July 28, 1936. B. STALLARD 2,049,179

FREQUENCY GENERATOR SYSTEM

Filed March 6, 1934

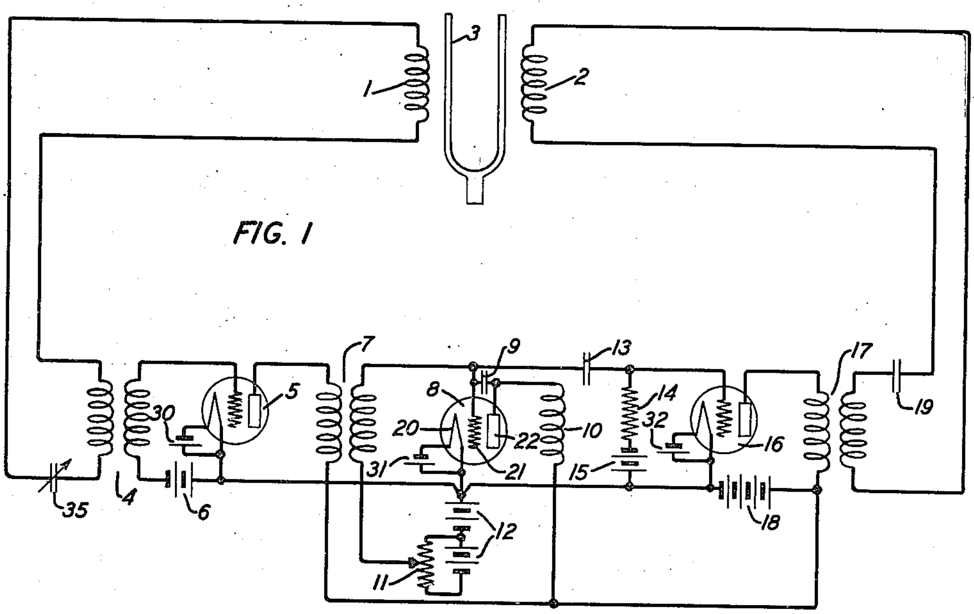

FIG. 1

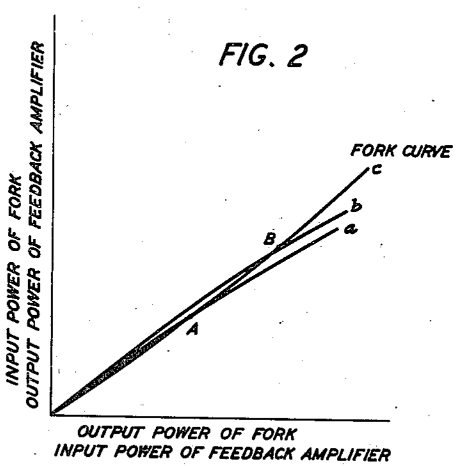

FIG. 2

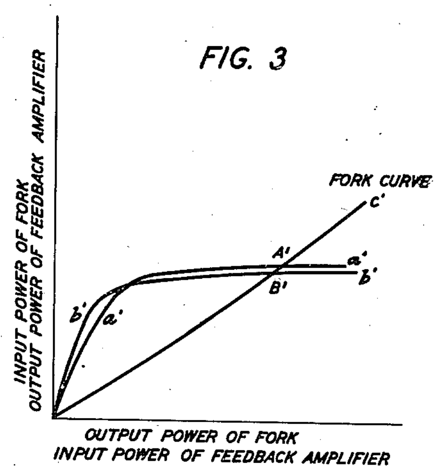

FIG. 3

INVENTOR
B. STALLARD

BY E. V. Griggs

ATTORNEY

Patented July 28, 1936 2,049,179

UNITED STATES PATENT OFFICE

2,049,179

FREQUENCY GENERATOR SYSTEM

Burrell Stallard, Bloomfield, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application March 6, 1934, Serial No. 714,356

4 Claims. (Cl. 250—36)

This invention relates to frequency generator systems and more particularly to the stabilization of frequencies of these systems.

An object of this invention is the stabilization of frequencies of frequency generators.

Another object of this invention is the regulation and efficient control of the amplitude of vibration of the mechanical elements of mechanically controlled oscillators.

Another object of this invention is the facilitation of starting of regeneratably driven forks employed in frequency generators.

The stabilization of the frequency of the current of the output of frequency generators is highly desirable in telephoto and other systems in which precise synchronization is required. Due to changes in circuit conditions and other causes variations in frequency of the current produced by mechanically controlled oscillators employed in these systems occur in relatively short periods of time. The variation in the amplitude of vibrations of the mechanical member of this type of oscillator causes an increase or decrease in the frequency in the output of the generator. An increase in the amplitude of vibration of the mechanical member produces a decrease in frequency, while a decrease in the amplitude of vibration results in an increase in frequency. Changes in the condition of the circuit, such as the power supply, are chiefly responsible for the variations in the amplitude of vibration of the mechanical members.

In accordance with this invention, the anode-cathode impedance of a space discharge device controlled by the varying potential of the control electrode of the device maintains the output power of these oscillators relatively constant. The anode-cathode impedance is associated with the circuit for the supply of power to the mechanical member, and by means of the potential of the control electrode varies with the generated electromotive force of this circuit. The control electrode is biased so that no appreciable current passes through the impedance when the electromotive force of the circuit does not exceed a value which produces an increase in power, a decrease in the amplitude of vibration of the mechanical member and an increase in the frequency of current of the oscillator. When the electromotive force of the circuit increases above this predetermined value, the impedance decreases rapidly and a fairly large proportion of the current of the circuit passes through the impedance. As a consequence, the power supply to the mechanical member of the oscillator is maintained relatively constant by this impedance.

In a tuning fork oscillator of the conventional type comprising a tuning fork, a driving and driven element and an amplifier, the anode-cathode impedance of the space discharge device is bridged across the amplifying circuit to which the driving element is coupled. The potential of the control electrode of the device varies directly with the fluctuation of the electromotive force produced by the amplifier. However, the control electrode is biased to prevent any appreciable current passing through the anode-cathode impedance until the electromotive force of the oscillator exceeds the limit necessary for the optimum range of the mechanical member. This limit may be varied by means of a variable resistance or potentiometer which controls the biasing potential. Any increase in the electromotive force of the amplifier above the limit produces a rapid decrease in the anode-cathode impedance. The proportion of the current of the amplifier passing through the impedance is markedly increased while the proportion passing through the driving element of the oscillator decreases. Accordingly, when the electromotive force of the amplifier remains below the selective predetermined limit, practically all of the current of the amplifier passes through the driving element. When the electromotive force exceeds this limit, approximately the same current passes through the driving element, the surplus current being absorbed by the impedance. Regardless of the value of the electromotive force produced by the amplifier and its fluctuation due to variations in the current supplied for the anode of the amplifier, a relatively constant current is applied to the driving element. The control of the power delivered to the driving element limits the variation of vibration of the amplitude of the fork and as a result, the frequency of current of the oscillator is stabilized.

A more comprehensive understanding of this invention may be obtained by reference to the drawing in which:

Fig. 1 is a schematic diagram of an application of the invention in a tuning fork oscillator;

Fig. 2 illustrates diagrammatically the effect that small changes in the power supply of a mechanically controlled oscillator produces in the amplitude of vibration of the mechanical member when the stabilization circuit of this invention is not employed;

Fig. 3 shows diagrammatically the variations in the amplitude of vibration of the mechanical member resulting from changes in the power supply of the oscillator embodying this invention.

In Fig. 1 the amplitude of vibration of the tuning fork 3 controls and determines the frequency of current of the oscillator. The vibrations of the fork generate an electromotive force in the driven or pick-up coil 1. This electromotive force is impressed upon the control electrode of the space discharge device 5 through the transformer 4. The waves generated by this electromotive force are amplified by the device 5 and pass through the transformer 7 to the space discharge device 16 in which they are further amplified. The amplified waves are transmitted through the transformer 17 to the driving coil 2 to actuate in a well known manner the tuning fork 3.

Bridged across the circuit of the oscillator between the space discharge devices 5 and 16 is a space discharge device 8. The anode-cathode impedance of this device is connected across the circuit. The anode 22 of the device is connected to one side of the circuit through the condenser 9, while the cathode 20 is connected to the other side of the circuit. The control electrode 21 of the device is connected to the same side of the circuit as the anode 22. The battery 12 furnishes the biasing potential for the control electrode 21 through the potentiometer 11. The biasing potential may be changed when desired by means of the potentiometer 11.

The space current for the devices 5, 8, and 16 is supplied by the battery 18. A series impedance coil 10 is provided through which the space current passes to the anode 22 of the space discharge device 8. The biasing potential for the control electrode of device 16 is furnished by battery 15 through resistance 14, while that for the control electrode of the device 5 is supplied by the battery 6. A blocking condenser 13 serves to prevent direct current from the output circuits of devices 5 and 8 from being impressed on the control electrode of space discharge device 16. A condenser 19 is inserted in the circuit between the secondary of transformer 17 and the driving coil 2. Cathode heating current for devices 5, 8 and 16 is supplied by batteries 30, 31, and 32, respectively.

Variable condenser 35 in inserted in series with the driving or pick-up coil. The function of this condenser is to compensate partially for the difference in physical dimensions of different forks for the production of the desired frequency, or for changes produced in the same fork as it ages. By adjusting the capacity of the condenser the necessity of filing a new fork or a fork, the characteristics of which have changed, is avoided.

The operation of the oscillator is as follows: The vibrations of the tuning fork 3 are induced in the winding of the driven member 1 and after passing through transformed 4 are amplified by the space discharge device 5. The amplified current passes through the secondary winding of the transformer 7. The anode-cathode impedance of the space discharge device 8 affords one path for the amplified current, while another path leads to the input of space discharge device 16. The potential bias of the control electrode is sufficient to prevent any appreciable amount of current passing through the anode-cathode impedance of the space discharge device 8. This bias is so regulated by means of the potentiometer 11 that the anode-cathode impedance is infinitely high until the potential of the control electrode exceeds a predetermined limit. This limit is determined by ascertaining the value of the electromotive force produced in the winding of the secondary of the transformer 7 above which the power output of the amplifier causes variations in the amplitude of vibration of the fork 3. If, due to physical changes in the fork, a different amplitude of the fork is necessary than that previously required or if a different frequency is desired, the circuit may be stabilized at the frequency desired by changing the bias of the control electrode by means of the potentiometer 11. When the predetermined value of the electromotive force is exceeded, the potential of the control electrode 21 increases and the anode-cathode impedance of the device is suddenly decreased. Accordingly, a greater proportion of the current impressed on the secondary of the transformer 7 passes through this impedance and a lesser proportion passes through the device 16. Expressed differently the increase of potential of the control electrode 21 above the operating point of the space discharge device results in the passage of current from the anode 22 to the cathode 20. The output current so produced is 180 degrees out of phase with that of the input from the secondary of transformer 7. This condition prevents further increase in the power to the input of the space discharge device 16. As a consequence the input power to the device 16 is maintained at a fairly constant value.

The current is further amplified by the space discharge device 16 and passes through the transformer 17 to the driving element 2. The power delivered to the driving element 2 due to the stabilization action of device 8 remains constant.

The operation of the oscillator and the function of this invention in the stabilization of the frequency of an oscillator is more readily demonstrated by reference to Figs. 2 and 3.

Fig. 2 shows the relationship between the input and output power of a single linear amplifier employed in a tuning fork oscillator without the stabilization circuit of this invention and the correlation between the input and output power of the tuning fork of this oscillator. Curve *a* represents the relation between the input and output of the amplifier that exists for the production of the frequency desired. Curve *c* shows the output power of the fork produced by varying the input power. In curve *b* the relation between the input and output power of the amplifier is shown when the circuit conditions of the amplifier have changed. These changes may be due to decreases in the current supply for the anode of the space discharge devices employed in the amplifier. The particular relation of the input and output power of the amplifier at which the fork operates is the intersection A and B of the amplifier power curve *a* or *b* and the fork power curve *c* since at these points equilibrium is attained.

Fig. 3 shows the relative output of the amplifier and fork of the oscillator produced by the input of the amplifier and fork in the oscillator shown in Fig. 1. Curve *a′* represents the input and output power of the amplifier which insures the production of a current the frequency of which is desired, while curve *b′* shows the relationship between the input and output power of the amplifier when the current conditions of the amplifier have changed. Curve *c′* shows the correlation between the input and output power of the fork employed in the oscillator. The fork operates at point A′ or B′ depending upon whether the input-output power characteristics of the amplifier is that represented by curve *a′* or *b′*, respectively.

The change in the power relation between curve a to curve b in Fig. 2 shifts the operating point on the fork curve from point A to point B. A substantial increase in the power of the fork accordingly results. A marked decrease in the amplitude of vibration of the fork follows with a consequential increase in the frequency of current of the oscillator. With the stabilization effected by the space discharge device **8**, however, the variations in the input and output power relation of the amplifier from curve a' to curve b' of Fig. 3 produces little change in the operating point of the fork as indicated by points A' and B' on the fork curve. Since little variation in the power of the fork results, the amplitude of vibration of the fork and the frequency of current of the oscillator are stabilized.

An important advantage inherent in this invention is that the fork or other vibratory element starts from rest when the power characteristics of the oscillator are those represented in Fig. 3. The mechanical member of an oscillator, the power characteristics of which are shown in Fig. 2, does not start from rest unless the amplification is so great that the mechanical member is normally driven at a considerable increase in amplitude which results in a decrease in frequency stability.

The particular embodiment described is illustrative and is not to be construed as a limitation of the scope of the invention. Various modifications utilizing the principle of this invention for the control of the amplitude of vibration of mechanical vibratory elements or for the stabilization of frequency of mechanically controlled oscillators, such as piezoelectric crystal oscillators and other oscillators may be employed without diverting from the scope of this invention.

What is claimed is:

1. In combination, a mechanically controlled oscillator comprising a mechanical vibratory member, a driving element for actuating said member, an electric discharge amplifier for supplying power to said element and a space discharge device controlled by the electromotive force generated by said amplifier for maintaining the power supplied by said amplifier to said element relatively constant.

2. In combination, a mechanically controlled oscillator comprising an amplifier having an input circuit, stabilizing means comprising a space discharge device including an anode-cathode impedance and a control electrode for maintaining the frequency of currents of said oscillator relatively constant, means for applying the electromotive force generated in said input circuit to said control electrode to vary said impedance, and means controlling said stabilizing means for varying the frequency of oscillations of said oscillator for which stabilization is effected.

3. A tuning fork oscillator comprising a tuning fork, a driving coil, a pick-up coil, an amplifier having an output circuit connected to said driving coil and an input circuit connected to said pick-up coil, said amplifier comprising two electric discharge devices, a pair of conductors connecting said electric discharge devices in cascade, a space discharge device comprising anode, cathode and control electrode bridged across said pair of conductors between the two said electric discharge devices of said amplifier, the anode and control electrode of said space discharge device being connected to one side of said pair of conductors and the cathode being connected to the other side of said pair of conductors, a source of biasing potential for said control electrode and means for varying said biasing potential.

4. A mechanically controlled oscillator comprising a mechanical vibratory element, an amplifier having input and output circuits coupled to said vibratory element for the production of sustained oscillations, a space discharge device comprising an anode-cathode impedance bridged across said input circuit and a control electrode and means including said control electrode for varying said impedance in accordance with the electromotive force generated in said input circuit for maintaining the energy supplied to said output circuit relatively constant.

BURRELL STALLARD.