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BI-DIRECTIONAL COUNTING CIRCUIT

Filed April 24, 1958

2 Sheets-Sheet 1

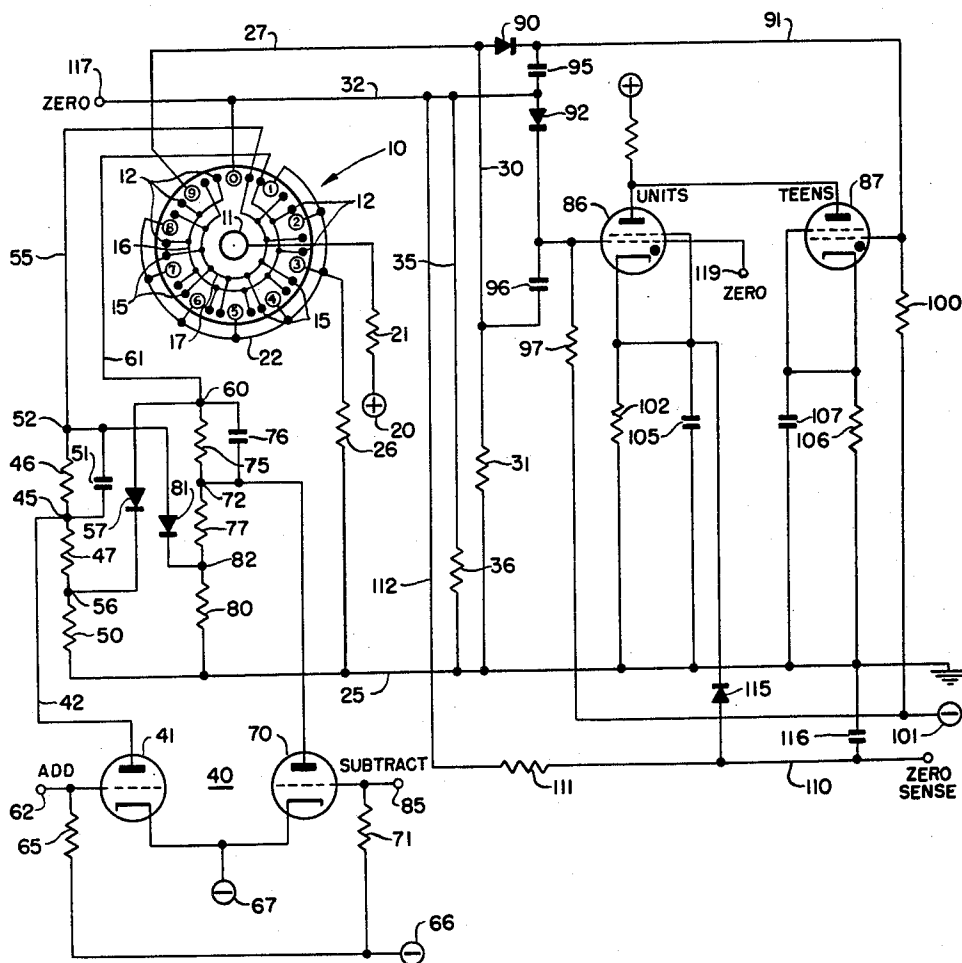


FIG. 1

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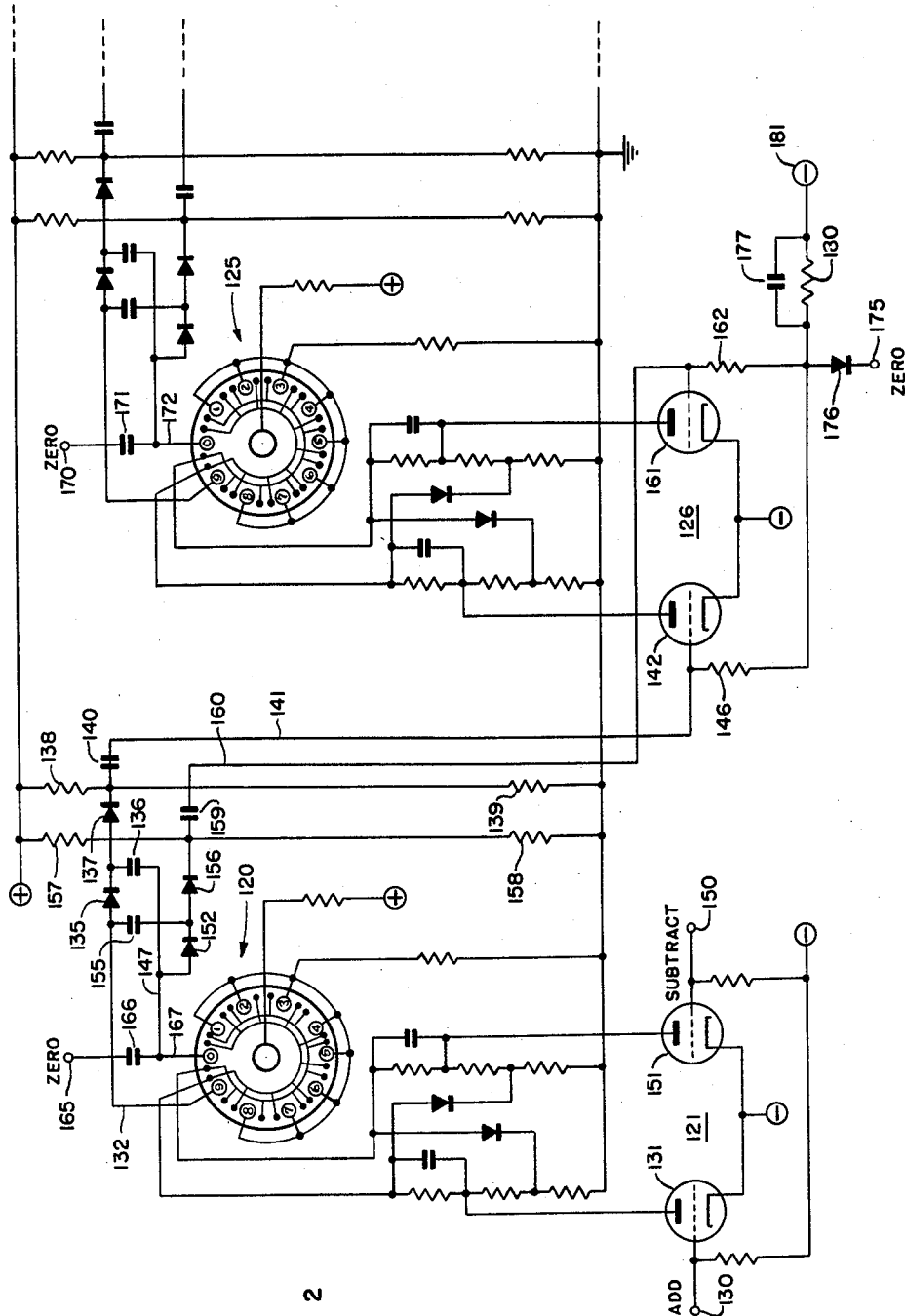


FIG. 2

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BI-DIRECTIONAL COUNTING CIRCUIT

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5 Claims. (Cl. 315—84.6)

This invention relates to bi-directional counting circuits and more particularly to circuits for driving in either of two directions a counter tube of the type having a plurality of cathodes and pair of guide electrodes positioned between adjacent cathodes.

Many circuits have been devised for reversibly driving so-called counting tubes such as the glow transfer counter tube. These tubes generally include a plurality of cathodes which are positioned radially about a centrally-located anode. Positioned between each pair of adjacent cathodes are two guide electrodes. In order to switch a conductive beam or glow which may exist between a cathode and the anode from one cathode to an adjacent cathode, it is necessary to provide potentials of proper polarity and precise amplitudes to the two guide electrodes in succession. When this is done properly, the glow will switch from a given cathode, will remain temporarily and successively on the two guide electrodes and will switch to the second, adjacent cathode. The circuits that have been devised heretofore to provide these switching functions in two directions have been expensive, complicated and critical in operation.

An object of the present invention is to provide new and improved bi-directional counting circuits.

Another object of the invention is to provide new and improved circuits for driving in either of two directions counter tubes of the type having a plurality of cathodes and a pair of guide electrodes positioned between adjacent cathodes.

A further object of the invention is to provide new and improved bi-directional counting circuits which are more economical than those devised heretofore.

With these and other objects in view, a bi-directional counting circuit employing certain features of the invention for driving a counter tube of the type having a plurality of operating electrodes and two groups of switching electrodes associated with the operating electrodes, may include means for alternately applying a predetermined maximum potential to each group of switching electrodes, voltage-divider means connected to each maximum-potential-applying means for providing second potentials which are less than the associated maximum potentials, and means including a diode for applying each of the second potentials to a group of switching electrodes other than the switching electrodes to which the maximum potential is applied.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the invention becomes better understood by reference to the following description, when taken in conjunction with the following drawings, wherein:

Fig. 1 is a schematic diagram of a bi-directional counting circuit which illustrates certain features of the invention, and

Fig. 2 is a schematic diagram of a bi-directional decade counting circuit which likewise embodies certain features of the present invention.

Referring now to Fig. 1, the circuit therein shows a bi-

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directional glow transfer counter circuit. A counter tube 10 is of the type wherein a plurality of cathodes, ten of which are shown and which are designated "0" to "9," inclusive, are positioned radially about a centrally-located anode 11. Positioned between each pair of adjacent cathodes is a pair of guide electrodes designated 12 and 15. Smilar guide electrodes 12—12 are connected together by a lead 16 which is shown schematically in Fig. 1 as being within the envelope of the tube 10, but which may be an external lead which is connected to each of a plurality of pins associated with the guide electrodes 12—12. Likewise, similar guide electrodes 15—15 are connected together by a lead 17. The tube 10 is called a glow transfer counter tube and may be of a gas filled tube such as Type 6476 or 6482, manufactured by Sylvania Electric Products, Inc., of Woburn, Massachusetts.

In these types of tubes, a conductive beam may be maintained between the anode 11 and any of the cathodes "0" to "9," inclusive, for any desired length of time. The conductive beam or, as it is sometimes termed, the glow, may be switched from one cathode to an adjacent cathode by applying proper potentials at proper times to the guide electrodes 12 and 15, connected between such cathodes, as will be described more fully herein below. These tubes have found great utility in various types of counter circuits. While somewhat simplified circuits have been devised for switching the conductive beam around the tube in one direction, the circuits hereinbefore devised for switching the conductive beam in both directions therearound have been complicated and expensive in that many electron discharge tubes and many components have been needed for their operation. The present invention provides a simple and inexpensive means for performing this function. In the present description, examples of typical voltages that may be used throughout the circuits embodying features of the invention will be given for illustrative purposes. It is to be understood, however, that these potential values are only illustrative and that such values should not be taken in a restrictive sense.

The anode 11 is connected to a source 20 of positive potential, such as +100 volts, through a resistor 21. The cathodes "1" to "8," inclusive, are connected together by a lead 22 and are connected to a lead 25 through a resistor 26. The lead 25 is placed at a reference or ground potential as illustrated in Fig. 1. The "9" cathode is connected over leads 27 and 30 and through a resistor 31 to the grounded lead 25. In a similar manner, the "0" cathode is connected over leads 32 and 35 and through a resistor 36 to the grounded lead 25. As mentioned hereinabove, the circuit for actually driving the tube 10 in either of two directions is connected to the guide electrodes 12—12 and 15—15 of the counter tube 10. This bi-directional driving circuit is designated generally by the numeral 40 in Fig. 1. The portion of the bi-directional driving circuit 40 for driving the glow around the tube 10 in a clockwise direction includes a triode vacuum tube 41. Since, when the counter tube 10 is driven in a clockwise direction, the glow is switched successively between the anode 11 and the cathodes "1" to "9," inclusive, the counter tube 10 is said to be performing the function of addition. Consequently, the triode 41 is designated in Fig. 1 as the "add" tube. The anode of the "add" triode 41 is connected over a lead 42 and to a junction point 45, located between two resistors 46 and 47. The resistors 46 and 47 and a resistor 50 form a series resistance circuit, with the resistors 47 and 50 dividing the anode potential of the "add" triode 41, and a capacitor 51 is connected directly across the resistor 46. The upper sides of the resistor 46 and the capacitor 51 are connected to a junction point 52 which is connected over a lead 55 to the commonly-connected guide elec-

trodes 15—15. A junction point 56, located between the resistors 47 and 50, is connected to one side of a diode 57, the other side of which is connected to a junction point 60. The junction point 60 is connected by a lead 61 to the second group of commonly-connected guide electrodes 12—12.

To illustrate the counter tube 10 performing the function of addition, assume that the conductive beam or the glow exists between the "0" cathode and the anode 11 of the counter tube 10. To switch this glow from the "0" cathode to the "1" cathode, so that the counter tube 10 adds one to the count registered thereon, a short, positive pulse is applied to an input terminal 62. This pulse is developed across a grid resistor 65, the lower end of which is connected to a negative source 66 of potential, and is applied to the control grid of the "add" triode 41. The cathode of the triode 41 is connected to a second negative source 67 of potential. For illustrative purposes, assume that the negative source 67 applies -150 volts to the cathode of the triode 41, and that the negative source 66 is at -165 volts.

Assuming, then, that there is conduction between the "0" cathode and the anode 11, and assuming that a single positive pulse is applied to the grid of the "add" triode 41, a negative pulse of approximately 100 volts appears on the anode thereof and is applied over the lead 42 to the junction point 45. The full negative amplitude of this pulse is applied through the capacitor 51 and the junction point 52 and over the lead 55 to the guide electrodes 15—15. Because of the voltage-divider action of the resistors 47 and 50, approximately three-fourths of such full negative voltage is applied to the guide electrodes 12—12. It can be seen from Fig. 1 that a guide 15 is immediately to the right of the "0" cathode and that a guide 12 is immediately to the left thereof. Since the guides 15—15 have a greater negative potential applied thereto than the guides 12—12 at this time, the conductive beam will switch to the guide 15 which is positioned between the "0" and "1" cathodes. However, the resistor 46 is chosen to be of a high value, and since the guide 15 is now connected through this resistor to the anode of the triode 41, the high-valued resistor 46 does not permit sufficient current to flow to maintain the glow on the guide 15. Also, the capacitor 51, which is chosen to be of a small value, quickly charges so the potential of the guides 15—15 quickly rises. Since the potential on the guides 12—12 is still three-fourths of the maximum potential on the anode of the triode 41, the glow switches to the guide 12 between the "0" and "1" cathodes. The glow remains on the guide electrode 12 until the positive pulse being applied to the grid of the triode 41 ceases. When this occurs, the triode 41 is rendered nonconductive so that its anode potential rises. Assume that its anode potential rises to such a value that the voltage being placed on the now-conducting guide electrode 12 is +60 volts. Since the potential of the cathode "1," immediately adjacent to the guide electrode 12, is connected to ground through the resistor 26, and since a more positive voltage is now being applied to the guide electrode 12, the glow will transfer from the guide electrode 12 to the "1" cathode. In a similar manner, as positive pulses are applied successively to the input terminal 62, the glow will transfer to successive cathodes and will travel around the counter tube in a clockwise direction.

In order for the counter tube 10 to perform the function of "subtraction," the glow must be switched in a counter-clockwise direction around the tube. To perform this function, a "subtract" triode 70 is provided, the control grid of which is connected through a resistor 71 to the negative source 66 of potential, and the cathode of which is connected directly to the negative source 67. The anode of the "subtract" triode 70 is connected to a junction point 72 which is connected to the lower end of a resistor 75 and a capacitor 76. The upper ends of these components are connected to the junction point

60 and over the lead 61 to the guide electrodes 12—12. Two resistors 77 and 80 are connected between the junction point 72 and the grounded lead 25, and a diode 81 is connected between the junction point 52 and a junction point 82, located between the resistors 77 and 80. It can be seen that the circuitry for the subtraction function is similar to that used for the function of addition, and that the interconnections therebetween permit common connections to be made from the junction point 60 to the guide electrodes 12—12 and from the junction point 52 to the guide electrodes 15—15.

In order for the counter tube 10 to perform the function of subtraction, and assuming that the glow is on the "2" cathode, a positive potential is applied to an input terminal 85, across the resistor 71 and to the control grid of the "subtract" triode 70. In this case, the maximum amplitude of the negative potential which appears on the anode of the "subtract" triode 70 is applied through the capacitor 76 and to the guide electrodes 12—12. Because of the voltage-divider action of the resistors 77 and 80, a voltage which is only three-fourths of the maximum negative voltage being applied to the guide electrodes 12—12, is applied through the diode 81, over the lead 55 and to the guide electrodes 15—15. Consequently, the glow will switch from the "2" cathode to the guide electrode 12 between the "1" and "2" cathodes. The potential of the junction point 82 will be maintained at this three-fourths of maximum negative potential for the duration of the pulse being applied to the grid of the "subtract" triode 70. The junction point 60, however, will rapidly rise in a positive direction since the resistor 75 is of a high value, thereby limiting the current to the guide electrode 12, and since the small capacitor 76 discharges through the resistor 75. Therefore, when the potential of the junction point 60 becomes more positive than the three-fourths maximum negative potential being applied to the junction point 82, the glow switches from the guide electrode 12 to the guide electrode 15 between the "2" and "1" cathodes. Then, when the pulse being applied to the control grid of the triode 70 ceases, the triode 70 is rendered nonconductive, its anode potential increases and the potential of the junction point 82 increases. Assume, again, that the potential of the junction point 82 at this time is +60 volts. Since the "1" cathode is at ground potential, the conductive beam will switch from the guide electrode 15 adjacent thereto to the "1" cathode. Consequently, the counter tube has subtracted a count of one from the count which was registered thereon. Further, it will be observed that in switching from the "2" cathode to the "1" cathode, the conductive beam has traveled around the counter tube 10 in a counter-clockwise direction.

With the remaining structure shown for the bi-directional glow transfer counter shown in Fig. 1, the counter circuit can "add" to a count of nineteen, and it can "subtract" from a count of nineteen to zero. This structure includes a "units" tube 86, a "teens" tube 87 and their connections to the counter tube 10. The "units" tube 86 and the "teens" tube 87 are gas tubes of the arc-discharge or thyratron type, and the connections between these tubes and the counter tube 10 include the lead 27, which is connected between the "9" cathode of the counter tube 10 and the left-hand side of a diode 90. The right-hand side of the diode 90 is connected over a lead 91 to the control grid of the "teens" tube 87. Similarly, the "0" cathode of the counter tube 10 is connected over the lead 32 to the upper end of a diode 92, the lower end of which is connected to the control grid of the "units" tube 86. A capacitor 95 is connected between the lead 91 and the upper end of the diode 92, and a capacitor 96 is connected between the lower end of the diode 92 and the lead 30 which is connected to the grounded lead 25 through the resistor 31. Biasing resistors 97 and 100 are connected between the control grids of the "units" tube 86 and the "teens" tube 87, respectively, and a negative

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source 101 of biasing potential. The screen grids of the "units" tube 86 and the "teens" tube 87 are connected to their respective cathodes, the cathode of the "units" tube 86 is connected to the grounded lead 25 through a parallel arrangement of a resistor 102 and a capacitor 105, and the cathode of the "teens" tube 87 is similarly connected to the grounded lead 25 through a resistor 106 and a capacitor 107. A zero sense lead 110 is connected through a resistor 111, over a lead 112 and the lead 32 to the "0" cathode of the counter tube 10, for a purpose which will be described more fully herein below. As shown in Fig. 1, a diode 115 is connected between the zero sense lead 110 and the cathode of the "units" tube 86, and a capacitor 116 is connected between this lead and the grounded lead 25.

As stated hereinabove, the bi-directional counter shown in Fig. 1 can register a count from zero to the count of nineteen. Therefore, if any number of positive pulses, between one and nineteen, are applied to the control grid of the "add" triode 41, the counter will add these pulses and register thereon a count equivalent to such number. If the number of pulses being applied to the control grid of the "add" triode 41 is between one and nine, the "units" tube 86 will be conducting, the "teens" tube 87 will be cut off and a conductive beam will exist between the anode 11 of the counter tube 10 and a cathode thereof which is similar in number to the number of pulses to be added by the circuit. When such number is between ten and nineteen, the "teens" tube 87 will be conducting, and the "units" tube 86 will be nonconducting. Also, a conductive beam will exist between the anode 11 of the counter tube 10 and that cathode thereof which is similar in number to the total number of pulses to be counted, less ten. How these results are achieved will now be described.

Assume that the counter circuit shown in Fig. 1 is zeroed, that is, assume that a conductive beam exists between the "0" cathode of the counter tube 10 and the anode 11, and that the "units" tube 86 is conductive. Assume, also, that the function of addition is to be performed by the counter circuit, so that a series of positive pulses is applied to the control grid to the "add" triode 41. As the applied pulses increase in number, the conductive beam in the counter tube 10 is switched progressively from the "0" cathode, in a clockwise direction around the counter tube and to the "8" cathode, in the manner described hereinabove with respect to the "0" cathode and the "1" cathode. To this point, the input pulses have had no effect on the states of conduction of the "units" tube 86 and "teens" tube 87. As the ninth pulse, in the series of pulses to be added, is applied to the control grid of the "add" triode 41, the conductive beam is switched to the "9" cathode of the counter tube 10. When the conductive beam exists between the "9" cathode and the anode 11, a positive potential of, for example, +30 volts appears on the "9" cathode. This positive potential is applied over the lead 27, through the diode 90 and over the lead 91 to the control grid of the "teens" tube 87. Assume, however, that the negative source 101 applies -40 volts to the control grid of the "teens" tube 87. Then, the +30 volts potential which appears on the lead 91 will not be sufficient to render the "teens" tube conductive. Consequently, the counter circuit registers a count of nine since the conductive beam is on the "9" cathode of the counter tube 10 and the "units" tube 86 is still conducting.

Then, when the tenth pulse is applied to the control grid of the "add" triode 41, the conductive beam is switched from the "9" cathode to the "0" cathode of the counter tube 10. At this time, a potential of +30 volts appears on the "0" cathode and is applied onto the lead 32. When the "9" cathode of the counter tube 10 had been rendered conductive, the +30 volt potential which appeared on the lead 27 and which was applied through the diode 90, was applied to the upper side of the capaci-

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tor 95 and had charged this capacitor to +30 volts. As stated hereinabove, this potential was not sufficient to render the "teens" tube 87 conductive. Then, when the "0" cathode of the counter tube 10 conducts, the +30 volt potential which appears on this cathode and is applied to the lead 32, is also applied to the lower side of the capacitor 95. This latter potential is effective to "double" the potential on the upper side of the capacitor 95 so that a potential in excess of +40 volts appears on the upper side of the capacitor, is applied over the lead 91 and is applied to the control grid of the "teens" tube 87. This potential is now sufficient, in view of the -40 volt bias being applied to the control grid, to render the "teens" tube 87 conductive. When the "teens" tube 87 is rendered conductive, its anode potential drops, and this drop in anode potential renders the "units" tube non-conductive because of the common anode connection between the "units" tube 86 and the "teens" tube 87, and because of the capacitors 105 and 106 which are connected, respectively, in the cathode circuits of these tubes.

More particularly, before the receipt of the tenth pulse to the counter circuit, the "units" tube 86 had been conducting, as described hereinabove. Such conduction of the "units" tube 86 causes the capacitor 105 to be charged to a predetermined positive potential, for example, +30 volts. Since the "teens" tube 87 is not conducting, the capacitor 106 in the cathode circuit thereof is not charged so that the cathode of the "teens" tube 87 is near ground potential. Then, upon receipt of the tenth input pulse to the circuit, the "teens" tube 87 is rendered conductive, its anode potential drops and this drop in anode potential is impressed on the anode of the "units" tube 86 because of the common anode connections therebetween. At this time, the capacitor 105 is still charged to +30 volts. Therefore, the capacitor 105 maintains the cathode of the "units" tube 86 at this increased positive potential so that the difference in potential between the cathode and anode of the "units" tube is insufficient to maintain the tube conductive. Conversely, the capacitor 106 holds the cathode of the "teens" tube 87 to a potential which is near ground potential. Therefore, in the case of the "teens" tube 87, the difference in potential between the anode and cathode thereof is sufficient to maintain the "teens" tube conductive. As a result, upon receipt of the tenth pulse on the control grid of the "add" triode 41, the "teens" tube 87 is rendered conductive, the "units" tube 86 is rendered nonconductive and the "0" cathode of the counter tube 10 is conducting. Consequently, the counter circuit has registered therein a count of ten.

To describe the operation of the circuit in Fig. 1 when the function of subtraction is to be performed, assume that a count of eleven is registered on the counter. In this case, the "teens" tube 87 is conducting, the "units" tube 86 is nonconducting and the "1" cathode of the counter tube 10 has the conductive beam thereon. As a pulse is applied to the control grid of the "subtract" triode 70, the conductive beam will be switched from the "1" cathode of the counter tube 10 to the "0" cathode thereof, in the manner described hereinabove. Then, as a second pulse is applied to the control grid of the "subtract" triode 70, a count of nine (11-2) is to be registered in the counting circuit. When the first pulse was applied to the control grid of the "subtract" triode 70, the "0" cathode of the counting tube was rendered conductive. At this time, a positive potential (e.g., +30 volts) appeared on the "0" cathode and was applied to the lead 32. This positive potential is applied through the diode 92, to the control grid of the "units" tube 86 and to the upper side of the capacitor 96 so that this capacitor is charged to +30 volts. Then, upon receipt of the second pulse to be subtracted from the original number registered in the counter, the "9" cathode of the counting tube 10 is rendered conductive. At this time, a positive potential of, for example, +30 volts appears on the "9" cathode, is

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applied over the leads 27 and 30 to the lower side of the capacitor 96. This positive potential causes the potential on the upper side of the capacitor 96 to be "doubled" to a voltage in excess of +40 volts so that the -40 volts from the negative source 101 on the control grid of the "units" tube 86 is overcome, and the "units" tube is rendered conductive. When the "units" tube 86 is rendered conductive, the anode potentials of the "units" tube 86 and the "teens" tube 87 are lowered, and since the "teens" tube had been conducting and had charged the capacitor 106 to +30 volts, the "teens" tube 87 is rendered nonconductive and the "units" tube 86 is maintained conductive. It can be seen, therefore, that a count of nine is registered on the counter circuit since the "units" tube 86 is conducting and the "9" cathode of the counter tube 10 is conducting.

In some cases, it may be desirable to obtain an indication when the counter shown in Fig. 1 is zeroed, that is, when the "units" tube 86 is conducting, and the conductive beam is on the "0" cathode of the counter tube 10. This zeroing can be achieved by applying a negative potential of -120 volts, for example, to a terminal 117. This negative potential is applied directly to the "0" cathode of the counter 10, thereby switching the conductive beam from whatever cathode it may be on to the "0" cathode. Also, a positive potential of +60 volts must be applied to a terminal 119 to render the "units" tube 86 conductive should this tube be nonconductive from a previous operation, and to assure nonconduction of the "teens" tube 87. To obtain an indication of such zeroing, the diode 115 is connected between the cathode of the "units" tube 86 and the zero sense lead 110, and the "0" cathode of the counter tube 10 is connected to this lead through the resistor 111.

When the circuit has the count of zero registered thereon, the conducting "units" tube 86 causes a positive potential (e.g., +30 volts) to appear on the cathode thereof and to be applied to the upper side of the diode 115, thereby rendering this diode nonconductive. Then, the positive potential which appears on the conducting "0" cathode, is applied across the resistor 111 and on to the zero sense lead 110. It can be seen, therefore, that the combination of a conducting "units" tube 86 and a zeroed counter tube 10 is necessary in order to apply a potential to the zero sense lead 110, and thereby indicate that the counter is zeroed. Any other combination will result in there being no potential applied to the zero sense lead 110. For example, assume that a count of ten is registered on the counter. In this case, the zero cathode of the counter tube 10 is conducting, but the "teens" tube 87 is also conducting, and the "units" tube 86 is nonconducting. Since the "units" tube 86 is nonconducting, its cathode is at a potential near ground potential. Consequently, the positive potential which appears on the conducting "0" cathode of the counter tube 10 is applied through the resistor 111 and is shorted through the diode 115 to ground. Also, it will be noted that when any other cathode of the counter tube 10 is conducting, other than the "0" cathode, no potential is applied to the leads 32 and 112 connected thereto, and none is applied to the zero sense lead 110. As a result, an output potential condition will be applied to the zero sense lead 110 only when the counter circuit is registering the zero count.

The capacitor 116 is connected between the zero sense lead 110 and grounded lead 25 to prevent a false indication of a zeroed counter when the counter passes through a count of ten. To illustrate, assume that a count of nine is registered on the counter circuit. In this case, the "units" tube 86 is conducting, and the "9" cathode of the counter tube 10 is conducting. Ten, as a tenth pulse is received and is to be added to the count registered on the counter, the "0" cathode of the counter tube 10 is rendered conductive almost immediately. It can be seen that if +30 volts appears on the "0" cathode of the counter tube 10 before the "units" tube 86 is rendered nonconduc-

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tive, the diode 115 might be held nonconductive for a sufficient length of time so that the +30 volts on the "0" cathode of the counter tube 10 will be applied to the zero sense lead 110. This would cause a false indication of the zeroed condition of the circuit during the transition. To prevent this from happening, the capacitor 116 integrates the +30 volt potential which appears on the "0" cathode of the counter tube 10 when this cathode is rendered conductive on a count of ten. Such integration causes a delay of this potential so that it can not reach any significant value before the "units" tube 86 is rendered nonconductive at the count of ten. Consequently, this delay permits the "units" tube to be rendered nonconductive so that the potential on the "0" cathode of the counter tube is shorted out through the diode 115 before it can reach any significant value that will cause a false indication of the zeroed condition of the circuit. With this structure, since the "units" tube 86 is maintained conductive when the counter is registering zero and not a count of ten, thereby preventing the shorting out of the positive potential on the "0" cathode of the counter tube only when a zero count is registered no false, momentary indication of the zeroed condition of the counter can exist.

Referring now to the bi-directional decade counter circuit shown in Fig. 2, two stages of this counter circuit are shown, but it will be appreciated that any number of stages may be provided. In the first stage shown in Fig. 2, a counter tube 120 is driven in either of two directions by a bi-directional driving circuit, designated generally by the numeral 121. Also, a counter tube 125 in the second stage may be driven in either of two directions by its associated bi-directional driving circuit, designated generally by the numeral 126. Each of the counter tubes 120 and 125 and its associated driving circuit are similar, respectively, to the counter tube 10 of Fig. 1 and the bi-directional driving circuit 40 associated therewith. Consequently, no detailed description of the individual circuits of Fig. 2 is necessary. The major difference between the circuit of Fig. 2 and that of Fig. 1 is that no tubes similar to the "units" tube 86 and the "teens" tube 87 are provided. Instead, when the counter tube 120 changes from a count of nine to a count of ten, the succeeding driving circuit 126 causes the conductive beam of the succeeding counter tube 125 to be driven up one stage. Generally speaking, when the decade counter shown in Fig. 2 is adding a number of pulses, and such number is between one and nine, the "0" cathode of the counter tube 125 will be conducting so that the total count is registered on the counter tube 120. Then, when a tenth pulse is received by the counter tube 120, this counter tube operates the driving circuit 126 to switch the conductive beam of the counter tube 125 to the "1" cathode thereof. In a similar manner, at a count of twenty, the counter tube 125 is driven up one stage so that the conductive beam is on the "2" cathode thereof. Several illustrative examples of the operation of the circuit shown in Fig. 2 will now be given.

Assume that the counter tubes 120 and 125 are zeroed, that is, that the conductive beams thereof are on their "0" cathodes, and that the function of addition is to be performed by the decade counter circuit. In this case, positive pulses, equal in number to the number of counts to be added by the circuit, are applied to an input terminal 130 and to the control grid of an "add" triode 131 in the driving circuit 121. The first nine of such pulses will switch the conductive beam in the counter tube 120 from its "0" cathode to its "9" cathode in the same manner described hereinabove with reference to the counting circuit of Fig. 1. At this time, that is, when the "9" cathode of the counter tube 120 is conducting, a positive potential of +30 volts, for example, appears thereon and is applied over a lead 132, through a diode 135 and to the upper side of a capacitor 136 to charge this capacitor to +30 volts. This +30 volts potential is also applied to the left side of a diode 137 but is insufficient to overcome

a +40 volt potential at a junction point between resistors 138 and 139 so that the diode 137 remains nonconductive.

Then, upon receipt of a tenth pulse to the control grid of the "add" triode 142, the conductive beam is switched from the "9" cathode of the counter tube 120 to the "0" cathode thereof. At this time, a +30 volt potential appears on the "0" cathode and is applied over a lead 147 to the lower side of the capacitor 136. This action "doubles" the potential appearing on the upper side of the capacitor 136 so that a voltage in excess of +40 volts is developed thereon and is applied to the diode 137 to render it conductive, to the capacitor 140 and to the control grid of the "add" triode 142, thereby rendering this tube conductive. When the "add" triode 142 in the driver circuit 126 is rendered conductive, its anode potential drops so that a negative potential appears thereon. This negative potential is applied to the driver circuit 126, which operates in the manner described with reference to the driver circuit 40 in Fig. 1, so that the conductive beam in the counter tube 126 switches from the "0" cathode thereof to the "1" cathode. Therefore, since this action occurred upon the receipt of a tenth pulse by the "add" tube 130, the decade counter circuit has registered therein a count of ten since the conductive beam in the counter tube 125 is on its "1" cathode, and the conductive beam of the counter tube 120 is on its "0" cathode.

As the number of pulses to be added by the decade counter increases from ten to nineteen, the counter tube 120 increases its count in the same manner as described with reference to Fig. 1. Then, upon receipt of the twentieth pulse, the same action as described hereinabove results so that the conductive beam of the counter tube 125 is switched from its "1" to its "2" cathode. In this manner, the function of addition is performed. It will be obvious that any number of stages may be added to the second stage including the counter tube 125. Since the first two stages shown in Fig. 2 will count the first ninety-nine pulses being received by the circuit, when the hundredth pulse is received thereby, the conductive beam of the counter tube 125 will switch to the "0" cathode thereof so that the conductive beam in a counter tube (not shown) in the third stage will switch from the "0" cathode to the "1" cathode thereof. Consequently, the first stage including the counter type 120 may be termed a "units" stage, the second stage including the counter tube 125 may be termed a "tens" stage and a third stage (not shown) may be termed a "hundreds" stage. In this manner, any number of stages can be added to the two stages shown in Fig. 2.

To illustrate the performance of the function of subtraction with the circuit shown in Fig. 2, assume that the two stages in this figure have a count of twenty-one registered thereon. In this case, the conductive beam in the counter tube 125 will be on the "2" cathode thereof, and the conductive beam of the counter tube 120 will be on its "1" cathode. When a count of one is to be subtracted from this number, a positive pulse is applied on an input terminal 150 and to the control grid of a "subtract" tube 151 in the driver circuit 121. In this instance, the driver circuit 121 will switch the conductive beam of the counter tube 120 in a counter-clockwise direction in the manner described with reference to the circuit shown in Fig. 1. Consequently, since the conductive beam in the counter tube 120 was on the "1" cathode thereof, the conductive beam will switch to the "0" cathode. When this occurs, a positive potential of, for example, +30 volts, is applied over the lead 147, through a diode 152 and to the lower side of a capacitor 155. This +30 volt potential is also applied to the left side of a diode 156, but the potential on a junction point between resistors 157 and 158 is at +40 volts which holds the diode 156 nonconducting, to prevent the pulse from being conducted to a capacitor 159 and over a lead 160 to the

control grid of a "subtract" tube 161. Consequently, the "subtract" tube 161 cannot be rendered conductive at this time. Also at this time, a count of one has been subtracted from the total count of twenty-one so that the decade counter has registered thereon a count of twenty. This has occurred since the conductive beam in the "tens" counter tube 125 has been maintained on the "2" cathode thereof, and the conductive beam in the "units" counter tube 120 has been switched to the "0" cathode.

When one more count is to be subtracted from the count of twenty now registered on the decade counter of Fig. 2, a pulse is again applied to the input terminal 150 and to the control grid of the "subtract" tube 151. At this time, the conductive beam is switched from the "0" cathode thereof to the "9" cathode. At this time, a potential of +30 volts is applied over the lead 132 and to the upper side of the capacitor 155, thereby "doubling" the voltage which had appeared on the lower side thereof. Since a +30 volt potential had been applied to the lower side of the capacitor 155 when the conductive beam was switched to the "0" cathode at a count of twenty, the potential now appearing on the lower side of the capacitor 155 will be in excess of +40 volts. This potential is sufficient to render the diode 156 conductive and is applied through the capacitor 157 and over the lead 160 to the control grid of the "subtract" tube 161 associated with the driver circuit 126. Consequently, the "subtract" tube 161 is rendered conductive, and its anode potential drops to drive the conductive beam in the counter tube 125 down one count in a counter-clockwise direction, in the same manner as described with reference to the counter circuit shown in Fig. 1. As a result, the conductive beam in the counter tube 125 will switch to the "1" cathode thereof. Since the conductive beam of the counter tube 120 had switched to the "9" cathode thereof, the decade counter shown in Fig. 2 will now have registered thereon a count of nineteen. Since this has occurred from two pulses being subtracted from the original count of twenty-one, the decade counter has subtracted two from twenty-one and properly resulted in a count of nineteen.

From the above description, it can be seen that the circuit shown in Fig. 2 can be used to add or subtract any number of pulses. In some cases, a large number of pulses may be added by the circuit, and the performance of the subtraction function may not be desired. In other words, it may be desired to zero the counter without applying a large series of pulses to the control grid of the "subtract" tube 151. In order to zero the counter tubes 120 and 125 and any other counter tubes provided, it is only necessary to apply a large, negative potential to the "0" cathodes thereof. Such a negative potential may be of the order of -120 volts since the application of such a potential to the "0" cathode will cause the conductive beam of the counter tube to switch immediately to the "0" cathode from whatever cathode it may be located. Referring to Fig. 2, a zeroing terminal 165 is provided for the application thereto of a negative pulse to zero the counter tube 120. This negative pulse is applied through a capacitor 166, over a lead 167 and to the "0" cathode of the counter tube 120. In a similar manner, a negative pulse may be applied to a zeroing terminal 170 associated with the counter tube 125. In this latter case, the zeroing pulse is applied through a capacitor 171, over a lead 172 and to the "0" cathode of the counter tube 125. Similar structure for zeroing any other counters in the decade counter may be provided. When the negative zeroing potential is applied to the terminal 165, this pulse may be differentiated by the capacitor 136, the lower side of which is connected to the "0" cathode by the lead 147. Consequently, at the cessation of the negative zeroing potential on the terminal 165, a positive rise in potential through the capacitor may cause, effectively, a drive pulse

to be applied through the diode 137 and the capacitor 140 and over the lead 141 to the control grid of the "add" triode 142, thereby rendering this triode conductive. To prevent such a false drive pulse during the reset period, a negative pulse is also applied to a terminal 175, to the lower end of a diode 176 and to the control grids of the tubes 142 and 161. This negative potential will hold the tubes 142 and 161 nonconductive for a period determined by the time constant of a capacitor 177 and a resistor 180 which is connected to a normally-applied negative potential source 181. This time constant is chosen to be sufficient to maintain the tubes 142 and 161 nonconductive until the zeroing pulse on the terminal has ceased.

It is to be understood that the above-described embodiments of the invention are merely illustrative of the principles thereof and that numerous modifications and embodiments of the invention may be devised within the spirit and scope thereof.

What is claimed is:

1. A circuit for driving in two directions a conductive beam in a counter tube of the type having a plurality of cathodes and two groups of guide electrodes associated with the cathodes, which comprises a capacitor connected to each group of guide electrodes, means for selectively applying a maximum negative potential to each of the groups of guide electrodes through the associated capacitor, a voltage divider connected to each maximum-potential-applying means to provide upon the selection thereof a predetermined potential which is less than such selected maximum potential, a diode connected between each of the voltage dividers and the group of guide electrodes other than the group selected to receive the maximum potential, and a resistor connected across each of the capacitors, the application of a maximum negative potential through the associated capacitor to a first group of the guide electrodes causing the beam to switch from one of the cathodes to a guide electrode of the first group, whereby the resistor associated therewith then limits the current flow through such guide electrode and the capacitor associated therewith is charged thereby increasing the potential of the first group of guide electrodes and causing the beam to switch to a guide electrode of the second group to which the lesser potential is applied and on which the beam remains until the cessation of the maximum negative potential, at which time the beam switches to a second cathode.

2. A circuit for driving a conductive beam in either direction between adjacent operating electrodes in a counter tube of the type having a plurality of such operating electrodes and two groups of switching electrodes associated with the operating electrodes, which comprises a pair of capacitors, means for alternately applying a predetermined potential through one of the capacitors to each group of switching electrodes, voltage-divider means connected to each predetermined-potential-applying means for providing second potentials which are less than the associated predetermined potentials, and means including a diode for applying each of the second potentials to a group of switching electrodes other than the switching electrodes to which the predetermined potential is applied through the associated capacitor, the initial application of a predetermined potential momentarily switching the beam from one of the operating electrodes to a switching electrode of the group to which such predetermined potential is applied until the capacitor associated therewith is charged such that the second potential exceeds the potential on the switching electrodes to which the predetermined potential is applied, whereby the conductive beam switches to a switching electrode of the group to which the second potential is applied and on which it remains until the cessation of the application of the predetermined potential.

3. A circuit for driving in either of two directions a counter tube of the type wherein a conductive beam is

established successively between one of a plurality of cathodes and an anode and wherein a pair of guide electrodes is associated with adjacent cathodes with similarly-associated guide electrodes being connected together to form two groups of equipotential guide electrodes, which comprises a first resistance circuit including a plurality of serially-connected resistors connected between a first of the groups of guide electrodes and a reference potential, a second resistance circuit including a plurality of serially-connected resistors connected between the second group of guide electrodes and the reference potential, a capacitor connected in each resistance circuit across the resistor which has one end connected directly to a group of guide electrodes, a pair of diodes, one of the diodes connected between each group of guide electrodes and a junction between two resistors in the resistance circuit connected to the other group of guide electrodes, and means for alternately applying a potential which is negative with respect to the reference potential to each of the groups of guide electrodes through the capacitor.

4. A circuit for reversibly driving a counter tube of the type having a plurality of operating electrodes and two groups of switching electrodes associated with the operating electrodes and for indicating a count which is greater than the number of operating electrodes in the counter tube, which comprises a pair of electron discharge devices including input and output electrodes, means interconnecting the electrodes of the discharge devices such that the conduction of either renders the other nonconductive, means connecting a predetermined one of the counter tube operating electrodes to each of the input electrodes of the electron discharge devices for determining which of the electron discharge devices is maintained conductive, means for increasing and decreasing the count registered on the counter tube so that one of the electron discharge devices conducts upon a predetermined count being registered thereon and the other conducts upon a count less than the predetermined count being registered thereon, the last-mentioned means comprising means for alternately applying a predetermined maximum potential to each group of the switching electrodes, voltage-divider means connected to each maximum-potential-applying means for providing second potentials which are less than the associated maximum potentials, and means including a diode for applying each of the second potentials to a group of switching electrodes other than the switching electrodes to which the maximum potential is applied.

5. A circuit for adding and subtracting between a count of nineteen and zero with a counter tube of the type having ten operating electrodes all of which are rendered conductive successively in a cycle of operation and two groups of switching electrodes associated with the operating electrodes, which comprises a pair of electron discharge devices including control electrodes, means for connecting a predetermined one of the operating electrodes of the counter tube to each of the control electrodes of the electron discharge devices, means for conditioning the electron discharge devices such that one of such devices is conductive and the second is held nonconductive during one cycle of operation of the counter tube, means connected to the operating electrodes of the counter tube to which the control electrodes of the electron discharge devices are connected for rendering the second electron discharge device conductive during a second cycle of operation of the counter tube and whereby the first electron discharge device is held nonconductive, and means for reversibly driving the counter tube, the last-mentioned means comprising means for alternately applying a predetermined potential to each of the two groups of switching electrodes, voltage-divider means connected to each potential-applying means for providing a second potential which is less than the predetermined potential, a pair of diodes, and means for connecting one of the diodes between each predetermined-potential-apply-

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ing means and the voltage-divider means associated with the other predetermined-potential-applying means.

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