Feb. 8, 1949. B. D. LOUGHLIN 2,461,120

SIGNAL GENERATOR

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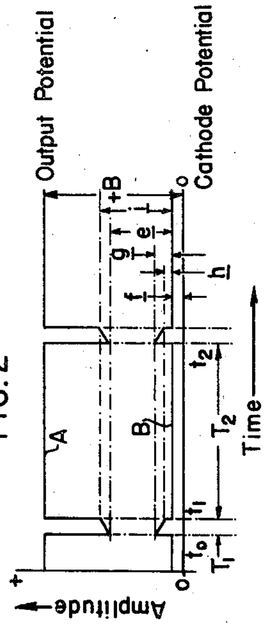

FIG. 2

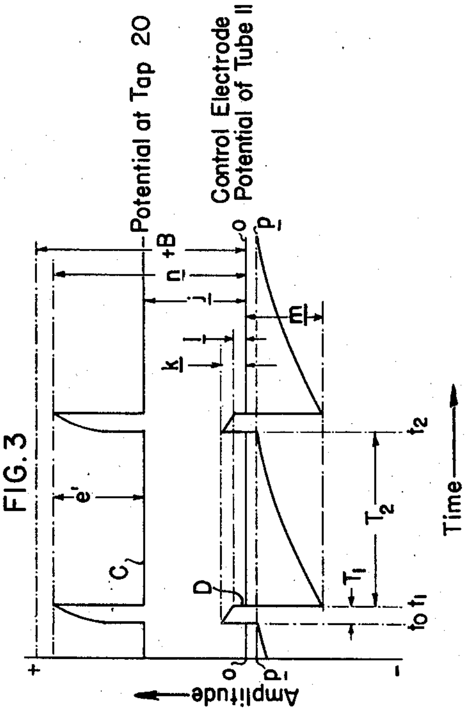

FIG. 3

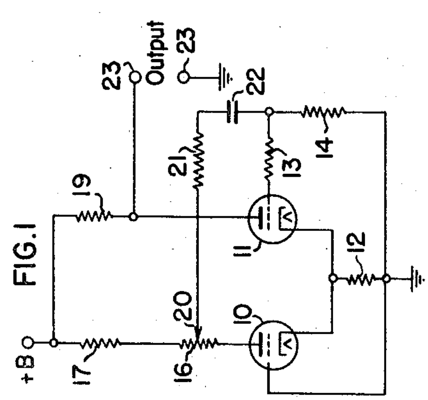

FIG. 1

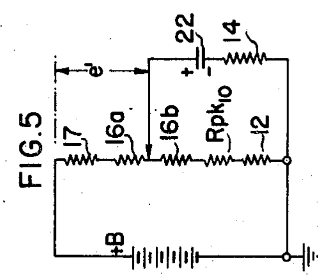

FIG. 5

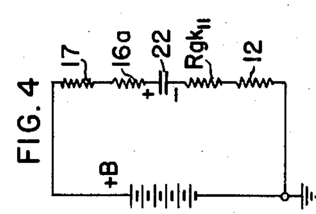

FIG. 4

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SIGNAL GENERATOR

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2 Claims. (Cl. 250—36)

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This invention relates generally to generators for generating signals of periodic wave form and of variable periodicity and particularly to a pulse generator of this type having an adjustable period and in which the ratio of the pulse duration to the interval between pulses is substantially constant.

For some purposes, such as in keying circuits, it is necessary to utilize a signal of periodic wave form which has a periodicity which may be varied over a relatively wide range of values. It is often desirable, during the time that the frequency or periodicity of this wave signal is being altered, to maintain substantially constant the ratio of the succeeding time intervals of the signal. For example, in a signal having a pulse-type wave form, it may be desirable to hold substantially constant the ratio of pulse duration to pulse separation with changes in frequency. Signal generators of the prior art for developing a signal of this general character are subject to several disadvantages which, in some cases, may limit the extent of their usefulness. For example, in some signal generators which heretofore have been used, the frequency of operation is controlled by means of a variable resistor or variable energy-storage device, such as an adjustable inductor or condenser, which comprise elements in a time-constant circuit. Control arrangements of this type, in varying the frequency of the generator over a substantial range, tend to upset the ratio of the succeeding portions of individual periods of the generated signals. Another method frequently employed in generators of periodic signals to alter the periodicity thereof comprises varying the magnitude of the unidirectional operating potential supplied to the system. Generators which are controlled in this manner are generally capable of developing a signal of a periodicity which is variable only over a relatively small range of values while maintaining substantially constant the ratio of the succeeding intervals of the generated signals. An additional disadvantage is inherent in a generator of the last-mentioned type when a signal of variable periodicity but of substantially constant amplitude is desired, since a change in the potential of the source of supply also results in a corresponding change in the amplitude of the generated signal. Prior art signal generators of the character under consideration employing electron tubes in the circuits thereof periodically require the replacement of tubes. Since the characteristics of individual tubes of the same type usually vary to some extent, it is generally necessary to readjust the control elements of the generator whenever a tube is replaced. This procedure is often rather complicated, thus making it more desirable to accomplish this readjustment by means of a simple arrangement such as a unicontrol adjusting device.

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It is an object of the invention, therefore, to provide an improved generator of the type under consideration which is substantially free from one or more of the above-mentioned disadvantages or limitations of generators of the prior art.

It is another object of the invention to provide a signal generator for generating a signal of periodic wave form and of variable periodicity, including relatively simple means for adjusting the periodicity of the generated signal over a relatively wide range of values while maintaining substantially constant the ratio of the succeeding time intervals of the generated signal.

It is a further object of the invention to provide a signal generator for generating a signal of periodic wave form and of variable periodicity, including means for adjusting the periodicity of the generated signal over a relatively wide range of values while maintaining substantially constant the ratio of the succeeding time intervals of the generated signal and for maintaining substantially constant the amplitude of the generated signal.

In accordance with the invention, a generator for generating a signal of periodic wave form and of variable periodicity comprises a first electron tube having an anode-cathode space-current path and at least two operating conditions and a second electron tube having a control electrode-cathode space-current path. The generator includes means including the second electron tube, a first time-constant circuit including an energy-storage device and the aforesaid control electrode-cathode space-current path, and a second time-constant circuit including an energy-storage device and the aforesaid anode-cathode space-current path for causing the first electron tube to alternate during succeeding time intervals from one of the operating conditions to the other to complete for successive pairs of time intervals operating cycles. The generator additionally includes an impedance included in an energizing circuit of the first electron tube to develop an output potential having an amplitude varying with the two operating conditions thereof. An adjustable contact engages the impedance for connecting a different portion of the impedance in each of the first and second time-constant circuits and for applying to the aforesaid means a selectable portion of the output potential while at the same time providing with adjustments of the contact an adjustment of the time constants of the first and second time-constant circuits, whereby the duration of each of the succeeding time intervals is adjusted in substantially the same proportion while the periodicity of the operating cycles is adjusted over a relatively wide frequency range.

For a better understanding of the present invention, together with other and further objects thereof, reference is had to the following description taken in connection with the accompanying drawing, and its scope will be pointed out in the appended claims.

In the accompanying drawing, Fig. 1 is a schematic circuit diagram of a signal generator in accordance with the invention; Figs. 2 and 3 comprise curves which are utilized in explaining the operation of the generator of Fig. 1; while Figs. 4 and 5 are elementary diagrams utilized in summarizing the operation of the generator of Fig. 1.

Referring now to Fig. 1 of the drawing, the generator for generating a signal of periodic wave form and of variable periodicity comprises means having at least two operating conditions. This means comprises an electron tube 10 which constitutes one element of a relaxation-type oscillator. The signal generator also comprises means including at least one time-constant circuit for causing the first-named means to alternate during succeeding time intervals from one of the above-mentioned conditions to the other to complete operating cycles for successive pairs of the intervals, the ratio of the time intervals of each of these pairs having a predetermined value. In addition to the aforementioned time-constant circuit, to be described in detail subsequently, this means comprises an electron tube 11 coupled to the input and output circuits of tube 10 for alternately rendering tube 10 conductive and non-conductive. The cathodes of tubes 10 and 11 are interconnected and are grounded through a common cathode resistor 12, while the control electrode of tube 10 is connected directly to ground and the control electrode of tube 11 is grounded through a resistor 13 in series with a resistor 14. Resistor 13 has a small value, say 100 ohms, whereas resistor 14 preferably has a large value of the order of several megohms. The resistance of element 14 is also materially higher than the conductive interelectrode impedances of the tubes and particularly the conductive anode-cathode impedances of tube 10 and also the control electrode-cathode impedance of tube 11 when the latter is drawing grid current. An impedance having a fixed value is included in an energizing circuit for the tube 10 to develop an output potential having an amplitude varying with the two operating conditions of the tube 10. This means comprises a resistor 16 having a high impedance. One of the fixed terminals of the resistor 16 is connected to the anode of tube 10 and the other fixed terminal is connected to a terminal of a resistor 17, the latter also having a high resistance. The anode of tube 11 is connected to the other terminal of resistor 17 and also to a source of potential indicated as +B through a resistor 19.

The signal generator also comprises an adjustable contact or tap 20 engaging the resistor 16 for applying to the aforementioned means which includes at least the one time-constant circuit a selectable portion of the output potential developed by the resistor 16 while at the same time providing with adjustments of the tap 20 an adjustment of the time constant of the aforesaid time-constant circuit, whereby the duration of each of the succeeding time intervals is adjusted in substantially the same proportion while the periodicity of the operating cycles is adjusted over a relatively wide range of values. The adjustable tap 20 is connected to the common junction of the resistor 13 and the resistor 14 through a portion of a time-constant circuit including a resistor 21 and an energy-storage device such as a condenser 22. A pair of output terminals 23, 23 may be connected between any two suitable points in the signal generator circuit such as between the anode of tube 11 and ground. It will be understood, however, that an output signal of a desired magnitude and wave form may be derived from other points in the multivibrator circuit.

In considering the operation of the signal generator of Fig. 1, it will be assumed that at time t_0, indicated in Figs. 2 and 3, the tube 11 becomes conductive. The flow of current through resistor 19 at time t_0 causes the potential between the anode of tube 11 and ground, and hence the potential across the terminals 23, 23, to drop from the +B value, indicated in curve A of Fig. 2, to a value designated e. Also at time t_0, the flow of current through cathode resistor 12 increases in magnitude so that the potential of the cathodes of tubes 10 and 11 rises in a positive direction above the original value f, which is illustrated in curve B of Fig. 2, and approaches a new value g. This increases the bias on the control electrode of tube 10 thereby driving tube 10 to cutoff, whereupon the potential at tap 20 initially rises sharply in a manner similar to that shown in curve C of Fig. 3 so that a more positive potential is applied to the control electrode of tube 11 through the resistor 21, condenser 22, and resistor 13. This causes an increased current flow through tube 11 and resistor 12 so that the cathode potential reaches the value g mentioned above at about the time anode current saturation is reached. Tube 11 thereupon draws grid current between the interval t_0—t_1, and the voltage developed across the resistor 12 decreases as illustrated in curve B, whereupon at time t_1 this voltage has dropped to the value h while the signal developed at terminals 23, 23 increases slightly to the value i indicated in curve A of Fig. 2. During the interval t_0—t_1, the potential between tap 20 and ground first rises abruptly from a predetermined positive value j, as shown in the curve C of Fig. 3, and then ascends more gradually until it reaches a value n approaching that of the +B level at time t_1. The wave form of the signal which is applied to the control electrode of tube 11 also rises abruptly at time t_0 to the value k, as shown in curve D of Fig. 3, and then, as a result of the flow of grid current, declines slightly to the value l at time t_1. At instant t_1, since the potential of the cathode of tube 10 has dropped to the critical value h as represented in curve B in Fig. 2, the bias on tube 10 is sufficiently reduced so that tube 10 becomes conductive. A sudden decrease in the cathode potential to the original value f then follows. The flow of current in tube 10 and in the anode load resistors 16 and 17 causes the potential between tap 20 and ground to decrease. As a result, a negative signal is translated to the control electrode of tube 11 through resistor 21, condenser 22, and resistor 13, thereby operating tube 11 to cutoff at time t_1 and increasing the potential developed across terminals 23, 23 to the +B value, as shown in curve A of Fig. 2.

At time t_1 the potential between tap 20 and ground drops from the value designated n to the value j illustrated in curve C of Fig. 3, while the voltage developed at the control electrode of tube 11 drops suddenly in a negative direction to the negative value m illustrated in curve D of Fig. 3. The magnitude of this potential change is determined by the setting of tap 20, and its effect will be more fully explained hereinafter. Since tube 11 becomes non-conductive at time t_1, the negative charge which is accumulated on the lower plate of condenser 22 decays exponentially in the manner illustrated by curve D of Fig. 3 over a period determined by the time constant of the circuit comprising the large resistor 14, the resistor 21, the portion of resistor 16 between tap 20 and the anode of tube 10, resistor 12, and the anode-cathode resistance of tube 10. The potential of the control electrode of tube 11 therefore becomes more positive until at time t_2 when it reaches the *p—p* level, indicated in connection with curve D of Fig. 3, tube 11 again becomes conductive and its cathode acquires a positive potential, as shown in curve B of Fig. 2. Tube 10 is again driven to cutoff, as previously explained, and the cycle of operation is repeated.

The manner in which the period of an operating cycle is adjusted over a relatively wide range while maintaining substantially constant the ratio of the succeeding time intervals T_1 and T_2 of the generated wave will now be explained. Tube 11 is conductive during period T_1 and also draws grid current. Since tube 10 is nonconductive at this time, the potential at tap 20 on the resistor 16 rises toward the +B value. During this portion of the cycle the condenser 22 is being charged through resistor 17, the upper portion of resistor 16, resistors 21 and 13, Rgk_{11} and resistor 12, where Rgk_{11} is the grid-cathode resistance of tube 11. As the charge on condenser 22 increases exponentially, the current through the aforementioned resistors decreases exponentially until the voltage drop across resistor 12 is low enough that tube 10 becomes conductive. The voltage drop e' of curve C of Fig. 3 occurs when tube 10 conducts current and the negative voltage m, shown in curve D of Fig. 3, appears on the grid of tube 11. Thus, tube 11 is biased to cutoff at time t_1 and tube 10 becomes conductive, thereby terminating the period T_1. When the tap 20 is adjusted in the direction of the junction between resistor 16 and resistor 17, the charging time constant is reduced thereby decreasing the duration of period T_1.

Movement of tap 20 toward the junction between resistor 16 and resistor 17 also decreases the variation in voltage between tap 20 and ground during period T_1 (i. e., reduces the voltage step e'), since tap 20 is thus positioned at a point nearer the potential of the source +B. A corresponding reduction in the magnitude of the signal which is translated to the control electrode of tube 11, and accordingly the charge which is developed on the lower plate of condenser 22, is effected. As a result, a shorter interval of time T_2 is required before the charge on condenser 22 leaks off and tube 11 again becomes conductive. Thus, the adjustment of the tap 20 on the resistor 16, which comprises the common adjusting element in the above-mentioned charging and discharging time-constant circuits, is effective to increase the generator frequency while maintaining the ratio T_1/T_2 substantially constant.

Conversely, adjustment of tap 20 on the resistor 16 toward the anode of tube 10 increases proportionately the duration of both the periods T_1 and T_2. Thus, this direction of adjustment is effective to decrease the generator frequency while maintaining the ratio T_1/T_2 substantially constant.

It will be seen, therefore, that a simple adjustment of the tap 20 engaging the resistor 16 is effective to alter the duration of succeeding time intervals T_1 and T_2 in the same sense while maintaining substantially constant the ratio of these periods. Also, it will be apparent that there is developed at the terminals 23, 23 an output signal of periodic-pulse wave form and of variable periodicity having a substantially constant amplitude.

From the above explanation of the operation of the system, it will also be apparent that resistor 17 is employed to provide sufficient voltage feedback to the input circuit of tube 11 regardless of the setting of the adjustable tap 20 of voltage divider 16. With some generator arrangements of the type under consideration, it may be unnecessary to include the resistors 13 and 21 to develop a satisfactory output signal, the frequency of which may be varied over a relatively wide range of values while maintaining substantially constant the ratio of the succeeding time intervals of the signal. When considerably greater accuracy in the ratio of the succeeding periods is desired, resistors 13 and 21 may be selected to provide a charging time constant for the condenser 22 which varies appropriately with the magnitude of the feed-back voltage applied to condenser 22, as in the preferred embodiment described above.

To provide a clearer picture of the time constants involved during the periods T_1 and T_2, reference is made to Figs. 4 and 5. In these equivalent circuits the small resistors 13 and 21 have been omitted since for many applications of the generator they are unnecessary.

During the shorter interval T_1 when tube 11 is fully conductive and tube 10 is nonconductive, the circuit condition is shown by the equivalent circuit of Fig. 4. The condenser 22 is charged from battery +B (the upper plate positive and the lower plate negative) through resistors 17, 16*a*, Rgk_{11} and 12 in series, where 16*a* represents the portion of resistor 16 between the tap 20 and the resistor 17. As the charge on condenser 22 increases exponentially the current, and hence the voltage drop across the several resistors, decreases exponentially until the voltage across resistor 12 no longer biases tube 10 beyond cutoff. At this point tube 10 becomes conductive and the regenerative action previously described cuts off tube 11.

The longer time interval T_2 thereupon starts and the equivalent circuit during the interval T_2 is shown in Fig. 5. The effective voltage from the battery is now divided by the several resistors 17, 16*a*, 16*b*, Rpk_{10} and 12, where Rpk_{10} is the plate-cathode resistance of tube 10 and 16*b* represents the portion of resistor 16 between the tap 20 and the anode of tube 10. The source voltage for condenser 22 is therefore that across resistors 16*b*, Rpk_{10} and 12 in series. The voltage charge on the condenser 22 is originally higher than the voltage of this new source and, hence, condenser 22 starts to discharge through resistors 16*b*, Rpk_{10}, 12, and 14 in series. Resistor 14 is very large and is the principal resistor in determining the larger time constant during the interval T_2.

It is evident from an examination of Fig. 4 that if resistor 16*a* is made smaller the time constant, and hence interval T_1, is decreased. Conversely, it is evident from Fig. 5 that, in making resistor 16*a* smaller, the resistor 16*b* is made larger, thus increasing the time constant during interval T_2. However, this change is relatively small because resistor 14 is very large and the major effect is the reduction of the source voltage by the voltage step e'. Hence, the time required for the condenser 22 to discharge to a point where tube 11 becomes conductive, resulting in the circuit conditions of Fig. 4, is shorter when resistor 16a is made smaller. That is, the time T_2 is made shorter.

It is noted, therefore, that, in both Figs. 4 and 5, the effect of decreasing the size of resistor 16a is to decrease both the time intervals T_2 and T_2, which results in an increase in the generator frequency while the ratio T_1/T_2 is maintained substantially constant. Conversely, an increase in the value of resistor 16a decreases the generator frequency while maintaining the ratio T_1/T_2 substantially constant.

In summary it is noted that the time interval T_1 is affected primarily by a change in the charging time constant due to a change in the value of resistor 16a, while the time interval T_2 is affected primarily by the change in the voltage step e' due to a change in the same resistor 16a. For a given change in resistor 16a, therefore, the corresponding changes in the periods T_1 and T_2 are in the same sense.

While applicant does not wish to limit the invention to any specific circuit constant, the following circuit constants are given as illustrative of values of circuit elements which may be utilized in the circuit of Fig. 1:

Tubes 10 and 11	6J6 (twin triode)
Resistor 12	10,000 ohms
Resistor 13	100 ohms
Resistor 14	2.2 megohms
Resistor 16	500 kilohms (max.)
Resistor 17	470 kilohms
Resistors 19 and 21	330 kilohms
Condenser 22	0.05 microfarad
+B	400 volts
Frequency range of generator	2½ to 10 cycles per second
Ratio of periods T_1/T_2	⅓

While there has been described what is at present considered to be the preferred embodiment of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is, therefore, aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A generator for generating a signal of periodic wave form and of variable periodicity comprising: a first electron tube having an anode-cathode space-current path and at least two operating conditions; a second electron tube having a control electrode-cathode space-current path; means including said second electron tube, a first time-constant circuit including an energy-storage device and said control electrode-cathode space-current path, and a second time-constant circuit including said energy-storage device and said anode-cathode space-current path for causing said first electron tube to alternate during succeeding time intervals from one of said conditions to the other to complete for successive pairs of said time intervals operating cycles; an impedance included in an energizing circuit of said first electron tube to develop an output potential having an amplitude varying with said two operating conditions thereof; and an adjustable contact engaging said impedance for connecting a different portion of said impedance in each of said first and second time-constant circuits and for applying to said means a selectable portion of said output potential while at the same time providing with adjustments of said contact an adjustment of the time constants of said first and second time-constant circuits, whereby the duration of each of said succeeding time intervals is adjusted in substantially the same proportion while the periodicity of said operating cycles is adjusted over a relatively wide frequency range.

2. A generator for generating a signal of periodic wave form and of variable periodicity comprising: a first electron tube having an anode-cathode space-current path and at least two operating conditions; a second electron tube having a control electrode-cathode space-current path; a cathode impedance common to both of said electron tubes; means including said second electron tube, a first time-constant circuit including an energy-storage device with said cathode impedance and said control electrode-cathode space-current path, and a second time-constant circuit including said energy-storage device and said anode-cathode space-current path for causing said first electron tube to alternate during succeeding time intervals from one of said conditions to the other to complete for successive pairs of said time intervals operating cycles; an impedance included in an energizing circuit of said first electron tube to develop an output potential having an amplitude varying with said two operating conditions thereof; said energizing-circuit impedance having a fixed value which is substantially greater than that of said cathode impedance, the conductive anode-cathode impedance of said first electron tube, and the conductive control electrode-cathode impedance of second electron tubes during one of said operating conditions; and an adjustable contact engaging said energizing-circuit impedance for connecting a different portion of said impedance in each of said first and second time-constant circuits and for applying to said means a selectable portion of said output potential while at the same time providing with adjustments of said contact an adjustment of the time constants of said first and second time-constant circuits, whereby the duration of each of said succeeding time intervals is adjusted in substantially the same proportion while the periodicity of said operating cycles is adjusted over a relatively wide frequency range.

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REFERENCES CITED

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

UNITED STATES PATENTS

Number	Name	Date
2,185,363	White	Jan. 2, 1940
2,193,868	Geiger	Mar. 19, 1940
2,346,396	Rider	Apr. 11, 1944
2,356,248	Koren	Aug. 22, 1944
2,375,950	Schlesinger	May 15, 1945
2,411,062	Schade	Nov. 12, 1946
2,414,323	Moe	Jan. 14, 1947
2,416,201	Nagel et al.	Feb. 18, 1947
2,438,638	Lakatos	Mar. 30, 1948

FOREIGN PATENTS

Number	Country	Date
485,934	Great Britain	May 26, 1938
352,401	Great Britain	July 3, 1931
528,806	Great Britain	Feb. 14, 1940