

UNITED STATES PATENT OFFICE

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RECTANGULAR WAVE GENERATOR
CONTROLHarry Nyquist, Millburn, N. J., assignor to Bell
Telephone Laboratories, Incorporated, New
York, N. Y., a corporation of New York

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5 Claims. (Cl. 250—27)

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The present invention relates, in one aspect, to the production of a large number of waves of closely adjacent frequencies all multiples of the same base frequency and all of great purity.

In another aspect, the invention relates to the production of a square wave consisting of equal halves and to maintaining the two halves of the wave equal in length. Such a wave is used as the base frequency wave in the practice of the invention for the production of a large number of waves of closely spaced frequencies.

Where the wanted frequencies are high numerical multiples of a given base frequency it becomes a problem to separate sufficiently completely the waves of the individual frequencies from one another. The requirements on the separating filters are made easier if no frequencies are impressed upon them except the harmonics which they are to select for individual use.

One way to generate the wave components of closely spaced frequency and to avoid generation of intervening frequency components is to use as the base frequency wave a square wave of fifty per cent break, that is, a square wave in which each complete cycle is divided exactly into two equal halves. Such a wave has only odd harmonic components, there being no even harmonic content. So long as the base wave can be maintained at exactly fifty per cent break, therefore, a series of frequency components can be impressed on the separating filters corresponding to the wanted harmonics (odd multiples) with no intermediate, or even harmonic, components present, in which case the filters are not relied upon to suppress the unwanted, in this case the even, harmonic components.

An object of this invention is to produce waves having substantially only odd harmonic components by maintaining the base wave at fifty per cent break.

In accordance with a feature of this invention, the presence of undesired even harmonic component is utilized in a self-bias, or backwardly acting control, arrangement to minimize the occurrence of the even harmonic component and thus maintain the base wave at substantially fifty per cent break at all times.

The invention together with its principal and subsidiary objects and features will be more fully understood from the following detailed description in connection with the accompanying drawing, the single figure of which is a schematic circuit diagram of a harmonic wave generating and control system according to the invention.

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Referring to the drawing, the harmonic generating system includes the single shot multivibrator circuit 11 driven by periodic pulses received from the source 10. These periodic pulses are short sharp pulses of a type commonly used for driving multivibrators and they may be generated in any known or suitable manner, for example in the manner disclosed in United States patent to W. A. Miller et al. 2,399,135, issued April 23, 1946. As shown in the diagram adjacent tube 12 only positive pulses are applied to the multivibrator 11 from the source 10.

The multivibrator itself is of known or suitable type and comprises two stages 12 and 13. Tube 13 is normally conducting saturation current since its grid is connected via resistance 24 to the positive pole of the plate battery. The resulting current flow through the common cathode resistor 15 normally holds the tube 12 cut off. Whenever a positive pulse is applied to the grid of the tube 12 this tube conducts current and transmits a negative pulse through coupling condenser 14 to the grid of tube 13 cutting tube 13 off. At the instant when the plate current in tube 13 is cut off, the rising portion of an output square wave is generated as shown in the diagram adjacent this tube. The length of the positive pulse so generated depends both upon the time constant of the capacity 14 together with its associated resistors, such as 24, and upon the amount of grid bias voltage applied to the grid of tube 13. It will be noted that the grid of tube 13 is connected to a bias resistor 16 and receives a bias voltage therefrom in a manner that will presently be described. When the time constant circuit together with the grid bias permits the grid of tube 13 to drift back sufficiently toward its normal positive voltage, tube 13 again conducts saturation current and cuts off tube 12. This action terminates the first pulse generated by the tube 13. The circuit 11 is now in its stable condition and ready to receive another pulse from the source 10. In this way a square wave is generated in the output of tube 13 and, as stated, it is desirable that each lobe or half of this wave be of exactly equal length in order that only odd harmonics will be generated and applied to the output circuit.

This square wave is passed through filter 17 which has a broad enough transmission band to accommodate the entire range of harmonic frequencies that are to be utilized.

The output circuit 18 leading from the filter 17 is shown as having a number of tuned circuits bridged across it for selecting respectively dif-

ferent harmonic frequency waves. In a typical case there may be a large number of these selective circuits such as a score or more. Tuned circuits 21 and 22 are each shown leading to individual output circuits, these two selective circuits being tuned to select respectively the 49th and the 51st harmonics of the base frequency wave.

Two other selective circuits 19 and 20 are shown bridged across circuit 18 and are used for control purposes. Circuit 19 is tuned to the 53rd harmonic while circuit 20 is tuned to the 106th harmonic frequency. As explained above, if the square wave in the output of tube 13 consists of two halves of exactly equal length, such a wave will have no even harmonic component content and therefore there will be no wave for the branch 20 to select since this branch is tuned to an even harmonic frequency. The purpose of this branch is to detect the presence of an even harmonic frequency component and therefore the existence of an unbalanced condition in the square wave output. For this purpose, the wave selected by circuit 20 is compared against the wave selected by circuit 19 to derive a control voltage.

The odd harmonic frequency wave selected by circuit 19 is doubled in frequency in the full wave rectifier circuit 35 to produce in its output the 106th harmonic frequency. This component is purified in the tuned bridge circuit 35 and the resulting filtered even harmonic component is sent through phase shifter 37 into the input of amplifier 40. Similarly, the wave selected by circuit 20 is sent over conductor 39 through a regulating pad 32 and phase shifter 33 to the grid circuit of amplifier 40. The output of the amplifier 40 is rectified in full wave rectifier 41 and applied as a bias current to the bias resistor 16. A smoothing condenser 42 is shown connected across the output circuit of rectifier 41.

By means of the phase shifters 33 and 37 the two waves applied through these phase shifters to the input of the amplifier 40 may be made to have exactly opposite phase to each other. The potentiometer 25 in the grid circuit of the tube 13 is adjusted until the voltmeter 31 reads zero, indicating absence of even harmonic frequency current. An adjustment of the pad 32 and potentiometer 25 is found by trial, or otherwise, such as to maintain the reading of voltmeter 31 substantially zero at all times. This means that whenever the square wave output from the multivibrator 11 tends to become unbalanced and thus to produce some even harmonic output current, such current is immediately detected in the even harmonic tuned circuit 20 and the effect of this current is to alter the bias voltage in the resistor 16 in such direction as to minimize the production of even harmonic current. As the square wave in the output of the multivibrator 11 tends to become unbalanced in one direction, the bias voltage received by the grid of tube 13 from the control resistor 16 varies in one direction and as the square wave tends to become unbalanced in the opposite direction, an opposite change is made in the grid bias applied to tube 13 in such manner as in both cases to restore the wave to a balanced condition.

The sharply selective circuits 19, 20, 21 and 22 for selecting the various harmonic frequencies may be of any suitable type such as piezoelectric crystals or other suitable narrow band sharply selective circuits. The types shown in the drawing, however, comprise bridge circuits

normally balanced by means of tuned reed relays since these have been found in practice to give good results. Each tuned branch includes an upper coil in which are mounted tuned reeds and a lower coil which is used for balancing. These form two arms of the bridge, the other two arms of which are formed by the two halves of the resistor 23, this resistor serving in common for all of the tuned circuits. This specific type of frequency selective circuit in and of itself forms no part of the present invention but is disclosed and claimed for another.

The use of the filter at 17, while preferable, is not essential to the practice of this invention and may be omitted if desired.

As indicative of a possible use for the system shown in the figure, this may be applied to the selective signaling system in a radio telephone system using tuned reeds for receiving the signals, thirty different selecting frequencies being required at the central office. A frequency spacing of 15 cycles is left between each two frequencies. These thirty different frequencies are generated as harmonics of a base frequency wave of 7.5 cycles per second frequency. The 49th to the 107th odd harmonics, inclusive, are used, these frequencies covering the band from 367.5 cycles to and including 802.5 cycles. In such a system the amount of unbalance in the output square wave from the multivibrator 11 can be calculated which is sufficient to cause the 107th harmonic to disappear and for the 106th and 108th harmonics to appear in full force. It is found by calculation that to keep the 106th harmonic to one-tenth of its full value, that is twenty decibels down from its full value, either half of the square wave must not be allowed to vary in length by more than .02 millisecond.

The over-all system of harmonic generation and selection disclosed herein is also disclosed and claimed in a copending application filed in the name of A. E. Bachelet, Serial No. 22,820, filed April 23, 1948 which also discloses and claims a different specific type of automatic bias control circuit.

The invention is not to be construed as limited to the details that have been disclosed nor to the values nor magnitudes cited since these are for illustration and by way of example rather than as limiting. The scope of the invention is defined in the claims.

What is claimed is:

1. In combination, a generator of alternating waves of a given fundamental frequency comprising two rectangular wave portions of opposite polarity in each cycle thereof, biasing means for said generator, means for selecting an even harmonic of said fundamental frequency, when one is present, from the output of said generator, and means responsive to the selected even harmonic for controlling said biasing means so as to maintain said two rectangular portions in each cycle of the wave output of said generator of equal width.

2. In combination, a source of alternating waves of a given fundamental frequency having two rectangular-shaped wave portions of opposite polarity in each cycle thereof, said waves including only odd harmonics of said fundamental frequency when said two wave portions are of equal width and both odd and even harmonics thereof when said two wave portions are of unequal width, filtering means for respectively selecting an odd harmonic, and, when

even harmonics are present therein, an even harmonic of twice the frequency of the selected odd harmonic from the wave output of said source, means for doubling the frequency of said selected odd harmonic, means for effectively balancing the resulting odd harmonic of doubled frequency against the selected even harmonic in such manner as to produce a difference voltage the value and sign of which is a function of the amount and direction of inequality between the two rectangular-shaped wave portions in each cycle of the wave induced by said source, and means to apply said difference voltage as a bias to said source so as to maintain the rectangular wave portions in the output of equal width.

3. In a harmonic generating system, a source of square waves, selective circuits tuned respectively to different odd multiples of the fundamental frequency of said square wave, another circuit tuned to twice one of said odd multiple frequencies, means to double the frequency of the wave of said one multiple frequency, means to oppose said doubled frequency wave against the wave from said other tuned circuit to produce a voltage representing the difference between said two opposed waves, and means to apply said difference voltage as a variable grid bias voltage to said source to minimize the production of even harmonic wave component.

4. A square wave generator comprising a grid-controlled device half-wave producer, a circuit for pulsing said grid to cause said device to produce opposite half-waves of a square wave in succession, a grid biasing circuit for said device for, in part, determining the length of each such half-wave produced, and means to maintain the two half-waves of each cycle of the generated square wave substantially equal in length com-

prising a selective circuit for detecting the presence of an even harmonic component of current in the output of said device and means responsive to the presence of such even harmonic component for varying the grid bias voltage on said grid in such direction and extent as to minimize the production of the even harmonic component.

5. In a harmonic generator system, a source of square waves, a grid bias circuit for said source, said bias determining the reversal time of said source and thus the pulse length of one lobe of said square wave, filter means to select different odd harmonic frequency waves from the output of said source for individual use, means to derive a direct current voltage from one of said harmonic frequency waves, and to apply said voltage to the grid of said source to serve as said bias therefor, a selective circuit in the output of said source for selecting an even harmonic frequency current when such is present, and means to derive from said even harmonic frequency current a supplemental bias voltage and apply the same to said source in a sense to oppose the production of said even harmonic frequency current.

HARRY NYQUIST.

REFERENCES CITED

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

UNITED STATES PATENTS

Number	Name	Date
1,885,728	Keith	Nov. 1, 1932
2,232,390	Katzin	Feb. 18, 1941
2,413,932	Sziklai	Jan. 7, 1947
2,416,333	Lehmann	Feb. 25, 1947
2,438,638	Lakatos	Mar. 30, 1948