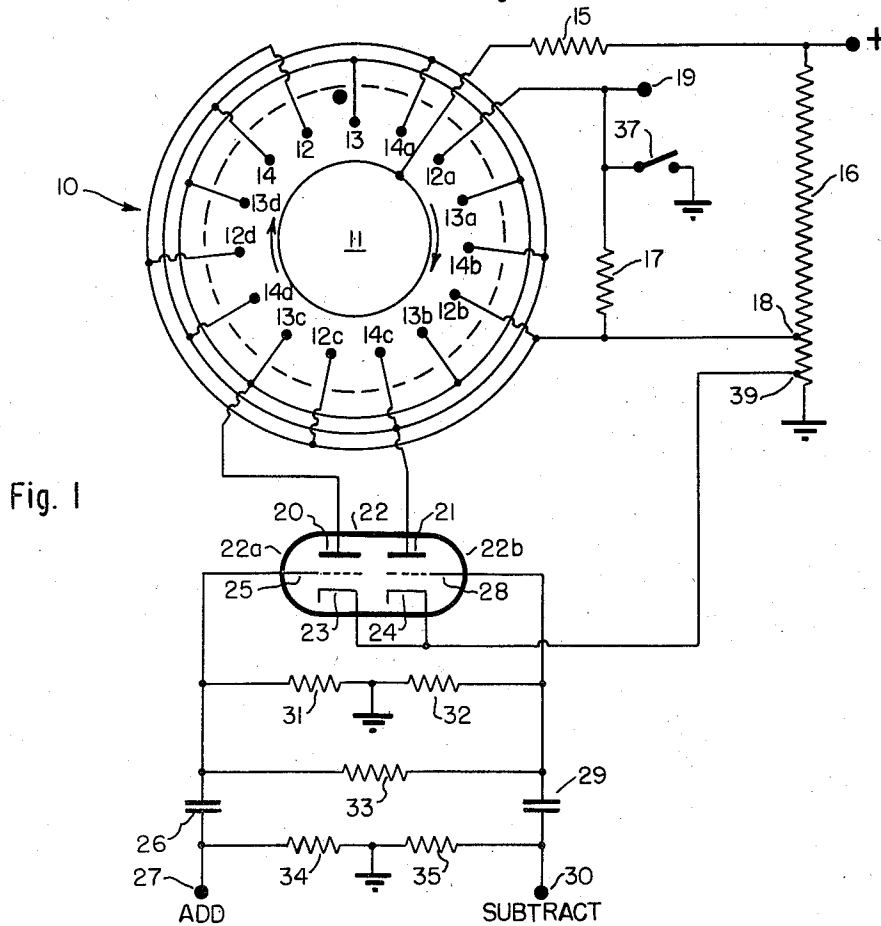


Fig. 2a

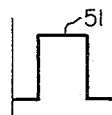


Fig. 2b

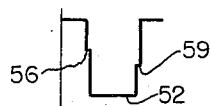


Fig. 2c

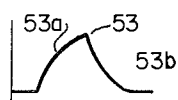
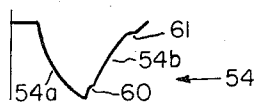


Fig. 2d



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ADDING AND SUBTRACTING DRIVE CIRCUIT FOR COUNTING TUBES

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12 Claims. (Cl. 315—84.6)

This invention relates to electronic counting devices and more specifically to drive circuits for gas-filled glow transfer counting tubes.

Electronic counting of electrical impulses is a relatively old concept. Perhaps the earliest practical system developed was the ring circuit. The circuit included a group of electron tubes arranged in a ring and operable one at a time. Each tube, as it conducted current, designated a digit or other unit of data. Recently, many types of counting tubes have become available which incorporate several counting stages within one tube envelope. These tubes are generally, although not necessarily, constructed to provide for a count of ten and may be cascaded to provide a decimal counting system to any order of magnitude desired. The count at any instant can be read out from the activated stage in each tube.

One category of these counting tubes is composed of the so-called gas-filled glow transfer counting tubes of which there are many differing types. All of the types, however, are multiple element tubes wherein a glow on one of the elements indicates visually and electrically a unit of data. Each impulse reaching the tube is either added to or subtracted from the number of impulses being indicated by a position of the glow. When pulses are added, the glow changes from one element to another in one direction, and when pulses are subtracted, the glow changes from one element to another in the opposite direction.

This invention contemplates the use of a glow transfer tube employing a central anode and three sets of cathodic electrodes. One set of the cathodic electrodes serves as the main or count indicating cathodes, and the other two sets are the so-called guide electrodes or guides. The transfer action of these tubes requires a driving circuit to convert input pulses into signals which are capable of switching the position of the glow from a main cathode in either direction to intervening guide electrodes and then on to the next main cathode in proper sequence.

The envelope of the tube is gas filled and has a disc-shaped anode located at its center. Arranged in an annular row about the anode are thirty (for a decimal counting system) equally spaced rod-like cathodic electrodes. Every third cathodic electrode is designated as a main or count indicating cathode. These main cathodes may be electrically connected together but generally one or more are arranged to provide independent electrical outputs. The remaining cathodes are divided into two groups, all of the members of each group being connected together to form two sets of guide or transfer electrodes. Switching of the glow from one main cathode to the next main cathode to effect a count is accomplished in the following manner. The potential of one set of guide electrodes is lowered to the point where the glow will leave its position on the main cathode and transfer to the nearest guide electrode of that set. The potential of the second set of guide electrodes is then lowered while the potential of the first set is allowed to return to its normal value. When the potential on the second

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set is sufficiently lower than that on the first set, the glow will transfer from its position on a guide electrode of the first set to the adjacent guide electrode of the second set. The potential of the second set of guide electrodes is then allowed to return to its normal value. The normal potentials on the second set of guide electrodes and on the main cathodes are such that the glow will then move from the second guide electrode to the adjacent main cathode. Thus, the glow is moved in either direction from one main cathode via two guide electrodes to the next main cathode to effect either an added or a subtracted count.

The result described above is achieved by means of a particular driving circuit for the tube. The driving circuit must provide appropriate signals of proper potential, wave shape, and time relationship for each input pulse received. Simple circuits have been devised in which an input pulse is applied directly to one set of guide electrodes and through an appropriate delay circuit to the second set of guide electrodes. In some applications, such a simple circuit has been adequate. A minor modification has been made in some instances to provide some amplification of the input pulses to improve performance.

At the other end of the scale, some very complicated circuits have been designed to produce in response to the input pulses being counted, signals to the guide electrodes which are nearly ideal in wave shape and timing. In fact, it is unnecessary that wave shapes be idealized, but it is highly desirable that reliability of counting be maintained and that the drive circuit be capable of operation at frequency rates at least as high as those at which the counting tube itself can operate. Neither the circuit of the simple type with its inherent unreliability nor the complicated circuit with its elaborate and expensive components has adequately filled these needs.

Most of the circuits presently known, in addition to suffering from the difficulties noted above, provide only for moving the glow transfer in one direction or the other around the counting tube. In some instances it is possible to use two or more of the known circuits, one to achieve a change in one direction for adding, and the other to achieve a change in the other direction for subtracting. However, it would be desirable to have the two functions of adding and subtracting combined in a single circuit for reasons of efficiency of operation, economy and reliability.

It is, therefore, an object of the present invention to provide a circuit for adding and subtracting electrical impulses over a broad range of frequencies.

It is another object of this invention to provide a highly reliable circuit for adding and subtracting electrical impulses.

It is still another object of this invention to provide a single driving circuit capable of moving the glow in a gas-filled glow discharge tube in either direction about a circular array of cathodes.

It is still another object of the present invention to provide a counting tube drive circuit in which pulses arriving at one terminal are added and pulses arriving at another terminal are subtracted from the quantity being indicated in the tube.

In general, the present invention consists in a circuit and glow transfer counting tube which operates to add or subtract input signals from a total of impulses or signals being displayed. A balanced circuit is utilized in which input signals are passed in unmodified shape to either of two sets of guide electrodes. The signal is modified and delayed before application to the other set of guide electrodes. The set of guide electrodes to which the pulses are applied in unmodified shape depends upon which of two sets of input terminals the signals arrive at. For a better understanding of the present invention together

with other objects, features and advantages, reference should be made to the following detailed description of a preferred embodiment thereof and the accompanying drawings wherein:

Fig. 1 is a schematic diagram of one embodiment of the tube and circuit of the present invention, and

Fig. 2 is a series of plots of voltage at various points in the circuit of Fig. 1.

The gas filled glow transfer counting tube 10 shown in the drawing includes a disc-shaped anode 11 surrounded by slim rod-like cathodic elements arranged in an annular row. Each third cathodic electrode 12, 12a, 12b, 12c and 12d is designated as a main or count-indicating cathode. In the drawing, there is illustrated a counting tube having only five rather than the ten stages previously noted as being preferred for easy adaptation to decimal counting. This has been done to avoid unduly complicating the drawing and to simplify the explanation of the invention. The ten stage device is preferred, and would, of course, operate in the same manner as that shown and described.

Adjacent each main cathode are two guide electrodes. For example, adjacent main cathode 12 in a clockwise direction is a guide electrode 13 and adjacent main cathode 12a in a clockwise direction is a guide electrode 13a. Similarly, the guide electrodes 13b, 13c and 13d are adjacent in a clockwise direction main cathodes 12b, 12c and 12d respectively. Going in a counter-clockwise direction, guide electrodes 14, 14a, 14b, 14c and 14d lie adjacent main cathodes 12, 12a, 12b, 12c and 12d respectively. Guide electrodes 13, 13a, 13b, 13c and 13d are all electrically connected together through the line shown as the innermost wiring ring in the drawing. Guide electrodes 14, 14a, 14b, 14c and 14d are similarly connected together through the middle wiring ring. Main cathodes 12, 12b, 12c and 12d are connected together through the outermost wiring ring, cathode 12a being independent of direct connection to the ring for purposes explained below.

The anode 11 is connected through a resistor 15 to a point of high positive potential at the top of a voltage divider 16. The main cathode 12a is selected as the output cathode and is connected through a resistor 17 to another and lower point of positive potential 18 on voltage divider 16. An output terminal 19 is also connected to the main cathode 12a. Similar connections may be provided for other main cathodes in those instances where it is desired to obtain additional outputs. In the embodiment shown, however, the four remaining main cathodes are all connected directly to the point of relatively low positive potential 18. A normally open reset switch 37 is connected between the main cathode 12a and ground to enable the glow to be removed from any other cathode and to be established on main cathode 12a as is more fully explained below.

A duo-triode 22 composed of a first triode section 22a and a second triode section 22b is shown. Separate triode tubes could, of course, be used instead of the duo-triode 22, since there is no interaction between the sections. The first set of guide electrodes 13, 13a, 13b, etc., is connected to the anode 20 of triode 22a. The second set of guide electrodes 14, 14a, 14b, etc., is connected to the anode 21 of triode 22b. The cathodes 23 and 24 of the duo-triode are connected together and to a point 39 of still lower positive potential on the voltage divider 16. The control grid 25 of triode section 22a is connected to the adding terminal 27 through a capacitor 26. The control grid 28 of triode section 22b is connected to the subtracting terminal 30 through a capacitor 29. Connecting the two control grids 25 and 28 to ground are resistors 31 and 32 respectively. An ungrounded resistor 33 is connected between the two grids. The Add terminal 27 and the Subtract terminal 30 are grounded through resistors 34 and 35 respectively.

In a typical circuit of the type described and shown,

the tubes employed were a Sylvania type 6802 as the glow transfer tube 10 and a Sylvania type 6J6 as the duo-triode 22. The voltage divider 16 provided 500 volts at its maximum tap. The plate resistor 15 connected to that tap had a value of 430,000 ohms. The resistor 17 connected to the output terminal 19 had a value of 68,000 ohms although a lesser value could have been used with equal success. The voltage at point 18 on the divider 16 was approximately 100 volts, and the voltage at point 39 on divider 16 was approximately 7 volts. The balancing resistors connecting the grids to ground, namely, resistors 31 and 32, had values of 3 megohms each. Resistor 33 connecting the two grids together had a value of 100,000 ohms. Each of the capacitors 26 and 29 had a value of .002 microfarad and the resistors 34 and 35 had values of 10,000 ohms each.

Considering the typical circuit for the moment, application of the cited voltages causes a glow to take place immediately at one of the main cathodes. The particular main cathode which assumes the glow will be determined by some asymmetrical condition existing in the tubes or circuit which causes a lower potential to appear at one main cathode. A main cathode will assume the glow rather than a guide electrode because all main cathodes are lower in voltage than the guide electrodes. In the typical circuit being considered presently the main cathodes are at approximately 100 volts derived from point 18 of the divider 16. It will be seen that the guide electrodes are at a potential greater than 100 volts.

Although duo-triode 22 is "cut off" by reason of the cathodes being connected to +7 volts at point 39 of divider 16 with no signal on the grids, a certain minimum plate current is actually flowing in the two sections of duo-triode 22. This minimum current is of a value (e. g., a few microamperes) determined by the requirement for electrons to neutralize the stray gaseous ions present in the annular zone between the anode and cathode array of the glow discharge tube at points other than the zone of the existing visible glow. At this minimum value of plate current, the voltage drop across the sections of duo-triode 22 is considerable. The voltage at the anodes 20 and 21 which is in fact the voltage on the guide electrodes is therefore also quite high, considerably in excess of the 100 volts on the main cathodes.

To initiate counting at a desired main cathode, a manually operable reset system is provided. In the circuit of Fig. 1, temporarily closing the normally open switch 37 grounds main cathode 12a placing it well below the potential of the other tube elements, and therefore the glow discharge takes place between anode 11 and cathode 12a. On reopening the switch to return the circuit to a normally biased condition the glow will remain on main cathode 12a since none of the counting tube elements is at a potential low enough to cause switching or transfer of the glow.

With the glow taking place at main cathode 12a, switch 37 having been momentarily depressed to ground cathode 12a as described, a circuit is completed from the top of voltage divider 16 through resistor 15, to anode 11, to cathode 12a, and through resistor 17 to a relatively low point 18 on voltage divider 16. Both sections 22a and 22b of duo-triode 22 remain just below cut-off in the absence of a signal on their control grids because their cathodes 23 and 24 are electrically tied to the point 39 of positive potential on divider 16.

The method by which the glow is transferred from one main cathode to the next may be more easily understood by reference to Fig. 2 in conjunction with the circuit diagram of Fig. 1. It will be necessary to refer several times to each of the voltage plots. To ease understanding of the operation, it should be borne in mind that Fig. 2a represents the voltage which appears at the input terminal 27; Fig. 2b the voltage on the guide electrodes of the 13 series; Fig. 2c the voltage appearing at grid 28 of triode section 22b; and Fig. 2d the voltage appearing on the guide electrodes of the 14 series.

The arrival of a pulse 51 to be added at input terminal 27 causes triode 22a to begin to conduct more heavily. The applied pulse is shown in Fig. 2a as it might be measured between terminal 27 or grid 25 and ground. Fig. 2b is a somewhat idealized showing of the voltage pulse 52 appearing at anode 20 and therefore on the guide electrodes including 13a. The actual voltage pulse at anode 20 in a circuit having the component values listed above would be a replica of the input pulse, inverted and amplified about ten times.

The voltage on the second set of guide electrodes 14, 14a, 14b etc. is determined by other elements of the balanced circuit. Besides initiating heavy conduction in triode section 22a, the application of the input pulse 51 at terminal 27 causes a charging current to flow into capacitor 29. The charging current flows through resistors 33 and 35 causing the voltage at the junction of resistor 33 and capacitor 29 to rise gradually to the full value of the applied voltage.

The voltage pulse 53 shown in Fig. 2c is present at the junction of resistor 33 and capacitor 29. It is also, of course, the voltage impressed upon the grid 28 of triode section 22b. The leading edge 53a of pulse 53 is a gradually increasing positive voltage which causes conduction in triode section 22b to increase gradually also. The voltage pulse 54 in Fig. 2d at the anode 21 has a leading edge which is a gradually negative-going voltage.

It has previously been noted that the voltage pulse at the anode 20 of triode 22a is a replica of the input pulse at the grid 25, inverted and amplified ten times. The voltage pulse shown in Fig. 2c is similarly inverted and amplified to appear at the anode 21 of triode 22b. An idealized version of the actual pulse is that shown in Fig. 2d, it not being practical to illustrate the full extent of the amplification.

The switching of the glow discharge in tube 10 in response to the voltages applied to the guide electrodes depends upon the charging and discharging of a capacitor. As the voltage on capacitor 29 increases, one of the first set of guide electrodes assumes the glow discharge. As the voltage on capacitor 29 begins to decrease, one of the second set of guide electrodes assumes the glow discharge, and as capacitor 29 becomes completely discharged another main cathode assumes the glow discharge.

During the occurrence of the leading edge of pulse 51, the voltage at terminal 27 rises rapidly. In like fashion, the potential of the first set of guide electrodes 13 is reduced rapidly to a point 56 as seen in Fig. 2b. The voltage normally present on main cathodes including 12a is considerably more positive causing the glow discharge to transfer from the main cathode 12a to the next adjacent guide electrode 13a in a clockwise direction as shown in Fig. 1 of the drawing. The irregularity on the curve at 56 is actually caused by the change in current flow which occurs as the discharge transfers from cathode 12a to first guide electrode 13a.

During the presence of the glow discharge on cathode 12a, a current flows through the resistor 17 developing a voltage positive with respect to point 18. When the flow of current ceases with the transfer of the glow discharge, the potential on cathode 12a drops to the same voltage which is present on the other main cathodes. Cathode 12a remains at that potential until the glow discharge again is present when the potential rises abruptly again. It may be seen that cathode 12a will produce an output pulse each time the glow discharge is assumed and relinquished.

During the charging of capacitor 29 through resistors 33 and 35, as shown in curve 53a of Fig. 2c, the voltage shown at 54a in Fig. 2d appears on the second set of guide electrodes including guide electrode 14b. At all times during the existence of the crest of pulse 51 as shown in Fig. 2a, the voltage on the guide electrodes including 14b is more positive than the voltage 52 (Fig. 2b) appearing on the guide electrodes including 13a. It is

thus apparent that the glow discharge will remain on guide electrode 13a during the entire duration of the applied pulse 51.

As the applied pulse terminates, the potential of guide electrode 13a rises rapidly toward its normal condition, there no longer being sufficient bias on grid 25 to cause conduction in triode 22a and thereby to maintain the voltage at anode 20 low. Simultaneously, capacitor 29 begins to discharge through resistors 33 and 35 as shown at 53b in Fig. 2c. The voltage at anode 21 swings toward the positive as shown at 54b as the voltage on grid 28 decreases with the discharge of capacitor 29. The irregularities indicated at points 59 and 60 in Figs. 2b and 2d indicate the transfer of ionization discharge from guide 13a to guide 14b.

The glow discharge remains on the guide electrode 14b until the capacitor is discharged. However, at the termination of the capacitor discharge, normal bias as described hereinabove is reached. The voltage on all of the guide electrodes again becomes more positive than the normal voltage on the main cathodes. This difference in voltage is sufficient to cause the glow discharge to leave the guide electrode 14b and to transfer to the next main cathode 12b. This transfer is indicated by the irregularity 61 seen in the curve of Fig. 2d which occurs at just about the time normal voltages are once more present on all of the tube elements.

The process whereby the ionization discharge is transferred from one main cathode to the next in response to an Add pulse has been outlined. It should be noted that in adding, the movement of the ionization discharge is in a clockwise direction. The application of Subtract pulses to terminal 30 results in a transfer of the glow discharge in a counter-clockwise direction, which transfer is entirely similar to that described above. In subtracting, however, it is the capacitor 26 and the resistors 33 and 34 with which we are concerned. The charge and discharge of the capacitor through the resistors provide the delay in the action of triode section 22a. Because the triode sections 22a and 22b are identical, as are resistors 31 and 32, capacitors 26 and 29, and resistors 34 and 35 respectively, the circuit is balanced and the subtraction accompanied by counter-clockwise movement of the glow discharge is accomplished in a manner identical with that of addition.

Although a particular circuit has been shown and described, applicant's invention should not be limited only to those details. The concept of providing a circuit which is responsive to drive the glow discharge in a transfer tube in either direction by a dissection of the applied pulse, portions of the pulse being used to trigger first one tube which controls a given set of electrodes, and then another tube controlling another set of guide electrodes is believed to be novel. The further feature of providing reversibility in that the drive circuit is responsive in transferring the glow discharge in either direction around the arrayed cathodes of the glow transfer tube is also believed to be novel. Therefore, the invention should not be limited to the embodiment shown, but only by the spirit and scope of the appended claims.

What is claimed is:

1. A pulse adding and subtracting drive circuit for a glow discharge transfer counting tube having an anode, a plurality of cathodes, a first plurality of electrodes each disposed adjacent one of said plurality of cathodes in a clockwise direction, and a second plurality of electrodes each disposed adjacent one of said plurality of cathodes in a counter-clockwise direction, said drive circuit comprising a first input terminal, means responsive to input pulses applied at said first input terminal for first driving said first plurality of electrodes more negative than said cathodes and said second plurality of electrodes and then driving said second plurality of electrodes more negative than said cathodes and said first plurality

of electrodes, a second input terminal and means responsive to input pulses applied at said second input terminal for first driving said second plurality of electrodes more negative than said cathodes and said first plurality of electrodes and then driving said first plurality of electrodes more negative than said cathodes and said second plurality of electrodes, said glow discharge from said anode being transferred from one of said cathodes in a clockwise direction in response to input pulses applied at said first input terminal and in a counter-clockwise direction in response to input pulses applied at said second input terminal.

2. A pulse adding and subtracting drive circuit for a glow discharge transfer counting tube having an anode, a plurality of circularly arranged cathodes, a first plurality of guide electrodes, and a second plurality of guide electrodes, each of said cathodes being disposed between one of said first plurality of guide electrodes and one of said second plurality of guide electrodes, said drive circuit comprising two input terminals, means responsive to input pulses applied at one of said terminals for first making said first plurality of electrodes less positive than said cathodes and said second plurality of electrodes and then making said second plurality of electrodes less positive than said cathodes and said first plurality of electrodes, and means responsive to input pulses applied at the other of said input terminals for first making said second plurality of electrodes less positive than said cathodes and said first plurality of electrodes and then making said first plurality of electrodes less positive than said cathodes and said second plurality of electrodes whereby the glow discharge from said anode moves from one of said cathodes to one of said first plurality of guide electrodes in response to input pulses applied to said one of said input terminals and from said one of said cathodes to one of said second plurality of guide electrodes in response to input pulses applied to said other of said input terminals.

3. A pulse adding and subtracting drive circuit for a glow discharge transfer counting tube having an anode, a plurality of circularly arranged cathodes, a first plurality of guide electrodes, and a second plurality of guide electrodes, each of said cathodes being disposed between one of said first plurality of guide electrodes and one of said second plurality of guide electrodes, said drive circuit comprising a balanced circuit having two input terminals, first means for lowering the potential on said first plurality of guide electrodes below that of said cathodes and said second plurality of guide electrodes, second means for lowering the potential on said second plurality of guide electrodes below that of said cathodes and said first set of guide electrodes, and delaying means, one of said input terminals being connected directly to said first means and connected through said delaying means to said second means, the other of said input terminals being connected directly to said second means and connected through said delaying means to said first means whereby pulses applied at one of said input terminals cause movement of said glow discharge from said anode in one direction and pulses applied at the other of said input terminals cause movement of said glow discharge from said anode in a direction opposite to said one direction.

4. A pulse adding and subtracting drive circuit for a glow discharge transfer counting tube having a plurality of cathodes, a first plurality of guide electrodes for transferring glow discharge from one to another of said cathodes, and a second plurality of guide electrodes for transferring glow discharge from one to another of said cathodes, each of said cathodes being disposed between one of said first plurality and one of said second plurality of guide electrodes, said drive circuit comprising a balanced circuit having first and second input terminals, first means for lowering the potential on said first plurality of guide

electrodes substantially immediately in response to pulses applied to said first input terminal and second means for lowering the potential on said second plurality of guide electrodes substantially immediately in response to pulses applied to said second terminal, said first means including a delay path for pulses passing from said first input terminal means and said second means including a delay path for pulses passing from said second input terminal to said first means.

5. A pulse adding and subtracting circuit comprising, in combination a glow discharge transfer counting tube having a plurality of cathodes, a first set of guide electrodes and a second set of guide electrodes, each of said cathodes being disposed between one of said first set and one of said second set of guide electrodes, first and second vacuum tubes each having at least a cathode, an anode and a grid, means for supplying operating voltages to said vacuum tubes, means connecting the anode of said first vacuum tube to said first set of guide electrodes, means connecting the anode of said second vacuum tube to said second set of guide electrodes, a first input terminal, first means connecting said first input terminal to said first vacuum tube grid, a second input terminal, second means connecting said second input terminal to said second vacuum tube grid, said first means being interconnected with said second means, whereby pulses applied to said first input terminal are coupled directly to said first vacuum tube grid and delayed before being applied to said second vacuum tube grid and pulses applied to said second input terminal are coupled directly to said second vacuum tube grid and delayed before being applied to said first vacuum tube grid.

6. A pulse adding and subtracting circuit comprising, in combination a glow discharge transfer counting tube having a plurality of cathodes, a first set of guide electrodes and a second set of guide electrodes, each of said cathodes being disposed between one of said first set and one of said second set of guide electrodes, first and second vacuum tubes each having at least a cathode, an anode and a grid, means for supplying operating voltages to said vacuum tubes, means connecting the anode of said first vacuum tube to said first set of guide electrodes, means connecting the anode of said second vacuum tube to said second set of guide electrodes, a first input terminal, a second input terminal, a first resistance-capacitance coupling circuit connected between said first input terminal and said first vacuum tube grid, and a second resistance-capacitance coupling circuit connected between said second input terminal and said second vacuum tube grid, whereby pulses applied to said first terminal are coupled by said first resistance-capacitance circuit directly to said first vacuum tube grid to cause substantially immediate conduction in said first vacuum tube and are delayed in said second resistance-capacitance circuit to cause conduction in said second vacuum tube subsequent to conduction in said first vacuum tube and pulses applied to said second input terminal are coupled by said second resistance-capacitance circuit directly to said second vacuum tube grid to cause substantially immediate conduction in said second vacuum tube and are delayed in said first resistance-capacitance circuit to cause conduction in said first vacuum tube subsequent to conduction in said second vacuum tube.

7. A pulse adding and subtracting circuit comprising, in combination a glow discharge transfer counting tube having a plurality of cathodes, a first set of guide electrodes and a second set of guide electrodes, each of said cathodes being disposed between one of said first set and one of said second set of guide electrodes, first and second vacuum tubes each having at least a cathode, an anode and a grid, means for supplying operating voltages to said vacuum tubes, means connecting the anode of said first vacuum tube to said first set of guide electrodes, means connecting the anode of said second vacuum tube to said second set of guide electrodes, a first input terminal

nal, a second input terminal, a first charging resistor connecting said first input terminal to a reference point, a second charging resistor connecting said second input terminal to a reference point, a common charging resistor connected between said first and said second vacuum tube grids, a first capacitor connected between said first input terminal and said first vacuum tube grid, and a second capacitor connected between said second input terminal and said second vacuum tube grid, whereby pulses applied to said first input terminal are applied directly to said first vacuum tube grid to cause substantially immediate high conduction in said first vacuum tube and to charge said second capacitor and cause gradually increasing conduction in said second vacuum tube and pulses applied to said second input terminal are applied directly to said second vacuum tube grid to cause substantially immediate high conduction in said second vacuum tube and to charge said first capacitor and cause gradually increasing conduction in said first vacuum tube.

8. A pulse adding and subtracting circuit comprising, in combination a glow discharge transfer counting tube having an anode, a plurality of circularly arranged cathodes, a first plurality of guide electrodes and a second plurality of guide electrodes, each of said cathodes being disposed between one of said first plurality of guide electrodes and one of said second plurality of guide electrodes, a first vacuum tube having at least a cathode, a grid, and an anode, means directly connecting the anode of said first vacuum tube to said first plurality of guide electrodes, a second vacuum tube having at least a cathode, a grid, and an anode, means directly connecting the anode of said second vacuum tube to said second plurality of guide electrodes, a voltage divider, means connecting the anode of said counting tube to a point of relatively high positive voltage on said voltage divider, said counting tube cathodes, less one, being connected directly to a first point of relatively low positive voltage on said voltage divider, an output terminal connected to said one counting tube cathode, a resistor connecting said output terminal and said one counting tube cathode to said first point of relatively low positive voltage on said voltage divider, said cathode of said first vacuum tube being connected to said cathode of said second vacuum tube and to a second point of relatively low positive voltage on said voltage divider, a first input terminal for receiving pulses to be added by said counting tube, a first input circuit connecting said first input terminal to the grid of said first vacuum tube, said first input circuit including a first capacitor connected between said first input terminal and said first vacuum tube grid, a second input terminal for receiving pulses to be subtracted by said counting tube, a second input circuit connecting said second input terminal to the grid of said second vacuum tube, said second input circuit including a second capacitor connected between said second input terminal and said second vacuum tube grid, a first charging resistor connecting said first input terminal to a reference point, a second charging resistor connecting said second input terminal to said reference point, a third common charging resistor connecting said first vacuum tube grid to said second vacuum tube grid, and grid-leak resistors connecting each of said vacuum tube grids to said reference point whereby input pulses applied to said first input terminal cause substantially immediate high conduction in said first vacuum tube and delayed high conduction in said second vacuum tube and input pulses applied to said second input terminal cause substantially immediate high conduction in said second vacuum tube and delayed high conduction in said first vacuum tube.

9. Pulse adding and subtracting circuit comprising a glow transfer tube having a plurality of cathodes, a like plurality of first guide electrodes, a like plurality of second guide electrodes and an anode common to said cathodes and guide electrodes, means including a first voltage source connected to said common anode for

establishing a glow discharge at one of said cathodes, first and second electron tubes each having anode, cathode and control grid electrodes, connections from the anodes of said first and second electron tubes to said first and second guide electrodes, respectively, first and second input terminals, and means in circuit with said first and second input terminals and the control grids of said first and second tubes operative to lower the potential on said first guide electrodes substantially immediately upon application of a pulse to said first input terminal and to delay the lowering of the potential on said second guide electrodes after application of a pulse to said first input terminal, and to lower the potential on said second guide electrodes substantially immediately upon application of a pulse to said second input terminal and to delay the lowering of the potential on said second guide electrodes after application of a pulse to said second input terminal.

10. Pulse adding and subtracting circuit comprising a glow transfer tube having a plurality of cathodes, a like plurality of first guide electrodes, a like plurality of second guide electrodes and an anode common to said cathodes and guide electrodes, means including a first voltage source connected to said common anode for establishing a glow discharge at one of said cathodes, first and second electron tubes each having anode, cathode and control grid electrodes, connections from the anode of said first and second electron tubes to said first and second guide electrodes, respectively, said connections together with said glow discharge affording a path for the application of operating voltages to the anodes of said electron tubes, first and second input terminals, and means in circuit with said first and second input terminals and the control grids of said first and second tubes operative to lower the potential on said first guide electrodes substantially immediately upon application of a pulse to said first input terminal and to delay the lowering of the potential on said second guide electrodes after application of a pulse to said first input terminal, and to lower the potential on said second guide electrodes substantially immediately upon application of a pulse to said second input terminal and to delay the lowering of the potential on said second guide electrodes after application of a pulse to said second input terminal.

11. Pulse adding and subtracting circuit comprising a glow transfer tube having a plurality of cathodes, a like plurality of first guide electrodes, a like plurality of second guide electrodes and an anode common to said cathodes and guide electrodes, means including a voltage source connected to said common anode for establishing a glow discharge at one of said cathodes, first and second electron tubes each having at least anode, cathode and control grid electrodes, means connecting the anode of said first electron tube to all of said first guide electrodes, means connecting the anode of said second electron tube to all of said second guide electrodes, first and second input terminals, separate means each including a capacitor connecting said first and second input terminals to the control grids of said first and second electron tubes, respectively, and a balanced resistor network in circuit with said capacitors and operative with said electron tubes to lower the potential on said first guide electrodes substantially immediately upon application of a pulse to said first input terminal and to delay the lowering of the potential on said second guide electrode after application of a pulse to said first input terminal, and to lower the potential on said second guide electrodes substantially immediately upon application of a pulse to said second input terminal and to delay the lowering of the potential on said second guide electrodes after application of a pulse to said second input terminal.

12. Pulse adding and subtracting circuit comprising a glow transfer tube having a plurality of cathodes, a like plurality of first guide electrodes, a like plurality of second guide electrodes and an anode common to said

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cathodes and guide electrodes, first and second electron tubes each having at least anode, cathode and control grid electrodes, separate means directly connecting the anodes of said first and second electron tubes to said first and second guide electrodes, respectively, first and second input terminals, separate means each including a capacitor respectively connecting said first and second input terminals to the control grids of said first and second electron tubes, means connecting the cathodes of said electron tubes together to a first potential source, means including said glow transfer tube connecting the anodes of said electron tubes to a second source of potential more

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resistors respectively connected between said first and positive than said first potential source, first and second second input terminals and a common point of reference potential, and a common charging resistor connected between the control grids of said first and second electron tubes.

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