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FREQUENCY MULTIPLIER

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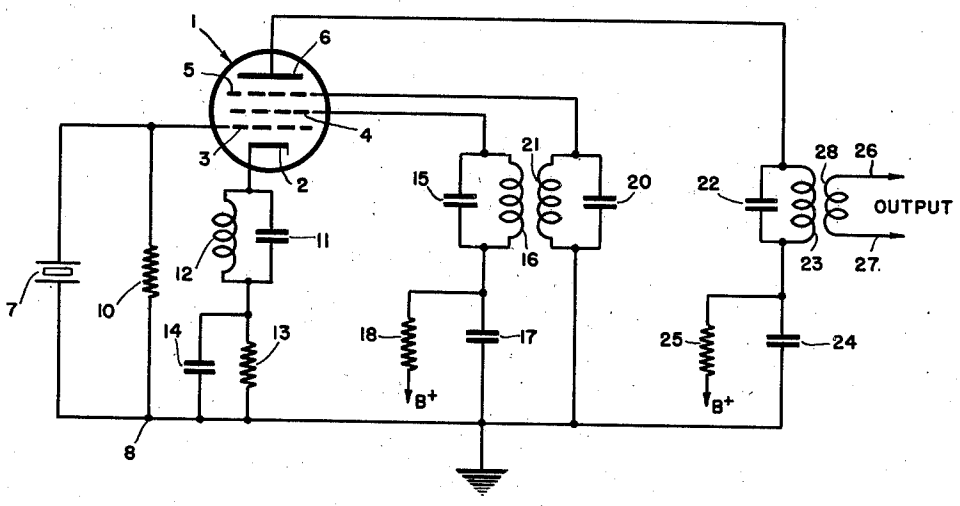

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FREQUENCY MULTIPLIER

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This invention relates to frequency multipliers and particularly to means for multiplying a fundamental high or ultra-high frequency in a single electric discharge path.

Numerous types of electrical frequency multipliers are known to those skilled in the art. However, for obtaining a high harmonic of a fundamental frequency a number of electric discharge tubes had to be employed in the past. The present invention is concerned particularly with devices for multiplying high and ultra-high frequencies and obtaining a high step-up of a fundamental frequency in a single electric discharge tube. As is well understood, there is an upper limit to the frequency range obtainable by means of piezo-electric crystal controlled frequency generating means. This is due to the fact that in order to obtain high frequencies the piezo-electric crystal must be made very small. Hence it is important to provide frequency multipliers which can appreciably step up the frequency obtainable with a piezo-electric device such as a quartz crystal in a simple manner and with a minimum of tube elements.

The object of the present invention, therefore, is to provide an improved means for and method of effecting multiplication of a fundamental frequency to obtain a high harmonic frequency thereof.

In accordance with the invention, there is provided means for generating and for filtering out a selected harmonic frequency of a fundamental frequency. This selected harmonic frequency is then amplified, and the same process is repeated again in the same electric discharge tube so that a harmonic frequency of the first harmonic frequency is obtained in the load circuit. Preferably, the fundamental frequency is controlled by a piezo-electric device such as a quartz crystal.

For generating harmonic frequencies of the fundamental frequency, filtering out a selected harmonic frequency, amplifying it and obtaining a harmonic of the first harmonic frequency, a multi-grid electron discharge tube such as a pentode may be used. To this end the screen grid circuit including the cathode, the control grid and the screen grid of the pentode is operatively connected with the means for controlling the fundamental frequency. Further connected to the screen grid circuit is a resonant circuit tuned to the fundamental frequency. The screen grid circuit including the resonant circuit effectively forms an oscillator for generating the fundamental frequency. Another resonant circuit tuned to the harmonic frequency to be filtered out is also connected to the screen grid circuit.

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By this arrangement, it is possible to filter out for instance the third harmonic of the fundamental frequency in the first stage of the discharge tube. Amplification of the thus selected harmonic frequency, for instance the third harmonic of the fundamental frequency, is obtained through the suppressor grid. The suppressor grid is connected to a resonant circuit tuned to the third harmonic and coupled to the resonant circuit for filtering out the selected third harmonic. The second stage of the discharge tube includes the screen grid, the suppressor grid and the anode which is operatively connected to another resonant circuit tuned for instance to the third harmonic of the third harmonic or the ninth harmonic of the fundamental frequency. To this last resonant circuit a load circuit is coupled for utilizing the ninth harmonic frequency.

For a better understanding of the invention, together with other and further objects thereof, reference is made 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, the single figure is a schematic circuit diagram of a frequency multiplier in accordance with the present invention.

Referring now to the single figure of the drawing, there is shown a multi-grid electron discharge tube 1 of the pentode type. Pentode 1 comprises cathode 2 which, as shown, is of the indirect heater type although a filament cathode may be used instead. Pentode 1 further includes control grid 3, screen grid 4, suppressor grid 5 and anode 6.

A fundamental frequency is obtained by means of piezo-electric crystal 7 having one plate thereof connected to ground at 8 and the other plate to control grid 3. Resistor 10 is arranged in shunt to piezo-electric crystal 7 and serves as the grid leak resistance of control grid 3. Cathode 2 is connected with a resonant circuit including condenser 11 and inductance element 12. The resonant circuit comprising condenser 11 and inductor 12 is tuned to the fundamental frequency controlled by piezo-electric crystal 7. Condenser 11 and inductor 12 are arranged in parallel with one terminal connected to cathode 2 and the other terminal connected to ground

through a parallel arrangement of bias resistor 13 and condenser 14.

Screen grid 4 of pentode 1 is operatively connected with another resonant circuit tuned to the third harmonic of the fundamental frequency. This resonant circuit includes condenser 15 and inductor 16 arranged in parallel. Blocking condenser 17 grounds condenser 15 and inductor 16. Resistor 18 connects the positive pole of a battery between condensers 15 and 17 for supplying the required positive potential to screen grid 4 through inductor 16.

Another resonant circuit including condenser 20 and inductor 21 arranged in parallel is tuned to the same frequency as resonant circuit 15, 16, that is, to the third harmonic of the fundamental frequency. Resonant circuit 20, 21 is connected to suppressor grid 5 and inductively coupled by inductance elements 21 and 16 to resonant circuit 15, 16. As indicated in the drawing, resonant circuit 20, 21 is grounded.

The circuit of anode 6 includes a parallel resonant circuit comprising condenser 22 and inductor 23 connected to ground through blocking condenser 24. Resistor 25 connects the positive pole of a battery between condensers 22 and 24 for supplying positive potential to anode 6 through inductor 23. An output or load circuit 26, 27 is inductively coupled through inductor 28 to inductor 23 of the anode resonant circuit. Resonant circuit 22, 23 is tuned to the ninth harmonic of the fundamental frequency, and therefore load circuit 26, 27 will receive energy at the ninth harmonic of the fundamental frequency.

The operation of the frequency multiplier of the invention may be explained as follows:

We may consider the screen grid circuit of pentode 1, which represents the first stage of the frequency multiplier as an oscillator. The screen grid circuit includes cathode 2, control grid 3 and screen grid 4. This circuit comprises a tuned cathode and a tuned "plate," if we consider screen grid 4 as the "plate" of the first multiplier stage. The frequency of the oscillator stage of the frequency multiplier or of the screen grid circuit is controlled by piezo-electric crystal 7.

Cathode 2 is connected to resonant circuit 11, 12 which is tuned to the fundamental frequency, generated in the oscillating circuit and controlled by piezo-electric crystal 7. Resonant circuit 11, 12 is connected to ground through bias resistor 30 and condenser 14 shunted thereacross. Hence, resonant circuit 11, 12 is effectively connected to control grid 3 through grid leak resistor 10, arranged between ground and control grid 3. The "plate" or screen grid 4 is operatively connected to resonant circuit 15, 16 which is tuned to the third harmonic of the fundamental frequency. The required positive potential is supplied to screen grid 4 from a battery through resistor 18 and inductor 16. Thus, the oscillator including the screen grid circuit comprising cathode 2, control grid 3 and screen grid 4 and its associated filter circuit 11, 12 generates a fundamental frequency which is controlled by piezo-electric crystal 7.

Harmonics of the fundamental frequency thus generated are created in pentode 1 by the distortion of the tube. The characteristic curves of a tube are never straight. The effect of this nonlinearity of the tube characteristics is to create new frequency components, that is harmonic frequencies. As far as pentodes and some other tubes are concerned we have to assume that in addition to the second harmonic the third harmonic is also present to an appreciable extent. This inherent property of electric discharge tubes and in particular of the pentode type of vacuum tubes is usually considered as a drawback. However, in accordance with the present invention the inherent distortion of an electric discharge tube is utilized for generating harmonics of the fundamental frequency. A more detailed treatment of the waveform distortion in electric discharge tubes will be found on pages 412–418 of "Applied Electronics" by members of the staff of the Department of Electrical Engineering, Massachusetts Institute of Technology, published by John Wiley & Sons, Inc., New York, in 1943.

Accordingly it will be obvious from the preceding explanation that the third harmonic frequency will be present in the screen grid circuit of pentode 1. This third harmonic is filtered out by means of resonant circuit 15, 16. It may be mentioned that the impedance of the resonant circuit 11, 12 which is tuned to the fundamental frequency is comparatively small with respect to energy oscillating at the third harmonic frequency and therefore the "plate" or screen grid 4 is effectively tuned to the third harmonic.

Energy at the third harmonic is transferred from resonant circuit 15, 16 to resonant circuit 20, 21 through inductors 16 and 21. Thus the third harmonic is impressed upon suppressor grid 5. The second stage of pentode 1 includes screen grid 4, suppressor grid 5 and anode 6 and acts mainly as an amplifier. The third harmonic is now amplified in the second stage of pentode 1 in the conventional manner through the intermediary of suppressor grid 5. Again in the second or amplifier stage of pentode 1 harmonics of the third harmonic are created by the inherent distortion of the tube. Resonant circuit 22, 23 is tuned to the third harmonic of the third harmonic or to the ninth harmonic of the fundamental frequency. The required positive potential is supplied to anode 6 from a battery through resistor 25 and inductor 23.

Resonant circuit 22, 23 serves for filtering out the ninth harmonic which is present in the amplifier stage of the tube including screen grid 4, suppressor grid 5 and anode 6. Here again the impedance of tuned circuits 20, 21 as well as 15, 16 is small with respect to energy at the ninth harmonic frequency.

In accordance with the invention it is not necessary to generate the fundamental frequency in the electron discharge tube which creates the harmonic frequencies by distortion and amplifies them. The fundamental frequency may also be applied to the tube from an external source.

While there has been described what is at present considered the preferred embodiment of the 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 frequency multiplier comprising an electric discharge tube having a cathode, a first grid, a second grid, a third grid and an anode, means for generating a fundamental frequency operatively connected between said cathode and said first grid, a source of common reference potential, means for connecting said source of common

reference potential to said cathode, a first resonant circuit tuned to a first selected harmonic of said fundamental frequency to filter out said first harmonic frequency, said first resonant circuit being effectively connected between said second grid and said common reference potential, a second resonant circuit tuned to said first harmonic of said fundamental frequency coupled to said first resonant circuit and connected between said source of common reference potential and said third grid to transfer back energy at said first harmonic frequency, a third resonant circuit tuned to a selected harmonic of said first harmonic frequency and connected between said source of common reference potential and said anode to filter out said harmonic of said first harmonic frequency, and an output circuit coupled to said third resonant circuit to utilize said harmonic of said first harmonic frequency.

2. A frequency multiplier comprising an electric discharge tube having a cathode, a first grid, a second grid, a third grid and an anode, a source of common reference potential, means for connecting said source of common reference potential to said cathode, means for generating a fundamental frequency operatively connected to said tube and including a first resonant circuit tuned to said fundamental frequency and effectively connected between said cathode and said first grid, a second resonant circuit tuned to a first selected harmonic of said fundamental frequency and effectively connected between said source of reference potential and said second grid for filtering out said first selected harmonic frequency, a third resonant circuit tuned to said first selected harmonic frequency coupled to said second resonant circuit and connected between said source of common reference potential and said third grid to transfer back energy at said first selected harmonic frequency, a fourth resonant circuit tuned to a selected harmonic of said first selected harmonic frequency and connected between said source of common reference potential and said anode to filter out said selected harmonic of said first harmonic frequency, and an output circuit coupled to said fourth resonant circuit to utilize said selected harmonic of said first harmonic frequency.

3. A frequency multiplier comprising an electric discharge tube having a cathode, a first grid, a second grid, a third grid and an anode, means for generating a fundamental frequency including a piezoelectric device and a first resonant circuit tuned to said fundamental frequency and effectively connected in series between said cathode and said first grid, a source of common reference potential connected between said device and said first resonant circuit, a second resonant circuit

tuned to the third harmonic of said fundamental frequency and effectively connected between said source of common reference potential and said second grid to filter out said third harmonic frequency, a third resonant circuit tuned to the third harmonic of said fundamental frequency inductively coupled to said second resonant circuit and connected between said source of common reference potential and said third grid to amplify said third harmonic frequency, a fourth resonant circuit tuned to the ninth harmonic of said fundamental frequency and effectively connected between said source of common reference potential and said anode to filter out said ninth harmonic frequency, and an output circuit coupled to said fourth resonant circuit to utilize said ninth harmonic frequency.

4. The method of multiplying an alternating current frequency in a single electric discharge path which comprises the steps of generating a fundamental frequency, distorting said frequency to generate harmonic frequencies of said fundamental frequency, filtering out a first selected harmonic frequency, transferring enery at said first harmonic frequency back into said discharge path for amplifying said first harmonic frequency, generating harmonics of said first harmonic frequency by distortion, filtering out a second selected harmonic frequency of said first harmonic frequency, and utilizing said second harmonic frequency.

5. The method of multiplying an alternating current frequency in a single electric discharge path which comprises the steps of generating a fundamental frequency, distorting said fundamental frequency to generate harmonic frequencies including the third harmonic frequency of said fundamental frequency, filtering out said third harmonic frequency, feeding back energy at said third harmonic frequency into said discharge path for amplifying said third harmonic frequency, generating further harmonic frequencies including the ninth harmonic frequency of said fundamental frequency by distortion, filtering out said ninth harmonic frequency, and utilizing said ninth harmonic frequency.

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