

Feb. 4, 1947.

J. A. RAJCHMAN

2,415,190

ELECTRONIC COMPUTER

Filed April 30, 1942

4 Sheets-Sheet 1

FIG. 1.

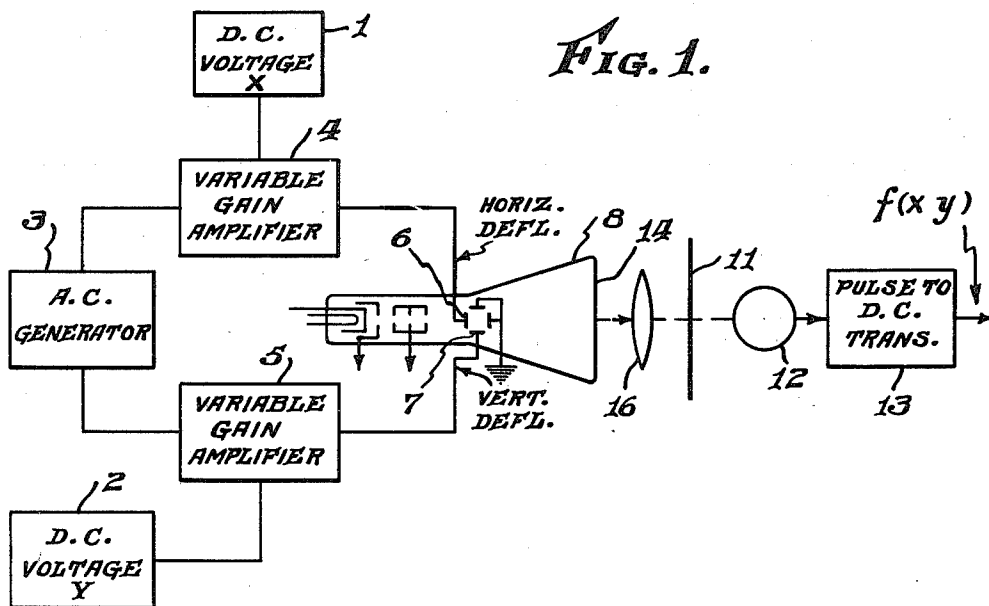
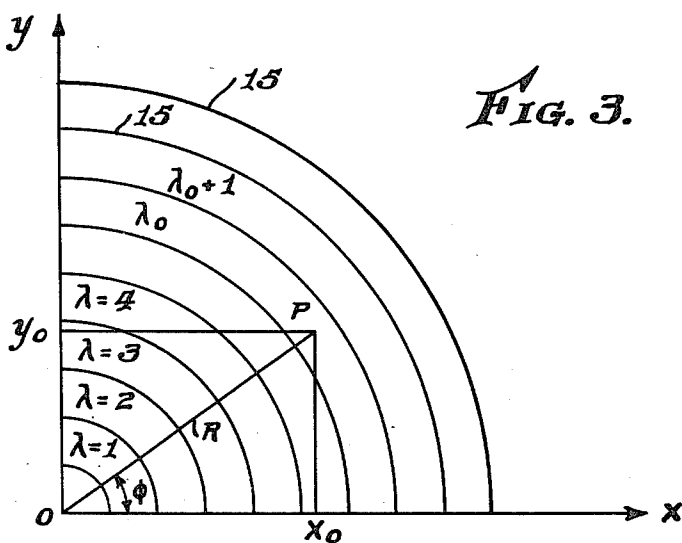


FIG. 3.



Jan A. Rajchman

By

C. D. Quaker

Inventor

Attorney

Feb. 4, 1947.

J. A. RAJCHMAN

2,415,190

ELECTRONIC COMPUTER

Filed April 30, 1942

4 Sheets-Sheet 2

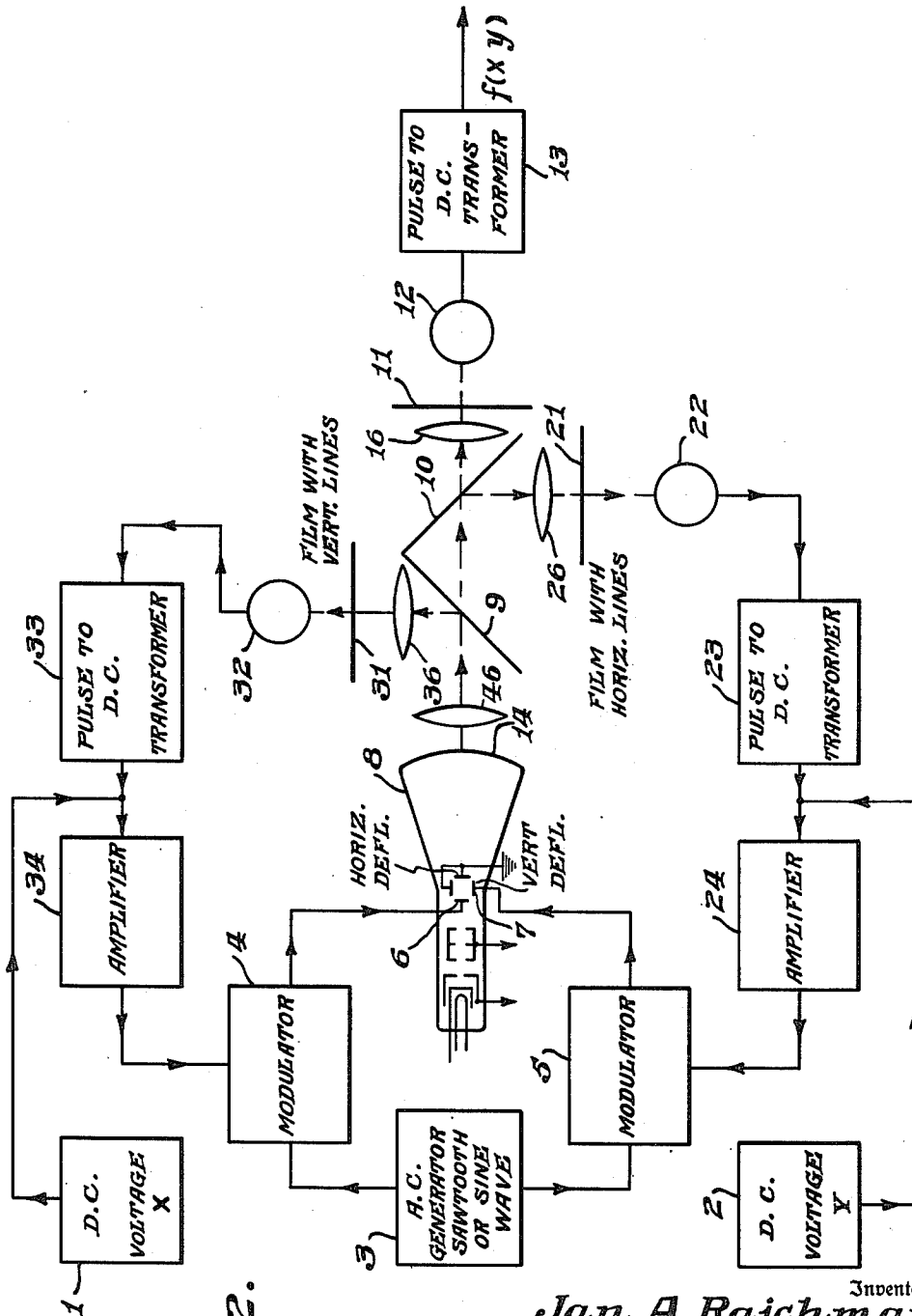


FIG. 2.

Jan A. Rajchman

C. P. Tucka

Inventor

Attorney

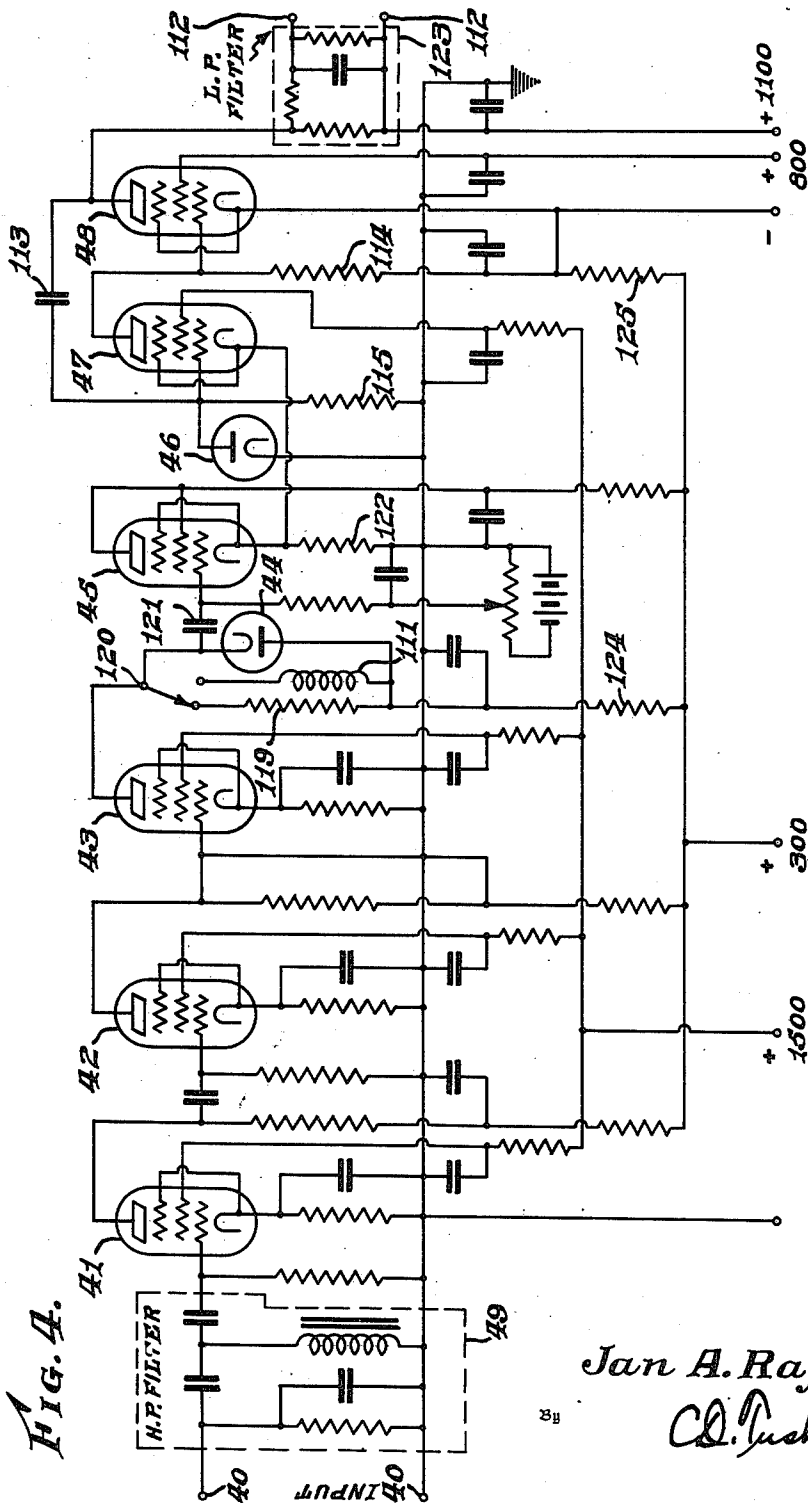
Feb. 4, 1947.

J. A. RAJCHMAN
ELECTRONIC COMPUTER

2,415,190

Filed April 30, 1942

4 Sheets-Sheet 3



Inventor
Jan A. Rajchman
C. D. Tucka

Attorney

Feb. 4, 1947.

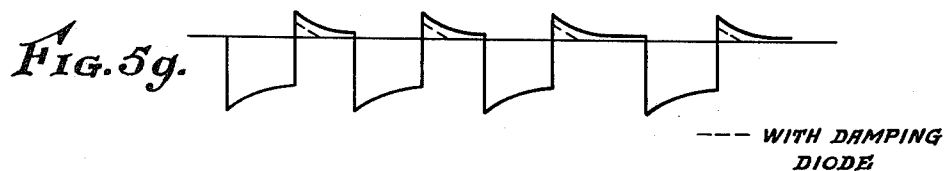
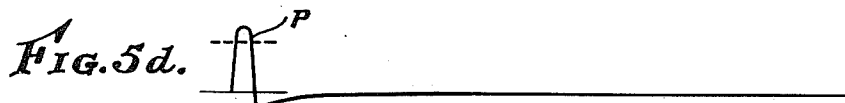
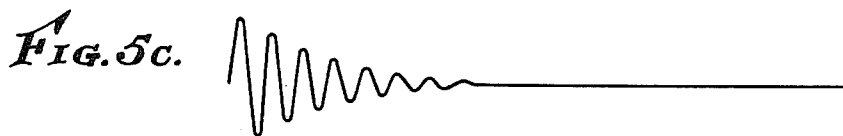
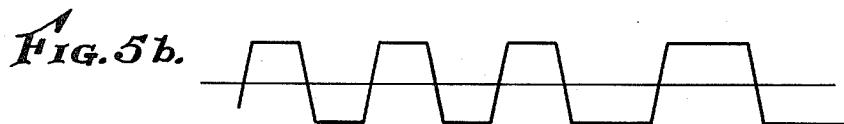
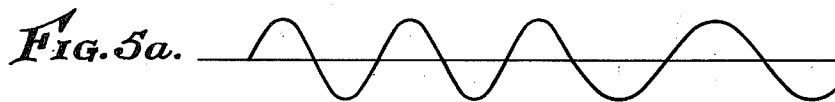
J. A. RAJCHMAN

2,415,190

ELECTRONIC COMPUTER

Filed April 30, 1942

4 Sheets-Sheet 4



Jan A. Rajchman

Inventor

By

C. D. Tucka

Attorney

UNITED STATES PATENT OFFICE

2,415,190

ELECTRONIC COMPUTER

Jan A. Rajchman, Philadelphia, Pa., assignor to
Radio Corporation of America, a corporation
of Delaware

Application April 30, 1942, Serial No. 441,169

7 Claims. (Cl. 235—61)

1

This invention relates generally to computing devices and particularly to electronic computers in which a function of two variables is continuously indicated in terms of an electric current or voltage.

Heretofore various electronic computers have been known which utilize moving mechanical parts for light scanning either predetermined fiducial marks or apertures formed by adjustable mechanical elements. This invention contemplates the elimination of all moving mechanical elements in the computer per se and utilizes the substantially inertialess movement of a cathode ray beam for scanning in any desired manner a transparent screen having predetermined fiducial markings. It will be clear that the accuracy of the device is determined principally by the fidelity with which the cathode ray beam may be made to travel along a predetermined path in response to deflecting voltages which are functions of the variables under consideration, the cross-sectional area of the cathode ray beam at the point of impingement on the fluorescent screen, and the accuracy of the fiducial markings on the transparent screen.

An object of the invention is to provide an improved method of and means for computing electronically a predetermined function of two variables. Another object is to provide an improved method of and means for computing electronically, without the use of moving mechanical elements, a function of two variables expressed in terms of voltages applied to a cathode ray tube, and for deriving an electric current proportional in amplitude to the desired function. Another object of the invention is to provide an improved method of and means for deriving continuously and electronically a current which is a predetermined function of two variables applied to the computer in terms of voltages proportional to the instantaneous value of each variable. Still another object is to provide an improved method of and means for correcting errors in such an electronic computer caused by non-linearity of the component electronic elements.

The invention will be described by reference to the drawings, in which Figure 1 is a schematic block diagram of one embodiment, Figure 2 is a block diagram of a preferred embodiment, Figure 3 is an elevational view of the transparent screen having typical fiducial markings, Figure 4 is a schematic circuit diagram of one element of the system, and Figures 5a, 5b, 5c, 5d, 5e, 5f and 5g

2

are graphs showing the operating characteristics of the circuit of Fig. 4.

Referring to Fig. 1, the horizontal deflection elements 6 and the vertical deflection elements 7 of a cathode ray oscillograph tube 8 are supplied with deflecting voltages from an A.-C. generator 3 which may have an output of either sawtooth or sine wave characteristics. Deflecting voltages for the horizontal deflecting elements 6 from the generator 3 are supplied through a variable gain amplifier 4, the gain of which is controlled by a D.-C. voltage source 1. The output voltage of the D.-C. source 1 is proportional to the value of a first variable X. The variable D.-C. voltage may be obtained, for example, from a battery and potentiometer, the sliding contact of which is actuated by the device under observation. Deflecting voltages for the vertical deflection elements are supplied from the same A.-C. generator 3 through a variable gain amplifier 5 in the same phase as the voltages applied to the horizontal deflecting elements. The gain of the variable gain amplifier 5 is controlled by a D.-C. voltage source 2. The output voltage of the second D.-C. source 2 is proportional to the value of a second variable Y. It will be apparent that the cathode ray in the oscillograph tube 8 will traverse a straight line which is a diagonal of a rectangle formed by the variables X and Y as abscissa and ordinate, respectively. The cathode ray beam will, in a well known manner, produce an illuminated line on the fluorescent screen 14 of the cathode ray tube 8. A transparent screen 11, including fiducial markings such as shown in Fig. 3, is located adjacent to and substantially coaxial with the fluorescent screen 14. A light responsive device 12, which may be a light sensitive electron multiplier, is located beyond the screen 14 in light responsive relation with respect thereto. An image of the fluorescent screen is formed by the lens 16 on the transparent screen 11 whereby the light from the fluorescent screen 14 scans the fiducial markings on the transparent screen 11 and actuates the light sensitive device 12 to derive a voltage varying in amplitude at the rate at which the fiducial markings 15 on the screen 11 are scanned. The output of the light sensitive device 12 is applied to the pulse or counter circuit 13 of Fig. 4, which is described and claimed in the copending application of Jan A. Rajchman and Edwin A. Goldberg, Serial No. 437,260, filed April 1, 1942, from which is derived a current proportional in amplitude to the frequency of the voltage applied to its input circuit.

3

It should be understood that the screen 11 may be opaque with transparent fiducial marks, or it may be in the form of a plain or curved reflector to deflect the light beam to the light responsive device 12. Also, if desired, the screen 11 may be omitted, and opaque fiducial markings applied in any well known manner, to the fluorescent screen 14. Furthermore, any other suitable optical system may be included to focus the interrupted light on the light responsive device 12.

Referring to Fig. 2, the electron beam of the cathode ray tube 8 scans the fluorescent screen 14 in much the same manner as described for the system of Fig. 1 with the exception that means are provided for correcting for non-linearity in the operation of the deflecting elements 6 and 7 of the cathode ray tube 8. Deflection of the cathode ray beam is accomplished by applying A.-C. voltages in the same phase derived from the A.-C. generator 3 through a modulator 4 to the horizontal deflection elements 6 and through a modulator 5 to the vertical deflection elements 7 of a cathode ray tube 8.

It will be seen that the cathode ray beam will traverse a straight line across the fluorescent screen 14 in the same manner as described heretofore for the device of Fig. 1. A half-silvered mirror 9 and a second half-silvered mirror 10 normal to the first mirror 9 are disposed between the fluorescent screen 14 and the lens 16 which forms an image of the fluorescent screen on the transparent screen 11 having fiducial markings 15 as described heretofore. A lens 46 may be located adjacent the fluorescent screen 14 to improve the optical efficiency of the system. A portion of the light impinging on the mirror 9 is reflected to the lens 36, which forms an image of the fluorescent screen on a transparent screen 31 having vertical fiducial markings, and is transmitted thereby to the light sensitive device 32 which may be a light sensitive electron multiplier. The remainder of the light beam from the fluorescent screen 14 passes through the half-silvered mirror 9 and a portion of this light is reflected to the lens 26, which forms an image of the fluorescent screen on the transparent screen 21 having horizontal fiducial markings, and is transmitted thereby to the light sensitive device 22 of a type similar to the above mentioned light sensitive device 32. The remaining portion of the light beam passes through the half-silvered mirror 10 to the lens 16, which forms an image of the fluorescent screen on the transparent screen 11, having fiducial markings, for example, of the type shown in Fig. 3, and is transmitted thereby to the light sensitive device 12 which may be of the electron multiplier type.

The voltages derived from the light sensitive device 12 are applied to the input of the counter circuit 13 of Fig. 4, the operation of which is described hereinafter, to derive currents which are proportional in amplitude to the frequency of the applied voltage. The output voltage of the light sensitive device 32 is applied to the input of another counter circuit 33 as described in Fig. 4. The D.-C. output of the counter circuit 33 and a D.-C. voltage from the source 1 which is proportional in amplitude to the value of the first variable X are subtracted, and applied to the input of a conventional D.-C. amplifier 34. The output voltage of the amplifier 34 is applied to the input of the modulator 4 to control the amplitude of the horizontal deflecting voltage from the generator 3. Voltages derived from the light

4

sensitive device 22 are applied to another counter circuit 23 of the type described in Fig. 4. The D.-C. output voltage from the circuit 23 is subtracted from the voltage from the D.-C. source 2, the amplitude of which is proportional to the value of the second variable Y, and applied to the input of the conventional D.-C. amplifier 24. The output voltage of the amplifier 23 is applied to the input of the modulator 5 to control the amplitude of the vertical deflection voltages derived from the generator 3. It will be apparent that the number of voltage pulses derived from the light sensitive devices 22 and 32 will be an indication of the cathode ray beam deflections in the X and Y coordinates. D.-C. voltages derived from the circuits 23 and 33 will therefore be proportional to the rate of deflection along the X and Y coordinates and when subtracted from the voltages derived from the D.-C. sources 1 and 2, will correct for non-linearity in the deflection system.

Fig. 3 is a greatly enlarged view of the characteristic markings on the transparent screen 11, showing the fiducial markings 15 and the path of the light spot R for the variables X_0 and Y_0 . It will be apparent that for the values shown for X_0 and Y_0 , the light beam will be interrupted by the fiducial markings 15 between the points O and P. Of course, in practice, the fiducial markings may be of the order of as many as several hundred to the inch to obtain the desired degree of accuracy. They may be etched, applied photographically, or provided in any other well known manner on a suitable transparent or reflecting support, as described heretofore. The fiducial marks may be equidistant from each other or in any other desired arrangement, depending on the particular function of the variables desired.

Referring to Fig. 4, the circuit for utilizing the voltage pulses derived from the light responsive devices 12, 22 and 32 utilizes a unique arrangement of thermionic tube circuits including a band pass filter, one or more saturation amplifiers, a differentiating circuit, a peak amplifier, and a novel trigger circuit, as well as means for damping the differentiating circuit and the trigger circuit.

Referring to Fig. 4, which shows the circuit details of the counter circuit 13, voltage pulses, which may include a plurality of frequency components, are applied to the input terminals 40 of a filter circuit 49 which is designed to pass the frequency band which is to be measured. The output of the filter 49 is applied to the grid circuit of a first thermionic tube 41. The grid bias is adjusted to limit the amplitude of the signals to be measured in order to eliminate, as much as possible, response to extraneous signals such as harmonics higher than the fundamental frequency. The first tube 41 is operated at the saturation portion of its static characteristic in order to derive an output signal which is substantially of square wave form. The signal is further amplified by a second thermionic tube 42 which is also operated at the saturation point of its static characteristic in order to further improve the square wave form of the signal. The signal of substantially square wave form is next applied to the input circuit of a third thermionic tube 43. The anode circuit of the third tube 43 includes a two-position switch 120 which is connected in one position to a resistor 119 and in another position to one terminal of an inductor 111. The movable arm of the switch 120 is connected to the cathode of a first diode 44 and to one terminal of the ca-

capacitor 121. The remaining terminals of the resistor 119, inductor 111 and the anode of the first diode 44 are all connected through an anode resistor 124 to the source of high potential for the anode of the third tube 43. The remaining terminal of the capacitor 121 is connected to the control electrode of a peak amplifier 45, which is biased to amplify only the positive voltage peaks of the applied signal. The cathode circuit of the peak amplifier 45 includes a cathode resistor 122. Voltage across this resistor is applied to the cathode circuit of a first trigger tube 47. The control electrode of the first trigger tube 47 is connected to the anode of a second diode 46, to one terminal of the grid resistor 115, and to one terminal of the capacitor 113. The cathode of the second diode 46 and the remaining terminal of the resistor 115 are connected to ground. The remaining terminal of capacitor 113 is connected to the anode of the second trigger tube 48 and to one terminal of a resistance network 123. The remaining input terminal of the resistance network 123 is connected to a source of anode potential for the second trigger tube 48. The anode of the first trigger tube 47 is connected to the control electrode of the second trigger tube 48 and to one terminal of a coupling resistor 114. The remaining terminal of the resistor 114 is connected through the resistor 125 to a source of anode potential for the first trigger tube 47.

The operation of the circuit is as follows: The desired frequency component of the signal to be measured is derived from the filter 49 and applied to the control electrode of the first tube 41 which provides high amplification and because of its saturation characteristics, clips the peaks of the signal wave. The signal is further amplified and clipped by a similar action in the second tube 42 and applied as a signal of substantially square wave form to the input of the third tube 43. When the switch 120 is connected to the inductor 111, the third tube 43 is operated to shock-excite the tuned circuit comprising the natural resonant characteristics of the inductor 111, to derive a series of pulses of decreasing amplitude from each square wave pulse applied to the circuit. The first diode 44 provides considerable damping of the pulses of decreasing amplitude to eliminate substantially all of the pulse signal except the first positive cycle. If the switch 120 is connected to the resistor 119, the resistance capacity network 119-121 acts as a differentiating circuit. In this network the voltage across the capacitor 121 will be substantially proportional to the rate of change of the square wave signal applied to the network and will therefore include only a sharp positive and negative pulse for each cycle of the square wave signal. When using the differentiating network, the damping diode 44 may be omitted, since it will have little effect on the circuit operation.

Signals derived from the circuit with either position of the switch 120 are then applied as pulses to the control electrode of the peak amplifier 45. This tube is biased to clip off and amplify only a positive peak portion of the pulse applied to the control electrode.

Sharply peaked voltages from the cathode circuit of the peak amplifier 45 are applied to the input circuit of the first trigger tube 47.

The operation of the trigger circuit is as follows: The first trigger tube 47 is biased so that it is normally conducting while the second trigger tube 48 is biased so that it is normally non-conducting. When a positive pulse from the peak

amplifier 45 is applied to the cathode of the first trigger tube 47, the first trigger tube 47 is biased to cut-off and the second trigger tube 48 is made to conduct. This condition continues after the exciting pulse has passed, and until the grid of the first trigger tube 47 which has been driven to cut off by the charge on the capacitor 113 becomes sufficiently positive for the first trigger tube 47 to again become conducting and the second trigger tube 48 non-conducting. For a single exciting pulse, the time during which the second trigger tube 48 will become conducting depends upon the capacitance of the capacitor 113, the grid capacitance of the first trigger tube 47, the resistance of the resistors 114 and 115, the cut-off voltage of the first trigger tube 47 as well as the rate of change of the maximum voltage on the anode of the second trigger tube 48 when the tube is suddenly made to conduct. Since all of these constants can be calculated and fixed, the circuit can be adjusted to any desired time constant. The limit frequency of the circuit is dependent on the time required for the trigger tubes to return to their normal bias condition after actuation by an exciting pulse. This time interval may be greatly reduced by the use of the second diode 46 which has a damping action on the grid circuit of the first trigger tube 47 by providing substantial attenuation in the circuit when the grid of the first trigger tube 47 is at positive potential. The action of the second diode 46 also tends to make the duration of the current pulse in the anode circuit of the second trigger tube 48 more uniform. The amplitude of this pulse may be maintained at a substantially constant level by proper voltage regulation of the potentials applied to the trigger tube circuits. The current derived from the output terminals 112 of the resistance network 123 will be a fairly accurate indication of the average rate of occurrence of the exciting pulses applied to the cathode of the first trigger tube 47.

Fig. 5a of the drawings shows a typical sine wave signal applied to the input circuit of the first saturation amplifier tube 41. Fig. 5b shows a signal of substantially square wave form derived from the anode circuit of the second tube 42 and applied to the input circuit of the third tube 43. Fig. 5c shows the wave form, on an expanded time scale, comprising pulses of diminishing amplitude derived from the tuned circuit 111 when the switch 120 is connected to the inductor 111. Fig. 5d shows the damping of the pulse current by the first diode 44. The portion of the graph above the dashed line P indicates the positive portion of the pulse current which actuates the peak amplifier 45. Fig. 5e shows the positive pulse derived from across the resistor 122 in the cathode circuit of the peak amplifier 45. Fig. 5g shows the potential variations on the grid of the first trigger tube 47 caused by the application of the pulse shown in Fig. 5e. Fig. 5f shows the corresponding potential variations in the anode circuit of the second trigger tube 48 which are applied to the resistance network 123. The dashed lines in Fig. 5g indicate the damping action of the second diode 46 and clearly show the action of this tube in decreasing the time required for the trigger tubes 47 and 48 to return to their normal bias condition.

It should be understood that the filter 49, tubes 41, 42, 43, 44 and 45, or any of them, may be omitted if the signal to be measured has suitable characteristics for the actuation of the trigger circuit comprising the tubes 46, 47 and 48. It

should also be understood that the second diode 46 may be omitted if the operating frequency of the circuit is sufficiently low to permit the trigger tubes 47 and 48 to return to normal bias condition without the damping action of the diode 46.

Thus the invention describes an electronic computer which comprises a cathode ray tube having a source of alternating potential applied to its deflecting elements through two variable gain amplifiers or modulators, the gain of which are functions of two D.-C. voltages proportional respectively to the values of the two variables. An image of the cathode ray tube fluorescent screen is formed on a second screen having predetermined fiducial markings whereby the light spot derived from the cathode ray beam scans the fiducial marks. Light transmitted by the second screen is applied to a light responsive device connected to a counter circuit from which is derived an indication of the scanning of the fiducial marks. It should be understood that any other suitable counter circuit, other than the circuit heretofore described in detail, may be utilized.

I claim as my invention:

1. A computer for deriving a predetermined function of two independent variables including means for deriving voltages proportional to the value of each variable, means including a cathode ray tube having ray deflection elements, means for applying said voltages to said deflection elements to deflect said ray, and means for deriving from said deflected ray a current substantially proportional to the value of said function.

2. An electronic computer for deriving a predetermined function of two variables including a cathode ray tube having a fluorescent screen in the path of said ray, means for deflecting said ray in a predetermined pattern on said screen, means for determining the horizontal deflection of said ray by the value of one of said variables, means for determining the vertical deflection of said ray by the value of the other of said variables, a second screen having predetermined fiducial markings, means for forming a light image of said fluorescent screen on said second screen, means for deriving voltages which are a function of the intensity of the light transmitted by said second screen, and means for deriving currents substantially proportional in amplitude to the average frequency of said voltages.

3. An electronic computer for deriving a predetermined function of two variables including a cathode ray tube having a fluorescent screen in the path of said ray, means for deflecting said ray in a predetermined pattern on said screen, means for determining the horizontal deflection of said ray by the value of one of said variables, means for determining the vertical deflection of

said ray by the value of the other of said variables, a transparent screen having predetermined fiducial markings, means for forming a light image of said fluorescent screen on said transparent screen, means for deriving voltages which are a function of the intensity of the light transmitted by said transparent screen, and means for deriving currents substantially proportional in amplitude to the average frequency of said voltages.

4. An electronic computer for deriving a predetermined function of two variables including a cathode ray tube having a fluorescent screen in the path of said ray, means for deflecting said ray in a predetermined pattern on said screen, means for determining the horizontal deflection of said ray by the value of one of said variables, means for determining the vertical deflection of said ray by the value of the other of said variables, a reflecting screen having predetermined fiducial markings, means for forming a light image of said fluorescent screen on said reflecting screen, means for deriving voltages which are a function of the intensity of the light reflected by said reflecting screen, and means for deriving currents substantially proportional in amplitude to the average frequency of said voltages.

5. Apparatus of the type described in claim 2 including means for diverting part of the light from said fluorescent screen, means for deriving from said diverted light voltages proportional to the maximum vertical and horizontal components of said ray deflection, and means for utilizing said voltages to compensate for non-linearity in the deflection of said ray.

6. Apparatus of the type described in claim 3 including means for diverting part of the light from said fluorescent screen, means for deriving from said diverted light voltages proportional to the maximum vertical and horizontal components of said ray deflection, and means for utilizing said voltages to compensate for non-linearity in the deflection of said ray.

7. Apparatus of the type described in claim 4 including means for diverting part of the light from said fluorescent screen, means for deriving from said diverted light voltages proportional to the maximum vertical and horizontal components of said ray deflection, and means for utilizing said voltages to compensate for non-linearity in the deflection of said ray.

JAN A. RAJCHMAN.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,244,369	Martin	June 3, 1941