

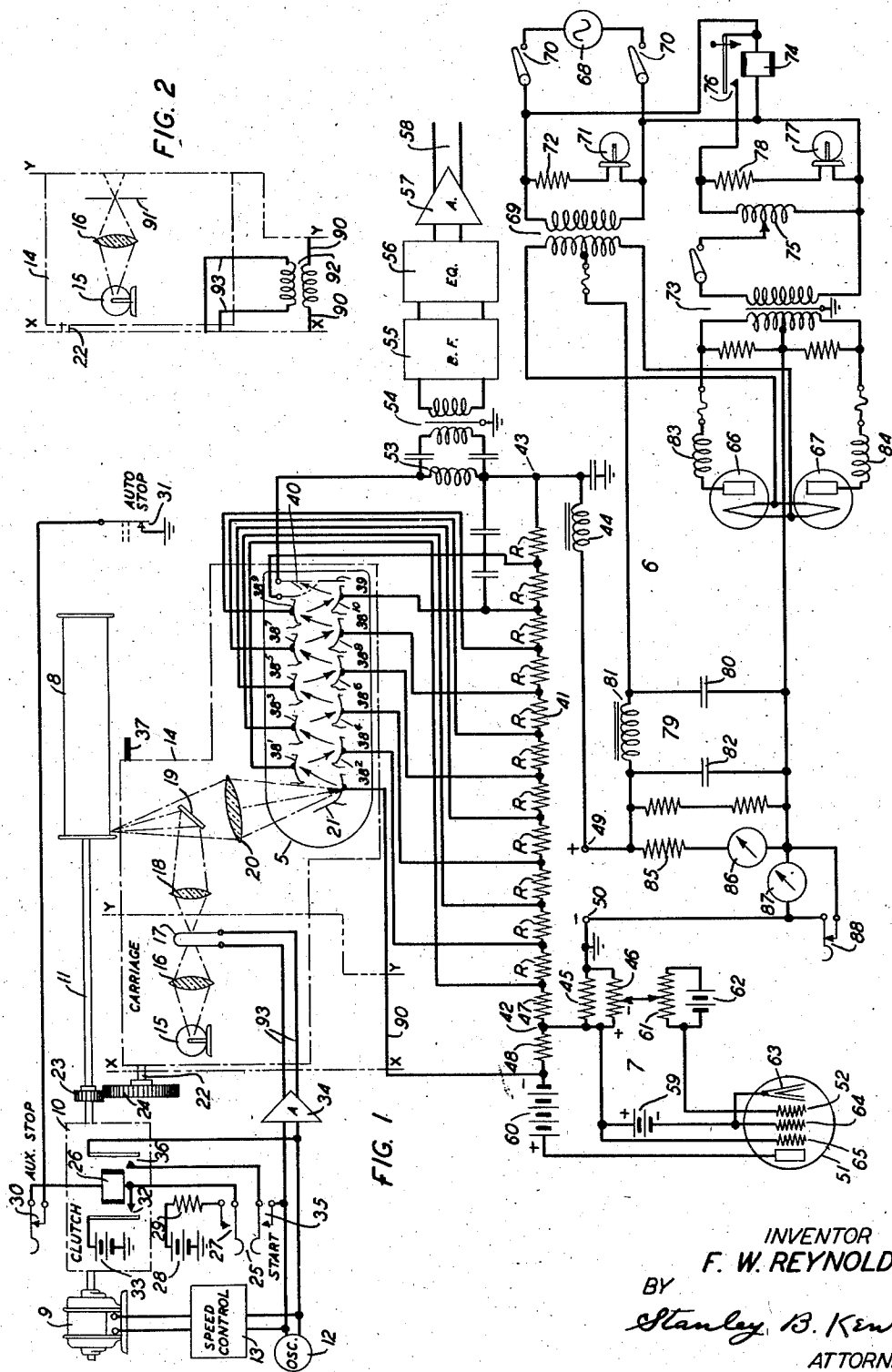
April 21, 1942.

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2,280,303

ELECTRON MULTIPLIER SYSTEM

Filed Jan. 4, 1941



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2,280,303

ELECTRON MULTIPLIER SYSTEM

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Application January 4, 1941, Serial No. 373,107

9 Claims. (Cl. 250—41.5)

This invention relates to electron multiplier systems and more particularly to methods and means for effecting automatic gain control in such a system.

An object of the invention is to provide an improved electron multiplier system.

In an example of practice illustrative of the invention a multistage photoelectric electron multiplier is supplied with power from a high voltage rectifier through a resistance type voltage divider. The photoelectric cathode is energized by light pulses modulated in accordance with the tone values of a scanned picture. In order to compensate for changes in the output current of the multiplier due to voltage changes in the power supply from the rectifier, a compensating voltage is applied between the photoelectric cathode and the first secondary electron emitter. Such compensating voltage is obtained from the output circuit of a pentode vacuum tube, the voltage of the control grid of which is varied in accordance with changes in the voltage of the power supply.

A simplified telephotographic system is made possible by this invention wherein a simple lens may be used to gather light from the scanned picture and a reasonably constant high voltage supply is used to furnish power. The quality of picture produced by this simplified system is equal to that produced by more elaborate systems previously known.

The invention is applicable to other electron multiplier systems than the example of practice described above.

A more detailed description of the invention now follows having reference to the accompanying drawing.

Fig. 1 of the drawing illustrates the invention embodied in a telephotographic transmitter.

Fig. 2 illustrates a modification in the system of Fig. 1 to form another embodiment of the invention.

Referring now to Fig. 1, the function of this transmitter is to produce carrier current modulated in accordance with the tone values of successively scanned elemental areas of a picture. This is accomplished by illuminating successive elemental areas of the picture by a chopped light beam varying in intensity according to the sine law at the carrier frequency. Light reflected from the picture is focussed on the photoelectric cathode of a multistage electron multiplier 5 supplied with power from high voltage rectifier 6 and a voltage compensating vacuum tube circuit 7.

The picture to be scanned is mounted on a drum 8 which is rotated by motor 9 through an electrically operated clutch 10 and shaft 11. The motor 9 is controlled by an oscillator 12 through a speed control mechanism 13.

A carriage 14, outlined by dot-dash lines in Fig. 1, is arranged to be moved parallel to the axis of the drum 8. Carriage 14 carries a light source 15, a lens 16, a light chopper 17, another lens 18, a small mirror 19, a third lens 20 and the electron multiplier 5. The lens 16 condenses light gathered from source 15 on the aperture of light chopper 17 which is a well-known type of string light valve. This light valve is energized by carrier current from the oscillator 12 after amplification in amplifier 34. The lens 18 forms an image of the aperture of light valve 17 at a surface of the picture on drum 8, the image forming light beam being reflected by the plane mirror 19. A part of the light reflected from the picture is gathered by lens 20 and directed to photoelectric cathode 21 of electron multiplier 5.

The carriage 14 is moved in well-known manner by threaded shaft 22 which is driven from shaft 11 by gears 23 and 24. Clutch 10 which connects the shaft 11 to the motor 9 is described in greater detail in the patent of C. C. Towne, No. 2,105,897, patented January 18, 1938. This clutch is engaged upon the energization of magnet 26 when start key 25 is operated. An energizing circuit for magnet 26 of clutch 10 is completed at the upper contact 27 of start key 25 and extends from ground through battery 28, resistance 29, contact 27, energizing coil of magnet 26, auxiliary stop key 30 and automatic stop switch 31 to ground. Magnet 26 locks up through contact 32 being then energized by current from battery 33.

When start key 25 and magnet 26 are operated the circuit from oscillator 12 to light valve 17 through amplifier 34 is shortcircuited through contact 35 of start key 25 and contact 36 of magnet 26. The purpose of this is to send a start signal to the receiver in the form of an interruption of the carrier current normally being transmitted to the receiver.

The clutch 10 is automatically disengaged when the scanning of a picture has been completed by reason of the stop pin 37 on the carriage 14 engaging and opening the automatic stop switch 31. The scanning mechanism is then manually returned to the starting position preparatory to the scanning of the next picture. The scanning

may be stopped at any time by manually opening auxiliary stop key 30.

The structure of electron multiplier 5 is fully described in Patent No. 2,245,624 of G. K. Teal, patented June 17, 1941, application Serial No. 205,931, filed May 4, 1938. In addition to the photoelectric cathode 21, electron multiplier 5 has ten secondary electron emitters 38', 38² . . . 38¹⁰, a shield or screen electrode 39 and an anode or collector electrode 40. All of these electrodes are mounted within an evacuated glass container which is provided with external contacts connected by lead-in wires to each of the electrodes.

Power is supplied to the various electrodes of electron multiplier 5 from a voltage divider 41 having terminals 42 and 43 to which power from high voltage rectifier 6 is applied through inductance coil 44, resistance 45 and potentiometer 46. Voltage divider 41 consists of eleven sections R, each of 10,000 ohms and a section 47 of 3,000 ohms. Positive terminal 49 of rectifier 6 is connected through coil 44 to terminal 43 and negative terminal 50 of rectifier 6 is connected to ground and through resistance 45 and potentiometer 46 to terminal 42 of voltage divider 41. Connection between the electrodes of multiplier 5 mounted on carriage 14 and voltage divider 41 which is mounted on a relay rack containing the rectifier 6, is furnished by a multiconductor flexible cable, four feet long, shielded with copper braiding.

In accordance with applicant's invention the voltage impressed between the photoelectric cathode 21 and the first secondary electron emitter 38' is the voltage drop through section 47 of voltage divider 41 supplemented by the voltage drop through resistance 48 which is connected in series in the output circuit of vacuum tube 51. The voltage drop in resistance 48 is determined by the voltage impressed on control grid 52 of vacuum tube 51 which voltage is dependent upon the current flowing in potentiometer 46. The current flowing in potentiometer 46 is substantially entirely dependent upon the voltage impressed between terminals 49 and 50 of the high voltage rectifier 6 since the current in the various sections of the voltage divider 41 represented by electrons passing between the electrodes in multiplier 5 is negligible compared with the current therein due to the voltage of the rectifier 6 impressed across the resistance sections of the voltage divider 41.

Compensating circuit 7 varies the voltage drop in resistance 48 in such a way that the output current of multiplier 5 remains substantially independent of voltage changes between rectifier terminals 49 and 50 providing these voltage changes are within reasonable limits. Since the action of the compensating circuit is practically instantaneous, it is also effective in reducing the effects of residual ripple in the output circuit of the rectifier.

The operation of the compensating circuit will now be described. Assuming a given illumination of the photoelectric cathode 21 and a given voltage at terminals 49 and 50 there will be a certain output current in inductance coil 53 and output transformer 54. If the voltage of the rectifier 6 at terminals 49 and 50 should be increased for any reason, the voltages impressed on the several electrodes of the multiplier 5 will also be increased. Assuming for the moment that we disregard the effect of the compensating circuit 7 operating through resistance 48, such increase in voltage would increase the output of the

multiplier. However, by taking advantage of the fact that the output of an electron multiplier can be changed by changing the voltage impressed between the photoelectric cathode and the first secondary electron emitter, applicant has devised a circuit to change such voltage just enough to offset a change in multiplier output due to changes in the output voltage of the rectifier. Under the condition of increased rectifier voltage described above the voltage drop across resistance 48 is sufficiently reduced to keep the output of the multiplier constant. When the voltage of the rectifier increases, the current through the resistance 45 and potentiometer 46 also increases. This increases the negative potential on control grid 52 and decreases the output current of vacuum tube 51 flowing through resistance 48 thereby reducing the voltage drop across resistance 48 and the total voltage impressed between photoelectric cathode 21 and secondary electron emitter 38'. Such decrease in voltage reduces the output of the multiplier 5 just enough to neutralize the increased output due to the increased voltage impressed on the other electrodes. A decreased output of multiplier 5 due to a decreased output voltage of rectifier 6 is offset by an increased current through resistance 48 resulting in an increased voltage between the photoelectric cathode 21 and secondary electron emitter 38' sufficient to maintain the output of the multiplier constant.

The output current of the electron multiplier circuit is transmitted through a suitable band filter 55, equalizer 56 and amplifier 57 to a transmission circuit 58.

The vacuum tube 51 of compensating circuit 7 is a pentode tube, preferably of Western Electric Code No. 310 vacuum tube. The plate battery is in two sections 59 and 60, each of 67½ volts. The bias for control grid 52 is furnished by potentiometer 61 across which is connected battery 62 of 45 volts. The negative terminal of battery section 59 is connected to cathode 63 and suppressor grid 64. The positive terminal of battery section 59 is connected to screen grid 65 and to terminal 42 of voltage divider 41. The voltages represented as being furnished by battery sections 59 and 60, may be obtained from suitably rectified alternating current.

The resistance of each section R of voltage divider 41 is 10,000 ohms; of resistance 47, 3,000 ohms; of resistance 45, 10,000 ohms; of potentiometer 46, 25,000 ohms; of resistance 48, 38,000 ohms; and of potentiometer 61, 100,000 ohms. It is thus seen that for a voltage of 1,200 volts supplied by high voltage rectifier 6 across terminals 49 and 50 the current in the sections of voltage divider 41 is about 0.01 ampere. The maximum signaling current produced by multiplier 5 is about 10 microamperes which is negligible in its effect on compensating circuit 7.

The high voltage rectifier 6 may be of any well-known type which provides a reasonably constant output voltage from a commercial alternating current source. The specific arrangement illustrated in the drawing is a full wave rectifier comprising two diode vacuum tubes 66 and 67, the filaments of which are supplied with heating current from alternating current source 68 through transformer 69. The source 68 is connected to transformer 69 through switches 70. Closure of switches 70 is indicated by the lighting of lamp 71 which is connected in series with resistance 72 across the primary winding of transformer 69. Voltage is impressed across the dis-

charge paths of tubes 66 and 67 by transformer 73, the primary winding of which is energized from source 68 through slow operating relay 74 and adjustable autotransformer 75. The closure of contact 76 of relay 74 is indicated by the lighting of lamp 77 which is connected in series with resistance 78 across autotransformer 75. The rectified current is smoothed out by filter 79 comprising input condenser 80, series inductance 81 and output condenser 82. Inductance coils 83 and 84 are radio frequency choke coils. Resistance 85 is a very high resistance connected in series with milliammeter 86. The current output of the rectifier is indicated by milliammeter 87 which may be short-circuited by the closure of switch 88.

By the use of applicant's invention in the telephotograph system hereinbefore described the transmitted image current for any given light intensity changes less than 0.01 decibel for a change in rectifier voltage up to one per cent. Such a change is not noticeable in the reproduced picture. For rectifier voltage changes up to three per cent the change in image current is not greater than 0.2 decibel.

A modified form of telephotograph system is illustrated by Fig. 2 in conjunction with Fig. 1. The elements illustrated in Fig. 2 are substituted for the elements of Fig. 1 which lie between the dot and double dash lines X—X and Y—Y. In this modified system the light chopper 17 is replaced by an apertured screen 91, the aperture of which is illuminated by light from source 15 which light is gathered by lens 16 and condensed on the aperture. An image of the aperture in screen 91 is formed by lens 18 at the surface of drum 8, the rays being reflected by the mirror 19, as previously explained. In this modification the successive elemental areas of the picture are illuminated by a steady light beam instead of by a chopped light beam as in the system of Fig. 1. Carrier current from oscillator 12 after amplification in amplifier 34 is applied between the photoelectric cathode 21 and the first secondary electron emitter 38' by transformer 92, the secondary winding of which is inserted in series with conductor 90. Modulation, therefore, occurs at the first stage of multiplier 5 and the output current of multiplier 5 is a carrier current modulated in amplitude in accordance with the tone values of successively scanned elemental areas of the picture on drum 8.

In the specific system having the circuit elements described in connection with Fig. 1, supply voltage variations at terminals 49 and 50 greater than plus or minus two or three per cent are not likely to be encountered. Since such variations can be compensated by voltage changes in resistance 48 of plus or minus 20 or 30 volts, there is still room for applying a carrier current having a peak value of 35 volts. If the specific apparatus elements specified for the system of Fig. 1 are used in the modified system according to Fig. 2, the voltage of the carrier current impressed on transformer 92 should be so adjusted that the carrier current voltage at the terminals of the secondary winding of transformer 92 is approximately 35 volts.

This invention is applicable to other systems employing electron multipliers of the type described or other types of electron multipliers wherein changes in the output current of the multiplier may be compensated by suitable changes in the voltage impressed between certain of the electrodes.

What is claimed is:

1. An electron multiplier having a plurality of electron emitting cathodes, an output electrode, a source of unidirectional voltage, means connecting said source to said cathodes and said output electrode to make each cathode more negative than the adjacent one on the side toward said output electrode, and means to supply a supplemental voltage across two of said cathodes to compensate for a change in the voltage of said source.

2. An electron multiplier having a plurality of electron emitting cathodes, an output electrode, a source of unidirectional voltage, means connecting said source to said cathodes and said output electrode to make each cathode more negative than the adjacent one on the side toward said output electrode, and means to apply a supplemental voltage between the most negative cathode and the cathode adjacent thereto to compensate for a change in the voltage of said source.

3. An electron multiplier having a plurality of electron emitting cathodes, an output electrode, a source of unidirectional voltage, means connecting said source to said cathodes and said output electrode to make each cathode more negative than the adjacent one on the side toward said output electrode, and means including a pentode vacuum tube to supply a supplemental voltage between the most negative cathode and the cathode adjacent thereto to compensate for a change in the voltage of said source.

4. An electron discharge multiplier having a primary cathode, an output electrode and a plurality of secondary electron emitting electrodes located between said primary cathode and said output electrode, an amplifying vacuum tube having a control electrode and an output circuit including a resistance connected in series in said output circuit, a voltage divider having one terminal connected to said output electrode, intermediate taps connected to said secondary electron emitting electrodes, respectively, and the other terminal connected through said resistance to said primary cathode, a source of unidirectional current having its positive terminal connected to that terminal of said voltage divider which is connected to said output electrode and its negative terminal connected through a control resistance to the other terminal of said voltage divider, and a connection from said control resistance to said control electrode to change the potential of said control electrode in accordance with a change of voltage of said source of unidirectional current.

5. The method of regulating the gain of an electron multiplier which comprises applying voltages to produce a plurality of streams of electrons including secondarily produced electrons in series, and changing the voltage producing one of said streams in a sense opposite to a change in the voltage producing another of said streams.

6. The method of regulating the gain of an electron multiplier which multiplier comprises a plurality of secondary electron emitting electrodes providing electron multiplication in succession which method comprises applying voltages to said secondary electron emitting electrodes to produce electron streams from one to the other of said secondary electron emitting electrodes with electron multiplication, changing the applied voltage for a plurality of said emitting electrodes, and changing the voltage on another

of said emitting electrodes in the opposite sense.

7. The method of operating an electron multiplier of the kind in which the electron multiplication is increased when the over-all voltage is increased and the multiplication is decreased when the voltage of one stage only is decreased which method comprises applying to said multiplier an over-all voltage which is subject to change, and adjusting the voltage applied to one stage only to neutralize a change in multiplication which results from a change in the over-all voltage.

8. An electron multiplier having a plurality of electron emitting cathodes, an output electrode, a source of unidirectional voltage, means connecting said source to said cathodes and said output electrode to make each cathode more negative than the adjacent one on the side toward said output electrode, and means effectively independent of the output current of the multiplier to supply a supplemental voltage across two of said cathodes to compensate for a change in the voltage of said source.

9. An electron discharge multiplier having a primary cathode, an output electrode and a plurality of secondary electron emitting electrodes located between said primary cathode and said

output electrode, an amplifying pentode vacuum tube having a control electrode, a suppressor electrode, a screen grid, an output electrode and a cathode, a voltage divider having one terminal connected to the output electrode of said multiplier and intermediate taps connected to said secondary electron emitting electrodes respectively, an output circuit for said vacuum tube connected between said output electrode of said tube on the one hand and the cathode and suppressor grid on the other hand comprising two sources of unidirectional current and a resistance in series therebetween, the negative terminal of said voltage divider being connected through said resistance to said primary cathode, a third source of unidirectional current having its positive terminal connected to that terminal of said voltage divider which is connected to the output terminal of said multiplier and its negative terminal connected through a control resistance to the other terminal of said voltage divider, and a connection from said control resistance to said control electrode to change the potential of said control electrode in accordance with a change of voltage of said source of unidirectional current.

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