

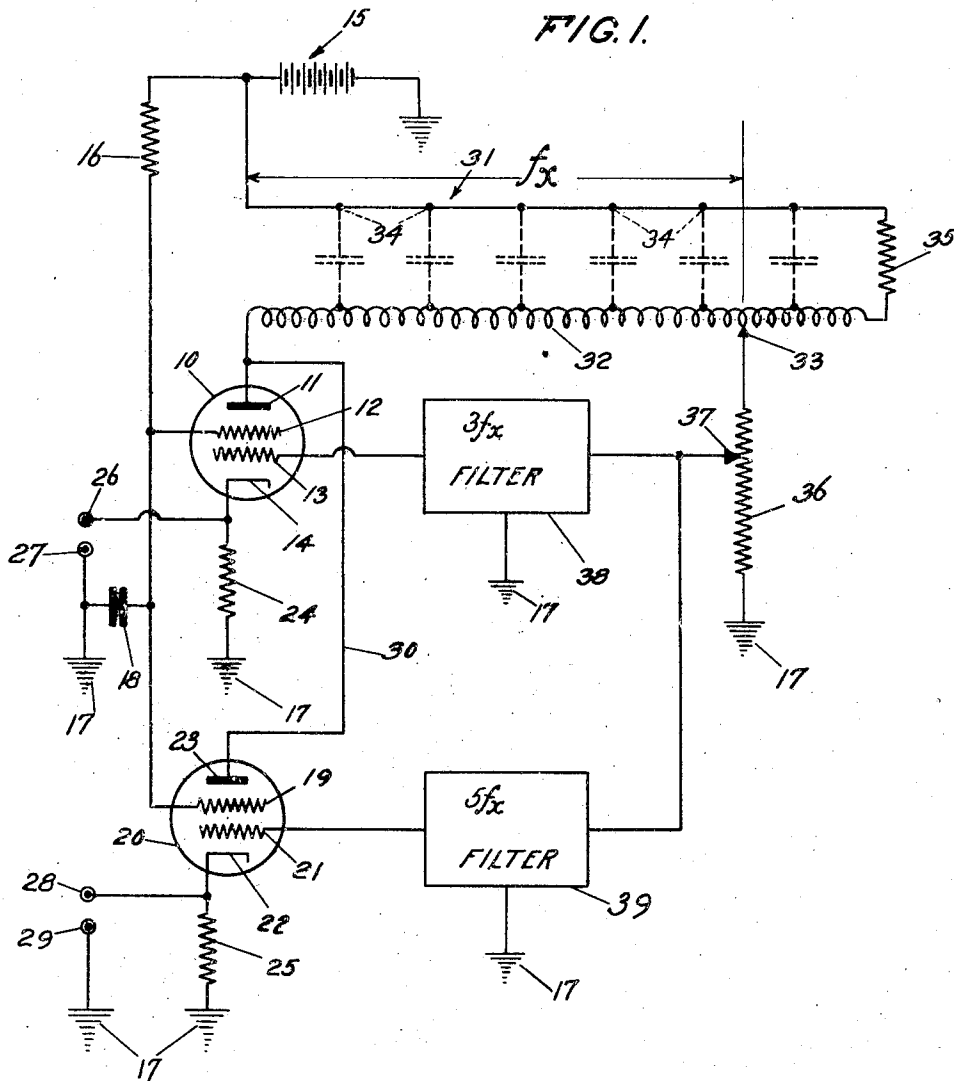
Oct. 18, 1949.

V. C. WESTCOTT
HARMONIC GENERATOR

2,485,124

Filed Nov. 30, 1946

2 Sheets-Sheet 1



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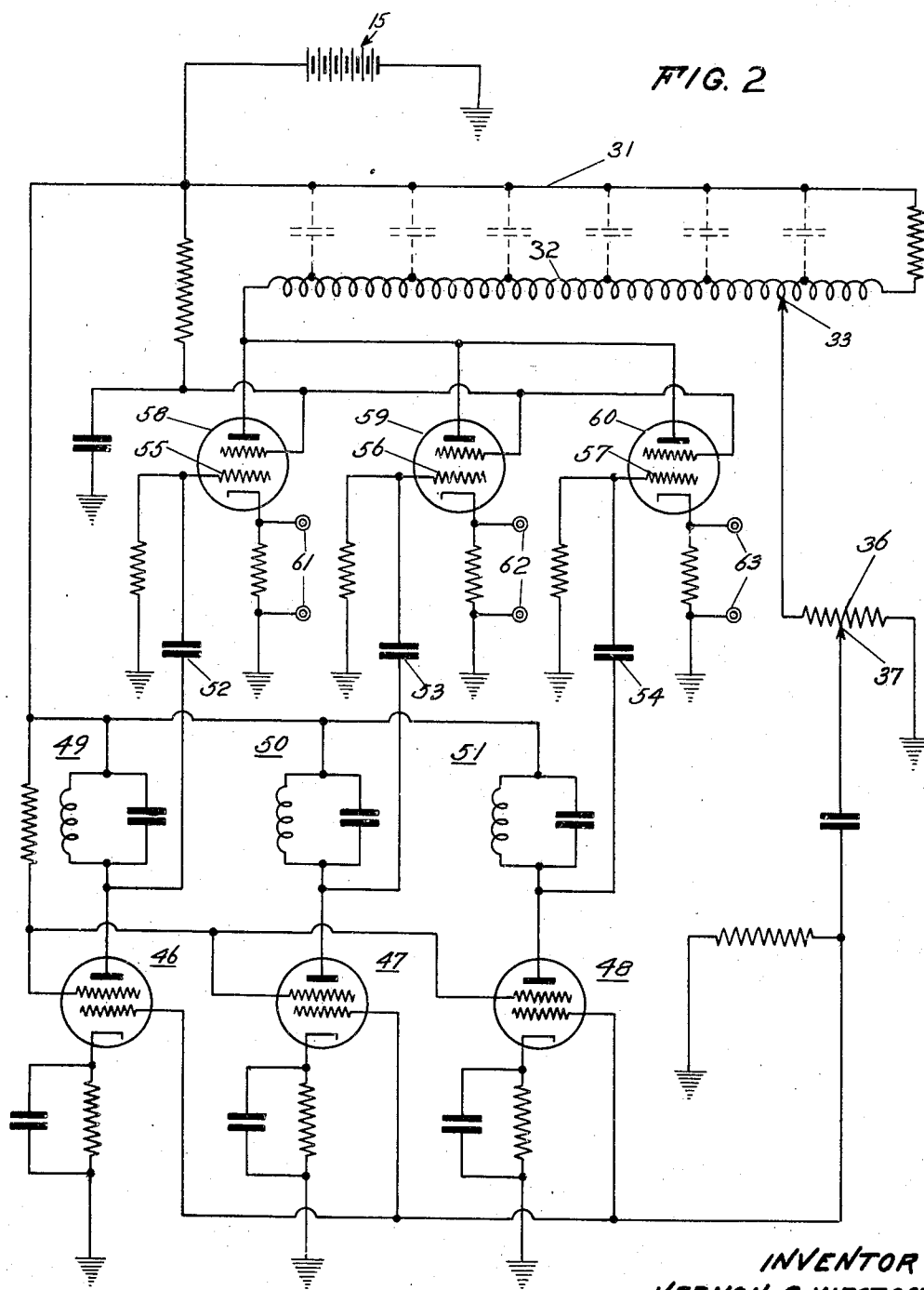
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2,485,124

HARMONIC GENERATOR

Filed Nov. 30, 1946

2 Sheets-Sheet 2



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2,485,124

HARMONIC GENERATOR

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Application November 30, 1946, Serial No. 713,251

1 Claim. (Cl. 250—36)

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This invention relates to electrical circuits and more particularly to circuits for producing a plurality of frequencies having and maintaining a predetermined ratio therebetween.

The main object of the present invention is to provide an electrical circuit capable of producing a plurality of frequencies which are harmonics of a fundamental frequency and maintaining between said harmonic frequencies a predetermined frequency ratio.

The above and other objects will become clear as the description of the present invention progresses and by reference to the accompanying drawing, in which:

Fig. 1 is a partial schematic and partial block diagram of the present invention; and

Fig. 2 is a schematic diagram of another embodiment of the present invention.

Referring now more particularly to Fig. 1, an electron-discharge tube, for example a tetrode, is shown at 10, said tube having an anode 11, a screen grid 12, a control grid 13, and a cathode 14, said cathode being heated by suitable means (not shown) to produce thermionic emission.

Screen grid 12 is connected to a source of potential, for example a battery 15, through a current-limiting resistor 16, and is also connected to ground 17 through a capacitor 18 and directly to a screen grid 19 of a second electron-discharge tube 20, said tube being, for example, a tetrode having, in addition to the screen grid, a control grid 21, a cathode 22, said cathode being suitably heated to produce thermionic emission, and an anode 23.

The cathodes 14 and 22 are connected through a self-biasing arrangement, comprising, respectively, resistors 24 and 25, to the ground 17, the ungrounded ends of said resistors being connected, respectively, to output terminals 26 and 28, terminals 27 and 29 being connected to the ground point 17.

The anodes 11 and 23 are connected in parallel by a conductor 30 and through a delay line 31 to the potential source 15. The line 31 consists of a series inductance 32 having a movable tap 33 thereon, and is so constructed as to provide distributed shunt capacitance 34 therealong. This line is terminated in its characteristic impedance as represented by a resistor 35, whereby reflections or waves travelling along said line are prevented.

Tap 33 is connected to one end of a potentiometer 36 having a movable tap 37 thereon, the other end of said potentiometer being connected to ground 17. The tap 37 is connected through

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a pair of band-pass filters 38 and 39 to the respective grids 13 and 21. The choice of a filter is determined by the particular frequency desired.

To produce oscillations in a tube circuit, it is essential that there be a phase shift of 360 degrees around the system, from the input to the output and back to the input again, and it is also essential that the gain around the system be at least equal to unity. If these conditions are fulfilled, the system will oscillate at a frequency for which there is a phase shift of 360 degrees around the system, if the system gain for such a frequency is at least equal to unity.

There is ordinarily a phase difference of 180 degrees between grid and anode potentials due to the inherent properties of an electron-discharge tube, so that if an additional phase shift of 180 degrees can be imparted to a wave by an external system, the required 360 degree shift will be procured.

Transmission or delay line 31, due to its inductance and capacitance, will impart a phase shift or phase delay to waves travelling therealong. For any fixed position of tap 33, there is a certain frequency for which the phase delay between anodes 11 and 23 and tap 33 will be substantially 180 degrees, and the circuit will oscillate at this certain frequency. In other words, for any fixed position of tap 33, there is a certain frequency at which the time required for a wave to travel from the anodes 11 and 23 to the tap 33, will be substantially equal to one-half cycle of this frequency, or 180 degrees, and the system will oscillate at this frequency.

The frequency of oscillation of the system may be varied by moving tap 33, since for each different position of said tap there is a certain different frequency at which the proper phase relations for oscillation occur. As it is possible to make the transmission line as long as desired, and since it is theoretically possible to bring tap 33 infinitely close to anodes 11 and 23, a broad-band oscillator is provided. Therefore, a tremendous frequency range, such as, for example, from 30 kilocycles to 20 megacycles, may be obtained with a single oscillator.

As indicated above, for any fixed position of tap 33 there exists a certain fundamental frequency and all odd harmonics of that fundamental. Thus, there may be obtained various wave forms, from a pure sinusoidal to a square wave. The delay line 31 attenuates the lower frequencies less than the higher ones, while the potentiometer 36 attenuates all frequencies equally. Therefore, by moving tap 37 on said potentiom-

eter toward the grounded end 17 thereof, the system gain may be made equal to unity for the fundamental frequency and less than unity for the odd harmonics, in which case the odd harmonics will not appear in the oscillator output and a pure sine wave will be produced.

The closer the tap 37 is to the delay line end of the potentiometer 36, the more harmonics will be mixed with the fundamental and the closer to a square wave the oscillator output will be. Therefore, the wave form of the oscillator output may be varied for any particular fundamental determined by the position of the tap 33 and the adjustment of the tap 37.

In the present invention, the output of the above-described oscillator is applied to the filters 38 and 39 through the potentiometer 36 and its associated tap 37. The filters 38 and 39 are designed to pass, respectively, different predetermined frequencies. In this particular embodiment the use of two filters are described, although any number of filters may be used. The predetermined frequencies are multiples or harmonics of the fundamental frequency of the delay line 31 oscillator as selected by manipulation of the taps 33 and 37.

The outputs of the filters 38 and 39 are applied, respectively, to the control grids 13 and 21 of the electron-discharge tubes 10 and 20. The particular frequencies selected are impressed across the bias resistors 24 and 25 and consequently appear between the terminals 26, 27, 28 and 29.

The invention, therefore, provides a means for deriving any number of different frequencies which are multiples of the fundamental frequency X . For example, the filters 38 and 39 are designed to pass frequencies, respectively, three times the fundamental frequency X and five times said fundamental. Actually, the present invention provides means for deriving a substantially large number of frequencies depending on the fundamental selected by manipulation of the taps 33 and 37.

Ordinarily, multiplication obtained by energizing a resonant frequency circuit, tuned to some multiple of the fundamental frequency of an oscillator, is limited to two or three times said fundamental. However, the present invention is capable of producing a substantially large number of multiples with the present system because of the extremely wide frequency range of the delay line oscillator used herein.

In addition, the system of the present invention is such that for any selected number of different frequencies, said frequencies are maintained in a fixed ratio to one another. For example, the present embodiment describes the selection of two frequencies which are to be maintained at a three to five ratio. It is only necessary to determine the ratio desired, within the harmonic limits of the fundamental frequency fX , and by proper selection of filters 38 and 39 provide the desired ratio.

Thereafter, with any drift from the selected multiple of the fundamental frequency, as in the

present embodiment, $3/X$ or $5/X$, the system of the present invention will cause either one or the other of said multiples to synchronize with one or the other to maintain said three to five ratio. As the complex wave form, comprising $3/X$ and $5/X$, goes through the delay line 31, it is either advanced or retarded, as the case may be, and thus influences both tubes simultaneously.

Fig. 2 represents another embodiment of the present invention. Here, a plurality of amplifying stages 46, 47 and 48 have been added, respectively, to a plurality of frequency-selecting circuits 49, 50 and 51. The outputs of said frequency-selecting circuits are connected, respectively, through a plurality of capacitors 52, 53 and 54 to the control grids 55, 56 and 57 of a plurality of electron-discharge tubes 58, 59 and 60. The selected frequencies will appear across a plurality of pairs of terminals 61, 62 and 63.

Selection of a fundamental frequency is accomplished in this particular embodiment in the same manner as hereinbefore described, namely, through manipulation of the taps 33 and 37.

The present invention, although illustrated and described in terms of lumped constants, is readily adapted for use in connection with ultra-high frequency systems wherein are employed wave guides, cavity resonators, etc.

Many modifications of the present invention will occur to those skilled in the art, and it is therefore, intended to cover by the appended claim all such modifications which fall within the true spirit and scope of said invention.

What is claimed is:

- 35 An electrical circuit including: an electrical delay line having a variable fundamental frequency characteristic; a plurality of electron-discharge devices having at least input and output electrodes; said output electrodes being connected to one end of said delay line; a plurality of frequency-selective circuits responsive, respectively, to different harmonics of any selected fundamental frequency of said delay line; means controlling the harmonic content of the output of said delay line and connecting said frequency-selective circuits between the other end of said delay line and the input electrodes of said electron-discharge devices; and means for deriving from said electron-discharge devices a plurality of harmonics having a predetermined frequency ratio therebetween.

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REFERENCES CITED

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

UNITED STATES PATENTS

Number	Name	Date
60 1,418,739	Schriren	June 6, 1922
1,442,781	Nichols	Jan. 16, 1923
1,678,199	Rettenmeyer	July 24, 1928
2,036,495	Pohontsch	Apr. 7, 1936