

Sept. 27, 1949.

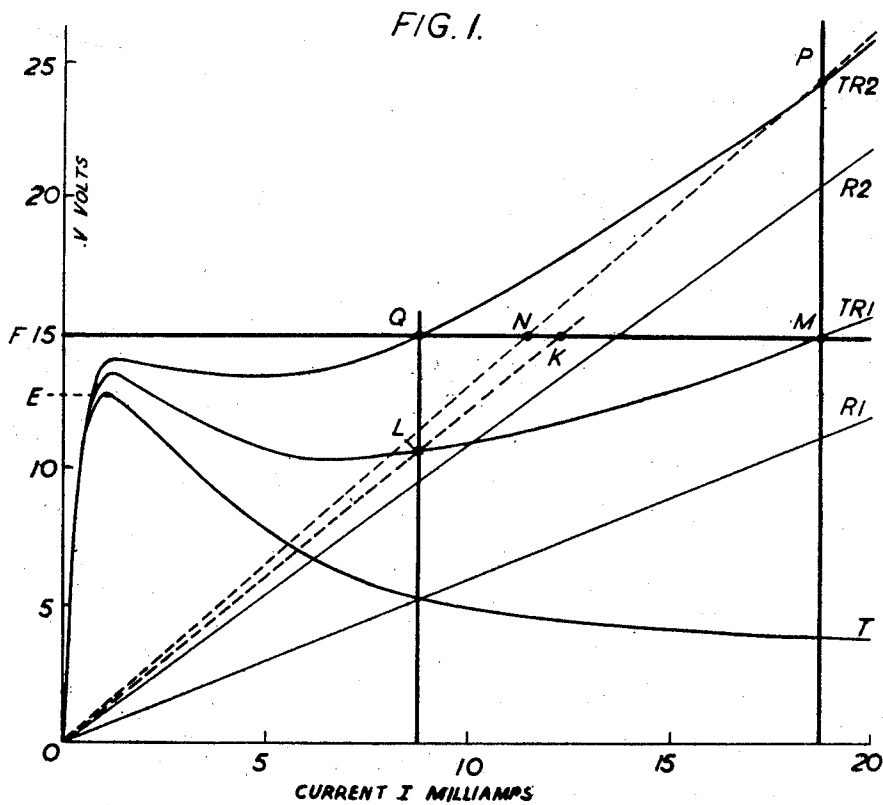
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2,482,820

PERIODIC ELECTROMAGNETIC RELAY

Filed April 17, 1943

2 Sheets-Sheet 1



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FIG. 2.

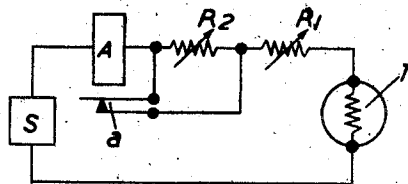


FIG. 3.

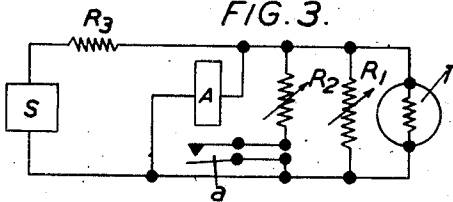


FIG. 4.

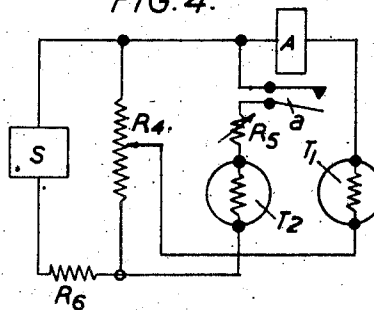


FIG. 5.

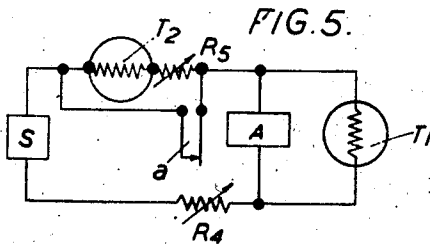


FIG. 6.

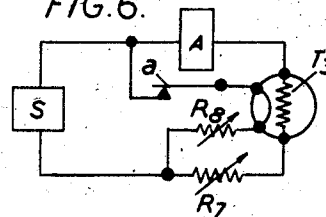
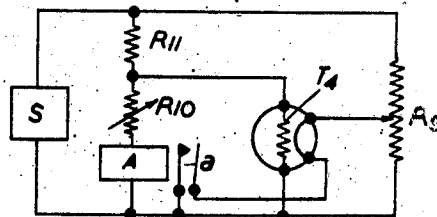


FIG. 7.



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2,482,820

PERIODIC ELECTROMAGNETIC RELAY

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Application April 17, 1943, Serial No. 483,521
In Great Britain May 28, 1942

3 Claims. (Cl. 175—373)

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The present invention relates to periodically operating electric relay circuits, and makes use of the heating delay in thermally sensitive resistance devices known as thermistors for timing the operation of the circuits.

Thermistors have been in use for some years and are characterized by a temperature coefficient of resistance which may be either positive or negative and which is moreover many times the corresponding coefficient for a pure metal such as copper. This property renders thermistors particularly suitable for a variety of special applications in electric circuits.

Various different materials are available for the resistance element of a thermistor, these various materials having different properties in other respects; as one example, a resistance material having a high negative temperature coefficient of resistance comprises a mixture of manganese oxide and nickel oxide, with or without the addition of certain other metallic oxides, the mixture being suitably heat treated.

Thermistors have been employed in two different forms: (a) known as a directly heated thermistor and comprising a resistance element of the thermally sensitive resistance material provided with suitable lead-out conductors or terminals, and (b) known as an indirectly heated thermistor comprising the element (c) provided in addition with a heating coil electrically insulated from the element. A directly heated thermistor is primarily intended to be controlled by the current which flows through it and which varies the temperature and also the resistance accordingly. Such a thermistor will also be affected by the temperature of its surroundings and may therefore be used for thermostatic control and like purposes with or without direct heating by the current flowing through it. An indirectly heated thermistor is chiefly designed to be heated by a controlling current which flows through the heating coil and which will usually, but not necessarily, be different from the current which flows through the resistance element, but this type of thermistor may also be subjected to either or both of the types of control applicable to a directly heated thermistor.

More detailed information on the properties of thermistors will be found in an article by G. L. Pearson in the Bell Laboratories' Record Dec. 1940, page 106.

Periodically operating electric circuits are used for a variety of purposes, and the present specification describes several simple circuits in which an ordinary relay is combined with one or more

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thermistors which control its rate of operation by reason of the time delay which occurs between any change of heating current and the completion of the corresponding change in the resistance of the thermistor element. Two series of circuits are described, suitable for thermistors with positive and negative temperature coefficients, respectively.

According to the invention there is provided a circuit arrangement for periodically operating an electromagnetic relay from a source of electromotive force comprising a thermistor connected to the relay winding and adapted to vary the current flowing through the relay in response to changes in the temperature of the thermistor, and a pair of contacts controlled by the relay and adapted when operated to change the rate of heating the thermistor.

The invention will be more clearly understood by reference to the following detailed description and to the accompanying drawing in which:

Figure 1 shows characteristic curves of a thermistor with a negative temperature coefficient of resistance, and of circuits including a thermistor; and

Figures 2 to 7 (inclusive) show schematic circuit diagrams of various embodiments of the invention.

The curve marked T in Fig. 1 shows a characteristic curve giving the relation between the current I through the resistance element of a typical thermistor having a negative temperature coefficient of resistance, and the corresponding difference of potential V across the element. It is found that the voltage at first rises rather steeply to a maximum value E as the current increases, and afterwards falls off along a curve which is concave upwards and has a negative slope. There are thus two currents corresponding to any voltage less than E, and if the applied voltage be E or greater the arrangement is unstable and the current will increase indefinitely until the thermistor is damaged, unless limited by resistance in the associated circuit. By arranging to operate the thermistor on the unstable part of the characteristic, rather large changes in current may be obtained for small changes in applied voltage.

Figure 2 shows one circuit according to the invention. The winding of a relay A is connected in series with a directly heated thermistor T and two adjustable constant resistances R₁ and R₂ to a source S of electromotive force. R₂ is short-circuited by the contacts a of the relay A when it is unoperated. The relay may have any num-

ber of other sets of contacts (not shown) for performing any desired switching operations.

It will be assumed that the relay resistance is included in R_1 . If the relation between the current I and the voltage V be plotted for the constant resistance R_1 , the straight line OR_1 in Fig. 1 will be obtained. By adding the ordinates of the curves T and OR_1 the curve TR_1 is obtained, giving the relation between the current I and the voltage V applied to the circuit of Fig. 2 when the resistance R_2 is short-circuited as shown.

The straight line OR_2 in Fig. 1 gives the characteristic for the resistances R_1 and R_2 together, the contacts a of Fig. 2 being open. By adding the ordinates of curves T and OR_2 the complete circuit characteristic TR_2 is obtained for the condition when contacts a are open.

Suppose that the source S supplies a constant voltage F (Fig. 1) which is greater than the initial maximum E . If the relay A (Fig. 2) is at first prevented from operating, the current obtained will be FM from the curve TR_1 , when the thermistor has reached a constant temperature. Assuming that the relay is adjusted to operate on the current FM , and is now freed, the contacts a will open, introducing the resistance R_2 . The circuit resistance is now given by the point P on the curve TR_2 where it is cut by the ordinate of M . Thus at the instant when the contacts a open, and before the thermistor temperature has had time to change, the dotted straight line OP gives the instantaneous characteristic of the total circuit resistance. As the voltage applied to the circuit is only F , the current must drop instantaneously to FN , where N is the point of intersection of FM and OP . Assuming now that the current FN is sufficient to hold the relay A operated, the thermistor will cool until the current is reduced to FQ , the point Q being on the curve TR_2 . If the relay be adjusted so that it just releases on the current FQ , the contacts a close and short circuit the resistance R_2 . In the same way as just explained in connection with the points M and P , the current will suddenly increase to FK , the point K being the intersection of the dotted straight line OL with FM , where L is the point on the curve TR_1 having the same ordinate as Q . If it be assumed that the current FK is insufficient to operate the relay A , the thermistor T will heat up until the current reaches the value FM again. If it now be assumed that the relay just operates on the current FM , the contacts a open, and the current falls to FN again and the process is repeated indefinitely.

It will be seen that the conditions for adjustment of the relay A are that it should operate on a current between FK and FM , and that it should release on a current between FQ and FN . It will also be evident that the range QM may be varied by suitably choosing the resistances R_1 and R_2 : by increasing R_1 the point M may be moved to the left, and by decreasing R_1+R_2 the point Q may be moved to the right. It will be evident, therefore, that the operate and release times may be separately controlled. The period of the cycle depends on the rate of heating and cooling of the thermistor, on the margin between the operate and release currents of the relay, and on the adjustment of R_1 and R_2 . If R_1 is adjusted so that the current FK is only a little less than the operate current, and R_2 is then adjusted so that FN is only a little more than the release current, the period of the cycle will be short. By making FQ a little less

than the release current and FM a little more than the operate current a long period will be obtained. Various periods and various ratios of operate to release times are clearly possible.

If the thermistor has a positive temperature coefficient of resistance, a corresponding parallel arrangement will give a similar result. This is shown in Fig. 3. When the relay A is unoperated the contacts a are in this case open. A suitable resistance R_3 is connected in series with the source S , and R_1 is adjusted so that when the thermistor T has heated up and increased its resistance the voltage across the relay A rises sufficiently to operate it. This throws the shunt resistance R_2 across R_1 , reducing the voltage, but not enough to release A . The thermistor T cools and its resistance ultimately decreases sufficiently to release A , and the cycle is repeated. The period may be set as before by suitably adjusting R_2 .

Fig. 4 shows another embodiment of the invention using two directly heated thermistors T_1 and T_2 having negative temperature coefficients of resistance.

The thermistor T_1 is connected in series with the relay A across an adjustable portion of the resistance R_4 which is connected in series with a resistance R_5 to the source S .

The contacts a are adapted to be closed when the relay A is operated and to connect the thermistor T_2 across the resistance R_4 in series with an adjustable resistance R_5 .

The resistance R_4 is first adjusted so that a suitable current for operating the relay is obtained. When the relay operates, the load comprising R_5 and T_2 is shunted across R_4 reducing the operating current, but not enough to release the relay. T_2 thereupon heats up and reduces its resistance, and T_1 cools and increases its resistance, both reducing the current through the relay until it releases. T_2 then cools, and T_1 heats up until the original operating current is again obtained when the cycle is repeated. Thus the operate time of the relay is controlled by T_1 and the release time by both T_1 and T_2 , and these times may be controlled by adjusting R_4 and R_5 .

Fig. 5 shows an arrangement corresponding to Fig. 4 for use when the thermistors have a positive temperature coefficient of resistance. The thermistor T_1 is in parallel with the relay A and T_2 and R_5 are now in series instead of in shunt and are arranged to be short-circuited by the contacts a when the relay is unoperated. The resistance R_4 is also in series with the main circuit. The thermistor T_1 will heat up and will increase its resistance so that the relay A ultimately operates. When this happens the contacts a are opened, and the thermistor T_2 and resistance R_5 are introduced, reducing the current without at once releasing the relay. As T_1 cools and T_2 heats up, the current through the relay becomes reduced until it releases. T_1 heats up again and the cycle is repeated. The adjustment of R_4 controls the rate of heating of T_1 which determines the operating time of the relay. The release time is controlled by both thermistors and is adjusted by means of R_5 .

Another embodiment employing one indirectly heated thermistor with a negative temperature coefficient of resistance is shown in Fig. 6. The relay A is connected to the source S in series with the resistance element of the thermistor T_1 and an adjustable resistance R_7 . The heating coil is connected to the source S through the closed

contacts *a* of Relay A and another adjustable resistance *R₈*.

The resistance *R₇* is first adjusted so that with the contacts *a* held open, the current through the relay does not become sufficient to operate it when the thermistor is hot. On allowing the contacts *a* to close the thermistor is further heated and reduces its resistance sufficiently to allow the relay to operate. This switches off the heating coil, the thermistor cools and the relay presently releases again, and the cycle is repeated as before. The release time is then controlled by adjusting *R₇* and the operate time by adjusting *R₈*.

In Fig. 6, if the thermistor *T₃* has a positive temperature coefficient, the circuit will operate if the contacts *a* are closed when the relay is operated and open when it is released. In this case it can be seen that if the source *S* is switched on when the thermistor is cold, the relay will operate at once, so that the thermistor will be heated by the current in the heating coil as well as by the current flowing in the resistance element. Its resistance will thus increase until the relay releases, switching off the heating coil, thereupon the thermistor cools, allowing the relay to operate again. Adjustment of *R₇* now controls the operate time and *R₈* the release time.

Another embodiment is shown in Fig. 7. The relay A is connected in series with resistances *R₁₀* and *R₁₁* across the source *S*, and the resistance element of a thermistor *T₄* is connected to shunt *R₁₀* and A. The heating coil is connected across an adjustable portion of the resistance *R₈* (also connected across the source *S*) through the relay contacts *a*. If *T₄* has a negative temperature coefficient of resistance the contacts *a* will be open as shown when the relay is unoperated, and if *T₄* has a positive temperature coefficient the contacts *a* will be open when the relay is operated. In the first case, *T₄* having a high resistance when cold, the relay operates directly the source *S* is switched on and *T₄* is heated by both currents. When its resistance has fallen to release the relay, the heating coil is switched off and it cools so that the relay presently operates again. Thus the cooling controls the operating time of the relay, which may be adjusted by means of *R₁₀*; and the heating which is controlled by *R₈* determines the releasing time of the relay. If *T₄* has a positive temperature coefficient the operation is inverted

so that *R₁₀* controls the releasing time and *R₈* the operating time.

What is claimed is:

1. A circuit arrangement for periodically operating an electromagnetic relay from a source of electromotive force comprising, an indirectly heated thermistor, a winding for the electromagnetic relay, said winding and the resistance element of said thermistor being connected in series to the source of electromotive force, a first adjustable constant resistance and a second adjustable constant resistance, a heating coil for said thermistor, the said heating coil being connected to the said source in series with the said second adjustable resistance, and a pair of contacts for said electromagnetic relay, said contacts being in series with said heating coil and said second adjustable resistance.

2. A circuit arrangement according to claim 1 in which the thermistor has a positive temperature co-efficient of resistance, the said pair of contacts being closed when the relay is operated.

3. A circuit arrangement according to claim 1 in which the thermistor has a negative temperature co-efficient and the said pair of contacts are closed except when the relay is operated.

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