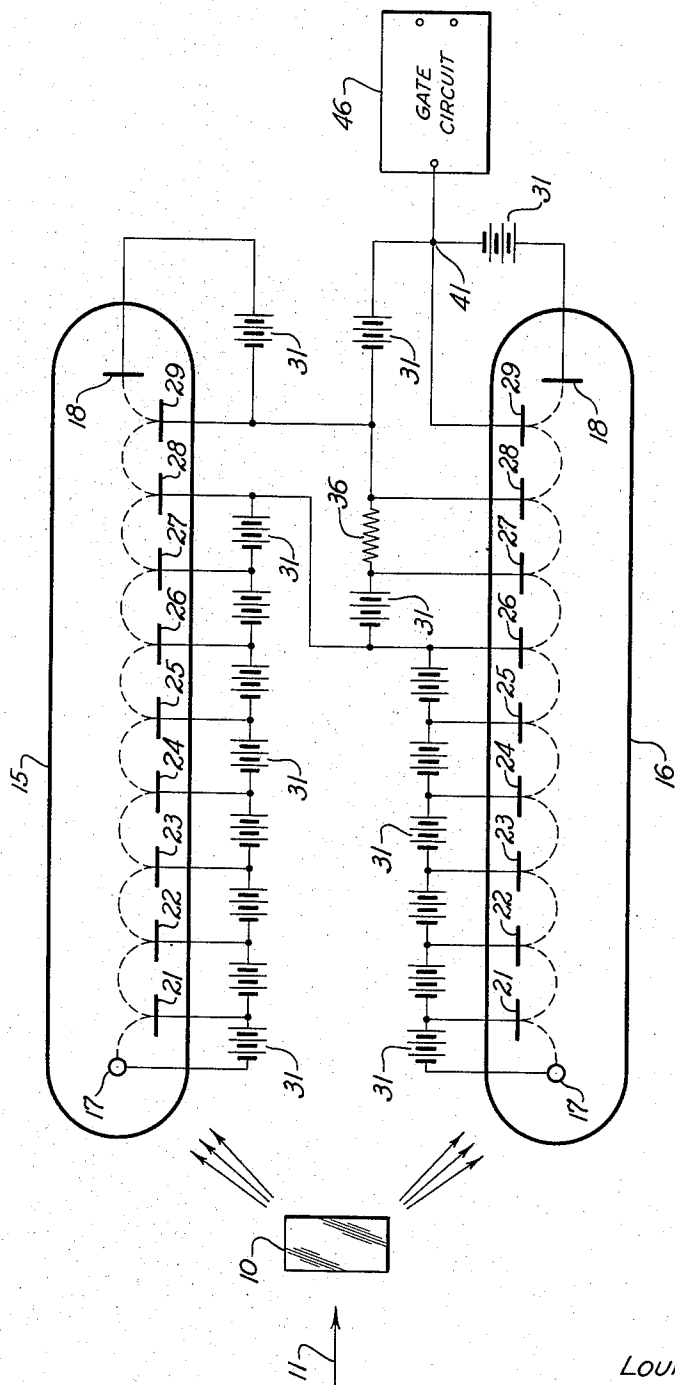


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PHOTO-MULTIPLIER CIRCUIT

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PHOTO-MULTIPLIER CIRCUIT

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This invention relates to an electronic circuit and more particularly to a photo-multiplier circuit useful as a scintillation counter.

Scintillation counters have been found useful in nuclear research since the earlier phases of such work. Experiments with fluorescent materials have been continuing and with the discovery of such materials having high intensity light pulses with very short resolving times it has become necessary to improve the resolving time of the counting circuits. For example, with a material such as trans-stilbene a high intensity light pulse having a resolving time in the order of 5×10^{-9} second is produced by bombardment of the material with charged particles. Comparing this resolving time with that of a conventional photo-multiplier and amplifier arrangement, which is in the proximity of $.25 \times 10^{-6}$ second, the need of a new and improved circuit is readily apparent.

In order to obtain a circuit for use with fluorescent materials having short resolving times the present invention utilizes a pair of photo-multiplier tubes with electrodes thereof interconnected in such a manner that the output of one controls the output of the other when the inputs to both are from a common source. The output of the second tube is then available to trigger a gate circuit which in turn may be connected to a recording device or an oscilloscope. It will be readily apparent that many of the disadvantages of a single photo-multiplier circuit, such as random output pulses due to thermionic emission in the tubes and release of electrons at the cathode of one tube by bombardment, are eliminated.

It is therefore an object of the present invention to provide a new and improved photo-multiplier tube arrangement.

Another object of the present invention is to provide a pair of photo-multiplier tubes positioned to receive light from a single source and having electrodes thereof interconnected so that the output of one tube controls the output of the other tube.

Still another object of the present invention is to provide a pair of photo-multiplier tubes having electrodes interconnected to trigger a gate tube only when both photo-multiplier tubes are exposed to a common source of light.

A further object of the present invention is to provide a photo-multiplier tube circuit having an improved resolution time for handling pulses of very short duration.

A still further object of the present invention is to provide a photo-multiplier tube circuit free

of spurious responses to emission occurring in one tube only.

Further objects and advantages will be apparent from the following description and claims considered together with the accompanying drawing which illustrates a schematic wiring diagram of the invention.

Referring to the drawing in detail there is shown a light source 10 which may be a fluorescent material, such as trans-stilbene, which fluoresces upon excitation by bombarding charged particles, represented by an arrow 11. Positioned to receive light from the source 10 are a pair of similar nine-stage photo-multiplier tubes 15 and 16, each of which has a cathode 17, an anode 18 and nine intermediate electrodes, or dynodes, 21, 22, 23, 24, 25, 26, 27, 28, and 29 (consecutively numbered on the drawing from the cathode 17 to the anode 18). From the following it will be appreciated that photo-multiplier tubes having more or less than nine stages may be readily used. To supply operating potentials to the tube 15 a source of unidirectional voltage 31 is connected between the cathode 17 and the dynode 21, a similar source 31 is connected between each of the dynodes 21, 22, 23, 24, 25, 26, 27, and 28 of the next seven stages, and a similar source 31 is connected between the last dynode 29 and the anode 18. In the form of the invention shown in the drawing the sources 31 have been illustrated as a series of batteries which will amply serve the purposes of the invention; however, it will be readily apparent that a single source of unidirectional voltage connected across a series of resistors which suitably divide the voltage may be used. Somewhat similarly, the operating potentials for the tube 16 are supplied to the elements thereof; that is, a voltage source 31 is connected between the cathode 17 and the dynode 21, between each of the dynodes 21, 22, 23, 24, 25, 26, and 27 of the next six stages, between the dynodes 28 and 29 and between the dynode 29 and the anode 18. Interconnections between the two tubes 15 and 16 are provided by connecting the dynode 28 of the tube 15 to the dynode 26 of the tube 16 and the dynode 29 of the former tube to the dynode 28 of the latter tube. A further connection of the tube 16 is made by connecting one end of a resistor 36 to the dynode 27 and the other end to the dynode 28. The action of the resistor 36 in the circuit will be more fully set forth hereinafter.

To utilize the circuit just described a connection 41 is made at the dynode 29 of the tube 16

and this connection 41 may be connected to the input terminal of an external circuit, such as a conventional gate circuit 46 illustrated in block form on the drawing. The output of the gate circuit is then available for connection to a recording device or an oscilloscope (not shown).

Now consider the operation of the invention arranged and connected in the above-described manner. The stream of charged particles 11 directed to strike the fluorescent material 10 causes scintillation. Because of the position of the photo-multiplier tubes 15 and 16 with respect to the fluorescent material 10, the light of the scintillations falls upon both of the cathodes 17 of the tubes resulting in photo-emission therefrom. The theory of operation of a photo-multiplier tube may be found in any textbook covering the art of phototubes, for example, pages 514-516 of *Theory and Applications of Electron Tubes* by Reich, first edition, 1939. The potential of the sources 31 applied to the dynodes 21 to 28 of the tube 15 causes the emission to progressively travel from the cathode 17 to the successive dynodes, the emission increasing at each stage. A potential exists between dynodes 28 and 29 by reason of the source 31 and resistor 36 connected serially therebetween. Thus the emission continues its travel from dynode 28 to 29 and finally to the anode 18 of the tube 15. Similarly the emission from the cathode 17 of the tube 16 is amplified progressively to the dynode 27. It will be noted that there is no source 31 of potential connected between the dynodes 27 and 28, but that the resistor 36 is connected therebetween. In order for electrons to travel from dynode 27 to dynode 28 it is necessary that a voltage of sufficient magnitude exist between them and this voltage is dependent, in this instance, upon the current flow through the resistor 36. Considering again the action taking place in tube 15, it is seen that when the electron emission reaches dynode 29 of the tube, a current drain occurs from the respective potential source 31 through the resistor 36 thereby establishing a potential thereacross. Since dynode 29 of the tube 15 is the last stage thereof, the emission has reached its maximum amplification and the potential across the resistor 36 biases the dynode 28 of the tube 16 to attract the emission of this latter tube from dynode 27. The emission from dynode 28 of the tube 16 is then attracted to the dynode 29. By connecting the dynode 29 to the input of a gate circuit 46 the gate circuit is triggered and an output voltage occurs. As stated previously the output voltage of the gate circuit 46 may be connected to a recording device or an oscilloscope as desired.

From the foregoing it is readily apparent that it is necessary for photo-emission to occur simultaneously at the cathodes 17 of both tubes thereby eliminating any spurious emission which occurs in one tube only. It can also be seen that, by using one photo-multiplier tube to render a second photo-multiplier tube operative, a well defined pulse of voltage at the output of the second tube is obtained, both as to pulse rise and pulse cut off, thereby improving the resolution.

While the salient features of the invention have been described in detail with respect to one embodiment it will, of course, be apparent that numerous modifications may be made within the spirit and scope of the invention and it is therefore not desired to limit this invention to the exact details shown except insofar as they may be defined in the following claims.

What is claimed is:

1. In a photo-multiplier tube circuit, the combination comprising a source of light pulses, a first and a second photo-multiplier tube disposed adjacent said source of light to receive light pulses therefrom, each of said tubes having a cathode, an anode, and a plurality of intermediate dynodes, means connected between a pair of dynodes of said first tube for developing a voltage proportional to the current flow between said pair of dynodes, a portion of said means being connected between a pair of dynodes of said second tube, and voltage supply means connected to the other electrodes of said first and second tubes to furnish operating voltages thereto, whereby the amplified emission in said first tube is utilized to bias a dynode of said second tube to further amplify the emission in said second tube.
2. In a photo-multiplier tube circuit, the combination comprising a source of light pulses, a first and a second photo-multiplier tube disposed adjacent said source of light to receive light pulses therefrom, each of said tubes having a cathode, an anode, and a plurality of intermediate dynodes, means connected between the final two dynodes of said first tube for developing a voltage proportional to the current flow between said final two dynodes, a portion of said means being connected between an adjacent pair of dynodes of said second tube which precede the final dynode thereof, and voltage supply means connected to the other electrodes of said first and second tubes to furnish operating voltages thereto, whereby the amplified emission in said first tube is utilized to bias a dynode of said second tube to further amplify the emission in said second tube.
3. In a photo-multiplier tube circuit, the combination comprising a source of light pulses, a first and a second photo-multiplier tube disposed adjacent said source of light to receive light pulses therefrom, each of said tubes having a cathode, an anode, and a plurality of intermediate dynodes, a series circuit including a source of voltage and a resistor connected between the final two dynodes of said first tube, said source of voltage being connected between two adjacent dynodes of said second tube, said resistor being connected to a third dynode of said second tube which is adjacent to the pair connected to the voltage source, voltage supply means connected to the other electrodes of said first and second tubes to furnish operating voltages thereto, and an output lead connected to the final dynode of said second tube for connection to an external circuit.
4. In a photo-multiplier tube circuit, the combination comprising a source of light pulses, a first and a second photo-multiplier tube disposed adjacent said source of light to receive light pulses therefrom, each of said tubes having a cathode, an anode, and a plurality of intermediate dynodes, a series circuit having a first portion and a second portion connected between the final two dynodes of said first tube, said first portion supplying a flow of current through said second portion when emission occurs in said first tube, said first portion also being connected between a pair of adjacent dynodes of said second tube, said second portion being connected to a third dynode adjacent said pair of dynodes in said second tube, whereby the voltage across said second portion due to current flow there-through is impressed, and voltage supply means

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connected to the other electrodes to furnish operating voltages thereto, whereby the amplified emission in said first tube is utilized to bias a dynode of said second tube to further amplify the emission in said second tube.

5. In a photo-multiplier tube circuit, the combination comprising a source of light pulses, a first and a second photo-multiplier tube disposed adjacent said source of light to receive light pulses therefrom, each of said tubes having a cathode, an anode, and a plurality of intermediate dynodes, a series circuit including a source of voltage and a resistor connected between the final two dynodes of said first tube, said source of voltage being connected between two adjacent dynodes of said second tube, said resistor being connected to a third dynode of said second tube which is adjacent to the pair

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connected to the voltage source, voltage supply means connected to the other electrodes of said first and second tubes to furnish operating voltages thereto, and a gate circuit connected to the final dynode of said second tube, whereby said gate circuit is triggered only when a light pulse causes simultaneous emission in both tubes.

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