

July 14, 1942.

L. E. NORTON

2,289,988

ELECTRONIC KEYING DEVICE

Filed Dec. 28, 1940

2 Sheets-Sheet 1

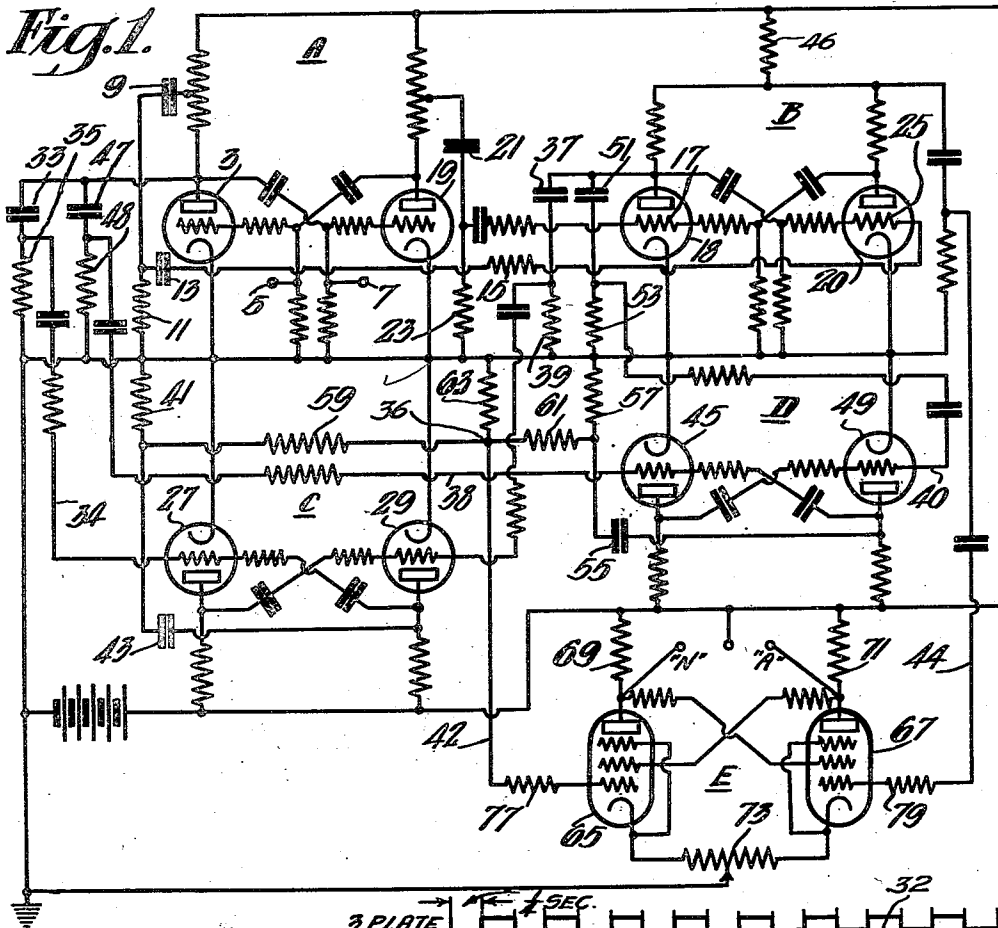
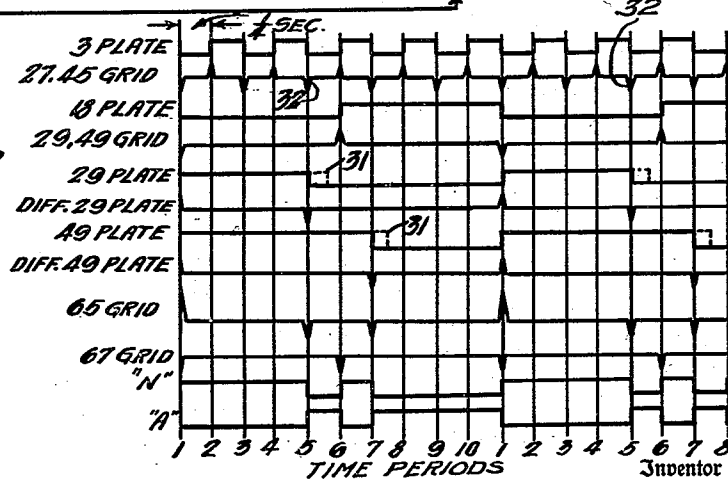


Fig. 2.



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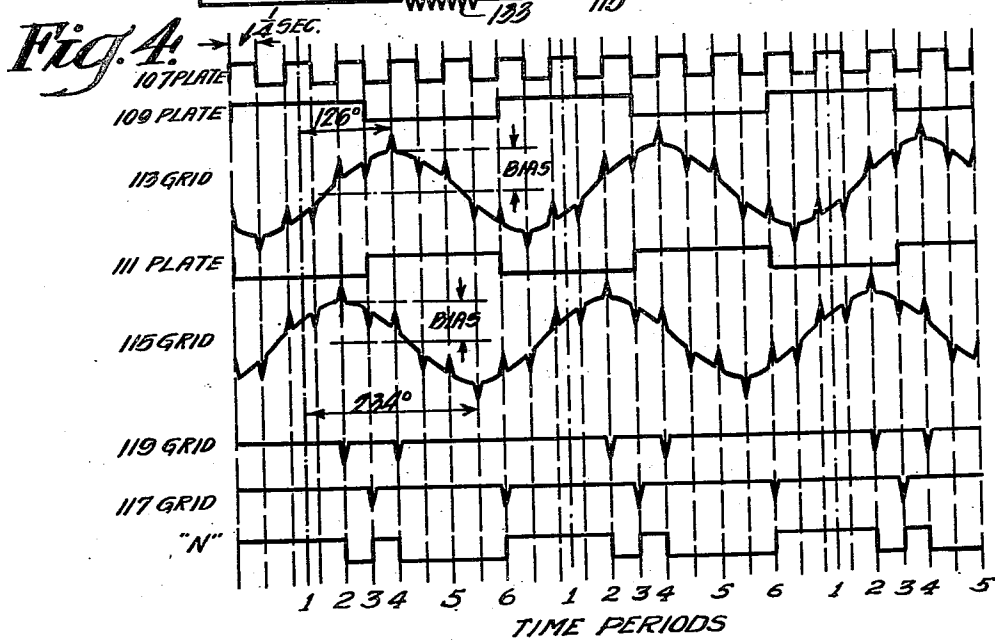
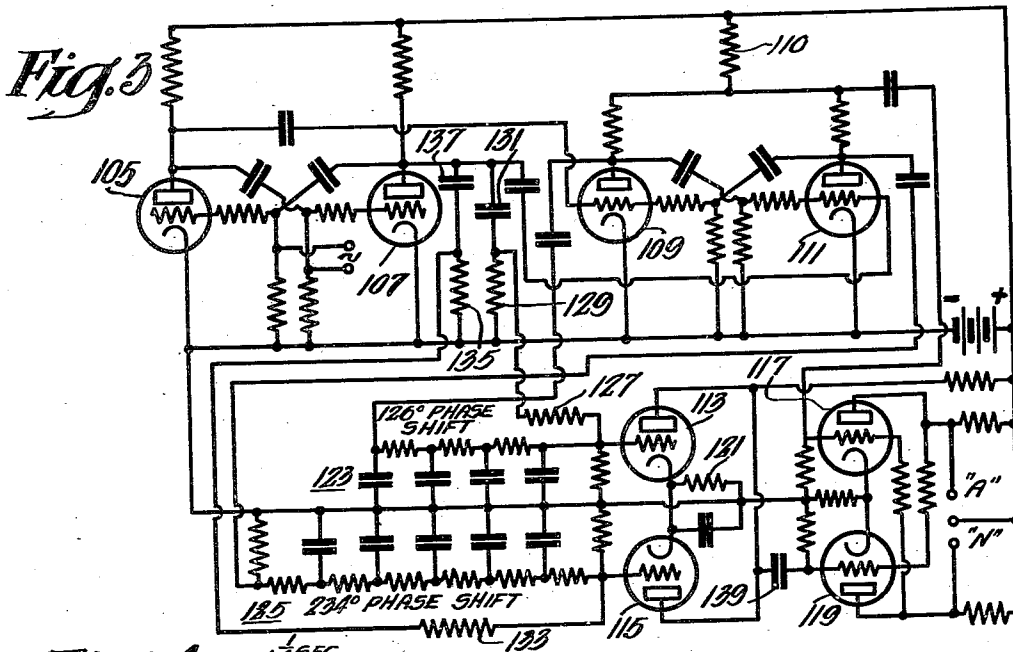
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ELECTRONIC KEYING DEVICE

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Application December 28, 1940, Serial No. 372,206

14 Claims. (Cl. 178-66)

This invention relates to electronic keying devices and has for its principal object the provision of an improved arrangement and method of operation for supplying keying impulses suitable for use in connection with radio ranges, and the like.

Conventional radio ranges employ four overlapping directional radio beams which are keyed, A and N in pairs. The A and N keying is in international Morse code. When these A and N signals are received with equal intensities a continuous dash is heard by the pilot of an aircraft flying the course, indicating that he is on the beam. Divergence from the beam to the right, for example, increases the amplitude of the A signal, and divergence to the left increases the amplitude of the N signal, thus indicating the course of the aircraft.

Previously known keying systems have involved the use of mechanical devices, usually energized by rotating commutators or moving relays. Such devices are subject to the common disadvantages of mechanically operated devices such as sparking contacts, corrosion and sticking, and high resistance contacts which may produce irregular keying. In accordance with the present invention, there are provided completely electronic keying systems which involve no moving parts, and provide accurately timed keying signals without the usual disadvantages referred to above.

Briefly, one embodiment of the invention utilizes four multivibrators A, B, C and D. Multivibrator A provides synchronizing impulses for the other multivibrators and may be synchronized itself from the commercial power line or any other suitable source of constant frequency control voltage, or from a high Q electromechanical resonator. Multivibrator B is a low frequency multivibrator for producing timing impulses and for controlling multivibrators C and D. Multivibrators C and D produce unsymmetrical output waves which are combined to produce timing impulses which define keying periods in a manner which will be described hereinafter. The system is completed by a pair of tubes E which have a toggle switch action such that each tube applies to the other a control potential which reduces the plate current of the other tube substantially to cut-off and maintains it in this condition until its plate current is, in turn, reduced by the application of a negative keying impulse.

In an alternative embodiment timed impulses from a pair of multivibrators are selected by a delayed sine-wave voltage, the selected impulses being utilized to control an electronic toggle

switch, as before. A somewhat different system is described in my copending application Serial No. 372,205, filed December 28, 1940.

The invention will be better understood from the following description when considered in connection with the accompanying drawings, in which Figure 1 is a schematic diagram of an embodiment of this invention, Figure 2 is a chart showing the time sequence of the various control impulses developed in the system, Figure 3 is a schematic diagram of an alternative embodiment, and Figure 4 is a chart showing the time sequence of control impulses in the alternative system.

Referring to Figs 1 and 2, multivibrator A produces at the plate of tube 3 a symmetrical square wave of the type illustrated in the first curve of Fig. 2, this voltage being referred to cathode. Terminals 5 and 7 may be connected to any suitable source of constant frequency voltage for accurately controlling the frequency of the multivibrator. This source may be a sine wave of suitable frequency, or a square wave voltage, derived by means of an auxiliary multivibrator, from the commercial power line or a high Q electromechanical resonator. The period of oscillation of this multivibrator A is equal to one-half second, this frequency being obtained by a proper selection of the resistor and capacitor elements in the coupling circuit, as is well known.

A first control impulse is derived from the multivibrator A through a circuit including a differentiating network 9, 11, a coupling capacitor 13 and an isolating resistor 15. The derived impulse is applied to the grid 25 of tube 20 of the multivibrator B. A similar control voltage is derived from the other multivibrator tube 19 through a similar differentiating circuit 21, 23 which is coupled to the grid 17 of the tube 18 of multivibrator B.

The natural frequency of the multivibrator B is approximately one-fifth that of the multivibrator A, the effect of the control impulses being to synchronize the low frequency oscillations with the high frequency oscillation at a frequency ratio of 1:5. The output voltage at the plate of tube 18 of the multivibrator B is indicated by the correspondingly labeled curve of Fig. 2.

The circuit constants of multivibrator C are adjusted so that the tube 29 produces an unsymmetrical square wave output approximately of the type illustrated in curve "29 plate" of Fig. 2. The uncontrolled oscillator period differs slightly from this curve, however, in that the

time constants of the circuit are such that the output voltage of the tube 29 tends to remain at its maximum value until a time somewhat after the time interval 5, but prior to time interval 6, as indicated by the dotted extension 31 of the curve. However, a negative control impulse 32 is applied to the grid of tube 27 from multivibrator A through a differentiating circuit 33, 35, by means of a conductor 34, at time interval 5, which shifts the plate current from tube 27 to tube 29, thus reducing the plate voltage of the latter tube. The grid of tube 27 is actually impressed with a series of alternate positive and negative impulses occurring every one-quarter second, but due to the natural period of oscillation only the impulse 32 at successive time periods 5 causes the current reversal to take place, and this happens slightly before the time at which it would normally occur. That is, the negative impulses occurring at time periods 1 and 3 are unable to produce this control since the positive voltage on the grid of tube 27 has not leaked off in time to allow any impulse except the one occurring just before the end of the normal period to have any effect.

The control or grid voltage for tube 29 may be derived from multivibrator A or B, preferably the latter, to avoid adjustment during starting periods. Thus, its grid is coupled to a differentiating network 37, 39 which produces a series of impulses of the type illustrated in "29 grid" curve of Fig. 2. It will be seen that a negative synchronizing pulse is applied to the tube at time period 1. Consequently, the frequency of the unsymmetrical wave is equal to the frequency of the symmetrical wave produced by the low frequency multivibrator B. A differentiating circuit 41, 43 coupled to the plate of tube 29 provides at point 36 a series of impulses which occur at the time intervals indicated in the curve "Diff. 29 plate" of Fig. 2.

Multivibrator D also produces an unsymmetrical wave. In the present instance, however, its dissymmetry is such that its reversal takes place at a later time than that of the multivibrator C or B. Referring to curve "49 plate" it will be noted that the frequency of oscillation is equal to that of multivibrator B, but that the intermediate reversal takes place at time period 7 instead of at time period 5 as in the other case. As before, the dotted line 31 indicates the approximate natural switching or reversal time of the multivibrator. It will be observed that tube 45 is coupled to a differentiating circuit 47, 48 by a conductor 38 which applies to the grid of tube 45 a series of control impulses of the type illustrated in curve "45 grid," one of which occurs at time period 7.

The ratio of the time duration of the first half cycle of the unsymmetrical square waves to the time duration of the second half cycle is known as the "dissymmetry ratio" of the wave. The dissymmetry ratio of multivibrator C is therefore 2:3 and the dissymmetry ratio of multivibrator D is 3:2.

A conductor 40 is connected between the grid of multivibrator tube 49 and a differentiating circuit 51, 53 for deriving impulses from the plate of tube 18. The derived negative impulses which occur at time period 1 control the frequency of the unsymmetrical multivibrator. Another differentiating circuit 55, 57 is connected to the output circuit of tube 49 for deriving impulses timed in accordance with the curve "Diff. 49 plate." These impulses are added to the dif-

ferentiated output impulses derived from the plate of tube 29 of multivibrator C by a circuit including series resistors 59 and 61 which are both connected to ground through a common resistor 63. The impedance of the common resistor 63 is small with respect to that of the series resistors 59 and 61 to prevent interaction between the circuits.

Electronic toggle switch E includes a pair of screen grid thermionic tubes 65 and 67. The plate of each tube is connected to the screen grid of the other tube through a series resistor. Plate voltage is supplied through output resistors 64 and 71. A balancing potentiometer 73 is connected between cathodes of the two tubes, the movable arm being connected to the ground circuit of the system. The operation of this toggle switch is as follows. Assuming tube 65 to be conducting, the voltage drop in resistor 69 reduces the screen voltage applied to tube 67, the effect of which is to decrease the plate current in tube 67, thus increasing the potential of its plate with respect to its cathode. This potential increase is applied to the screen grid of tube 65 tending to increase its plate current still further. This continues until tube 65 is operating at plate current saturation and tube 67 is at plate current cut-off. This condition may be maintained indefinitely, but when a negative impulse is applied to the control grid of the tube 65 the plate current of the tube decreases, applying a more positive voltage to the screen grid of tube 67 to produce an increase in plate current in the latter tube. The reversal continues until tube 65 is reduced to plate current cut-off, and tube 67 is operating at saturation. This condition again is maintained until a negative impulse is applied to the control grid of tube 67, upon which the process is again repeated.

The two tubes 65 and 67 are coupled to control circuits by conductors 42 and 44. The former applies the added impulses which are present at point 36 and which are produced by the two unsymmetrical multivibrators, to tube 65, while the latter applies an output impulse which is obtained by differentiation of a current in a resistance 46 common to both anode-cathode circuits of the two tubes of multivibrator B. Two negative control impulses per cycle of multivibrator B, spaced 180 degrees in phase, are therefore obtained. The voltages applied to the two grids are illustrated in Fig. 2.

Assuming that the tube 65 is conducting, and tube 67 is cut off, the voltage drop across resistor 69 is a maximum, and that across resistor 71 is a minimum. Curves N and A are the output voltages produced across the correspondingly lettered output terminals. At time interval 5 a negative impulse is applied to tube 65 over lead 42 causing the toggle switch action to shift the plate current from tube 65 to tube 67. The voltage across output terminals N is therefore reduced to a low value, while that across output terminals A is a maximum. A quarter second later a negative impulse is applied to tube 67 over connection 44, which then causes tube 67 to go to plate current cut-off in the manner described above. A quarter second later, a second impulse is applied to tube 65 over conductor 42 and the toggle switch action again takes place.

The next impulses occur at time period 1. The positive impulse applied to tube 65 has no effect because of the series grid resistor 77 which prevents the grid voltage from rising above a value approximately equal to the cathode voltage. At

the same time, however, a negative impulse is applied to tube 67 to repeat the cycle. Consideration of curves N and A shows that the output voltage at the N terminals is the dash-dot of the letter N, while that across the A terminals is the interlocked or complementary dot-dash of the letter A. These voltages may be applied to key or control the directional transmitters in any conventional manner.

An alternative embodiment of this is illustrated in Figs. 3 and 4, to which reference is now made. Briefly, this invention differs from the previously described embodiment in that the timed impulses which operate the toggle switch are produced by a somewhat different arrangement. Thus, instead of combining asymmetrical square waves, two symmetrical square waves are produced having a 5:1 frequency ratio and the desired pulses selected by means of sine wave voltages whose phase is adjusted so that the positive maximum occurs at a time which includes a desired impulse.

Tubes 105 and 107 and the associated condensers and resistors constitute a multivibrator operating to produce symmetrical square waves having a period of a half second. This multivibrator may be synchronized with some constant frequency potential source, or by a high Q electromechanical resonator in the usual manner. The voltage appearing at the plate of tube 107 is indicated in the correspondingly tilted curve of Fig. 4. A pair of tubes 109, 111 are also connected in a multivibrator circuit and are synchronized by suitable coupling connections between their grids and the respective plates of tubes 105 and 107. The time constant of the second multivibrator is adjusted so that it operates at one-fifth the frequency of the first multivibrator, the plate voltage of the tube 109 being illustrated in Fig. 4.

A pair of triodes 113 and 115 have their anode electrodes connected in parallel, and biasing means, such as a resistor 121, in the common cathode circuit. The input electrodes of these tubes are coupled, respectively, to a pair of resistance-capacitance phase shifting networks 123 and 125. The plate electrode of multivibrator tube 109 is coupled to the input of the phase shifting network 123, and the plate electrode of multivibrator tube 111 is coupled to the input of the phase shifting network 125. In addition, the input electrode of tube 113 is coupled through an isolating resistor 127 to differentiating network 129, 131 coupled to the plate of multivibrator tube 107. The input electrode of tube 115 is coupled through a similar isolating resistor 133 to a differentiating network 135, 137, which is also connected to the plate of multivibrator tube 107.

The resultant voltage which is applied to the input grid electrode of tube 113 is shown in the correspondingly titled curve of Fig. 4. The phase shifting network 123 is essentially a low pass filter which modifies the rectangular applied voltage from the plate of tube 109 to produce substantially a sine wave, the phase of which is shifted 126 degrees with respect to the fundamental component of the square wave. Thus, if the time period 1 represents the center of the positive peak of the rectangular plate voltage at tube 109, and if the period of oscillation of the low frequency wave is equal to two and one-half seconds, each reversal of the high frequency multivibrator is spaced apart, in time, one-tenth of a cycle or 36 degrees. By delaying the volt-

age applied to the grid of tube 113 126 degrees, the peak of the resultant sine wave will occur at time interval 4. In addition to the sine wave voltage, a series of differentiated impulses are also applied to the grid of tube 113. These impulses are superimposed upon the sine wave and occur upon each alternation of the high frequency multivibrator. The resultant grid voltage on tube 113 is therefore that indicated in Fig. 4. Resistor 121 is selected so that the normal negative bias of tube 113 is at least equal to or greater than the peak of the applied sine wave voltage. Consequently, during the major portion of the cycle, tube 113 is inoperative since it is biased far beyond cut-off. Only during intervals near the peak of the positive half of the sine wave voltage will the tube be in an operative condition, and it is at this instant, time period 4, that a timing impulse arrives which then appears in the output circuit of the tube. Consequently, the sine wave selects desired ones of the high frequency impulses and applies them to the grid of tube 119.

The plate voltage of tube 111 is in phase opposition to that of tube 109, and is applied to the input of the phase shifter 125. The resultant voltage applied to the grid of tube 115 is illustrated in Fig. 4. As before, the resultant voltage comprises a sine wave voltage and a series of impulses. The time delay of the phase shifter 125 is adjusted so that the phase of the grid voltage is 234 degrees behind that of the fundamental component of the applied square wave. Consequently, the positive peak of the applied sine wave voltage occurs at time interval 2, and only the derived impulse reaching the grid at that instant is able to operate tube 115. The output circuits of the tubes 113 and 115 are connected in parallel, and therefore the sum of the voltages appearing in their respective input circuits appears in the common output circuit and is applied through a capacitor 139 to the grid of tube 119. Tubes 113 and 115 may therefore be termed "adder tubes". Tubes 119 and 117 constitute an electronic toggle switch which functions in a manner similar to that illustrated in Fig. 1. However, it is to be noted that the interconnection is between the plate and grid electrodes, since triodes have been employed in the present instance.

The grid voltage of tube 119 is illustrated in the correspondingly titled curve of Fig. 4. The positive impulses selected at the input circuits of the tubes 113 and 115 are inverted in sign by these tubes and appear at successive intervals 2 and 4. The grid of tube 117 is coupled to a resistor 140 in the common plate circuit of tubes 109 and 111 of the second multivibrator. As in the case described above, the sudden increase in plate current at each alternation of this multivibrator produces two negative impulses per cycle which occur at time intervals 3 and 6. It will be observed that the control impulses which are applied to the electronic toggle switch are identical to those which operated the device in the arrangement illustrated in Fig. 1, and it therefore follows that the output available at the terminals A and N will conform to the characteristic keying letter as desired.

While this invention has been described in connection with A—N keying, it is to be understood that the principles herein disclosed may also be employed to produce interlocked keying impulses of the E—T type, if desired, or any other simple, repetitive switching sequence.

While I have illustrated separate triodes in each of the multivibrators, it is to be understood that tubes employing double triode elements may be utilized. In addition, while I have indicated a timing cycle which produces a keying impulse timed in accordance with the conventional practice, the various timing elements of the multivibrator tubes may be selected to produce control voltages of greater or less frequency if desired.

I claim as my invention:

1. An electronic keying device for producing complementary keying signals comprising a pair of thermionic tubes having input and output circuits, means interconnecting the input circuit of each tube with the output circuit of the other for causing output currents in each tube to bias off the other tube, means including a symmetrical multivibrator for producing first control impulses which occur at regular spaced intervals, means including a pair of unsymmetrical multivibrators for producing second impulses which occur at fixed intervals before and after alternate impulses from said symmetrical multivibrator, and means for applying said first and second control impulses to the input circuits of said tubes, respectively each control impulse causing the output current of the controlled tube to vary once between predetermined limits, whereby the output current of the other tube is varied oppositely, and means for deriving keying signals proportional to the amplitudes of said output currents.

2. An electronic keying device for producing complementary keying signals comprising means for producing a first symmetrical square wave of a predetermined frequency, means for producing a second symmetrical square wave having a second frequency equal to one-fifth said predetermined frequency, means for producing an unsymmetrical square wave whose frequency is equal to said second frequency, the duration of the first half cycle being related to the second half cycle in the ratio of 2:3, means for producing a second unsymmetrical square wave whose frequency is also equal to said second frequency, the duration of the first half cycle being related to the second half cycle in the ratio of 3:2, means for deriving timing impulses from said square waves, a pair of thermionic tubes having input and output circuits, means interconnecting said tubes for causing output currents flowing in each of said tubes to bias the other of said tubes to cut-off, and means for applying said timing impulses to said thermionic tubes to cause output currents to alternate between said tubes in a desired sequence.

3. An electronic keying device for producing complementary keying signals comprising means for producing a symmetrical square wave of a predetermined frequency, means for producing a second symmetrical square wave having a second frequency less than said predetermined frequency, means for producing an unsymmetrical square wave whose frequency is equal to said second frequency, and whose ratio of dissymmetry is 2:3, means for producing a second unsymmetrical square wave of said second frequency whose ratio of dissymmetry is 3:2, means for synchronizing said second symmetrical and said unsymmetrical square waves by said first symmetrical square wave, means for deriving timing impulses from said synchronized impulses, and means for producing keying signals varying in accordance with said timing impulses.

4. A device of the character described in claim 3 in which said means for producing keying signals includes a pair of tubes having their control and plate circuits interconnected for applying a controlling potential to each tube proportional to the plate current of the other.

5. A device of the character described in claim 3 in which said means for producing keying signals includes a pair of screen grid tubes having the plate of each tube connected to the screen grid of the other, and means for applying said timing impulses to the control grids of said tubes.

6. An electronic keying device for producing complementary keying signals comprising means for producing a symmetrical square wave of a predetermined frequency, means for producing a second symmetrical square wave having a second frequency less than said predetermined frequency, means for producing an unsymmetrical square wave whose frequency is equal to said second frequency and whose ratio of dissymmetry is 2:3, means for producing a second unsymmetrical square wave of said second frequency whose ratio of dissymmetry is 3:2, means for synchronizing said second symmetrical and said unsymmetrical square waves by said first symmetrical square waves, means for deriving timing impulses from said synchronized impulses, means for adding timing impulses derived from said unsymmetrical impulses, a pair of screen grid tubes having the plate of each tube connected to the screen grid of the other, means for applying said added timing impulses to the control grid of one of said tubes, and means for applying timing impulses derived from said second symmetrical square wave to the control grid of the other of said tubes.

7. An electronic keying device for producing complementary keying signals comprising a pair of thermionic tubes having input and output circuits, means interconnecting the input circuit of each tube with the output circuit of the other for causing output currents in each tube to cut off the current in the other tube, a source of equally spaced timing impulses, means for selecting desired ones of said timing impulses and rejecting undesired impulses, and means for applying selected impulses to said thermionic tubes alternately, each impulse causing the output current of the controlled tube to vary once between predetermined limits, whereby the output current of the other tube is varied oppositely, and means for deriving keying signals proportional to the amplitudes of said output currents.

8. A device of the character described in claim 7 in which said means for selecting desired ones of said timing impulses includes a pair of biased tubes, and means for applying sine wave voltages of predetermined phase and said equally spaced timing impulses to the grid electrodes of said tubes so that said impulses appear in the output of said tubes only when the polarity and amplitude of said sine wave is sufficient to overcome the bias of said tubes.

9. An electronic keying device for producing complementary keying signals comprising means for producing a first symmetrical square wave of a predetermined frequency, means for producing a second symmetrical square wave having a second frequency equal to one-fifth said predetermined frequency, means for filtering and determining the phase of said second square wave, means for deriving timing impulses from said first symmetrical square wave, means for utilizing a sine wave voltage to select desired ones of

said timing impulses, a pair of thermionic tubes having input and output circuits, means interconnecting said tubes for causing output currents flowing in each of said tubes to bias the other of said tubes to cut-off, and means for applying said timing impulses to said thermionic tubes to cause output currents to alternate between said tubes in a desired sequence.

10. An electronic keying device for producing complementary keying signals comprising means for producing a first symmetrical square wave of a predetermined frequency, means for producing a second symmetrical square wave having a second frequency equal to one-fifth said predetermined frequency, means for deriving two sine wave voltages of predetermined phase for said second symmetrical square wave, means for deriving timing impulses from said first symmetrical square wave, means for combining said sine wave voltages with said derived timing impulses to produce spaced controlling impulses occurring at differently spaced intervals, a pair of thermionic tubes having input and output circuits, means interconnecting said tubes for causing output currents flowing in each of said tubes to bias the other of said tubes to cut-off, and means for applying said controlling impulses to said thermionic tubes to cause output currents to alternate between said tubes in a desired sequence.

11. An electronic device comprising in combination, a pair of discharge devices having input and output circuits, means interconnecting said circuits for causing currents flowing in the output circuit of each tube to apply a biasing voltage to the other tube so that one of said devices is biased to cut-off when the other is conducting, means for producing differently timed control pulses, and means for applying said pulses to said devices, respectively, the first series of pulses occurring at regular intervals, the second series of pulses occurring at intervals spaced equally before and after alternate pulses of said first series.

12. An electronic device comprising the combination of means for producing a symmetrical

square wave of a predetermined frequency, means for producing a second symmetrical square wave having a second frequency less than said predetermined frequency, means for producing an unsymmetrical square wave whose frequency is equal to said second frequency and whose ratio of dissymmetry is 2:3, means for producing a second unsymmetrical square wave of said second frequency whose ratio of dissymmetry is 3:2, means for synchronizing said second symmetrical and said unsymmetrical square waves by said first symmetrical square waves, and means for deriving timing impulses from said synchronized impulses.

13. An electronic device comprising, in combination, a pair of discharge devices having input and output circuits, means interconnecting said circuits for causing currents flowing in the output circuit of each tube to apply a biasing voltage to the other tube so that one of said devices is biased to cut-off when the other is conducting, means for producing timed control pulses, means for applying said pulses to each of said devices, each pulse causing the state of conductivity of said devices to be reversed, and output means coupled to said output circuits for deriving complementary voltage alternations.

14. An electronic device comprising, in combination, a pair of discharge devices having input and output circuits, means interconnecting said circuits for causing currents flowing in the output circuit of each tube to apply a biasing voltage to the other tube so that one of said devices is biased to cut-off when the other is conducting, means for producing control impulses, means for applying said control impulses to said devices, each impulse causing the state of conductivity of said devices to be reversed, said pulses being timed so as to produce regular alternate short and long periods of conductivity in each of said devices, and means for deriving complementary output voltage alternations from said discharge devices.

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