

Dec. 30, 1947.

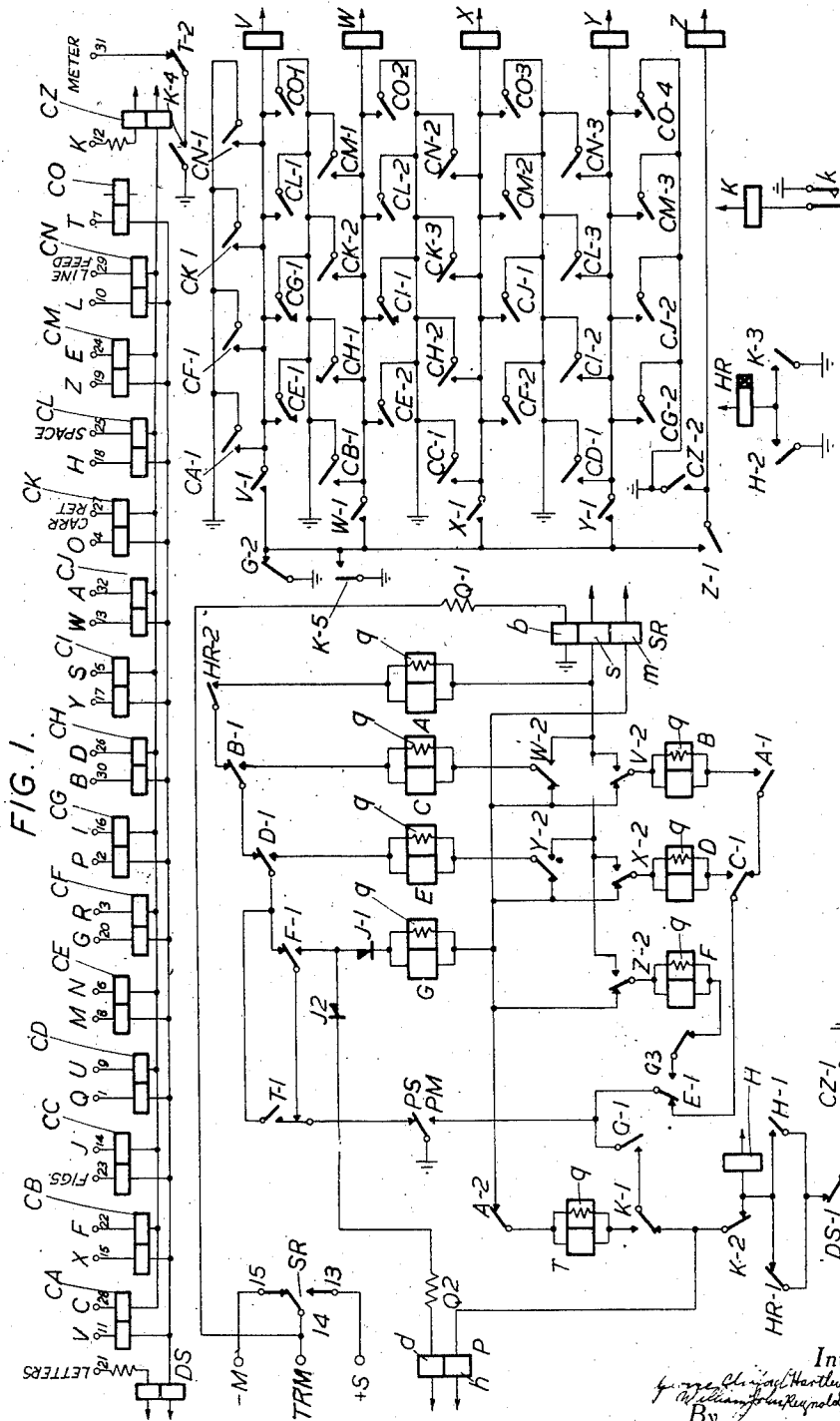
G. C. HARTLEY ET AL

2,433,362

PENDULUM RELAY CONTROLLED START-STOP TELEGRAPH TRANSMITTER

Filed March 10, 1943

3 Sheets-Sheet 1



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FIG. 2.

MILLISECONDS

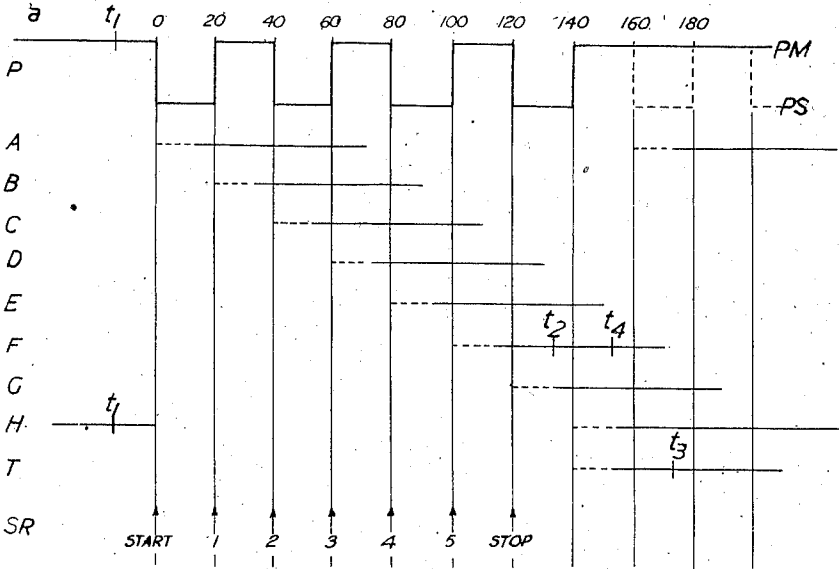
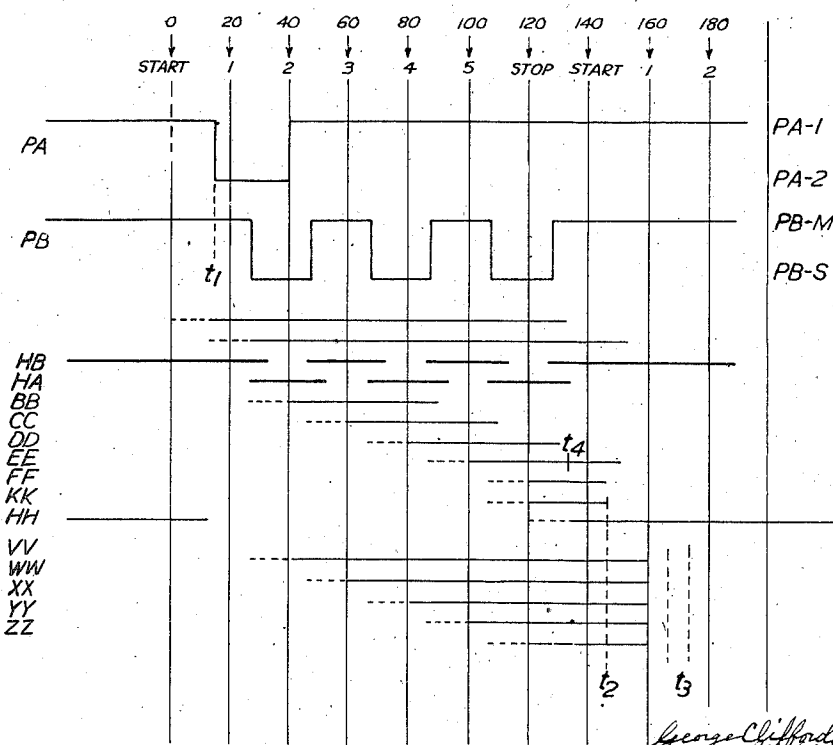


FIG. 4.



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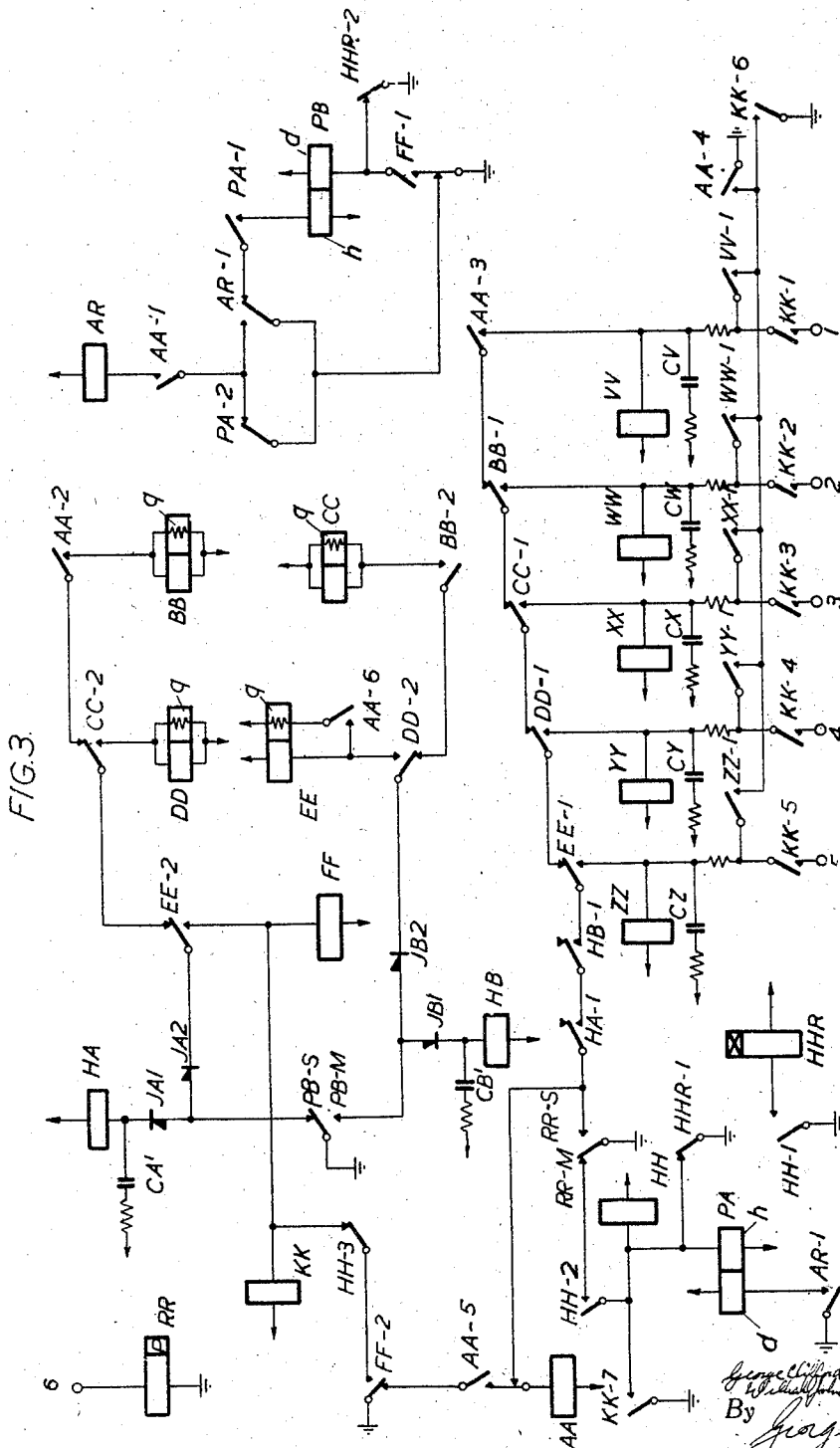
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PENDULUM RELAY CONTROLLED START-STOP TELEGRAPH TRANSMITTER

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3 Sheets-Sheet 3



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UNITED STATES PATENT OFFICE

2,433,362

PENDULUM RELAY CONTROLLED START-STOP TELEGRAPH TRANSMITTER

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In Great Britain March 13, 1942

26 Claims. (Cl. 178—79)

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The present invention relates to telegraph systems operating with a code such as the five-unit code, and is more particularly concerned with circuit arrangements for transmitting and receiving such a code, which do not involve rotating mechanical systems.

Probably the most important application of the five-unit code at the present time is in the transmission of teleprinter signals where the well known "start-stop" principle is employed. The power required to operate a teleprinter is derived from an electric motor coupled to a rotating mechanical system, and on account of the functions which it has to perform it is necessarily an intricate and expensive machine requiring a relatively large amount of maintenance. There are certain cases where a telegraph channel is required to convey information of a limited character in which the cost of teleprinters would not be justified, particularly where the information is not required to be recorded on paper in the usual way. A typical case of this kind is that in which an electric power supply authority requires a means for periodically reporting the indications of wattmeters or other like instruments located at a distance; the necessary information can in this case be conveyed by means of a few characters, and might be used to operate appropriate indicators, instead of being typed out. Another example is the case where a circuit is used for the transmission of certain standardised orders to a distant point where they might be displayed on an indicator.

It is evident that a system suitable for this sort of service should be economical to construct and should require the minimum of maintenance. The present invention provides circuit arrangements chiefly employing ordinary commercial telephone type relays not requiring any special adjustments, and not involving any motor-driven mechanical systems. These circuits comprise a code sender which will transmit any "start-stop" character; and a code receiver which can be used to store the characters and to use them to operate any suitable form of indicator or other receiving device. The code sender could, if desired, be used to operate the printing section of an ordinary teleprinter over a telegraph channel and would therefore prove an economical alternative one-way transmitter for ordinary messages if a home record can be dispensed with.

According to the invention there is provided a telegraph system for start-stop code signals comprising a pendulum relay, means for releasing the relay armature from a locked position to execute

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free oscillations, and means for returning the armature to a locked position after a predetermined number of swings.

According to another aspect, the invention consists in a telegraph system comprising a relay having a vibrating armature, and means for causing the said armature to time the transmission or reception of a code combination of signal elements, each such combination comprising a start element and a stop element.

The invention will be more clearly understood by reference to the following detailed description of embodiments and to the accompanying drawings, in which

Fig. 1 shows a schematic circuit diagram of a code sender according to the invention;

Fig. 2 shows a diagram used to explain the operation of Fig. 1;

Fig. 3 shows a schematic circuit diagram of a code receiver according to the invention; and

Fig. 4 shows a diagram used to explain the operation of Fig. 3.

In order that the invention may be clearly understood, it will be assumed that the signals to be transmitted are start-stop five-unit code signals suitable for the conventional teleprinters operating at a speed of 50 bauds. It will be evident, however, that the same circuits are adaptable for other codes and speeds: it is quite possible, for example, that in some of the cases mentioned above to which the invention is specially suited, the information could be conveyed on a code with fewer units; in other circumstances more than five units might be preferable.

In all machine systems using codes, it is essential to have some means of sending out signals at accurately spaced intervals. In teleprinters this is generally done by means of a shaft rotating at an accurately controlled speed and carrying a cam which operates contacts once per revolution. In the present invention, use is made of a pendulum relay having an armature which can execute isochronous vibrations with small damping, and which is adapted to operate contacts approximately at the centre of its travel, in such manner that the intervals between successive operations are closely equal. Such an armature might consist of a weight mounted on a flat spring which also carries the means for operating the contacts, and may be held in a locked position on one side when the relay winding is energised. The weight should preferably be adjustable on the spring so that the vibration frequency can be varied. The armature can be caused to exe-

cute free vibrations by cutting off the energising current, and so releasing it, and by a suitable circuit it may be given suitably timed impulses to maintain it indefinitely in vibration, if desired. The preferred type of relay is that which forms the subject of the co-pending British Patent No. 549,971, granted March 11, 1943. This relay is of cheap construction, and is capable of manufacture from parts similar to those of commercial telephone relays, and does not require critical adjustments, except for the oscillation frequency, which is easy to carry out.

Figs. 1 and 3 are schematic circuit diagrams according to the invention, drawn on the "detached contact" principle.

In order to simplify the circuits, any connection to the battery or other constant potential source is indicated by an arrow-head pointing away from a relay, and earth connections are indicated by the conventional symbol. The positive terminal of the battery is supposed to be connected to earth, though the circuit would operate the other way just as well. Generally, spark quenching arrangements, current adjusting resistances and other like accessories not essential to the invention have been omitted, and may be supplied in any suitable manner known to those skilled in the art.

The circuits are shown with all relays in the unoperated condition, that is, the condition which holds before the battery has been switched on. Actually certain relays are normally operated during the idle periods between the transmissions of the individual characters, and these will be pointed out in the course of the explanation of the operation of the circuits.

In the description of the circuits, use will be made of the terms "mark" and "space," and "marking" and "spacing." The marking condition of a line or circuit used for start-stop signals is the condition during which the circuit is temporarily idle, though ready to transmit characters, and the spacing condition is the opposite condition. The actual state of the line or circuit, that is, whether it is connected to positive or negative battery, or whether in the case of single current operation it is open or closed (and so on) during the marking condition will depend on the arrangements which have been chosen, and is immaterial, so long as the chosen conditions are consistently maintained. The signal element which is produced by the change to the marking condition will be called a "marking" element or "mark," and the other element is the "spacing element" or "space." Thus the start element is always a "space," and the stop element is always a "mark."

When the pendulum relay armature vibrates, it makes alternate swings from side to side and is always locked, and released from, the same side. The word "swing" will be used to denote one movement of the armature; a complete vibration period therefore comprises two swings.

Although in the detailed description below various particular relay timings and the like have been specified for clearness, these are not in any sense necessary to the invention, and other timings can be arranged for other cases.

Referring to Fig. 1, there is shown a schematic circuit diagram of a code sender according to the invention. It employs a pendulum relay P, a sending relay SR which is preferably a polar telegraph relay, and a number of ordinary commercial telephone relays.

General account of the code sender circuit (Fig. 1)

The line over which the signals are to be transmitted is connected to terminal TRM, which leads directly from the armature 14 of the sending relay SR. Transmission of the code for any character is effected by momentarily earthing by any convenient means one of the terminals 1 to 30 or 32, which have been labelled with the characters they represent. These terminals could, for example, be connected to a typewriter key system provided with the necessary contacts. The timing of the signals corresponding to each separate character is determined by the pendulum relay P which operates the sending relay SR at the proper times to the marking or spacing side, according to setting of the code storing relays V, W, X, Y, Z. These relays are selectively operated by code setting relays connected to the above terminals. A train of successively operated counting relays A, B, C, D, E, F and G counts the swings of the relay P, and causes it to be locked up when the transmission of the character is completed.

Grouping of characters

The characters are divided into two groups depending upon whether the last unit element of the code is a marking or a spacing element; and earthing a character terminal, for example B (No. 30), operates a relay DS giving a final marking element, while operating D (No. 26), operates relay CZ and gives a final spacing element. The characters B and D have the same first four unit elements, and share a code setting relay CH. All the other characters are similarly paired except K (which has four marking elements and a space), and the letter shift, which has five marking elements. As will presently be clear, neither of these characters needs a code setting relay.

Earthing a character terminal operates in series one winding of the corresponding code setting relay CA to CO and the relay DS or CZ (according to the type of the last unit element), the circuit being obvious.

Setting the operating condition of the circuit

When the battery supply is first switched on to put the circuit in the operating condition, relay H operates through the contacts HR—1, and locks through its own contacts H—1. This relay remains operated all the time that the circuit is idle. Relay H operates the slow-release relay HR by closing the contacts H—2, which thereupon opens its contacts HR—1. This relay remains permanently operated for the whole of the time the circuit is working, and does not release during the transmission of the characters. Its sole purpose is to reset the idle condition of the circuit when the batteries are first switched on. Switching on the battery also operates the pendulum relay P through its holding winding *h* and contacts HR—1 or H—1, and holds it with the armature on the PM side. Thus, in the idle or ready to operate condition, relays H and HR are operated, and the pendulum relay P is locked with the armature on the PM side.

Setting of the code storing relays

When a character terminal is earthed, for example, B, relays CH and DS operate in series. CH operates relays W and X through its contacts CH—1 and CH—2 respectively, and W and X lock themselves through contacts W—1 and

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X-1. This will cause a spacing element to be transmitted for the second and third code units. Earthing of other character terminals will cause the operation of other selections of the code storing relays, and a spacing element is sent for units corresponding to code storing relays which have been operated, and marking elements for those which have not. Thus since the first four code units for K and "letters" are all marking elements, none of the relays V to Y have to be operated, as the code setting relay CZ only is required for K, to operate relay Z.

Preparing the code

Marking and spacing batteries are respectively connected to terminals -M and +S, and thence to the marking and spacing contacts 15 and 13 of the sending relay SR. The relay has two equal main windings *m* and *s* connected to battery, as shown, so that when earth is applied to *m* the armature 14 is operated to the marking contact 15, and when earth is applied to *s* it is operated to the spacing contact 13. The bias winding *b* is connected through a resistance Q-1 to the armature to provide a current just great enough to hold the armature on the contact on which it was last placed, when there is no current in either of the main windings.

The coding contacts V-2 to Z-2 of the code storing relays are respectively associated with the counting relays B, C, D, E and F. When the character B is to be transmitted, relays W and X are operated and connect the spacing winding *s* of relay SR to relays C and D. Since the other code storing relays are not operated, the marking winding *m* of relay SR is connected to relays B, E and F. Relay A is connected to the spacing winding, and relay G to the marking winding irrespective of the code storing relays. They correspond respectively to the start and stop elements.

It will be understood that if the character to be transmitted had been D, relay CZ would have been operated instead of DS, and by closing its contacts CZ-2 would have operated Z to prepare a spacing element for the last code unit.

The relay SR is ultimately operated by the armature of the pendulum relay P through the contacts of the counting relays, which are closed in turn in the manner to be presently explained, and the code storing relays W and X, being operated, decide that spacing elements are to be sent for the second and third units by preparing the connection of the spacing winding *s* of the relay SR. It will be evident that when some other character is to be sent, the code storing relays will prepare the spacing winding of SR for operation in some other selection of units.

Transmission of the code

The earthing of a character terminal, besides setting the code storing relays, also operates relay DS or CZ as has been explained. One of these relays opens the contacts DS-1 or CZ-1 and releases relays H and P by removing the earth connection from their windings. H opens its contacts H-1 thus rendering open the earth connection during the transmission of the character, (since relay HR remains operated owing to its slow releasing character). On removal of the earth from the character terminal, relay DS or CZ is released, so that the earth connection is prepared for the subsequent locking of relay H.

The pendulum relay P on its release executes a number of free vibrations so that the armature makes alternate contact with PS and PM at times

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spaced by equal intervals, which for a telegraph speed of 50 bauds will be 20 milliseconds. The sequence of operations involved in transmitting the code will be more clearly understood from Fig. 2, in which the graph *a* indicates the operations of the pendulum relay referred to a horizontal time scale. The armature is initially on the PM side and after release at *t*₁ by relay DS or CZ, contact with PM will be broken say, 12 milliseconds later, at zero time, and contact with PS is made after a negligible interval. The pendulum then swings regularly, the change-over occurring substantially every 20 milliseconds as shown by the graph *a*.

The operations of the various relays are shown in Fig. 2 by horizontal lines the lengths of which indicate the time during which the contacts are operated. The dotted portions of these lines cover the periods during which the winding is energized but before the contacts have operated. The counting relays A to G may take about 12 milliseconds to operate, and their windings are shunted by resistances *q* to delay the release for about 50 milliseconds after the operating current is cut off. Relay H is not so shunted and may release in about 10 milliseconds.

At the moment *t*₁ some of the relays V to Z are energized as already explained and will have operated before zero time. The relay H will also have released by this time as shown in Fig. 2.

When the relay P makes contact on the PS side at zero time, the counting relay A is energized through the contacts B-1, D-1, F-1 and T-1 and through the contacts HR-2, which are closed. The sending relay SR is at the same time operated to space, giving the start signal. When relay A closes its contacts A-1 at about 12 milliseconds, it prepares relay B for operation after the next swing of relay P. As already explained, contacts A-1 will remain closed for about 70 milliseconds, that is for 50 milliseconds after disconnection on the next swing of relay P at 20 milliseconds, to allow B to be energized when relay P makes contact on the PM side at that time.

When this occurs the sending relay will also be operated to mark (for the character B). When relay B operates at about 32 milliseconds it prepares C, and cuts off A to prevent it from being re-operated when P swings to PS next time. Relays C, D, E, F and G then operate in turn on alternate swings of the relay P in the same manner, each preparing the next one and cutting off the previous one. Meanwhile the sending relay SR is operated on each swing to mark or space as determined by the code storing relays, (giving a space at 40 and 60 milliseconds for character B).

After the operation of F, a marking stop element is given when relay P swings to PS at 120 milliseconds, the sending relay being energized through the rectifier J1 whose purpose will be presently explained. A circuit is also completed through the rectifier J2 and a resistance Q2 to the winding *d* of the pendulum relay P for a reason also to be explained later on. When the pendulum finally swings back to PM at 140 milliseconds, it locks itself up through the circuit including winding *h* prepared by contacts G-1 of relay G through contacts K-1. Relay H is also again energized through the contacts G-1 and K-2 and locks itself up at about 152 milliseconds. The relay G also releases the code storing relays by opening its contacts G-2, and the circuit is again in the idle condition.

It will be noted that contacts G-3 have been

included between the contacts E—1 and relay F. Reference to Figs. 1 and 2 will show that when relay P swings to PM at 140 milliseconds the relay F would be again energised because E has not released. Accordingly contacts G—3 are put in to cut off relay F at about 128 milliseconds as indicated at t_2 .

The locking up of relays H after the completion of the transmission of the character depends upon the circuit being closed at contacts DS—1 and CZ—1. If the earth should be left connected to the character terminal, relay DS or CZ will remain operated and the circuit will be broken. H does not lock up, but HR will ultimately release, closing contacts HR—1; and H will be re-operated as soon as the earth is removed from the character terminal, so that the circuit ultimately returns to the idle condition.

Testing arrangements

For testing purposes, an extra counting relay T is provided, with a test relay K controlled by a key k . On the operation of this relay by closing the key, relay H is cut off at the contacts K—2 and the pendulum relay P is released. Relay HR is maintained permanently operated by contacts K—3. The counting relays then operate in turn as before starting from A (HR—2 being closed), until the operation of G which instead of causing P to lock up, energises relay T, which has a resistance q shunting the winding and is otherwise similar to the other counting relays. When T operates at about 148 milliseconds it bypasses contacts F—1 as indicated at t_4 in Fig. 2 and causes the cycle to be repeated by the re-operation of A at about 172 milliseconds, after the pendulum has swung to PS at 160 milliseconds. Relay T is cut off by the contacts A—2 as shown at t_3 to prevent its re-operation on the next swing, and the cycle is repeated indefinitely.

These operations are shown in Fig. 2. The dotted lines in the curve a represent the continued swinging of the pendulum relay P, and a second operation of A is indicated to show how the cycle re-commences after the operation of T.

The operations of the circuit may be counted and timed by means of the contacts T—2 which earths a test terminal 31 (through the contacts K—4 which are closed) for each cycle. Any suitable testing device may be connected to terminal 31.

The circuit already mentioned leading from contacts F—1 through rectifier J2 to the winding d of relay P are for the purpose of giving it an impulse near the end of each cycle. While the preferred type of pendulum relay will oscillate freely for some seconds, it is necessary to sustain its oscillations over the comparatively long period of the test. The rectifiers J1 and J2 are provided to prevent impulses from being applied to the pendulum relay through the winding of G and the other counting relays each time they are operated.

The contacts K—5 are provided to short-circuit the contacts G—2 to prevent the release of the code storing relays at the end of a cycle. This enables any desired character to be continuously repeated during the test in order to permit distortion or other like tests to be made.

The code setting relays CA to CO are required if any code is identified by conditions on a single wire; as would be the case if the circuit is associated with a teleprinter keyboard. It will be obvious however that in many applications these relays can be omitted altogether and the re-

quired codes set up by operating the code storing relays V to Z directly to give the required combination. Relay CZ would be unnecessary and relay DS could operate in series with the code storing relays and have the same function as in Fig. 1.

Fig. 3 shows a code receiver which will operate in conjunction with the code sender of Fig. 1 or with any other device which transmits start-stop code signals at certain predetermined code unit intervals.

General account of the code receiver circuit (Fig. 3)

The incoming signals are applied at terminal 6 to the receiving relay RR, which is preferably a polar relay having marking and spacing contacts RR—M and RR—S. The unit signals repeated by the relay RR are inspected by a series of code storing relays VV, WW, XX, YY and ZZ each of which applies an earth to a corresponding terminal 1 to 5 (which may be connected as desired to a receiving apparatus or storage system of any type), when the corresponding unit signal is a space. A pendulum relay PB determines that the inspection shall be made during a short interval, say, about 5 milliseconds, in the middle of each 20 millisecond unit interval, and a train of counting relays BB, CC, DD, EE and FF counts the swings of the pendulum relay and causes it to be locked up when the character has been received. A second pendulum relay PA is used to delay the release of the first pendulum relay PB, so that the inspection periods occur in the middle of the 20 milliseconds signal intervals. The description below is based on a 5 millisecond inspection period, the first of which lasts from about $27\frac{1}{2}$ to about $32\frac{1}{2}$ milliseconds after the receipt of the start signal, that is, in the middle of the first code interval. It will be evident, however that the circuit can be arranged to operate with an inspection period of any desired length, and timed as required, with respect to the code unit elements.

The details of the operation are as follows:

Idle, or ready to operate condition

In the working condition of the circuit it is necessary for the two pendulum relays PA and PB to be locked up and for relay HH to be operated. For this purpose a slow-release relay HHR is provided as before. As soon as the batteries are switched on, HH and PA operate through contacts HHR—1, and PB operates through its winding d and HHR—2. These contacts, however immediately break when HHR is operated by the closing of contacts HH—1, the relay HH locking itself and holding PA through its winding h and contacts HH—2 from the earth obtained from contact RR—M. The relay HHR remains operated during the transmission of each character, as before. After the operation of HHR, PB is held through its winding h , and contacts PA—1, AR—1, and FF—1; contacts PA—2 being now open.

Effect of the start signal

On receipt of the start signal, the receiving relay RR changes its armature over to the spacing side RR—S. This operates relay AA which locks itself through its contacts AA—5 and the contacts FF—2. Relay AA prepares for subsequent operation relays AR (through AA—1; PA—2 being open); BB (through AA—2); and

VV (through AA—3); and further, it prepares a locking earth for the code storing relays VV to ZZ, by closing its contacts AA—4.

The removal of the earth connection from RR—M also releases the pendulum relay PA, which starts to swing. Nothing further happens until it opens the contacts PA—1 which releases the other pendulum relay PB, which thereupon also starts to swing. The closing of the contacts PA—2 which occurs at about the same time, operates relay AR which applies earth to the winding δ of PA through contacts AR—1 for the purpose of locking it up on the return swing. PA plays no further part in the transmission of the character. PB continues to execute a few free vibrations until it becomes locked up on the completion of the operation.

The removal of earth from RR—M also releases relay HH which opens its contacts HH—2; this is in order to prevent subsequent marking signals from affecting relays HH and PA. HH also closes the contacts HH—3 to prepare a locking circuit for relay FF, and an operating circuit for KK.

It will thus be seen that the start signal releases the timing relays and prepares a number of circuits for later operation.

Operation of the timing relays

The working of the relays PA and PB and of the other relays will be understood from the diagram of Fig. 4. The various operations are there indicated with reference to a horizontal time scale divided at intervals of 20 milliseconds. The start element is supposed to be received at zero time; the code elements arrive at 20, 40, 60, 80 and 100, milliseconds, and the stop element at 120 milliseconds as indicated.

It is assumed that the start element for the next character is received again at 140 milliseconds, which is the earliest possible time, and the corresponding first and second unit elements are also shown at 160 and 180 milliseconds.

As already stated, the first inspection is to take place between $27\frac{1}{2}$ and $32\frac{1}{2}$ milliseconds, and is made to commence when relay PB closes its contacts PB—S, as will be presently explained. The relay PB must execute free vibrations at as nearly as possible 25 complete cycles per second in order to time the inspection correctly. It is found that relays of the type described in the above mentioned specification and adjusted to 25 cycles take about 12 milliseconds to operate their contacts after being released from the locked position. The inspection relays are high speed relays having an operate time of the order of 1 millisecond. To achieve the timing mentioned above the relay PA must introduce a delay of $14\frac{1}{2}$ milliseconds and this will be attained if the relay is adjusted to a frequency of about 20 cycles per second. It will be understood that in practice the PA relay can be adjusted to give the exact time required for the case quoted above or to function with an inspection period of any other duration which may be convenient.

Thus in Fig. 4, relay PA is released by the start signal at zero time. It opens the contacts PA—1 and releases PB at $14\frac{1}{2}$ milliseconds. PB swings over to the PB—S side at about $27\frac{1}{2}$ milliseconds. Meanwhile, of course, relay RR has changed back to the marking side for the first code element (assuming the character B as before), but this has no immediate effect. The changing over of the armature of relay PB has removed the earth from the inspecting relay HB and applied it to

the other inspecting relay HA. These two relays should be very quick to operate, but should be given a releasing time of say, 5 or 6 milliseconds by means of the rectifier and condenser arrangement shown, for example. Thus HB does not release until about $32\frac{1}{2}$ milliseconds, while HA is operated at $27\frac{1}{2}$ milliseconds, so that both relays are operated together for the required period of about 5 milliseconds in the middle of the code interval. Thus the circuit leading from the spacing contact RR—S to the contacts of the counting relays is closed for this period only, through the relay contacts HA—1 and HB—1. This can be seen from Fig. 4, where the horizontal lines marked HA and HB denote the periods during which these relays have their contacts closed: the 5 millisecond overlap is clearly shown with reference to the operations of PB. It will be clear that the same process occurs in the middle of each of the code intervals. At approximately 40 milliseconds, the relay PA swings back and locks up, as shown by the graph labelled PA. PB goes on swinging until locked up at about $127\frac{1}{2}$ milliseconds, after the operation of relay FF as will be explained later on.

Operation of the counting and code storing relays

The relay VV has been prepared for operation by the closing of contacts AA—3, and if the first code unit element is a space, it will be operated and locked through its contacts VV—1 during the first inspection period, but not otherwise. Relay BB, prepared by contacts AA—2, is energised on the swing of PB—S at $27\frac{1}{2}$ milliseconds and operates at about 40 milliseconds, and cuts off VV and prepares CC for operation at about $47\frac{1}{2}$ milliseconds on the next swing of the relay PB. Relay BB remains operated for about 50 milliseconds until about 90 milliseconds, by reason of the resistance q shunting its winding. Relay BB also prepares WW by closing its contacts BB—1, which will operate in the second code interval for the character B. The same series of operations then follows. Relays CC, DD and EE operate one after the other, allowing XX, YY and ZZ to operate if the corresponding code element is a space.

When relay EE has operated, by closing its contacts EE—2 it prepares relays FF and KK to be energised by the pendulum relay on its swing at $107\frac{1}{2}$ milliseconds. These relays operate at about 120 milliseconds. Relay KK re-operates relay HH by closing its contacts KK—1, which then locks on receipt of the stop element. Relay FF releases AA and locks up through the contacts FF—2, holding KK energised at the same time. When HH has operated at about 132 milliseconds, FF and KK are disconnected by the opening of the contacts HH—3 and release about 12 milliseconds later (since they are unshunted).

The relay KK by closing its contacts K—1 to K—5 connects earth to the terminals 1 to 5 according to the setting of the code storing relays VV to ZZ. This earth is obtained through contacts AA—4, and relay KK provides an alternative earth through contacts KK—6 because relay AA is released before the operation is complete. When relay KK is finally released at about 144 milliseconds (t_2 , Fig. 4) it disconnects all the code storing relays which have been operated and these relays all release at about 158 milliseconds. All the operations which have been described are diagrammatically shown in Fig. 4.

While the operate and release times of these relays are not of critical importance, it is neces-

sary that these times should not be so long that the code relays fail to release before about 160 milliseconds. It is possible for the second character to be transmitted so closely following the first that the interval between the stop and the start elements is reduced to 20 milliseconds. The first inspection interval for the second character can thus occur from $167\frac{1}{2}$ to $172\frac{1}{2}$ milliseconds shown at t_3 in Fig. 4, and it is therefore clearly necessary that the code storing relays should be released before this interval.

The swing of the pendulum relay PB at $107\frac{1}{2}$ milliseconds is the last effective swing, and it must be locked up on its return at $127\frac{1}{2}$ milliseconds. The operation of relay FF provides the necessary locking circuit by closing its contacts FF—1. In the meanwhile, the release of AA has released AR by opening its contacts AA—1. This takes the locking ground off relay PA (now held through winding h), and prepares the holding circuit for PB through AR—1 and PA—1. When relay FF is finally released after the operation of KK, the earth is transferred from the winding d to the winding h of relay PB, and the circuit is restored to the idle condition.

It will be noted that the contacts AA—6 associated with the winding of relay EE disconnect the shunting resistance q when AA is released. This is to ensure the release of EE.

The timing of the release of the inspecting relays HA and HB is carried out by shunting the windings with condensers CA and CB respectively having current limiting resistances of low value connected in series, and by providing the series rectifiers JB1 and JA2. Each relay is energised through the associated rectifier and should operate very quickly as already explained, and the condenser is at the same time charged. When the circuit is broken by the pendulum relay PB, the condenser discharges through the relay holding it operated for the desired time, the other path being blocked by the rectifier. Two other rectifiers JA2 and JB2 are provided to block the undesired alternative paths through the contacts of the counting relays by which the inspecting relays could be operated.

The earth for operating the code storing relays VV to ZZ is only applied for the 5 millisecond inspection period, and in order to ensure their proper operation, their windings are shunted by condensers CV, CW, CX, CY and CZ in series with current limiting resistances. Each condenser is charged up at the same time as the relay is energised, and when the circuit is broken at HA—1 or HB—1, the condenser discharges through the winding of the relay and ensures its complete operation, and it then locks itself as already explained.

It will be understood that the final effect of receiving a character is that relay KK momentarily connects to earth any of the terminals 1 to 5 for which the corresponding code signal element is a space. It is assumed that these terminals will be connected to some storage or indicating device of any desired type: for example each terminal could be connected to a self-locking relay which operates a corresponding lamp; or the particular combination of relays which are operated would operate a lamp corresponding to the character transmitted. Additional contacts on the relay KK with corresponding terminals could be provided for performing other operations, such as for stepping up a selector switch for setting up several characters in succession. These arrangements are not any part

of the invention and will be supplied as required by those skilled in the art.

By combining the circuits of Figs. 1 and 3 a start-stop regenerative repeater may be obtained. One way of doing this would be to provide the code storing relays VV to ZZ of Fig. 3 with the same contact combinations as those of Fig. 1 and to connect them in place of those relays. The code setting relays CA to CZ and DS would be omitted, and a starting contact operated for example by relay BB, Fig. 3, would replace DS—1 or CZ—1 in Fig. 1. Distorted signals received by the relay RR in Fig. 3 would be inspected by the code storing relays VV to ZZ which would prepare the relay SR in Fig. 1 for operation in the manner already described, and accurate signals would be sent out again, timed by the pendulum relay P in Fig. 1. Unnecessary duplication of relays could, of course, be removed. Other simpler arrangements of the combined circuit are possible and will be easily prepared by those skilled in the art in accordance with the principles which have been explained.

For claims to the regenerative repeater just described, as well as claims to the receiver, per se, reference is to be had to our divisional application No. 660,100, filed April 6, 1946.

Although the invention has been described for clearness in terms of particular embodiments, it is not intended to be limited thereto, nor to the numerical values which have been quoted as examples.

What is claimed is:

1. A telegraph system for start-stop code signals comprising a relay having an armature capable of oscillating freely at a predetermined rate, means for holding said armature displaced from its normal position, means for releasing said holding means to permit free oscillation of said armature, means for operating said holding means after a predetermined number of oscillations of said armature to secure said armature again in said displaced position, a coding apparatus for producing sequential code elements, electrical means for causing said armature to time the operation of said coding apparatus, and means for simultaneously setting said coding apparatus and operating said means for releasing said holding means.

2. A telegraph system in accordance with claim 1, in which the relay is a pendulum relay.

3. A telegraph system in accordance with claim 1, in which the relay has a vibrating armature.

4. A telegraph system in accordance with claim 1, in which the code elements of the coding apparatus include a start element and a stop element.

5. A telegraph system in accordance with claim 1, in which the coding apparatus comprises means to store information relating to a combination of code elements corresponding to any character to be transmitted, means to transmit the information so stored, and means to release said storing means after the transmission of said information.

6. A telegraph system in accordance with claim 1, in which the coding apparatus comprises a train of counting relays operated in sequence by alternate oscillations of the oscillating relay.

7. A telegraph system in accordance with claim 1, in which the coding apparatus comprises a train of counting relays operated in sequence by alternate oscillations of the oscillating relay and the operation of each counting relay except the last prepares a circuit for the operation of the

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next relay in the series and in which the operation of each counting relay except the first disconnects the winding of the preceding relay in the series.

8. A telegraph system in accordance with claim 1, in which the coding apparatus comprises a train of counting relays operated in sequence by alternate oscillations of the oscillating relay and the operation of each counting relay except the last prepares a circuit for the operation of the next relay in the series, and in which the operation of each counting relay except the first disconnects the winding of the preceding relay in the series, and in which at least one of the counting relays is provided with means for delaying the release thereof after disconnection by the preceding relay until after the next relay has operated.

9. A telegraph system in accordance with claim 1, in which the coding apparatus comprises a train of counting relays operated in sequence by alternate oscillations of the oscillating relay and the operation of each counting relay except the last prepares a circuit for the operation of the next relay in series, and in which the operation of each counting relay except the first disconnects the winding of the preceding relay in the series, at least one of the counting relays being provided with a resistance connected in shunt therewith for delaying the release after disconnection by the preceding relay until after the next relay has operated.

10. A telegraph system in accordance with claim 1, in which the coding apparatus comprises a train of counting relays operated in sequence by alternate oscillations of the oscillating relay and in which the operation of the last counting relay by the oscillating relay prepares a circuit for locking the armature of the oscillating relay on the next following swing.

11. A telegraph system in accordance with claim 1, in which the coding apparatus comprises a train of code storing relays equal in number to the number of units in the code for storing information relating to a combination of code elements corresponding to any character to be transmitted, means to transmit the information so stored, and means to release said storing relays after the transmission of said information.

12. A telegraph system in accordance with claim 1, in which the coding apparatus comprises a train of code storing relays equal in number to the number of units in the code for storing information relating to a combination of code elements corresponding to any character to be transmitted, means for locking said relays after operation, means to transmit the information so stored, and means to release said storing relays after the transmission of said information.

13. A telegraph system in accordance with claim 1, in which the coding apparatus comprises a train of code storing relays equal in number to the number of units in the code for storing information relating to a combination of code elements corresponding to any character to be transmitted, means to operate a code storing relay only when the corresponding code unit element is a space, means to transmit the information so stored, and means to release said storing relays after the transmission of said information.

14. A telegraph code sender for start-stop code signals comprising a relay having an armature capable of oscillating freely at a predetermined rate, means for holding said armature displaced from its normal position, means for releasing said holding means to permit free oscillation of said

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armature, means for operating said holding means after a predetermined number of oscillations of said armature to secure said armature again in said displaced position, a plurality of code storing relays, electrical means controlled by said oscillating relay for selectively operating said code storing relays in accordance with the code corresponding to any character to be transmitted, and means for simultaneously operating said means for releasing said holding means when a code is introduced into said sender.

15. A telegraph code sender in accordance with claim 14, in which the means for operating the code storing relays comprises one or more code setting relays corresponding to each character, the operation of which relays causes operation of the appropriate code storing relays.

16. A telegraph code sender in accordance with claim 14, in which one code setting relay is provided for every pair of characters which differ only in the last unit element, two other code setting relays being provided, the first of which is common to all characters having a final marking element and the second of which is common to the remaining characters.

17. A telegraph code sender in accordance with claim 14, in which one code setting relay is provided for every pair of characters which differ only in the last unit element, two other code setting relays being provided, the first of which is common to all characters having a final marking element and the second of which is common to the remaining characters, and in which is provided means to cause the operation of the second common relay to operate the last code storing relay, and means to cause the operation of either of the common relays to cause the release of said oscillating relay.

18. A telegraph code sender in accordance with claim 14, in which the operation of the last counting relay prepares a circuit for locking the armature of the oscillating relay on the next following swing, and in which the last counting relay is provided with break contacts for releasing the code storing relays when said last counting relay is operated by the penultimate swing of said oscillating relay.

19. A telegraph code sender in accordance with claim 14, in which the means for operating said code storage relays comprises one or more character keys with associated relays, adapted on operation to set the code storing relays in accordance with the code for the corresponding character, and at the same time to release said oscillating relay.

20. A telegraph code sender in accordance with claim 14, comprising a polar sending relay for transmitting the code signals to the outgoing line, the said polar relay having a marking and spacing winding, one of which is adapted to be energized in series with a counting relay on each swing of the oscillating relay.

21. A telegraph code sender in accordance with claim 14, comprising a polar sending relay for transmitting the code signals to the outgoing line, the said polar relay having a marking and spacing winding, one of which is adapted to be energized in series with a counting relay on each swing of the armature of said oscillating relay, and in which each coding storing relay is provided with contacts adapted to prepare the spacing winding or the marking winding of said polar relay for energization on the corresponding swing of the armature of said oscillating relay, accord-

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ing as said storing relay is or is not operated respectively.

22. A telegraph code sender in accordance with claim 14, provided with testing means under the control of a test key for causing the sender periodically to repeat the transmission of any given character.

23. A telegraph code sender in accordance with claim 14, provided with testing means under the control of a test key for causing the sender periodically to repeat the transmission of any given character, and means for giving the oscillation relay an impulse once during each cycle of the test operation for the purpose of maintaining said relay in oscillation.

24. A telegraph code sender in accordance with claim 14, in which a train of counting relays is arranged to operate the code storing relays and in which testing means is provided under the control of a test key for causing the sender periodically to repeat the transmission of any given character, and in which said testing means comprises an extra counting relay adapted to be adapted to be added to the counting train on operation of the test key in such a manner that it is prepared for operation by the last counting relay and when operated by the oscillating relay it disconnects the said last counting relay and prepares the first counting relay for operation on the next swing of the oscillating relay.

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25. A telegraph code sender in accordance with claim 14, provided with testing means under the control of a test key for causing the sender periodically to repeat the transmission of any given character and with means associated with the test key for preventing the release of the code storing relays at the end of each test cycle.

26. A telegraph code sender in accordance with claim 14, in which there are five code storing relays and in addition seven counting relays, the apparatus being arranged so that the armature of the oscillating relay will make eight single swings during the transmission of each character.

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