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L. F. WOUTERS

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PHOTOMULTIPLIER TUBE CIRCUIT

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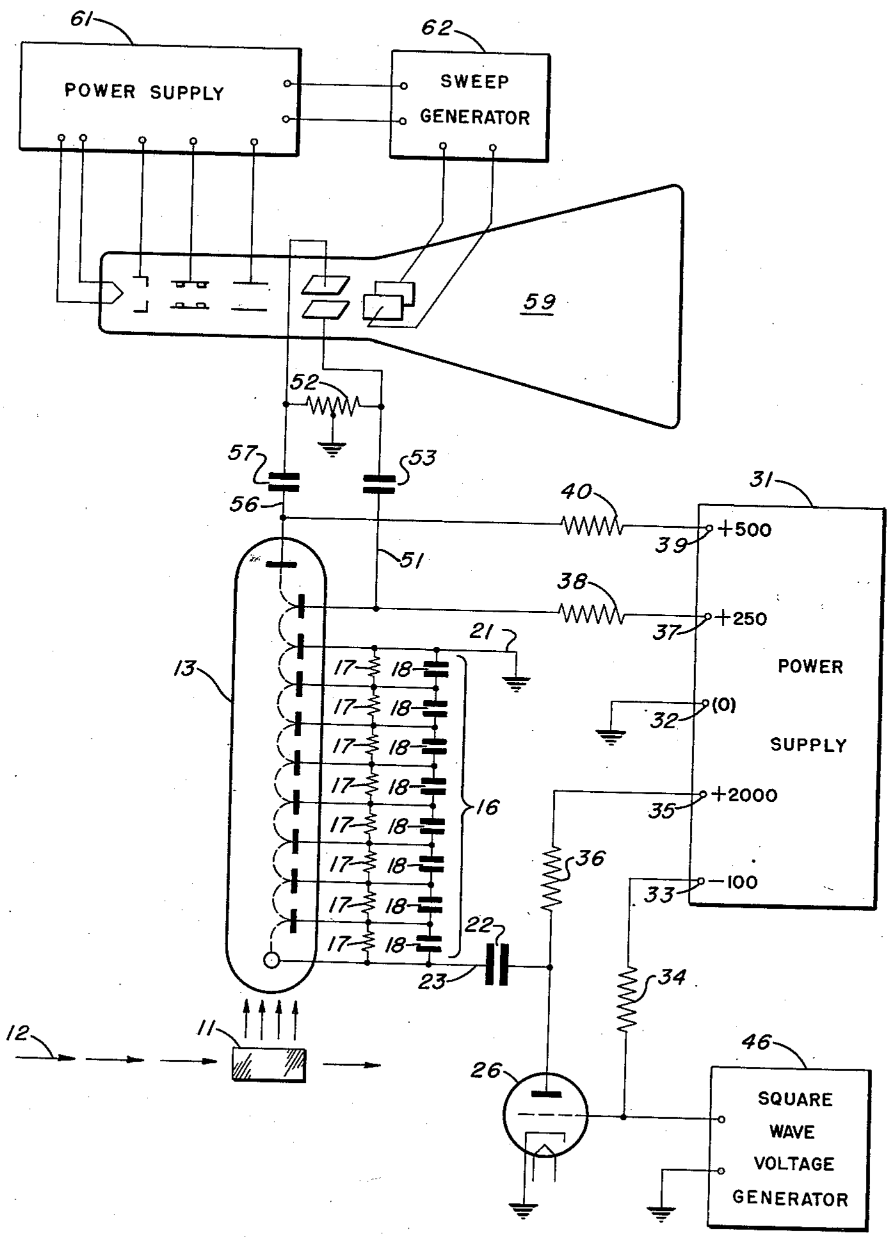

INVENTOR.
LOUIS F. WOUTERS

BY

Roland A. Anderson

ATTORNEY.

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PHOTOMULTIPLIER TUBE CIRCUIT

Louis F. Wouters, Oakland, Calif., assignor to the United States of America as represented by the United States Atomic Energy Commission

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This invention relates to a photomultiplier tube circuit and more particularly to a method and apparatus for increasing the output of a photomultiplier tube.

In many circuits utilizing photomultiplier tubes it is necessary to amplify the output of such tubes so that they may be applied to auxiliary circuits. Thus, if the source of light is faint, the electron multiplication of the photomultiplier tube may be insufficient to raise the output to a readily useful level requiring expensive, as well as, extensive amplifier circuits. In some instances the desire to maintain the pulse shape and resolution time of the output requires additionally complex pulse forming and shaping amplifiers.

The present invention provides a photomultiplier tube circuit which overcomes the above-outlined difficulties by operating the photomultiplier tube at voltages many times the normal operating voltages for such tube. The foregoing is made practical by pulsed operation which prevents deleterious overloading of the photomultiplier tube.

It is therefore an object of the present invention to provide a new and improved photomultiplier tube circuit.

Another object of the invention is to provide a photomultiplier tube circuit which may directly drive an auxiliary circuit.

Still another object of the invention is to provide a photomultiplier tube circuit having a pulsed power supply therefor to provide greater amplification through such tube.

A further object of the invention is to provide a photomultiplier tube circuit which is simple in construction and which eliminates the necessity of amplifiers in the output circuit.

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

Referring to the drawing in detail there is provided a source of light, such as a scintillation crystal 11, placed in the path of a beam of charged particles 12. Disposed adjacent the crystal 11 is a photomultiplier tube 13 in such position that light from the crystal falls upon the light-sensitive cathode of the tube. The photomultiplier tube 13, as illustrated in the drawing, has nine dynodes disposed between the cathode and anode and it will be readily apparent that other types of photomultiplier tubes may be substituted. A voltage divider 16, com-

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prising a plurality of similar resistors 17 and similar capacitors 18, is connected between the cathode and penultimate dynode with intermediate connections thereof connected to the first seven dynodes, so that a resistor and a capacitor are parallel-connected between each of such electrodes. In the present embodiment of the invention the penultimate dynode is connected directly to ground by a lead 21 while the cathode is connected to one side of a storage capacitor 22 by a lead 23. The other side of the capacitor 22 is connected to the anode of a triode type tube 26, the cathode of which is grounded.

As a means for supplying unidirectional voltage to the photomultiplier tube 13 there is provided a conventional power supply 31 having a plurality of output voltages. For purposes of illustration the values of such output voltages will hereinafter be numerically identified by the voltage existing with respect to a grounded terminal 32, but should not be understood as limiting the circuit to the exact voltages set forth. A negative terminal 33 having a value of −100 volts is connected to the control grid of the tube 26 through a biasing resistor 34. A positive terminal 35 having a value of +2000 volts is connected through a dropping resistor 36 to the anode of the tube 26 to supply operating voltage thereto and also a charging voltage to the capacitor 22. A second positive terminal 37 having a value of +250 volts is connected to the final dynode of the tube 13 to supply a suitable operating potential thereto through a dropping resistor 38. A third positive terminal 39 having a value of +500 volts is connected to the anode of the tube 13 through a dropping resistor 40 to supply a suitable operating potential thereto.

It will be seen that with the power supply 31 suitably energized that the capacitor 22 will become charged to the value of the power supply terminal 35, that is +2000 volts, but that the side of the capacitor connected to the cathode of the tube 13 is at ground potential. Now, if the positively charged side of the capacitor 22 is suddenly connected to ground, the voltage of the cathode of the tube 13 will be effectively lowered to a value of −2000 volts which will be evenly distributed across the resistors 17 to ground. Thus the photomultiplier tube 13 will be operative to pass electrons between the cathode and anode by way of the dynodes upon activation of the cathode by light striking thereon. To accomplish such mode of operation a square wave voltage generator 46 of conventional design and having an output sufficient to overcome the negative grid bias of the tube 26 is connected between the control grid and cathode thereof. The duration of the square wave output of the generator 46 should be short as compared to the time constant of the capacitor 22 and the resistance of the resistors 17 so that the high voltage across the elements of the photomultiplier tube will not be damaged by prolonged overvoltage. The repetition rate of the generator 46 is not critical, but should be sufficiently rapid to energize the circuit for each scintillation of the crystal 11 in the present embodiment of the invention and still have an average value which is not in excess of the voltage rating of the tube 13.

The output of the photomultiplier tube 13 may be taken from between the final dynode and anode thereof and will be of sufficient magnitude to directly drive an auxiliary circuit. As illustrated in the drawing a lead 51 is connected to the final dynode of the tube 13 and coupled to one end of a center-grounded resistor 52 by a capacitor 53. A lead 56 is similarly connected to the anode of the tube 13 and coupled to the other end of the resistor 52 by a capacitor 57. Thus a push-pull voltage is developed across the resistor 52 which may then be impressed between the vertical deflecting plates of an oscilloscope 59. The oscilloscope 59 is equipped with a power supply 61 to energize the electron gun and to energize the sweep generator 62 which is in turn connected to the horizontal deflecting plates.

Now consider the operation of the present invention, as described above, with the power supplies 31 and 61 and the square wave generator 46 suitably energized. Under such condition a square wave of voltage at the output of the generator 46 renders the triode tube 26 conductive to ground the positively charged side of the capacitor 22. Thus the cathode of the photomultiplier tube 13 is biased to —2000 volts. Such voltage difference with respect to ground is evenly divided across the voltage divider 16 so that each successive electrode of the tube 13 is substantially 250 volts more positive than the preceding electrode. The particular type of photomutliplier tube 13 selected for purposes of the description has a maximum rated voltage difference between successive electrodes of approximately 150 volts. It is thus seen that the voltage of the electrodes of the tube 13 is in excess of the rated value so it is necessary to maintain a repetition rate of the generator 46 at such a value that the average voltage of the electrodes does not exceed the maximum rated voltage.

While the voltages of the electrodes of the tube 13 render the tube operative a charged particle striking the crystal results in light reaching the cathode of the tube. Such light at the cathode frees electrons which are accelerated at greater than the normal rate to the first dynode because of the higher voltage. Since secondary emission is directly proportional to the acceleration of the electron striking, it will be seen that a greater than normal number of secondary electrons will result at the first dynode and be attracted to the second dynode. Each of the successive dynodes and the anode are similarly biased so that the electron flow between the final dynode and the anode is much larger than would exist under the condition of rated voltages applied to the tube 13. By coupling the final dynode of the tube 13 to one side of the center-grounded resistor 52 by the capacitor 53 and the anode to the other side of the resistor 52 by the capacitor 57 the unidirectional voltages at such electrodes are blocked and only the varying voltage caused by the electron flow is passed. Such varying voltage establishes a push-pull voltage across the resistor 52 and thereby causes deflection of the electron beam of the oscilloscope 59. Thus a pattern of the magnitude and duration of the light scintillation at the crystal 11 is formed on the screen of the oscilloscope 59.

From the foregoing it will be readily apparent that any desired light source may be utilized in the position of the crystal 11. It will also be readily understood that numerous types of loads may be connected to the output of the photomultiplier tube to be driven thereby, in the place of the oscilloscope 59.

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

What is claimed is:

1. In a photomultiplier tube circuit, the combination comprising a source of light, a photomultiplier tube having an anode, a plurality of dynodes, and a cathode with substantially low values of operating voltages, said tube being disposed adjacent said source to receive light therefrom, a voltage divider having a plurality of equally spaced taps connected between the penultimate dynode and said cathode with the taps respectively connected to the dynodes, said penultimate dynode being connected to ground, said cathode being connected to a storage capacitor, power supply means having a grounded terminal, a positive terminal connected to said capacitor for charging the capacitor to a high value of voltage, and terminals connected to said anode and penultimate electrode for impressing suitable biasing voltages, and means connected to the power supply side of said capacitor for intermittently grounding said capacitor to apply high potentials to said dynodes with respect to said substantially low values of operating voltages.

2. In a photomultiplier tube circuit, the combination comprising a source of light, a photomultiplier tube having an anode, a plurality of dynodes, and a cathode with substantially low values of operating voltages, said tube being disposed adjacent said source to receive light therefrom, a voltage divider having a plurality of equally spaced taps connected between the penultimate dynode and said cathode with the taps respectively connected to the dynodes, said penultimate dynode being connected to ground, said cathode being connected to a storage capacitor, power supply means connected to said capacitor and to said anode and penultimate electrode, a triode tube having an anode, control grid, and cathode with the anode thereof connected between said capacitor and power supply and the cathode thereof connected to ground, means for applying a negative voltage to the control grid of said triode tube, and a square wave generator connected to the control grid of said triode tube for intermittently rendering said triode tube conductive.

3. In a photomultiplier tube circuit, the combination comprising a source of light, a photomultiplier tube having an anode, a plurality of dynodes, and a cathode with substantially low

values of operating voltages, said tube being disposed adjacent said source to receive light therefrom, a voltage divider having a plurality of equally spaced taps connected between the penultimate dynode and said cathode with the taps respectively connected to the dynodes, said penultimate dynode being connected to ground, said cathode being connected to one side of a storage capacitor, power supply means connected to the other side of said capacitor, to said anode, and to said penultimate electrode, and electronic switching means connected to the junction between said capacitor and said power supply for recurrently grounding said capacitor.

4. In a photomultiplier tube circuit, the combination comprising a source of light, a photomultiplier tube having an anode, a plurality of dynodes, and a cathode, said tube having substantially low values of operating voltages and being disposed adjacent said source to receive light therefrom, a voltage divider connected at one end to ground and to the penultimate dynode and at the other end to said cathode, said voltage divider having a plurality of taps with equal

values of resistance therebetween with such taps sequentially connected to said dynodes, a power supply having a terminal connected to ground and positive terminals connected to said anode and final dynode to furnish operating voltages thereto, energy storage means connected between said cathode and a positive terminal of said power supply, electronic switching means connected to the junction between said energy storage means and said power supply for the recurrent grounding thereof, and means coupled to said anode and final dynode for developing an output voltage to directly drive an auxiliary circuit.

LOUIS F. WOUTERS.

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