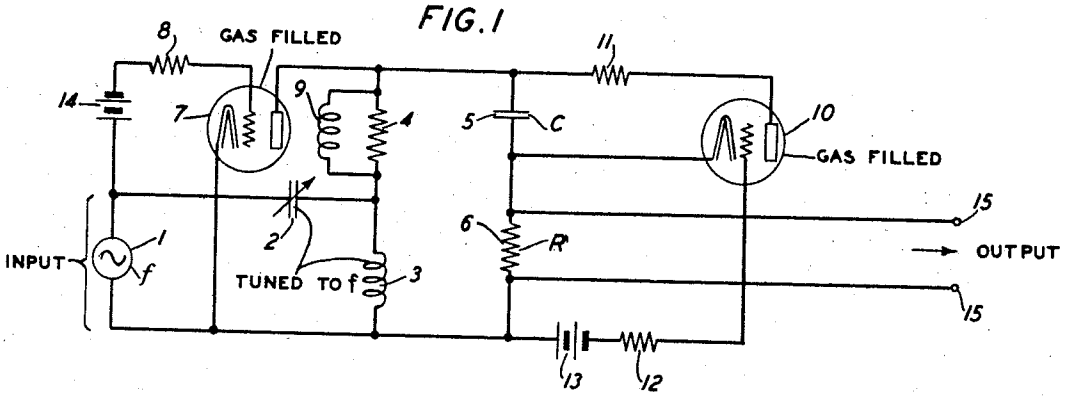
June 24, 1941. E. PETERSON 2,246,534

ALTERNATING CURRENT WAVE PRODUCTION

Filed June 26, 1940

FIG. 1



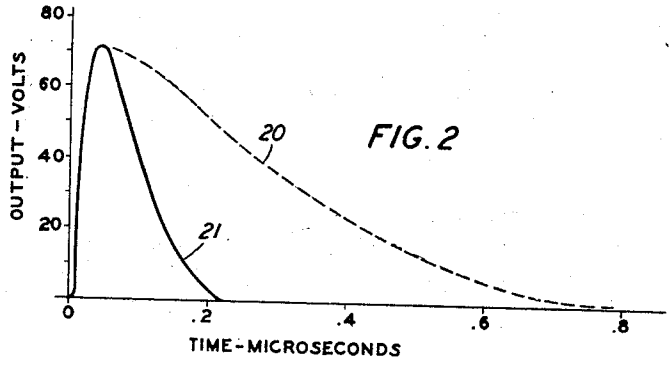


FIG. 2

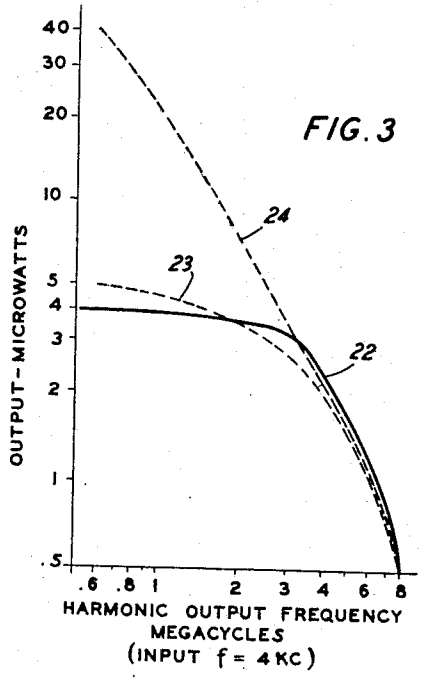


FIG. 3

INVENTOR
E. PETERSON
BY
Earl C. Laughlin
ATTORNEY

Patented June 24, 1941

2,246,534

UNITED STATES PATENT OFFICE

2,246,534

ALTERNATING CURRENT WAVE PRODUCTION

Eugene Peterson, New York, N. Y., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application June 26, 1940, Serial No. 342,427

8 Claims. (Cl. 172—281)

This invention relates to the generation of alternating current waves, and particularly to the generation of a number of waves of different frequency by derivation from a single wave of given base frequency.

The invention is an improvement over that of my Patent No. 2,174,165, issued September 26, 1939, wherein a timing circuit including a capacitor in series with a resistive impedance is periodically charged from a source of waves of base frequency and is abruptly discharged once during each cycle of the base frequency wave to produce a series of impulses from which the desired harmonics are obtained. While a wide frequency range of harmonics of uniform amplitudes and relatively high power levels is obtainable by the invention of my patent mentioned above, it is desirable for some purposes to obtain an even wider frequency range of such harmonics.

An object of the present invention is to increase the width of the frequency range of harmonics of uniform amplitudes and relatively high power levels which may be obtained from a single wave of given base frequency.

Another object is to increase the number of harmonics of uniform amplitudes and relatively high power levels which may be derived from a single wave of given base frequency.

A further object is to improve the circuit described in my Patent No. 2,174,165, so that the time constant of the impulse timing circuit may be increased to improve the efficiency of operation.

These objects are attained in accordance with one aspect of the present invention, by a circuit employing in addition to a first gas-filled electron discharge device of my above-mentioned patent, a second gas-filled electron discharge device so connected with the capacitor-impedance timing circuit in the output of the first device through which the capacitor discharges during a part of each cycle of the given base frequency wave, as to chop off the trailing end of each discharge impulse in response to the first part of the impulse, whereby a wider frequency range of harmonics of uniform amplitudes and relatively high power levels may be obtained from the resulting shortened impulses than from impulses unshortened by the chopping operation.

These and other objects and features of the invention will be understood from the following detailed description thereof when read in connection with the accompanying drawing in which:

Fig. 1 shows schematically a harmonic producer circuit; and

Figs. 2 and 3 show curves illustrating the results of operation of the circuit of Fig. 1.

Fig. 1 shows an impulse producer or harmonic producer in which the alternating current wave source 1 of a given fundamental or base frequency f is connected across the pair of input terminals across which is connected the resonant circuit 2, 3, including the condenser 2 and the inductance 3 in series, tuned to the frequency f. The terminals of the inductance 3 are connected through the resistor or resistive impedance 4 across the timing circuit CR including the capacitor C,5 and the resistor or resistive impedance R,6 in series, the impedance 4 being connected between the capacitor 5 end of the timing circuit 5, 6 and the junction between the condenser 2 and inductance 3. The three-electrode gas-filled electron discharge device 7 has its anode connected with the capacitor 5 end of the timing circuit 5, 6, and its cathode connected with the impedance 6 end of circuit 5, 6 so that the main discharge path of device 7 directly shunts the timing circuit 5, 6.

The control grid of the device 7 is connected through the series current limiting resistance 8 with the condenser 2 end of the resonant circuit 2, 3 and with one terminal of the source 1, the cathode of device 7 being connected with the other terminal of source 1. An inductance 9 is preferably connected in shunt with impedance 4, as explained in my patent mentioned above.

Another three-electrode gas-filled electron discharge device 10, used as a chopper, has its cathode connected with the junction between the capacitor 5 and impedance 6, its anode being connected with the capacitor 5 end of circuit 5, 6 through the series current limiting resistance 11, and its control grid being connected with the impedance 6 end of the circuit 5, 6 through the series current limiting resistance 12.

The source of potential 13 in series with the grid circuit of device 10, and the source 14 in series with the grid circuit of device 7, provides the usual negative polarization for the respective grids for blocking the discharge of current through devices 7 and 10 until predetermined control potentials are applied to the grids. The harmonics of the base frequency taken off from the output terminals 15 extending from the terminals of the impedance 6 may be separated in any suitable manner by the use of parallel filters or tuned circuits (not shown) respectively selective to the different harmonics.

The operation of the circuit of Fig. 1, without the chopper device 10, will be understood from

the description in my Patent No. 2,174,165. The curve **20**, Fig. 2, obtained by an oscillograph from the Fig. 1 circuit with arbitrarily chosen constants but without the device **10**, shows how the output voltage impulse across impedance **6** varied with respect to time during a part of each cycle of a base frequency wave of four kilocycles per second from the source **1**, while current was discharged through the device **7**, the capacitor **5** being 500 micromicrofarads, the impedance **6** being a resistance of 300 ohms, resistance **4** being 25,000 ohms, resistance **8** being 50,000 ohms, inductance **9** being 50 millihenries, and the device **7** being a Western Electric tube D98857. The duration of impulse **20** was approximately .73 microsecond.

Considering now the operation of the combination with the device **10**, it will be seen that when the charge on capacitor **5** is poled in a direction to discharge through device **7**, it is also poled properly for a discharge through device **10**, and that discharge of current from capacitor **5** through device **7** and impedance **6** reduces the negative polarization or produces positive polarization of the grid of device **10**. The capacitor **5** starts to discharge through device **7**, as described in my Patent 2,174,165, while the device **10** is blocked. The source **13** is adjusted to such a value that during the first part of the discharge of the current impulse through device **7** and impedance **6**, the polarization of the grid of device **10** is quickly changed sufficiently to unblock and cause ionization of device **10**, thereby producing a relatively low impedance path directly across capacitor **5**, thus chopping off the trailing end of the discharge impulse and greatly accelerating the discharge of the capacitor. The adjustment of the sources **13** and **14** may be conveniently made while watching the impulse curve traced by an oscillograph of the electron discharge type. The shortened output voltage impulse resulting from the chopping operation, using arbitrarily chosen constants, is shown by the curve **21**, Fig. 2, obtained by an oscillograph, the device **10** being of the same type as device **7** as stated above, the resistance **11** being 25 ohms, the resistance **12** being 500 ohms, and the other constants being the same as those mentioned above in connection with curve **20**. The arbitrarily chosen constants mentioned above are given merely by way of illustration of a typical case, and it will be understood that the circuit is not limited thereto but may have a wide range of values to suit the occasion.

It will be seen that the effect of the chopper device **10** is to divert current from the impedance **6**, so that the current through the impedance quickly returns to zero and the potential across the output terminals **15** drops much more abruptly to zero than in the case of the circuit not using the chopper, the duration of the impulse **21** being about .2 of a microsecond or less than one-third that of impulse **20**.

I have found that the output impulse of shortened duration yields a considerably wider frequency range of harmonics of uniform amplitudes and relatively high power levels, as shown by curve **22**, Fig. 3, than in the case of the impulse unshortened by the chopping operation, the harmonic yield of which is shown by curve **23**. The ordinates of curve **23** have been multiplied by a factor of four, in order to provide a ready comparison with the frequency distribution of curve **22**. Furthermore, when the duration of the output impulse is made as nearly as possible equal for the circuits with and without the chopper device **10**, the shape of the impulse produced by the chopper is such as to yield a much wider frequency range of harmonics of uniform amplitudes and relatively higher power levels by a factor of four, roughly, than the impulse produced without the chopper. Under these circumstances, the timing circuit **5,6** of the harmonic producer using the chopper may have a time constant which is much larger than that of the circuit **5,6** operating without the chopper. This situation is indicated to some extent by the yield of harmonics shown by curve **22** for a chopper circuit with which the timing circuit had a time constant CR of 15 times 10^{-8}, as compared with the harmonic yield shown by curve **23** for a circuit in which the time constant CR was 1.5 times 10^{-8} without a chopper. When the time constant of the circuit **5, 6** without the chopper **10** was made equal to that with the chopper, the other constants of the circuit remaining the same as above, the amplitudes of the resulting harmonics were no longer uniform but decreased rapidly with increase of frequency, as shown by curve **24**, Fig. 3. The circuit **5, 6** when used with the chopper **10**, should preferably have a time constant greater than 3 times 10^{-8}, as contrasted with a time constant of less than this value in cases where the chopper is not used.

It is, of course, to be understood that variations, substitutions and extensions as desired may be made within the scope of the claims without departing from the spirit of the invention.

What is claimed is:

1. In combination with a harmonic producer employing a gas-filled electron discharge device to control the charge and discharge of a capacitor-impedance circuit in response to an alternating current wave of a given base frequency to produce sharp impulses containing harmonics of said base frequency, means for increasing the frequency range over which harmonics of uniform amplitudes may be obtained by said harmonic producer comprising means including a second gas-filled electron discharge device responsive to the discharge of said capacitor for shortening the duration of said discharge, and means for taking off harmonics of said base frequency wave from said capacitor-impedance circuit.

2. In combination with a harmonic producer employing a gas-filled electron discharge device to control the charge and discharge of a capacitor through an impedance in response to a wave of given base frequency to produce sharp impulses containing harmonics of said base frequency, means for increasing the efficiency of production of harmonics of uniform amplitudes by said harmonic producer, comprising means for shortening the duration of the discharge of said capacitor, said means including a second gas-filled electron discharge device, and means for causing the operation of said second device in timed relation with the operation of said first device, and means for taking off harmonics of said base frequency wave from said capacitor-impedance circuit.

3. A harmonic producer, including a gas-filled electron discharge device havin an input circuit and an output circuit, a capacitor and a resistive impedance in series in said output circuit, a circuit for charging said capacitor, means responsive to an alternating current wave of a given base frequency for applying said wave to said input circuit to periodically cause ionization

in said device so as to allow said capacitor to discharge through said device and said impedance during a part of each cycle of the applied wave, means for taking off from said output circuit harmonics of said base frequency thereby produced in said output circuit, means including a second gas-filled electron discharge device having its discharge path connected across said capacitor for making the amplitudes of said harmonics more uniform over a wide frequency range, and means responsive to the discharge current of said capacitor through said first device to cause ionization in said second device to provide a low impedance discharge path for said capacitor.

4. In an impulse producing circuit, a timing circuit including a capacitor in series with a resistive impedance, a first gas-filled electron discharge device having an anode connected with the capacitor end of said timing circuit, a cathode connected with the impedance end of said timing circuit, and a control element, a second gas-filled electron discharge device having an anode connected with the capacitor end of said timing circuit, a cathode connected with the junction between said capacitor and impedance, and a control element connected with the impedance end of said timing circuit, input terminals having connections with said timing circuit and the control element of said first discharge device, means in said connections for controlling the relative time of response of the anode and control element of said first discharge device to current from said terminals, and means for taking off impulses from said timing circuit in response to predetermined impulses applied to said input terminals.

5. In a harmonic producer, a gas-filled electron discharge device having an input circuit and an output circuit, a capacitor and a resistive impedance in series in said output circuit, terminals for applying to said producer a source of periodic current of given base frequency, a charging circuit connecting said terminals with said capacitor-impedance circuit, means responsive to said base frequency current from said terminals for causing ionization in said device during a part of each cycle of said base frequently current to allow said capacitor to discharge through said output circuit, a second gas-filled electron discharge device having an input circuit including said impedance and an output circuit including said capacitor, means responsive to capacitor discharge current through said first discharge device for causing said second discharge device to ionize and thereby shorten the duration of discharge of said capacitor, and means to take off harmonics of said base frequency current from the output of said first discharge device.

6. In the harmonic producer of claim 5, a resistive impedance in series with said capacitor and the output circuit of said second discharge device.

7. In an impulse producer, a timing circuit including a capacitor and a resistive impedance in series, a first gas-filled electron discharge device having an anode, a cathode, and a control element, a connection from said anode to the capacitor end of said timing circuit, said cathode being connected with the impedance end of said timing circuit, a second gas-filled electron discharge device having an anode, a cathode, and a control element, a resistance-including connection from the anode of said second device to the capacitor end of said timing circuit, the cathode of said second device being connected with the junction between the capacitor and impedance of said timing circuit, a resistance-including connection from the control element of said second device to the impedance end of said timing circuit, a pair of input terminals for said producer, a circuit including a condenser and an inductance in series connected between said terminals and tuned to resonance for a given frequency, an impedance-including connection from the junction of the condenser and inductance of said resonant circuit to the capacitor end of said timing circuit, a connection from the inductance end of said resonant circuit to the impedance end of said timing circuit, a resistance-including connection from the condenser end of said resonant circuit to the control element of said first discharge device, and means for taking off impulses from said timing circuit in response to current of resonant frequency applied to said terminals.

8. In combination with a harmonic producer employing a gas-filled electron discharge device to control the charge and discharge of a capacitor-impedance circuit in response to a wave of given base frequency to produce sharp impulses containing harmonics of said base frequency, means including a second gas-filled electron discharge device having its discharge path connected across said capacitor for making the energy distribution of said harmonics more uniform over a wider frequency range, said means being responsive to the discharge of said capacitor to ionize said second device and provide a low impedance discharge path for said capacitor.

EUGENE PETERSON.