March 18, 1941. W. P. OVERBECK 2,234,978

HIGH-SPEED RELAY

Filed May 3, 1938

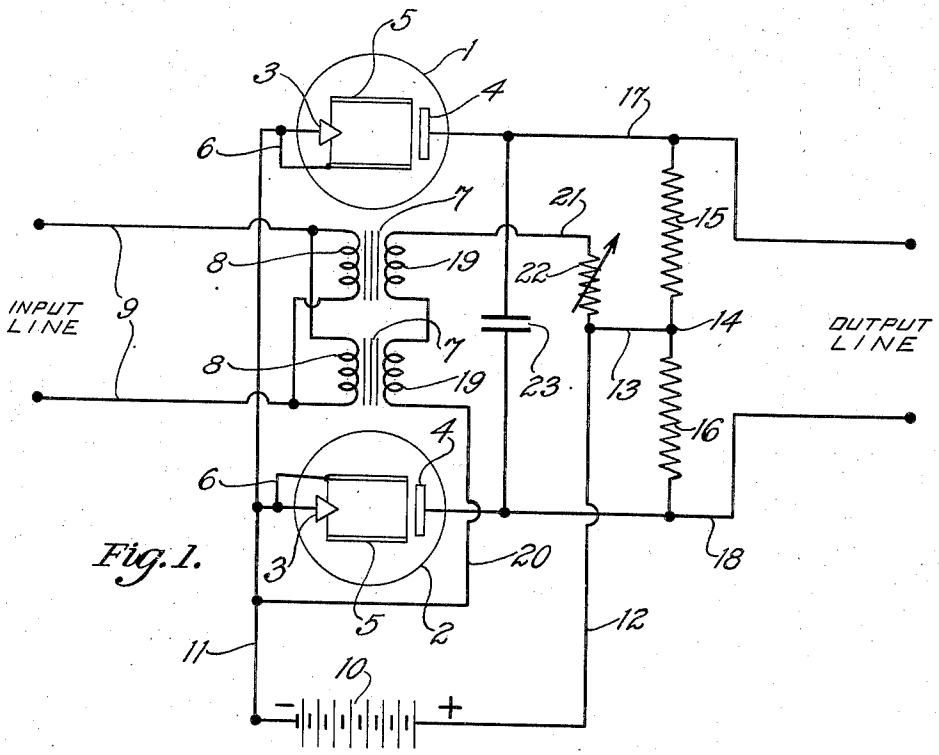

Fig. 1.

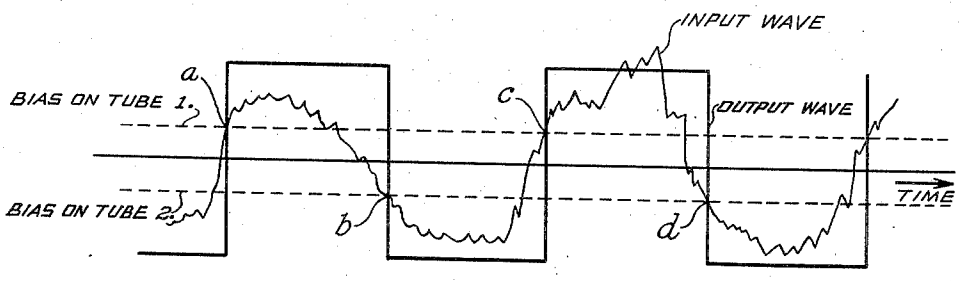

Fig. 2.

Inventor
Wilcox P. Overbeck
by Elmer J. Gorn.
Attorney.

Patented Mar. 18, 1941 2,234,978

UNITED STATES PATENT OFFICE

2,234,978

HIGH-SPEED RELAY

Wilcox P. Overbeck, Waltham, Mass., assignor to Raytheon Manufacturing Company, Newton, Mass., a corporation of Delaware

Application May 3, 1938, Serial No. 205,858

11 Claims. (Cl. 250—27)

This invention relates to a high-speed relay, and more particularly to such a relay as is used in signalling systems in which it is desired to convert a distorted signal into a perfectly square-topped current wave. In such systems a square-topped current wave is generated by the transmitter, and is sent out over a transmission system. After it has traveled over this system for a substantial distance, it becomes distorted due to a variety of causes. In order to permit the signal to be transmitted farther and still produce proper response in the receiving apparatus, a relay station is necessary in order to convert the distorted current wave back into its original square shape.

Mechanical relays in the above type of system possess appreciable inertia so that reversal of the output current cannot occur instantaneously, and thus a perfectly square-topped current wave which demands such an instantaneous reversal cannot be obtained with such mechanical relays. If an attempt is made to utilize electrical discharge tubes as a relay in such systems, care must be taken not to reflect currents back into the input line because such an action introduces various disadvantageous effects.

In accordance with my present invention I eliminate the difficulties heretofore encountered, and accomplish the desired results.

One of the objects of my invention, therefore, is to produce a high-speed relay having no mechanical inertia.

Another object is to produce such a relay having no connection between the input and output circuits.

A further object is to produce such a relay system in which no reflected energy goes back into the input lines.

An additional object is to produce such a relay having a minimum number of local power sources.

A still further object is to accomplish the foregoing objects by the use of an electromagnetically-controlled electrical space discharge tube.

The foregoing and other objects of my invention will be best understood from the following description of an exemplification thereof, reference being had to the accompanying diagrammatic drawing, in which

Fig. 1 represents a circuit embodying one form of my invention; and

Fig. 2 is an oscillographic diagram showing the relationships between various factors involved in Fig. 1.

The system illustrated involves the use of two controlled electrical space discharge tubes 1 and 2. Each tube is provided with a cathode 3 which is preferably of the indirectly-heated theremionic type, and likewise with an anode 4. The tubes are each filled with a suitable ionizable gas or vapor at a sufficiently high pressure so that the filling becomes strongly ionized upon the passage of a discharge between each anode 3 and its associated cathode 4, whereupon conduction of current at relatively low voltage drop may occur. This gas may be mercury vapor at a suitable pressure, for example between 1 and 100 microns, or a noble gas, such as argon, at a pressure of the order of one millimeter or less. In any event the gas pressure is of a suitable value so that the ionization and low voltage conduction mentioned above may occur. Gaseous discharge tubes of this type may be adapted to control the initiation of the discharge between each cathode and anode. I prefer to use a magnetic control wherein by the application of a magnetic field to the discharge space initiation of the discharge between the cathode and anode of each tube is delayed until said magnetic field passes through a predetermined value.

In order to utilize the magnetic control of the starting of the discharge through each tube 1 and 2, these tubes are preferably constructed, as more fully described and claimed in the copending application of Percy L. Spencer, Serial No. 612,235, filed May 19, 1932, for an improvement in Electrical gaseous discharge devices. As pointed out in said application, each of the tubes 1 and 2 is provided with an intermediate electrode 5 surrounding the discharge path between the cathode 3 and the anode 4. This intermediate electrode is made of some suitable non-magnetic electrical conducting material, and may be in the form of a cylinder open at both ends so that the discharge when initiated may pass freely between each cathode 3 and anode 4. Each of the intermediate electrodes 5 is preferably connected by means of a conductor 6 to its associated cathode 3. In such tubes, if a transverse magnetic field is impressed upon the discharge space within the intermediate electrode 5, initiation of the discharge after the anode becomes positive is delayed until the transverse magnetic field falls to a predetermined minimum, which for all practical purposes may be considered as being substantially zero. In order to provide such a transverse magnetic field, each tube 1 and 2 has associated therewith a control magnetic core 7, which when energized by suitable magnetomotive forces impresses a transverse field across its corresponding tube 1 or 2. One source

of such magnetomotive force on each control core 7 is a coil 8 which is connected to a pair of conductors 9, constituting the input line over which the distorted signal to be relayed is received. The coils 8 may either be connected in parallel, as indicated in Fig. 1, or in series.

In order to furnish the relay system with power, a local source of direct current 10 is provided. This source is illustrated as a battery. The negative terminal of the source 10 is connected by means of a conductor 11 to the two cathodes 3. The positive terminal of the source 10 is connected by means of conductors 12 and 13 to the center tap 14 on a potentiometer consisting of two resistances 15 and 16 connected in series. A conductor 17 is connected to the anode 4 of tube 1, and a conductor 18 is connected to the anode 4 of tube 2. The outer ends of the resistances 15 and 16 are connected respectively to the two conductors 17 and 18. The two conductors 17 and 18 extend to the output line of the system over which the perfectly square-topped current wave generated by the relay system is sent out to the subsequent receiving or relay apparatus. The resistances 15 and 16 are preferably substantially equal in value, and the total impedance across these resistances is preferably substantially less than the impedance of the output line and its associated apparatus.

The magnetic cores 7 are each provided with a biasing coil 19. Each coil 19 is adapted to be supplied with direct current from the source 10, and is wound so as to oppose the magnetomotive force of its associated coil 8 when the input current wave travels through said coil 8 in one direction, and to assist the coil 8 when the input current reverses therein. Also the coils 19 are wound so that when one of said coils is opposing its associated coil 8, the other of said coils 19 is aiding its associated coil 8. In order to supply the coils 19 with their biasing current, a conductor 20 extends from the conductor 11 to one end of the coils 19 while a conductor 21 extends from the other end of said coils through a control resistance 22 to the conductor 12. In this way the coils 19 are connected across the source 10 in series with the resistance 22. Although the coils 19 may be connected in parallel, they are preferably connected in series as shown. The resistance 22 is adjustable so that the value of the biasing magnetic fields set up by the coils 19 may be adjusted to a desired predetermined value. A condenser 23 is connected between the two conductors 17 and 18 to produce the action as will be described below.

The operation of the circuit shown in Fig. 1 will be explained in connection with the oscillographic diagram of Fig. 2. Each coil 19 impresses on its associated tube a bias of a constant value. These bias values are represented by the two horizontal dotted lines in Fig. 2. The bias magnetic field is ordinarily of sufficient value to prevent a discharge from being initiated between the cathode 3 and anode 4 of the associated tube under the voltage conditions to which the tube is subjected. The signal current supplied by the input lines 9 may be represented by the jagged wave of Fig. 2. This input signal sets up corresponding magnetomotive forces in the coils 8. When the input wave reaches the point *a*, the magnetomotive force of the coil 8 associated with tube 1 is substantially equal and opposite to the magnetomotive force of the coil 19 associated with said tube, and thus the magnetic field across tube 1 falls substantially to zero, at which point a discharge is permitted to start between the cathode 3 and anode 4 of tube 1. Under these conditions current flows from the positive terminal of the source 10 through the conductors 12 and 13, the resistance 15, the conductor 17, the anode 4 and cathode 3 of tube 1, and the conductor 11 back to the negative terminal of source 10. Since the voltage drop between the cathode 3 and anode 4 of tube 1 is relatively low, the conductor 17 in effect is connected substantially directly to the negative terminal of the source 10, and thus the upper output line becomes negative while the lower output line becomes positive with respect thereto. Under these conditions a maximum value of output current in one direction flows through the outlines. This output current is represented by the square-shaped wave in Fig. 2. The condition described above is exemplified by the fact that at the point *a* this square-shaped wave rises instantaneously to its maximum value above the horizontal time axis.

Due to the flow of current through the circuit traced above, a voltage drop occurs across the resistance 15. Since the impedance of the output line and its associated apparatus is considerably greater than the impedance of 15, the resultant current flowing through the resistance 16 is small as compared to the current flowing through the resistance 15. For the purposes of analyzing the operation therefor, the drop across the resistance 16 can be neglected. Thus the drop in voltage across the resistance 15 is impressed across the condenser 23. Since the lower end of the resistance 15 is more positive than its upper end, the condenser 23 will be charged so that its upper end is negative and its lower end is positive.

As the input current wave continues, the output current continues to flow at its maximum value until the point *b* is reached. At that point the magnetomotive force of the coil 8 associated with the tube 2 is substantially equal and opposite to the magnetomotive force 19 associated with said tube, and the magnetic field across tube 2 falls substantially to zero. Thus a discharge is permitted to start between the cathode 3 and anode 4 of tube 2. As described above in connection with tube 1, this action effectively connects the lower end of resistance 16 and thus the lower end of the condenser 23 to the negative terminal of the source 10. Since the condenser 23 has been charged, due to the previous initiation of current through the tube 1, so that its upper end is more negative than its lower end, the connection of the lower end of said condenser to the negative terminal of the source 10 makes the anode connected to the upper end of said condenser more negative, and thus said anode momentarily becomes negative with respect to its cathode 3. When this happens, the discharge through tube 1 is momentarily extinguished. However, when this occurs, the magnetomotive forces of the coils 8 and 19 associated with the tube 1 are aiding each other, and therefore the magnetic field across the tube 1 is of sufficient magnitude to prevent the re-initiation of a discharge through tube 1 even if the anode 4 thereof immediately becomes positive with respect to its cathode. Since the passage of a discharge through tube 2 effectively connects the conductor 18 to the negative terminal of the source 10, the lower output line now becomes negative and the upper line becomes positive. Under

these conditions the current through the output lines immediately reverses and rises to a maximum value in the opposite direction from which the previous flow occurred. This is represented in Fig. 2 by the fact that the square-topped wave at point *b* drops vertically to a maximum value below the horizontal time axis.

As described above in connection with the initiation of a discharge through tube 1, the initiation of such a discharge through tube 2 causes a current flow through resistance 16 which sets up a voltage drop therein in which the upper end of said resistance is positive and the lower end thereof negative. As in the previous case the drop across the resistance 15, due to the flow of the current in the output line, may be neglected for purposes of analysis. Under these conditions the voltage drop across the resistance 16 is impressed across the condenser 23. This voltage, it will be noted, is in the reverse direction from the voltage previously impressed upon said condenser. When this occurs, the previous charge upon the condenser 23 is discharged through the resistances 15 and 16, and said condenser becomes charged to substantially the same value in the opposite direction.

The system persists in the above condition with a maximum and constant value of current supplied to the output lines until the input wave reaches point *c*, at which the discharge is reinitiated in tube 1, and the tube 2 is extinguished substantially as described above in connection with the extinguishment of the discharge in the tube 1. As the input wave periodically changes in direction, as indicated in Fig. 2, the tubes 1 and 2 have a discharge alternately started and extinguished therein resulting in the furnishing of a perfectly square-topped current output wave supplied to the output lines.

The only deviation which might occur from the operation as set forth above is a slight rounding of the front edge of the output current wave due to the charging and the discharging of the condenser 23. The circuit should be so designed that the condenser 23 maintains a sufficient charge to cause extinguishing of the discharge in either tube long enough to permit substantially complete deionization of the discharge path in the tube. Therefore, the charging time of the condenser must likewise be greater than this deionization time, and since the discharge in the tube to be extinguished does not stop until the voltage across the condenser has risen to a predetermined value, the instantaneous reversal of the output current described above does not actually occur. However, since the deionization time in a tube such as herein described can be made extremely short, the charging and discharging period of the condenser 23 likewise can be made extremely short, and therefore in a practical system the reversal of the output current wave is substantially instantaneous.

Of course it is to be understood that this invention is not limited to the particular details as described above as many equivalents will suggest themselves to those skilled in the art. For example, since the cathodes of the two tubes 1 and 2 are connected together, a single tube having a single cathode and two anodes, the discharge to each of which can be controlled, could be used. Also other arrangements of the magnetic fields with respect to the tubes could be utilized, provided such fields produced a control of the initiation of the discharge. It is therefore desired that the appended claims be given a broad interpretation commensurate with the scope of the present invention.

What is claimed is:

1. A relay system comprising an input circuit, an output circuit, a pair of controlled space discharge devices, each comprising an envelope containing an ionizable atmosphere and a pair of electrodes of opposite polarity between which an ionizing discharge is adapted to pass, a source of direct current having one terminal thereof connected to a common terminal of one polarity of said pair of discharge devices, the electrodes of the other polarity being connected to the two sides of said output circuit, an impedance branched across said output circuit, the other terminal of said source being connected to an intermediate point on said impedance, control means for impressing a magnetic field on each of said discharge devices for controlling the initiation of an ionizing discharge in each of said discharge devices, means for energizing said control means from said input circuit, whereby an alternating current wave supplied by said input circuit causes an ionizing discharge to be initiated alternately in said two discharge devices, and means responsive to the starting of an ionizing discharge in one of said discharge devices for stopping the ionizing discharge in the other of said discharge devices.

2. A relay system comprising an input circuit, an output circuit, a pair of controlled space discharge devices, each comprising an envelope containing an ionizable atmosphere and a pair of electrodes of opposite polarity between which an ionizing discharge is adapted to pass, a source of direct current having one terminal thereof connected to a common terminal of one polarity of said pair of discharge devices, the electrodes of the other polarity being connected to the two sides of said output circuit, an impedance branched across said output circuit, the other terminal of said source being connected to an intermediate point on said impedance, control means for impressing a magnetic field on each of said discharge devices to prevent the initiation of an ionizing discharge therein at values of magnetic field above a predetermined value, means for energizing said control means from said input circuit so that an alternating current wave supplied by said input circuit alternately causes said magnetic fields to drop momentarily below said predetermined values to initiate ionizing discharges alternately in said two discharge devices, and means responsive to the starting of an ionizing discharge in one of said discharge devices for stopping the ionizing discharge in the other of said discharge devices.

3. A relay system comprising an input circuit, an output circuit, a pair of controlled unidirectional conduction space discharge devices, each comprising an envelope containing an ionizable atmosphere and a pair of electrodes of opposite polarity between which an ionizing discharge is adapted to pass, a source of direct current having one terminal thereof connected to a common terminal of one polarity of said pair of discharge devices, the electrodes of the other polarity being connected to the two sides of said output circuit, an impedance branched across said output circuit, the other terminal of said source being connected to an intermediate point on said impedance, control means for impressing a magnetic field on each of said discharge devices to prevent the initiation of an ionizing discharge therein at values of magnetic field above a predetermined value, means

for energizing said control means from said input circuit so that an alternating current wave supplied by said input circuit alternately causes said magnetic fields to drop momentarily below said predetermined values to initiate ionizing discharges alternately in said two discharge devices, and a condenser connected across said impedance for stopping the ionizing discharge in one of said discharge devices upon the starting of an ionizing discharge in the other of said discharge devices.

4. A relay system comprising an input circuit, an output circuit, a pair of controlled space discharge devices, each comprising an envelope containing an ionizable atmosphere and a pair of electrodes of opposite polarity between which an ionizing discharge is adapted to pass, a source of direct current having one terminal thereof connected to a common terminal of one polarity of said pair of discharge devices, the electrodes of the other polarity being connected to the two sides of said output circuit, an impedance branched across said output circuit, the other terminal of said source being connected to an intermediate point on said impedance, magnetic control means for impressing a magnetic field on each of said discharge devices to prevent the initiation of an ionizing discharge therein at values of magnetic field above a predetermined value, means for biasing said magnetic field above said predetermined value, means for energizing said control means from said input circuit so that an alternating current wave supplied by said input circuit alternately opposes and assists said bias fields in opposite phase on said discharge devices, whereby said fields alternately drop below said predetermined values to initiate ionizing discharges alternately in said two discharge devices, and means responsive to the starting of an ionizing discharge in one of said discharge devices for stopping the ionizing discharge in the other of said discharge devices.

5. A relay system comprising an input circuit, an output circuit, a pair of controlled unidirectional conduction space discharge devices, each comprising an envelope containing an ionizable atmosphere and a pair of electrodes of opposite polarity between which an ionizing discharge is adapted to pass, a source of direct current having one terminal thereof connected to a common terminal of one polarity of said pair of discharge devices, the electrodes of the other polarity being connected to the two sides of said output circuit, an impedance branched across said output circuit, the other terminal of said source being connected to an intermediate point on said impedance, magnetic control means for impressing a magnetic field on each of said discharge devices to prevent the initiation of an ionizing discharge therein at values of magnetic field above a predetermined value, means for biasing said magnetic field above said predetermined value, means for energizing said control means from said input circuit so that an alternating current wave supplied by said input circuit alternately opposes and assists said bias fields in opposite phase on said discharge devices, whereby said fields alternately drop below said predetermined values to initiate ionizing discharges alternately in said two discharge devices, and a condenser connected across said impedance for stopping the ionizing discharge in one of said discharge devices upon the starting of an ionizing discharge in the other of said discharge devices.

6. A relay system comprising an input circuit, an output circuit, a pair of controlled space discharge devices, each comprising an envelope containing an ionizable atmosphere and a pair of electrodes of opposite polarity between which an ionizing discharge is adapted to pass, a source of direct current having one terminal thereof connected to a common terminal of one polarity of said pair of discharge devices, the electrodes of the other polarity being connected to the two sides of said output circuit, an impedance branched across said output circuit, the other terminal of said source being connected to an intermediate point on said impedance, magnetic control means for impressing a transverse magnetic field on each of said discharge devices to prevent the initiation of an ionizing discharge therein at values of magnetic field above a predetermined value, means for biasing said magnetic field above said predetermined value, means for energizing said control means from said input circuit so that an alternating current wave supplied by said input circuit alternately opposes and assists said bias fields in opposite phase on said discharge devices, whereby said fields alternately drop below said predetermined values to initiate ionizing discharges alternately in said two discharge devices, and means responsive to the starting of an ionizing discharge in one of said discharge devices for stopping the ionizing discharge in the other of said discharge devices.

7. A relay system comprising an input circuit, an output circuit, a pair of controlled unidirectional conduction space discharge devices, each comprising an envelope containing an ionizable atmosphere and a pair of electrodes of opposite polarity between which an ionizing discharge is adapted to pass, a source of direct current having one terminal thereof connected to a common terminal of one polarity of said pair of discharge devices, the electrodes of the other polarity being connected to the two sides of said output circuit, an impedance branched across said output circuit, the other terminal of said source being connected to an intermediate point on said impedance, magnetic control means for impressing a transverse magnetic field on each of said discharge devices to prevent the initiation of an ionizing discharge therein at values of magnetic field above a predetermined value, means for biasing said magnetic field above said predetermined value, means for energizing said control means from said input circuit so that an alternating current wave supplied by said input circuit alternately opposes and assists said bias fields in opposite phase on said discharge devices, whereby said fields alternately drop below said predetermined values to initiate ionizing discharges alternately in said two discharge devices, and a condenser connected across said impedance for stopping the ionizing discharge in one of said discharge devices upon the starting of an ionizing discharge in the other of said discharge devices.

8. A relay system comprising an input circuit adapted to supply a signal current, an output circuit, a controlled space discharge device comprising a pair of electrodes of opposite polarity between which a discharge is adapted to pass, said output circuit being connected across said electrodes in series with a source of direct current, electromagnetic control means for controlling the initiation of a discharge in said discharge device, means for energizing said control means from said input circuit, said control means

being responsive to a predetermined magnitude of said signal current to cause a discharge to be initiated in said discharge device, and means for extinguishing said discharge when said signal current reaches another predetermined value, said input circuit and said control means being electrically independent of said discharge device and output circuit.

9. A relay system comprising an input circuit adapted to supply a signal current, an output circuit, a controlled unidirectional conduction space discharge device comprising a pair of electrodes of opposite polarity between which a discharge is adapted to pass, said output circuit being connected across said electrodes in series with a source of direct current, electromagnetic control means for controlling the initiation of a discharge in said discharge device, means for energizing said control means from said input circuit, said control means being responsive to a predetermined magnitude of said signal current to cause a discharge to be initiated in said discharge device, and means for extinguishing said discharge when said signal current reaches another predetermined value, said input circuit and said control means being electrically independent of said discharge device and output circuit.

10. A relay system comprising an input circuit adapted to supply a signal current, an output circuit, a controlled space discharge device comprising a pair of electrodes of opposite polarity between which a discharge is adapted to pass, said output circuit being connected across said electrodes in series with a source of direct current, magnetic control means for impressing a magnetic field on said discharge device to prevent the initiation of a discharge therein at values of magnetic field above a predetermined value, means for energizing said control means from said input circuit, said control means being responsive to a predetermined magnitude of said signal current to cause a discharge to be initiated in said discharge device, and means for extinguishing said discharge when said signal current reaches another predetermined value, said input circuit and said control means being electrically independent of said discharge device and output circuit.

11. A relay system comprising an input circuit adapted to supply a signal current, an output circuit, a controlled space discharge device comprising a pair of electrodes of opposite polarity between which a discharge is adapted to pass, said output circuit being connected across said electrodes in series with a source of direct current, magnetic control means for impressing a transverse magnetic field on said discharge device to prevent the initiation of a discharge therein at values of magnetic field above a predetermined value, means for energizing said control means from said input circuit, said control means being responsive to a predetermined magnitude of said signal current to cause a discharge to be initiated in said discharge device, and means for extinguishing said discharge when said signal current reaches another predetermined value, said input circuit and said control means being electrically independent of said discharge device and output circuit.

WILCOX P. OVERBECK.