

April 7, 1942.

A. L. HOPPER

2,278,444

VIBRATING POLAR RELAY SYSTEM

Filed March 5, 1941

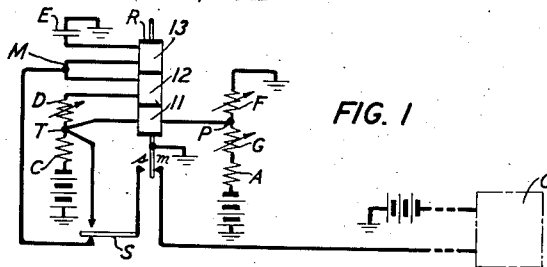


FIG. 1

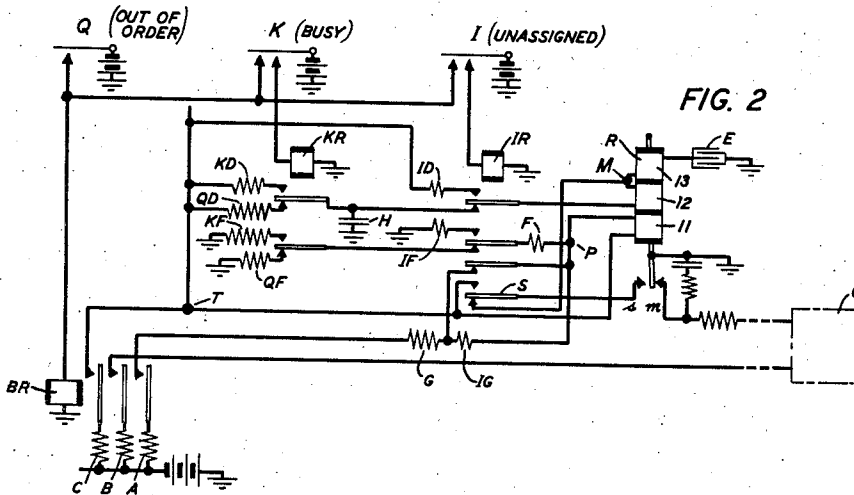


FIG. 2

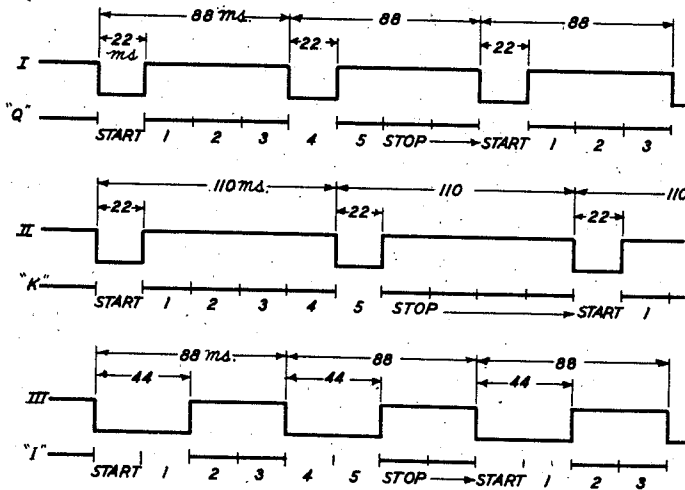


FIG. 3

INVENTOR
A. L. HOPPER

BY

O. J. Pasmussen

ATTORNEY

UNITED STATES PATENT OFFICE

2,278,444

VIBRATING POLAR RELAY SYSTEM

Andrew L. Hopper, River Edge, N. J., assignor to
Bell Telephone Laboratories, Incorporated, New
York, N. Y., a corporation of New York

Application March 5, 1941, Serial No. 381,813

14 Claims. (Cl. 178-69)

The invention relates to vibrating polar relay systems and more particularly to systems of this kind which are adapted to produce current impulses at different frequencies and of different characteristics.

Vibrating relay systems of this kind have found many uses and have particularly been incorporated in certain telegraph switching systems for teletypewriter subscribers using start-stop telegraph signals. A telegraph switching system of this kind has been disclosed in an application for U. S. Patent, Serial No. 262,158, filed by C. W. Lucek on March 16, 1939 and issued as Patent No. 2,228,279 on Jan. 14, 1941. In accordance with the Lucek system, a manual teletypewriter central office is arranged to serve subscribers grouped at different distant offices. Thus, a group of subscribers may be connected to what is called a concentrator, which is a station for responding to calls from the local subscribers and selecting trunks to the central office and for receiving calls over the trunks from the central office to the locally associated subscribers. All the signaling, incident to the setting up of connections, utilizes the usual seven and one-half unit start-stop code and subscribers as well as central office operators are equipped with sending and receiving teletypewriter apparatus for this purpose.

A particular function of the concentrator system is that of notifying the distant central office operator of unusual conditions at the concentrator made evident by calls incoming from the central office. For this purpose automatic equipment is provided at the concentrator office which is responsive in different ways to the different unusual conditions by repeatedly sending certain code signals capable of operating the teletypewriter at the operator's position for repeated printing of certain predetermined characters, thereby informing the operator of the special condition.

Thus, in the Lucek system, when the central office operator calls a subscriber at the concentrator office, the call is automatically extended to the called line in response to proper signals of the start-stop code. However, three irregular conditions are contemplated by the system, namely, that the call ends in a "busy" line, or in a line made "out of order," or in an "unassigned" line, that is, in a point to which no line has been assigned. In order to report these three conditions back to the operator the concentrator circuit is adapted to transmit back over the trunk circuit signals corresponding to the letter "K"

for the "busy" condition, the letter "Q" for the "out of order" condition, and the letter "I" for the "unassigned" condition, and any one of these letters is printed repeatedly on the operator's printer until she abandons the call and disconnects the calling circuit from the concentrator.

For the purpose of transmitting the "K," "Q" and "I" letters, the Lucek system has at the concentrator office a vibrating polar relay circuit so arranged that three different series of regularly occurring impulses are transmitted which may be impressed directly upon the receiving printer for printing of the corresponding characters. Lucek has provided two polar relays and associated circuit equipment for producing such three different series of impulses capable of direct translation by the printer. One is a vibrating relay which repeatedly operates to marking and spacing at equal intervals and at two different frequencies, depending upon the resistance of the operating circuit for the relay. Thus, with low resistance the relay vibrates at a frequency of approximately eleven cycles per second and with high resistance it vibrates at a frequency of approximately nine cycles per second, more accurately speaking, the relay in the first case spends the time of exactly two dot periods on the marking contact and of two dot periods on the spacing contact and in the latter case the relay spends the time of exactly two and one-half dot periods in each of the marking and spacing positions. The other polar relay is a pulsing relay; it is normally in marking position and operates to spacing for exactly one dot period each time the vibrating relay operates to marking.

The circuit for operation of the two polar relays is controlled by neutral type relays in different manners in response to predetermined circuit conditions established for the three irregular conditions of subscribers' lines referred to above.

Thus, for the sending of the character "Q," the outgoing impulse circuit is extended to the contact of the pulsing relay which transmits a unit spacing pulse into the pulsing circuit every fourth dot period. The distant printer receiving this series of impulses will repeatedly print the letter "Q," indicating to the distant operator that the selected line is out of order.

For the "K" condition, the circuit is arranged the same as for the "Q" condition except that a resistance is cut into the operating circuit of the vibrating relay, which in this case operates at the lower frequency, thereby causing the pulsing relay to send a spacing signal once for every fifth

dot period. The code thus translated by the printer will result in the repeated printing of the letter "K."

For the "I" condition the circuit is changed to exclude the pulsing relay from the pulsing circuit, the pulsing circuit now being extended over the marking contact of the vibrating relay; for this condition the resistance is cut out of the operating circuit for the relay, which thus operates at the higher frequency and produces alternate marking and spacing impulses each two dot periods in length. At the printer these pulses will result in the repeated printing of the letter "I."

It will thus be observed that the vibrating relay circuit in Lucek's system includes two polar relays arranged to produce impulses at two different frequencies and to produce symmetrical and unsymmetrical impulse cycles, that is, to produce cycles in which the spacing and the marking periods are of equal duration or in which the marking and spacing periods are of different duration in a ratio as high as 4 to 1.

It is an object of the present invention to provide a vibrating polar relay system for producing symmetrical and unsymmetrical impulse cycles and for operation at at least two different frequencies, which requires only one polar relay with associated circuit elements and which thus is simpler and less expensive than that disclosed by Lucek. Thus, the invention may be considered as being an improvement on the prior art, particularly as represented by the Lucek disclosure.

In accordance with a feature of the invention, a single polar relay is associated with a single timing condenser and with a plurality of impedance elements for control of the duration of the spacing and marking periods produced by the relay. It is a specific feature of the invention that the marking and spacing periods may be separately adjusted and that the relay circuit may be adjusted to produce highly unsymmetrical impulse cycles in which the ratio between the marking and the spacing periods may be as high as 4 to 1.

Fast operating polar relays are equipped with only two contacts, the marking and the spacing contacts, and therefore can control no more than two independent circuits. When such a relay is used as a self-controlled vibrating relay, the marking contact is usually reserved for producing impulses in an output circuit, leaving only the spacing contact for control of the various branches of the relay control or local circuit. It is therefore a rather difficult problem to provide the necessary accurate control of the relay under any given condition, and more so when the relay must operate accurately under two or more conditions.

In accordance with the invention the polar relay has a biasing winding mainly for operating the relay in one direction, say to spacing, and an operating winding cooperating with the biasing winding, so that their effective ampere-turns will operate the relay in the other direction, say to marking. The relay also has a timing winding energized by the charging and discharging currents of a timing condenser to temporarily oppose the operations of the relay in both directions.

In accordance with the invention the charging and discharging circuits through the timing and operating windings are controlled by the single control or local contact of the relay and the current through the biasing winding is also,

though more indirectly, dependent upon the contact operations.

For the production of unsymmetrical impulse cycles, in which for example a short spacing pulse and a long marking pulse are included in each cycle, the circuit is arranged as follows: During the spacing pulse, the operating and biasing windings by their combined effective ampere-turns tend to operate the armature to marking; at the same time the condenser discharging current passes through the timing winding only, thereby delaying for a comparatively short time by its comparatively few ampere-turns the operation to marking. During the marking pulse the biasing winding tends to operate the armature back to spacing; at the same time the condenser charging current passes through both the operating and timing winding, thereby producing a comparatively large number of ampere-turns opposed to the biasing winding and thus requiring a comparatively long time to be reduced sufficiently to be overcome by the biasing winding.

The duration of the marking pulse may be varied over a wide range by varying the current in the biasing winding. Variation of the charging current will not appreciably affect the delaying action of the operating and timing windings. The duration of the spacing pulse may be controlled by properly combining the ampere-turns of the operating and biasing windings, their currents being dependent on the adjustments made for the marking pulse. The duration of the spacing pulse will depend to some extent on the charge acquired by the condenser during the previous marking period.

When, by adjustment of the circuit constants, the marking pulse approaches the spacing pulse in length it becomes preferable to operate the relay in the opposite directions by current reversals in the biasing winding, and to time the operations by the charging and discharging currents through either or both of the other windings. In accordance with the invention the currents are reversed for this purpose both in the condenser circuit and in the biasing winding by the single control contact of the relay.

Aside from the adjustment of circuit constants for any particular timing the circuit change necessary for switching from unsymmetrical to symmetrical operation, or vice versa, has been so simplified in accordance with a specific feature of the invention that it may be accomplished by a single switching contact having alternate circuit contacts. This is accomplished by, under both of these conditions, using all three windings of the polar relay, having one side of the biasing winding connected to an intermediate point of a potentiometer and having the other side connected to the resistance protected battery supply, which also supplies the charging current, under both conditions. The single switching contact is operated to one position for conditioning the relay circuit for production of unsymmetrical vibrations; in this position it connects the intermittently grounded spacing contact to the discharge circuit through the timing winding. For conditioning the relay for production of symmetrical vibrations the switching contact is operated to its alternate position where it connects the intermittently grounded spacing contact to the common resistance for the discharge circuit and the biasing winding.

The invention will now be described as applied to a specific embodiment which should be considered as a typical example capable of being

modified in various ways without affecting the principles of the invention. Reference will be made to the accompanying drawing, in which:

Fig. 1 is a simplified circuit diagram of a vibrating relay system embodying the main features of the invention;

Fig. 2 is a more detailed circuit diagram showing a vibrating polar relay system controlled by conventional relay means in response to three different operating conditions; and

Fig. 3 is a schematic diagram of the three different types of pulse series produced by the relay system shown in Fig. 2 and the corresponding printer operating code signals.

Referring now to Fig. 1, the polar relay R has three windings, namely, the biasing winding 11, the operating winding 12, and the timing winding 13. A timing condenser E is connected from ground to the timing winding 13. The relay armature is connected to apply ground over its marking or output contact *m* to an output circuit including a start-stop recording equipment O and to supply ground over its spacing contact *s* to the relay control circuit.

The relay control circuit includes an adjustable potentiometer of impedances A, G, F for supplying an intermediate voltage at point P to one side of the biasing winding 11. Another potentiometer circuit may be traced from battery through impedances C, D, windings 12, 13 and timing condenser E to ground. The other side of the biasing winding 11 is connected to the point T of this potentiometer circuit thereby receiving an intermediate voltage. Thus winding 11 is included in the conjugate circuit of a Wheatstone bridge, and the current therein may readily be varied and even reversed by adjustment of the arms of the two potentiometer circuits. The potentiometer circuit through condenser E constitutes the charging circuit, which is established when the relay is operated to marking.

Switching means S in one position connects intermittent ground from the spacing contact to the connecting point M between windings 12 and 13 for discharge of the condenser E through timing winding 13. In its alternate position switch S connects the intermittent ground to the common connecting point T between windings 11 and 12 for reversing the currents in all the windings without disconnecting the battery from those windings.

The operation of this oscillating relay system is briefly as follows: With the circuit in condition as shown in Fig. 1 the biasing winding 11 will be continuously energized to operate the relay armature to the spacing contact. The condenser is in circuit to be charged over windings 12 and 13 in series, which windings will be opposing winding 11 and delay the operation to spacing until the charging current is reduced to a predetermined value. When the spacing contact closes, ground will be applied directly to winding 12 which then will tend to operate the relay armature back to marking. However, condenser E is being discharged through winding 13 which now is opposed to winding 12 and thus delays the operation to marking until the charging current has been reduced to a predetermined value, at which the effective combined ampere-turns of the windings 11 and 12 overcome the ampere-turns of winding 13. On return to marking condition, the charging circuit for condenser E is reestablished and the operating cycle will be repeated. For each such cycle an impulse will be sent into

the output circuit O while the relay has its marking contact closed.

By reducing the impedance D the voltage at point T may be decreased and by increasing the impedance F the voltage at point P may be increased; by such adjustment the current in the biasing winding 11 will be reduced and may in fact be reduced to such an extent that it reverses when the relay closes its spacing contact. With the armature in marking position thus, the reduced ampere-turns of the biasing winding acting toward spacing will be opposed by the ampere-turns of windings 12 and 13. The delay due to the charging current through windings 12 and 13 thus will be prolonged and the relay will remain in marking position for a longer time. With the assumed adjustment the discharge current flowing through winding 13 while the relay is in spacing will remain unaffected, except to the extent that it depends on the preceding charging time, whereas the resultant ampere-turns of windings 11 and 12 acting toward marking will depend upon the relative adjustment of impedances D and F which, however, may be such that the spacing pulse will remain unaffected while the marking pulse is varied over a wide range.

Assuming now that switch S is operated continuously to its alternate contact, the mode of operation of the system will be changed. The conditions during marking are the same as before, but when ground is applied in spacing to the point T the current in winding 11 will be reversed tending to operate the armature back to marking; the condenser current through windings 12 and 13 will, however, also be reversed and these windings will temporarily oppose winding 11 until the condenser has been discharged to a predetermined potential.

Increasing impedance G and decreasing impedance F results in increasing the ampere-turns of winding 11 with the armature in marking position, therefore the charging current will decay less before the biasing winding can operate the relay to spacing; thus the marking pulse may be shortened. With the armature in spacing position the current in the bias winding is likewise dependent on the adjustment of impedances F and G so that for a given delay effect of windings 12 and 13 the spacing pulse may be varied in length and thus may be made of the same length as the marking pulse.

Referring now to the more detailed circuit arrangement shown in Fig. 2 the polar relay R has three windings 11, 12 and 13 and is connected substantially as in Fig. 1. The relay circuit is, however, more particularly adapted for automatic response to three different conditions external of the relay system, such as has been described hereinbefore.

For the operation of relay R in three different manners, three contact devices Q, K and I are shown in the drawing. These contact devices may be of any suitable construction and may be operated by any means in response to the three different conditions which it is desired should be indicated in the recording equipment O. Thus, these contact devices may be operated manually by an operator observing the different conditions in any set of varying circumstances or they may be operated automatically, as by three doors or windows in a burglar alarm system, or as by the three irregular line conditions referred to above in the Lucek system.

As shown, the vibrating system is assumed to

be used in a system like that disclosed by Lucek. The contact device Q would respond to an "out of order" condition by closing its contact, thereby operating relay BR for applying battery to the relay system; the contact device K would respond to a "busy" condition by closing its contact and operating relay BR and relay KR; and contact device I would respond to the "unassigned" condition by closing its contact and operating relays BR and IR. Relays BR, KR and IR are neutral type relays, each having a plurality of contacts for control of the polar relay R. These relays may of course be replaced by one or more keys having corresponding contacts and operating positions for manual operation in any convenient manner well known in the art. A plurality of resistances are connected in the contact circuits for controlling the currents in the windings of relay R in accordance with the settings of the neutral relays.

It will first be assumed that the relay system is to respond to an "out of order" condition, in which case the Q contact is closed. When relay BR operates, battery is applied by one of its contacts over resistance B to the output circuit including recording equipment O, over the marking contact *m* of relay R to ground, thereby establishing a marking condition in the output circuit. Relay BR also applies battery to a potentiometer circuit including resistances A and G, break contact of relay IR, the point P, resistance F, break contacts of relays IR and KR, and resistance QF to ground, thereby establishing a definite potential at the point P less than that of the battery. Relay BR also applies battery over the resistance C, point T, resistance QD, break contacts of relays KR and IR, through the operating winding 12 and the timing winding 13 in series and through condenser E to ground, thereby causing a charging current for condenser E to flow through windings 12 and 13 in a direction such that windings 12 and 13 both tend to hold the relay armature against the marking contact. With these circuits established the biasing winding 11 of relay R is connected directly between the points of intermediate potentials P and T and the adjustment of potentiometer A, G, F is such that the current through winding 11 tends to operate relay R to spacing, the varying potential of point T being made appreciably higher than that of point P even at the beginning of the charging period. For a time nothing happens but, when the charging current has reduced sufficiently, the biasing winding 11 will overcome the two other windings and operate the armature to spacing, thereby producing a spacing condition in the output circuit.

Immediately upon the armature reaching the spacing contact, ground is applied from the spacing contact over contact S of relay IR to the mid-point M between windings 12 and 13, establishing a discharge circuit for condenser E through timing winding 13 which now holds the armature against the spacing contact, and also establishing an operating circuit through winding 12 over the previously traced circuit, including resistances QD and C to battery; the operating winding 12 now tends to operate the armature to marking. The current in the biasing winding 11 is somewhat reduced under this condition inasmuch as the potential of point P has been lowered; however for the particular timing of the outgoing spacing pulse desired for the Q signal, the current in winding 11 continues in the direction for operating the relay to spacing.

When the discharge current through winding 13 has decreased sufficiently, the effective ampere-turns of the opposed windings 11 and 12 will overcome the effect of winding 13 and will operate the armature back to the marking contact, thereby reestablishing the marking condition in the output circuit.

As soon as the ground is removed from the spacing contact of relay R, the discharge circuit for condenser E is opened and the previously traced charging circuit is reestablished and the windings 12 and 13 again for a time prevent the operation of the relay to spacing by the winding 11.

Thus, when the operating cycle has been established, the biasing winding 11 will repeatedly operate the relay to spacing but is temporarily prevented each time by the charging current through the aiding windings 12 and 13; with the relay in spacing position, the opposed windings 11 and 12 tend to operate the relay to marking but are temporarily prevented by the discharge current through winding 13. It will be noted that a comparatively slow charging circuit is established for condenser E through the two windings 12 and 13 in series so that it will take a comparatively long time for the current to subside sufficiently to permit winding 11 to operate the relay to spacing; it will also be noted that a quicker discharge circuit is established for condenser E through the single winding 13, so that the current quickly subsides sufficiently to permit the opposed windings 11 and 12 to operate the relay to marking. In this manner the relay is operated at a predetermined frequency to send comparatively short spacing impulses into the output circuit. With the proper circuit constants, an output current may be produced as that depicted by curve I in Fig. 3 according to which a spacing pulse of 22 milliseconds is transmitted once for every 88 milliseconds and the recording printer in the recording circuit O will interpret these impulses as start-stop impulses for repeated printing of the letter "Q," as shown at "Q" in Fig. 3. As is well known, a commercial start-stop code is based on a signal impulse series composed of $7\frac{1}{2}$ dot periods, each about 22 milliseconds long, and consisting of first a start pulse then 5 selecting pulses and last a stop pulse which is at least 1.4 dot periods long.

In due time the contact device Q will open its contact and the circuit will be restored to normal with the polar relay R either in marking or spacing position.

Assuming now that the relay system is to respond to a "busy" condition, the contact device K will be closed, thereby operating relays BR and KR. Relay BR supplies battery to the different circuits the same as before, except that by the operation of relay KR the resistances QD and QF have been replaced by resistances KD and KF, respectively. By the substitution of smaller resistance KD for larger resistance QD and of larger resistance KF for smaller resistance QF the current in the biasing winding is reduced. The smaller resistance KD does increase the charging current through windings 12 and 13 at the very beginning of the charging period, but thereafter the time-charge characteristic of the charging circuit is only slightly affected. The extent of the delay in operation to spacing therefore is principally dependent on the ampere-turns of the biasing winding, and with the indicated adjustments will result in a longer marking pulse for the K signal than for the Q signal.

In spacing position of relay R initial values of the discharge current through timing winding 13 will be greater than for the Q signal due to the longer charging period and the consequent higher potential of condenser E. The current through operating winding 12 will also be greater than before, tending more strongly to operate the relay back to marking. During this discharging period the potential of point T will be nearer to ground than that at point P with the result that the current in biasing winding 11 will be reversed, and this winding will be aiding winding 12 in operating the relay back to marking. Thus the stronger delaying action by winding 13 may be overcome by the aiding windings 11 and 12 after a discharging period of the same length as that for the Q signal.

Thus, in this condition, the relay R will produce in the output circuit a spacing impulse of the same length as before but at a lower frequency and, by the proper choice of circuit constants, a series of impulses may be produced as shown by curve II in Fig. 3 according to which spacing impulses 22 milliseconds long will be transmitted once for every 110 milliseconds; the printer will interpret these impulses as start-stop impulses for the repeated printing of the letter "K" in accordance with the line "K" in Fig. 3.

It will be noted that during the "Q" and "K" conditions described above the combined effective ampere-turns of windings 11 and 12 for operating the relay from spacing to marking are proportioned to the ampere-turns of winding 13 so that the spacing pulse will have the same length. In marking position, however, a heavier charging current is established through windings 12 and 13 and a lower biasing current in winding 11 during the "K" condition than during the "Q" condition, thereby causing the relay to vibrate at a higher frequency during the "Q" condition than during the "K" condition.

It will now be assumed that the relay system is to respond to the "unassigned" condition in which case the contact device I is operated for operation of relays BR and IR, relay KR remaining unoperated. In this case, low resistance ID is substituted for higher resistances KD or QD, low resistance IF is substituted for higher resistances KF or QF on the grounded side of the potentiometer, and low resistance IG is added to resistance G in the battery side of the potentiometer by the opening of a break contact of relay IR. The circuit is further modified by the operation of relay IR in that the spacing contact of relay R now is continuously disconnected from the midpoint M between the windings 12 and 13 and is connected to intermittently ground the point T of the potentiometer circuit through windings 12 and 13.

The operation of relay BR applies battery over resistance B to the output circuit. Battery is also applied over resistances C and ID, through windings 12 and 13 in series to condenser E for charging of the condenser with a still greater current than before, holding the relay in marking. The potential of point T will vary over a still lower range than in the case of the Q and K signals, as the condenser becomes charged. Battery is furthermore applied to the potentiometer which now includes the resistances A, G, IG, F, IF of such values that the potential of point P is lower than for the Q and K signals. With the quick charging of the condenser the charging current quickly subsides through windings 12 and 13 and the potential of point T quickly rises

to a value above that of point P at which the consequent current in winding 11 causes the relay to operate to spacing. The marking pulse will therefore be still shorter than for the Q and K signals.

Ground is now applied by the spacing contact of relay R over the make contact S of relay IR to winding 11; the biasing current will be approximately of the same strength but is reversed and now tends to operate relay R back to marking. The ground applied by the spacing contact of relay R also establishes a discharge circuit for condenser E through resistance ID and windings 12 and 13 in series, thereby reversing the current through these two windings which, consequently, delay the operation of the relay to marking. Both windings 12 and 13 now being included, the discharge circuit is slower than before and the spacing pulse will be longer. The dimensions of the circuit elements may in this case be such that the delay in operating from spacing to marking will be the same as the delay in operating from marking to spacing.

Thus, the relay system under the "I" condition produces equal marking and spacing impulses at a predetermined frequency, and with proper dimensions of the circuit elements a series of impulses may be produced as that shown in curve III of Fig. 3, in which a spacing impulse of 44 milliseconds is transmitted once for every 88 milliseconds. This impulse current, when received by the printer in the output circuit, will be interpreted as a series of start-stop impulses as shown in line "I" for producing the character "I."

For effecting the timing of the three different output impulse series indicated in Fig. 3, the following circuit constants may be used:

Battery, volt potential	130
Condenser E	microfarads 25
Condenser H	do 4.3
Resistances A, B, C, each	ohms 1000
Resistance QD	do 900
Resistance KD	do 400
Resistance ID	do 200
Resistance F	do 400
Resistance QF	do 1000
Resistance KF	do 2200
Resistance IF	do 700
Resistance G	do 800
Resistance IG	do 300

The condenser H is connected to the operating winding 12 during the "Q" and "K" conditions and serves to effect a desirable wave shape of the charging current through windings 12 and 13 and the size of this condenser will depend to some extent upon the inductances of the windings 12 and 13.

What is claimed is:

1. A vibrating polar relay having a plurality of windings and alternately opened and closed contacts and a timing condenser, a first of said windings being permanently connected to bias said relay for closing of said contacts when open, a second of said windings being connected by said closed contacts for opening of said contacts, and a third of said windings being serially connected with said second winding when said contacts are open for charging said condenser to delay the closing of said contacts by said first winding and being alternately connected over said closed contacts for discharging said condenser to delay the opening of said contacts by said second winding.

2. An oscillating polar relay having contacts biased when open to be closed and a timing condenser, said relay having two windings connected in a charging circuit for said condenser to temporarily oppose the closing of said biased contacts, and said contacts being connected to close an energizing circuit through one of said windings for opening said contacts and to close a discharge circuit for said condenser through the other of said windings to temporarily oppose the opening of said contacts.

3. An impulse producing relay circuit comprising a polar relay having contact means including alternately opened and closed contacts, a timing condenser and an output circuit connected to receive timed impulses from said contact means, said relay having a biasing winding connected for operating said contacts, said relay also having an operating winding connected through said closed contacts for opening said contacts, said relay further having a timing winding connected through said closed contacts for discharge of said condenser to delay the opening of said contacts by said operating winding, and said condenser being connected to be charged through said operating and timing windings when said contacts are opened to delay the closing of said contacts by said biasing winding.

4. A multifrequency vibrating relay circuit comprising a three-winding polar relay having contact means including local contacts for self-control of said relay, a timing condenser, and an output circuit connected to receive timed impulses from said contact means, a first of said windings being continuously connected for closing of said local contacts when open, a second of said windings being connected by said local contacts in closed position for opening of said contacts, a third of said windings being serially connected with said second winding for charging said condenser to delay the closing of said local contacts by said first winding and being alternately connected over said local contacts in closed position for discharging said condenser to delay the opening of said local contacts by said second winding, variable impedance means serially connected with said condenser for varying the periodicity of said vibrating relay circuit.

5. A multifrequency vibrating relay circuit in accordance with claim 4 further comprising variable impedance means connected with said first winding to vary the ratio of the open period to the closed period of said local contacts.

6. An oscillating polar relay having windings and contacts, biasing means for closing said contacts when open, a timing condenser, a charging circuit for said condenser connected through a winding of said relay for delaying for a predetermined period the closing of said contacts when open, and a discharging circuit for said condenser through another winding of said relay for delaying for a predetermined period the opening of said contacts when closed.

7. A vibrating polar relay system which comprises a polar relay having contacts and a plurality of windings, a timing condenser, a grounded source of direct current, a potentiometer connected across said source and having a first point of intermediate potential, a potentiometer circuit connected across said source and having another point of intermediate potential and serially including said timing condenser and two of said windings for charging of said condenser through said two windings, the third of said

windings being connected between said first and other points for energizing said relay in opposition to said two windings, an intermittently grounded circuit including said relay contacts, said condenser and one of said two windings for discharging said condenser.

8. An oscillating polar relay having contacts, a biasing winding connected to close said contacts when said contacts are open, an operating winding, a timing winding, a timing condenser, a charging circuit through said condenser and said operating winding and timing winding for delaying the closing of said contacts by said biasing winding for a predetermined period, a discharging circuit connected by said contacts through said condenser and said timing winding when said contacts are closed for delaying the opening of said contacts by said operating winding for a predetermined period.

9. A vibrating relay system comprising a polar relay having output contact means for producing impulses in an output circuit, local contact means for producing impulses in a local circuit, an operating winding and a timing winding; adjustable means for biasing said relay toward either position of said relay; a timing condenser; a source of direct current; a series charging circuit for said condenser from said source through said operating and timing windings in series for delaying the operation of said relay to its local contact position by said biasing means until the charging current has subsided to a predetermined value; a discharging circuit for said condenser closed by said local contact means through said timing winding for delaying the operation of said relay to its output contact position by said operating winding until the discharging current has subsided to a predetermined value.

10. A vibrating polar relay system which comprises a polar relay having contacts and a plurality of windings, a timing condenser, a source of direct current having a grounded side, a potentiometer connected across said source and having an intermediate potential point, impedance means, a condenser circuit from ground through said condenser and two of said windings in series and over said impedance means to said source, an operating circuit from said intermediate potential point through a third of said windings and over said impedance means to said source, and a pulsing circuit extending intermittently from ground over said relay contacts to the point of connection between said windings and said impedance means to reverse the currents in said condenser circuit and in said operating circuit.

11. A vibrating polar relay system which comprises a polar relay having contacts and a plurality of windings, a timing condenser, a grounded source of direct current, switching means having alternate contacts, a potentiometer connected across said source and having an intermediate potential point, impedance means, a charging circuit from ground through said condenser, two of said windings in series, and over said impedance to said source, an energizing circuit for said relay from said intermediate potential point through a third of said windings and over said impedance to said source, said switching means being connected for discharging of said condenser at different rates by extending intermittent ground from said relay contacts to a point between said two series windings in one position

and over said impedance to said source in the alternate position of said switching means.

12. A vibrating polar relay system which comprises a polar relay having contacts and a plurality of windings, a timing condenser, a grounded source of direct current, switching means having alternate contacts, a potentiometer connected across said source and having a first point of intermediate potential, a potentiometer circuit connected across said source and having another point of intermediate potential and serially including said timing condenser and two of said windings for charging of said condenser through said two windings, a third of said windings being connected between said first and other points for energizing said relay in opposition to said two windings, an intermittently grounded circuit including said relay contacts and connected through said switching means in one position to discharge said condenser through one of said two windings and in the alternate position to discharge said condenser through both of said two windings and to reverse the current in said third winding.

13. A vibrating polar relay system which comprises a polar relay having contacts and a plurality of windings, a timing condenser, a source of direct current, a first bridge arm connected across said source and including two ratio arms of impedance means, a second bridge arm connected across said source for charging said condenser and including impedance means, two of said windings and said condenser, a third of said windings being connected between intermediate points of said bridge arms for energizing said

relay in opposition to said two windings when said condenser is being charged, an intermittent discharge circuit over said relay contacts through at least one of said two windings and said condenser, said impedance means in said second bridge arm being adjustable to vary the charging current through said condenser to thereby vary the frequency of vibration of said relay, and said ratio arms in said first bridge arm being adjustable to vary the current through said third winding to thereby control the operating time of said relay within each cycle of vibration.

14. A vibrating polar relay system which comprises a polar relay having contacts and a plurality of windings, a timing condenser, a grounded source of direct current, a potentiometer connected across said source and having an intermediate potential point, a charging circuit from ground through said condenser and two of said windings in series to said source, an operating circuit from said intermediate potential point through a third of said windings and over said impedance to said source for overcoming said two windings and operating said relay contacts in one direction and a pulsing circuit for intermittently extending ground over said relay contacts to the point of connection between the said two windings in series to discharge the condenser through the first of said two windings and to increase the current in the other of said two windings for overcoming said first and third windings and operating said relay contacts in the opposite direction.

ANDREW L. HOPPER.