

March 9, 1948.

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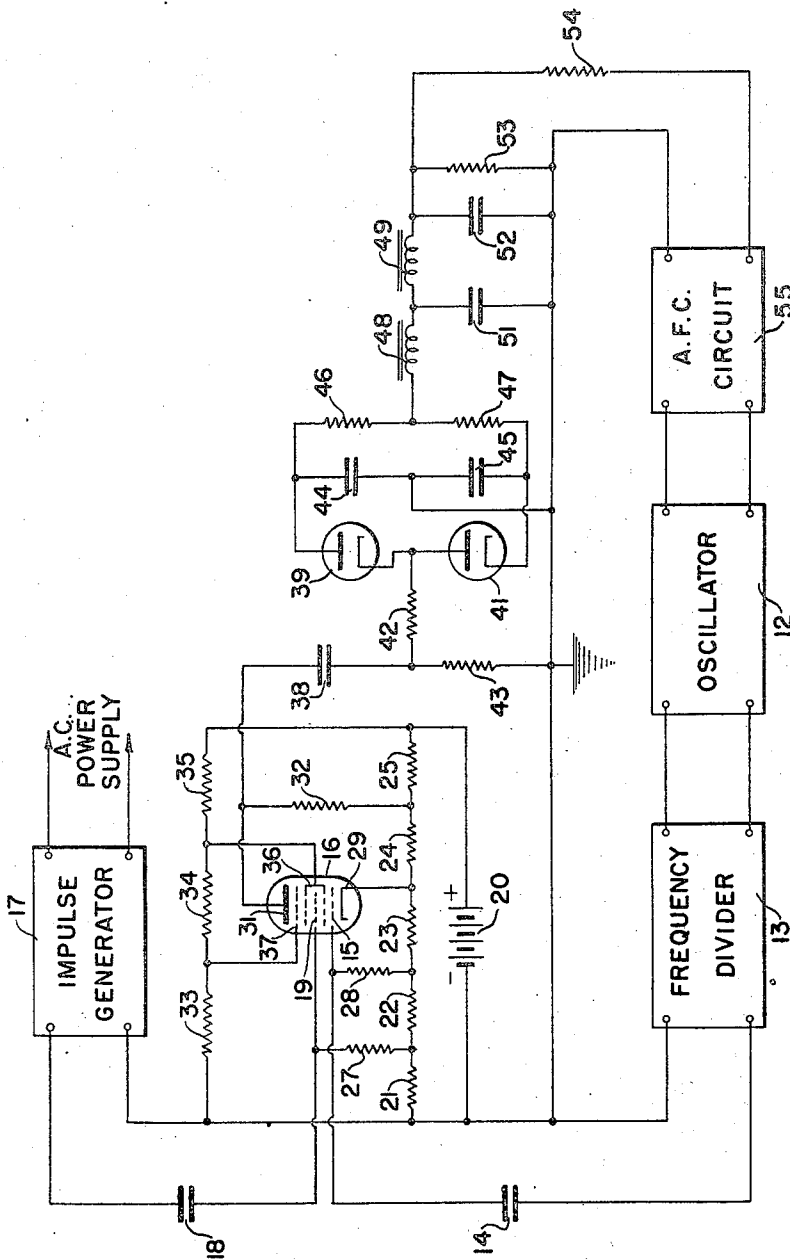
2,437,609

FREQUENCY COMPARISON APPARATUS

Original Filed April 15, 1943

2 Sheets-Sheet 1

FIG. 1



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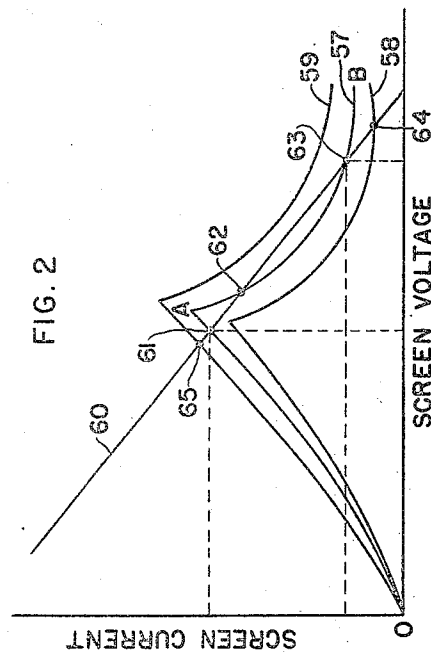
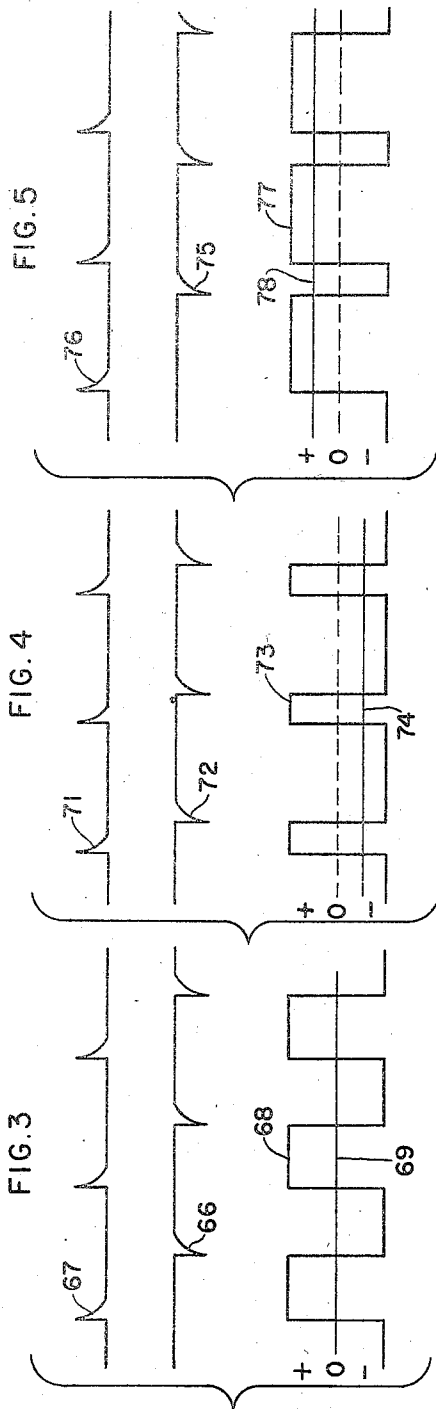
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FREQUENCY COMPARISON APPARATUS

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FREQUENCY COMPARISON APPARATUS

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Substituted for abandoned application Serial No.
483,139, April 15, 1943. This application August
7, 1946, Serial No. 688,852

7 Claims. (Cl. 250—36)

1

This invention relates to automatic frequency control apparatus and particularly to such apparatus used in connection with a television timer.

This application is a substitute for abandoned application of Louis F. Mayle, Serial No. 483,139, filed April 15, 1943, for Frequency comparison apparatus.

According to conventional television practice it is customary to employ timer apparatus for definitely correlating the frequency of the synchronizing signals with a source of standardizing frequency such as a commercial alternating current power supply. The timer apparatus includes an oscillator operating at a frequency of twice that of horizontal scanning (where interlaced scanning is employed), and a timer chain or frequency divider. By means of the latter device the high frequency oscillations are converted into control impulses at a frequency suitable to synchronize the scanning generators of the transmitter and to provide synchronizing signals to combine with the video signal to be transmitted.

In order to control the frequency of the oscillator so that the frequency of the oscillations is related at all times to a standardizing frequency, there are also derived from the frequency divider relatively low frequency impulses which are compared with the frequency of impulses, or of a sinusoidal wave, of substantially the same frequency which are derived from the standardizing source. Any deviation of the compared frequencies is detected and a control voltage is generated representative of the deviation. The control voltage is utilized to adjust the frequency of the oscillator to restore it to the desired relationship with the standardizing frequency.

As is well known in the art, however, numerous arrangements of electronic apparatus have been employed for making the frequency comparison and for generating the control voltage. Many of these devices are considerably complicated and do not accomplish the desired result in the most effective manner.

An object of the present invention, therefore, is to provide improved means for detecting frequency deviations from a standardizing frequency, whereby to control the frequency of a high frequency oscillator employed in a television timer.

Another object of the invention is to provide an improved frequency comparison device, whereby to facilitate the generation of control voltages for the frequency determining circuit of an oscillator employed in a television timer.

In accordance with the present invention there is provided a multi-grid electronic device connected for operation as a trigger device. Two series of impulses are applied to respective control grids of the electronic device in opposite

2

polarity and normally displaced in phase by 180°. One series of impulses is derived from television timer apparatus and the other series of impulses is derived from a source of standardizing frequency. The effect of the oppositely poled impulses applied to the control grids of the electronic device is to render it alternately more conducting and less conducting. The auxiliary grid elements of the device are interconnected in a manner such that the device is changed from a more conducting to a less conducting state or vice versa substantially instantaneously.

The abrupt voltage changes appearing at the anode of the electron device are impressed upon a rectifier circuit functioning as a voltage doubler. So long as the frequencies of the two series of impulses applied to the control circuits of the electronic trigger device are the same and are applied 180° out of phase with each other, the voltage doubler produces no control voltage. However, there is generated by this apparatus, in response to a deviation of the oscillator-derived frequency from the standardizing frequency a control voltage representative of the deviation. This control voltage is applied to the input circuit of an automatic frequency control circuit which is connected to the frequency determining circuit of the high frequency oscillator, whereby to adjust the frequency of this device to reestablish the desired relationship with the standardizing frequency.

For a better understanding of the invention together with other and further objects thereof, reference is had to the following description taken in connection with the accompanying drawings, and its scope will be pointed out in the appended claims.

In the accompanying drawings,

Fig. 1 is a circuit diagram of frequency comparison apparatus embodying the instant invention;

Fig. 2 is a graphical representation of a characteristic of the electronic discharge device used in the frequency comparator; and,

Figs. 3, 4 and 5 are other graphical representations showing the relationship between the various voltages under different conditions.

Referring now to Fig. 1 of the drawings, there is shown an oscillator 12 for generating energy at a relatively high frequency. The output circuit of the oscillator is connected to a television timer chain or frequency divider 13. A connection is made from a relatively low frequency section of the frequency divider 13 through a coupling condenser 14 to one of the control grids 15 of a pentagrid electronic device 16.

An impulse generator 17 is connected to a source of standardizing frequency such as a commercial alternating current power supply. The

output circuit of the impulse generator is connected through a coupling condenser 18 to a second control grid 19 of the tube 16.

Associated with the tube 16 is a source of direct current potential, such as a battery 20. Connected across the terminals of the battery 20 is a voltage divider comprising a series connection of resistors 21, 22, 23, 24 and 25. Various electrodes of the tube 16 are connected to different points on the voltage divider. The control grid 19 is connected by a resistor 27 to the junction point between resistors 21 and 22, and the control grid 15 is connected by a resistor 28 to the junction point between resistors 22 and 23. The cathode 29 of the tube is connected to the junction point between resistors 23 and 24. The anode 31 is connected through a load resistor 32 to the junction point between resistors 24 and 25.

An auxiliary voltage divider is provided for a purpose to be described and comprises resistors 33, 34 and 35 arranged in a series connection between the negative and positive terminals of the battery 20. The screen grid 36 of the tube 16 is connected to the junction point between resistors 34 and 35, and the suppressor grid 37 is connected to the junction point between resistors 33 and 34.

The anode 31 of the tube 16 also is coupled by means of a condenser 38 to a voltage doubler rectifier circuit. This apparatus includes two diodes 39 and 41 which are arranged in inverse relationship as shown. There is provided a connection including a resistor 42 from the coupling condenser 38 to the cathode of the diode 39 and to the anode of the diode 41. A leak resistor 43 for the coupling condenser 38 connects this condenser to ground.

Connected between the anode of the diode 39 and the cathode of the diode 41 is a series arrangement of two identical condensers 44 and 45. The mid-point of this condenser arrangement is connected to ground. The condenser arrangement is also shunted by a series connection of two identical resistors 46 and 47. The mid-point of the resistor arrangement is connected through a filter including series choke coils 48 and 49 and shunt condensers 51 and 52 to a terminating impedance such as a resistor 53.

The voltages developed across the resistor 53 are impressed by means of a circuit including a resistor 54 upon the input terminals of an automatic frequency control circuit 55. The A. F. C. circuit may take any conventional form which is known to adjust the frequency of the oscillator 12 in accordance with the polarity and magnitude of the voltages developed in resistor 53.

Before considering the operation of the automatic frequency control system as a whole, consideration will be given to two of the components thereof. There is a characteristic of an electron discharge device having at least a cathode, a control grid, a screen grid, a suppressor grid and an anode that, when the electrodes are connected so that the voltage applied to the suppressor grid is varied in proportion to a variation of the screen grid voltage and in the same direction, the screen grid exhibits a negative resistance in one region of its operation. As seen in Fig. 1, the screen grid 36 and the suppressor grid 37 of the tube 16 are connected to the auxiliary voltage divider in a manner to satisfy the voltage variation condition referred to. The resistors 33, 34 and 35 constitute a load resistance for the screen grid of the tube. As the current drawn by the screen grid increases, the potential of the junction point

between resistors 34 and 35 become more negative. This potential is the impressed screen grid voltage. As a consequence of the increased negative potential of the junction point between resistors 34 and 35 the potential of the junction point between resistors 33 and 34 becomes more negative. This potential is impressed upon the suppressor grid 37 of the tube. Variations in the screen grid voltage in the opposite sense cause similar proportional variations in the opposite sense in the suppressor grid voltages.

Referring now to Fig. 2 of the drawings, there are shown three curves, each representing a variation in the current drawn by the screen grid with variations in the voltage impressed upon the screen grid when the suppressor voltage is varied in a proportionate amount in the same direction. The curve 57 represents this characteristic of the tube when the potentials of the control grids thereof have normal negative values determined by the respective biasing circuits including the resistors 27 and 28. The curve 59 represents this characteristic when the control grid potential is less negative or even in the positive grid region. The curve 58 represents this characteristic when the control grid potential is more negative. These curves are but three of a family of curves which may be plotted for different control grid voltages.

Considering the curve 57, it is seen that in the region OA, as the screen voltage increases the screen current also increases. But after reaching the point A further increases in the screen voltage produce decreases in the screen current as shown by the curve in the region AB. The line 60 represents the load line corresponding to the screen grid resistance and may intersect the characteristic curve 57 in three points 61, 62 and 63 at the same time. Points 61 and 63 represent stable conditions and point 62 an unstable condition. Advantage is taken of this characteristic of the tube so that it is made to operate as a trigger device.

Assume, for example, that normal biasing potentials are applied to the control grids of the tube and that the screen voltage and current are represented by the point 61 on curve 57. If, now, the control grid potential is made more negative the screen voltage vs. screen current is represented by the curve 58 which is intersected by the load line 60 only at the point 64. When the control grid potentials are restored to normal so that the curve 57 again represents the screen voltage and current characteristics, the intersection of the load line 60 with this curve at the point 63 represents the stable screen voltage which exists until the control grids of the tube are subjected again to potentials other than the normal biasing potentials.

When the control grid voltage is made less negative, or even positive, the screen voltage vs. screen current characteristic is represented by the curve 59 which is intersected by the load line 60 only at the point 65. The restoration of the control grid potentials to normal results in a screen grid voltage and current represented by the point 61 on curve 57. These conditions obtain until there are further changes made in the control grid voltages.

Consequently, if the control grid voltages are alternately made positive and negative, the screen voltage of the tube 16 in Fig. 1 may be made to change abruptly from a value indicated by the point 61 of Fig. 2 to a more positive value represented by the point 63 of this figure, and vice versa. Since, by reason of the connection be-

5

tween the screen grid 36 of Fig. 1 and the suppressor grid 37, the voltages applied to these grids vary in proportion and in the same direction, the voltage of the suppressor grid may be made alternately negative and positive with respect to the cathode 29. It may be made sufficiently negative to minimize the anode-to-cathode current in the tube and also its positive value may be sufficient to effect a maximum conduction of anode-to-cathode current. Thus, the tube is operated as a trigger device, and, since it is provided with two control grids, there may be applied to one of the grids positive voltage impulses derived from one of the frequency sources such as the alternating current power supply as illustrated, and there may be applied to the other control grid negative voltage impulses derived from the local oscillator.

By the trigger operation of the tube 16 there are developed at the anode 31 thereof voltages which vary abruptly in their positive magnitudes. When the tube is less conducting the potential of the anode is at a maximum positive value and when the tube is more conducting this potential is at a minimum positive value. The wave form of the anode voltage is substantially square topped and, when these voltages are impressed upon the voltage doubler circuits, they produce substantially square topped alternating current voltages in the output circuit of the voltage doubler. If the voltage developed in the output circuit of the trigger tube 16 is equivalent to a series of equal half cycles of opposite polarity, the voltage which appears between the junction point of the resistors 43 and 47 and the junction point of the condensers 44 and 45 will be zero. This may be seen by considering that, in response to the equal half cycles applied to diodes 39 and 41, each has impressed thereon the same peak voltage. Thus, with both positive and negative half cycles of equal time duration, and consequently equal heights above and below the time axis, the average voltage appearing between the junction points of the condenser and resistor branches of the network is zero.

The relationship between the time duration of the positive and negative half cycles is determined by the phase relationship of the voltage impulses applied to the control grids of the tube 16. In order to generate a voltage having positive and negative half cycles of equal time duration, the voltage impulses from the respective alternating current sources must be 180° out of phase. These conditions are illustrated by the curves of Fig. 3. The negative voltage impulses such as 66 are derived from the frequency divider 13 of Fig. 1 and the positive voltage impulses such as 67 are derived from the impulse generator 17 of Fig. 1. Both of these series of impulses are illustrated as being of the same frequency and are displaced 180° with respect to one another. The curve 68 of Fig. 3 illustrates the voltage appearing at the terminals of the voltage doubler input circuit of Fig. 1. It is seen that, coincident with the occurrence of the positive impulses 67, a positive half cycle of the curve 68 is initiated. This results from the triggering "off" of the tube 16, whereby the potential of the anode 31 thereof is raised to its maximum positive value. Also, coincident with the occurrence of the negative impulses 66, the positive half cycle of the curve 68 is terminated and the succeeding negative half cycle is initiated. Under the control of succeeding positive and negative impulses applied to the trigger device, the

6

succeeding positive and negative half cycles of the wave 68 are generated. It is seen that, by reason of the phase relationship between the impulses 66 and 67, the positive and negative half cycles of the wave 68 are of equal time duration. Consequently, in order to balance the positive and negative energy, the alternating current reference axis 69 of this wave is symmetrically located with respect to the positive and negative voltage peaks.

Fig. 4 illustrates the operation of the apparatus when, by reason of a decrease in the frequency of the oscillator, there is produced a phase shift of the impulses of opposite polarity which are applied to the control grid of the tube. In order to facilitate the description of the operation of the apparatus it is assumed that the frequencies of the two series of impulses are substantially the same for a few cycles but that the impulses are so displaced in phase because of an earlier assumed decrease of oscillator frequency that the positive standardizing impulses 71 precede the negative oscillator-derived impulses 72 by less than 180°. The curve 73 illustrates the voltage appearing at the terminals of the voltage doubler input circuit of Fig. 1. By reason of the illustrated and described phase relation of the positive and negative impulses the time durations of the positive half cycles of the voltage wave 73 are decreased and those of the negative half cycles are increased correspondingly. It will be noted, however, that the peak-to-peak voltage difference between the positive and negative half cycles is the same as in the previously described case of perfect synchronism.

In order to balance the positive and negative energy represented by the curve 73, the alternating current reference axis of the voltage wave is represented at 74. Thus, it is seen that the positive half cycles have greater peak values with reference to the alternating current axis than do the negative half cycles. The condensers 44 and 45 are charged to these respective peak voltages, but the numerical sum of the voltages to which the condensers are charged, remains equal to the peak-to-peak voltage of the wave 73. However, it is seen that the voltage at the junction point of resistors 46 and 47 will be positive with respect to the grounded junction point of condensers 44 and 45.

Fig. 5 illustrates the functioning of the voltage doubler apparatus when the oscillator frequency is increased to produce a phase shift of the negative oscillator-derived impulses 75 with respect to the positive impulses 76 derived from the alternating current power supply. In this case the negative impulses 75 follow the positive impulses 76 by more than 180°. The resulting alternating current voltage wave is represented by the curve 77 in which it again is seen that the peak-to-peak voltage of the positive and negative half cycles is the same as in previously described cases. In this instance the time duration of the positive half cycles is greater than that of the negative half cycles. Consequently, in order to balance the positive and negative energy the alternating current reference axis of the voltage wave 77 is represented at 78. Now, it is seen that with reference to the alternating current reference axis the negative half cycles have greater peak values than do the positive half cycles. Thus, there is developed at the junction point of the resistors 46 and 47 of Fig. 1 a negative voltage with respect to the grounded junction point of the condensers 44 and 45.

Referring now to the operation of the frequency comparator apparatus as a whole, assume that in Fig. 1 the negative impulses derived from the frequency divider 13 are of exactly the same frequency as the positive impulses derived from the impulse generator 17, and that these positive and negative impulses are displaced in phase by 180°. These impulses then control the triggering of the tube 16, whereby there is generated in the output circuit thereof a square wave alternating current in which the positive and negative half cycles are of equal time duration. Thus, there is developed by the voltage doubler apparatus a rectified voltage whereby the potential of the junction point of the resistors 46 and 47 is at all times the same as the potential of the junction point of the condensers 44 and 45. In this case there is no voltage developed across the terminating resistor 53, and as a result there is not applied to the input terminals of the automatic frequency control circuit 55 any frequency correcting voltage.

If now, by reason of a frequency deviation between the two sources of impulses, there occurs a phase shift between the positive and negative impulses, the time durations of the positive and negative half cycles of the voltage developed in the output circuit of the tube 16 are no longer equal. Consequently, there is developed between the junction point of the resistors 46 and 47 and the junction point of the condensers 44 and 45 a control voltage which has a polarity representative of the sense of the frequency deviation and a magnitude representative of the amount of the frequency deviation. This voltage is, of course, slightly pulsating and, when properly filtered by the apparatus provided for that purpose, appears as a substantially constant direct voltage across the terminating resistor 53. This constant direct voltage is impressed upon the automatic frequency control circuit 55 to control this apparatus in a manner to restore the oscillator 12 to a frequency having the predetermined relationship to the frequency of the alternating current power supply.

While it will be understood that the circuit specifications of the automatic frequency control apparatus may vary according to the design for any particular application, the following circuit specifications and apparatus employed for the purpose described are included, by way of example only:

Condenser 14—500 micro-microfarads
 Tube 16—7Q7
 Condenser 18—500 micro-microfarads
 Battery 20—135 volts
 Resistor 21—3300 ohms
 Resistor 22—100 ohms
 Resistor 23—100 ohms
 Resistor 24—2500 ohms
 Resistor 25—7500 ohms
 Resistor 32—10,000 ohms
 Resistor 33—100,000 ohms
 Resistor 34—50,000 ohms
 Resistor 35—100,000 ohms
 Condenser 38—20 microfarads
 Tubes 39 and 41—6H6
 Resistor 42—1,000 ohms.
 Resistor 43—20,000 ohms
 Condensers 44 and 45—0.1 microfarad
 Resistors 46 and 47—100,000 ohms
 Choke coils 48 and 49—1,000 henries
 Condensers 51 and 52—1 microfarad
 Resistor 53—100,000 ohms
 Resistor 54—2.2 megohms

While there has been described what at present is considered the preferred embodiment of the invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and therefore, it is aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

10 What is claimed is:

1. Automatic frequency control apparatus for a television timer comprising, an electronic trigger device for developing an alternating current wave, means for varying the conductivity of said trigger device in response to series of positive and negative impulses, the positive and negative energy content of said alternating current wave being determined by the phase relationship of said positive impulses with respect to said negative impulses, means for developing a control voltage representative of the predominant energy content of said alternating current wave, and means under the control of said control voltage for adjusting the phase relationship between said negative and positive impulses to synchronize said impulses.

2. Automatic frequency control apparatus for a television timer comprising, an electronic trigger device for developing a square wave alternating current, means for varying the conductivity of said trigger device in response to series of positive impulses derived from a source of standardizing frequency and negative impulses derived from said television timer, the positive and negative energy content of said alternating current wave being determined by the phase relationship of said positive and negative impulses, means including a voltage doubler circuit for developing a control voltage representative of the predominant energy content of said alternating current wave, and means under the control of said control voltage for adjusting the phase relationship between said negative and positive impulses to synchronize said impulses.

3. Automatic frequency control apparatus for a television timer comprising, an electronic trigger device for developing an alternating current wave, means for rendering said trigger device less conducting in response to a series of positive impulses derived from a source of standardizing frequency, means for rendering said trigger device more conducting in response to a series of negative impulses derived from said television timer, the positive and negative energy content of said alternating current wave being determined by the phase relationship of said positive and negative impulses, means including a voltage doubler circuit for developing a control voltage having a polarity and a magnitude dependent upon the dominant energy content of said alternating current wave, and means variable under the control of said control voltage for adjusting the phase relationship between said negative and positive impulses to synchronize said impulses.

4. Automatic frequency control apparatus for a television timer comprising, a source of negative impulses, a source of positive impulses, an electronic trigger device having a first control grid responsive to said positive impulses to render said device less conducting and a second control grid responsive to said negative impulses to render said device more conducting, whereby to develop an alternating current wave, the time durations of the positive and negative half cycles of said alternating current wave being determined

by the phase relationship between said positive and negative impulses, means controlled by said alternating current wave for developing a control voltage representative of the average time duration of half cycles of one polarity with respect to the average time duration of half cycles of the opposite polarity, and means responsive to said control voltage to vary the frequency of said negative impulses, whereby to maintain the frequency of said negative impulses equal to the frequency of said positive impulses.

5. Automatic frequency control apparatus for a television timer comprising, a source of negative impulses, a source of positive impulses, an electronic trigger device having a first control grid responsive to said positive impulses to render said device less conducting and a second control grid responsive to said negative impulses to render said device more conducting, whereby to develop an alternating current wave, the time durations of the positive and negative half cycles of said alternating current wave being determined by the phase relationship between said positive and negative impulses, a voltage doubler circuit responsive to said alternating current wave for developing a control voltage representative of the average time duration of half cycles of one polarity with respect to the average time duration of half cycles of the opposite polarity, and a frequency controlling circuit for said negative impulse source responsive to said control voltage, whereby to maintain the frequency of said negative impulses equal to the frequency of said positive impulses.

6. Automatic frequency control apparatus for a television timer comprising, a source including an oscillator of negative impulses, a source including an alternating current power supply of positive impulses, an electronic trigger device having a first control grid responsive to said positive impulses to render said device less conducting and a second control grid responsive to said negative impulses to render said device more conducting, whereby to develop an alternating current wave, the amplitudes of the positive and

negative half cycles of said alternating current wave being equal at all times and the time durations of said positive and negative half cycles being determined by the phase relationship between said positive and negative impulses, a voltage doubler circuit for developing from said alternating current wave a control voltage representative of the average time duration of half cycles of one polarity with respect to the average time duration of half cycles of the opposite polarity, and a variable frequency controlling circuit for said oscillator responsive to said control voltage, whereby to adjust the frequency of said oscillator to a definite relationship to the frequency of said alternating current power supply.

7. Automatic frequency control apparatus for a television timer comprising, a source including an oscillator of negative impulses, a source including an alternating current power supply of positive impulses, an electronic trigger device having a first control grid responsive to said positive impulses to render said device less conducting and a second control grid responsive to said negative impulses to render said device more conducting, whereby to develop an alternating current wave, the amplitudes of the positive and negative half cycles of said alternating current wave being equal at all times and the time durations of said positive and negative half cycles being determined by the phase relationship between said positive and negative impulses, a voltage doubler circuit for developing from said alternating current wave a control voltage having a polarity determined by the average time duration of half cycles of one polarity with respect to the average time duration of half cycles of the opposite polarity and a magnitude determined by the magnitude of the difference of said time durations, and a frequency controlling circuit for said oscillator variable in response to said control voltage, whereby to adjust the frequency of said oscillator to a definite relationship to the frequency of said alternating current power supply.

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