Nov. 29, 1949 E. R. SHENK 2,489,824

SQUARE WAVE GENERATOR WITH IMPULSE COUNTER TIMING CONTROL FOR FREQUENCY DIVISION

Filed Dec. 24, 1943 2 Sheets-Sheet 1

Fig. 1.

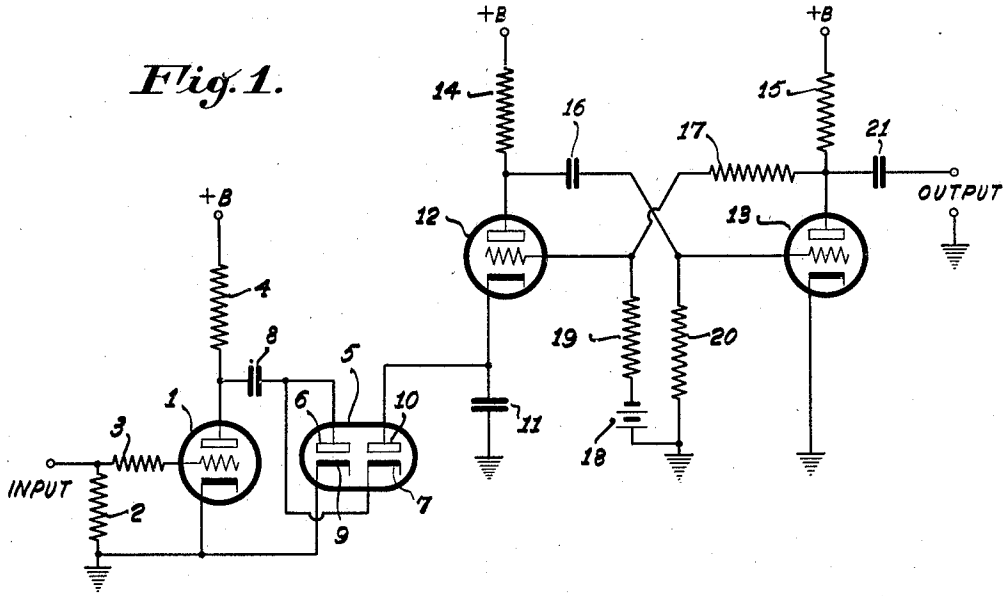
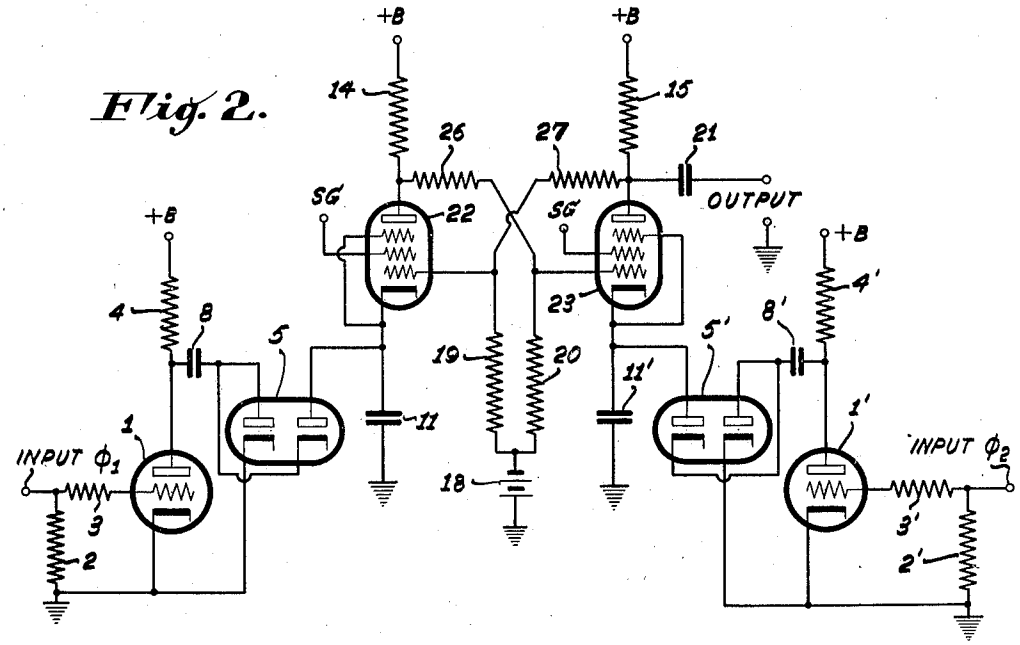


Fig. 2.



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Fig. 3.

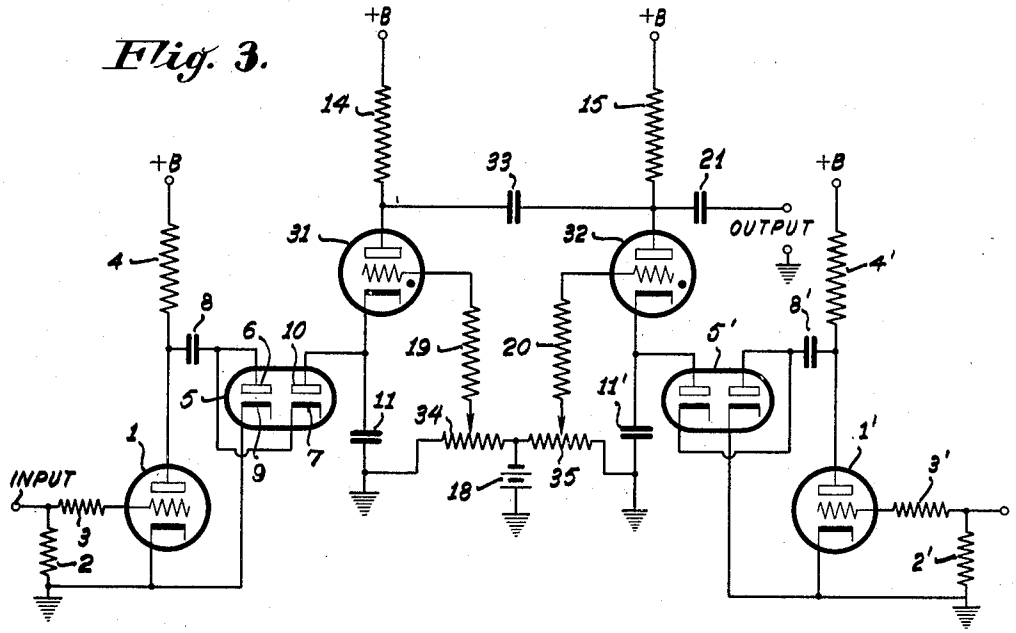
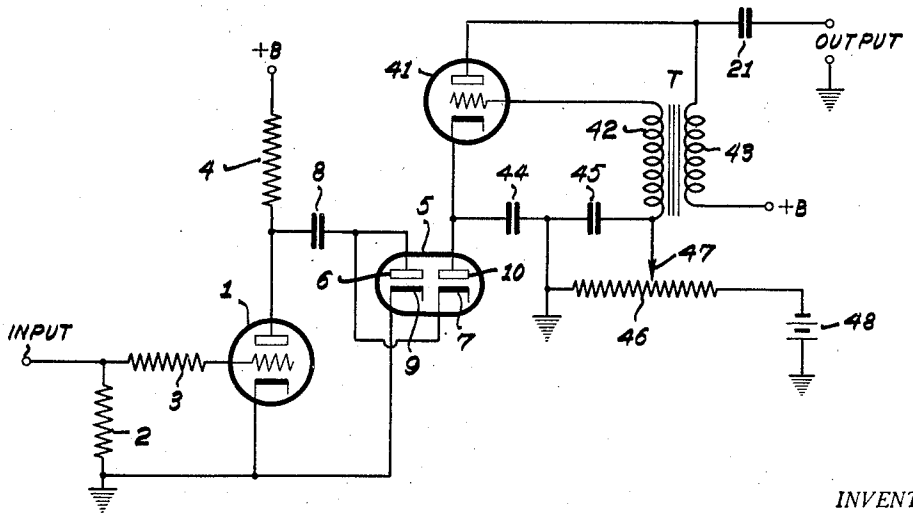


Fig. 4.



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SQUARE WAVE GENERATOR WITH IMPULSE COUNTER TIMING CONTROL FOR FREQUENCY DIVISION

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8 Claims. (Cl. 250—27)

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This invention relates to frequency dividing circuits. Counting circuits of various types are well known in the art and are frequently used as frequency dividers.

Heretofore frequency dividers have possessed the disadvantage of operating at a natural frequency of their own in the absence of a controlling frequency. Also small variations of the circuit constants, or of the amplitude of the controlling frequency, were likely to change the order of division. A further disadvantage is that the order of division is a function of the controlling frequency. The multivibrator and the blocking oscillator are examples of frequency dividers of this type.

One type of frequency divider that does not possess a natural frequency of its own is the so-called "counter circuit." In this circuit the voltage across a condenser is built up in steps (one step for each cycle of the controlling frequency) until it reaches a critical value, at which point it actuates a blocking oscillator which oscillates for a very short time and discharges the condenser. Then the voltage stepping or "counting" process begins all over again. The output of the divider is, therefore, limited to a short pulse occurring at some submultiple of the controlling frequency.

It is an object of my invention to provide a frequency divider circuit which has no natural frequency of its own, i. e., it must be driven.

Another object is to provide a locking circuit for counting purposes which functions under control of aperiodic impulses.

Still another object is to provide a frequency divider circuit of simple design capable of useful operation under widely varying conditions.

A more specific object of my invention is to provide a rectangular wave generator which is subject to control by alternating current waves of a given frequency harmonically related to the cyclic period of the rectangular wave output, where such output is composed of flat wave crests (or "mesas") and valleys, the time ratio between which is adjustable in accordance with the ratio between any two small integers.

My invention will now be described in more detail, reference being made to the accompanying drawings, in which:

Fig. 1 shows the combination of a counting circuit with a locking circuit having no natural period of oscillation;

Fig. 2 shows a modification wherein the control pulses can be applied in two different phases;

Fig. 3 shows another circuit having the contraphasal control feature of Fig. 2, but with the provision of "back-to-back" interaction between two gaseous discharge tubes of its locking circuit; and

Fig. 4 shows a novel form of counting circuit per se.

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Referring first to Fig. 1, I show therein a circuit arrangement comprising a discharge tube 1, which may be used for amplifying the waves of an input potential. This tube is provided with an input circuit comprising resistors 2 and 3 serially connected between the cathode and control grid. Input potentials of any frequency or even aperiodic impulses are applied at the junction between the two resistors 2 and 3. Anode potential is supplied through a resistor 4.

A twin diode tube 5 has one anode 6 and one cathode 7 coupled to the anode circuit of tube 1 through capacitor 8. The cathode 9 in tube 5 is grounded, as is the cathode in tube 1. The anode 10 in tube 5 is coupled to ground through a capacitor 11. This capacitor 11 is also connected between ground and the cathode of a discharge tube 12, the latter being one of two tubes connected in a well-known locking circuit. The other tube 13 in this circuit has a cathode which is directly grounded.

Positive potential is supplied from a suitable direct current source to the anode of tube 12 through resistor 14. The same source can be used to supply potential to the anode of tube 13 through resistor 15.

The anode in tube 12 is coupled through capacitor 16 to the control grid in tube 13. A resistive connection including resistor 17 is made between the anode of tube 13 and the control grid of tube 12.

The control grid in tube 12 is preferably negatively biased with respect to ground, this being accomplished by means of a negative biasing source 18, the negative terminal of which is connected through resistor 19 to the grid in tube 12. The control grid in tube 13 is connected to ground through a resistor 20.

In the operation of the circuit arrangement shown in Fig. 1, capacitor 11 is used for triggering the locking circuit by building up a negative voltage on the cathode in tube 12. The actual tripping of the trigger is, however, delayed for a number of counting impulses delivered through the input circuit of tube 1 until the desired number of impulses has been counted. Consider first that the counting cycle commences with a pulse of negative polarity so as to bias the grid in tube 1 to cut-off. Each such impulse raises the anode potential in this tube to that of the direct current source and a positive charge is supplied to capaci-

tor 8. The charging circuit traverses the left hand section of tube 5 wherein the space path between cathode 9 and anode 6 becomes conductive.

During the positive half cycle of the counting impulse, tube 1 becomes conductive. Capacitor 8 discharges by virtue of a conductive state which occurs between the cathode 7 and anode 10 in the right hand section of the tube 5, and this action produces an increment of negative charge on the ungrounded side of capacitor 11. The step-by-step accumulation of charges on capacitor 11 takes place until the threshold bias in tube 12 is overcome. Tube 12 then becomes conductive. The circuit constants are so chosen that the desired number of control impulses may be counted during the build-up of charges on capacitor 11 to the triggering level.

During the conductive state in tube 12, the charge on capacitor 11 is dissipated and thereafter current flows through the two space paths of tube 5 as a series circuit to ground. After a period of time determined primarily by the values of capacitor 16 and resistor 20, the conductive state ceases in tube 12 and the counting process repeats itself.

Output potentials may be derived from any suitable point in the circuit, but for the sake of illustration, the output is shown as taken off from the anode in tube 13 through coupling capacitor 21. In order to satisfy certain utilization requirements, the output may, however, be derived from a point such as the connection between the resistor 14 and the anode in tube 12.

Referring now to Fig. 2, I show a circuit arrangement which is similar in many respects to that of Fig. 1. There are two counting circuits both exactly the same as the one shown in Fig. 1. Like parts are given like reference numbers. Certain of the symmetrically disposed parts are distinguished by affixing the prime (') to the reference number for the right hand element.

The tubes 22 and 23 are shown as pentodes. Tube 23 has its own triggering circuit comprising discharge tube 1' and twin diode tube 5'. These tubes occupy positions which are the counterparts of tubes 1 and 5 and are used for providing dual control of the locking circuit. The symmetrical relationship between the two counting circuits may readily be seen. Tube 1' has an input circuit comprising resistors 2' and 3' and the junction between these two resistors has a connection to a source of input potentials which under certain conditions may be 180° phase displaced with respect to the input potentials applied to tube 1. Such contraphasal relationship may, for example, be obtained by the use of a transformer, the secondary of which has its outside terminals connected one to the input circuit of tube 1 and the other to the input circuit of tube 1' while the center tap is grounded.

The anode in tube 22 is connected to the grid in tube 23 through a resistor 26. The biasing source 18 is used to apply the same negative bias to the control grids in tubes 22 and 23 so that these tubes operate in balanced relationship to one another.

If each portion of the triggering circuit of Fig. 2 is to count by an integer, the input pulse should be supplied in the same phase to both inputs. If, however, each portion of the circuit is to include a fraction of a tone cycle in its count, then the phase of the input potential applied to tube 1 must be different from that which is

applied to the input circuit of tube 1'. If one portion of the circuit includes in its division a certain fraction, r, of the period of the applied input tone frequency, then the other portion must—and automatically will—include the complementary fraction $(1-r)$ in its division. The order of division of the circuit as a whole will always be an integer. The difference between phase #1 (applied to tube 1) and phase #2 (applied to tube 2') must be $360\ r$ degrees.

The count obtained by means of either of the circuits of Figs. 1 and 2 can be adjusted by varying the values of the anode potential source or the grid biasing source or both. However, changing either of these voltages results in a similar change in the action of both tubes 22 and 23. This is sometimes undesirable since under these conditions changing the count of one tube by variation of one of its supply voltages will also alter the count of the other tube. This same interlocking is experienced if the count is varied by means of changes in the values of resistors 19, 20, 26, and 27.

A preferred means of adjusting the count is by varying the load resistors 14 and 15. An advantage of this adjustment is that the value of resistor 15, for example, will change the net grid voltage applied to the grid in tube 22 when this tube is non-conducting, but the same adjustment will have a negligible effect on the grid voltage when the tube is conducting. Thus, if resistor 15 is much less than the combined resistive values of elements 19 and 27, the count of tube 22 will increase and decrease in accordance with the value assigned to resistor 15.

Furthermore, if the value of resistor 14 is much less than the combined ohmic values of resistors 20 and 26, then the count of tube 23 will vary with the value of resistor 14. In a pentode tube the D. C. anode current is independent of the value of the anode load resistor over a wide range. Therefore, the method of adjusting the count as above described is especially successful with pentodes.

The circuit arrangement of Fig. 3 is one which provides a number of advantageous features among which may be mentioned the following:

It is arranged with a pair of gaseous discharge tubes 31 and 32, the anodes of which are intercoupled by means of a capacitor 33 for so-called "back-to-back" interaction. This circuit has no natural period of its own but must be driven by external control voltage. It delivers a substantially rectangular waveform output voltage. It is very conveniently and simply adjusted to count impulses within a considerable range. The ratio is adjustable between the number of impulses counted on the positive half cycle as compared with the negative half cycle of output voltage. The order of count is independent of the input frequency over a number of octaves.

The circuit connections as shown in Fig. 3 are substantially identical with those of Fig. 2 except that in Fig. 3, I preferably provide two adjustable potentiometers 34 and 35 for independently controlling the quiescent bias on the grids of tubes 31 and 32 respectively. The operation of the circuit of Fig. 3 will be readily understood in view of the foregoing description of Figs. 1 and 2.

In accordance with the well-known manner of igniting and extinguishing two "back-to-back"-connected thyratron tubes, such as tubes 31 and 32, it will be remembered that when either of these tubes ignites the surge impulse impressed

across capacitor 33 causes the other tube to be extinguished.

The number of impulses counted by tube 31 during its period of non-conduction is readily varied in accordance with the adjustment of the tap on potentiometer 34. Likewise, the number of impulses counted during the period of non-conduction in tube 32 is determined by the adjustment of the tap on potentiometer 35. The anode voltage applied to tube 1 may or may not be equal to that which is applied to tube 31. The reliability of the count can be increased by increasing the anode voltage applied to the anode of tube 1.

Fig. 4 shows an embodiment of my invention which comprises the same counting circuit as shown in the other figures, but this is operatively associated with a blocking oscillator. The oscillator tube 41 has its anode circuit connected through the primary winding 43 of a transformer T, and thence to the positive terminal of a direct current source. The grid of tube 41 is connected through the secondary 42 of the same transformer and thence to a ground connection through tap 47 which is adjustably associated with a potentiometer 46. Across the terminals of potentiometer 46, I preferably connect a biasing source 48. In this manner, the D. C. bias voltage applied to the grid in tube 41 may be suitably adjusted. A bypass condenser 45 is connected between the tap 47 and ground, thus shunting the grounded portion of potentiometer 46.

In the operation of the circuit arrangement shown in Fig. 4, a negative charge on capacitor 44 is built up in steps as determined by the impress of counting pulses via capacitor 8 and through the right hand section of the rectifier tube 5. Upon the occurrence of a certain step, the cathode in tube 41 will be rendered sufficiently negative so that this tube will oscillate and its anode and grid current will discharge the capacitor 44. The number of the count is determined by the setting of the potentiometer tap 47.

While I have shown and described a number of different embodiments of my invention, it will be seen that there is a common basic principle which is inherent in all of the circuit arrangements.

Other modifications of my invention will doubtless suggest themselves to those skilled in the art in view of the foregoing description.

I claim:

1. A frequency divider circuit arrangement comprising a pair of discharge tube structures each having a cathode, an anode and a control grid, a direct current energy source having a grounded negative terminal and resistive connections from its positive terminal to each of said anodes, two capacitors each individually coupling one of the cathodes respectively to ground, an inter-control impedance network constituting means for causing each tube structure when it is conductive to render the other tube structure non-conductive, and two impulse counting circuits each separately associated with a respective one of said capacitors and arranged to build up incremental charges therein, said counting circuits being further characterized in that each offers a unidirectionally conductive path to ground from a respective one of said cathodes.

2. A circuit arrangement according to claim 1 and including on said inter-control network two resistors each interconnected between the anode of one tube and the control grid of the other tube, and means for applying to each of said grids a negative direct current bias with respect to ground.

3. A circuit arrangement according to claim 1 in which said tubes are of the gaseous type, and said inter-control network includes a capacitor intercoupling the anodes in the two tubes.

4. In a rectangular wave generator subject to control by an external source of alternating current, an electronic counting circuit arranged and adapted to count the half cycles of one polarity during a predetermined time interval, a second electronic counting circuit arranged and adapted to count the half cycles of opposite polarity during an immediately following predetermined time interval, each of said counting circuits including a capacitor in which incremental charges are built up by way of integrating the effects of said half cycles, a pair of gaseous discharge tubes of the triode type, a direct current energy source having a grounded negative terminal and separate resistive connections from its positive terminal to each of the anodes in said tubes, a condenser intercoupling said anodes, and means for causing each of said time intervals as measured by said counting circuits to be terminated by discharge of an alternate one of said capacitors through the ionization path of a respective tube.

5. In a rectangular wave generator subject to control by an external source of alternating current, a pair of gaseous discharge tubes each having a cathode, an anode and a control grid, means for applying an independently adjusted negative bias to the grid with respect to the quiescent-state potential of the cathode in each tube, unidirectionally conductive devices individually connecting said cathodes to ground, a capacitor in shunt with each said device, a direct current operating potential source connected between said anodes and ground, a load impedance connecting each anode to said source, a condenser intercoupling said anodes and constituting means for reciprocally extinguishing each tube when the other ignites, means for incrementally charging each said capacitor from uni-polar half cycles of said alternating current, the operation of said means being effective after integration of a predetermined number of half-cycle charges to ignite the gaseous tube with which the particular capacitor is connected, thus causing said capacitor to discharge through said gaseous tube.

6. Apparatus for producing a rectangular wave having a desired time relation between the mesa-portion and the valley-portion of each cycle, said time relation being determined by a suitable choice of circuit parameters in an electronic generator of such a wave, where said generator is subject to control by two separate counting circuits, one for timing the mesa-portion and the other for timing the valley portion of said wave, said apparatus comprising means for causing each of said counting circuits to store a succession of capacitive charges which are derivable from uni-polar half cycles of a given alternating current, said counting circuits being successively operable, means for producing an ionization discharge which dissipates the energy of the stored capacitive charges of one counting circuit and terminates one count of half cycles, means for producing a second ionization discharge which dissipates the energy of the stored charges of the other counting circuit, thus terminating the other count of half cycles, and means for deriving said rectangular wave from potential variations which are due to the alter-

nately successive occurrences of the first and the second ionization discharges.

7. A frequency divider comprising a pair of electron discharge device structure whose electrodes are interconnected to provide a circuit of two degrees of electrical stability, such that one structure is conductive when the other structure is non-conductive for one degree of electrical stability, and vice versa for the other degree of electrical stability, separate impulse counters coupled to said structures, each counter adapted to change the condition of stability of said devices after a predetermined count, and means for varying the interval of conductivity of one structure relative to that of the other structure over a complete cycle of operation of said circuit.

8. A frequency divider comprising a pair of gaseous tubes each having an anode, a cathode and a grid, commutating condenser coupled between the anodes of said tubes, separate potentiometers for the grids of said tubes for individually adjusting the bias thereon, a condenser coupling the cathode of each tube to ground, and a source of anode polarizing potentials for said tubes, whereby said pair of tubes constitute a circuit having two degrees of electrical stability in which one tube is conductive and the other tube non-conductive for one degree of stability,

and vice versa for the other degree of stability, a first impulse counter coupled across the cathode condenser of one gaseous tube, and a second impulse counter coupled across the cathode condenser of the other gaseous tube.

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REFERENCES CITED

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

UNITED STATES PATENTS

Number	Name	Date
2,059,562	Curtis et al.	Nov. 3, 1936
2,113,011	White	Apr. 5, 1938
2,122,464	Golay	July 5, 1938
2,185,199	Kahn	Jan. 2, 1940
2,185,363	White	Jan. 2, 1940
2,193,850	Andrieu	Mar. 19, 1940
2,258,943	Bedford	Oct. 14, 1941
2,403,615	Sanders, Jr.	July 9, 1946
2,418,521	Morton et al.	Apr. 8, 1947
2,421,018	Rosa	May 27, 1947
2,430,547	Anderson et al.	Nov. 11, 1947
2,442,256	Bartlett	May 25, 1948
2,442,403	Flory et al.	June 1, 1948
2,452,549	Cleeton	Nov. 2, 1948