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DIGITAL-TO-ANALOG CONVERTERS

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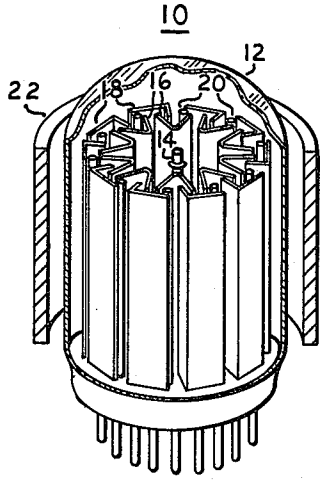


Fig. 1

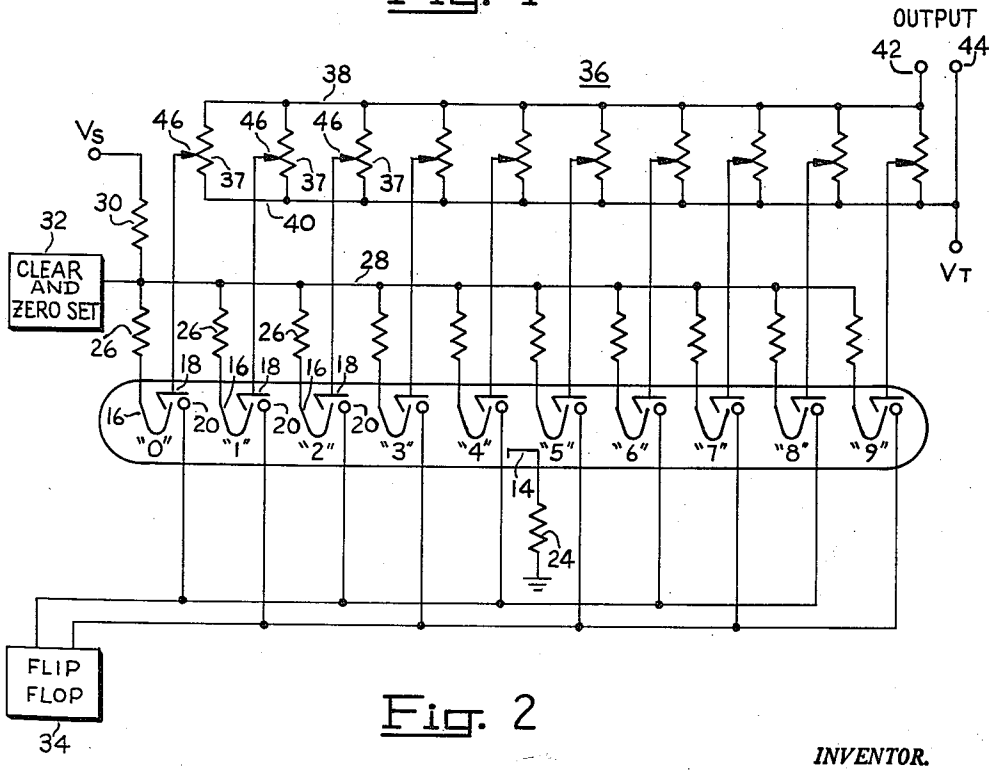


Fig. 2

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This invention relates to signal conversion circuits and patricularly to circuits for digital-to-analog signal conversion.

The present invention is particularly adapted for use with a multiple output electron discharge counting device and provides a separate analog output signal at each output position of the device. These separate output signals are available at a single pair of output terminals having a constant output impedance and each output is independently adjustable without affecting any of the others.

Although there are many circuits known for performing digital-to-analog conversions, none of these includes the features of or provides the functions and advantages of the present invention.

The objects of the present invention are concerned with the provision of an improved signal conversion circuit and, particularly, the provision of an improved digital-to-analog conversion circuit.

Briefly, a circuit embodying the invention utilizes a multiple output electron discharge device which includes, among other electrodes, a single cathode and a plurality of output electrodes. The output electrodes provide consecutive output current signals of constant amplitude. The output electrodes are coupled to an output circuit which comprises a network of parallel-connected tapped load resistors, each of which includes two end terminals and an adjustable tap. One end terminal of each resistor is connected to a first common buss, and the other end of each resistor is connected to a second common buss. The variable tap on each resistor is connected to one of the output electrodes of the multiple output device. The busses, between which the load reisistors are connected, are coupled to output terminals between which the output voltages, generated by current flow to each output electrode, appear.

In operation of the circuit, each time the discharge device performs a counting operation under the influence of an input digital signal, a corresponding analog voltage is generated across the appropriate output load resistor and appears at the output terminals of the resistor network. The magnitude of the analog voltage at each position depends on the setting of the load resistor at that position. The analog voltage generated at each position may be varied by changing the resistor setting. The setting of each resistor and the analog voltage developed are substantially independent of all of the others, and each resistor may be set independently to provide a desired analog voltage without affecting the analog voltages generated at any of the other load resistors.

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

FIG. 1 is a perspective view of a multiple output electron discharge device utilized in the present invention; and

FIG. 2 is a schematic representation of the device of FIG. 1 and a circuit in which it is operated according to the invention.

Referring to FIG. 1, an electron discharge device which may be used in practising the present invention is of the type shown in U.S. Patent No. 2,721,955 to Fan et al. This type of tube 10 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 and a constant current is obtained from each 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 in schematic, linear form with the positions or groups of electrodes thereof numbered serially from "0" to "9." In the circuit, the cathode 14 is connected through a suitable resistor 24 to ground. Each of the spade electrodes 16 is coupled through a spade load resistor 26 to a spade buss 28. The spade buss 28 is coupled through a common spade resistor 30 to a suitable positive D.C. power supply V_S. A suitable zero-set circuit 32 for clearing an electron beam in the tube and resetting it at the "0" position is coupled to the spade buss and the spade electrode at the "0" position. A typical zero-set circuit operates by first reducing the potential of the spade buss to a level at which a beam cannot be maintained at any position and then holding the "0" spade at a lower voltage level than the other spades until a beam forms at the "0" position.

The switching grid electrodes 20 may be connected in several different ways. In one arrangement, shown in FIG. 2, the grids at the even-numbered positions are connected together in one set and the grids at the odd-numbered positions are connected together in another set. Each set of grids is then connected to one of the outputs of a suitable flip-flop circuit 34. As first one and then the other output of the flip-flop operates, the beam is moved from position to position in the tube.

According to the invention, the targets 18 are connected to an output circuit 36 as follows. The output circuit comprises a network made up of ten tapped load resistors 37 connected in parallel, one resistor for each output target electrode 18. One end of each resistor 37 is connected to a first buss 38, and the other end of each resistor is connected to a second buss 40. The first buss is provided with a first output terminal 42, and the second buss is provided with a second output terminal 44 and is coupled to a suitable positive D.C. power supply V_T. Output voltages are developed across each load resistor and between the two output terminals 42 and 44. An adjustable tap 46 on each resistor is connected to one of

the target electrodes in the tube. Thus, each target is provided with an adjustable or variable load resistor.

In operation of the circuit of FIG. 2, an electron beam in the tube **10** is switched from position to position by the operation of the flip-flop circuit **34**. As the beam flows to each position, output current flows from the target electrode at the position through a load resistor **37**. The output voltage which is developed across the variable resistor coupled to each output electrode depends on the setting of the adjustable tap **46**. The setting of each resistor is independent of all of the others, and the current flow through each and the output voltage developed across each one do not affect any of the others. Thus, the circuit of the invention provides a series of different, independent output pulses at the output terminals.

In using the circuit of FIG. 2 as a digital-to-analog converter, the tube **10** is caused to execute a counting operation in response to a digital input signal. Thus, for example, a digital "six" input signal causes an electron beam in the tube to count to the "6" position. The resultant output voltage generated across the variable load resistor **37** coupled to the target **18** at the "6" position and appearing at the output terminals **42** and **44** of the resistor network is the equivalent analog output voltage of the digital "six." Subsequently, if the load resistor at the "6" position is changed, the resultant analog voltage for a digital "six" count will have a different value. Thus, the analog voltage generated across each load resistor may be varied. However, any such variation is achieved without affecting any of the other loads and without affecting the characteristic output impedance of the network.

What is claimed is:

1. A signal generating circuit including a multiple output electron discharge device having a cathode for generating an electron beam and electrode means for switching an electron beam sequentially through a plurality of positions in said device,

a plurality of output electrodes in said discharge device each of which is adapted to receive an electron beam from said cathode and provide an output signal when an electron beam flows thereto,

a plurality of impedances connected in parallel in a network,

each impedance having an adjustable tap with each tap being coupled to one output electrode so that when an electron beam flows to an output electrode, output current therefrom flows through a tap and a portion of an impedance,

a pair of output terminals provided on said network and coupled each to one end of each of said impedances, the output current from each output electrode providing an output potential at said output terminals,

the amplitude of the output potential provided by each output electrode depending on the setting of the tap on the impedance coupled thereto,

the impedance looking into said terminals being substantially constant whatever the settings of said adjustable taps.

2. The circuit defined in claim 1 wherein said impedances comprise adjustable resistors.

3. A signal generating circuit including a multiple output electron tube having a central cathode and a plurality of groups of electrodes surrounding said cathode,

each group of electrodes comprising a position to which an electron beam may flow from said cathode,

each of said groups of electrodes including a target output electrode from which an output signal flows and a spade electrode which forms and holds an electron beam on its target electrode,

a plurality of load resistors connected in parallel to form a network,

a pair of output terminals coupled to said network with each terminal coupled to one end of each resistor, each resistor having an adjustable tap coupled to a separate one of said target electrodes so that when an electron beam flows to a target electrode, output current flows through a tap and a portion of one of said resistors and provides an output potential at said output terminals,

the amplitude of the output potential provided by each output electrode depending on the setting of the tap on the resistor coupled thereto, the impedance looking into said terminals being substantially constant regardless of the settings of said adjustable taps.

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