Aug. 20, 1946. M. MORRISON 2,406,096

ELECTRONIC REGENERATIVE REPEATER

Filed Oct. 23, 1943 2 Sheets-Sheet 1

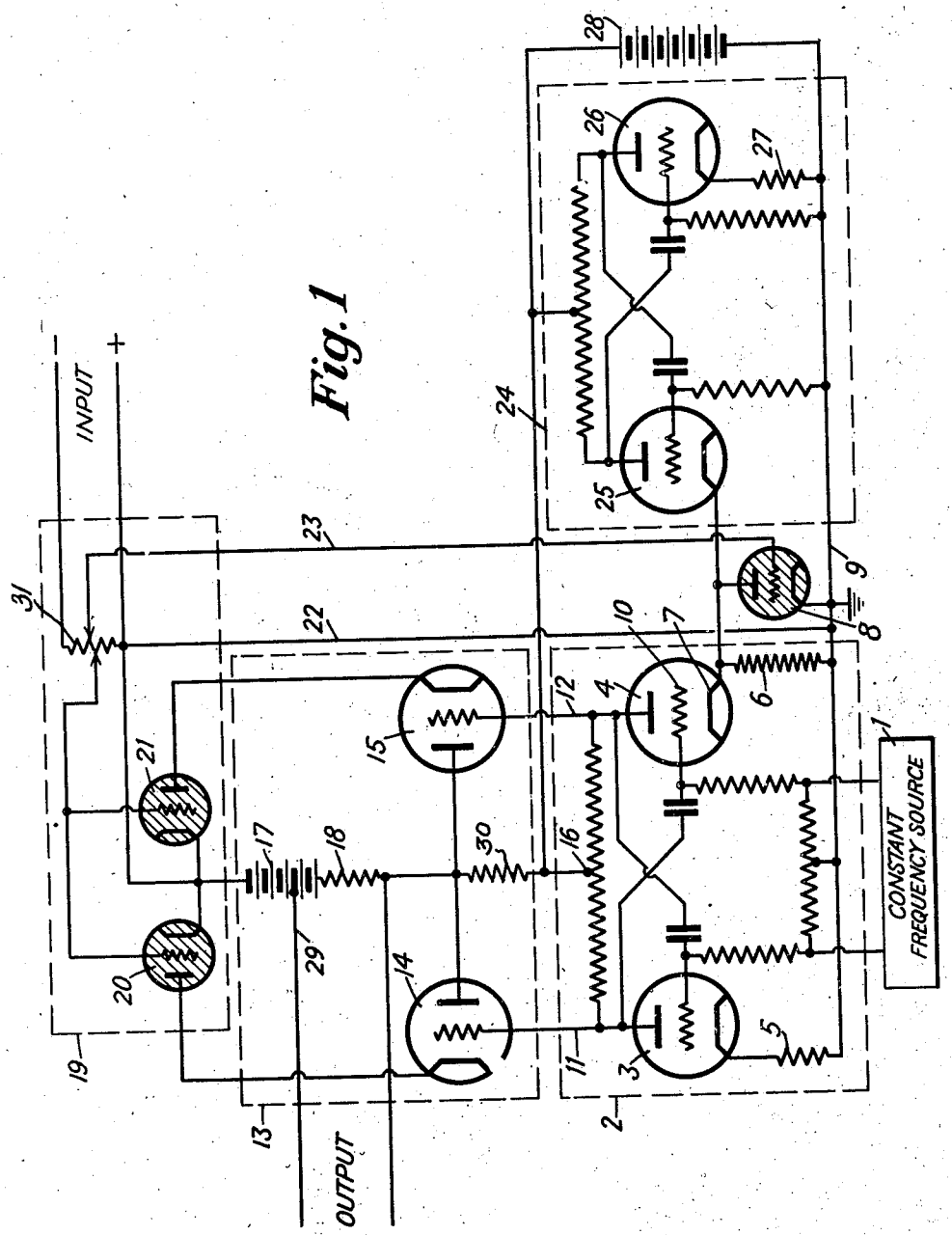


Fig. 1

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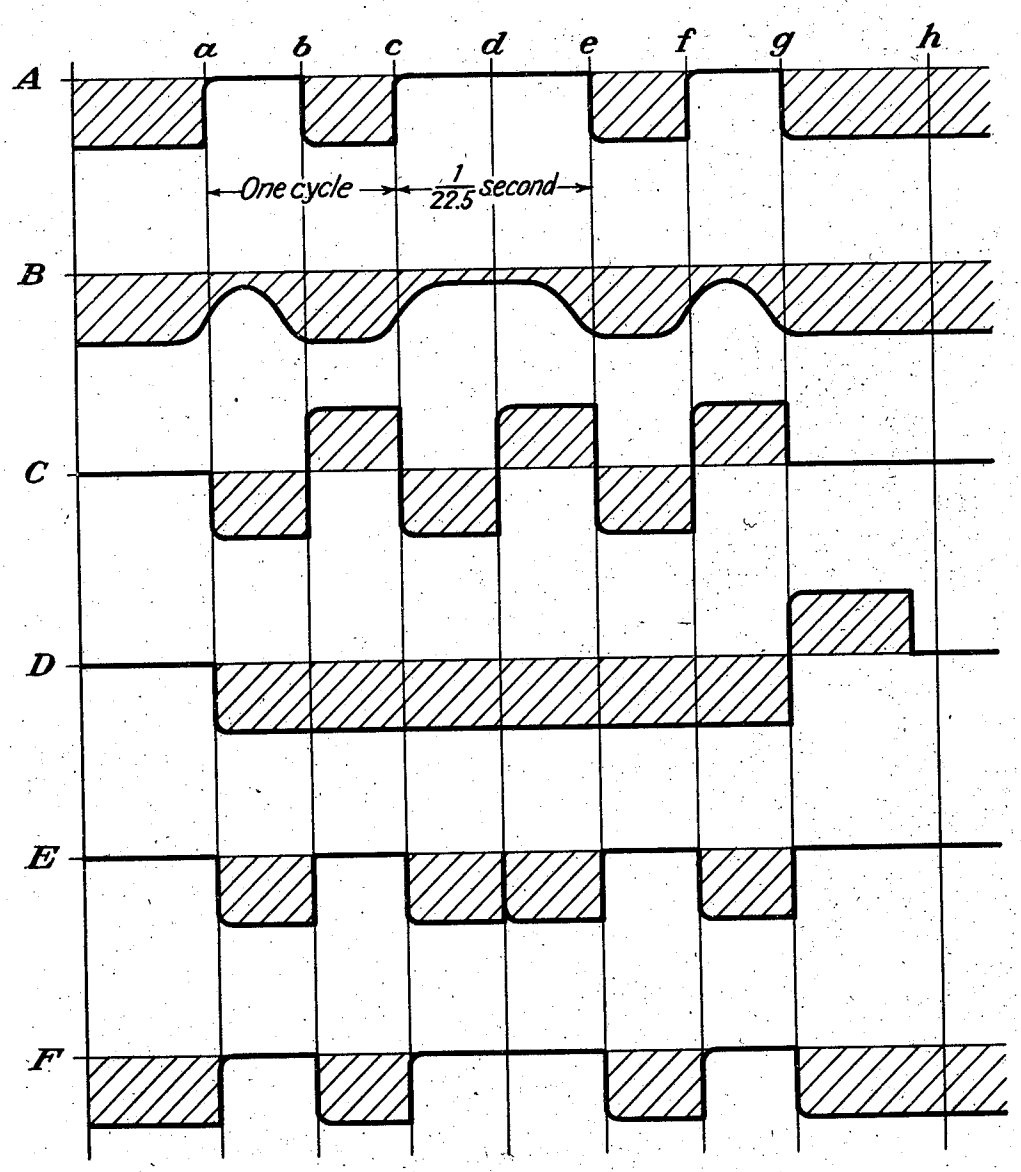


Fig. 2

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Patented Aug. 20, 1946

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UNITED STATES PATENT OFFICE

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ELECTRONIC REGENERATIVE REPEATER

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Application October 23, 1943, Serial No. 507,424

7 Claims. (Cl. 178—70)

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This invention relates to regenerative telegraph repeaters and relates in particular to electronic means for, and electronic methods of, repeating and regenerating equal-unit-code telegraph signals.

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 have 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 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

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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 expediencies have been avoided and the embodiment of the invention in the description will be limited to a uni-directional 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 multi-vibrator circuit well known in the art, and the constant frequency source 1 injects a synchronizing voltage into the multi-vibrator circuit, which, as is well known in the art, will, under proper conditions, fix the frequency of the multi-vibrator circuit at a definite sub-multiple of the frequency of source 1.

Multi-vibrator 2 is constructed to operate at a sub-multiple frequency of the frequency of source 1, represented by the 21st sub-multiple thereof, which means an operating frequency for multi-vibrator 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 multi-vibrator 2, which means that there are 10.5 constant-frequency-source cycles for each half-cycle of the multi-vibrator. The usefulness of this 10.5 cycle constant frequency source ratio to one-half cycle of the multi-vibrator 2 will be hereinafter pointed out.

The multi-vibrator circuit is provided with two tubes, 3 and 4, and this multi-vibrator circuit differs from the common form of multi-vibrator 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 multi-vibrator, 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 multi-vibrator 2, is not oscillating.

When gaseous triode 8 is in a non-conducting 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 multi-vibrator operation.

If source 1 is under proper operation and cathode 7 is connected to ground-lead 9, the multi-vibrator 2 will start into operation instantly, producing 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 multi-vibrator 2, since the multi-vibrator 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 multi-vibrator 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 multi-vibrator circuits to maintain an invariable procedure in operation depends upon all parameters of the multi-vibrator circuit being maintained constant, including the circuits loading the said multi-vibrator.

In the present invention, it is desirable to not only maintain an unvarying performance in the multi-vibrator 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 multi-vibrator circuit 2. This arrangement provides sufficient grid plate bias voltage from multi-vibrator circuit 2 to cut off plate current in tubes 14 and 15 in the presence of multi-vibrator operation.

Those skilled in the art appreciate that in multi-vibrator 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 multi-vibrator 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 multi-vibrator 2 and without distortion. Since the operation of tubes 14 and 15 is such that no appreciable load is taken from multi-vibrator 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 multi-vibrator 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 multi-vibrator 2 and, therefore, always has a positive or always a negative outline, as the case may be.

With multi-vibrator 2 in operation, the form of 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 multi-vibrator 2 only when the cathode circuits of tubes 14 and 15 are closed for an entire half-period of operation of the multi-vibrator circuit.

The circuit enclosed 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 embodimeni, 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 multi-vibration 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 multi-vibrator 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 multi-vibrator 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 multi-vibrator 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 multi-vibrator 2 and its gaseous conduction is extinguished by the disappearance of plate voltage on tube 20 at the end of the half-period of multi-vibrator 2. Under these conditions of operation, the output circuit has produced in it a replica of a half cycle, rectified or otherwise, of multi-vibrator 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 multi-vibrator 2 is produced in the output circuit, rectified or otherwise. This process is repeated at the beginning of each half-period of the multi-vibrator 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 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 multi-vibrator circuit which produces an unsymmetrical wave-form. Those skilled in the art of making and using multi-vibrators appreciate that the length of the duration of the positive and negative lobes of the multi-vibrator 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 multi-vibrator 2, it follows necessarily from the description thereof, has a symmetrical lobe output circuit of a frequency of 22.5 cycles per second.

The multi-vibrator in area 24, is so constructed that one of its voltage lobes has a duration equal to a multiplicity of the lobes of multi-vibrator 2, the actual length of which depends upon the number of lobes of multi-vibrator 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 multi-vibrators 2 and 24 are connected together. Multi-vibrators 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 28, over and above that provided by resistor 18.

The function of gaseous triode 8 is to set the two multi-vibrators 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. Multi-vibrators 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 non-conducting electrical state. Tube 3 of multi-vibrator 2 has full plate current flowing which biases out tube 14. Tube 15 is passing plate current because tube 21 was left 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 multi-vibrator 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 multi-vibrators start in operation producing the wave-forms for which they are constructed. Frequency source **1**, being in operation, multi-vibrator **2** locks in with it, not more than 10% of a single dot period behind the phase instant *a*, and multi-vibrator **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 multi-vibrator **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 multi-vibrator 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 multi-vibrator **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 multi-vibrator **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 multi-vibrator 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 multi-vibrator shown along curve C is 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 dot or marking period equal to a half a period of the multi-vibrator **2**.

The period of multi-vibrator **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.

A detailed operation of the device for the regeneration of the character D, shown in graph A, after transmission with distortion into form shown in graph B, will now be set forth.

The distorted signal wave-form of the outline shown in graph B is to be received through the input circuit identified in Fig. 1. Previous to the reception of any character signal current, normal line current is flowing through the input resistor **31**. Tubes **20** and **21**, are both in a non-conducting electrical state, due to their previous history of operation and to the grid bias supplied by resistor **31**.

Tube **8** is in a non-conducting electrical state, due likewise, to the grid bias supplied by resistor **31**. Under this condition, the plate circuits of tubes **4** and **25** are substantially open-circuited and tubes **3** and **26** are conducting their normal plate currents. Under these conditions, the plate current of tube **26** serves no operatively useful function. The plate current of tube **3**, through its associated plate resistor, provides plate current cutoff bias for tube **14**, which maintains tube **14** in an electrically non-conducting state. The absence of plate current in tube **4** causes an absence of grid bias in tube **15**, but in view of tube **21** having been left in an electrically non-conducting state, the circuit of battery **17**, through tube **21**, through tube **15** and through resistor **18**, is effectively open. Likewise the circuit of battery **17**, through tube **20**, through tube **14** and through resistor **18**, is effectively open. Normal output line current is supplied by bias provided by battery **17**. Thus with a normal steady current in the input circuit, a normal steady current is repeated in the output circuit. This status corresponds to the zero time position of the curve shown in graph B.

When the signal wave shown in graph B arrives at the time position *a*, the grid bias of tube **8** is lowered, due to the reduction in signal current, to a value which causes tube **8** to acquire an electrically conducting state.

The constant frequency source, illustrated in Fig. 1, is in continuous operation and is continuously supplying small amounts of grid voltage to tubes **3** and **4**, sufficient to cause this multi-vibrator to lock in, when once started into operation, but insufficient to cause any operational manifestation in the absence of an electrically conducting state in tube **8**.

Since tube **3** has been carrying its normal plate current, multi-vibrator **2** is therefore in a condition to start its normal operation immediately upon completing the multi-vibrator circuit, by causing tube **8** to become electrically conducting.

It may be well to mention at this point, that properly designed multi-vibrators, unlike capacitor-reactor oscillators, are set into normal operation under conditions set forth above, instantaneously with the establishment of the normal circuit thereof; so that at the instant that tube **8** forms a closed circuit for multi-vibrator **2**, this multi-vibrator is set into normal operation and it locks in with the constant frequency source at the first half cycle of the proper polarity that coincides with the normal grid voltage of the said multi-vibrator, as is well understood in the art relating to this apparatus.

Tube **26** of multi-vibrator **24** was conducting plate current simultaneously with tube **3** of multi-vibrator **2**, and tube **25** was in a non-

conducting state, coinciding with the status of tube 4, so that when tube 8 became electrically conducting, both multi-vibrators 2 and 24 were instantaneously set into normal operation.

Multi-vibrator 2 produces a voltage wave-form in accordance with graph C so long as the tube 8 is electrically conducting, and likewise, multi-vibrator 4 produces a wave-form in accordance with graph D so long as tube 8 remains in an electrically conducting state. The function of multi-vibrator 24 is to maintain tube 8 in an electrically conducting state for a duration of approximately six half cycles of multi-vibrator 2, by maintaining current through tube 8, for the periods of time during which tube 4 is not passing plate current, namely, during every other half cycle, and then permitting tube 8 to become electrically non-conducting by removing the plate current caused by multi-vibrator 24 at the end of this period, since at this instant of time, there is no plate current in tube 4 to maintain electrical conductivity in tube 8 either. In other words, at the end of six half cycles of operation of multi-vibrator 2 and at the end of the same duration of time in multi-vibrator 24, there is no current available from either multi-vibrator to maintain electrical conductivity in tube 8 and therefore both multi-vibrators are returned to the initial inoperative status described for them. These two complete cycles of operation for these multi-vibrators is performed each and every time tube 8 has its bias reduced sufficiently to cause it to assume an electrical conducting state, whether this bias persists through the period of operation or not. That is to say, one initial removal of bias from tube 8 will cause a complete cycle to be performed by multi-vibrator 2, in accordance with graph C, and simultaneously, a complete cycle performed by multi-vibrator 2, in accordance with graph D. This may be likened to the release of a start-stop rotary regenerative repeater, the half cycles of graph C corresponding to the timing of six of the segments and the length of wave-form D, corresponding to one complete rotation of the distributor.

Slight phase shifts between the input and the output circuit are ignored in this description since they can be made as small as desirable and may be constant for any properly designed system employing this invention.

Return now to the signal current shown in graph B at the time instant *a*, tube 8 is made electrically conducting and multi-vibrators 2 and 24 start into operation in accordance with graphs C and D.

The instant that tube 8 sets the multi-vibrators into operation, tube 4 draws normal plate current, producing, due to its plate resistor, sufficient grid bias for tube 15 to cut off its plate current. The plate current of tube 4 is represented by the first half cycle of graph C, and under conditions of multi-vibrator operation, the plate current of tube 3 ceases. With the cessation of plate current in tube 3, tube 14 has its plate-grid bias removed, and due to the reduction in signal current at the instant *a* in graph B, the plate voltage applied to tube 20 by the removal of grid bias from tube 14, produces plate current in resistor 18 of a wave-form corresponding to the first half cycle in graph C. The voltage drop across resistor 18, due to said plate current in the said resistor, produces the wave-form shown in graph E, for the period *a*—*b*, and this voltage reduces the output bias voltage accordingly, as shown for the period *a*—*b*, graph F, thus regenerating the spacing signal of the corresponding period in graph B.

When the signal current of graph B has reached the time instant *b*, multi-vibrator 2 reverses polarity in accordance with graph C, and the grid bias of tubes 20 and 21, in accordance with graph B, has risen to a value above the necessary cutoff voltage for the said tubes 20 and 21.

The reversal of the polarity of the voltage of multi-vibrator 2 cuts off the plate current of tube 14, extinguishes the ionization in tube 20 and stops the flow of current from battery 17, through resistor 18 in the circuit including tubes 14 and 20. At this instant the disappearance of plate current in tube 4 allows tube 15 to become electrically conducting and impresses voltage upon tube 21, but since the grid bias of tube 21 has risen above the cutoff value for the normal plate voltage, no current flows through resistor 18 in the circuit including tubes 20 and 15 for the next half period of the multi-vibrator 2; hence the output circuit returns to its normal current due to bias, as previously described and as illustrated in graph F, period *b*—*c*.

Multi-vibrator 24 maintains tube 8 in an electrically conducting state, in the absence of plate current in tube 4, during the 2nd, 4th and 6th half cycles of operation of multi-vibrator 2, as has been previously described.

When the time instant *c*, graph B, is reached, the previous status of operation is exactly as described for the period immediately preceding the time instant *a*, and therefore for the succeeding time period *c*—*d*, the operation repeats that through which the apparatus went for the period *a*—*b*. However, when the time instant *d* is reached and the multi-vibrator 2 reverses its polarity, the grid bias of tubes 20 and 21 is held below the cutoff value, as illustrated at the time instant *d*, graph B, and therefore a reversal of the polarity of multi-vibrator 2 does not result in an extinction of plate current in resistor 18, as was the case for the period *b*—*c*, graphs C, E and F, but allows the plate current to continue in resistor 18, as illustrated in graph E, period *d*—*e*, with the resulting line signal shown in graph F for the same period.

When the time instant *e* has been reached, the conditions and operation are exactly identical with that described for the time instant *b* and the succeeding half cycle. When the time instant *f* has been reached, the conditions and operation are exactly identical with that described beginning at the time instant *a* and continuing through the time period *a*—*b*. Thus, we have the distorted signal current for the period of six half cycles from *a* to *g*, graph B, regenerated into the form shown in graph A for the same period of time. However, during the period *f*—*g*, multi-vibrator 24 held tube 8 in an electrically conducting condition and this continued up to the time instant indicated by *g* in the graphs, and at this instant multi-vibrator 24 reverses its polarity and tube 25 ceases to supply conduction current for tube 8, and in the absence of conduction current in tube 4, both multi-vibrator circuits are returned to their initial starting conditions. Thus, a complete cycle of operation of the device for the letter *d* has been traversed. In the general case, the period of the multi-vibrator 24 is slightly less than the sum of the complete number of units in the code

used and as illustrated in graph D, which prevents the possibility of overlapping of signals.

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" multi-vibrator 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. In an apparatus for regenerating signal currents in an equal-unit-code telegraph system, an input circuit adapted to receive distorted signal currents in a code of equal-units at random combinations, two electrically associated multi-vibrator circuits, an output circuit, means electrically associated with said output circuit for fixing under operation by said random combinations the period of duration of each of said units in said output circuit by the half-period length of one of said electronic multi-vibrator circuits, and means for fixing the period of the sum of the total said units of a single operation in said output circuit by the whole-period length of the other of said electronic multi-vibrator circuits.

2. In an apparatus for regenerating currents representing signal characters in an equal-unit-code telegraph system over an outgoing line from signal currents received over an incoming line comprising, an input circuit to receive code signals at random combinations, one electronic oscillatory circuit having a period equal to twice that of a single unit length of said code to regenerate the period of the units of said signals, a second electronic oscillatory circuit having a period equal substantially to the length of the sum of all the units and fractions thereof in the code employed to regenerate the period of a complete code-character operation, and means electrically coupling said two oscillatory circuits coordinating said periods.

3. In an apparatus for regenerating currents representing signal characters in an equal-unit-code telegraph system over an outgoing line from signal currents received over an incoming line comprising, an input circuit to receive code signals at random combinations, one electronic oscillatory circuit having a period equal to twice that of a single unit length of said code to regenerate the period of the units of said signals, a second electronic oscillatory circuit having one short impulse of one polarity and one long impulse of opposite polarity, said long impulse having a period equal substantially to the length of the sum of all the character code-units employed in said code combined, and means electrically coupling said two oscillatory circuits coordinating said periods.

4. In an apparatus for regenerating currents representing signal characters in an equal-unit-code telegraph system over an outgoing line from signal currents received over an incoming line comprising, an input circuit to receive code signals at random combinations, one electronic regenerative switching circuit having a switching period equal to the length of a single unit of said code, a second electronic switching circuit having a switching period equal in length substantially to that of all the character code-units combined, a sinusoidal oscillator to control the period of the first said switching circuit, and means electrically coupling said two switching circuits coordinating said periods.

5. In an apparatus for regenerating currents representing signal characters in an equal-unit-code telegraph system over an outgoing line from signal currents received over an incoming line comprising, an input circuit to receive code signals at random combinations, one electronic regenerative switching means to fix the period of the duration of a single unit of said code, a second electronic switching means to fix the number of units employed in said code in a single operation thereof, and a sinusoidal oscillator to control the period of the first said switching means.

6. In an apparatus for regenerating currents representing signal characters in an equal-unit-code telegraph system over an outgoing liine from signal currents received over an incoming line comprising, an input circuit to receive code signals at random combinations, one electronic square-wave generator to provide output currents of regenerated signal-wave-forms, a second electronic square-wave generator to determine the cycle of operation of said system, and electronic-tube means electrically coupling said two generators coordinating said output currents of regenerated signal-wave-forms with said cycle of operation.

7. In an apparatus for regenerating currents representing signal characters in an equal-unit-code telegraph system over an outgoing line from signal currents received over an incoming line comprising, an input circuit to receive code signals at random combinations, one square-wave alternating-current electronic generator to provide output currents of regenerated signal-wave-forms, one electronic means responsive to distorted input line currents providing signal timing for said output currents, and a second square-wave alternating-current electronic generator cooperating electrically with first said generator determining the cycle of operation of said system.

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