May 17, 1949. M. L. GREENOUGH 2,470,303

COMPUTER

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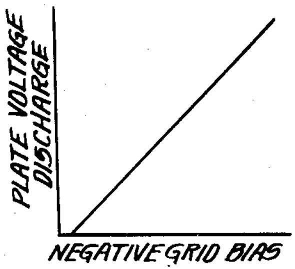

Fig. 1.

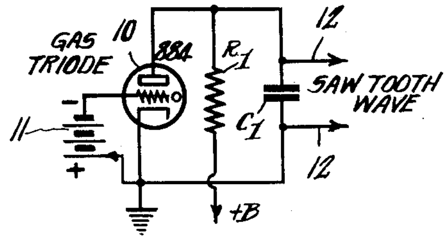

Fig. 2.

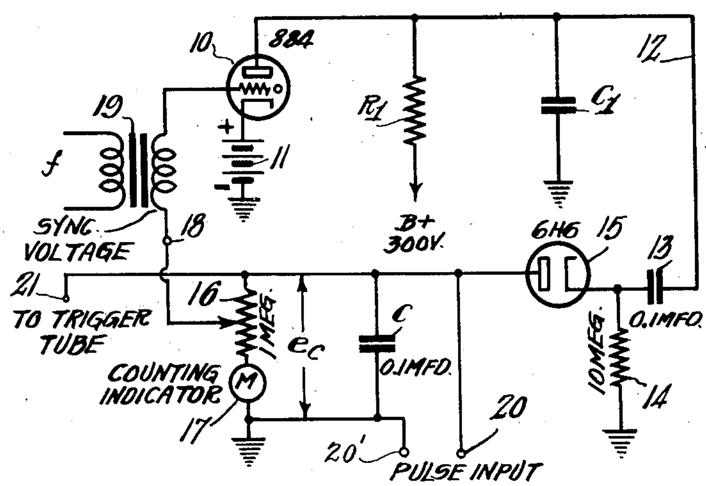

Fig. 3.

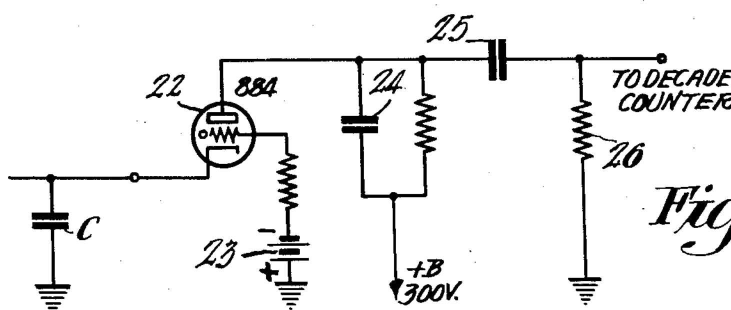

Fig. 4.

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COMPUTER

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This invention relates to computers which are operated to perform a mathematical calculation in response to trains of electrical impulses representative of the numbers involved in such calculation. It has for its principal object the provision of an improved computer and method of operation whereby different types of calculations may be effected more simply and with less apparatus than that heretofore required for this purpose.

There have been provided in the past, various types of computers which operate in response to trains of electrical pulses representative of the numbers involved in a calculation to produce a train of electrical pulses representative of the result of the calculation. Many of these computers have been based on the binary numerical system in order to minimize the required number of electron discharge tubes and have involved the use of multivibrator units so operated that each unit represents a different digital position of the number and the digit for that position determines which electron discharge element of the unit is conducting current. Such a computer leaves something to be desired in the way of simplicity for the reason that it requires two electron discharge elements for each digital position of the numbers involved in the calculation. In some cases, there is also involved the additional difficulty of converting the calculated data from the binary system to the decimal system.

In accordance with the present invention, these difficulties are avoided by the provision of a gas-triode saw tooth oscillation generator which is operated from one stable operating condition to another in response to pulses of the pulse trains representative of the numbers involved in the calculation. As such a generator passes from one stable operating condition to another, its output voltage varies in discrete steps each of which may represent a different digit of the decimal system.

Important objects of the invention are the provision of an improved computer and method of operation whereby voltage pulses are translated into a voltage which changes by a discrete step in response to each of such pulses; and the provision of an improved computer which may be operated readily to perform calculations in any preferred numerical system.

The invention will be better understood from the following description considered in connection with the accompanying drawings and its scope is indicated by the appended claims.

Referring to the drawings:

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Figure 1 is an explanatory diagram indicating the relation between the grid bias and plate current starting voltages of a saw tooth oscillation generator including a gas tube,

Figure 2 is a wiring diagram of a saw tooth oscillation generator having the output voltage characteristic illustrated by Fig. 1,

Figure 3 is a wiring diagram of a single computer unit which, for example, may form one decade of a complete computer, and

Figure 4 is a wiring diagram of a coupling circuit which is adapted to be connected between units similar to that of Fig. 3 for triggering the following decade once each time the count of the preceding decade is completed.

Fig. 1 shows the relation between grid bias potential and the voltage at which current starts through the plate or anode circuit of a gas triode such as the RCA 884. It will be noted that increasing the negative bias increases the plate voltage at which the gas triode takes current and vice versa. With the exception of a fixed component, the voltage required to start plate current is a constant times the grid bias voltage. If such a gas tube is connected to operate as a saw tooth oscillation generator, as illustrated by Fig. 2, the peak amplitude of the generated saw tooth wave increases in direct proportion to the grid bias potential.

The saw tooth oscillation generator of Fig. 2 includes a gas triode tube 10 which has its grid bias potential applied from an adjustable source shown as a battery 11 and its plate or anode potential applied from a terminal +B through a resistor R_1. Connected between the cathode and anode of the tube 10 is a capacitor C_1 which is provided with output terminals 12. In the operation of the generator of Fig. 2, the capacitor C_1 is charged from the terminal +B through the resistor R_1 and is discharged through the tube 10 when the capacitor voltage has attained a value dependent on the grid potential of the tube 10. After each discharge of the capacitor, the voltage again rises, resulting in a saw tooth wave, at the terminals 12.

As previously indicated, the peak amplitude of the generated saw tooth pulse or wave increases in direct proportion to the grid bias potential of the tube 10. If this grid bias potential is derived from and is directly proportional to the saw tooth output pulse amplitude, the saw tooth oscillation generator maintains any established operating condition for the reason that the generated grid bias potential at any saw tooth pulse amplitude is just that required to sustain oscillations at that amplitude. How this principle of operation is utilized to produce a voltage which changes by discrete steps is readily understood in connection with the computer unit of Fig. 3.

The computer unit of Fig. 3 includes a peak detector or rectifier 15 which is coupled to the capacitor C_1 through a capacitor 13 and resistor 14 and functions to charge a capacitor C connected in parallel with a circuit including a resistor 16 and an indicator 17 which may be a micro-ammeter or other instrument suitable for indicating the voltage of the capacitor C. Bias potential is applied from the resistor 16 through a terminal 18 and the secondary winding of a transformer 19 to the grid of the tube 10. Input pulses are applied to the terminal 20, output pulses are delivered at a terminal 21. A synchronization voltage of frequency f is applied to the grid of the tube 10 through the transformer 19.

With a synchronizing voltage of frequency f thus applied to the grid of the tube 10, oscillations can be generated only at a frequency

$$f, \frac{f}{2}, \frac{f}{3}, \text{etc.}$$

Saw tooth pulse amplitude at a frequency of

$$\frac{f}{2}$$

will be twice that at a frequency of f because the build-up or capacitor charging time is twice as long. Similarly saw tooth pulse amplitude at a frequency of

$$\frac{f}{3}$$

is three times that at a frequency of f etc. Since the frequency of oscillation can have only certain discrete values, such as

$$f, \frac{f}{2}, \frac{f}{3}, \frac{f}{4} \quad . \quad . \quad . \quad \frac{f}{17}$$

so can the voltage e_c across the capacitor C have only certain distinct values which are separated by equal discrete steps. Whenever established at some arbitrary value, the frequency and grid bias potential will always swing to the nearest of these allowable or stabilized values. By establishing successive values of grid bias potentials there are established successive conditions of stable equilibrium.

This mode of operation follows from the fact that the grid bias voltage of the tube 10 is the resultant of (1) the unidirectional voltage of the battery 11 which is constant, (2) the synchronizing voltage applied through the transformer 19 which has a constant frequency and amplitude, and (3) the voltage drop of the upper part of the resistor 16 which is unidirectional and has a value dependent on the output voltage of the oscillator. Since the oscillator has a constant amplitude output voltage for any given bias potential of the tube 10, it is apparent that the charge of the capacitor C, the voltage drop of the resistor 16 and the potential of the output lead 21 will be maintained constant so long as no pulses are applied to the input lead 20.

It will be noted that the unidirectional voltage of the battery 11 is opposed to the unidirectional voltage drop across the upper part of the resistor 16 so that the grid bias potential of the tube 10 becomes more positive as the voltage drop across the resistor 16 increases.

As pointed out above, the oscillator can operate only at the frequency of the synchronizing voltage applied through the transformer 19 or at some submultiple of that frequency. This is so because the oscillator is locked in step with the synchronizing frequency and must therefore operate at this or a submultiple frequency.

If the oscillator is operating at the synchronizing frequency, for example, the application of a negative pulse to the input lead 20 makes the grid of the tube 10 more positive so that the operating frequency of the oscillator is reduced by one half and the oscillator output voltage is increased by one discrete step. This voltage increase is somewhat larger than the input pulse voltage required to push the oscillator into its new stable operating condition. The final charge of the capacitor C, the final grid bias voltage of the tube 10 and the final voltage of the output lead 21 are therefore independent of the voltage of the input pulse and are altogether dependent on the output voltage of the oscillator.

The next pulse applied to the input lead functions in the same way to temporarily unlock the oscillator from the synchronizing frequency so that the operating frequency of the oscillator is reduced by the same amount as by the first input pulse. Under these conditions, the voltage of the output lead 21 is changed by one discrete step as previously explained and is maintained at this new value until a subsequent input pulse is applied.

Thus, to operate the unit of Fig. 3 as a computer, it is necessary to apply through the terminal 20 pulses of sufficient energy to push the unit into successive conditions of stable operation. As these pulses are applied one after another, the voltage of the capacitor C is changed by discrete steps until it attains a value at which a pulse is delivered through the coupling circuit of Fig. 4 to a following unit or decade which is similar to that of Fig. 3.

The coupling or trigger circuit of Fig. 4 includes a gas triode 22 which has its cathode connected to the ungrounded terminal 21 of the capacitor C of Fig. 3, has its grid biased to a potential determined by a battery 23 and functions to charge a capacitor 24 when its cathode is driven sufficiently negative by the potential of the capacitor C. When this occurs, there is transmitted through a coupling capacitor 25 and resistor 26 to the next unit a pulse whereby a count of one is registered in this decade. The capacitor 24 is discharged through its parallel-connected resistor while a potential representative of a count of ten (in the case of a decade) is being built up on the preceding unit.

The unit of Fig. 3 has been operated quite satisfactorily to accumulate a count of ten input pulses. A greater number of pulses may be accumulated if a higher plate supply voltage is provided. The best results have been obtained by starting with e_c equal to zero and applying negative pulses through the lead 20 to raise the voltage of the capacitor C for adding the applied pulses. Pulses of positive polarity are applied to the lead 20 to lower the voltage of the capacitor C for substracting the applied pulses. The instantaneous net number of pulses must, of course, be greater than zero.

The computer unit of Fig. 3 has the advantage of simplicity. A gas triode and a diode are all the tubes required to add and subtract up to ten. Only one additional gas triode is required for discharging the capacitor C and triggering the following unit or decade. The required amplitude of the triggering or input pulse is not critical but may vary between limits of ±50% for the reason that it "rounds off" to the nearest whole number. Only a total of fifteen tubes are required to count to one million. This is an economy of apparatus not heretofore realized in connection with other types of electronic computers.

I claim as my invention:

1. The combination of an oscillation generator including a storage device, impedance means for controlling the rate at which current is stored in said device and a gaseous electron discharge device provided with an anode circuit arranged to discharge said storage device and with a grid circuit arranged to control the potential at which said discharge is initiated, and means connected between said storage device and said grid for applying to said grid a bias potential which is stabilized at successive prodetermined values dependent on the charge of said storage device.

2. The combination of an oscillation generator including a storage device, impedance means for controlling the rate at which current is stored in said device and a gaseous electron discharge device provided with an anode circuit arranged to discharge said storage device and with a grid circuit arranged to control the potential at which said discharge is initiated, means connected between said storage device and said grid for applying to said grid a bias potential which is stabilized at successive predetermined values dependent on the charge of said storage device, and means for controlling said values so that they are all different from one another and are separated by discrete steps.

3. The combination of an oscillation generator including a storage device, impedance means for controlling the rate at which current is stored in said device and a gaseous electron discharge device provided with an anode circuit arranged to discharge said storage device and with a grid circuit arranged to control the potential at which said discharge is initiated, parallel connected resistance and capacitance means, means for detecting the output potential of said generator and applying said detected potential to said parallel connected means, and means for applying a component of said detected potential to said grid.

4. The combination of an oscillation generator including a storage device, impedance means for controlling the rate at which current is stored in said device and a gaseous electron discharge device provided with an anode circuit arranged to discharge said storage device and with a grid circuit arranged to control the potential at which said discharge is initiated, parallel connected resistance and capacitance means, means for detecting the output potential of said generator and applying said detected potential to said parallel connected means, means for applying a component of said detected potential to said grid, and means for superimposing a synchronizing potential on said detected potential component.

5. The combination of an oscillation generator including a storage device, impedance means for controlling the rate at which current is stored in said device and a gaseous electron discharge device provided with an anode circuit arranged to discharge said storage device and with a grid circuit arranged to control the potential at which said discharge is initiated, parallel connected resistance and capacitance means, means for detecting the output potential of said generator and applying said detected potential to said parallel connected means, means for applying a component of said detected potential to said grid, means for superimposing a synchronizing potential on said detected potential component, and means for superimposing on said detected potential control pulses whereby said generator output voltage is stabilized at values separated by discrete steps.

6. The combination of an oscillation generator including a storage device, impedance means for controlling the rate at which current is stored in said device and a gaseous electron discharge device provided with an anode circuit arranged to discharge said storage device and with a grid circuit arranged to control the potential at which said discharge is initiated, parallel connected resistance and capacitance means, means for detecting the output potential of said generator and applying said detected potential to said parallel connected means, means for applying a component of said detected potential to said grid, means for superimposing a synchronizing potential on said detected potential component, means for superimposing on said detected potential control pulses for changing said generator output voltage by discrete steps, and means responsive to a predetermined value of said detected potential for transmitting a pulse to a utilization device.

7. The combination of a plurality of units each including a saw tooth generator of the type wherein a gaseous conduction electron discharge device has a storage device connected in its output circuit and functions to discharge said storage device in response to the application of a predetermined potential to its input circuit, means for detecting the output potential of said generator, parallel-connected capacitance and resistance means through which a component of said detected potential is utilized to control the input potential of said generator and means for superimposing a synchronizing potential on said component, means for applying to a first of said units control pulses whereby the potential of its parallel-connected capacitance and resistance means is changed by discrete steps, and means connected between the parallel-connected capacitance and resistance means of said first unit and those of a second of said units for increasing the generator output potential of said second unit by one discrete step in response to a predetermined potential of the parallel-connected capacitance and resistance means of said first unit.

8. The combination of an oscillation generator of the type wherein a gaseous conduction electron discharge device has a storage device connected in its output circuit and functions to discharge said storage device in response to the application of a predetermined potential to its control grid, means for applying to said grid a bias potential proportional in value to the output voltage of said generator, means for applying to said grid a constant frequency alternating potential whereby the operating frequency of said generator may be stabilized at successive values differing from one another by a predetermined amount, and means for applying to said grid successive voltage pulses whereby said operating frequency is pushed from one to another of said successive values.

9. The combination of an oscillation generator of the type wherein a gaseous conduction electron discharge device has a storage device connected in its output circuit and functions to discharge said storage device in response to the application of a predetermined potential to its control grid, means for applying to said grid a bias potential proportional in value to the output voltage of said generator, means for apply-

ing to said grid a constant frequency alternating potential whereby the operating frequency of said generator may be stabilized at successive values differing from one another by a predetermined amount, and means for applying to said grid successive positive pulses whereby said operating frequency is pushed to successive values each lower than the preceding value by said predetermined amount.

10. The combination of an oscillation generator of the type wherein a gaseous conduction electron discharge device has a storage device connected in its output circuit and functions to discharge said storage device in response to the application of a predetermined potential to its control grid, means for applying to said grid a bias potential proportional in value to the output voltage of said generator, means for applying to said grid a constant frequency alternating potential whereby the operating frequency of said generator may be stabilized at successive values differing from one another by a predetermined amount, means for applying to said grid successive voltage pulses whereby said operating frequency is pushed from one to another of said successive values, and means for applying to said grid successive negative pulses whereby said operating frequency is pushed to successive values each higher than the preceding value by said predetermined amount.

11. The combination of an oscillation generator of the type wherein a gaseous conduction electron discharge device has a storage device connected in its output circuit and functions to discharge said storage device in response to the application of a predetermined potential to its control grid, means for applying to said grid a bias potential proportional in value to the output voltage of said generator, means for applying to said grid a constant frequency alternating potential whereby the operating frequency of said generator may be stabilized at successive values differing from one another by a predetermined amount, means for applying to said grid successive voltage pulses whereby said operating frequency is pushed from one to another of said successive values, and means for producing an output pulse in response to a predetermined number of changes in said operating frequency.

12. The combination of an oscillation generator of the type wherein a gaseous conduction electron discharge device has a storage device connected in its output circuit and functions to discharge said storage device in response to the application of a predetermined potential to its control grid, means including a detector and a capacitor and resistor each connected across said detector for applying to said grid a bias potential proportional in value to the output voltage of said generator, means for applying to said grid a constant frequency alternating potential whereby the operating frequency of said generator may be stabilized at successive values differing from one another by a predetermined amount, and means including said resistor for applying to said grid successive voltage pulses whereby said operating frequency is pushed from one to another of said successive values.

13. The combination of an oscillation generator of the type wherein a gaseous conduction electron discharge device has a storage device connected in its output circuit and functions to discharge said storage device in response to the application of a predetermined potential to its control grid, means including a detector and a capacitor and resistor each connected across said detector for applying to said grid a bias potential proportional in value to the output voltage of said generator, means for applying to said grid a constant frequency alternating potential whereby the operating frequency of said generator may be stabilized at successive values differing from one another by a predetermined amount, means including said resistor for applying to said grid successive voltage pulses whereby said operating frequency is pushed from one to another of said successive values, and means connected across said capacitor for producing an output pulse in response to a predetermined number of said changes in said operating frequency.

14. The combination of an oscillation generator of the type wherein a gaseous conduction electron discharge device has a storage device connected in its output circuit and functions to discharge said storage device in response to the application of a predetermined potential to its control grid, means including a detector and a capacitor and resistor each connected across said detector for applying to said grid a bias potential proportional in value to the output voltage of said generator, means for applying to said grid a constant frequency alternating potential whereby the operating frequency of said generator may be stabilized at successive values differing from one another by a predetermined amount, means including said resistor for applying to said grid successive voltage pulses whereby said operating frequency is pushed from one to another of said successive values, a second electron discharge device having its input circuit connected across said capacitor, and means including a second capacitor connected in the output circuit of said second electron discharge device for producing an output pulse in response to a predetermined number of said changes in said operating frequency.

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