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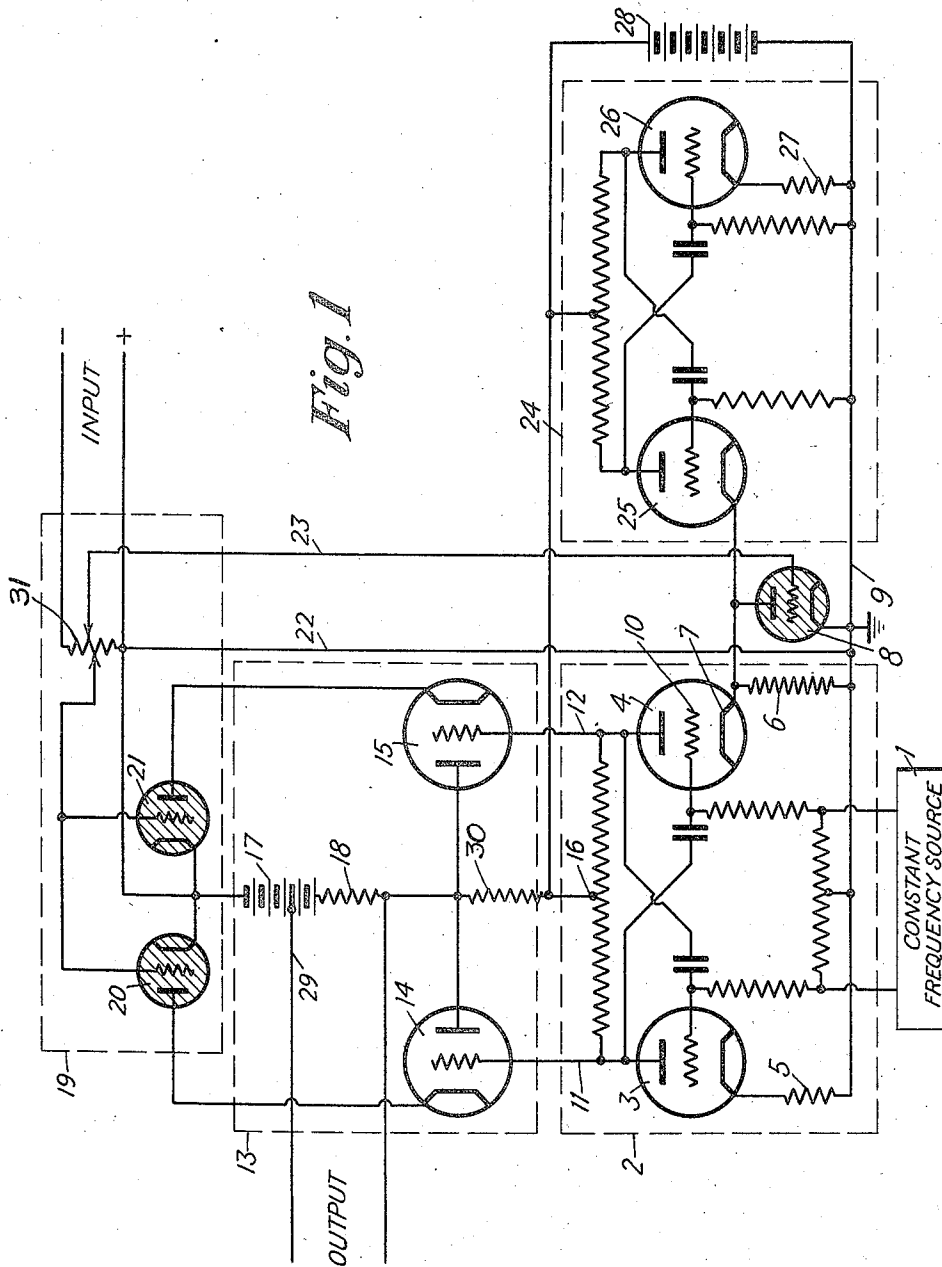
M. MORRISON

2,436,725

ELECTRONIC TIMING APPARATUS

Filed Oct. 23, 1943

2 Sheets-Sheet 1



INVENTOR
Morrison

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2 Sheets-Sheet 2

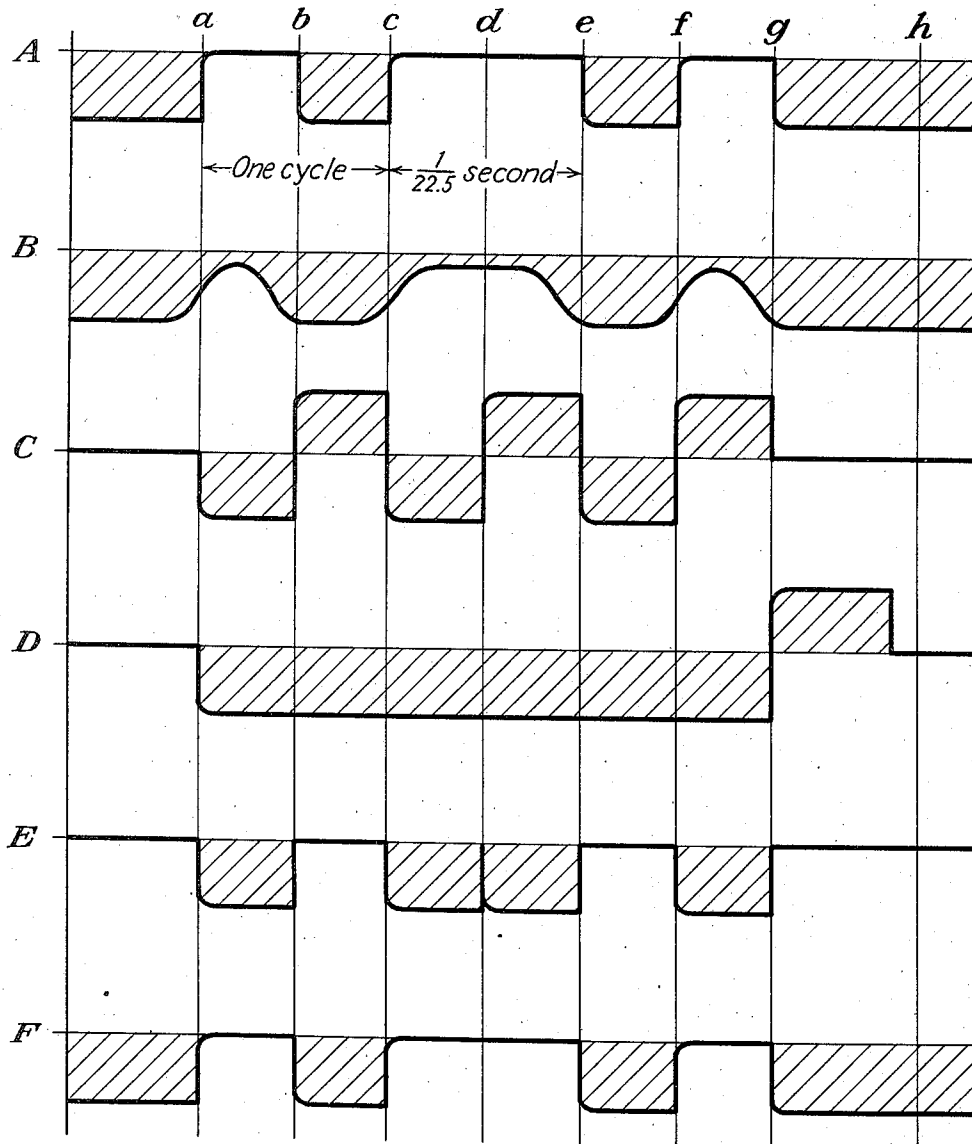


Fig. 2

INVENTOR
Morrison

UNITED STATES PATENT OFFICE

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ELECTRONIC TIMING APPARATUS

Montford Morrison, Upper Montclair, N. J.

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4 Claims. (Cl. 250-27)

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The invention claimed in this application relates to electric timing apparatus and relates in particular to electronic timing art not necessarily associated with electronic regenerative telegraph repeaters, in which latter art the applicant's claims under the disclosure herein, appear in a copending application, Serial No. 507,424 filed on October 23, 1943, United States Patent 2,406,096 dated August 20, 1946.

Among the objects of the invention claimed hereunder are; to provide an electronic means of, and method for, precise timing of short periods; to provide a method of electronic timing in which the time reckoned is a result of two frequencies; to provide an improved method of voltage-capacitance-resistance timing; to provide a method of electronic timing in which an improved precision is achieved and to provide such objects with simplified apparatus.

Among the objects of the invention are; to provide more dependable means for repeating equal-unit-code telegraph signals in a regenerated form; to provide an improved method of synchronism between the sending distributor and the receiving distributor employed, and equally applicable to, start-stop and continuous distributor systems; to reduce the liability of error common to present equal-unit-code telegraph systems; to provide greater precision in the timing, to permit a large number of repeaters to be used in tandem; to accomplish these objects without the use of any mechanical moving parts, and to achieve the results by electronic tubes and circuits.

In the prior art methods of, and apparatus for, regenerating equal-unit-code telegraph signals, there has been employed mechanical distributors and mechanical relays, principally for performing the functions required, and in some cases electronic tubes have been added to or employed to supplement and/or substitute for some of the functions and operations previously performed by some of the mechanical devices.

In the present invention, the entire operation of receiving the distorted signal and repeating it in a regenerated form is performed entirely and completely by electronic and electrical means without the necessary employment of any mechanical devices.

While this system is described as, and disclosed as, a telegraph repeater, it will be obvious to those skilled in the art that this invention is not limited to repeater circuits and may be advantageously used as a receiving circuit if and when desired.

In the mechanical devices of the prior art, great

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difficulty is encountered in maintaining a high degree of permanent relativity between the speed of operation at the sending circuit and the speed of operation at the receiving circuit.

In the present invention, means is provided whereby the speed of the operation in the sending circuit and the speed of the operation in the receiving circuit may be maintained at any rate desired, having a fixed permanent value with an accuracy up to one part in one million, if desired.

In the prior art systems employing mechanical devices as means for local circuit distribution, considerable difficulty is experienced in maintaining the proper phase relation between the sending and receiving distributors, quite often resulting in printing errors.

In the present invention, the difference between the phase position of the sent signal and that of the received signal can be reduced to almost any practical value desired and a limit of 10% may be easily achieved in practical applications of the present invention.

In the prior art mechanical devices, particularly those employing rotating distributors, when used in start-stop systems, it has been found expedient to operate the receiving distributor at a faster speed than that at which the sending distributor is operated because of the several inertias encountered in the operation of the system.

In the present invention, since no means nor methods are employed which possess any practical inertia, the sending and receiving distributors may operate at the same speed, if and when desired. In the embodiment set forth in the description hereunder, and for simplicity in teaching the fundamental spirit of the invention, the engineering refinements and the practical expediences have been avoided and the embodiment of the invention in the description will be limited to a unidirectional repeater, but it will be obvious to those skilled in the art to which this invention appertains, that this invention may be embodied in a two-way repeater system of a common balanced type well known in the art.

As set forth among the objects hereof, the present invention may be embodied in continuous distributor systems, as well as in start-stop distributor systems; but in the embodiment disclosed herein, the description will be limited to start-stop systems, as those skilled in the art will be able to apply the teachings given for start-stop distributor telegraph systems to telegraph systems employing continuously operating distributors.

Other and further objects and features will

be pointed out and will be obvious in the reading of the description hereunder, particularly when taken in connection with the drawings in which Fig. 1 is a diagrammatic embodiment of one form of the invention, and Fig. 2 is a series of graphs representing signals, useful in understanding the operation of the invention.

Referring to Fig. 1, 1 is a constant frequency source which may be any suitable source but specifically may be a compensated tuning fork amplifier such as is commonly used for time measurements and which is commonly sold on the market, with a guaranteed accuracy of one part in a hundred thousand and which may on special order be furnished with an accuracy up to one part in one million, for frequencies within the lower audio range. The frequency of source 1 will be set at, for the present embodiment, a frequency of 472.5 cycles per second. The usefulness of this value in the present embodiment will be hereinafter pointed out.

The circuit enclosed within the dotted area 2 represents a multivibrator circuit well known in the art, and the constant frequency source 1 injects a synchronizing voltage into the multivibrator circuit, which, as is well known in the art, will, under proper conditions, fix the frequency of the multivibrator circuit at a definite submultiple of the frequency of source 1.

Multivibrator 2 is constructed to operate at a submultiple frequency of the frequency of source 1, represented by the 21st submultiple thereof, which means an operating frequency for multivibrator 2, of 22.5 cycles per second for the fundamental frequency represented by a dot and a space. This means that the constant frequency source operates at the 21st harmonic of the fundamental frequency of the multivibrator 2, which means that there are 10.5 constant-frequency-source cycles for each half-cycle of the multivibrator. The usefulness of this 10.5 cycle constant frequency source ratio to one-half cycle of the multivibrator 2 will be hereinafter pointed out.

The multivibrator circuit is provided with two tubes, 3 and 4, and this multivibrator circuit differs from the common form of multivibrator circuit only necessarily in respect to the cathode grid circuit of tube 4, which is provided with a resistor 6 connected to the cathode 7 and to the plate of the gaseous triode 8, having its cathode connected to ground-lead 9. The ohmic value of resistor 6 is too high to permit the circuit enclosed within the area 2, to function as a multivibrator, when the plate current of tube 4 is limited by said resistor, and said resistor has substantially the same effect as an open circuit between cathode 7 and ground-lead 9, but said resistor is low enough to prevent the potential difference between said cathode and said ground-lead, from drifting to different and indefinite values, when multivibrator 2, is not oscillating.

When gaseous triode 8 is in a nonconducting state, the cathode 7 is substantially in effect disconnected from the ground-lead 9, under which conditions only the resistor 6 is interposed between cathode 7 and ground-lead 9, and said resistor being sufficiently high to produce in effect cut-off of the plate current in tube 4, so that under these conditions tube 4 is conducting no current and tube 3 is conducting the normal amount of current for the plate voltage employed under normal multivibrator operation.

If source 1 is under proper operation and cathode 7 is connected to ground-lead 9, the multivibrator 2 will start into operation instantly, pro-

ducing a fundamental frequency between leads 11 and 12 of 22.5 cycles per second with a fundamental frequency accuracy determined by the accuracy of the source 1 and with a phase lag behind the instant of closing of cathode 7 onto lead 9 of a maximum not to exceed 10% of the half-period of the frequency of the multivibrator 2, since the multivibrator 2 will lock in with the first lobe of the frequency source having the proper polarity for synchronization and this cannot be more than the time represented by one cycle of the frequency source 1. Since there are 10.5 cycles of source 1 for a single half-period of the fundamental frequency of multivibrator 2, this lag in phase position in getting started cannot exceed 10% of the half-period value, as will be understood by those skilled in the art.

The means of, and method for, closing cathode 7 onto lead 9 by the employment of gaseous triode 8 will be hereinafter pointed out.

It is well known in the art that the ability of multivibrator circuits to maintain an invariable procedure in operation depends upon all parameters of the multivibrator circuit being maintained constant, including the circuits loading the said multivibrator.

In the present invention, it is desirable to not only maintain an unvarying performance in the multivibrator circuit, but its wave-form is desirably maintained under varying conditions of employment. This may be accomplished in one of several ways, one of which is illustrated diagrammatically in the dotted area 13, which forms a highly practical arrangement. Two tubes, 14 and 15, have the control grids thereof connected respectively to the plates of tubes 3 and 4, and the plates of tubes 14 and 15 are connected together and thence connected to the load center 16 of the multivibrator circuit 2. This arrangement provides sufficient grid plate bias voltage from multivibrator circuit 2 to cut off plate current in tubes 14 and 15 in the presence of multivibrator operation.

Those skilled in the art appreciate that in multivibrator operation the voltage is developed first between leads 11 and point 16, with substantially no voltage between point 16 and lead 12, for one half-period of operation of multivibrator 2, and the conditions are reversed for the other half-period of operation; that is, voltages develop between lead 12 and point 16 with substantially no voltage between lead 11 and point 16.

Under this condition of operation, tubes 14 and 15, under the potential of plate battery 17, and a properly closed circuit, produce in the load 18 an accurate replica of the voltage wave-form produced by multivibrator 2 and without distortion.

Since the operation of tubes 14 and 15 is such that no appreciable load is taken from multivibrator 2, under any condition of operation of these tubes, that is, whether plate current is present or not in said tubes, the shape of the grid control voltage of these said tubes, will follow the shape of the voltage in the multivibrator circuit 2 always, and if and when the tube circuits 14 and 15 are properly closed, the plate currents of said tubes will assume so-called square wave-forms. Tubes 14 and 15, being a push-pull circuit, or in effect the reverse of this which may be referred to as a pull-push circuit, the wave-form in load resistor 18 is, of course, a rectification of the wave-form in multivibrator 2 and, therefore, always has a positive or always a negative outline, as the case may be.

With multivibrator 2 in operation, the form of

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the voltage across load resistor 18, which represents the form of voltage across the output circuit of the repeater and so designated in Fig. 1, will follow the rectified outline of the lobes of multivibrator 2 only when the cathode circuits of tubes 14 and 15 are closed for an entire half-period of operation of the multivibrator circuit.

The circuit closed in dotted area 19 represents one means of closing the circuits of tubes 14 and 15 referred to above, and this means comprises gaseous triodes 20 and 21 so connected into the cathode circuits of tubes 14 and 15, as to close these said cathode circuits when the said tubes 20 and 21 are caused to assume an electrically conducting state.

In the present embodiment, the input circuit so designated in Fig. 1, is assumed to be a closed circuit system having the correct polarity to provide the proper bias for the grids of tubes 20 and 21, to prevent said tubes from becoming electrically conductive under the cathode plate potentials applied to them, when the input line current is at its normal steady state value in a closed circuit system, as commonly employed in the art.

Under operation, tube 20 has cathode plate voltage applied to it only during one half-period of the multivibration operation, when tube 14 is drawing plate current. At the same time, tube 15 is biased beyond cut-off and tube 21 has no cathode plate voltage applied to it. This is the status for one half-period of the multivibrator 2, and for the other half-period the conditions are reversed, when tube 21 has voltage applied to it for one half-period of the multivibrator circuit during which time tube 20 has no cathode plate potential applied to it.

Under these conditions of operation, when the input line voltage is reduced to a value which permits tubes 20 and 21 to become electrically conducting under the operating cathode-plate potentials, only one of the two gaseous triodes 20 and 21 will become electrically conducting and that particular one is the one which has the plate potential applied to it under the multivibrator operation already discussed. Assuming this to be tube 20, tube 20 closes the cathode circuit of tube 14 and holds it closed as long as there is plate potential produced by tube 14 which means that tube 20 is closed for a complete half cycle of multivibrator 2 and its gaseous conduction is extinguished by the disappearance of plate voltage on tube 20 at the end of the half-period of multivibrator 2. Under these conditions of operation, the output circuit has produced in it a replica of a half cycle, rectified or otherwise, of multivibrator 2.

If, at the end of the said half-cycle and at the beginning of the second half-cycle, the line input voltage remains at a reduced value, tube 21 becomes electrically conducting and a replica of the wave-form of the second half-cycle of multivibrator 2 is produced in the output circuit, rectified or otherwise. This process is repeated at the beginning of each half-period of the multivibrator 2, only if, and when the input voltage is sufficiently reduced at that instant to cause such operation.

Similarly, gaseous triode 8 has its grid biased by the input voltage through leads 22 and 23, sufficiently to prevent gaseous conduction through tube 8 under normal steady state input line current conditions.

In an operation similar to that of tubes 20 and 21, tube 8 assumes a state of electrical conductivity by reduction of input line voltage, and the

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gaseous conduction once instituted in tube 8 continues as long as the plate voltage thereof is above the ionization value for the tube employed.

Within the dotted area 24 there is contained a multivibrator circuit which produces an unsymmetrical wave-form. Those skilled in the art of making and using multivibrators appreciate that the length of the duration of the positive and negative lobes of the multivibrator output voltages do not necessarily have to be made equal and that great differences in the base lengths of these positive and negative lobes may be easily attained in practice.

The multivibrator 2, it follows necessarily from the description thereof, has a symmetrical lobe output circuit of a frequency of 22.5 cycles per second.

The multivibrator in area 24, is so constructed that one of its voltage lobes has a duration equal to a multiplicity of the lobes of multivibrator 2, the actual length of which depends upon the number of lobes of multivibrator 22 that are to be used in the operation of the device, as will be more fully hereinafter pointed out.

The cathodes of tubes 4 and 25 are connected in parallel and to the plate of tube 8 and the cathode-ground leads of multivibrators 2 and 24 are connected together. Multivibrators 2 and 24 may be fed from a common plate-voltage supply 28.

A resistor 30 may be employed, if and when desired, to further limit the circulating current between batteries 17 and 23, over and above that provided by resistor 18.

The function of gaseous triode 8 is to set the two multivibrators 2 and 24 into operation simultaneously, which will be more fully understood from a description of the operation of Figure 1, in connection with a typical example of its employment, which in the present case, will be taken to be that of a start-stop printer of one of the commercial designs commonly found in practice and employing a so-called 7.42 unit code.

It is pointed out here, however, that the invention is not limited to start-stop circuits but may be used in systems employing continuous distributors, which has been hereabove pointed out.

Referring to Fig. 2, the curve along abscissa A represents the line signals for the letter D sent out from a start-stop printer of the kind referred to. The duration of one complete operation is represented by the distance from *a* to *h*. The curve along abscissa B represents the appearance of this signal after some distortion has been encountered along the line and in the circuits and it is desired to repeat and regenerate curve B back into the form A, as is well understood by those skilled in the art.

Referring to Fig. 1, it will be necessary to set the status of the circuit when the input voltage B is received to be repeated and regenerated. Multivibrators 2 and 24, having the cathode circuits of tubes 4 and 25 open, allow the passage of current through tubes 3 and 26 as a steady state condition. The plate current of tube 26, under these initial conditions, has no specific function, but its useful function under operation will be pointed out later on.

Before any input signal is received, the input line voltage is at its normal value, and tubes 8 and 20 are in a nonconducting electrical state. Tube 3 of multivibrator 2 has full plate current flowing which biases out tube 14. Tube 15 is passing plate current because tube 21 was left

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in an electrical conducting state from the previous operation. The output voltage has a continuous form due to plate current through tube 15, thus repeating from the input circuit to the output circuit the steady state condition.

Referring to Fig. 2, curve B, as time advances from zero to the instant a , the grid bias of tube 8 is reduced sufficiently to effectively connect the cathodes of tubes 4 and 25 to the ground-lead 9. The small drop in potential across tube 8 may be balanced, if and when desired, by any suitable means and indicated in the figure as resistors 5 and 27.

Referring to Fig. 2, curve B, time is assumed to have progressed from the zero position to the instant a when the input voltage, Fig. 1, has reduced the bias voltage value of tubes 8 and 20 sufficiently to permit of gaseous conduction in these tubes upon the appearance of the operating plate voltage.

The value of the resistance of 6 is too high to permit the two multivibrator circuits to operate as such, but is sufficient to insure a definite plate voltage across the tube 8 and therefore at the time instant a , the cathodes of tubes 4 and 25 are effectively connected to the ground-lead 9 and the two multivibrators start in operation producing the wave-forms for which they are constructed. Frequency source 1, being in operation, multivibrator 2 locks in with it, not more than 10% of a single dot period behind the phase instant a , and multivibrator 2 continues in operation as long as the cathode 7 is effectively connected to the ground-lead 9.

Referring to Fig. 2, curve C represents the voltage output of multivibrator 2 and a rectification of this curve represents the line output voltage which may be biased if and when desired, as indicated by the connection at point 29, Fig. 1.

It will be appreciated that the plate voltage impressed upon tube 8 by multivibrator circuit 2 is only present for each certain half cycle thereof and means is provided for maintaining gaseous conduction in this tube for the necessary duration of the operation cycle. This is accomplished by multivibrator 24, the wave-form of which is indicated by curve D, Fig. 2, and which provides plate current for tube 8 for the three half cycles of six units of the repeater operation during which tube 4 is idle and allows tube 8 to be restored to its non-conducting status at the ends of the code cycle.

Referring to Fig. 2, reduction of voltage in curve B, between the time intervals $a-b$, operates to utilize the lobe of multivibrator 2, curve C, for that period, to produce the line current curve E during the same period. There being no reduction in line voltage for the period $b-c$ for the curve B, the multivibrator lobe for that period, curve C, produces no line voltage, as shown in curve E.

In the case where the reduction in line voltage lasts for two units as indicated between the lines $c-e$, curve B, two consecutive lobes of the multivibrator shown along curve C are caused to produce two units of line signal current for that period, as shown along curve E.

If line bias is used, the signals shown along curve E can be restored to the equivalent closed circuit form indicated along curve F, as is fully understood by those skilled in the art.

The curve along abscissa A is assumed to be sent out at a conventional rate of 60 words per minute which fixes combined frequency of a dot and a space at 22.5 cycles per second, making the

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dot or marking period equal to a half a period of the multivibrator 2.

The period of multivibrator 24 is slightly less than 7.42 units, or less than the distance $a-h$, as shown along curve D, Fig. 2, one lobe having six units of duration, as illustrated by the curve for the embodiment herein given. The length of duration of the long lobe of curve D depends upon the use to which it is to be put in the particular system incorporating the invention. In a continuous distributor system employing a five unit code, the duration of the long lobe would amount to fewer units, in some cases less than five units, in other cases more than five units.

In the claims hereunder where the number of units of an equal-unit-code is referred to, the number is defined by the sense in which it is employed and is dependent upon whether the number of units is odd or even. In a start-stop system, six units are required to print a character, though the cycle of operation requires 7.42 units. In a continuous distributor system, five units are required to print a character, but in the case of an odd number of units, the "holding in" multivibrator may release at any time between the end of the fourth unit and the end of the fifth unit, and so forth, as will be understood by those skilled in the art.

Square-waves are defined to be the common form found in so-called square-wave generators.

Having described one embodiment of the invention, the scope thereof is set forth in the claims hereunder.

What I claim is:

1. The combination of two vacuum tube oscillators arranged to operate with a common negative power-supply connection with vacuum tubes having a plate and a cathode, a direct-current source of power-supply for said tubes, a conducting link between the cathode of one tube of one of said oscillators and the cathode of one tube of the other of said oscillators, a gas-filled electron-tube having a plate, a control-electrode and a cathode, with said plate connected to said link and said cathode connected to said common connection, said electron-tube substantially constituting a common cathode power-supply conducting means for first two said cathodes under gaseous ionization in said electron-tube and substantially constituting a common cathode power-supply interrupting means for said cathodes in the absence of said ionization, and a control circuit including said control-electrode adapted to initiate gaseous ionization in said tube.

2. The combination of two vacuum tube oscillators arranged to operate with a common negative power-supply connection with vacuum tubes having a plate and a cathode, a direct-current source of power-supply for said tubes, a conducting link between the cathode of one tube of one of said oscillators and the cathode of one tube of the other of said oscillators, a gas-filled electron-tube having a plate, a control-electrode and a cathode, with said plate connected to said link and said cathode connected to said common connection, said electron-tube substantially constituting a common cathode power-supply conducting means for first two said cathodes under gaseous ionization in said electron-tube, said ionization constituting means providing articulated operation of said oscillators, and means in said oscillators jointly maintaining said ionization for a predetermined period of time.

3. The combination of two vacuum tube oscillators arranged to operate with a common nega-

tive power-supply connection with vacuum tubes having a plate and a cathode, a direct-current source of power-supply for said tubes, a conducting link between the cathode of one tube of one of said oscillators and the cathode of one tube of the other of said oscillators, a gas-filled electron-tube having a plate, a control-electrode and a cathode, with said plate connected to said link and said cathode connected to said common connection, said electron-tube substantially constituting a common cathode power-supply conducting means for first two said cathodes under gaseous ionization in said electron-tube, said ionization constituting means providing articulated operation of said oscillators, means in said oscillators jointly maintaining said ionization for a predetermined period of time, and said period of time being determined by the difference of frequency in said oscillators.

4. The combination of two vacuum tube oscillators arranged to operate with a common negative power-supply connection with vacuum tubes having a plate and a cathode, a direct-current source of power-supply for said tubes, a conducting link between the cathode of one tube of one of said oscillators and the cathode of one tube of the other of said oscillators, a gas-filled electron-tube having a plate, a control-electrode and

a cathode, with said plate connected to said link and said cathode connected to said common connection, said electron-tube substantially constituting a common cathode power-supply conducting means for first two said cathodes under gaseous ionization in said electron-tube, said ionization constituting means providing articulated operation of said oscillators, means in said oscillators jointly maintaining said ionization for a predetermined period of time, and said period of time being determined by the phase relation of the two said means in said electron-tube.

MONTFORD MORRISON.

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