Oct. 7, 1947. A. H. DICKINSON 2,428,617

GAS-FILLED TUBE TYPE OF RELAXATION OSCILLATOR SYSTEM

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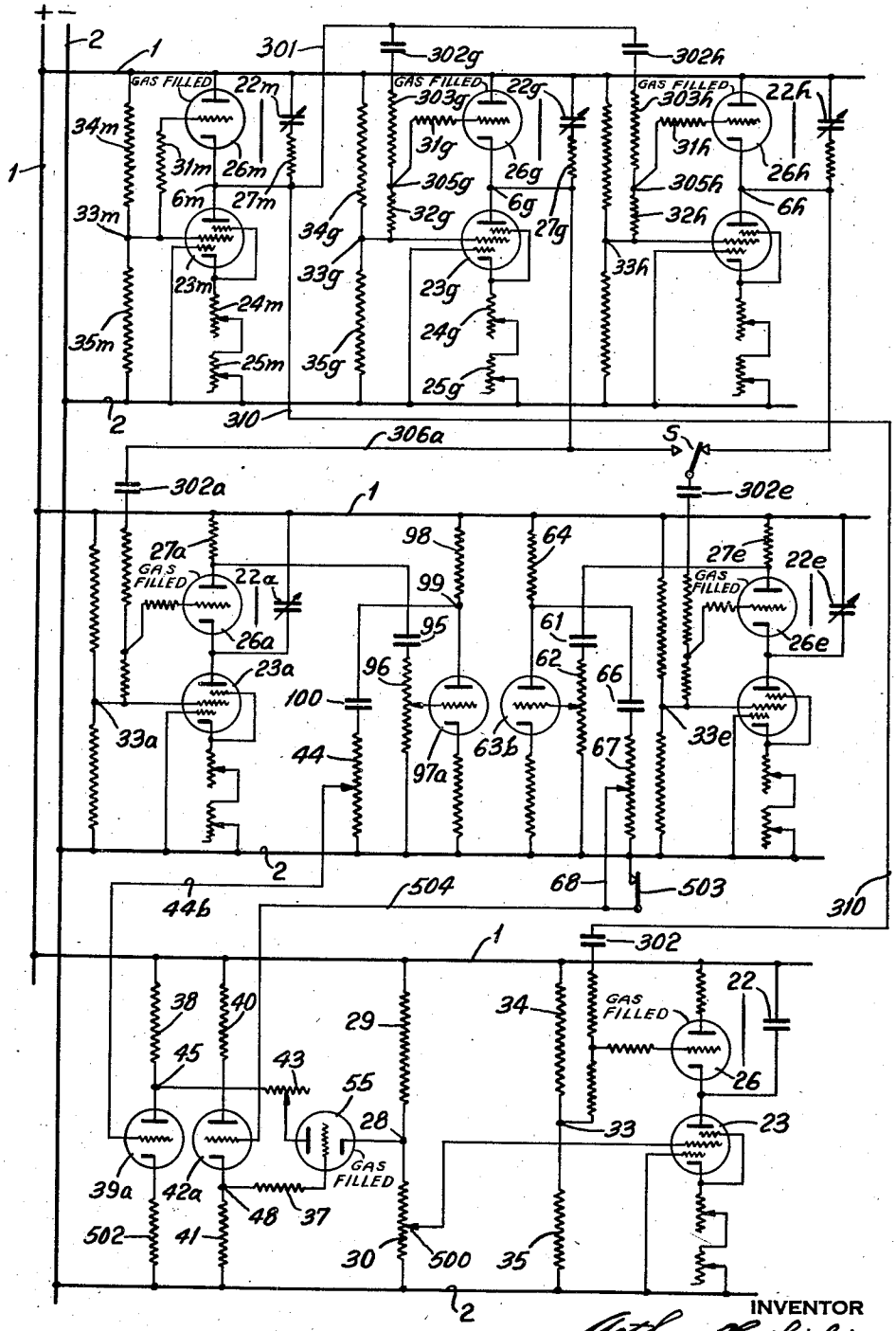


FIG. 1.

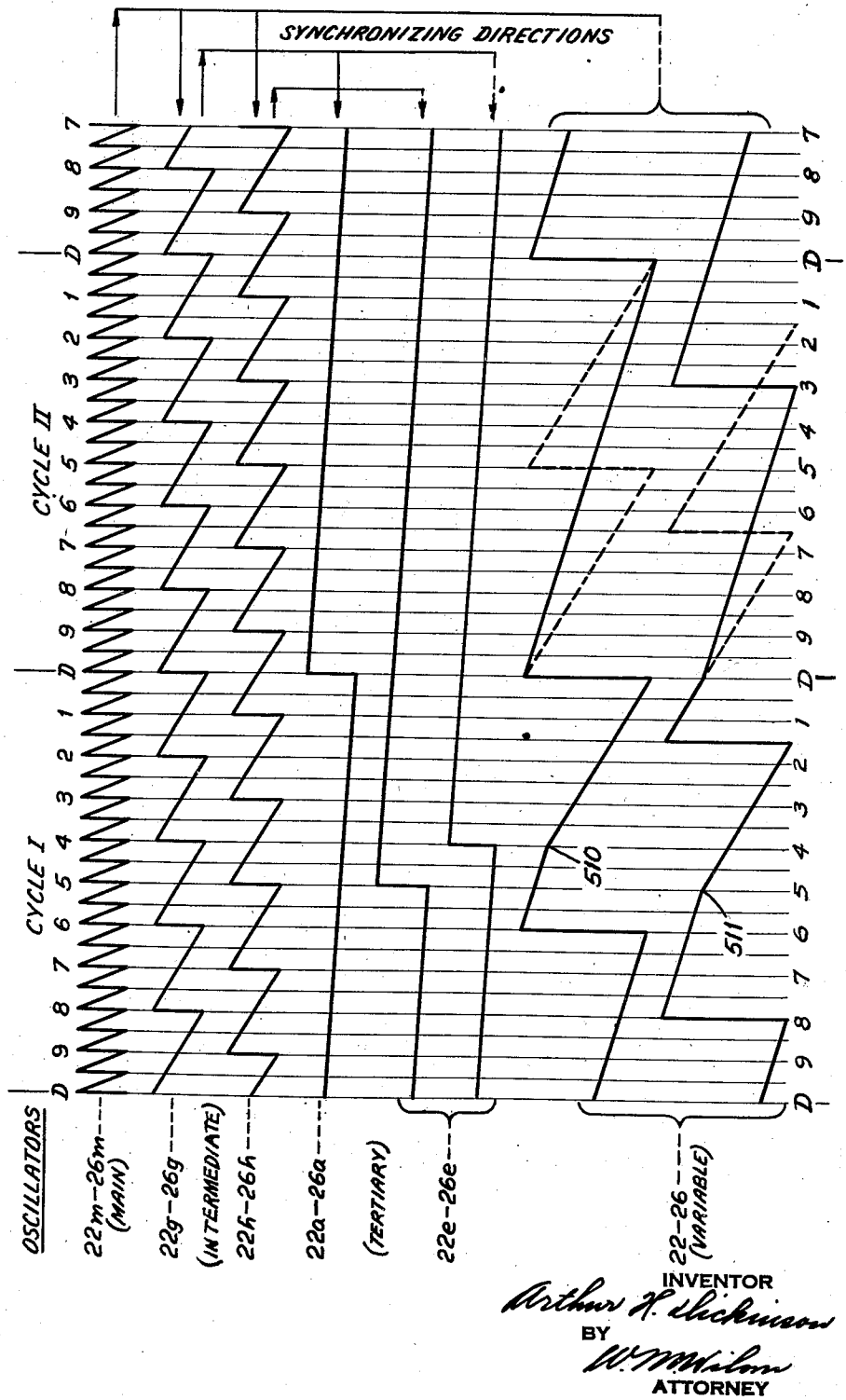
INVENTOR
Arthur H. Dickinson
BY
W. M. Wilson
ATTORNEY

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GAS-FILLED TUBE TYPE OF RELAXATION OSCILLATOR SYSTEM

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FIG. 2.



INVENTOR
Arthur H. Dickinson
BY
W. M. Milam
ATTORNEY

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GAS-FILLED TUBE TYPE OF RELAXATION OSCILLATOR SYSTEM

Arthur H. Dickinson, Scarsdale, N. Y., assignor to International Business Machines Corporation, New York, N. Y., a corporation of New York

Application June 19, 1943, Serial No. 491,440

8 Claims. (Cl. 250—36)

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This application relates to electrical oscillators and is a continuation-in-part of my copending application Serial No. 314,767, filed January 20, 1940.

An object of the invention is to provide means to keep an oscillator in desired synchronism despite changes in its phase or frequency or both.

Another object is to provide means to keep an oscillator in synchronism, when operating at different frequencies and phases, in combination with a circuit network to change the frequency and phase automatically.

Another object is to provide means to keep in synchronism a group of oscillators, each having either a different frequency or phase.

Another object is to provide means whereby commonly synchronized oscillators are prevented from reacting upon each other.

Other ob'ects of the invention will be pointed out in the following description and claims and illustrated in the accompanying drawings, which disclose, by way of example, the principle of the invention and the best mode, which has been contemplated, of applying that principle.

In the drawings:

Fig. 1 shows a circuit network embodying the invention, and

Fig. 2 is a timing chart showing waves generated by the oscillators.

The apparatus exemplifying my invention includes a primary synchronizing means which is preferably an electrical oscillator, hereafter called the main oscillator. Intermediate oscillators are synchronized by the main oscillator, these intermediate oscillators being adjusted to operate in different phase relation but at the same frequency, such frequency being a selected submultiple of the main oscillator frequency. The intermediate oscillators synchronize a plurality of other oscillators which may be called, for convenience, tertiary oscillators. The latter are synchronized for operation at the same frequency but in different phase, such frequency being a selected submultiple of the intermediate oscillator frequency and, hence, a smaller submultiple of the main oscillator frequency. A variable frequency and phase oscillator is directly synchronized by the main oscillator. A control network is provided for automatically changing frequency of this variable oscillator. The waves generated at the changed frequency have different phases than the waves which were generated at the previous frequency. The control network also functions automatically to return the variable oscillator to operation at the previous frequency. The waves then generated will have either the same or a different phase than the waves previously produced at this frequency depending on the duration of the intervening operation at the changed frequency. Operation of the control network is governed selectively by the tertiary oscillators. The variable oscillator frequencies are all submultiples of the main oscillator frequencies.

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As illustrative, relaxation oscillators are used but it will be understood that other suitable electrical oscillators may be used.

A relaxation oscillator includes a condenser, an impedance through which it is charged, and a short circuiting device to cause its discharge. The charging period is relatively gradual, while the discharging period is substantially instantaneous. The charge and discharge of the condenser are repeated periodically, and saw-toothed waves are generated. In the present case it is preferred to use a pentode as the impedance in the charging circuit and a gas filled, grid-controlled tube as the short circuiting device. The pentode is preferred because for a given grid bias the current flow remains practically constant even through large swings in anode potential. Thus, at whatever rate the condenser is being charged, the pentode so controls the charging circuit as to cause the voltage rise across the condenser to be substantially linear. The three-element gas tube is preferred as the short circuiting device because its grid bias may be readily varied or regulated to determine at what anode potential the gas tube is to fire and short circuit the condenser. In a manner explained later, the grids of the gas tubes contained in the oscillators to be synchronized receive an increment of synchronizing voltage, reducing the grid bias of these tubes. The anode voltage of these tubes is determined by the voltage across the related condensers. Only those tubes whose anode potential has reached a critical value coordinate with the reduced grid bias will ignite in response to the increment of synchronizing voltage.

Fig. 1 shows circuits which are generally similar to circuits found in my said copending application and, wherever convenient, correspondence of parts will be indicated by using the same reference characters as in the copending application.

In detail, plus and minus lines 1 and 2 are connected to a suitable D. C. supply. The upper part of Fig. 1 shows, at the left, the main oscillator, which will be identified as 22*m*—26*m*, and at the right, two intermediate oscillators which will be

identified as 22g—26g and 22h—26h. The middle part of Fig. 1 shows two tertiary oscillators 22a—26a and 22e—26e, flanking two triodes and related elements. The bottom part of Fig. 1 shows the variable oscillator 22—26 and the control network for automatically charging its frequency or phase or both. Since all the oscillators are of the same nature, only one need be described in essential detail. The others will be described only in respect to features peculiar to themselves. Similar parts of the different oscillators will be recognized by common reference numbers applied thereto.

The main oscillator will be described in detail. This oscillator includes condenser 22m connected via resistance 27m in series with pentode 23m and in parallel with gas tube 26m. Pentode 23m has its control grid connected to line 2 and is self-biased by respectively coarsely and finely adjustable resistors 24m and 25m. The screen grid of the pentode is connected to point 33m between resistors 34m and 35m serving as a voltage divider across lines 1 and 2. The return circuit of the control grid of the gas tube is through resistance 31m to point 33m and thence via resistor 35m to line 2. Thus, the voltage at point 33m determines both the screen voltage of the pentode and the grid bias of the gas tube. A suitable frequency for the oscillator may be selected by changing the adjustment of one or more of the following: condenser 22m, resistance 24m, and resistance 25m. When the voltage across the condenser reaches critical value for the maintained grid bias of the gas tube, this tube fires, short circuiting the condenser. Such discharge is substantially instantaneous and sharply raises the potential at point 6m. Following the discharge, the condenser begins to recharge, and the operations repeat periodically. Fig. 2 shows an example of waves of voltage produced at point 6m.

The oscillators to be synchronized have different gas tube grid circuits than the main oscillator. Only such grid circuit of the intermediate oscillator 22g—26g will be described in detail, the others having similar grid circuits. The grid of the gas tube 26g is connected by resistor 31g to point 305g of a voltage divider comprised of resistances 303g and 32g. Resistance 32g is wired to point 33g of the voltage divider 34g—35g of the oscillator 22g—26g. Resistance 303g is coupled by condenser 302g to wire 301 which connects to point 6m of the main oscillator. In the absence of a pulse of rising voltage on point 6m, the potential at point 305g is relatively low and the grid bias of tube 26g is then at what may be called a normal value. Upon each sharp rise in voltage on point 6m, it transmits a pulse via line 301 and condenser 302g to voltage divider 303g—32g, momentarily applying an increment of voltage to point 305g. This increment of voltage supplements the normal voltage on the grid of tube 26g to reduce the grid bias below normal value. Thereupon, the tube 26g tends to ignite, but whether this actually takes place depends on wheher the anode potential of tube 26g, determined by the potential across the condenser 22g, has reached the requisite ionizing value in relation to the momentarily reduced grid bias of the tube.

Similarly, point 6m transmits synchronizing pulses of positive voltage via line 301 and a condenser 302h to the intermediate oscillator 22h—26h, and via line 310 and condenser 302 to the variable oscillator 22—26. In a similar manner, the grid of tube 26a receives synchronizing pulses via condenser 302a and line 306a from point 6g of intermediate oscillator 22g—26g; hence tertiary oscillator 22a—26a is synchronized by this intermediate oscillator. Tertiary oscillator 22e—26e selectively receives synchronizing pulses either from intermediate oscillator 22g—26g or from 22h—26h, depending on the position of switch S. With the switch in shown position, the pulses on point 6h act through condenser 302e to reduce the grid bias of tube 26e, while with the switch in the reverse position, the pulses on point 6g act through this condenser upon the grid of the tube 26e.

To aid in the further description, the operations of the oscillators will be referred to a common chosen time base or cycle. This cycle is here chosen, for convenience, as the cycle of the variable oscillator 22—26 during its operation at the lower of two frequencies. For convenience, such lower frequency may be called the base frequency. A complete oscillation at the base frequency requires one cycle period, as indicated in cycle II of Fig. 2. The variable oscillator, in a manner explained later, is shiftable automatically to a frequency double the base frequency. This shift, if occurring an odd number of index points from the peak of the base oscillation causes the double frequency oscillations to be phased at mid-index points, as indicated by the partially dotted waves at the bottom of Fig. 2. If the shift occurs at an even number of index points from the peak of the base oscillation, the double frequency oscillations have an exact index point phase as indicated by the partially dotted wave in the next to last timing line of Fig. 2. Thus, the base oscillations of the variable oscillator may have any exact point phase while the double frequency oscillations may have any exact index point or any mid-index point phase. In all, with the example chosen, there are twenty possible phases of the variable oscillator, ten exact index point phases and ten mid-index point phases. The scheme of my invention accordingly provides, for the chosen example, at least twenty synchronizing pulses a cycle, each potentially capable of synchronizing the variable oscillator in any of its twenty possible phases and at either of its two frequencies. These synchronizing pulses are applied by the main oscillator which is adjusted for a frequency of twenty oscillations a cycle, as indicated in Fig. 2. With the oscillator 22—26 operating at normal frequency, there will be one effective synchronizing pulse a cycle, such pulse being applied at an exact index point. With the oscillator 22—26 operating at double the normal frequency, two synchronizing pulses will be effective each cyclic period, such pulses being either exact or mid-index point pulses. The other pulses, while reducing the grid bias of the tube 26, do not cause ignition of the tube because condenser 22 is not applying the necessary ionizing potential at the times such pulses are being applied. Manifestly, different synchronizing pulses become effective when the variable oscillator changes its phase.

For reasons which will be clear later, the oscillator 22e—26e is required to generate oscillations at half the normal frequency of the variable oscillator; that is, to produce one oscillation every two cyclic periods. It is desired, further, that such oscillation have any of ten possible phases, although it may be mentioned that only nine of these phases are utilized; namely, phases at index points "9" to "1." Oscillator 22e—26e thus

requires synchronization at any of the index points of a cycle. Such synchronization is effected either by intermediate oscillator 22*g*—26*g* or 22*h*—26*h*, depending on the position of switch S (Fig. 1). Each intermediate oscillator is adjusted to a frequency of five oscillations a cycle, but the oscillations of 22*g*—26*g* are phased at even index points, "8," "6," "4," "2," and "D" and those of 22*h*—26*h* at odd index points "9," "7," "5," "3," and "1." Thus, a synchronizing pulse is produced by one or the other intermediate distributors at each index point. When the oscillator 22*e*—26*e* is to operate at an odd index point phase, it is connected by switch S to oscillator 22*h*—26*h*, as indicated at the right of Fig. 2 where the arrows indicate the direction of flow of the synchronizing pulses or which of the oscillators are adapted to be synchronized by others of the oscillators. When oscillator 22*e*—26*e* is to have an even index point phase, switch S is shifted to connect it to oscillator 22*g*—26*g* for synchronization. With this arrangement, one pulse every two cyclic periods, produced either by 22*g*—26*g* or 22*h*—26*h* is effective to synchronize the oscillator 22*e*—26*e* at its selected index point phase.

As previously explained, the intermediate oscillators are synchronized by pulses from the main oscillator. Every fourth pulse produced at even index points by the main oscillator takes effect upon oscillator 22*g*—26*g* to keep it synchronized, and every fourth pulse produced at odd index points is effective to synchronize the oscillator 22*h*—26*h*.

Oscillator 22*a*—26*a*, for reasons explained later, is adjusted to operate at a frequency of one oscillation every two cycles and at a "D" phase. This oscillator is locked in such phase by a pulse produced at the D cycle point by intermediate oscillator 22*g*—26*g*.

The foregoing has described, as an example, means whereby a primary synchronizing means—the main oscillator—produces twenty synchronizing pulses a cycle, the intermediate oscillators produce five such pulses a cycle, the tertiary oscillators have a frequency of one oscillation every two cycles, and the variable oscillator has a frequency of either one or two oscillations a cycle. It will be noted that all the synchronized oscillators operate at submultiple frequencies of the main oscillator, and the tertiary oscillators also operate at a submultiple of the frequency of the intermediate oscillators. Further, the oscillations of the synchronized oscillators may have any of a plurality of different phases. By the means employed here and described above, all of the oscillators are maintained in locked or synchronized relation despite their operations at various frequencies and phases, such frequencies, however, being in all cases submultiples of the main oscillator frequency. The relations between the oscillators hold true for different submultiple frequencies, other than those illustrated in Fig. 2.

It is understood that the increment of synchronizing voltage acting on the grid of a gas tube should be insufficient by itself to cause ignition as, otherwise, there would be a tendency for the controlled oscillator to operate at the same frequency and in step with the synchronizing oscillator. The increment of synchronizing voltage should be such that when added to the normal voltage, there is a total grid potential which is effective to fire the tube only upon condition that the potential across the condenser has attained a predetermined critical value. The resistances of the voltage divider to which the grid is connected and to which the synchronizing pulse is applied are so proportioned that only a small proportion of the pulse voltage is effective upon the grid. Considering oscillator 22*g*—26*g*, for instance, the resistance 303*g* has a higher value than resistance 32*g*, so that the proportion of the synchronizing pulse applied to the grid of tube 26*g* is relatively small. The condensers, such as 302*g*, further attenuate the synchronizing pulses.

It is well known that when the grid-controlled gas tube is ignited, there is grid current flow. Since, in a relaxation oscillator, the time during which the gas tube is ignited is of the order of microseconds, the current flow is in the nature of a steep pulse. As previously explained, the two intermediate oscillators while having the same frequency are to operate at different phases. As indicated in Fig. 2, the phase difference between these two oscillators is the cycle portion between two successive cycle points. It follows that as the gas tube of one intermediate oscillator ignites, the anode potential of the gas tube of the other intermediate oscillator is approximately one-half the desired critical anode potential. Since, in the circuits, as shown in Fig. 1, the grids of the gas tube 26*g* and 26*h* are connected to a common line 301, there is a tendency for the pulse produced by grid current flow in one tube when ignited to raise the potential of the grid of the other tube. Such interaction, if allowed to occur, might throw the intermediate oscillators out of their desired phase relation by causing undesired pre-ignition of the gas tubes at lower than the desired critical anode potentials. Further both the intermediate oscillators, by reason of their grid current flow, tend to react upon the main oscillator to alter its frequency. Similarly, with switch S in position opposite the one shown, there is a tendency for the oscillators 22*a*—26*a* and 22*e*—26*e* to react upon each other as well as upon oscillator 22*g*—26*g*. In the shown position of the switch, oscillator 22*e*—26*e* tends to react upon oscillator 22*h*—26*h*. Oscillator 22—26 has a tendency to react upon the main oscillator. To counteract these reactions and interactions, the grid current pulses are almost completely attenuated. Part of such attenuation is obtained by making the grid resistors 31 and 31*g*, *h*, *a*, and *e* as high in value as possible without affecting stability of the associated gas tubes. Further attenuation is obtained by making the upper resistors of the voltage dividers, to which the grid resistors are directly connected, higher in value than the lower resistors; e. g., resistor 303*g* is made larger in value than resistor 32*g*. Still further attenuation is effected by the condensers 302, 302*g*, *h*, *a*, and *e*.

It may be mentioned that it is preferred to synchronize the tertiary oscillators by the intermediate oscillators rather than by the main oscillator because the tertiary oscillators thereby may be more readily adjusted to their desired phase relations. This is because the intermediate oscillators together produce only one synchronizing pulse for each possible phase of the tertiary oscillators.

Since the main, intermediate, and tertiary oscillators, once adjusted to desired frequencies, are to remain at these frequencies, the screen grids of their pentodes are connected to points of fixed potentials. On the other hand, it is intended to operate the variable oscillator at a

base frequency or a multiple thereof; twice the base frequency in the assumed example. To enable the variable oscillator to be varied in frequency, the screen grid of its pentode is connected to a point which is at either of two voltages. This point is in a control network which will now be described.

The control network includes a voltage divider comprised of resistors 29 and 30. Resistor 30 is tapped at a chosen point 500 by a connection to the screen of pentode 23. A point 28 of this voltage divider is connected to the cathode of a gas tube 55. The anode of this tube is connected via a resistor 43 to a point 45 of a voltage divider comprised of resistor 38, tube 39*a*, and self-biasing resistor 502. The grid of tube 55 is connected via a resistance 37 to a point 48 of a third voltage divider comprised of resistor 40, tube 42*a*, and self-biasing resistor 41. The resistances of the control network are so related that with tube 39*a* at relatively high impedance, tube 42*a* similarly at relatively high impedance, and gas tube 55 shut off, the point 45 is near the potential of line 1, point 28 is near the potential of line 2, and point 48 is still nearer the potential of line 2. Under these conditions, the voltage difference between points 45 and 28 is sufficient to supply ionization potential for tube 55 but the grid bias, which is the difference in potential between points 28 and 48 is so high as to prevent ignition of the tube. With the tube 55 in non-conductive condition, point 28 is at the lower of two possible potentials and point 500 of resistor 30 also is at the lower of two possible potentials. The screen potential of pentode 23 is then relatively low and the tube impedance relatively high, causing the variable oscillator to function at the lower or base frequency.

Assume that the frequency of the variable oscillator is to be multiplied. Positive potential is applied, in a manner explained later, to the grid of tube 42*a*, reducing its bias and impedance, and, thereby, increasing the voltage at point 48. As a result, the grid bias of the gas tube 55 is lowered to such an extent as to cause ignition of the gas tube. Current now flows from point 45 to point 28, raising the potential at this point and at point 500. Consequently, the screen voltage of pentode 23 is raised and the pentode's impedance reduced, causing the variable oscillator to start operating at the higher frequency. In the assumed example, the variable oscillator values and the values of the control network are so chosen and adjusted that, upon ignition of the gas tube 55, the frequency of the variable oscillator is doubled. It is understood that other multiples of the base frequency may be provided for by suitable pre-adjustments of the circuit values.

Assume now that the variable oscillator is to be restored to operation at base frequency. In a manner described later, positive potential is applied to the grid of tube 39*a*, reducing its grid bias and its impedance. Current flow in resistor 38 thereupon increases to such extent as to reduce the potential at point 45 below the value required to apply ionization potential to gas tube 55. Hence, the gas tube is extinguished and points 28 and 500 return to their original low potentials and the impedance of the pentode 23 returns to its original high value. Accordingly, the variable oscillator again functions at the base frequency.

The firing pulse; that is, the pulse applied to the grid of the tube 42*a* to cause ignition of gas tube 55, is indirectly derived from the tertiary oscillator 22*a*—26*e*. The shut-off pulse; that is, the pulse applied to the grid of tube 39*a* to extinguish gas tube 55, is indirectly derived from the tertiary oscillator 22*a*—26*a*.

Considering first the oscillator 22*a*—26*a*, upon the breakdown of its tube 26*a*, there is an extremely rapid drop in potential across the resistor 27*a*, causing discharge of a condenser 95, which produces a sharp negative pulse on resistor 96. The grid bias of tube 97*a* rises, reducing current flow through resistor 98 and the tube. Point 99 thereupon rises in potential, charging up a condenser 100 to produce a positive pulse on resistor 44. This pulse has the same steep characteristic as the pulse produced in resistor 27*a* upon breakdown of the tube 26*a*. The positive pulse on resistor 44 is applied via wire 44*b* to the grid of tube 39*a*, causing shut-off of gas tube 55.

Similarly, upon the breakdown of tube 26*e* of oscillator 22*e*—26*e*, condenser 61 discharges, producing a steep negative pulse, on resistor 62, which is converted by the action of the tube 63*b*, resistor 64, and the condenser 66 to a steep positive pulse on a resistor 67. Assuming a switch 503 to be open, the positive pulse on resistor 67 is transmitted by wires 68 and 504 to the grid of tube 42*a*, causing ignition of the gas tube 55.

In the present example, it is assumed that oscillator 22*a*—26*a* is adjusted to operate at half the base frequency of the variable oscillator 22—26 and that each oscillation has a "D" phase. Thus, at alternate D index points, the oscillator 22*a*—26*a* produces a shut-off pulse, causing the tube 55, if ignited, to be shut off at such times. It is assumed, further, that oscillator 22*e*—26*e* is to have the same frequency as oscillator 22*a*—26*a* but that its phase shall be adjusted to any of the index points 9 to 1. Thus, as indicated in Fig. 2, the oscillator 22*e*—26*e* has been adjusted in one instance to produce a pulse at index point 5 of every two cycles and in the other instance to produce a pulse at index point 4 of every two cycles. When the oscillator 22*e*—26*e* is to be adjusted to any odd index point phase, switch S is left in the position shown, in which case it will be synchronized by oscillator 22*h*—26*h*. When the oscillator 22*e*—26*e* is to be adjusted to an even index point phase, switch S is shifted to reverse position, so that the oscillator 22*e*—26*e* will be synchronized by oscillator 22*g*—26*g*.

As an example, assume the variable oscillator 22—26 is to be shifted from a "6" phase to a "D" phase (see the next to last line of Fig. 2). The oscillator 22*e*—26*e* is adjusted to the "4" phase and thereafter the switch 503 (Fig. 1) is opened. Accordingly, the pulse produced on resistance 67 at the "4" time of the first or second cycle following the opening of switch 503, will be applied via lines 68 and 504 to the grid of tube 42*a*, causing ignition of the tube 55. The frequency of the variable oscillator 22—26 immediately doubles as indicated at point 510 of the next to last line of Fig. 2. If the operation of the variable oscillator were permitted to continue at the doubled rate, its oscillations would be in successive phases "D" and "5" as indicated by the dotted portion in the next to last line of Fig. 2. However, at the "D" time following its shift to a doubled frequency, the variable oscillator is restored to base frequency operation. At this "D" time, the oscillator 22*a*—26*a* causes a positive pulse to be produced on resistor 44. This pulse is transmitted via wire 44*b* to the grid of tube 39*a*, as a result of which the gas tube 55 is

shut off, restoring the variable oscillator to its base frequency. The quenching of gas tube 55, in the example under discussion, is coincident with the "D" phase of the double frequency oscillations, and the variable oscillator begins immediately to charge the condenser 22 at the reduced rate. The variable oscillator will then continue to operate at base frequency and its oscillations will have a "D" phase until the next shift is effected.

As another example, assume the variable oscillator 22—26 is operating at base frequency and at "8" phase and is to be shifted to a "3" phase. The oscillator 22*e*—26*e* is adjusted to a "5" phase, as indicated in the upper of the two lines in Fig. 2 pertaining to this oscillator. The switch 503 is then opened and the next discharge of the condenser 22*e* at the "5" time produces a positive pulse on resistor 67 which is transmitted by wires 68 and 504 to tube 42*a*. The gas tube 55 is thereupon ignited, and the variable oscillator begins to operate at the double frequency, as indicated at point 511 of the bottom line of Fig. 2. At this doubled frequency, the oscillator 22—26 would be phased at "1.5" and "6.5," as indicated, partially in dotted lines, at the bottom of Fig. 2. At the "D" time following the change in its frequency, the oscillator 22—26 is restored to base frequency under control of oscillator 22*a*—26*a* in the manner described before. The variable oscillator will now generate the base frequency oscillations at phase "3."

It should be understood that if the oscillator 22*e*—26*e* has been adjusted to a particular phase, and switch 503 is re-closed after the phase of the variable oscillator 22—26 has been shifted once, the latter will remain in the shifted phase. Should it be desired to effect a different phase shift, the oscillator 22*e*—26*e* is adjusted according to the extent of the new phase shift and switch 503 is re-opened. If the oscillator 22*e*—26*e* is adjusted to a particular phase, and switch 503 is left open for a multiple number of two-cycle intervals, successive phase shifts of the variable oscillator will be effected, one shift every two cycles, to an extent determined by the phase of the oscillator 22*e*—26*e*. Thus, if this oscillator is phased at "5" and the variable oscillator is initially in an "8" phase, the latter will be shifted first from the "8" phase to the "3" phase (see the last line of Fig. 2), then from the "3" phase to the "8" phase, and so on, one such shift occurring every two cycles as long as switch 503 is left open.

As previously explained, the main oscillator supplies at least as many pulses a cycle as the possible number of phases of the variable oscillator when operating at the base frequency and the multiple frequency. In the present instance, synchronizing pulses are afforded at intervals of half a cycle division; i. e., at mid-index points and exact index points. By supplying potentially effective synchronizing pulses at this rate to the variable oscillator, the main oscillator assures accurate phasing of the variable oscillator when it is shifted from one frequency to the other. Further, since the main oscillator also serves to synchronize the intermediate oscillators and, through them, the tertiary oscillators, it is assured that the control network will operate in predetermined relation to the phases of the variable oscillator. Hence, the extent of phase shift of the variable oscillator may be accurately controlled.

While there have been shown and described and pointed out the fundamental novel features of the invention as applied to a preferred embodiment it will be understood that various omissions and substitutions and changes in the form and details of the device illustrated and in its operation may be made by those skilled in the art, without departing from the spirit of the invention. It is the intention, therefore, to be limited only as indicated by the scope of the following claims.

What is claimed is:

1. In combination with an electrical oscillator circuit including a variable impedance determining by its value one or another of different frequencies of the oscillator circuit, a control network including a gaseous discharge tube determining by its status one or another of alternative electrical conditions of the network, means so operatively associating the control network with said impedance as to alter its value and, thereby, the frequency of the oscillator circuit, upon a change in said electrical condition, means supplying a firing pulse to the control network to fire the tube therein and thereby to change the condition thereof, whereupon the frequency of the oscillator circuit is changed, means supplying an extinguishing pulse to the network to extinguish the tube therein and return the network to its previous condition, whereupon the oscillator circuit is restored to its previous frequency, means for supplying synchronizing pulses to the oscillator circuit at a rate at least equal to one of said frequencies and a multiple of the different frequency, so as to lock the oscillator circuit at any of its frequencies in desired phase relation to a given time base, and means for so timing the production of the firing and extinguishing pulses with respect to the operation of the oscillator circuit at any of its frequencies that the changes in frequency of the oscillator circuit, resulting from changes in electrical condition of the network produced by the firing and extinguishing pulses, occur in definite, known time base relation to the operation of the oscillator circuit at any of its frequencies.

2. In combination with a relaxation oscillator operable either at a given frequency or double this frequency, said oscillator when operating at a given frequency being phased at any chosen cycle point of a given cycle and when operating at the double frequency being phased either at any chosen cycle point or at any chosen mid-cycle point of the cycle, means responsive to an electrical pulsation for automatically shifting the frequency and phase of the oscillator, and means producing synchronizing pulses and impressing them upon the oscillator at a frequency at least equal to the double frequency of the oscillator so as to lock the oscillator, while operating at either frequency, in any phase or phases to which the oscillator is adjusted.

3. In combination with an electrical oscillator circuit adjustable to operate at a given frequency or a multiple frequency, means including electronic discharge means responsive to an electrical pulsation for automatically adjusting a constant or constants of the circuit to effect a transition from one frequency to the other or vice versa, means producing synchronizing pulses at a rate at least equal the multiple frequency, and means for impressing said pulses upon the circuit to assure fly-back operation of the circuit at definite phase times of a chosen cycle while operating at either frequency and upon a transition from either frequency to the other.

4. In combination with an electrical oscillator circuit adjustable to operate at a given frequency or a multiple frequency, a control circuit, including electronic discharge means responsive to an electrical pulsation for automatically adjusting the circuit value to effect a transition from one frequency to the other or vice versa, means producing synchronizing pulses at a rate at least equal to the multiple frequency, and means for impressing said pulses upon the circuit to lock the circuit in predetermined chosen phase relations to a given time base while operating at the given frequency and also while operating at the multiple frequency, whereby upon the transition in frequency of the oscillator circuit it is brought from one said locked phase relation to another said locked phase relation at the new frequency.

5. In combination, a plurality of relaxation oscillators, each including a short-circuiting gas tube and a condenser applying anode-to-cathode potential to the tube, each tube including a control grid responsive to a synchronizing pulse to ignite the tube when requisite anode-to-cathode potential is being impressed upon the tube by the condenser, each said oscillator being adjusted to operate at a different phase or frequency, a synchronizing oscillator producing synchronizing pulses, circuits commonly fed from the synchronizing oscillator for applying the synchronizing pulses to the relaxation oscillators, one circuit applying the pulses to the control grid of one relaxation oscillator and the other circuit applying the pulses to the control grid of another of the relaxation oscillators, and current choking means in said circuits to choke grid current produced in each relaxation oscillator upon ignition of the tube therein so as to prevent such grid current in one relaxation oscillator from effectively reacting upon the grid of another said relaxation oscillator and so as to prevent said grid current in either oscillator from effectively reacting upon the synchronizing oscillator, whereby the frequencies and phases for which the oscillators are set remain undisturbed.

6. The combination with an electrical oscillator circuit including electrical control means variable in value to establish one or another of different frequencies of the oscillator circuit, one frequency being a multiple of the other, of a control circuit operatively connected to the variable means and adjustable in electrical condition to so affect the value of the variable means as to produce a change in frequency of the oscillator circuit, means producing an electrical pulse and impressing the pulse upon said control circuit to adjust its electrical condition and thereby produce a change in frequency of the oscillator circuit, means impressing synchronizing pulses upon the oscillator circuit at a fixed frequency equal to at least the higher of said different frequencies, so as to synchronize operation of the oscillator circuit at each frequency with respect to a chosen cycle, and means so timing operation of the pulse producing means with respect to operation of the oscillator that the change in electrical condition of the control circuit occurs in definite time relation to the operation of the oscillator.

7. In combination with an electrical oscillator circuit including electrical means variable in electrical value to cause a change in operation of the oscillator circuit from a given frequency to a different frequency, a control circuit operatively connected to the electrical, variable means to determine the electrical value thereof and, thereby, to determine at which frequency the oscillator circuit is operating, means for producing and impressing an electrical pulse upon said control circuit to change its electrical condition and thereby, through the variable means, to change the frequency of the oscillator circuit, means applying synchronizing potential to the oscillator circuit at a frequency which is at least equal to one of the frequencies of the oscillator circuit and a multiple of the different frequency, means for applying synchronizing potential to the pulse producing means, and a pulsing means electrically coupled to both of the two aforementioned synchronizing potential applying means for locking both the latter means into synchronism, whereby a change in condition of the control circuit occurs in synchronized time relation to phases of the oscillator circuit while operating at any of its different frequencies.

8. The combination with a relaxation oscillator including a variable impedance electronic discharge device determining by its impedance value a base frequency of the oscillator or an alternative frequency thereof, said discharge device including control means variable in potential to vary the impedance value of the device, of a control circuit reversible in electrical condition and so operatively electrically connected to the control means of the discharge device as to alter the potential thereof and cause a change in impedance value of the device upon a reversal in electrical condition of the circuit, whereupon the frequency of the oscillator is changed from its previous frequency upon one change in electrical condition of the control circuit and returned to its previous frequency upon a reverse change in condition of the circuit, one said frequency being a submultiple of the other said frequency, a synchronizing oscillator producing synchronizing pulses at a frequency at least equal to the higher of the two frequencies of the oscillator, and means applying said synchronizing pulses to an input circuit of the oscillator so as to synchronize it in relation to a given time base while operating either at the higher frequency or the submultiple frequency.

ARTHUR H. DICKINSON.

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