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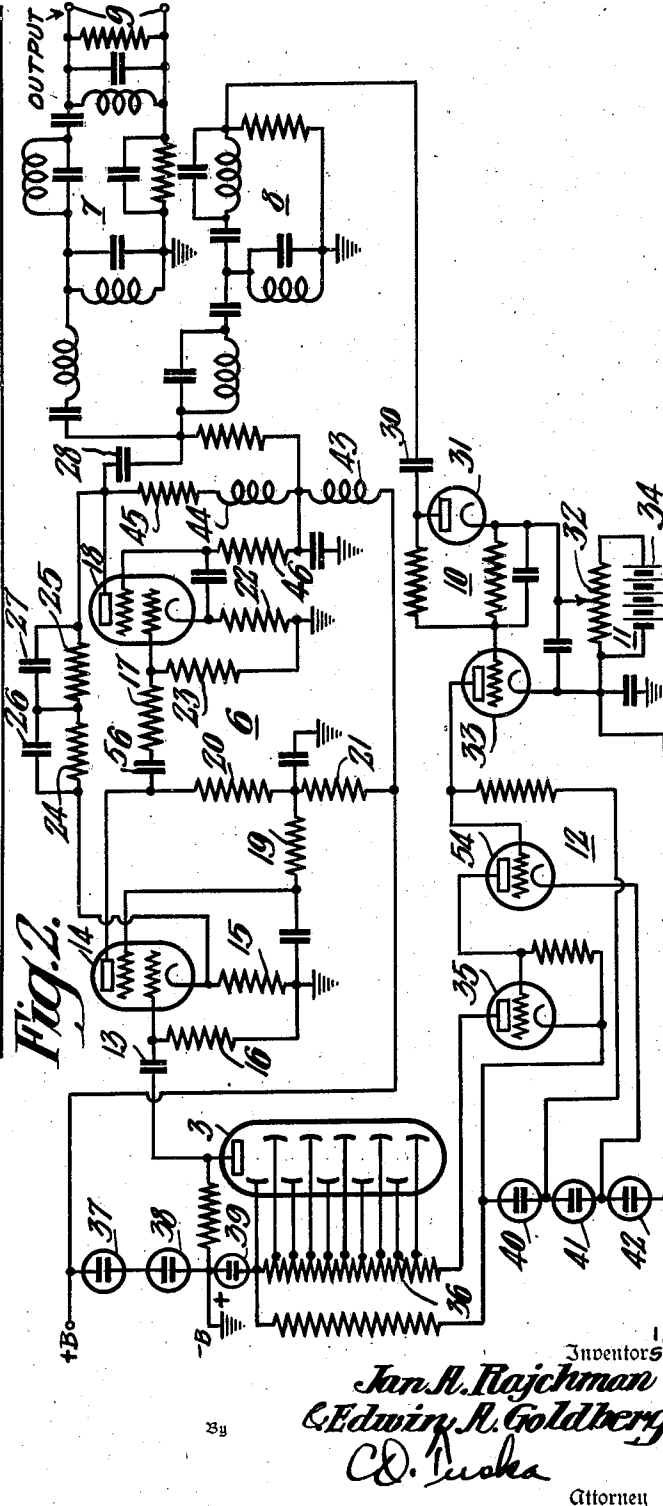
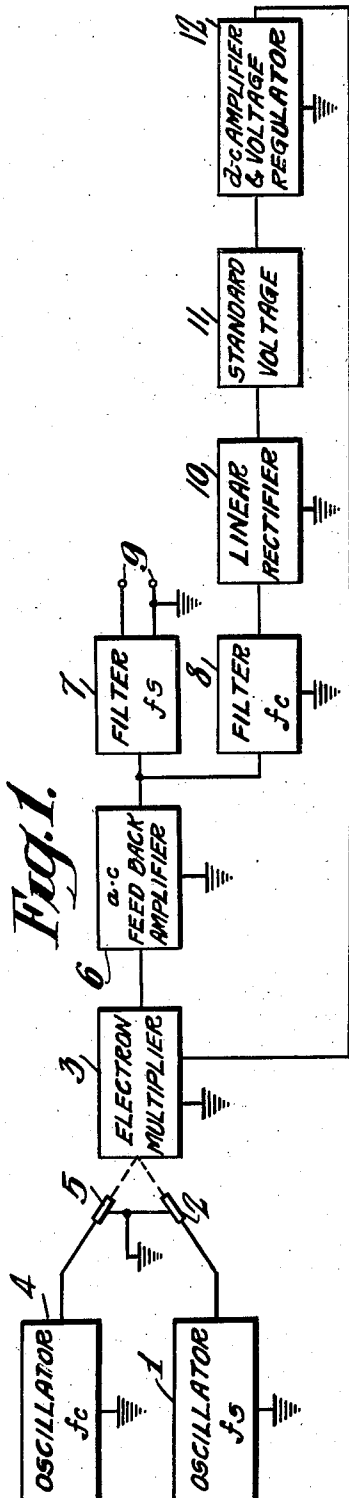
J. A. RAJCHMAN ET AL

2,412,423

AUTOMATIC GAIN CONTROL CIRCUIT

Filed April 29, 1943

3 Sheets-Sheet 1



Inventors
Jan A. Rajchman
Edwin R. Goldberg
C. D. Tucka
 Attorney

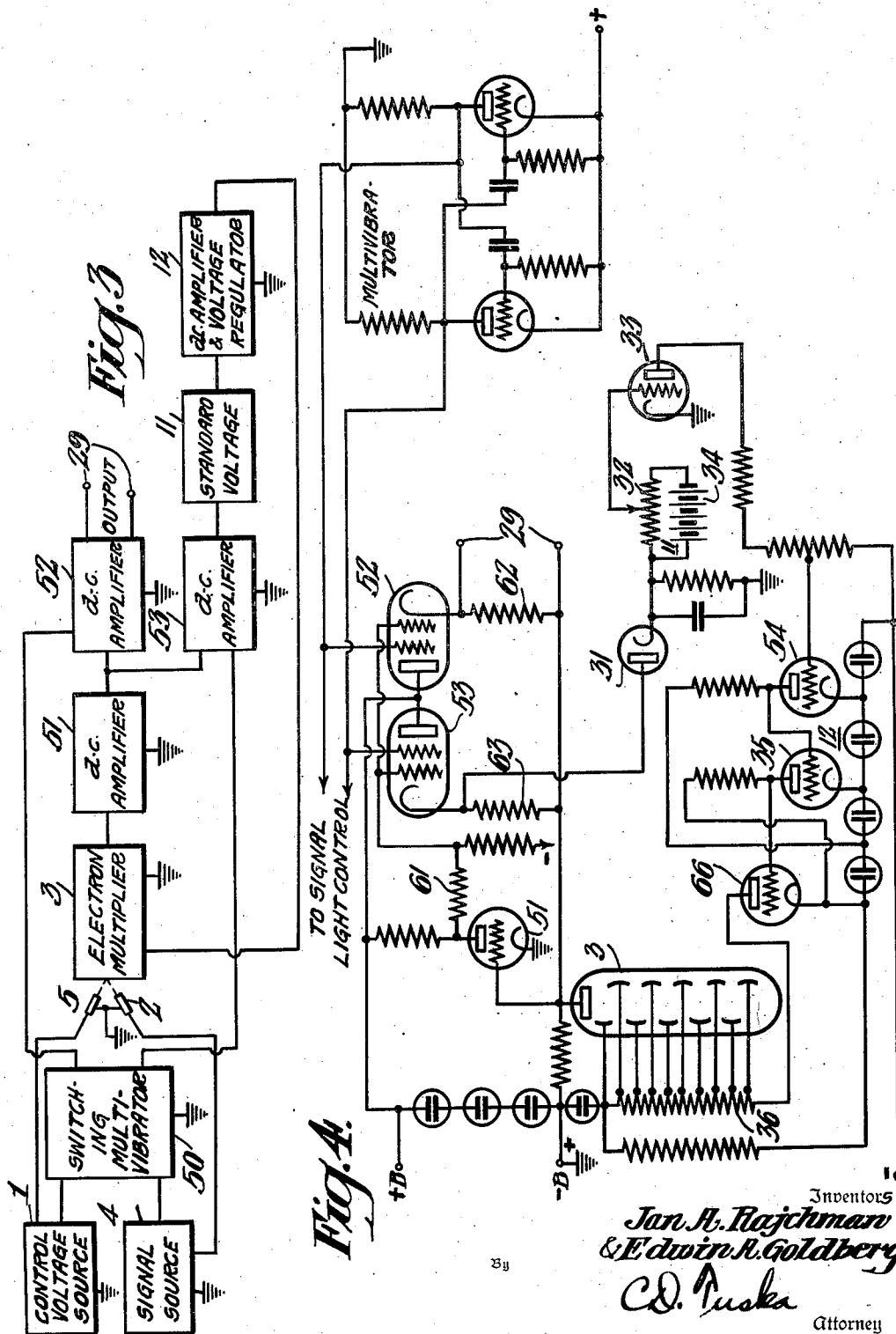
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Inventors
Jan A. Rajchman
& Edwin R. Goldberg
C. D. Tucka
Attorney

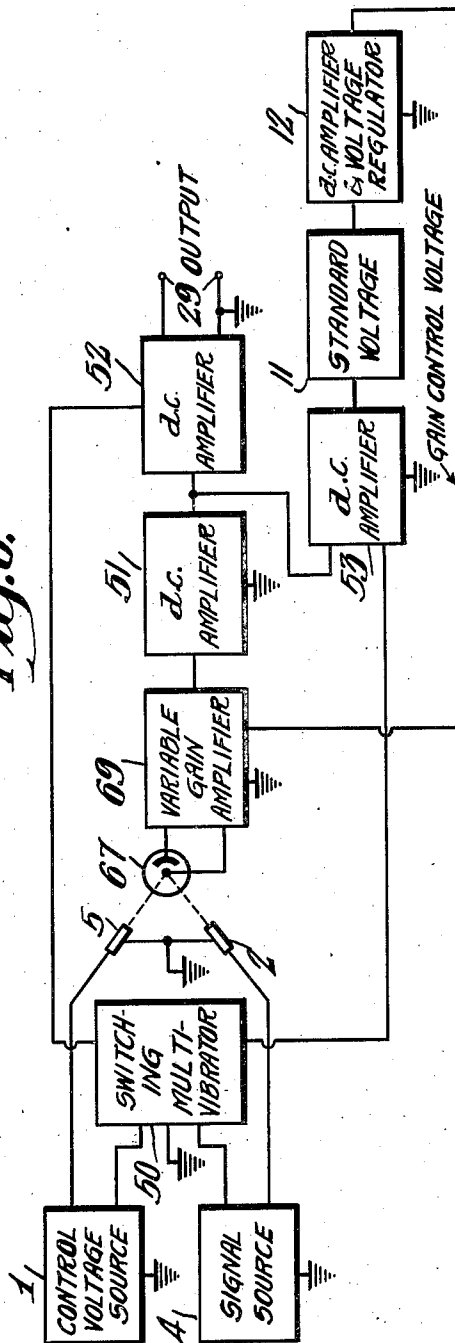
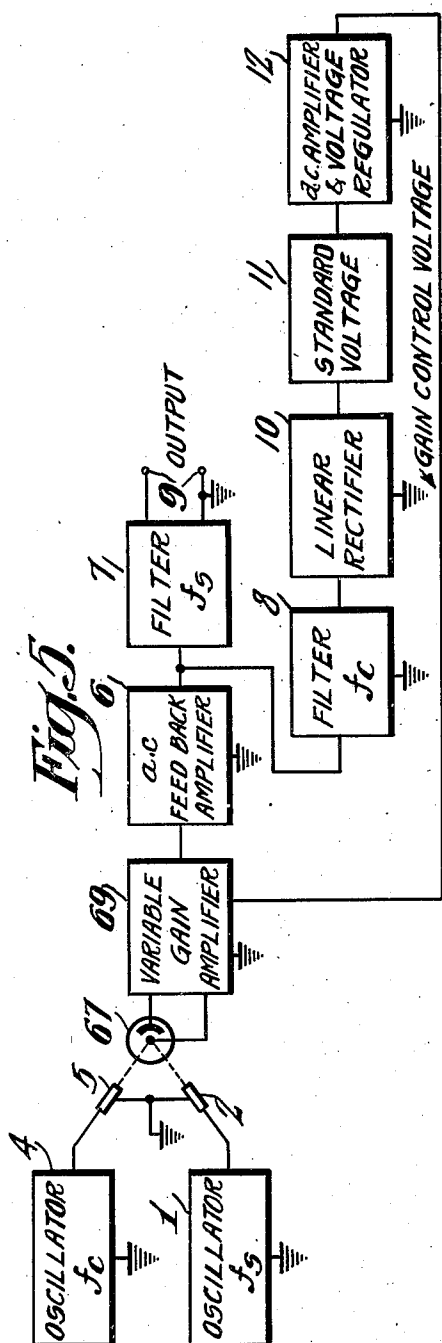
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Inventors
Jan A. Rajchman
Edwin H. Goldberg
C. H. Tucker
Attorney

UNITED STATES PATENT OFFICE

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AUTOMATIC GAIN CONTROL CIRCUIT

Jan A. Rajchman and Edwin A. Goldberg, Princeton, N. J., assignors to Radio Corporation of America, a corporation of Delaware

Application April 29, 1943, Serial No. 485,040

20 Claims. (Cl. 250—41.5)

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This application is a continuation-in-part of our copending U. S. application, Serial No. 449,244, filed July 1, 1942, and assigned to the same assignee.

This invention relates generally to electron discharge devices and particularly to an improved method of and means for controlling the gain of an electron multiplier or other photo-sensitive electronic amplifying device.

One of the principal difficulties encountered in the use of electron multipliers or other photo-sensitive amplifying devices is that of maintaining the gain of the device at a constant value irrespective of changes in tube characteristics and supply voltages. Richard L. Snyder, Jr. has described one method of gain control for electron multipliers in his U. S. Patent 2,198,233, granted April 23, 1940. The subject patent, however, requires a specially designed electron multiplier for efficient operation, whereas the instant invention is adapted to the automatic gain control of multipliers of all types.

Briefly, one embodiment of the invention contemplates the control of any electron multiplier (for example, of the RCA type 931) which is actuated by a light beam modulated by some predetermined signal source. The output of the electron multiplier may, if desired, be further amplified and applied in a load circuit. In order to stabilize the gain of the electron multiplier, a second light source, which is modulated by any other predetermined frequency source, is also focused upon the photo-cathode element of the electron multiplier. The output of the multiplier is applied to separate filters. One filter is designed to pass only the signal frequency, while the second filter is designed to pass only the control frequency. The control frequency component is applied to a linear rectifier, and after comparison with a source of reference voltage, is further amplified and stabilized. The stabilized control voltage derived from the last mentioned amplifier is applied to the electron multiplier to control the gain thereof.

A second method of controlling the gain of an electron multiplier utilizes a multivibrator, or similar device, which alternately applies voltages, from a signal source and a control source, to two light sources which are focused upon the photo-cathode of the electron multiplier. The output of the electron multiplier is fed into a buffer amplifier, the output of which is connected to the input circuits of a signal amplifier and a control amplifier. The gain of the signal and control amplifiers is synchronously controlled by

the same multivibrator, whereby the electron multiplier alternately is responsive to the signal source and the control source. The output of the control amplifier is rectified and compared with a source of reference voltage. The combined voltages are further amplified and regulated, and applied to the electron multiplier to control the gain thereof. A third embodiment of the invention includes the utilization of either of these two methods to control the gain of a photo-electric cell and a photocell amplifier.

Among the objects of the invention is to provide an improved method of and means for controlling the gain of an electron discharge device. Another object is to provide an improved method of and means for controlling the gain of an electron multiplier having only one electron stream. Another object is to provide an improved method of and means for controlling the gain of an electron multiplier wherein a control frequency applied to the multiplier is selected, rectified, compared with a source of reference potential, and applied to the electron multiplier to control the gain thereof. Another object is to provide an improved method of and means for controlling the gain of an electron multiplier wherein a control voltage is intermittently generated by the electron multiplier, and compared with a source of reference potential and applied to the multiplier as a gain control voltage. A further object is to provide an improved method of and means for controlling the gain of a photo-cell amplifier actuated by a photocell.

The invention will be described by reference to the accompanying drawings, of which Figure 1 is a schematic block diagram of one embodiment of the invention, Figure 2 is a schematic circuit diagram of the principal features of Fig. 1, Figure 3 is a schematic block diagram of a second embodiment of the invention, Figure 4 is a schematic circuit diagram of the principal features of the modification of Fig. 3, and Figures 5 and 6 are modifications of a third embodiment of the invention. Similar reference numerals are applied to similar elements throughout the drawings.

Referring to Fig. 1, a source of signals 1, which may be an oscillator having an output frequency f_s , is connected to a first light source 2 which is focused upon the photocathode element of a conventional electron multiplier 3. The light source 2 may be any device such as, for example, a neon lamp, which may be utilized to provide a modulated light beam. A control frequency source 4, which may be an oscillator having an output fre-

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quency f_c , is connected to a second light source 5, which may be of the same type as the first light source 2. The second light source 5 is also focused upon the photocathode element of the electron multiplier 3. The collector electrode circuit of the electron multiplier 3 is connected, through a conventional A.-C. feedback amplifier 6, to the input circuits of a first filter 7, tuned to pass the signal frequency f_s , and a second filter 8 tuned to pass the control frequency f_c . The output of the first filter 7 is connected to the signal output terminals 9. The output of the second filter 8 is connected to a linear rectifier 10. The rectified voltage derived therefrom is combined with a standard or reference voltage 11 and applied to the input of a conventional D.-C. amplifier 12. The voltages applied to the D.-C. amplifier 12 may, if desired, be stabilized by the use of conventional voltage regulator tubes, such as RCA type VR-150. The amplifier output is applied to the electron multiplier 3 to control the gain thereof.

Fig. 2 is a circuit diagram of one practical embodiment in which the collector electrode of the electron multiplier is connected through a coupling condenser 13 to the control electrode of a first amplifier tube 14. The cathode circuit of the first amplifier tube 14 includes a resistor 15 connected between the cathode and ground. A grid bias resistor 16 is connected between the control electrode and ground. The anode of the amplifier tube 14 is connected, through a second coupling condenser 56 and a series grid resistor 17, to the control electrode of a second amplifier tube 18. Anode and screen potentials for the first amplifier tube 14 are derived from a source of positive potential through conventional series coupling resistors 19, 20 and 21. A cathode resistor 22 is connected between the cathode of the second amplifier tube 18 and ground. A grid resistor 23 is connected between the control electrode of the second amplifier tube 18 and ground. A feedback circuit, comprising the series resistors 24 and 25 connected in parallel with the series capacitors 26 and 27, is connected between the anode of the second amplifier tube 18 and the cathode of the first amplifier tube 14. Anode potential is applied through serially connected choke coils 43 and 44 and a series resistor 45. Screen potential is applied through the choke coil 43 and screen resistor 46. The anode of the second amplifier tube 18 is coupled, through a coupling condenser 28, to the input of the signal frequency filter 7, which may be of any well known type designed to effectively limit the output at the terminals 9 to the signal frequency component. The anode of the second amplifier tube 18 is also coupled through the coupling capacitor 28 to the input of the control frequency filter 8, which is also of conventional design. The output of the control frequency filter 8 is coupled, through a coupling capacitor 30, to the anode of a diode 31. The rectified output of the diode 31 is combined with an adjustable D.-C. potential derived from a potentiometer 32, and is applied to the control electrode of a D.-C. amplifier 33. A source of reference potential 34, which may be a battery, is connected across the terminals of the potentiometer 32. The output of the first D.-C. amplifier tube 33 is further amplified by second and third D.-C. amplifier tubes 54 and 35, respectively, and is applied to the terminals of a bleeder resistance 36, which supplies the operating voltages for the electron multiplier 3. Separate sources of potential are preferably provided for the anode

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circuits of the A.-C. amplifier and the biasing potentials applied to the electron multiplier. Conventional voltage regulator tubes 37, 38, 39, 40, 41 and 42 (for example, RCA type VR-150), are connected across the various power supply circuits to stabilize the potentials applied to the various electrodes.

The operation of the circuit of Fig. 2 is as follows: Signal and control sources of different frequency modulate the light sources 2 and 5 which are focused on the photocathode of the electron multiplier 3. Potentials of both frequencies are amplified by the tubes 14 and 18 and the signal frequency is selected by the filter 7 and applied to the signal output terminals 9. Potentials of the control frequency are selected by the filter 8 and rectified by the diode 31. The rectified control signals are then combined with the adjustable bias voltage derived from the battery 34 and the potentiometer 32 and applied to the grid of the amplifier tube 33. After additional amplification in the D.-C. amplifier tubes 54 and 35, the control signals are applied to the multiplier supply circuit to compensate for multiplier variations.

In Fig. 3 the signal source 1 and the control voltage source 4 are connected to multivibrator 50, which alternately triggers the sources 1 and 4 to energize the signal light source 2 and the control light source 5, respectively. The light from the two sources 2 and 5 is focused upon the photocathode of the electrode amplifier 3. The output of the electron multiplier 3 is applied to the input circuit of a D.-C. amplifier 51. The output circuit of the D.-C. amplifier 51 is connected to the input circuits of a second D.-C. amplifier 52 and a third D.-C. amplifier 53. The output circuit of the second D.-C. amplifier 52 is connected to the signal output terminals 29. The switching multivibrator 50 is also connected to the second D.-C. amplifier 52 and the third D.-C. amplifier 53 to control intermittently and alternately the gain thereof in synchronism with the energization of the first and second light sources 2 and 5, whereby the signal and control frequencies are alternately and intermittently amplified. The output of the third D.-C. amplifier 53 is combined with a source of reference potential 11 in the same manner as in Figs. 1 and 2, and is applied to the input of a fourth D.-C. amplifier 12. The output of the fourth D.-C. amplifier 12 is applied to the electron multiplier to control the gain thereof. The control voltage source 4, in this modification, may be either A.-C. or D.-C. since the signal and control sources are not applied to the multiplier circuit at the same time, and since D.-C. amplifiers are used throughout.

Fig. 4 is a circuit diagram of another practical embodiment of the system in which the electron multiplier 3 is provided with biasing potentials derived from the bleeder resistor 36. The collector electrode of the electron multiplier 3 is connected to the control electrode of a first D.-C. amplifier 51. The anode of the first D.-C. amplifier 51 is connected through a first coupling resistor 61 to a first control electrode of the second D.-C. amplifier 52 and a first control electrode of a third D.-C. amplifier 53. Signal output is applied to the output terminals 29 from across a cathode resistor 62 in the cathode circuit of the second D.-C. amplifier 52. Control potentials are derived from the third amplifier tube 53 from across a resistor 63 in the cathode circuit of the tube 53. These control potentials are applied

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to the anode of a diode 31 and are combined with the reference voltage, derived from the potentiometer 32. The resulting voltage is amplified by the D.-C. amplifiers 54, 35 and 66 in the same manner as described heretofore for the circuit of Fig. 2. The output current of the last D.-C. amplifier tube 66 flows through the bleeder resistance 36, to control the gain of the electron multiplier 3. Similarly, the potentials applied to the anode circuits and electron multiplier electrodes are stabilized by conventional voltage regulator tubes such as the type VR-150, as in the circuit of Fig. 2.

A conventional multivibrator circuit 50 is connected to a second control electrode of the second D.-C. amplifier tube 52 and applied to trigger the signal source 1. The multivibrator is also connected to the second control electrode of the third D.-C. amplifier 53 and applied to trigger the control voltage source 4, whereby the signal and control channels are alternately and intermittently energized and conditioned. The multivibrator circuit 50 may be of any suitable type known in the art, for example, the circuit described in the Review of Scientific Instruments, vol. 9, July 1938, at page 222.

Thus, the operation of the circuit of Fig. 4 is as follows: Modulated light is alternately applied to the electron multiplier 50 by the keying action of the multivibrator on the signal source 1 and the control source 4. Simultaneously, the D.-C. amplifiers 52 and 53 are keyed by the multivibrator 50 to synchronize their operation with the signal and control sources. The signal output is derived from the terminals 29 of the cathode resistor 62 in circuit with the amplifier 52.

Control voltages from across the cathode resistor 63 in circuit with the amplifier 53 are rectified by the diode 31 and combined with the adjustable bias voltage derived from the battery 34 through the voltage divider 32. The combined voltages, which include signals representative of variations in the characteristics of the multiplier, are amplified and applied to the multiplier supply circuit to compensate for such multiplier variations.

Fig. 5 is similar to Fig. 1, with the exception that a conventional photocell 67 and variable gain amplifier 69 are substituted for the electron multiplier 3. The operation is generally the same as that of Fig. 1.

Fig. 6 is similar to Fig. 3, with the exception that the photocell 67 and variable gain amplifier 69 are substituted for the electron multiplier 3. The operation is generally the same as that of Fig. 3.

The variable gain amplifiers of Figs. 5 and 6 may be of any type known in the art wherein the gain is controlled by a gain control voltage derived from associated apparatus.

The systems disclosed in Figs. 5 and 6 differ from previously disclosed devices in that the instant systems employ a common photocell and photocell amplifier for both the control voltage and the signal voltage components.

We claim as our invention:

1. The method of controlling the gain of an electron multiplier device comprising generating separate distinctively modulated light beams, one of said beams providing signal intelligence and another of said beams providing a control signal, applying said light beams to said multiplier to produce a common electron stream therein, deriving from said multiplier combined signals each characteristic of the distinctive features of said light beams, separating said signals, deriving

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control potentials from one of said separated signals, and applying said control potentials to said device as bias voltages to control the velocity of said electron stream and hence the gain of said multiplier.

2. The method of controlling the gain of an electron multiplier device comprising generating separate light beams modulated at different frequencies, simultaneously applying said light beams to said multiplier to produce a common electron stream therein, deriving combined signals from said multiplier, separating signals of different frequency components, deriving control potentials from one of said separated signals, and applying said control potentials to said device as bias voltages to control the velocity of said electron stream and hence the gain of said multiplier.

3. The method of controlling the gain of an electron multiplier device comprising generating separate light beams, one of said beams providing signal intelligence and another of said beams providing a control signal, alternately applying said light beams to said multiplier, deriving from said multiplier combined signals each characteristic of a different one of said alternately applied light beams, separating said signals, deriving control potentials from one of said separated signals, and applying said control potentials to said device as bias voltages to control the velocity of said electron stream and hence the gain of said multiplier.

4. A circuit for controlling the gain of an electron multiplier device including means for generating separate distinctively modulated light beams, one of said beams providing signal intelligence and another of said beams providing a control signal, means for applying said light beams to said multiplier to produce a common electron stream therein, means for deriving from said multiplier combined signals each characteristic of the distinctive features of said light beams, means for separating said signals, means responsive to one of said separated signals for deriving control potentials therefrom, and means for applying said control potentials to said device as bias voltages to control the velocity of said electron stream and hence the gain of said multiplier.

5. A circuit for controlling the gain of an electron multiplier device including means for generating separate light beams, means for modulating said beams at different frequencies, means for simultaneously applying said beams to said multiplier to produce a common electron stream therein, means for deriving combined signals from said multiplier, means for separating said signals, means responsive to one of said separated signals for deriving control potentials therefrom, and means for applying said control potentials to said device as bias voltages to control the velocity of said electron stream and hence the gain of said multiplier.

6. A circuit for controlling the gain of an electron multiplier device including means for generating separate light beams, one of said beams providing signal intelligence and another of said beams providing a control signal, means for alternately applying said light beams to said multiplier, means for deriving from said multiplier combined signals each characteristic of a different one of said alternately applied light beams, means for separating said signals, means responsive to one of said separated signals for deriving control potentials therefrom, and means for applying said control potentials to said de-

vice as bias voltages to control the velocity of said electron stream and hence the gain of said multiplier.

7. A circuit of the type described in claim 6, including means for modulating at least one of said light beams.

8. A circuit of the type described in claim 5, including means for deriving a gain controlled signal from said multiplier.

9. A circuit of the type described in claim 6, including means for deriving a gain controlled signal from said multiplier.

10. A circuit for controlling the gain of an electron multiplier device including means for generating separate light beams, one of said beams providing signal intelligence and another of said beams providing a control signal, means including a multivibrator for alternately applying said light beams to said multiplier, means for deriving from said multiplier combined signals each characteristic of a different one of said alternately applied light beams, means including said multivibrator for separating said signals, means responsive to one of said separated signals for deriving control potentials therefrom, and means for applying said control potentials to said device as bias voltages to control the velocity of said electron stream and hence the gain of said multiplier.

11. A circuit for controlling the gain of an electron multiplier device including means for generating separate light beams, means for modulating said beams at different frequencies, means for simultaneously applying said beams to said multiplier to produce a common electron stream therein, means for deriving combined signals from said amplifier, filter means for separating said signals, means responsive to one of said separated signals for deriving control potentials therefrom, and means for applying said control potentials to said device as bias voltages to control the velocity of said electron stream and hence the gain of said multiplier.

12. A circuit for controlling the gain of an electron multiplier device including means for generating separate light beams, means for modulating said beams at different frequencies, means for simultaneously applying said beams to said multiplier to produce a common electron stream therein, means for deriving combined signals from said multiplier, filter means for separating said signals, means including a source of reference potential and responsive to one of said separated signals for deriving control potentials therefrom, and means for applying said control potentials to said device as bias voltages to control the velocity of said electron stream and hence the gain of said multiplier.

13. A circuit for controlling the gain of an electron multiplier device including means for generating separate light beams, one of said beams providing signal intelligence and another of said beams providing a control signal, means including a multivibrator for alternately applying said light beams to said multiplier, means for deriving from said multiplier combined signals each characteristic of a different one of said alternately applied light beams, means including said multivibrator for separating said signals, means including a source of reference potential and responsive to one of said separated signals for deriving control potentials therefrom, and means for applying said control potentials to said device as bias voltages to control the velocity

of said electron stream and hence the gain of said multiplier.

14. The method of controlling the gain of a photo-sensitive amplifying device comprising generating separate distinctively modulated light beams, one of said beams providing signal intelligence and another of said beams providing a control signal, applying said light beams to said device to produce a common electronic circuit therein, deriving from said device combined signals characteristic of the distinctive features of said light beams, separating said signals, deriving control potentials from one of said separated signals, and applying said control potentials to said device as bias voltages to control the velocity of said electron stream and hence the gain of said device.

15. The method of controlling the gain of a photo-sensitive amplifying device comprising generating separate light beams modulated at different frequencies, simultaneously applying said light beams to said device to produce a common electronic circuit therein, deriving combined signals from said device, separating signals of different frequency components, deriving control potentials from one of said separated signals, and applying said control potentials to said device as bias voltages to control the velocity of said electron stream and hence the gain of said device.

16. The method of controlling the gain of a photo-sensitive amplifying device comprising generating separate light beams, one of said beams providing signal intelligence and another of said beams providing a control signal, alternately applying said light beams to said device, deriving from said device combined signals each characteristic of a different one of said alternately applied light beams, separating said signals, deriving control potentials from one of said separated signals, and applying said control potentials to said device as bias voltages to control the velocity of said electron stream and hence the gain of said device.

17. A circuit for controlling the gain of a photo-sensitive amplifying device including means for generating separate distinctively modulated light beams, one of said beams providing signal intelligence and another of said beams providing a control signal, means for applying said light beams to said device to produce a common electronic circuit therein, means for deriving from said device combined signals each characteristic of the distinctive features of said light beams, means for separating said signals, means responsive to one of said separated signals for deriving control potentials therefrom, and means for applying said control potentials to said device as bias voltages to control the velocity of said electron stream and hence the gain of said device.

18. A circuit for controlling the gain of a photo-sensitive amplifying device including means for generating separate light beams, means for modulating said beams at different frequencies, means for simultaneously applying said beams to said device to produce a common electronic circuit therein, means for deriving combined signals from said device, means for separating said signals, means responsive to one of said separated signals for deriving control potentials therefrom, and means for applying said control potentials to said device as bias voltages to control the velocity of said electron stream and hence the gain of said device.

19. A circuit for controlling the gain of a photo-sensitive amplifying device including means

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for generating separate light beams, one of said beams providing signal intelligence and another of said beams providing a control signal, means for alternately applying said light beams to said device, means for deriving from said device combined signals each characteristic of a different one of said alternately applied light beams, means for separating said signals, means responsive to one of said separated signals for deriving control

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potentials therefrom, and means for applying said control potentials to said device as bias voltages to control the velocity of said electron stream and hence the gain of said device.

5 20. A circuit of the type described in claim 19 including means for modulating at least one of said light beams.

JAN A. RAJCHMAN.
EDWIN A. GOLDBERG.