ELECTRON BEAM SWITCHING TUBE COUNTER CIRCUIT
WITH LOW IMPEDANCE DRIVING MEANS
Original Filed June 23, 1958

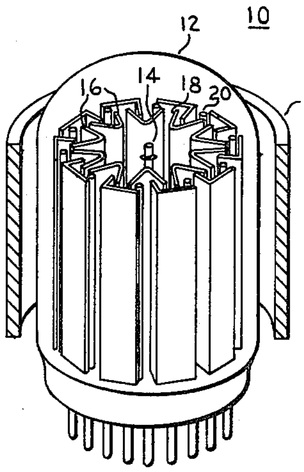

Fig. 1

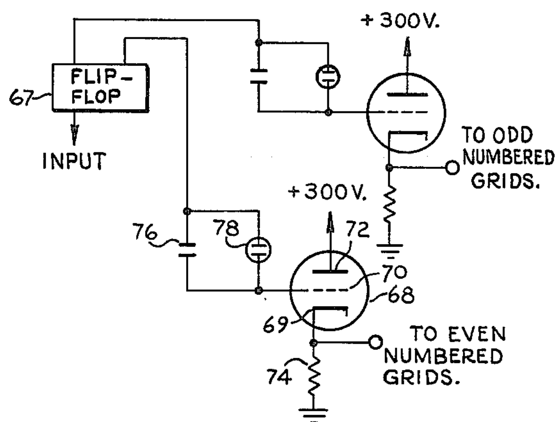

Fig. 4

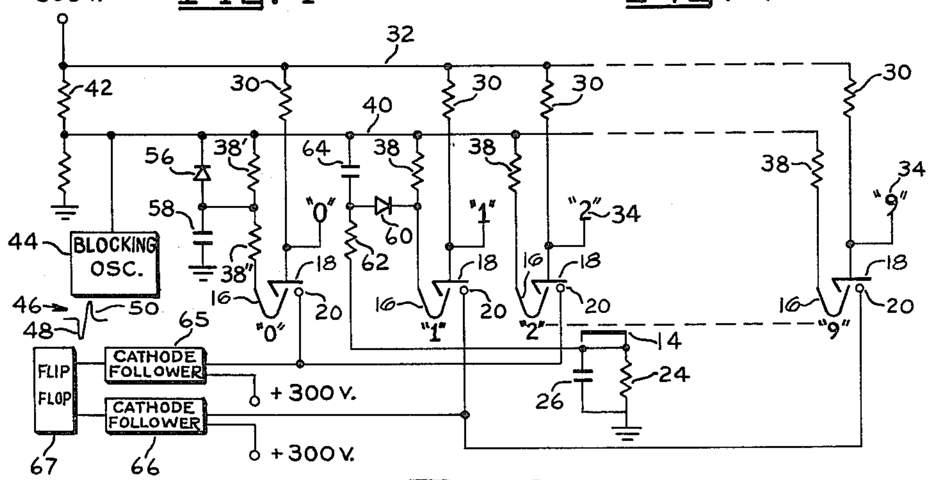

Fig. 2

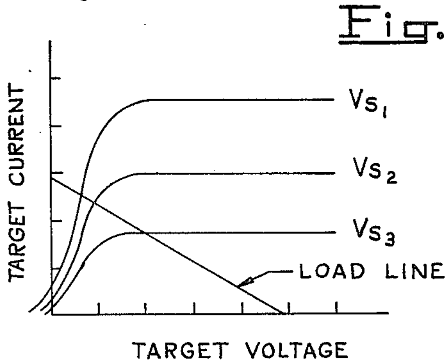

Fig. 3

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ELECTRON BEAM SWITCHING TUBE COUNTER CIRCUIT WITH LOW IMPEDANCE DRIVING MEANS

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11 Claims. (Cl. 315—21)

This invention relates to electronic counters and particularly to electronic counters capable of improved high speed operation. This application is a continuation of application Serial No. 743,523, filed June 23, 1958, and now abandoned.

The principles of the invention are particularly applicable to electronic counters of the type which employ multi-position electron beam switching tubes. One tube of this type is described in U.S. Patent No. 2,721,955 of Fan et al. Tubes of this type have been used in counters such as decade counters, and these counters have been generally satisfactory. However, there is an ever present need for achieving higher speeds of operation in all electronic circuits including such counter circuits.

Accordingly, the objects of the present invention are concerned with the provision of an improved electronic counter capable of operating accurately and efficiently at high speeds.

In brief, the principles and objects of the invention are embodied in an electronic counter circuit which uses a multi-position electron beam switching tube. The tube includes a plurality of positions, at each of which an electron beam may form and from each of which an output signal may be derived. Each position includes an output electrode, a beam forming electrode, and a switching electrode, the principal function of the last electrode being to promote the switching of an electron beam from position to position within the tube. Each target electrode is coupled to a load impedance of such magnitude that the target tends to be unstable in operation when an electron beam is flowing to it. This instability is due to the presence of excess electrons, all of which cannot be collected by the target to which the beam is flowing. These excess electrons tend to flow toward the next leading position and finally the entire beam switches automatically to the next leading positon. To counteract this tendency and render stable the target to which an electron beam is flowing, the switching electrodes are operated at a high positive potential and are coupled to their power supply through a low impedance path. Such a connection allows excess electrons, which create the instability, to be removed by the appropriate switching electrode without its potential being lowered significantly so that the associated target is rendered stable and the undesired and uncontrolled switching of an electron beam is prevented. Since the potential of a switching electrode is not lowered by this electron flow, it does not cause spurious switching of an electron beam. When it is desired to perform a switching operation, the appropriate switching electrode is pulsed negative and normal switching is achieved.

The invention is described in greater detail by reference to the drawing wherein:

FIG. 1 is a perspective view, party in section, of some of the elements of a multiple output electron discharge device used in practicing the invention;

FIG. 2 is a schematic representation of the tube of FIG. 1 and a circuit in which it may be operated;

FIG. 3 is a graph showing the operating characteristics of the target electrodes of the tube 10 at several different operating spade voltages; and

FIG. 4 is a detailed schematic representation of a portion of the circuit of FIG. 2.

The present invention may be practised with a multi-position electron beam tube of the type shown in U.S. Patent No. 2,721,955 of Fan et al. This type of tube is shown in FIG. 1 as tube **10** and includes, briefly, an envelope **12** which contains a central longitudinally elongated cathode **14** and ten groups of electrodes spaced radially equidistantly from the cathode and surrounding the cathode. Each group of electrodes includes a generally U-shaped elongated spade electrode **16** and a generally L-shaped target electrode **18** positioned so that each target occupies the space between adjacent spade electrodes. Each spade electrode serves to form and hold an electron beam on its corresponding target electrode. A generally rod-like switching electrode **20** is also included in each group of electrodes and is positioned between one edge of each target electrode and the adjacent spade electrode. The switching electrodes are known as switching grids. An open-ended cylindrical permanent magnet **22** is provided surrounding the tube envelope and coaxial therewith. The magnet provides an axial magnetic field which is utilized in conjunction with electric fields within the tube to form and switch an electron beam from the cathode to each of the groups of electrodes. The direction in which the beam switches, that is clockwise or counterclockwise, is always the same and is determined by the orientation of the electric and magnetic fields.

Briefly, in operation of tube **10**, electrons emitted by the cathode are retained at the cathode if each of the spades, targets and switching grids carries its normal operating electrical potential. When a spade or switching grid experiences a suitable lowering of its potential, an electron beam is formed and directed to the corresponding target electrode. The electron beam may be switched from one target electrode to the next by thus suitably altering the electrical potentials of a spade or switching grid. Under normal operating conditions, whenever electrode voltages are such that a beam might be supported at several positions, the beam will switch to the most leading position and lock in at this position.

In the circuit of FIG. 2, the tube **10** is shown schematically with the groups of electrodes arranged in linear form. Only four of the usual ten positions, or groups of electrodes, are shown and are numbered "0," "1," "2," . . . "9." In the circuit, the cathode **14** is connected through a resistor **24** to a source of reference potential such as ground. The resistor **24** is bypassed by capacitor **26** to smooth transient pulses which occur during a beam switching operation.

With respect to the circuit connections of the target electrodes **18**, each target is coupled through a load resistor **30** to a target buss **32** which is coupled to a positive D.C. power supply of about 300 volts. Each target is also coupled to an indicator means, for example, one of the glow cathode numerals **34** of an indicator tube such as the type 6844A tube. Thus, the target at the "0" position is connected to the cathode numeral zero; the target at the "1" position is connected to the cathode numeral one, etc. If desired, the targets **18** may also be provided with suitable auxiliary output terminals (not shown) for connection to any other type of utilization device, such as a mechanical printer or the like.

According to the invention, the magnitude of resistance of the load resistors **30** is such that, when current flows to a target, the potential of this current-receiving target is reduced to such a level that it is operating along an unstable portion of its characteristic curve (FIG. 3) as described below. As a result, target-switching tends to take place, that is, due to the influence of the unstable target, the beam tends to switch from the unstable current-receiving target to the next leading target. The required magnitude of resistance for the target resistors depends on all of the other parameters of the circuit including the spade resistors and spade and target supply voltages. A resistance of 36,000 ohms has been found suitable for the target resistors when used in conjunction with the other operating parameters described herein. In other circuits, where stable target operation is used, target load resistors in the range of 5,000 to 10,000 ohms are commonly employed.

In FIG. 3 are shown typical target characteristic curves which relate target current and target voltage for different spade supply voltages V_S. The unstable portion of each curve lies below the knee of the curve, that is, between the abscissa and the flat horizontal portion of each curve. A typical unstable load line for a spade voltage V_{S_2} is also shown.

With respect to the circuit connections of the spade electrodes **16**, each spade is connected through a spade load resistor **38** to a common spade buss **40**. In order to facilitate the resetting of an electron beam at the "0" position, as described below, the "0" spade load resistor is provided in substantially two separate equal portions **38'** and **38''**. The spade buss **40** is coupled through a common spade load resistors **42** to the 300 volt power supply and to a "clear and reset" pulse generator **44**. The generator **44** may comprise a conventional blocking oscillator and provides pulses **46** including a negative portion **48** and a positive portion **50**. This pulse shape is typical of the output of blocking oscillators.

Further means coupled to the "0" spade to facilitate resetting of a beam includes a connection from the spade buss **40** through a diode **56** and a capacitor **58** to ground. The diode **56** is oriented to provide easy current flow to the spade buss and spade power supply from the capacitor **58**. The junction point of the diode **56** and capacitor **58** is connected to the junction point of the "0" spade resistors **38'** and **38''**. The resistor **38'** and capacitor **58** comprise a time delay circuit and are selected to provide the desired circuit time constant to control the rise in potential of the "0" spade during the resetting operation which is described below.

The "1" spade is also provided with circuitry to facilitate the clearing of a beam from the "1" position and its resetting at the "0" position. In the circuit, the "1" spade is connected through a diode **60** and resistor **62** to the cathode **14** and through a capacitor **64** to the spade buss. The diode **60** is oriented to present its reverse or high resistance to the negative portions of the pulses **46**. Thus, the cathode of the diode is connected to the "1" spade, and its anode is connected to the cathode **14**. This diode thus substantially prevents the negative portion of the clear and reset pulse from being applied to the "1" spade but allows it to be applied to the other spades.

The switching grid electrodes **20** are connected in two sets with the grids at the even-numbered positions being in one set, and the grids at the odd-numbered positions being in another set. According to the invention, each set of grid electrodes is coupled through a low impedance path to the 300 volt power supply. In one suitable arrangement, each set of said electrodes is connected through an amplifier having a low output impedance to the 300 volt power supply. The even-numbered switching grids are connected through amplifier **65**, and the odd-numbered electrodes are coupled through amplifier **66**. Such amplifiers may be cathode follower amplifiers, with each amplifier being driven from one side of a flip-flop circuit **67** which provides the required switching pulses. These amplifiers **65** and **66** may also be transistor emitter followers.

A typical suitable cathode follower circuit is shown in FIG. 4 and includes as electron tube **68** having a cathode **69**, control grid **70** and anode **72**, with the cathode being connected to ground through a suitable resistor **74** and with the anode being connected to the 300 volt power supply. The cathode **69** is also connected to one of the sets of switching electrodes **20**, for example the even-numbered electrodes. The control grid of the tube **68** is coupled through a parallel connected capacitor **76** and neon tube **78** to one output terminal of the flip-flop circuit **67**. The neon tube **78** serves to reduce the output potential of the flip-flop to a suitable level for use by the cathode follower. This is a necessary expedient in the circuit of FIG. 2 which utilizes a single power supply of 300 volts since most flip-flop circuits which use a 300 volt supply provide an output voltage, the level of which is too positive for use with the cathode follower circuit shown. Of course, under other circumstances when other power supply arrangements are used, then the neon tube **78** and capacitor **76** circuit may be omitted and the control grid of the tube **68** may be coupled, in effect, directly to the output of the flip-flop. The cathode follower circuit coupled to the other set of switching electrodes may be identical to that described above.

In operation of the circuit of FIG. 2, it is assumed that the orientation of the electric and magnetic fields is such that the normal tendency of an electron beam is to move in order from positions "0" to "1" to "2," etc., to "9" and then to "0" again. An electron beam is cleared and reset in the following manner. A pulse **46** from the oscillator **44** is applied to the spade buss **40** and the negative portion **48** reduces the potential of the spades **16** to about cathode potential, and this renders the tube **10** unable to sustain an electron beam at any one of its positions, and the beam is cleared. Immediately thereafter, the positive portion **50** of the pulse drives the spade buss and the spade electrodes positive toward their normal operating potentials. However, the rise in potential at the "0" spade is comparatively slow as a result of the time constant of the resistor **38'**-capacitor **58** network. Thus, the "0" spade is at a lower potential than any of the other spades for a short time, and an electron beam forms on the target at the "0" position. At the same time, since the "1" spade has been driven positive by the pulse **46** through the diode **60**, there is substantially no opportunity for the electron beam to switch immediately to the "1" position.

According to the invention, the circuit of FIG. 2 operates as a counter having a high switching speed in the following manner. In normal beam switching tube counting operation, when a switching grid is at a certain positive potential with respect to the other electrodes of the tube, the grid cannot cause an electron beam to switch from one position to the next. If the potential of a grid is reduced sufficiently below the other electrodes, switching can take place. In addition, as the flip-flop operates, at any one instant it applies a positive pulse to one cathode follower whose current flow increases and a negative pulse to the other cathode follower whose current flow decreases. As the current flow of the one cathode follower increases, its cathode becomes more positive and the switching grid to which it is connected becomes more positive and the grid cannot cause beam switching. As the current flow of the other cathode follower decreases, its cathode becomes more negative as does the switching grid to which it is coupled, and normal beam switching takes place. Referring to the circuit of FIG. 2 and the operation of the invention, the target resistors **30** have a higher resistance value than that usually employed and the magnitude of resistance and the target load line are such that, when beam current flows to a target, the target voltage is reduced to a low level at which the target operates on an unstable portion of its characteristic curve below the knee as shown in FIG. 3. Since the target is operating at this low voltage, it is unable to collect all of the electrons in the electron beam. Thus, some of the electrons tend to flow to the spade electrode at the adjacent leading position. However, with the corresponding grid maintained at a positive potential by its cathode follower in the high conduction state, the grid is able to draw off excess electrons which cannot be collected by the target. Since the switching grid looks into a low impedance as represented by the cathode follower, it is able to draw current without experiencing any appreciable reduction in its potential and without itself causing beam switching. Thus, the instability of each target is overcome, as is the tendency of the beam to switch to the next position, and the beam may be maintained at a position substantially indefinitely.

However, when it is actually desired to switch the beam, the switching is aided by the above-described instability as follows. The flip-flop 67 applies a negative pulse to the appropriate cathode follower and its current flow is reduced. Thus, a negative pulse is coupled to the appropriate switching grid and normal beam switching occurs. This switching operation is aided by the normal instability of the target in question, and the speed of switching is thus increased and may take place in less than one microsecond. The high-speed switching achieved by the present invention is also effective over a wide range of power supply voltages extending from about 200 volts positive to about 400 volts positive. Thus, a single unregulated power supply is suitable to operate the circuit.

What is claimed is:

1. An electronic switching circuit including a multi-position electron beam switching tube having a cathode and a plurality of groups of electrodes to each of which an electron beam may flow; each group including a target electrode which receives an electron beam and produces an output signal therefrom, a spade electrode adapted to form and hold an electron beam on its associated target electrode, and a switching electrode which serves to switch an electron beam from one group of electrodes to the next; said switching electrodes being connected in two sets with alternate electrodes being in the same set; a load impedance coupled to each target electrode through which output current flows when an electron beam flows to a target electrode, said load impedance having a relatively large value of resistance, larger than that which would normally be employed for stable operation of each position of the tube, so that when current flows therethrough, the potential of the associated target electrode drops to a relatively low value at which the target would be unable to collect all of the current available in an electron beam and some of the excess current which is not collected by a target electrode would flow to the leading spade electrode and thus cause the electron beam to switch involuntarily to the leading position; drive circuit means coupled to the switching electrode at each position in said tube for removing excess electrons which cannot be collected by a target electrode to which an electron beam is flowing and which is thus at a relatively low potential, each position and each target electrode thus being rendered stable and not subject to involuntary switching of an electron beam; and a pulse source coupled to said drive circuit means and adapted to energize said drive circuit means and cause it to apply switching potentials to said switching grid electrodes whereby the desired switching of an electron beam is effected.

2. The circuit defined in claim 1 wherein said drive circuit means comprises a low impedance, relatively high potential source coupled to the switching electrode at each position in said tube for removing excess electrons which cannot be collected by a target electrode to which an electron beam is flowing and which is thus at a relatively low potential.

3. The circuit defined in claim 1 wherein said drive circuit means includes a pair of cathode follower amplifiers having a low output impedance and having the outputs thereof each connected to one set of switching grid electrodes.

4. The circuit defined in claim 1 wherein said drive circuit means includes a pair of cathode follower amplifiers each having a cathode load resistor coupled to one set of switching electrodes whereby in one mode of operation excess electrons may be absorbed from a position to which an electron beam is flowing in the beam switching tube and in another mode of operation a switching pulse may be applied to a switching electrode at the position to which a beam is flowing.

5. The circuit defined in claim 1 wherein each set of switching electrodes includes auxiliary circuit means coupled thereto for alternately applying successively to said switching electrodes relatively high positive potentials, at which a switching electrode is able to collect electrons and promote target stability, and considerably lower potentials at which an electron beam is caused to switch.

6. The circuit defined in claim 1 wherein said drive circuit means includes auxiliary circuit means for operating said switching electrodes in two electrical states such that when a switching electrode is in one electrical state it is able to render its corresponding target stable and thereby prevent undesired switching of an electron beam from that target and when a switching electrode is in the other electrical state it causes an electron beam to switch from its corresponding target aided by the instability of that target.

7. The circuit defined in claim 1 wherein drive circuit means includes two cathode follower amplifiers each comprising an electron discharge device having an anode, a cathode, and a control grid; a cathode load resistor coupled to each cathode of the two cathode follower amplifiers and to one set of switching electrodes; the anode of each discharge device being connected to a positive power supply; said pulse source being coupled to said cathode follower amplifiers for turning them on separately and thus causing a switching electrode to which it is coupled to cause an electron beam to switch from one group of electrodes to another and, when turned on, causing a switching electrode to collect electrons and thus counteract the tendency of its associated target to be unstable whereby undesired beam switching is prevented; each cathode follower amplifier, when turned off, representing a high impedance to the set of switching electrodes to which it is coupled and, when turned on, representing a low impedance to the same set of switching electrodes.

8. The circuit defined in claim 7 wherein said pulse source comprises a flip-flop circuit having two output connections.

9. A counter circuit including an electron beam switching tube having a cathode and a plurality of groups of electrodes; each group including a target electrode which receives an electron beam and produces an output signal therefrom, a spade electrode which holds an electron beam on its associated target electrode, and a switching electrode which serves to switch an electron beam from one group of electrodes to the next; means connecting said switching electrodes in two separate groups with adjacent electrodes being in different groups; and a driver circuit for said beam switching tube; said driver circuit including a flip-flop circuit having two output connections, a pair of cathode follower circuits each having input and output connections, the input of each cathode follower circuit being coupled to one of the outputs of the flip-flop, and the output of each cathode follower being connected to one of the groups of switching electrodes, each cathode follower circuit presenting a low input impedance to said switching electrodes whereby said switching electrodes are able to draw current and overcome any tendency of a target to be unstable due to the presence of excess electrons.

10. A counter circuit including an electron beam switching tube having a cathode and a plurality of groups of electrodes; each group including a target electrode which receives an electron beam and produces an output signal therefrom, a spade electrode which holds an electron beam on its associated target electrode, and a switch-

ing electrode which serves to switch an electron beam from one group of electrodes to the next; means connecting said switching electrodes in two separate groups with adjacent electrodes being in different groups; and a driver circuit for said beam switching tube; said driver circuit including a flip-flop circuit coupled to two cathode follower amplifiers, the cathode follower amplifiers being connected one to each group of switching electrodes, each cathode follower circuit presenting a low input impedance to said switching electrodes whereby said switching electrodes are able to draw current and overcome any tendency of a target to be unstable due to the presence of excess electrons.

11. The circuit defined in claim 9 wherein said cathode follower circuits are adapted to apply alternately positive-going and negative-going signals to said switch-

ing electrodes whereby a switching electrode having a positive-going signal applied thereto is able to draw current without having its potential significantly altered so that its target electrode which receives current is rendered stable and undesired beam switching is prevented, each switching electrode also being adapted when a negative-going signal is applied thereto to switch an electron beam from its associated target electrode to another target electrode.

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