Aug. 23, 1960 H. J. LOVEGROVE 2,950,423

ELECTRIC RELAY CONTROL CIRCUITS

Filed Dec. 4, 1956 2 Sheets-Sheet 1

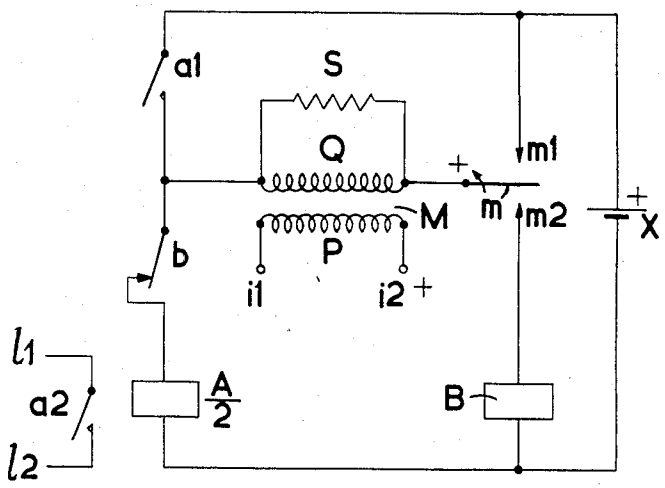


FIG.1.

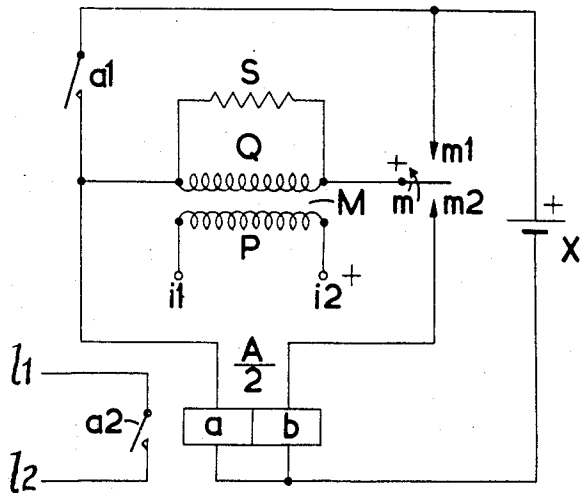


FIG.2.

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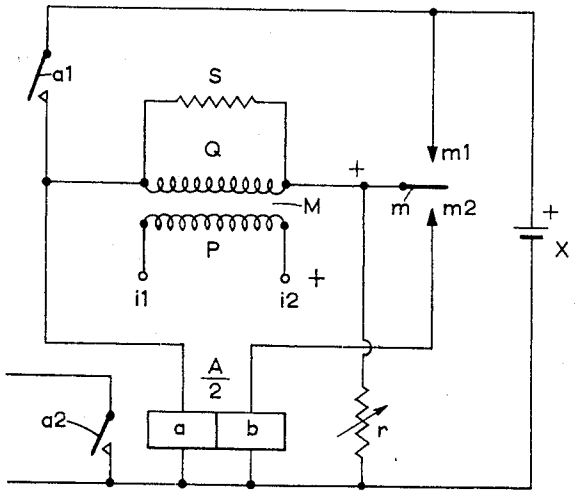


FIG. 3.

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ELECTRIC RELAY CONTROL CIRCUITS

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2 Claims. (Cl. 317—152)

This invention relates to electric relay control circuits and is more particularly concerned with arrangements using relays of the sensitive moving-coil type.

With an attracted-armature type relay the armature is attracted and moved in order to effect the required switching operation or operations when the applied ampere-turns reach a certain predetermined value. Such movement of the armature causes a change in the inductance and reluctance of the associated magnetic circuit whereby the armature remains attracted and effectively held in the operated condition until the applied ampere-turns are reduced to a much smaller value than that which was necessary to cause the initial attraction of the armature. There is accordingly a relatively large amount of "back-lash" or a large make/break current differential and this is particularly useful when the relay is employed in the presence of mechanical vibration since the value of ampere-turns necessary to cause the initial attraction of the armature in order to operate the switch contacts is then more than adequate to hold the armature firmly in the attracted position in spite of disturbing mechanical forces. Unfortunately, however, such attracted-armature type relays are relatively insensitive and require comparatively large ampere-turn values for their operation.

Moving-coil type relays, on the other hand, while advantageous from the aspect of overall sensitivity, suffer a disadvantage compared with normal attracted-armature type relays by reason of the fact that the back-lash or make/break current differential is very small. Upon application of the requisite ampere-turns in the moving coil system of a moving coil relay, the coil system is caused to move and the contacts to be closed. In this case, however, there is no change or substantially no change in the overall circuit conditions and only a very small reduction in the number of applied ampere-turns will cause the contacts to open again. In the presence of any substantial degree of mechanical vibration there is necessarily a consequential chattering of the contacts.

A further disadvantage arising with a moving-coil type relay operating under conditions where maximum sensitivity is required, is that the contact pressure necessary to provide reliable electrical connection is derived from the supply to the moving coil of current from the input control current source additional to that actually required to bring the contacts into the closed condition. There is accordingly a loss of overall sensitivity.

One object of the present invention is to provide a relay circuit arrangement in which the difficulties noted above are substantially reduced or even avoided and by which the equivalent of a "back-lash" condition is provided in a moving-coil type relay but which, at the same time, does not reduce the high value of sensitivity obtainable with such moving-coil type relays.

Another object of the invention is to provide a relay circuit arrangement which is particularly adapted for use under conditions of severe vibration, such as in aircraft.

In accordance with the broadest aspect of the present invention, means are provided for applying current in positive feedback sense to the moving-coil system of a moving-coil type relay upon initial closure of operated contacts of such relay under the influence of the input controlling current whereby the contact resistance between such closed contacts is immediately lowered to a value sufficient to cause operation of an associated further relay connected in series with such contacts and a local current source which further relay is arranged, upon its operation, to effect a desired control function corresponding to the change of value of the input controlling current and at the same time to cause the removal of the aforesaid feedback current from the moving-coil system so as to release the latter to its normal highly sensitive state in readiness to respond to a change in the input controlling current in the opposite sense to that which has just caused contact closure.

In order that the nature of the invention may be more readily understood, a number of practical embodiments thereof will now be described by way of illustrative example with reference to the accompanying drawings, in which:

Fig. 1 is a circuit diagram of one relay arrangement in accordance with the invention.

Fig. 2 is a similar circuit diagram of a modification, while

Fig. 3 is a circuit diagram of a further modification.

Referring first to Fig. 1 of the drawings, M indicates the moving coil system of a sensitive moving-coil type relay having a double-wound moving coil system comprising the separate windings P and Q. The winding P is the normal control winding of the moving coil system to which the relatively weak input controlling current is applied through the input terminals *i*1 and *i*2. The winding Q of the moving coil system is a feedback winding and has one end connected directly to the common or moving contact *m* which is carried by the moving coil system for oscillatory movement between fixed contacts *m*1 and *m*2. The moving contact *m* engages either with the fixed contact *m*1 when the control winding P is appropriately energised with input current having the polarity indicated or with the opposite fixed contact *m*2 when the control winding P is either energised to a sufficiently lesser extent or is energised with current of the opposite polarity to that indicated in the drawing, depending upon whether or not a counter control torque is applied to the moving coil system.

The feedback winding Q is shunted by a resistance S which may conveniently be made variable for purposes of adjustment. The end of the feedback winding Q opposite to that connected to the moving contact *m* is connected by way of normally-closed contacts *b* of an attracted-armature type relay B and thence through the operating winding of a further relay

$$\frac{A}{2}$$

to the negative terminal of a local current supply source X, shown schematically as a battery. The operating winding of the relay B is connected between the fixed contact *m*2 of the moving type relay and the same negative terminal of the local current supply source X. The opposite or positive terminal of the local current source X is connected directly to the fixed contact *m*1 of the moving coil relay and also through normally-open contacts *a*1 of the relay

$$\frac{A}{2}$$

to the same end terminal of the feedback winding Q as that to which the contact *b* is joined.

The relay

$$\frac{A}{2}$$

has at least one pair of further contacts *a*2, shown as normally-open but which obviously may be normally-closed, which serve to control the function control or work circuit indicated schematically as independently powered by the leads *l*1 and *l*2.

The operation of this circuit arrangement is as follows. The weak input controlling current flowing in the operative winding P of the moving coil system of the moving coil relay, when of appropriate value, causes the moving contact *m* carried by the moving coil system to come gently into contact with the fixed contact *m*1. Current thereupon flows from the local supply source X through the fixed contact *m*1 and the moving contact *m* to the feedback winding Q and thence through the normally-closed contacts *b* and the operating winding of relay

$$\frac{A}{2}$$

to the opposite terminal of such supply source X. This feedback current in winding Q is in a direction which causes the moving coil system to turn in the direction which causes an increase in the contact pressure exerted by the moving contact *m* upon the aforesaid fixed contact *m*1 and as a result operates to decrease the contact resistance to a value where the current flowing is sufficient to operate the relay

$$\frac{A}{2}$$

When this occurs the relay

$$\frac{A}{2}$$

becomes locked-in by the current path from the positive terminal of the supply source X through the now-closed contacts *a*1 and the still-closed contacts *b* and so through the operating winding

$$\frac{A}{2}$$

to the negative terminal of the said supply source. Immediately the contacts *a*1 close, whilst the moving contact *m* is still in contact with the fixed contact *m*1, the feedback winding Q becomes short-circuited and the influence, in positive feedback sense, of the feedback current previously passing therethrough is removed from the moving coil system M whereby the latter is thereafter free to move or float again under the sole control of the current flowing in the control winding P. Should the contacts *m* and *m*1 chatter due to vibration or other causes, the energising circuit of the relay

$$\frac{A}{2}$$

is in no way affected as this relay is now latched in by way of its holding contact *a*1. No current is flowing through the contacts *m* and *m*1 and in consequence no damage or disadvantageous effects are produced by sparking thereat. In the meantime the operation of the relay

$$\frac{A}{2}$$

has caused positive closure of the contacts *a*2 and the consequential positive execution of the required control function effected over the leads *l*1 and *l*2.

When the moving contact *m* of the moving coil system M moves in the opposite direction to an extent sufficient to bring it into engagement with the second fixed contact *m*2, current again flows through the feedback winding Q of the moving coil system, this time by way of the operating winding of relay B and the still-closed contacts *a*1. This feedback current in winding Q is now in the opposite direction to that of the previous operation and hence is appropriate to cause the moving coil system to move in a direction which urges the moving contact *m* against the fixed contact *m*2 thereby to increase the contact pressure between the two contacts so that the contact resistance thereof is lowered to the point where the current flowing through the operating winding of the relay B is sufficient to cause operation of the relay. Immediately this operation of relay B occurs, the contacts *b* are opened thereby opening the holding circuit of the relay

$$\frac{A}{2}$$

Immediately relay

$$\frac{A}{2}$$

releases the contacts *a*1 are opened to break the feedback current path through the feedback winding Q of the moving coil system so that the circuit is again restored to the original condition where the moving coil system M is free to move or float again under the sole control of the current flowing in the control winding P. Simultaneously the contacts *a*2 of the relay

$$\frac{A}{2}$$

open to influence in the appropriate sense the control circuit comprising the leads *l*1 and *l*2.

By making the fixed contacts *m*1 and *m*2 of the moving coil relay physically widely spaced apart, but electrically representing only a very small differential of the input controlling current through the control winding P of the moving-coil type relay, the system can be made immune to relatively severe mechanical vibration particularly when electromagnetic damping is also applied to the moving coil system. Normally damping of a relatively high order is permissible.

An alternative and in many cases preferable arrangement is shown in Fig. 2. In this modification the moving coil system M is provided, as in the previous embodiment, with separate control and feedback windings P and Q. In this embodiment, however, only a single relay

$$\frac{A}{2}$$

is employed, this relay being of the differentially-wound type with separate operating windings *a* and *b* so arranged that on appropriate energisation of each of the windings simultaneously the operating flux can be reduced substantially to zero and the relay contacts accordingly released to their normal condition. The relay

$$\frac{A}{2}$$

has two controlled contacts, namely, *a*1 and *a*2, both of which are normally-open. The contacts *a*1 are connected in a similar manner to that shown in Fig. 1 so as to control the locking-in of the relay winding section *a* of the relay, while the contacts *a*2 serve to control the function control circuit comprising leads *l*1 and *l*2 in a manner identical with that of the first embodiment.

In the operation of this modified arrangement, movement of the moving coil system M by appropriate input current flow through the control winding P thereof in the sense to bring the moving contact *m* of the moving coil system into engagement with the fixed contact *m*1, closes a path for the supply of positive feedback current from the positive terminal of the supply source X through the contacts *m*1, *m* to the winding Q and thence through the relay winding section *a* of the relay

$$\frac{A}{2}$$

to the negative terminal of such supply source X. This

feedback current flow causes increase of the contact pressure between contacts *m* and *m*1 to an extent sufficient to the lower the resistance thereof to a value which causes operation of the relay

$$\frac{A}{2}$$

The contacts *a*1 and *a*2 thereupon close, the former serving to lock the relay

$$\frac{A}{2}$$

in its operated condition by the direct flow of current from the positive terminal of the supply source X through the now-closed contacts *a*1 and the relay winding section *a* to the negative terminal of the supply source X. The contacts *a*2 serve to control the function control circuit in the desired manner. The feedback winding Q is automatically short-circuited at the same time and the moving coil system M is accordingly left free to move or float once more under the sole control of the input current in the control winding P. When at a later time instant, the moving coil system M is moved by the current in the control winding P in the opposite direction to bring its moving contact *m* into engagement with the fixed contact *m*2, a second positive feedback current path for the winding Q, with a current flow in a direction opposite to that previously referred to, is set up from the positive terminal of the supply source X through now-closed contacts *a*1, the feedback winding Q, contacts *m*, *m*2 and relay winding section *b* to the negative terminal of the supply source X. This causes movement of the moving coil system M in the direction whereby the contact resistance between moving contact *m* and fixed contact *m*2 is lowered to such a value that the current now flowing in the relay winding section *b* is sufficient to neutralise the effect of the energisation of winding section *a* and thereby to cause the release of the relay

$$\frac{A}{2}$$

This immediately opens the contacts *a*1 and *a*2. The opening of the contacts *a*1 breaks the aforesaid feedback current path set up through the feedback winding Q and again allows the moving coil system M to move or float under the sole control of the input controlling current applied to the terminals *i*1 and *i*2. The controlled circuit of leads *l*1 and *l*2 is likewise appropriately operated at contacts *a*2.

As with the previous embodiment shown in Fig. 1 the fixed contacts *m*1 and *m*2 of the moving coil relay may be physically widely spaced apart but electrically such wide spacing represents only a very small differential of the input controlling current through the control winding P of the moving-coil type relay. The system is immune to relatively severe mechanical vibration particularly when electro-magnetic damping is also applied to the moving coil system.

The relatively wide physical spacing of the two fixed contacts may, in some circumstances, be disadvantageous on account of the time taken for the moving contact *m* to shift from fixed contact *m*1 to the opposite fixed contact *m*2 when the alteration in the controlling current through the control winding P is only very small, that is to say, when such current falls to a value only just below that at which the moving contact *m* makes contact with the upper fixed contact *m*1. The available torque on the moving coil system M may be very small under these conditions. If a speeding-up of the change-over operation is required without recourse to bringing the two fixed contacts *m*1 and *m*2 physically closer to one another with the resultant risk of faulty operation due to chattering or bouncing of the moving contact *m* from one to the other of the fixed contacts whilst it is in the free or floating condition, recourse may be had to the modification of the arrangement of Fig. 2 as shown in Fig. 3 where a resistor *r*, preferably variable in value, is connected between the moving contact *m* and the negative terminal of the current supply source X.

The effect of this additional current path through the resistor *r* is as follows. For as long as the moving contact *m* is in contact with the upper fixed contact *m*1 owing to the fact that the controlling current input to the control winding P is at or above the critical level chosen to cause contacts *m* and *m*1 to close, the feedback winding Q is short-circuited as already described and there is merely a slight current drain on the source X through the said resistor *r*. Immediately the controlling current in the control winding P drops below the aforesaid critical level and as a result the moving contact *m* begins to move away from the upper fixed contact *m*1 towards the lower fixed contact *m*2, a current of a strength determined by the value of the resistor *r* commences to flow through the feedback winding Q of the moving coil system in a direction such as will tend to turn such moving coil system in the direction which moves the moving contact *m* towards the fixed contact *m*2. The value of such current and hence the speed of transfer movement of the moving contact *m* from the fixed contact *m*1 to the fixed contact *m*2, can be adjusted by alteration of the value of the resistor *r*. Immediately the moving contact engages the lower fixed contact *m*2, then the cycle of operations already described takes place. Thus, it can be arranged that there is a very rapid change-over from fixed contact *m*1 to fixed contact *m*2 once the controlling input has fallen below the critical level calling for the making of contacts *m* and *m*1 while still retaining a relatively wide physical spacing between the two fixed contacts.

A precisely similar modification may be made in the arrangement shown in Fig. 1 of the drawings.

The invention has particular application to temperature control arrangements, for instance that of controlling the temperature of the jet pipe in a jet aircraft, where a very small operating current is available for energising the moving-coil type relay and where conditions of extreme vibration are frequently present. It will be appreciated, however, that the invention has many other obvious applications of far wider scope and is not restricted in its usefulness to conditions where vibration is present. The invention also is clearly capable of modification in various ways such as by a different arrangement of controlled circuit contacts and the like and/or by other circuit arrangements for effecting the desired flow of feedback current in positive feedback sense to achieve operation of the further and relatively insensitive relay or relays and/or other circuit arrangements for latching the relay or relays and removing the aforesaid feedback current from the moving coil system after operation of such relay or relays. A moving-coil type relay having only a single moving coil winding may be used for both control and feedback purposes when the character of the controlling current input source permits.

I claim:

1. An electric relay control circuit arrangement consisting of a sensitive movable coil type relay having a double wound movable coil system consisting of a normal control winding and a feedback winding and said movable coil carrying a movable contact adapted to engage a first or a second fixed contact; means for applying controlling current to the said control winding; means connecting one end of the feed back winding to the said movable contact; a differential relay having a first operating winding and a second operating winding for controlling a set of contacts in an independently powered work circuit; means connecting the other end of the feedback winding through said second operating winding to one terminal of a voltage source; means connecting the said first operating winding between said first fixed contact and the said terminal; circuit elements connecting a resistance

across the said first operating winding when the said movable contact engages the said first fixed contact; means connecting the other terminal of the voltage source to the second fixed contact; normally open contacts controlled by the said second operating winding; and means connecting the said second fixed contact through the said normally open contacts to the said other end of the feedback winding; whereby the contact resistance between the said movable contact and the engaged second fixed contact is immediately lowered to a value sufficient to cause operation of the said second operating winding which then effects a desired control function by closing the work circuit and, at the same time, causes discontinuance of the feedback current from the movable coil system to thereby release the latter to its normal highly sensitive state in readiness to respond to a change in the controlling current.

2. The invention as recited in claim 1 wherein the said resistance is adjustable.

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