Oct. 14, 1947. J. A. RAJCHMAN 2,428,990

ELECTRONIC COMPUTER

Filed Jan. 22, 1943 2 Sheets-Sheet 1

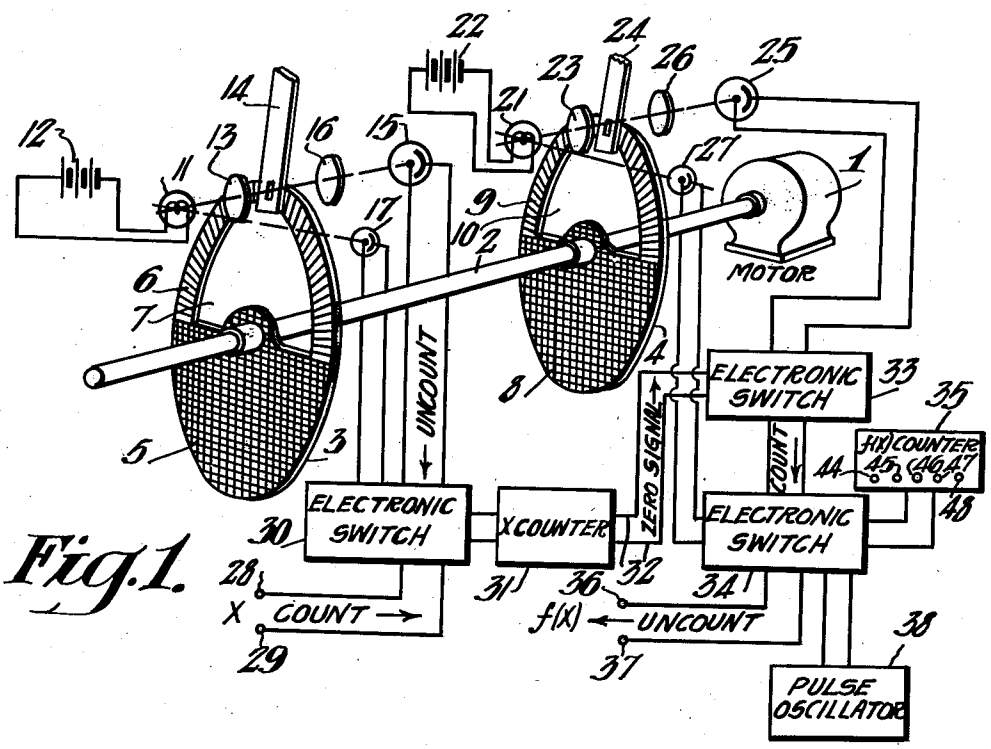
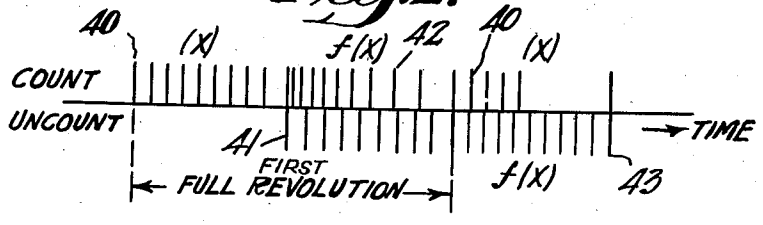


Fig. 1.

Fig. 2.



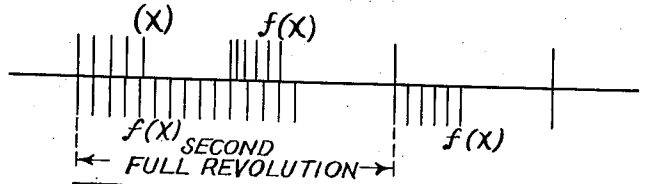


Fig. 2a

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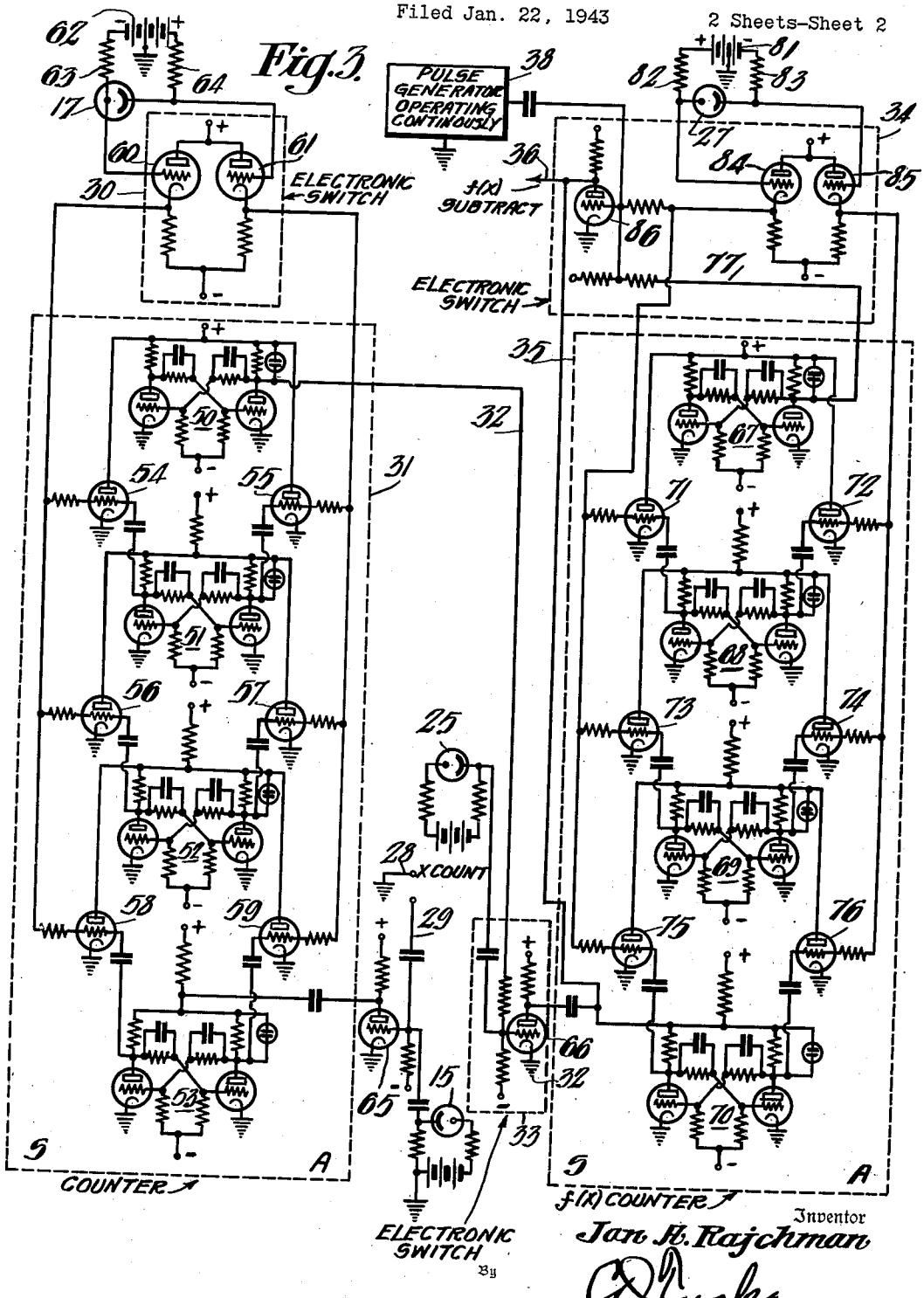
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Oct. 14, 1947. J. A. RAJCHMAN 2,428,990

ELECTRONIC COMPUTER

Filed Jan. 22, 1943 2 Sheets-Sheet 2



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Patented Oct. 14, 1947

2,428,990

UNITED STATES PATENT OFFICE

2,428,990

ELECTRONIC COMPUTER

Jan A. Rajchman, Princeton, N. J., assignor to Radio Corporation of America, a corporation of Delaware

Application January 22, 1943, Serial No. 473,255

9 Claims. (Cl. 235—61)

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This invention relates generally to electronic computers and particularly to an improved method of and means for generating voltage pulses which are a predetermined function of other voltage pulses applied to the device.

While the particular device to be disclosed hereinafter utilizes some mechanical means, it should be understood that variations in speed and arrangement thereof will not materially affect the accuracy of the computation performed by the device. For purpose of illustration, apparatus is disclosed herein which will provide any desired function of a single variable which is applied to the device in the form of voltage pulses.

A variable X may be applied to the apparatus in the form of regularly occurring voltage pulses. These pulses are applied through an electronic switch of any type well known in the art to, and counted upon, a conventional pulse counter which may be of the type described in the copending U. S. application of George A. Morton and Leslie E. Flory, Serial No. 464,293, filed November 2, 1942. Two transparent discs, having opaque fiducial marks, are rotated in phase by a motor. Separate light sources, associated with each rotating disc, respectively actuate two light-sensitive devices. One of the light sensitive devices associated with each disc may, for example, be actuated continuously during each half revolution of the disc, while the other light sensitive device is actuated simultaneously therewith by the interruption of the light beam by the fiducial marks on the disc. One disc should preferably have equally spaced fiducial marks while the other disc has fiducial marks spaced according to the particular function to be derived from the apparatus.

The first light sensitive device which is actuated continuously during each alternate half revolution, and inactive during the next half revolution, controls the operation of an electronic switch in such a manner that the X pulses are counted upon the X counter during the inactive interval of the light sensitive device. The light sensitive device then actuates the electronic switch to apply the pulses derived from the light sensitive device actuated by the equi-spaced fiducial marks to subtract pulses from, or "uncount" the counter until its count is zero. At this point, a zero control signal is derived from the X counter.

Similarly, the light sensitive device associated with the second rotating disc which is actuated continuously during each alternate half revolution of the disc, controls a second electronic switch

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which is connected to a second counter for the desired function of X, i. e., $f(X)$. The pulses derived from the light sensitive device which is associated with the fiducial marks on the second rotating disc, are applied to a third electronic switch which is opened by the zero signal from the X counter. When the first light sensitive device associated with the second disc is actuated, the pulses derived from the second light sensitive device associated with the same disc are applied through the second and third electronic switches to the $f(X)$ counter. The zero signal derived from the X counter when the count thereon reaches zero value interrupts the application of these pulses to the $f(X)$ counter. When the second disc has completed one half revolution, the first light sensitive device associated therewith operates the second electronic switch to subtract pulses from, or "subtract" the $f(X)$ counter and provide a train of pulses at the output terminals which is characteristic of the desired function of X.

Among the objects of the invention are to provide an improved method of and means for counting voltage pulses. Another object is to provide an improved method of and means for deriving a predetermined function of a variable in which the variable is in the form of regularly occurring voltage pulses which control duration of the count of irregularly occurring voltage pulses applied to an electronic counter.

The invention will be described by reference to the accompanying drawing of which Figure 1 is a schematic block circuit diagram of one embodiment thereof, Figures 2 and 2A are a series of graphs illustrating the pulses occurring throughout the system, and Figure 3 is a wiring diagram of the various connections of Fig. 1. Similar reference numerals are applied to similar elements throughout the drawing.

Referring to Figure 1, a motor 1 having a shaft 2 synchronously drives a flat disc 3 in phase with a second flat disc 4. One half of the flat disc 3 has an opaque portion 5 while the other half of the disc is transparent and has regularly spaced opaque fiducial marks 6 near its periphery and an interior transparent portion 7. One half of the second flat disc 4 comprises an opaque section 8. The remaining half of the disc 4 is transparent and has irregularly spaced opaque fiducial marks 9 near its periphery while the interior portion 10 is transparent. The spacing of the fiducial marks 9 is determined by the function of the variable X which is to be generated.

A light source 11 actuated by a source of power,

such as a battery 12, is focused upon the fiducial marks 6 of the disc 3 by means of a lens 13 and an apertured mask 14. The light, after interruption by the fiducial marks 6, is focused upon a first light sensitive device 15 by a second lens 16. Light from the source 11 is also applied simultaneously to a second light sensitive device 17 through the transparent inner portion of the rotating disc 3 during each alternate half revolution thereof.

Similarly, a second light source 21 is energized by a second power source, such as a battery 22. Light from the light source 21 is focused upon the fiducial marks 9 of the second disc 4 by means of a third lens 23 and a second apertured mask 24. The light, after interruption by the fiducial marks 9, is focused upon a third light sensitive device 25 by means of a fourth lens 26. Light from the source 21 is also transmitted simultaneously through the transparent inner portion of the second disc 4 to a fourth light sensitive device 27 during alternate half revolutions of the second disc 4.

The value of the variable X may be represented by a series of regularly occurring voltage pulses which are applied to the input terminals 28, 29. These regularly occurring pulses may be derived in any manner well known in the art.

A control voltage, derived from the second light sensitive device 17 during the interval that the opaque portion 5 of the first disc 3 obscures the first light source 11, operates a first electronic switch 30 to apply the input X pulses to be counted upon a conventional electronic counter 31, which may be of the general type described in the copending application referred to heretofore. The voltage generated by the second light sensitive device 17, during the interval when it is actuated by light from the first light source 11, next actuates the first electronic switch 30 to discontinue the application of the X pulses to the X counter 31 and to apply voltage pulses derived from the first light-sensitive device 15 to subtract from the counter 31. When the counter is completely cleared, a control signal is derived therefrom and applied to a control circuit 32 which actuates a second electronic switch 33.

During the interval that the light from the second light source 21 is applied to the fourth light sensitive device 27, a control potential is derived from the light sensitive device which opens the circuit through a third electronic switch 34. During this period, the pulses derived from the third light sensitive device 25 are supplied through the switch 33 and counted upon a second $f(X)$ counter 35 for recording the function of X. When the zero signal is applied by the X counter 31 to the control circuit 32 it operates the second electronic switch 33 to interrupt the application of the pulses from the third light sensitive device 25 to the $f(X)$ counter 35. It will be seen, therefore, that the $f(X)$ counter 35 records the pulses from the third light sensitive device 25 at the same time that the pulses from the first light sensitive device 15 are being subtracted from the X counter 31. If desired, the count recorded upon the $f(X)$ counter 35 may be indicated upon a plurality of gaseous discharge lamps 44, 45, 46, 47, 48 in the manner described in the copending U. S. application mentioned heretofore.

Similarly, while the two light sources 11 and 21 are obscured by the opaque portions 5 and 8 of the discs 3 and 4, respectively, the X pulses are set up in the X counter 31 and the $f(X)$ count upon the second counter 35 is caused to be subtracted and applied to the output terminals 36, 37. This subtraction may be accomplished, for example, by a pulse oscillator 38, and is controlled by operation of the third electronic switch 34 in response to the absence of a control voltage from the fourth light sensitive device 27 which is connected thereto. A counter adapted to both counting and subtraction is described in the copending U. S. application mentioned heretofore.

Referring to Figure 2, which represents the condition for the maximum value of the function, it will be seen that the regularly occurring X pulses 40 occur during some portion of the first half of each revolution of the disc 3 while the opaque portion 5 of the disc obscures the second light-sensitive device 17. These pulses are recorded upon the X counter 31. During the next succeeding half revolution of the discs 3 and 4, pulses 41 derived from the light-sensitive device 15 uncount the X counter, while pulses 42 derived from the third light-sensitive device 25 are counted simultaneously upon the $f(X)$ counter 35.

During the next repetition of the first half revolution of both discs, X pulses 40 are again counted upon the X counter 31, while the $f(X)$ pulses 43 are subtracted from the $f(X)$ counter 35 and applied to the output terminals 36, 37.

Fig. 2A is a continuation of Fig. 2 and represents the condition for a less than maximum value of the function. This value is of course selected in response to the value of X set up in the counter 31 during the last half revolution shown by Fig. 2.

It should be understood that the pulses may be counted and subtracted from the respective counters by the method disclosed in the copending application mentioned heretofore, or in any other manner known in the art.

Since the timing of the two discs is mechanically synchronized by the rotation of a common shaft, speed variations thereof may be substantially disregarded, providing each count and uncount is completed in less time than is required for a half revolution of the shaft 2.

It should be understood further that variations of the mechanical, optical and electrical elements may be employed in any manner well known in the art. For example, rotating cylinders may be utilized instead of rotating discs. Also, the fiducial marks may extend completely around the discs or cylinders, and pulses may be derived therefrom on alternate revolutions by any known switching means.

In considering the wiring diagram of Fig. 3, it is helpful to remember that the cycle of operation involves one period when light reaches the various photocells and another period when no light reaches these cells. During the dark period, (1) the cell 17 operates to connect the leads 28—29 through the switch 30 to the set-up device 31 so that a value of X is established or stored in this set-up device and (2) the photocell 27 operates to maintain the switch 34 closed so that any number established in the set-up device 35 is transferred to the leads 36—37.

The cells 15 and 25 perform no useful function during this dark period.

During the light period which follows (1) the cell 27 operates to open the switch 34, (2) the cell 25 operates to store a value of the function f in the set-up device 35, (3) the cell 17 interrupts the connection to the leads 28—29, and (4) the

cell 15 operates through the switch 30 to turn back the device 31 till it registers zero. When the device 31 registers zero, a pulse from the device 31 functions to open the switch 33. Otherwise stated, the value of the function is derived from the disc 4 and stored in the set-up device 35 during one-half revolution of the discs 3 and 4 and is delivered at the output terminals 36—37 during the next one-half revolution of these discs. The selected value of the function is, of course, determined by the X value established in the device 31.

The set-up devices 31 and 35 in which the X and $f(X)$ values are stored are of a well known type which includes a plurality of multivibrator units interconnected through transfer tubes. Thus the device 31 includes units 50 to 53, the units 50 and 51 being connected through transfer or blocking tubes 54 and 55, the units 51 and 52 being connected through transfer tubes 56 and 57, and the units 52 and 53 being connected through the transfer tubes 58 and 59.

The switch 30 includes a pair of tubes 60 and 61 which have their grid potentials controlled by the cell 17 to which a battery 62 is connected through resistors 63 and 64. When the cell 17 is not illuminated, it conducts little or no current, the grid of the tube 61 is at a more positive potential, and the grid of the tube 60 is at a more negative potential. Under these conditions, the tube 61 conducts current, the tube 60 is biased down, a more positive potential is applied to the grids of the tubes 55, 57 and 59 which are biased to cut off and a more negative potential is applied to the grids of the tubes 54, 56 and 58 which are biased beyond cut off. Under these conditions, the device 31 stores the pulses applied to the leads 28—29 and through these leads and a control tube 65 to the common anode terminal of the unit 53. Each of these pulses (applied to the leads 28—29) increases the current of the tube 65 and causes a negative pulse to be applied to the common anode terminal.

Thus, the first pulse transfers current from the left to the right-hand side of the unit 53; the second pulse transfers current to the left side of the unit 53 and produces at the grid of the tube 59 a positive pulse which increases the current of the tube 58 and produces at the common anode terminal of the unit 52 a negative pulse by which current is transferred to the right-hand side of this unit; and the third pulse transfers current to the right side of the unit 53. There are now three pulses stored in the device 31. Further steps in the operation of the device 31 are apparent from the following tabulation, remembering that tubes 54, 56 and 58 are blocked and 55, 57 and 59 are biased for normal operation. In this tabulation an R indicates that the right side of the unit is conducting and an L indicates that the left side of the unit is conducting.

Pulse No.	Unit 50	Unit 51	Unit 52	Unit 53
1	L	L	L	L
2	L	L	L	R
3	L	L	R	L
4	L	L	R	R
5	L	R	L	L
6	L	R	L	R
7	L	R	R	L
8	L	R	R	R
9	R	L	L	L

When current is transferred to the right side of the unit 50, the tube 66 is biased down. As hereinafter explained, this biasing down of the

tube 66 has for its purpose to terminate the supply of pulses from the cell 25 to the counter 35 when the count of the counter 31 is reduced to zero and the zero signal is applied to the switch 33.

When the cell 17 is illuminated and takes current, the tubes 55, 57 and 59 are biased beyond cut off, the tubes 54, 56 and 58 are provided with their normal bias, and the device 31 is in a condition to have its stored number diminished in response to pulses applied from the cell 15 through the tube 65 to the common anode terminal of the unit 53. Turning back of the device 31 to zero may be done with any number of stored pulses. Assuming five pulses to have been stored in the device 31, the various steps are indicated by the following tabulation:

Pulse No.	Unit 50	Unit 51	Unit 52	Unit 53
5	L	R	L	L
1	L	L	R	R
2	L	L	R	L
3	L	L	L	R
4	L	L	L	L
5	R	R	R	R

It is apparent that the fifth subtracting pulse results in a more negative potential at the grid of the tube 66 and the interruption of the supply of pulses from the cell 25 through the tube 66 to the device 35.

The device 35 is similar to the device 31 with the exception that its storing and subtracting operations are controlled by the cell 27 and the switch 34 and its subtracting pulses are supplied from the generator 38. It includes units 67 to 70, the units 67 and 68 being interconnected through the tubes blocking or transfer tubes 71 and 72, the units 68 and 69 being connected by the tubes 73 and 74 and the units 69 and 70 being connected by the tubes 75 and 76.

The cell 27 is connected to a battery 81 through resistors 82 and 83 and functions to control the grid potential of tubes 84 and 85. With no illumination on the cell 27, the grid of the tube 84 is more positive and that of the tube 85 more negative, the tubes 72, 74 and 76 are biased beyond cut off and the tubes 71, 73 and 75 are provided with normal bias and the tube 86 transmits subtracting pulses from the generator 38 to the common anode terminal of the unit 70. These pulses subtract from the count stored in the device 35 in the same manner as that set forth in connection with the device 31 and the cell 15. When the subtraction operation is complete, a pulse applied through the lead 77 operates to interrupt the supply of oscillations from the generator 38.

When the cell 27 is illuminated, the tubes 71, 73 and 75 are biased beyond cut off, the tube 86 is biased off and the tubes 72, 74 and 76 are provided with normal bias. Under these conditions, pulses are supplied from the cell 25 through the tube 66 to the device 35 as previously indicated.

Obviously, the devices 31 and 25 will include as many units as are required to express the desired function in the binary numerical system as pointed out in the aforesaid application Serial No. 464,293.

Thus the invention described comprises an improved method of and means for generating voltage pulses which are a predetermined function of other applied pulses which represent the instantaneous value of a variable quantity.

I claim as my invention:

1. The combination of first and second set-up

devices, means for establishing in said first device a representation of the value of a variable, synchronously operated sources of timing pulses and of function pulses timed with respect to said timing pulses in accordance with a function of said variable, means for applying said timing pulses to change said representation to represent progressively lower values, means for establishing in said second device a representation of said function pulses simultaneously with said change in representation, and means for interrupting the supply of said function pulses to said second device in response to a zero value representation of said first device.

2. The combination of first and second set-up devices, means for establishing in said first device a representation of the value of a variable, synchronously operated sources of timing pulses and of function pulses timed with respect to said timing pulses in accordance with a function of said variable, means for applying said timing pulses to change said representation to represent progressively lower values, means for establishing in said second device a representation of said function pulses simultaneously with said change in representation, and means controlled by said second device for delivering a number of pulses determined by the representation in said second device simultaneously with the establishment in said first device of a representation of a successive value of said variable.

3. The combination of first and second set-up devices, means for establishing in said first device a representation of the value of a variable, synchronously operated sources of timing pulses and of function pulses timed with respect to said timing pulses in accordance with a function of said variable, means for applying said timing pulses to change said representation to represent progressively lower values, means for establishing in said second device a representation of said function pulses simultaneously with said change in representation, and means including a continuously operating generator controlled by said second device for delivering pulses determined by the representation established therein.

4. The combination of first and second set-up devices, means for establishing in said first device a representation of a value of a variable, a first member having a timing record, a second member having a function record, means for simultaneously moving said members, means responsive to said timing record for changing said representation to represent progressively lower values, means responsive to said function record for establishing in said second device a representation of the value of a function of said variable, and means responsive to a zero value representation of said first device for terminating the establishing of said function value representation.

5. The combination of first and second set-up devices, means for establishing in said first device a representation of a value of a variable, a first member having a timing record, a second member having a function record, means for simultaneously moving said members, means responsive to said timing record for changing said representation to represent progressively lower values, means responsive to said function record for establishing in said second device a representation of the value of a function of said variable, an output circuit and means controlled by said second device for delivering from said output terminals pulses determined by said function value representation.

6. The combination of first and second set-up devices, means for establishing in said first device a representation of a value of a variable, a first member having a timing record, a second member having a function record, means for simultaneously moving said members, means responsive to said timing record for changing said representation to represent progressively lower values, means responsive to said function record for establishing in said second device a representation of the value of a function of said variable, and means including a continuously operating generator controlled by said second device for delivering a number of pulses determined by said function value representation.

7. The combination of first and second set-up devices, means for establishing in said first device a representation of a value of a variable, a first member having a timing record, a second member having a function record, means for simultaneously moving said members, means responsive to said timing record for changing said representation to represent progressively lower values, means responsive to said function record for establishing in said second device a representation of the value of a function of said variable, means including a pulse generator for changing the representation established in said second device, and means responsive to a zero value representation of said second device for terminating the effect of said generator on said second device.

8. The combination of first and second set-up devices, means for establishing in said first device a representation of one value of a variable, a first member provided with opaque, transparent and timing record areas, a second member provided with opaque, transparent and function record areas, means for simultaneously moving said members, means responsive to light transmitted through the transparent area of said first member for terminating said representation, means for deriving from said timing record timing pulses whereby said representation is changed to represent progressively lower values, means responsive to said function record for establishing in said second device a representation of the value of a function of said variable, and means responsive to a zero value representation of said first device for interrupting the establishing of said function value representation in said second device.

9. The combination of first and second set-up devices, means for establishing in said first device a representation of one value of a variable, a first member provided with opaque, transparent and timing record areas, a second member provided with opaque, transparent and function record areas, means for simultaneously moving said members, means responsive to light transmitted through the transparent area of said first member for terminating said representation, means for deriving from said timing record timing pulses whereby said representation is changed to represent progressively lower values, means responsive to said function record for establishing in said second device a representation of the value of a function of said variable, output terminals, and means responsive to said second member for controlling the delivery to said output terminals of a number of pulses determined by said function value representation.

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