Sept. 2, 1952 A. M. SKELLETT 2,609,508

WAVE GENERATING CIRCUITS

Original Filed April 24, 1943 2 SHEETS—SHEET 1

FIG. 1

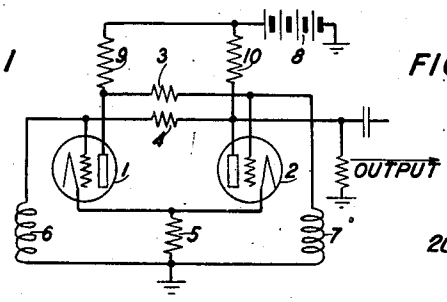


FIG. 2

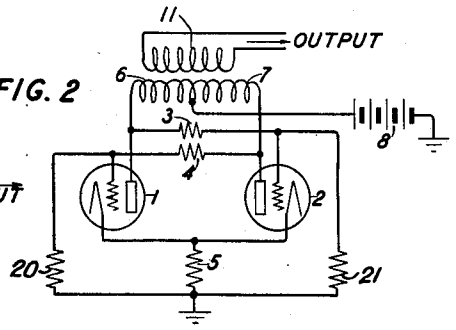


FIG. 3

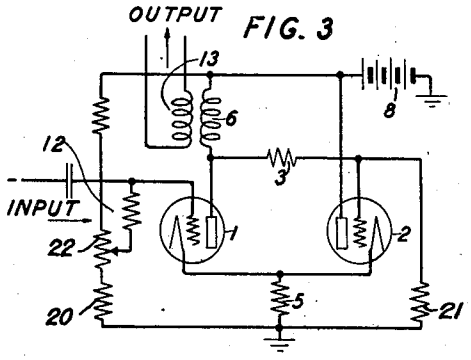


FIG. 4

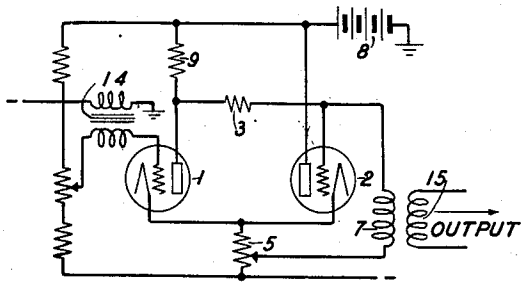


FIG. 5

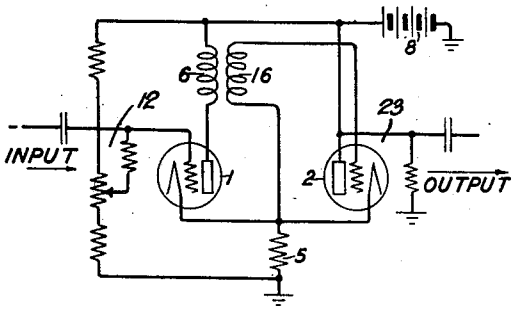


FIG. 6

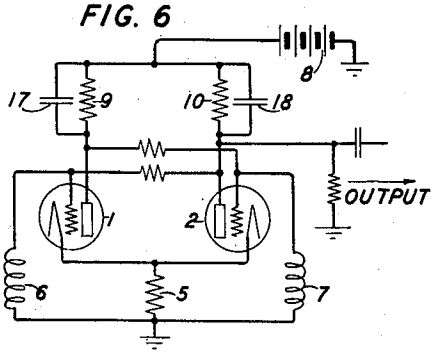
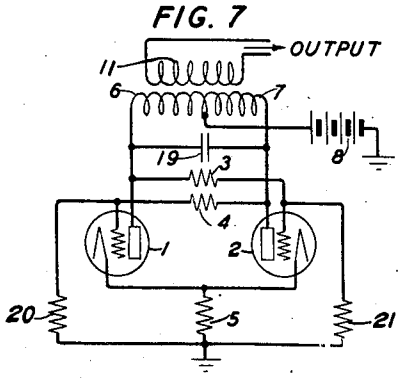


FIG. 7



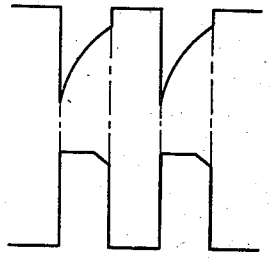
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Sept. 2, 1952 A. M. SKELLETT 2,609,508

WAVE GENERATING CIRCUITS

Original Filed April 24, 1943 2 SHEETS—SHEET 2

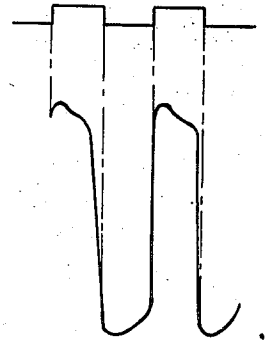
FIG. 8



GRID POTENTIAL VARIATION

PLATE POTENTIAL VARIATION

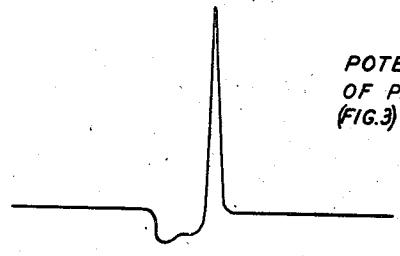
FIG. 9



GRID POTENTIAL VARIATION

PLATE POTENTIAL VARIATION

FIG. 10



POTENTIAL VARIATION OF PLATE OF TUBE 1 (FIG.3)

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WAVE GENERATING CIRCUITS

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8 Claims. (Cl. 250—36)

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The invention relates to wave generation and particularly to alternating wave generating circuits of the multivibrator type.

The so-called "multivibrator" is an arrangement of electric space discharge tubes operating as a distorted wave oscillator to produce a discontinuous wave the frequency of which may be adjusted to have any value within wide limits. In its original form as devised by H. Abraham and E. Bloch and described in an article by them in the Annalen de Physique, volume 12, page 237, 1919, it comprises a two-stage resistance-capacity coupled vacuum tube amplifier in which the anode of each tube is capacitively coupled to the control grid of the other tube. The period of oscillation of such a circuit is primarily determined by the time constant of the combination of coupling condenser and the grid resistor through which it discharges in the course of half a cycle.

An object of the invention is to provide the multivibrator type of operation in a wave generating circuit without the use of capacitance for timing control.

Another object is to generate alternating current waves of any desired stable frequency at a high voltage.

Another object is to generate alternating pulses of various wave forms.

These objects are obtained in accordance with the invention by the use of combinations of inductance and resistance to perform the functions of the condenser-resistance arrangements in the usual multivibrator circuit as well as to obtain other useful characteristics not ordinarily obtainable with such a circuit. In one embodiment, the modified multivibrator circuit may comprise a pair of multielectrode electron discharge tubes connected in a symmetrical or unsymmetrical circuit arrangement with highly resistive impedance coupling between the plate of one or both tubes and the control grid of the other tube, and an inductance coil in the control grid or plate circuit of one or both tubes, the time constant of the inductance coils and the resistive impedances with which they work primarily determining the period of oscillation of the multivibrator circuit.

The various objects and features of the invention will be better understood from the following detailed description when read in conjunction with the accompanying drawing in which:

Figs. 1 to 7 show schematically wave generating circuits embodying different modifications of the invention; and

Figs. 8 to 10 show curves illustrating typical wave forms for the control grid and anode potentials of the tubes in the circuits of Figs. 1 to 3 obtained by actual tests of those circuits.

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The symmetrical multivibrator circuit of Fig. 1 includes the two three-electrode amplifying vacuum tubes 1 and 2. The anode or plate of tube 1 is connected directly to the control grid of tube 2 through the highly resistive impedance (resistor) 3, and the anode or plate of tube 2 is connected directly to the control grid of tube 1 through an equivalent highly resistive impedance (resistor) 4. The cathodes of the tubes 1 and 2 may be heated to incandescence from any suitable source (not shown) which may be a direct current battery. The control grid-cathode circuit of tube 1 comprises the cathode resistor 5 and the inductance coil 6 in series, and the control grid-cathode circuit of the tube 2 comprises the same cathode resistor 5 and another inductance coil 7, equivalent to the coil 6, in series. Space current is supplied from the common plate battery 8 in parallel to the plates of tubes 1 and 2 through the individual equivalent series resistors 9 and 10, respectively.

Let it be assumed that the plate battery 8 and cathode battery sources of the tubes 1 and 2 have been connected as described so that the circuit is oscillating, and that the discharge has just been transferred from tube 2 to tube 1. The potential of the plate of tube 1 will then be negative with respect to the supply voltage from battery 8, and the control grid of tube 1 will be at or near zero potential with respect to the cathode of that tube. The control grid potential of the other tube 2 will then be more negative than the cut-off value and the current will be building up in the inductance 7 in the control grid-cathode circuit of the tube 2 thus gradually bringing up the potential of the grid of that tube toward the cut-off value. The potential of the plate of tube 2 will be the same as the supply voltage from battery 8.

As the current in inductance coil 7 increases, the potential across it decreases until the potential of the control grid of tube 2 is brought up to cut-off and current starts to flow through that tube. This will cause the potential of the plate of tube 2 to drop, and this potential drop will be transmitted through the coupling resistor 4 to the control grid of tube 1. Since this happens suddenly, the inductance coil 6 in the control grid-cathode circuit of tube 1 acts as a very high impedance, much higher than that of the coupling resistor 4, so that most of the voltage drop is impressed on the control grid of tube 1. Tube 1 amplifies this voltage change and its plate po-

tential starts to rise toward that of the supply voltage from battery 8. This rise of plate potential is transferred through the coupling resistor 3 to the control grid of tube 2, so that tubes 1 and 2 operate as a two-stage amplifier. This accelerated action quickly transfers the discharge to tube 1 and the cycle repeats. The potentials of the cathodes of tubes 1 and 2 do not vary appreciably during each cycle.

The upper and lower curves of Fig. 8 respectively show the wave form (variation of amplitude with time) of the grid and plate potentials for one of the tubes of the circuit of Fig. 1. The period of oscillation of the multivibrator circuit is determined approximately by the time constant of the coils 6, 7 and the resistances 4, 3 they work with. That is, the period

$$P \doteq \frac{2L}{R}$$

where L is the inductance of a coil and R is the resistance of a coupling resistor.

The constant frequency wave generated by the circuit of Fig. 1 may be taken off at any point, for example, through a resistance-capacity coupling from one plate circuit, as shown.

Fig. 2 shows a modified symmetrical multivibrator circuit in accordance with the invention differing essentially from that of Fig. 1 merely in that the inductance coils 6 and 7 are connected in push-pull relation with respect to each other, respectively, in series with the individual portions of the plate-cathode circuits of tubes 1 and 2 in place of the resistors 9 and 10, instead of in series with the control grid-cathode circuits of those tubes as in Fig. 1; the equivalent resistors 20 and 21 are connected in the control grid-cathode circuits of tubes 1 and 2, respectively, in series with the common cathode resistor 5; and the generated wave is taken off through another coil 11, symmetrically inductively coupled to the coils 6 and 7. As shown by the curves of Fig. 9, in the circuit of Fig. 2 the grid potentials are of square wave form and the plate potentials swing over a rather large voltage range, greater than the supply voltage.

Fig. 3 shows an unsymmetrical multivibrator arrangement in accordance with the invention differing from the circuit of Fig. 2 in the following particulars: The connection between the plate of tube 2 and the grid of tube 1 through resistor 4 is eliminated, the connection between the plate of tube 1 and the grid of tube 2 through series resistor 3 being retained. The inductance coil 6 is connected in series with the individual portion of the plate-cathode circuit of tube 1 as in Fig. 2, but the series coil 7 in the individual portion of the plate-cathode circuit of tube 2 is eliminated. A potentiometer 22 having its resistance element connected between the grid resistor 20 and the positive terminal of battery 8 and its variable arm connected to the grid of tube 1, is provided for obtaining in conjunction with battery 8 and cathode resistor 5 a negative grid bias of suitable value in tube 1. The circuit is driven by an alternating control wave, for example, a wave comprising a series of sharp pulses recurring at regular intervals so as to provide "trigger" operation, applied to the control grid-cathode circuit of tube 1 through the resistance-capacity coupling 12; and the generated wave output of the multivibrator is taken off through a coil 13 inductively coupled to the coil 6.

In the circuit of Fig. 3, the tube 2 is normally conducting and the tube 1 is normally cut-off

(non-conducting) by the resultant negative bias applied to its grid from battery 8 through the discharge path of tube 2 with that tube conducting, cathode resistor 5 and potentiometer 22 with proper adjustment of its variable arm. The circuit is triggered off by the application of each control pulse to the control grid-cathode circuit of tube 1. The trigger input suddenly raises the potential of the control grid of tube 1 so that the tube starts to conduct immediately. This action is so sudden that the plate impedance of tube 1 at this time is very high, and the plate potential starts to drop, causing the potential of the control grid of tube 2 to be pushed down through the coupling resistor 3. This lowers the current flow through tube 2 and hence the current through the common cathode resistor 5 dropping the cathode potential of that tube. This action effectively decreases the grid bias on tube 1 and hastens the transfer of the discharge from tube 2 to tube 1 through this regenerative action. In this case, the cathode resistor 5 acts to provide positive feedback.

This action continues at a very fast rate until the discharge has transferred to tube 1. The current continues to build up in the coil 6 in the plate-cathode circuit of tube 1, raising the plate potential of tube 1 and thus the potential on the grid of tube 2 through the coupling resistor 3. When the potential of the grid of tube 2 is built up through this action to the cut-off value, tube 2 starts to conduct. This increases the current flow through the common cathode resistor 5 increasing the bias on tube 1, and through the same action as described above, but in the opposite sense, the discharge quickly transfers to the grid of tube 2 to remain there until the next trigger pulse comes along.

The duration of the pulse thus generated in the coil 6 is determined approximately by the time constant of that coil 6 in series with the tube resistance. When the discharge transfers to tube 2, a very high potential is generated in the coil, as indicated by the curve of Fig. 10. In order to generate a high voltage output wave by this means, the coil 6 may be used as the primary winding of a step-up transformer, and the coil 13 in the output circuit, inductively coupled to coil 6 as the secondary winding of that transformer. By the use of a small double triode for tubes 1 and 2, sparks of several thousand volts have been obtained with the circuit of Fig. 3. If the bias on the control grid of tube 1 is increased, this circuit, like those of Figs. 1 and 2, will oscillate by itself when the batteries are connected to the tubes.

The coil 6 in the circuit of Fig. 3 may be the operating winding of an electromagnetic relay, in which case the relay will remain operated for a definite time, no matter what the duration of the trigger pulse, provided, of course, that it is less than the duration of the generated pulse. Thus the circuit may operate as a hold-up circuit. Another use might be that of pulse preshaping in telegraphy, etc.

Fig. 4 shows another unsymmetrical multivibrator circuit embodying the invention, differing essentially from that of Fig. 3 in that the resistor 9 is substituted for the inductance coil 6 in series with the plate-cathode circuit of tube 1 and an inductance coil 7 is connected in place of the series resistor 21 (shown in Fig. 3) between the control grid of tube 2 and a variable contact on the common cathode resistor 5. This multivibrator circuit is triggered off by pulses ap-

plied by the saturable magnetic core input transformer 14 to the control grid-cathode circuit of tube 1, and the generated wave is supplied to an output circuit through coil 15 inductively coupled to coil 7.

The operation of the circuit of Fig. 4 is similar to that of the circuit of Fig. 3 described above. The cathode resistor 5 again provides positive feedback, and the duration of the square pulse generated by the multivibrator is determined by the resistances which are effectively in series with the coil 7 when the current is building up through it (and the voltage across it is decreasing). Like the circuits of the other figures, the circuit of Fig. 4 will self-oscillate providing the biases applied to the grids of both tubes are sufficient to make them both conducting at once under which condition the circuit set-up is unstable and acts like a two-stage amplifier with positive feedback.

The unsymmetrical multivibrator circuit of Fig. 5 differs essentially from that of Fig. 3 in that the coupling from the plate of tube 1 to the control grid of tube 2 is obtained by a coil 16 coupled to the coil 6 in the plate-cathode circuit of tube 1, that is, by a transformer formed by these two coils instead of by the resistor 3. As in the circuit of Fig. 3, the trigger pulse is applied to the control grid-cathode circuit of tube 1 through a resistance-capacity coupling 12, and the output is taken off from the plate circuit through another resistance-capacity coupling 23 instead of through a coil inductively coupled to the coil 6. The operation of the circuit of Fig. 5 will be obvious from that described for the similar circuits of Figs. 3 and 4.

Figs. 6 and 7 show modifications of the multivibrator circuits of Figs. 1 and 2, respectively, which will be effective to make the outputs of these circuits closely approximate sine waves. Fig. 6 differs from the circuit of Fig. 1 merely in the addition of the condensers 17 and 18, connected across the resistances 9 and 10, respectively, in series with the plate-cathode circuits of tubes 1 and 2, and Fig. 7 differs from Fig. 2 merely in the addition of the condenser 19 connected across the plate circuit inductance coils 6 and 7 in series. The function of the added elements is to smooth out the abrupt transitions from one tube to the other and thus to enable sine wave outputs to be produced. The arrangement of Fig. 7 particularly should produce a very good sine wave.

It is obvious that the principles of the invention are applicable to multivibrator circuits employing any even number of tubes, or electron discharge tubes having more than three electrodes, as well as to multivibrator frequency step-up and step-down circuits, in which case the control oscillation injected into the grid or plate circuit would be of a frequency which is a submultiple or a harmonic of the multivibrator frequency, respectively.

Other modifications of the circuits illustrated and described which are within the spirit and scope of the invention will occur to persons skilled in the art.

This application is a division of my copending application, Serial No. 484,324, filed April 24, 1943, now U. S. Patent 2,501,620.

What is claimed is:

1. A multivibrator circuit having two degrees of electrical stability comprising a pair of electrode structures each having an anode, a cathode and a grid, an inductance coil connecting the grid of each structure to its cathode, and a resistor connecting the anode of each electrode structure to the grid of the other structure.

2. A multivibrator circuit having two degrees of electrical stability comprising a pair of electrode structures each having an anode, a cathode and a grid, an inductance coil connecting the grid of each structure to its cathode, and a resistor connecting the anode of each electrode structure to the grid of the other structure, the correspondingly positioned inductance coils and resistors of said multivibrator circuit having equal values whereby said multivibrator circuit produces essentially square waves of 50 per cent mark and 50 per cent space.

3. A multivibrator circuit comprising a pair of electrode structures each having an anode, a cathode and grid, an inductance coil connecting the grid of each structure to its cathode, and a connection devoid of concentrated capacity connected between the anode of each electrode structure and the grid of the other structure, said connection including an impedance having a resistive component.

4. An electron discharge device system comprising a pair of electrode structures each having an anode, a cathode, and a grid, an inductance coil connecting the grid of each structure to its cathode, a resistor interconnecting the grid of each electrode structure with the anode of the other electrode structure, and means for supplying to said anodes potentials which are positive relative to the cathode.

5. A multivibrator comprising a pair of electron discharge devices each having a heated cathode, an anode and a control grid, circuits respectively interconnecting the anode and cathode of each device having one portion in common including a source of space current and other portions of like electrical characteristics individual to the respective devices, other circuits respectively interconnecting the control grid and cathode of each device having portions of like electrical characteristics individual to the respective devices and a resistive portion in common, said common resistive portion of the grid-cathode interconnecting circuits being also included in said common portion of the anode-cathode interconnecting circuits, each of the individual portions of said anode-cathode interconnecting circuits including resistance but no inductance, each of the individual portions of said grid-cathode interconnecting circuits including inductance, the period of oscillation of said multivibrator circuit being determined primarily by the time constant of said inductance and the circuit resistance effectively in series therewith, and an output circuit coupled to the individual portion of the anode-cathode interconnecting circuit of at least one of said devices for receiving the generated oscillations.

6. An oscillation generator of the multivibrator type comprising two electron discharge devices each having a cathode, an anode and a control grid, circuits respectively interconnecting the anode and cathode of each of said devices having one portion in common including a source of space current and other portions individual to the respective devices, other circuits respectively interconnecting the grid and cathode of each of said devices having a portion in common including a resistance and other portions individual to the respective devices, a connection comprising resistance only between the anode of each device and the grid of the other device, inductance in each of the individual portions of

the grid-cathode interconnecting circuits of said devices, resistance in each of the individual portions of the anode-cathode interconnecting circuits of said devices, said inductances forming with the associated resistances non-resonant circuits which determine the frequency of oscillation of said generator, and means for picking off the generated oscillations from one of the individual portions of the anode-cathode interconnecting circuits of said devices.

7. The multivibrator of claim 5, in which equivalent inductance coils are respectively connected in series in the individual portions of said control grid-cathode interconnecting circuits, and equivalent resistors are respectively connected in series in the individual portions of said cathode-anode interconnecting circuits.

8. A multivibrator comprising two electron discharge tubes each having a heated cathode, an anode and a control grid, control grid-cathode circuits for said tubes including a common cathode resistor, anode-cathode circuits for said tubes having a common portion including a source of space current and two other portions individual to the respective tubes, equivalent

inductance coils respectively connected in series in each of said control grid-cathode circuits, equivalent resistors shunted by equivalent capacitors respectively connected in series in the individual portions of said anode-cathode circuits, a resistance connected between the anode of each tube and the control grid of the other tube, said multivibrator being capable of self-oscillation at a frequency primarily determined by the time constants of said inductance coils and the resistances with which they work, to produce oscillations closely approximating a sine wave form, and an output circuit for taking off the generated oscillations from one of said circuits.

ALBERT M. SKELLETT.

REFERENCES CITED

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

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