

Oct. 17, 1950

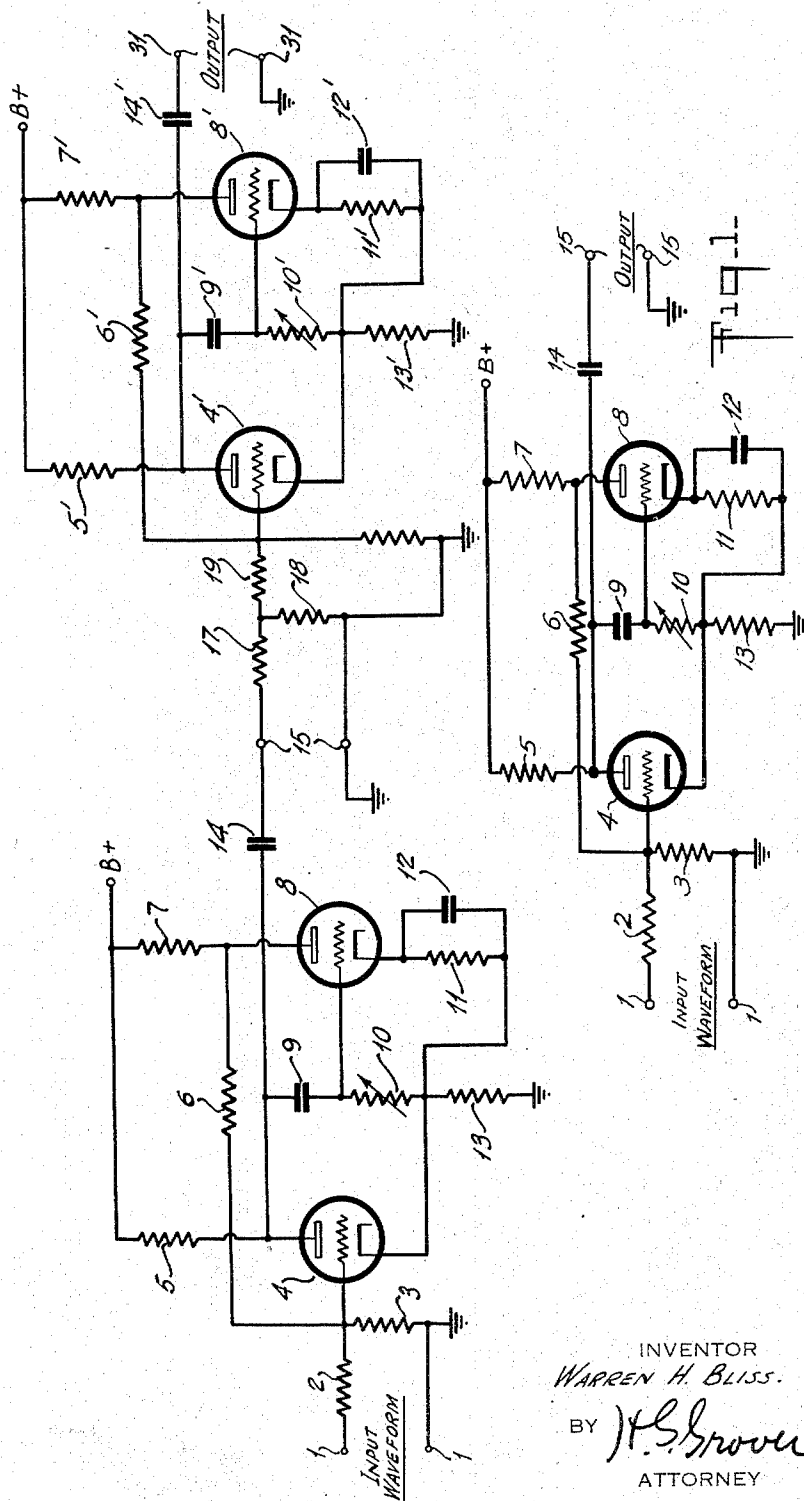
W. H. BLISS
FREQUENCY DIVIDER

2,526,000

Filed May 26, 1945

2 Sheets-Sheet 1

Fig. 2.



INVENTOR
WARREN H. BLISS.
BY *H. S. Brown*
ATTORNEY

Oct. 17, 1950

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Fig. 3.

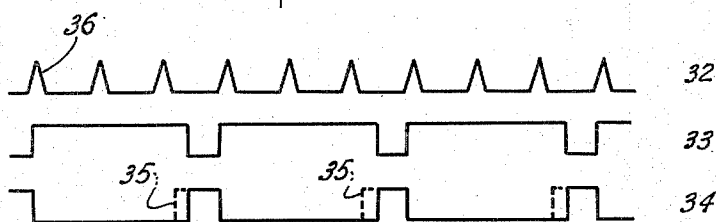
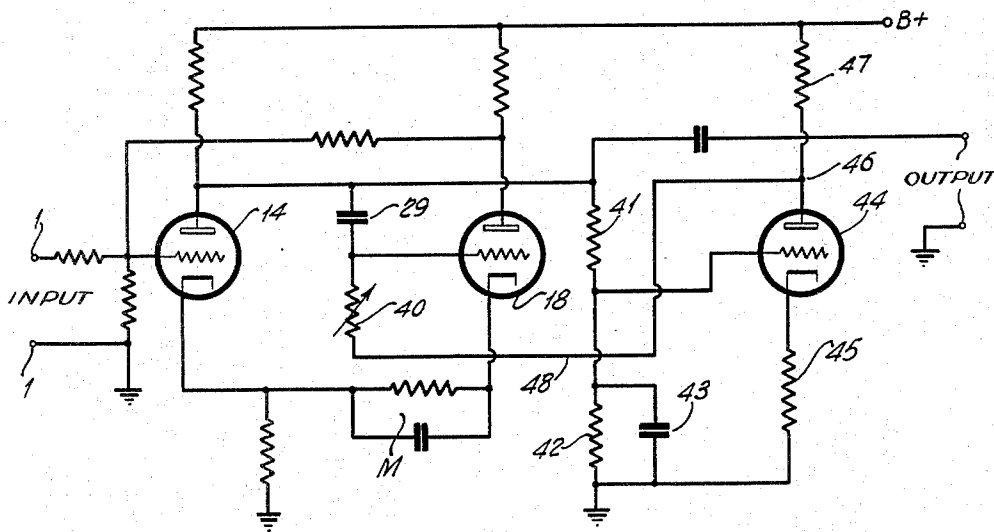


Fig. 4.



INVENTOR
WARREN H. BLISS.

BY *J. S. Snover*
ATTORNEY

UNITED STATES PATENT OFFICE

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FREQUENCY DIVIDER

Warren H. Bliss, Riverhead, N. Y., assignor to
Radio Corporation of America, a corporation of
Delaware

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15 Claims. (Cl. 250—27)

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This invention relates broadly to an electron discharge device system for dividing the frequency of a periodic wave form of voltage variation by an exact integral number, and specifically to a frequency divider of the type which employs a self-restoring trigger circuit.

An object of the present invention is to provide an improved frequency divider which is very stable in operation and can tolerate relatively wide variations in operating voltages, circuit factors and driving voltage without interfering with the desired output frequency.

Another object of the invention is to provide a self-restoring trigger circuit type of frequency divider having circuit means for compensating for any tendency of the trigger circuit to restore itself at a time earlier or later than the normal time.

Briefly stated, the frequency divider of the invention comprises a "flip-flop" or self-restoring trigger circuit composed of two multi-electrode electron discharge device structures whose electrodes are interconnected regeneratively. This trigger circuit is designed to have one degree of electrical stability; that is, a stable state and an unstable or active state. Thus, where two separate tube structures are employed for the trigger circuit, one tube is normally biased to be non-conducting while the other tube is biased to conduct in the stable state of the trigger circuit. The application of a voltage of desired magnitude and polarity will trigger off or fire the trigger circuit into the unstable or active state, in which state the current conductive conditions of the two tube structures are reversed. The interval of time in which the trigger circuit remains in the unstable or active state is primarily controlled by the time constants of the trigger circuit, and after a period of time in the active state the trigger circuit will return or restore itself to the stable state. By suitable design of the trigger circuit, the application of a voltage sufficient to trip the circuit from its stable to its active state will cause the trigger circuit to remain unresponsive to further applied pulses for a certain interval of time corresponding to a period covering a certain number of applied pulses. The output pulse frequency or repetition rate will then be equal to the input pulse frequency divided by the number of applied pulses impressed on the trigger circuit during its active or non-responsive period. Frequency division is thus accomplished by tripping or triggering the circuit by each Nth cycle of the frequency to be divided, where N is an integer.

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An important feature of the invention is the compensating circuit which produces a lock-in effect. Because of this feature, frequency division by any given integer or sub-multiple of the applied frequency is very stable, and variations in operating voltages, circuit factors, and driving voltage can be tolerated.

A more detailed description of the invention follows in conjunction with a drawing, wherein:

Fig. 1 illustrates a specific embodiment of the invention;

Fig. 2 illustrates another embodiment showing two trigger circuits or units of Fig. 1 connected in tandem or cascade;

Fig. 3 graphically illustrates different voltage wave forms appearing in various parts of the system of Fig. 1, given in explanation of the operation of the invention; and

Fig. 4 illustrates another modification of the system of Fig. 1.

Referring to Fig 1, there is shown a frequency divider system in accordance with the invention for providing an output in the form of pulses whose repetition rate is an integral sub-multiple of the applied pulses. This system includes a trigger circuit comprising a pair of vacuum tubes 4 and 8 arranged unsymmetrically so as to possess one degree of electrical stability. If desired, the electrode structures of the two tubes 4 and 8 can be included within a single evacuated envelope. The grid and anode electrodes of the tubes 4 and 8 are interconnected to provide a regenerative action. The anodes are supplied with positive polarizing potentials from source B+ through separate resistors 5 and 7, as shown. The anode of tube 4 is connected to the grid of tube 8 through a condenser 9, while the anode of tube 8 is connected to the grid of tube 4 through a resistor 6. The input or tripping pulses are applied to the tube 4 through a series input resistor 2 and shunt input or grid resistor 3, connected as shown. The cathode of tube 4 is connected to ground through a resistor 13, which is common to the cathodes of both tubes. A variable grid resistor 10 is connected between the grid of tube 8 and the upper terminal of resistor 13. The cathode of tube 8 is provided with a biasing resistor 11 which is by-passed by a condenser 12. An output coupling condenser 14 connects the anode of triode 4 to one of the output terminals 15.

Normally, in the operation of the trigger circuit of Fig. 1, tube 4 is non-conductive and biased to cut-off. Tube 8, however, is normally in a conductive state. This condition of operation,

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wherein tube 4 is normally non-conductive and tube 8 is conductive is called the stable state. In the active or unstable state, however, the current passing conditions of tubes 4 and 8 are reversed from that just described. After an interval of time in the active state, depending in part upon the time constants of condenser 9 and resistor 10, the trigger circuit will restore itself to the stable state. In order to change the trigger circuit from the stable state to the active or unstable state, it is necessary to apply a positive voltage or pulse to the grid of tube 4 of sufficient magnitude to overcome the bias on this tube.

The operation of the trigger circuit of Fig. 1 may be more readily understood from the graphical representation of Fig. 3, wherein line 32 shows a periodic pulse type of voltage waveform having a frequency of F cycles per second. This periodic voltage waveform comprises a series of positive pulses of sufficient magnitude and polarity to overcome the bias on tube 4 and to trip or fire the trigger circuit from its stable to its unstable or active state. These pulses are applied to the input terminals 1, 1' of Fig. 1. Let us assume that it is desired to convert this periodic waveform of frequency F of line 32 into another periodic waveform whose frequency is $F/3$, by way of example. When the waveform of voltage of line 32 is applied to the control grid of triode 4, this tube will start conduction by virtue of the fact that the voltage on the control grid of tube 4 is raised momentarily above the cut-off value by one of the pulses 36. Because of the feed-back or regenerative action produced by the connections of resistor 6 and condenser 9, the trigger circuit will quickly change over from its stable to its unstable or active state, in which triode 4 becomes conductive and triode 8 non-conductive. As the trigger circuit trips to the unstable state, the voltage on the control grid of triode 8 is driven considerably below the cut-off point and remains below this point for an interval of time determined by the values of resistor 10 and the condenser 9. If it is desired to divide the frequency F of waveform 32 by three, resistor 10 is adjusted or set to such a value that the voltage on the control grid of triode 8 does not reach the cut-off point until after three pulses or cycles of the input waveform have been applied to triode 4. It will be seen that the value of resistor 10 controls the time it takes the charge on condenser 9 to gradually leak off through its associated resistor network. When the charge on condenser 9 has dissipated to such an extent that the cut-off point for the tube 8 has been reached, the trigger circuit quickly snaps back or restores itself to its stable state, in which condition the trigger circuit is again ready to be triggered by the fourth pulse of waveform 32. From this it will be seen that during the active or unstable state of the trigger circuit this circuit remains unresponsive to a certain number of pulses after the triggering pulse for a time interval corresponding to a period covering a desired number of applied pulses.

In Fig. 3 the waveform of line 33 represents the conduction versus time curve for triode 4. Since the anode current and anode voltage variations with time are inverse functions, it will be appreciated that the waveform of line 33 also represents the anode voltage versus time curve for triode 8. This waveform has a frequency of one-third that of waveform 32. In Fig. 3, waveform 34 is the conduction-versus-time curve for triode 8 and is essentially the output waveform appear-

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ing at output leads 15 as taken from the anode of triode 4 through condenser 14. Similarly, waveform 34 is the anode voltage versus time curve for triode 4.

The compensating or lock-in feature will now be described. This effect is produced by cathode resistor 11 with its shunting filter condenser 12. The time constant RC of this resistor-condenser combination 11, 12 is selected to have a value sufficiently greater than the period of waveform 34 so as to filter or smooth this waveform of current which comes out of the cathode of triode 8. The filtered voltage occurring across resistor 11 acts as a portion of the bias voltage for the control grid of triode 8. Variation in the value of this voltage causes a variation in the time that the trigger circuit snaps back or restores itself from the unstable to the stable condition.

To illustrate the compensating action, it may be assumed that because of change in supply voltage to the anodes, or for some other reason, the snap-back to the stable state occurs earlier than normal, and is illustrated by the dotted lines 35 of waveform 34. If this condition persists for a short time, the bias voltage developed across resistor 11 will increase due to the longer conduction period of triode 8. This increased bias voltage added to the varying voltage across resistor 10 will retard the time at which the grid voltage on triode 8 reaches the cut-off point after it has been driven negative and will cause triode 8 to conduct at a later time than normal, thus compensating for the early triggering assumed above. In a similar manner there is also compensation when the snap-back tends to occur later than normal.

Fig. 2 illustrates a modification of the system of Fig. 1, wherein two trigger circuits of the type shown in Fig. 1 are connected in tandem or cascade in order to divide the frequency or repetition rate of the applied pulses (see line 32 of Fig. 3) by a larger integer than can be handled by only one trigger circuit. In Fig. 2, the output terminals 15 of the first trigger circuit 4, 8 are connected to the input terminals of a second trigger circuit 4', 8'. In effect, both trigger circuits are frequency dividers. Resistors 17, 18 and 19 act as a coupling and buffer network between the two trigger circuits or frequency divider units and also prevent these trigger circuits from reacting on each other in an adverse manner. The circuit elements associated with the vacuum triodes 4', 8' of the second trigger circuit are identical with corresponding circuit elements associated with the first trigger circuit 4, 8, and have been given the same reference numerals with prime designations, except that condenser 9' should be approximately N times as large as condenser 9, if N is the dividing integer used in this second trigger circuit or frequency divider unit. The operation of the second trigger circuit or divider stage 4', 8' is the same as that of the first trigger 4, 8, except that it is operated at a lower frequency which requires a larger value for the timing circuits 9', 10'. Putting it in other words, the second trigger circuit 4', 8' serves to convert the pulses applied thereto by the first trigger circuit to an output waveform of still lower frequency. Thus, if the first divider stage 4, 8 provides an output which has a frequency one-third that of the input pulses supplied to terminals 1, 1', then the second divider stage 4', 8' can be made to have such time constants that it will provide a still lower frequency, let us say by way of example, one-half that of

the frequency or repetition rate of the output pulses of the first divider unit. Stated in still other words, the final output from the second divider stage appearing on terminals 31, 31 can be made to have a frequency or repetition rate which is one-sixth that of the frequency of the periodic waveform applied to the input terminals 1, 1.

Although the system of Fig. 1 has been described as suitable for furnishing a frequency division by three, and the system of Fig. 2 has been described as suitable for providing a frequency division by six, it should be understood that these numbers have been given by way of example only, and that the systems of Figs. 1 and 3 will divide by any desired integer from one up to such values which are unusable because of inherent circuit limitations. Furthermore, as many trigger circuits as are desired may be connected in tandem for additional frequency division. Thus, three, four or more frequency divider units of the type shown in Fig. 1 may be connected in cascade or tandem in the same manner illustrated in Fig. 2.

Another modification of the invention is shown in Fig. 4 which illustrates a self-restoring trigger circuit comprising triode vacuum tubes 14, 18 whose electrodes are interconnected in regenerative fashion in the same manner as the trigger circuit of Fig. 1. The time constant circuit of the trigger circuit 14, 18 comprises a condenser 29 and a resistor 43. The main difference between the frequency divider of Fig. 4 and the frequency divider of Fig. 1 lies in the use of different type of compensation feature which is effected in Fig. 4 by a vacuum tube 44. Triode 44 operates class A and is normally and continuously conducting. This vacuum tube serves to amplify the compensation effect and to produce even greater compensation and lock-in than the circuits of Figs. 1 and 2. Vacuum tube triodes 14 and 18 of Fig. 4 operate in the same manner as do triodes 4 and 8 of Fig. 1. The output waveform 34 of Fig. 3 is obtained at the anode of tube 14 and is applied to the control grid of vacuum tube 44 through a voltage dropping resistor 41. A smoothing RC filter comprising a resistor 42 and a shunt condenser 43 is connected between the control grid of tube 44 and ground. Triode 44 is also provided with an anode resistor 47 which is located between the anode and the source B+ and a cathode resistor 45 located between the cathode and ground. The term ground is used to designate any reference point of fixed radio frequency potential. The lower end of variable grid resistor 40 is connected to the anode of triode 44 at point 46.

The compensating action of Fig. 4 is somewhat similar to that previously described except for differences which are now to be mentioned. In the case of too early snap back or restoration of the trigger circuit from the active state to the stable state, as illustrated by the dotted lines 35 of waveform 34 of Fig. 3, the decreased conduction period of triode 14 will cause the grid of triode 44 to become more positive. This will cause point 46 at the anode of triode 44 to drop in potential due to the increase of current through resistor 47. Since triode 18 receives a major portion of its control grid bias from point 46 over lead 48 and resistor 49, the reduction in potential at point 46 will cause the snap back action to occur later, thus furnishing a desired compensation. The time constant circuit M corresponds in value and function to the time constant circuit 11, 12 of Fig. 1. Fig. 4, therefore, provides two compensation circuits working together;

namely, that produced by circuit M and that produced by the action of triode 44.

Among the advantages of the invention are: A compensation or lock-in effect is provided which enables very stable operation of the frequency divider in the presence of variations on the operating voltages and other circuit factors; various types of waveform may be used directly to drive the frequency divider by application to the input terminals 1, 1; and two or more frequency divider stages or units may be operated in tandem without additional electronic devices intervening for the purpose of achieving frequency division by larger integers than can be handled by only one frequency divider unit.

What is claimed is:

1. A frequency divider for a periodically recurring waveform, comprising an unsymmetrical biased trigger circuit having a pair of vacuum tube electrode structures whose input and output electrodes are interconnected regeneratively, one of said electrode structures being normally conductive and the other normally non-conductive in the stable state, and vice versa in the active state, the time constants of said trigger circuit having such values that said trigger circuit after being tripped into the active state will restore itself to the stable state after the lapse of a time interval overlapping a desired number of cycles of said recurring waveform, and a resistor-condenser combination in the space current path of only the normally conductive electrode structure, said resistor-condenser combination having a time constant sufficiently greater than the period of said periodically recurring waveform to effect a filtering action which maintains substantially constant voltage across said resistor-condenser combination for a time longer than the period of operation of said trigger circuit.

2. A frequency divider for a periodically recurring waveform, comprising an unsymmetrical biased trigger circuit having a pair of vacuum tube electrode structures whose input and output electrodes are interconnected regeneratively, one of said electrode structures being normally conductive and the other normally non-conductive in the stable state, and vice versa in the active state, the input electrode of said normally conductive structure being connected to the output electrode of said normally non-conductive structure through a capacitor, the time constants of said trigger circuit having such values that said trigger circuit after being tripped into the active state will restore itself to the stable state after the lapse of a time interval overlapping a desired number of cycles of said recurring waveform, and a series resistor-shunt condenser combination in the space current path of the normally conductive electrode structure, said shunt condenser being connected across the resistor of said combination through connections of negligible impedance, said resistor-condenser combination having a time constant sufficiently greater than the period of said periodically recurring waveform to effect a filtering action which maintains substantially constant voltage across said resistor-condenser combination for a time longer than the period of operation of said trigger circuit.

3. A pulse frequency divider comprising a trigger circuit having a pair of electron discharge devices whose input and output electrodes are so interconnected that it has only one stable state, a source of periodically recurring pulses coupled to the input of said trigger circuit, said pulses be-

ing of such polarity and magnitude as to trip said trigger circuit when it is in its stable state, the time constants of said trigger circuit having such values and being so adjusted that said trigger circuit after being tripped will restore itself to the stable state after the lapse of a time interval overlapping a desired number of input pulses, said normally conductive device having its input electrode coupled to the output electrode of the normally non-conductive device through a capacitor, a connection to the output electrode of one of said devices for deriving output pulses whose repetition rate bears a submultiple relation to the frequency of said source, and a resistor-shunt condenser combination in the space current path of the normally conductive electron discharge device, said resistor-condenser combination having a time constant appreciably greater than the period of the recurring pulses and of such value as to effect a filtering action which maintains substantially constant voltage across said resistor-condenser combination for a time longer than the period of operation of said trigger circuit.

4. A frequency divider for a periodically recurring waveform, comprising a trigger circuit of one degree of electrical stability having first and second vacuum tube triodes, a capacitor coupling the anode of the first triode to the grid of the second triode, a resistor coupling the anode of the second triode to the grid of the first triode, whereby said grids and anodes are interconnected regeneratively, each of said triodes having a cathode, one of said triodes being normally conductive and the other normally non-conductive in the stable state, and vice-versa in the active state, a resistor connected between a point of reference potential and the cathode of said first triode, and a resistor-condenser circuit having a time constant appreciably greater than the period of said periodically recurring waveform located between the cathode of the second triode and a point on said last resistor removed from said point of reference potential, the time constants of said trigger circuit having such values that said trigger circuit, after being tripped into the active state, will restore itself to the stable state after the lapse of a time interval overlapping a desired number of cycles of said periodically recurring waveform.

5. A frequency divider for a periodically recurring waveform, comprising a trigger circuit of one degree of electrical stability having a pair of vacuum tube triodes whose grids and anodes are interconnected regeneratively, each of said triodes including a cathode one of said triodes being normally conductive and the other normally non-conductive in the stable state, and vice-versa in the active state, a common cathode resistor for both of said triodes, and a resistor-condenser circuit having a time constant sufficiently greater than the period of said periodically recurring waveform located in the cathode circuit of said normally conductive triode to effect a filtering action which maintains substantially constant voltage across said resistor-condenser combination for a time longer than the period of operation of said trigger circuit, the time constants of said trigger circuit having such values that said trigger circuit after being tripped into the active state will restore itself to the stable state after the lapse of a time interval overlapping a desired number of cycles of said periodically recurring waveform.

6. A frequency divider for a periodically recurring waveform, comprising first and second flip-flop or self-restoring trigger circuits connected in tandem, each of said trigger circuits having a pair of vacuum tube electrode structures whose input and output electrodes are interconnected regeneratively, one of said electrode structures being normally conductive and the other normally non-conductive in the stable state, and vice versa in the active state, the time constants of each trigger circuit having such values that said trigger circuit, after being tripped into the active state, will restore itself to the stable state after the lapse of a time interval overlapping a desired number of cycles of said recurring waveform, and a resistor-condenser combination in the cathode circuit of the normally conductive electrode structure, said resistor-condenser combination having a time constant greater than the period of said periodically recurring waveform, the time constants of the second trigger circuit having a larger value than the time constants of the first trigger circuit.

7. A frequency divider for a periodically recurring waveform, comprising first and second trigger circuits connected in tandem through a coupling and buffer resistor network, each of said trigger circuits having one degree of electrical stability and including a pair of vacuum tube triodes whose grids and anodes are interconnected regeneratively, a cathode for each of said triodes one of said triodes being normally conductive and the other normally non-conductive in the stable state, and vice-versa in the active state, a common cathode resistor for both of said triodes, and a resistor-condenser circuit having a time constant several times greater than the period of said periodically recurring waveform located in the cathode circuit of the normally conductive triode said common resistor connecting one end of said resistor-condenser circuit and the cathode of said normally non-conductive triode to ground, the time constants of each trigger circuit having such values that the trigger circuit, after being tripped into the active state, will restore itself to the stable state after the lapse of a time interval overlapping a desired number of cycles of said periodically recurring waveform, the time constants of the second trigger circuit having a larger value than the time constants of the first trigger circuit.

8. A frequency divider for a periodically recurring waveform, comprising an unsymmetrically biased trigger circuit having a pair of vacuum tube electrode structures whose input and output electrodes are interconnected regeneratively, one of said electrode structures being normally conductive and the other normally non-conductive in the stable state, and vice-versa in the active state, the time constants of said trigger circuit having such values that said trigger circuit after being tripped into the active state will restore itself to the stable state after the lapse of a time interval overlapping a desired number of cycles of said recurring waveform, and stabilizing means including a capacitor in the cathode circuit of only the normally conductive electrode structure for supplying an additional bias of such sense and magnitude to said normally conductive electrode structure as to cause said trigger circuit to tend to maintain always the same active period.

9. A frequency divider for a periodically recurring waveform, comprising an unsymmetrically biased trigger circuit having a pair of vacuum

tube electrode structures whose input and output electrodes are interconnected regeneratively, one of said electrode structures being normally conductive and the other normally non-conductive in the stable state, and vice-versa in the active state, the time constants of said trigger circuit having such values that said trigger circuit after being tripped into the active state will restore itself to the stable state after the lapse of a time interval overlapping a desired number of cycles of said recurring waveform, and stabilizing means including a time constant circuit in the cathode circuit of only the normally conductive electrode structure for supplying an additional bias voltage thereto of such sense and magnitude as to cause said trigger circuit to tend to maintain always the same active period.

10. A frequency divider for a periodically recurring waveform, comprising an unsymmetrically biased trigger circuit having a pair of vacuum tube electrode structures whose input and output electrodes are interconnected regeneratively, one of said electrode structures being normally conductive and the other normally non-conductive in the stable state, and vice-versa in the active state, the time constants of said trigger circuit having such values that said trigger circuit after being tripped into the active state will restore itself to the stable state after the lapse of a time interval overlapping a desired number of cycles of said recurring waveform, and stabilizing means in circuit with the normally conductive electrode structure for supplying an additional bias voltage thereto of such sense as to cause said trigger circuit to tend to maintain always the same active period, said stabilizing means including a vacuum tube responsive to the output of one of said electrode structures for supplying greater or less bias to the input electrode of the other electrode structure.

11. A frequency divider for a periodically recurring waveform, comprising a trigger circuit of one degree of electrical stability having a pair of vacuum tube electrode structures whose grids and anodes are interconnected regeneratively, each of said structures including a cathode, one of said structures being normally conductive and the other normally non-conductive in the stable state, and vice-versa in the active state, a resistance-condenser bias network located between the cathodes of said electrode structures and having a time constant sufficiently greater than the period of said periodically recurring waveform to effect a filtering action which maintains substantially constant voltage across said bias network for a time longer than the period of said recurring waveform, a resistor connecting one end of said bias network to ground, the time constants of said trigger circuit having such values that said trigger circuit, after being tripped into the active state, will restore itself to the stable state after the lapse of a time interval overlapping a desired number of cycles of said periodically recurring waveform.

12. The method of stabilizing the operation of a trigger circuit of the type having a pair of electrode structures whose input and output electrodes are interconnected regeneratively and which has a stable state and an active state extending over a desired interval of time, one electrode structure being normally conductive and the other non-conductive in the stable state, and vice versa in the active state, which comprises automatically varying the bias on the normally conductive electrode structures of said trigger

circuit in varying amounts in such sense and magnitude as to compensate for any tendency toward undesired changes in the active period of the trigger circuit.

13. A frequency divider for a periodically recurring waveform, comprising an unsymmetrically biased trigger circuit having a pair of vacuum tube electrode structures whose input and output electrodes are interconnected regeneratively, one of said electrode structures being normally conductive and the other normally non-conductive in the stable state, and vice-versa in the active state, the time constants of said trigger circuit having such values that said trigger circuit after being tripped into the active state will restore itself to the stable state after the lapse of a time interval overlapping a desired number of cycles of said recurring waveform, and stabilizing means in circuit with the normally conductive electrode structure for supplying an additional bias voltage thereto of such sense as to cause said trigger circuit to tend to maintain always the same active period, said stabilizing means including a resistor-shunt condenser network in the cathode circuit of said normally conductive electrode structure and a vacuum tube responsive to the output of one of said electrode structures for supplying greater or less bias to the input electrode of the other electrode structure.

14. A frequency divider for a periodically recurring waveform, comprising an unsymmetrically biased trigger circuit having a pair of vacuum tube electrode structures whose input and output electrodes are interconnected regeneratively, one of said electrode structures being normally conductive and the other normally non-conductive in the stable state, and vice-versa in the active state, the time constants of said trigger circuit having such values that said trigger circuit after being tripped into the active state will restore itself to the stable state after the lapse of a time interval overlapping a desired number of cycles of said recurring waveform, and stabilizing means in circuit with the normally conductive electrode structure for supplying an additional bias voltage thereto of such sense as to cause said trigger circuit to tend to maintain always the same active period, said stabilizing means including a vacuum tube having a grid, a cathode and an anode, a direct current connection from said anode to the input electrode of said normally conducting electrode structure, a direct current connection from said grid to the output electrode of said normally non-conductive electrode structure, a direct current connection from said cathode to a point of reference potential, and means for supplying unidirectional potential of positive polarity to said anode relative to said cathode.

15. In combination, a trigger circuit having a pair of electron discharge devices whose input and output electrodes are so interconnected that it has only one stable state, a source of periodically recurring pulses coupled to the input of said trigger circuit, said pulses being of such polarity and magnitude as to trip said trigger circuit when it is in its stable state, the time constants of said trigger circuit having such values and being so adjusted that said trigger circuit after being tripped will restore itself to the stable state after the lapse of a time interval overlapping a desired number of input pulses, said normally conductive device having its input electrode coupled to the output electrode of the normally non-conductive

device through a capacitor, a connection to the output electrode of one of said devices for deriving output pulses whose repetition rate bears a submultiple relation to the frequency of said source, and a resistor-shunt condenser combination in the cathode circuit of said normally conductive electron discharge device, said resistor-condenser combination having a time constant appreciably greater than the period of the recurring pulses, and a vacuum tube having a grid, a cathode and an anode, a direct current connection from said anode to the input electrode of said normally conducting electrode structure, a direct current connection from said grid to the output electrode of said normally non-conductive electrode structure, a direct current connection from said cathode to a point of reference potential, and means for supplying unidirectional potential of positive polarity to said anode relative to said cathode.

WARREN H. BLISS.

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