

Oct. 11, 1938.

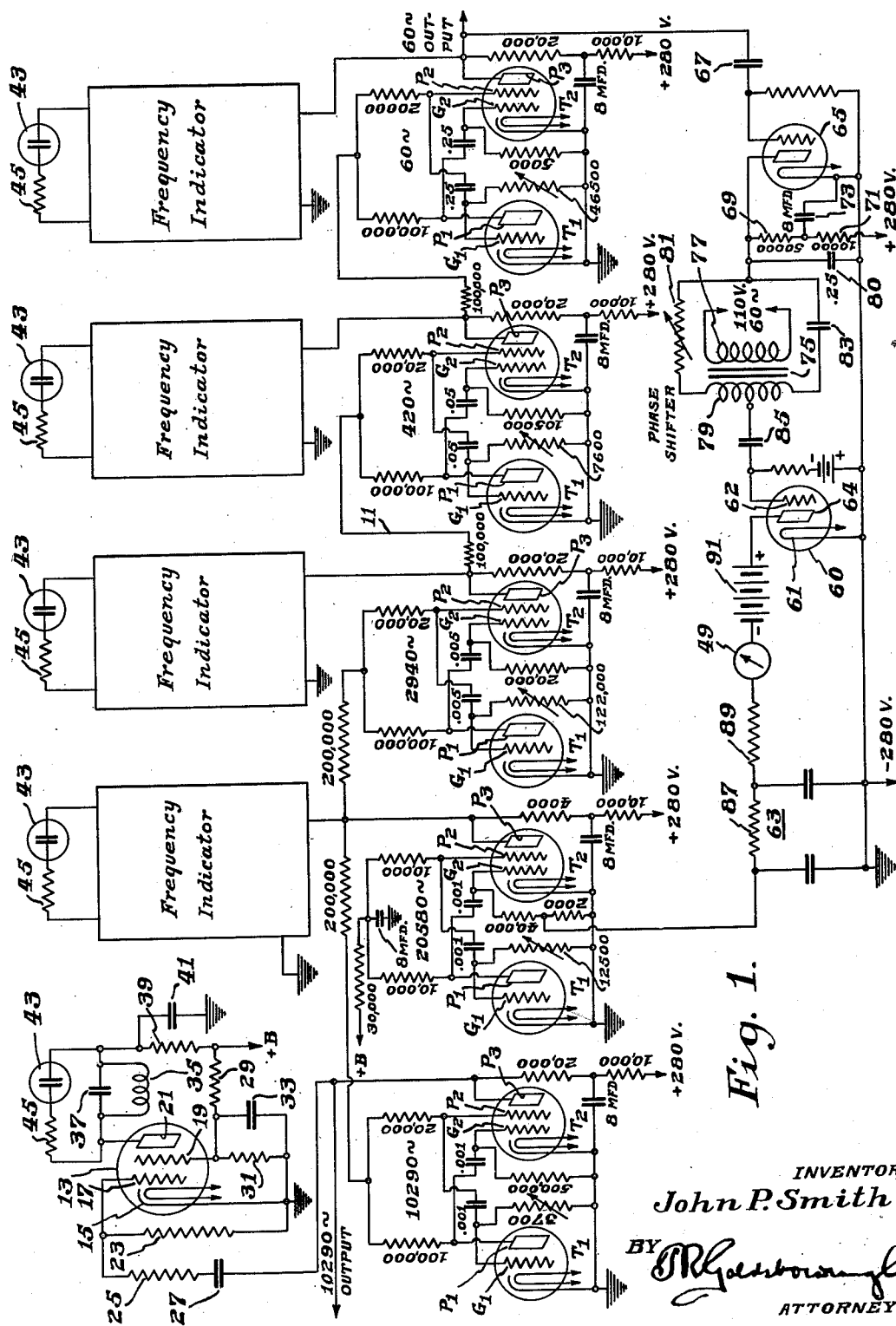
J. P. SMITH

2,132,654

ELECTRICAL APPARATUS

Filed Oct. 18, 1934

4 Sheets-Sheet 1

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Fig. 2.

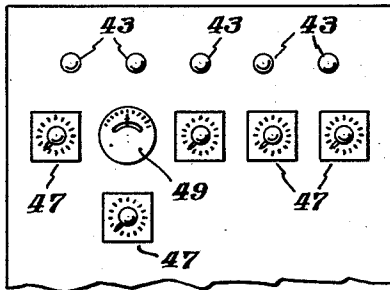


Fig. 6.

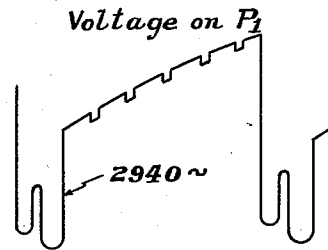


Fig. 7.

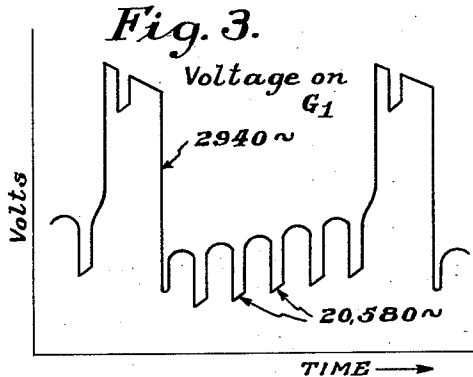
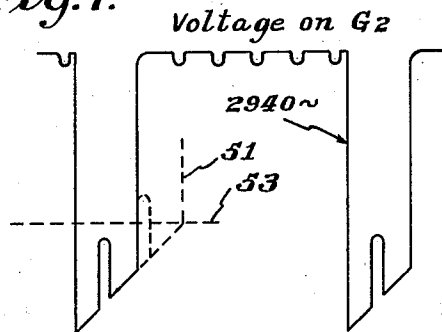


Fig. 8.

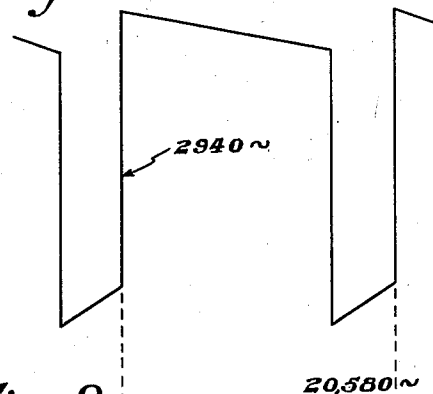


Fig. 4.

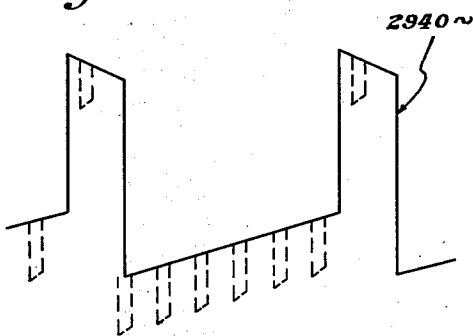


Fig. 5.

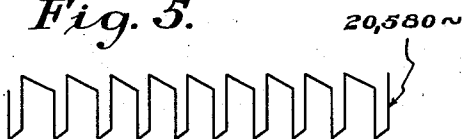
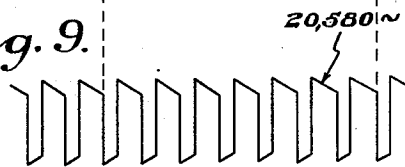


Fig. 9.



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Fig. 10.

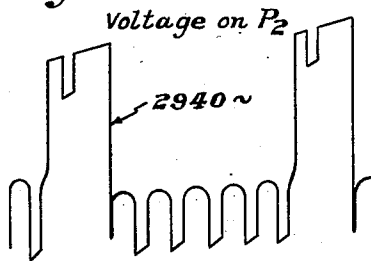


Fig. 11.

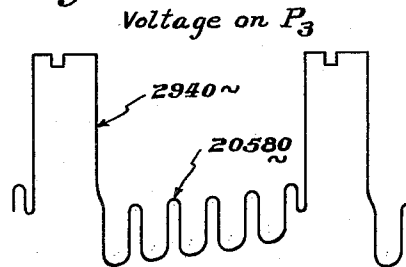


Fig. 12.

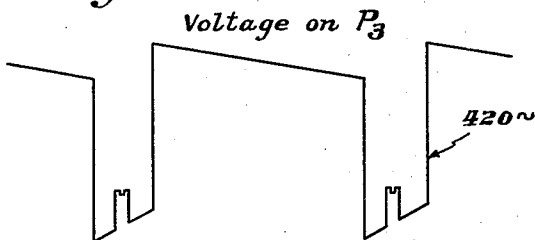


Fig. 15.

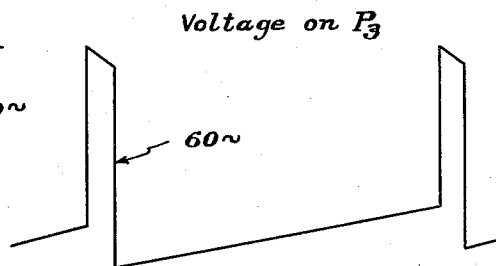


Fig. 13.

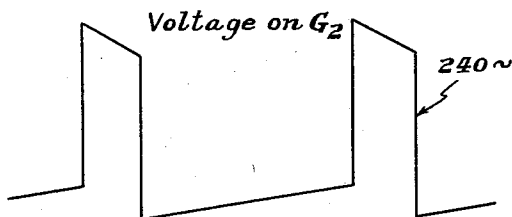


Fig. 16.

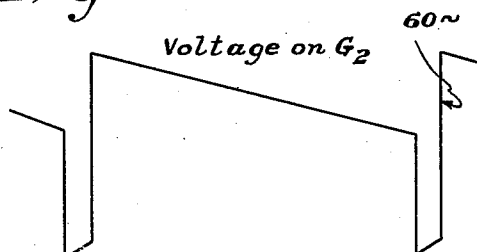


Fig. 14.



Fig. 17.



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Fig. 18.

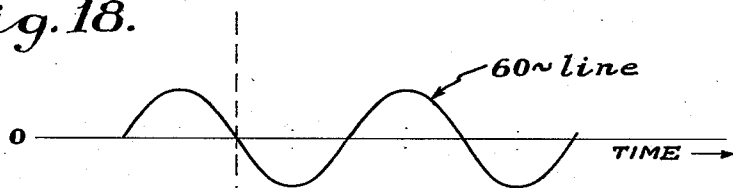


Fig. 19.

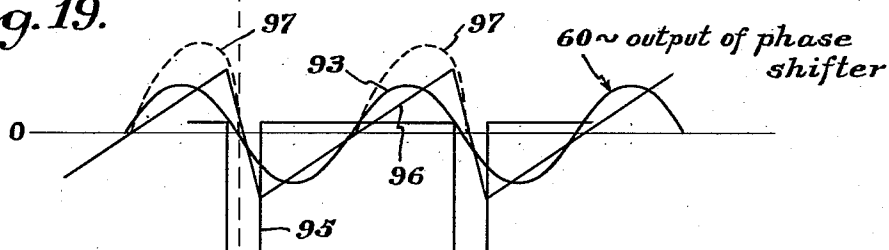


Fig. 20.

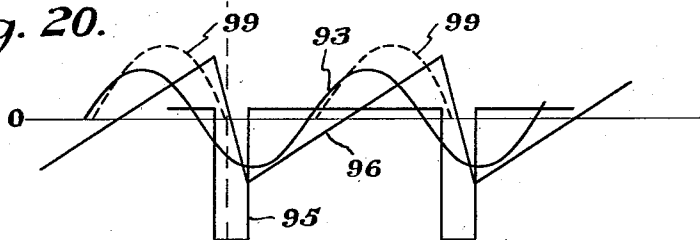
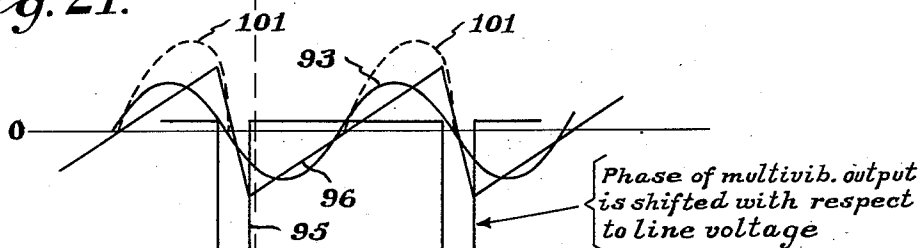


Fig. 21.



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UNITED STATES PATENT OFFICE

2,132,654

ELECTRICAL APPARATUS

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Application October 18, 1934, Serial No. 748,773

12 Claims. (Cl. 250—36)

My invention relates to picture transmitting apparatus and particularly to a generator of electrical impulses which may be utilized for various purposes such as for scanning control and synchronizing.

In a television transmitter which employs a cathode-ray transmitter tube, it is necessary to utilize electric impulses occurring at a comparatively high frequency for deflecting the cathode-ray horizontally and other impulses occurring at a comparatively low framing frequency for deflecting the cathode-ray vertically. These impulses may be generated by means of a high speed disc and a photo-electric cell but it has been found preferable to generate them by means of electric discharge devices, such as vacuum tubes, whereby all moving parts are avoided.

An object of my invention is to provide an improved electric discharge tube generator of the above-mentioned type.

A further object of my invention is to provide an improved method of and means for operating a plurality of multivibrators in controlled relation to each other.

A further object of my invention is to provide an improved means for determining what unit of a tube impulse generator has failed to function in the event that the generator fails to supply impulses at the proper frequency.

A still further object of my invention is to provide means for shifting the phase of the impulses supplied by a tube generator with respect to a standard frequency.

In a preferred embodiment of my invention I employ a chain of multivibrators which divide a comparatively high frequency in several steps to the desired synchronizing and framing frequencies. The multivibrators are so adjusted with respect to each other that each one is positively controlled or "locked in" by the preceding multivibrator even though variations occur in the high frequency being divided.

In order to permit adjustment of the multivibrator chain, each multivibrator is provided with an indicator lamp which is lighted so long as the multivibrator is operating at the proper frequency. If, for any reason, a particular multivibrator "falls out of step" with the controlling multivibrator, its associated indicator lamp is extinguished and the operator knows which one of the several multivibrators to readjust.

In accordance with one feature of my invention, I provide means for shifting the phase of the output of the impulse generator with respect to a 60 cycle power line. This is especially desirable

if the impulse generator is being employed in a system which is transmitting pictures from a film being run through a motion picture projector.

Other objects, features, and advantages of my invention will appear from the following description taken in connection with the accompanying drawings, in which

Figure 1 is a circuit diagram of one embodiment of my invention,

Fig. 2 is a view of a portion of the control panel for my improved impulse generator,

Figs. 3 to 17 are curves which are referred to in explaining the operation of the multivibrator chain shown in Fig. 1, and

Figs. 18 to 21 are curves which are referred to in explaining the operation of the phase shifting circuit shown in Fig. 1.

Referring to Fig. 1, there is illustrated an electrical impulse generator which is designed to supply horizontal synchronizing impulses and vertical synchronizing or framing impulses having the proper frequency relation for producing interlaced scanning as described and claimed in application Serial No. 726,258, filed May 18, 1934, in the name of A. V. Bedford and assigned to the Radio Corporation of America. The impulse generator comprises a multivibrator adjusted to oscillate at a frequency of 20,580 cycles per second and a chain of multivibrators, shown on the right-hand side of the drawings, which divide the frequency of 20,580 cycles in three steps of 7 to 60 cycles, which is the frequency desired for vertical deflection or framing. Therefore, the multivibrator chain includes a multivibrator which supplies an output having a frequency of 2,940 cycles, another multivibrator which supplies an output having a frequency of 420 cycles and the last multivibrator which has the 60 cycle output.

The 20,580 cycle frequency of the first multivibrator is divided by two by means of another multivibrator, shown on the left hand side of the drawings, in order to produce the desired horizontal deflecting frequency of 10,290 cycles.

Except for the circuit constants, the five multivibrators are constructed alike. In the drawings, each multivibrator is shown as comprising a vacuum tube T_1 and a vacuum tube T_2 . Actually, in a preferred embodiment, the circuit of which is shown in Fig. 1, the elements of tubes T_1 and T_2 are in the same glass envelope, the triode portion of a 6F7 tube being used for a T_1 and the pentode portion of the same 6F7 tube being used for the tube T_2 .

In order to avoid unnecessary crowding of the

drawings, the suppressor grid of the pentode portion of the 6F7 tube is not illustrated. The suppressor grid serves merely as a shielding electrode to reduce capacity coupling between the electrodes P₂ and P₃.

The control grid and the plate of the tube T₁ are identified by the reference characters G₁ and P₁, respectively, while the control grid, the screen grid and the plate of the tube T₂ are identified by the reference characters G₂, P₂ and P₃, respectively. The screen grid P₂ functions as a plate or anode rather than as a screen grid in the multivibrator circuit, while the plate P₃ functions as a coupling electrode for coupling the one multivibrator to a succeeding multivibrator.

In the drawings, the values of the resistors have been indicated in ohms and the values of the capacitors have been indicated in microfarads. It will be understood that these values are given for only one specific embodiment of the invention and may be varied within wide limits in other embodiments.

Referring specifically to the 20,580 cycle multivibrator, the indirectly heated cathodes of the tubes T₁ and T₂ are connected to ground. The electrodes P₁ and P₂ are connected through 10,000 ohm resistors to a 30,000 ohm resistor and through the 30,000 ohm resistor to a suitable positive voltage supply. The plate end of the 30,000 ohm resistor is connected to ground through an 8 microfarad by-pass capacitor.

The electrode P₁ is coupled to the grid G₂ through a .001 microfarad capacitor while the electrode P₂ is connected through another .001 microfarad capacitor to the grid G₁. The grid G₁ is connected to its cathode through a 12,500 ohm variable resistor, while the grid G₂ is connected to its cathode through a 40,000 ohm resistor and 2,000 ohm resistor connected in series. It will be understood that all variable resistors are set at the values shown on the drawings in the particular circuit being described. However, the stability of the circuit is such that they may be varied considerably without the multivibrators falling out of step.

The above described circuit functions in a well known manner to produce oscillations having a wave form shown in Fig. 5. This wave shape is produced by tubes T₁ and T₂ alternately blocking and unblocking, the control of the tubes being effected by the .001 microfarad capacitors becoming charged to bias a tube beyond its cut-off point and then gradually discharging through the grid and plate resistors.

The electrode P₃ is supplied with positive potential through a 10,000 ohm resistor and a 4,000 ohm resistor connected in series. An 8 microfarad by-pass capacitor is connected between the lower end of the 4,000 ohm resistor and ground.

Referring to the 2,940 cycle multivibrator, the circuit connections are the same as described above but certain of the circuit constants have been changed both for making the uncontrolled or free running frequency of the oscillator lower and for making the wave shape of the multivibrator output more unsymmetrical. It will be noted that the coupling capacitors have been increased in capacity to .005 microfarad and that the resistor coupling the grid G₁ to the cathode has been increased to 122,000 ohms, while the resistor coupling the grid G₂ to its cathode has been decreased in value to 20,000 ohms. Also, the plate P₁ and the electrode P₂ are coupled to a common 200,000 ohm resistor through a 100,000

ohm resistor and a 20,000 ohm resistor, respectively.

Voltage is supplied to the electrodes P₁ and P₂ of the 2,940 cycle multivibrator through a connection to the electrode P₃ of the preceding multivibrator. This connection from the electrode P₃ to the electrodes P₁ and P₂ of the succeeding multivibrator serves both as a voltage supply connection and as a coupling connection for causing the multivibrators to operate in a fixed frequency relation to each other. The unsymmetrical wave shape produced by the 2,940 cycle unit will be seen by referring to the curve in Fig. 4.

It will be noted that the coupling between multivibrators is a result of the electrode P₃ being in the same electron stream as the electrodes G₂ and P₂, this being referred to as "electron coupling".

The 420 cycle multivibrator is the same as the preceding one except that the coupling capacitors have been increased in capacity to .05 microfarad, while the resistor connecting the grid G₁ to its cathode has been given the comparatively low value of 7,600 ohms and the resistor connecting the grid G₂ to its cathode has been given the comparatively high value of 105,000 ohms. The 420 cycle multivibrator is connected to the electrode P₃ of the preceding multivibrator through a conductor 11 and a 100,000 ohm resistor.

The 60 cycle multivibrator is the same as the 420 cycle multivibrator except that the coupling capacities have been increased in value to .25 microfarad, while the resistor connecting the grid G₁ to its cathode has been given the comparatively high value of 46,500 ohms and the resistor coupling the grid G₂ to its cathode has been given the comparatively low value of 5,000 ohms.

Particular attention is called to the fact that if, in one multivibrator, the grid resistor for tube T₁ is higher than the grid resistor for tube T₂ in the succeeding multivibrator the grid resistor for tube T₁ is lower than the grid resistor for tube T₂. This circuit arrangement is employed for the purpose of reversing the phase in alternate multivibrators as will be described in detail later in connection with the description of the multivibrator operation.

The 10,290 cycle multivibrator which supplies the horizontal deflecting impulses is similar to the previously described multivibrators and is coupled to the electrode P₃ of the 20,580 cycle unit through a 200,000 ohm resistor.

In the past, it was found that a chain of frequency dividers or frequency multipliers was very difficult to operate for the reason that if one unit of the system fell out of step, the operator could bring the output of the system back to the desired frequency only by adjusting various units in the system until the system as a whole was again operating properly. As a rule, this was a very tedious procedure. In accordance, therefore, with one feature of my invention I provide the 20,580 cycle oscillator and each frequency divider unit with a frequency-indicator which includes a neon lamp that remains lighted so long as the oscillator or frequency divider is operating at the correct frequency.

The circuit of the frequency indicator connected to the 10,290 cycle multivibrator is shown in detail while the frequency indicators connected to the other units are indicated schematically. Referring to the 10,290 cycle indicator, it comprises an electric discharge tube 13 which may be of the screen grid type having a cathode 15, a control grid 17, a screen grid 19 and a plate 21. The

control grid 17 is connected to the cathode 15 through a resistor 23 and coupled to the electrode P₂ of the 10,290 cycle unit through a resistor 25 and coupling capacitor 27. The screen grid 19 is supplied with a suitable positive potential through a resistor 29, a bleeder resistor 31 being connected between the screen grid and cathode. A suitable by-pass capacitor 33 is connected between the screen grid 19 and ground.

The plate circuit of the tube 13 includes a parallel resonant circuit consisting of an inductance coil 35 and a capacitor 37 tuned to the frequency of 10,290 cycles. The plate 21 is supplied with a positive potential through a plate resistor 39 and through the inductance coil 35, a by-pass capacitor 41 being connected between the upper end of the resistor 39 and ground. A gaseous discharge device such as neon glow tube 43 is connected across the parallel resonant circuit in series with a resistor 45 which has a resistance value sufficiently high to prevent the neon tube from loading the tuned circuit too much when the glow tube breaks down.

In operation, if the 10,290 cycle multivibrator is operating to give an output having the frequency of 10,290 cycles, a voltage of that frequency appears across the parallel resonant circuit having a magnitude great enough to break down the neon tube 43 and cause it to glow. If the frequency of the multi-vibrator output changes, the voltage across the tuned circuit drops to a low value and the glow tube is extinguished. Thus it will be seen that if the system is operating properly, all the neon tubes 43 of the several frequency indicators will be lighted, but that if any multivibrator unit fails to provide an output of the proper frequency, the neon tube corresponding to that unit will be extinguished. The operator immediately knows which multivibrator unit must be readjusted and it is a simple matter to again put the system in operation.

Fig. 2 shows a preferred control panel layout for the multivibrator controls and frequency indicator lamps 43. The indicator lamp for each multivibrator is mounted directly above the control knob 47 for that multivibrator. The multivibrator control knobs 47 are for varying the values of the variable grid resistors indicated in Fig. 1, the knob positioned below the meter 49 being the control knob for the 20,580 cycle unit, and the control knob for the 10,290 cycle unit being at the left of the meter 49. In operation, if the neon lamp above the control knob 47 of the 10,290 cycle unit is extinguished, for example, that control knob is turned until the neon lamp again lights.

The operation of the multivibrator chain will now be described with special reference to the 2,940 cycle unit. Figs. 3, 6, 7, 10 and 11 are reproductions of actual curves that were obtained by means of an oscillograph which was connected between ground and the various electrodes of the 2,940 cycle multivibrator in the multivibrator chain illustrated in the drawings.

Fig. 3 is a curve of the voltage which was observed on the control grid G₁ on the 2,940 cycle unit. This voltage wave is the sum of the voltage wave produced by the 2,940 cycle unit and the voltage wave produced by the 20,580 cycle unit. These two components of the voltage observed on the G₁ are illustrated in Figs. 4 and 5. It will be understood that the solid line curve shown in Fig. 4 represents the voltage produced by the 2,940 cycle unit while being controlled by

the higher frequency unit and is not exactly the same voltage wave as would be produced if the unit were running free or uncontrolled. It will be noted that the positive impulses are much narrower than the negative impulses due to the fact that one grid resistor in the multivibrator has a much larger value than the other grid resistor.

The curve shown in Fig. 5 represents the voltage output of the 20,580 cycle unit, this unit being free running except for the control provided from a 60 cycle power line through a circuit which will be described hereinafter.

By referring to the drawings, it will be seen that the 20,580 cycle impulses are applied to the grid G₁ of the 2,940 cycle unit through one of the coupling capacitors and that the same impulses are applied to the grid G₂ through the other coupling capacitor. Since the two plate resistors in the multivibrator unit have different values, the synchronizing impulses are not balanced out even though they are applied to the grids G₁ and G₂ simultaneously.

The two voltage components appearing upon the grid G₁ combine to produce the slotted 2,940 cycle voltage wave. These slots are indicated by the dotted line portions in Fig. 4 and are clearly shown in the actual curve in Fig. 3.

A curve of the voltage observed on the plate P₁ is shown in Fig. 6. As would be expected, in this curve the narrow impulse is in a downward or negative direction while the wide impulse is in an upward or positive direction. The phase of the slot in the narrow impulse is also reversed but the phase of the slots in the wide impulse has not been reversed, the narrow slots being in a downward direction just as in Fig. 3. The reason that the phase of the slots is not reversed in the wide impulse is that during this period the tube T₁ is blocked so that the slots appearing on the wide impulses are due to 20,580 cycle impulses being impressed directly upon the plate P₁. The particular slopes at the bottom and top of the negative and positive impulses, respectively, might not be expected and it is believed that they are the result of a coupling capacitor being effectively in shunt to the 100,000 ohm plate resistor whereby a certain amount of time is required for the capacitor to receive a full charge.

In Fig. 7 there is shown a curve of the voltage observed on the grid G₂. This is probably the most important of the voltage curves which were observed as it is believed that this curve shows the manner in which one multivibrator is held in step with a preceding multivibrator. It would be expected that the voltage appearing on G₂ would have the same phase as the voltage appearing on P₁ since the two electrodes are coupled together through a coupling capacitor. It will be seen that this is true of both the 2,940 cycle component and the 20,580 cycle component which is producing the slots.

In Figs. 8 and 9 are shown the 2,940 cycle component and the 20,580 cycle component of the voltage wave illustrated in Fig. 7. By referring to Fig. 1, it will be seen that the controlling impulses from the higher frequency multivibrator are impressed upon the grid G₂ through two paths. They are impressed upon G₂ directly through the 100,000 ohm resistor and a .005 microfarad coupling capacitor and they are impressed upon the grid G₂ through another path comprising the 20,000 ohm plate resistor, the other .005 microfarad coupling capacitor, the tube T₁ and through the first coupling capacitor to

the grid G_2 . Impulses traversing the first path are not amplified while the impulses traversing the other path are amplified by the tube T_1 when it is in an amplifying condition, that is, when it is not blocked.

What is believed to be the method by which the multivibrators are locked in step will now be described with reference to Fig. 7. If the 2,940 cycle multivibrator were free running, the negative impulse would have a width indicated by the dotted line curve 51. The horizontal dotted line 53 represents the cut-off point of the tube T_1 . As is well known, in a free running multivibrator, the width of the negative impulse is determined by the time required for the charge of a coupling capacitor to leak off through a grid resistor to a value such that the control grid potential is brought to a value just above the cut-off point. At this time the tube starts to amplify and the positive impulse is started.

When the multivibrator is operated in the controlled condition, the voltage on a control grid is changed by an incoming impulse whereby the positive impulse is started before the coupling capacitor has time to discharge sufficiently to bring the voltage on the control grid above the cut-off point.

It will be understood that while tube T_2 is blocked to produce the narrow negative impulse, shown in Fig. 7, the tube T_1 has plate current flowing therethrough and is in an amplifying condition. Therefore, the narrow negative synchronizing impulses from the 20,580 cycle unit which are impressed through a .005 microfarad coupling capacitor upon G_1 cause a reduction in the plate current of the tube T_1 whereby they appear amplified and in reversed phase relation upon the grid G_2 .

In the circuit just illustrated, two of these synchronizing impulses appear while the negative impulse is being produced by the 2,940 cycle unit. As will be seen by referring to Fig. 7, the first impulse does not reduce the negative voltage on G_2 sufficiently to bring it above the cut-off point. The second impulse, however, does bring it beyond the cut-off point and at the beginning of this second synchronizing impulse the positive 2,940 cycle impulse begins.

During the flow of plate current in T_2 , T_1 is blocked whereby it cannot amplify synchronizing impulses and the only synchronizing impulses appearing upon G_2 are those impressed directly through the 100,000 ohm resistor and the .005 microfarad coupling capacitor, these, of course, being in opposite phase to the preceding ones which were amplified by the tube T_1 .

In Fig. 10 there is illustrated the wave shape of the voltage which was observed on the electrode P_2 of the 2,940 cycle multivibrator. It will be seen that this curve has the same relation to the voltage curve for G_2 as the curve for voltage on P_1 has to the voltage curve for G_1 .

In Fig. 11, there is shown the curve for the voltage observed on the electrode P_3 of the 2,940 cycle multivibrator. It will be evident that this curve is substantially the same as the curve for voltage on G_2 except that it is 180 degrees out of phase. Also the peaks of the positive impulses have been clipped off due to the fact that the tube operates at plate current saturation.

The 420 cycle multivibrator is so adjusted that the voltage appearing on its electrode P_3 is 180 degrees out of phase with respect to the voltage output of the preceding multivibrator as will be seen by comparing Figs. 11 and 12. The voltage

appearing on the grid G_2 of the 420 cycle multivibrator is shown in Fig. 13 while the 2,940 cycle controlling impulses are shown in Fig. 14. As in all the other figures, the curves of Figs. 13 and 14 are drawn on the same time axis so that the phase relation of the impulses is shown. It will be seen that the narrow controlling impulses are in the same direction as the narrow impulses appearing on the grid G_2 of the multivibrator which is to be controlled. A comparison of Figs. 8 and 9 will show that this is the adjustment for the 2,940 cycle multivibrator also. This is the preferred adjustment for the multivibrator chain in order to obtain the greatest stability of operation.

It is because this adjustment is desired that the 420 cycle multivibrator is adjusted to make its output 180 degrees out of phase with the output of the preceding multivibrator. In a similar manner the 60 cycle multivibrator is so adjusted that its voltage output is 180 degrees out of phase with the voltage output of the 420 cycle multivibrator as will be seen by referring to Fig. 15.

The proper phase relation between the controlling impulses and the impulses to be controlled could be obtained by interposing an amplifier tube between multivibrators for the purpose of reversing the phase of controlling impulses. In my circuit I have obtained the same effect with a considerable saving in vacuum tubes by making the grid resistor for the tube T_1 greater than the grid resistor for the tube T_2 in alternate multivibrator stages and by making the grid resistor for the tube T_2 greater than the grid resistor for the tube T_1 in the remaining stages as indicated in Fig. 1.

A comparison of Figs. 16 and 17 will show that in the 60 cycle multivibrator the narrow controlling impulses are in the same direction as the narrow impulse on the grid G_2 just as in the preceding multivibrators.

In the 60 cycle multivibrator the narrow impulse has been made sufficiently narrow to prevent a controlling impulse from being superimposed thereon. By referring to the curves for the preceding multivibrator stages it will be seen that the narrow impulse of the voltage output of the multivibrators has a slot therein which was produced by one of the controlling impulses. It has been found in practice that there is a satisfactory lock-in of the multivibrators with one slot or irregularity on the controlling impulse. However, if the number of slots or irregularities on an impulse is increased there is a decided tendency for the multivibrator chain to be unstable. This lack of stability appears to be a result of the multivibrator which is being controlled jumping back and forth from one irregularity to another on the controlling impulse.

It may be desirable to adjust certain stages of the multivibrator chain for the greatest stability of lock-in, this being an adjustment such as illustrated in Figs. 15 to 17 where the narrow impulse of the multivibrator being controlled has a width less than the interval between synchronizing impulses. It will be seen that this prevents the formation of an irregularity on the impulse appearing in the 60 cycle multivibrator output whereby it would be especially suitable for synchronizing another multivibrator.

It may be stated that, although the curves for the 2,940 cycle multivibrator were obtained by means of an oscillograph, the curves for the other multivibrators are simplified curves which have

been drawn mainly to show the polarity and width of the voltage impulses.

Attention is called to the fact that my method of coupling the output circuit of one multivibrator to a succeeding multivibrator not only provides a very positive lock-in of the multivibrators but it also compensates to a considerable degree for variations in the amplitude of the voltage supply. The compensation is provided because of the flow of plate current through the coupling resistors, any increase in plate voltage causing the plate current to increase a certain amount whereby the voltage drop in a coupling resistor is increased and the increase in voltage on the electrodes P₁ and P₂ is caused to be a minimum. This method of coupling also is desirable since there is no phase shift or change in amplitude in the transfer of an impulse through the coupling circuit whereby the 60 cycle regulator circuit, which will now be described, always exercises the proper control over the multivibrator chain.

For some applications of my impulse generator it may be desired to control the phase of its output with respect to the 60 cycle current of a power line. Such a phase control may be obtained by means of the regulator circuit illustrated in Fig. 1. In the particular embodiment illustrated, the regulator circuit includes a rectifier tube 60 which may consist of a three element vacuum tube having a cathode 61, a grid 62 and a plate 64. The output circuit of the rectifier is coupled through a filter 63 to the 20,580 cycle multivibrator while the input circuit is supplied with both 60 cycle current from a power line (not shown) and 60 cycle impulses from the output circuit of the 60 cycle multivibrator.

The circuit through which the 60 cycle impulses are supplied to the rectifier 60 includes an amplifier tube 65 which may be a vacuum tube of the three element type having its input circuit coupled through a coupling capacitor 67 to the electrode P₃ of the 60 cycle multivibrator. The plate of the amplifier tube 65 is supplied with positive potential through two resistors 69 and 71 connected in series, the point intermediate the two resistors being connected to the cathode of the tube 65 through a by-pass capacitor 73.

The output circuit of the amplifier tube 65 is coupled to the input circuit of the rectifier tube 60 through a phase-shifting network which includes a transformer 75 having a primary winding 77 and a secondary winding 79. The secondary winding 79 is connected in series with a resistor 81 and a capacitor 83. The point intermediate the resistor 81 and the capacitor 83 is connected to the plate of the amplifier tube 65 while the mid-point of the secondary winding 79 is connected to the input of the rectifier 60 through a coupling capacitor 85. The primary winding 77 is connected to a 60 cycle power line (not shown).

The phase of the 60 cycle current appearing across the output terminals of the phase-shifting network may be varied with respect to the 60 cycle current supplied to the primary winding from the line by varying the value of the resistor 81. It may be noted that this phase shift is produced without changing the amplitude of the 60 cycle current. It is desired that the 60 cycle current from the phase shifter and the 60 cycle impulses appearing in the output circuit of the tube 65 shall add in the input circuit of the rectifier 60.

In order that the outputs of the phase shifter and tube 65 shall add in the positive direction it is necessary, in effect, to reverse the phase of the impulse appearing in the output circuit of tube 65 since this tube has reversed the phase of the positive impulse impressed upon it by the 60 cycle multivibrator. This phase reversal is accomplished by means of the .25 microfarad capacitor 80 connected between the plate of tube 65 and ground. The action of the capacitor will be explained later with reference to Figs. 18 to 21.

Referring now to the manner in which the output circuit of the rectifier 60 is coupled to the 20,580 cycle multivibrator, it will be seen that the plate circuit of the rectifier tube may be traced from the cathode 61 to ground, through ground to the 2,000 ohm resistor in the grid circuit of the multivibrator tube T₂, through the 2,000 ohm resistor and through filter resistors 87 and 89, the meter 49 and a plate supply battery 91 to the rectifier plate 64. The purpose of the filter in the rectifier output circuit is to filter out any 60 cycle component which may appear in that circuit whereby only pure direct current is supplied by the rectifier tube to the 2,000 ohm multivibrator resistor.

The operation of the phase control circuit will be understood by referring to Figs. 18 to 21. The curve in Fig. 18 represents the 60 cycle current which is supplied from the power line. In Fig. 19, the 60 cycle output of the phase-shifting network is indicated by the sine wave curve 93, in this instance the phase-shifting network being set so that its output is in phase with the line current.

The 60 cycle impulses which the multivibrator causes to appear in the plate circuit of the tube 65 are indicated by the curve 95. The voltage which appears across the capacitor 80 has substantially a saw-tooth wave form as shown by the curve 96. The positive portion of this saw-tooth voltage adds to the positive half cycle of the sine wave voltage in the input circuit of the rectifier tube 60 to give a voltage of the magnitude indicated by the dotted line 97. The negative half cycles of the voltages are not passed by the rectifier since it is biased to cut-off.

The direct current output of the rectifier tube 60 has a value depending upon the magnitude of the voltage applied to the rectifier grid circuit, and the bias voltage applied to the grid G₂ of the 20,580 cycle multivibrator, in turn, has a magnitude depending upon the magnitude of the output current of the rectifier. It will be understood that, if the rectifier output causes the grid G₂ to become more negative, the frequency of the multivibrator will be lowered momentarily while, if the rectifier output decreases, the frequency of the multivibrator will tend to increase.

Fig. 19 represents an equilibrium condition where the multivibrator chain is controlled by a 60 cycle power line, the electrical impulses appearing in the output circuit of the multivibrator chain having a certain fixed phase relation with respect to the 60 cycle current of the line.

If the resistor 81 in the phase shifter is changed to shift the phase of the 60 cycle current appearing across the phase shifter terminals, as indicated by the curve 93 in Fig. 20, the sum of the 60 cycle voltage and the saw-tooth voltage will be decreased as indicated by the dotted line curve 99 whereby the output of the rectifier 60 will be decreased and the 20,580 cycle multivibrator will be speeded up momentarily until the multivibrator

impulses assume a different position with respect to the 60 cycle line current as indicated in Fig. 21. It will be understood that the multivibrator impulses will shift to such a phase relation with respect to the 60 cycle output of the phase shifting network that an equilibrium condition is again reached where the sum of the voltages represented by the dotted line curve 101 is the same as for the condition shown in Fig. 19 and the multivibrator chain is again operating in a fixed phase relation with respect to the 60 cycle line. The condition shown in Fig. 20 is greatly exaggerated, of course, since the multivibrator impulses follow the change in phase of the 60 cycle sine wave very closely.

The use of a rectifier tube for controlling the frequency of a vacuum tube impulse generator with respect to a power line is described and claimed in application Serial No. 729,730, filed June 9, 1934, in the name of A. V. Bedford and assigned to Radio Corporation of America.

In the claims, expressions such as "a plurality of tubes" or "a pair of tubes" are to be construed as including a single envelope having two or more sets of electrodes therein as in a tube of the 6F7 type.

From the foregoing description it will be understood that various modifications may be made in my invention without departing from the spirit and scope thereof and I desire, therefore, that only such limitations should be imposed thereon as are necessitated by the prior art and set forth in the appended claims.

I claim as my invention:

1. In combination, a plurality of multivibrators, each multivibrator being an oscillator of the type comprising two electric discharge tubes, each of said tubes having an anode circuit coupled to the grid circuit of the other tube by resistance coupling, each multivibrator being adjusted to produce narrow and wide impulses alternately with respect to an alternating current axis, said multivibrators being connected in cascade with alternate multivibrators having the narrow impulses appearing in their output circuits with a polarity which is the opposite of the polarity of the narrow impulses appearing in the output circuits of the other multivibrators, whereby the ratio of the frequencies of said cascaded multivibrators is kept substantially constant.

2. A multivibrator chain for obtaining frequency division which comprises a multivibrator, said multivibrator being an oscillator of the type comprising two electric discharge tubes, each of said tubes having an anode circuit coupled to the grid circuit of the other tube by resistance coupling, said multivibrator being adjusted to produce narrow and wide impulses alternately with respect to an alternating current axis and at a certain frequency when free-running, an output circuit for said multivibrator, and means for introducing synchronizing impulses into the anode circuit of said multivibrator which occur at a higher frequency than said certain frequency and which have a polarity which is the opposite of the polarity of the said narrow impulses which appear in said output circuit, whereby comparatively low frequency impulses are obtained which have a fixed time relation to said synchronizing impulses.

3. An electrical impulse generator comprising a plurality of multivibrators, each multivibrator being an oscillator of the type comprising two electric discharge tubes, each of said tubes having an anode circuit coupled to the grid circuit of

the other tube by resistance coupling, each multivibrator being so adjusted that it produces narrow impulses and wide impulses alternately with respect to an alternating current axis, and means for so connecting said multivibrators in cascade that the narrow impulses which are impressed upon a certain multivibrator from a preceding multivibrator have a polarity which is the opposite of the polarity of the narrow impulses in the output of said certain multivibrator, whereby the ratio of the frequencies of said cascaded multivibrators is kept substantially constant.

4. In combination, a multivibrator comprising an electric discharge tube having an input circuit including a control grid and an output circuit including an anode and a second electric discharge tube having an input circuit including a control grid and an output circuit including an anode, each of said anodes being connected through an impedance unit to a source of potential whereby each tube has a plate or anode current, the grid of each tube being coupled to the anode of the other tube, said multivibrator being adjusted to produce narrow and wide impulses alternately with respect to an alternating current axis, and means for introducing synchronizing impulses into said anode circuits in such phase that they have the same polarity as the said narrow impulses which appear in said grids.

5. In combination, a multivibrator comprising two electric discharge tubes, each having a grid circuit and a plate circuit, the grid circuit of each tube being so coupled to the plate circuit of the other tube that oscillations are produced, one of said tubes including an additional electrode positioned in the same electron stream as the grid and plate of said one tube, a second multivibrator comprising two electric discharge tubes having grid circuits and plate circuits coupled to produce oscillations, each of said last mentioned plate circuits including a plate resistor, said plate resistors being connected to said additional electrode through a coupling resistor, and an impedance unit connected to said additional electrode through which voltage may be supplied both to said electrode and to said last mentioned plate circuits.

6. In combination, a multivibrator comprising a pair of electric discharge tubes, each tube having an input circuit including a grid and an output circuit including an anode, the grid of each tube being coupled to the anode of the other tube, one of said tubes having an additional electrode in the same electron stream as its grid and anode, an impedance unit connected to said additional electrode through which voltage may be supplied, a second multivibrator comprising a pair of electric discharge tubes, each having an input circuit including a grid and an output circuit including an anode, the grid of each tube in said second multivibrator being coupled to the anode of the other tube in said second multivibrator, one of said last-mentioned anodes being connected to said additional electrode through a resistor adjacent to said one anode and a second resistor in series, and the other of said last-mentioned anodes being connected to said additional electrode through another resistor adjacent to said other anode and through said second resistor, the said resistors adjacent to said anodes being unequal in value.

7. Apparatus according to claim 6 characterized in that said second multivibrator is adjusted to produce narrow and wide impulses alternately with respect to an alternating current axis and

is locked in on an odd sub-harmonic of the output of said first multivibrator.

5 8. Apparatus according to claim 6 characterized in that said second multivibrator is so adjusted that it produces narrow and wide impulses alternately with respect to an alternating current axis with the narrow impulse occurring in the same direction as the narrow impulses from said first multivibrator appearing upon said additional
10 electrode during the wide impulses.

15 9. In combination, a multivibrator, said multivibrator being an oscillator of the type comprising two electric discharge tubes, each of said tubes having an anode circuit coupled to the grid circuit of the other tube by resistance coupling, said multivibrator being so adjusted that it has an output of such wave shape that narrow and wide impulses are produced alternately with respect to an alternating current axis at a certain
20 frequency, and means for impressing synchronizing impulses upon said multivibrator which occur at a frequency which is an odd harmonic of said certain frequency, said narrow impulses having a width which is no greater than the width of a synchronizing impulse plus twice the interval between successive synchronizing impulses.
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10. In combination, a multivibrator, said multivibrator being an oscillator of the type comprising two electric discharge tubes, each of said
30 tubes having an anode circuit which is coupled to the grid circuit of the other tube by resistance coupling, said multivibrator being so adjusted that it has an output of such wave shape that narrow and wide impulses are produced alternately with respect to an alternating current axis
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at a certain frequency, and means for impressing synchronizing impulses upon said multivibrator which occur at a frequency which is an odd harmonic of said certain frequency, said narrow impulses having a width which is no greater than the interval between successive synchronizing impulses. 5

11. In an impulse generator, a plurality of multivibrators connected in cascade and indicator means connected with each of said multivibrators for identifying the multivibrator unit which has fallen out of step in the event that the multivibrator chain fails to function properly, said indicator means comprising an amplifier tube having a plate circuit tuned to said desired frequency, and a glow lamp and impedance unit connected in series across said tuned circuit. 10 15

12. In combination, an oscillator, a source of current having a control frequency, means for deriving voltage from said oscillator having a frequency equal to said control frequency, a rectifier, an adjustable phase shifting network, means for passing said control frequency current through said network whereby a control frequency voltage appears at the output terminals of said network, means for adding said derived voltage and the voltage appearing at the output terminals of said network and impressing them upon said rectifier, and means for so controlling the frequency of said oscillator in accordance with the amplitude of said rectifier output that the phase of said derived voltage may be shifted with respect to said control frequency current. 20 25 30

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