Aug. 4, 1970 L. R. WOOD 3,522,442

SWITCH

Filed June 4, 1968 2 Sheets-Sheet 1

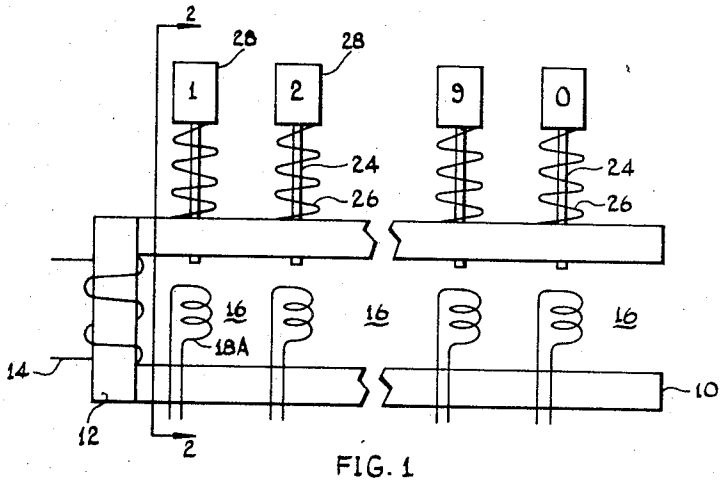


FIG. 1

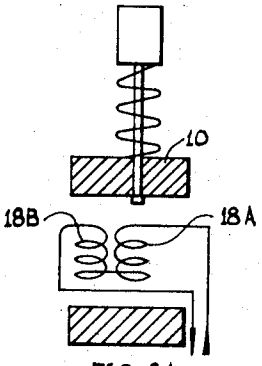


FIG. 2A

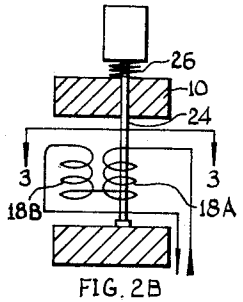


FIG. 2B

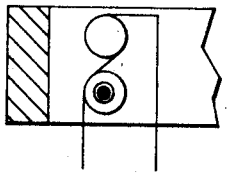


FIG. 3

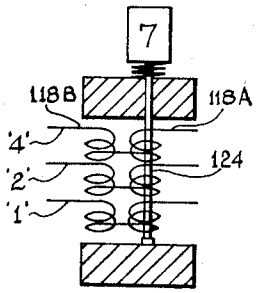


FIG. 4

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SWITCH

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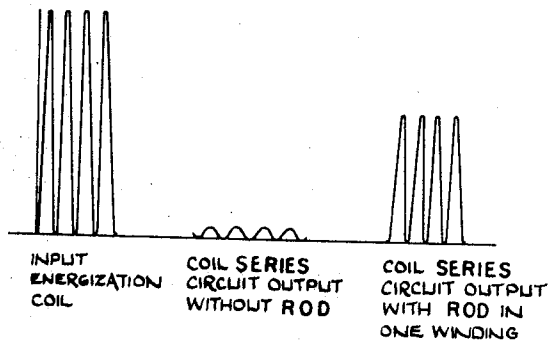


FIG. 5

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United States Patent Office 3,522,442 Patented Aug. 4, 1970

3,522,442

SWITCH

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Filed June 4, 1968, Ser. No. 734,465
Int. Cl. H02b 1/24
U.S. Cl. 307—115 5 Claims

ABSTRACT OF THE DISCLOSURE

Opposed sense series wound coils are located in a variable magnetic field. A core is locatable in or out of one of the coils. The other coil is arranged to provide an equal and opposite E.M.F. to the first in the varying field in either the "core-in" or "core-out" state of the first coil. An unbalanced E.M.F. condition exists in the opposite core state of the first coil. Switching is therefore performed in the coil circuit by movement of the core and the coil circuit produces a substantial output in one state and substantially zero output in the other state.

This invention deals with a switching actuator or switch and has particular but not exclusive application to switches operating responsive to keyboard operation.

The device in accord with the invention, is thought to be of principal value in replacing switches having connect-disconnect contacts, the most common of which is that type known as a "micro-switch." Such switches have been found, particularly in applications where the contacts have a high rate of operation (such as in a keyboard) to have a high failure rate due to contact wear, and various types of contact and mechanical failure.

It is therefore the object of this invention to provide a switch and/or switch actuator which is adapted to provide a change of signal state in an electrical circuit of a type capable of performing a switching function but where the change of state is performed without the necessity of connection or interruption of a circuit by contact movement.

It is an object of this invention, to provide a ferromagnetic circuit having an air gap, and means for creating a varying magnetic field across said air gap, locating a plurality of windings connected in series in a circuit arranged, wound and connected to give a net substantially null potential output from the series circuit when no ferromagnetic material is contained in any of the windings and wherein means are provided for selectively moving a ferromagnetic core into or out of one or more (but not all) selected ones of the windings with the windings into which said core is inserted being selected to produce a substantial output when such core is inserted in the selected windings. The windings are arranged to produce, with such insertion of the magnetic core, from the series circuit a signal materially different from the zero potential. The result is that a switching or switch actuation function is performed by the insertion or withdrawal of the core without any interruption or connection of the series circuit including the windings.

The insertion of the ferromagnetic core in some, but not all of the windings, will act as the switching circuit, with the "unbalance" signal produced when the core is inserted, appearing as a connected AC source at the output of the series circuit in which the windings are connected; and the substantially null signal when the core is withdrawn appearing to the circuitry like a disconnected circuit. On the other hand, the series connected windings may be connected to actuate another circuit like a transistor switch circuit to one state with the null output and the other state with the unbalance output.

It is a preferred object of the invention to provide that two series connected electrical windings shall be wound in an opposite sense relative to the varying magnetic field, and of flux sensitivity to provide from the series circuit including the two windings in approximately null or zero output potential when neither winding is provided with a ferromagnetic core. Thus when, in response to a desire to perform a switching function, a ferromagnetic core is moved into one only of the opposed windings, and the varying magnetic field is applied, the resulting unbalance of the potential outputs of the two windings provides a net series circuit output signal relatively much larger than the net signal therefrom before insertion of the core. Means connected for operation by the signal thus produced may thus be easily designed to discriminate between the signals produced with and without the core in one of the windings.

A number of advantages accrue. Firstly, the switching function in the series circuit is achieved without the opening or closing of contacts. Wear and tear on contacts and operating arms is avoided. Spark and arc-over is avoided and this, it will be realized, has many advantages including the fact that the reciprocal movement of the cores to perform the switching function, may be performed in an explosive atmosphere where arcs or sparks would not be tolerated. Secondly, it will be appreciated that the opposed winding arrangement has substantial advantage over a single winding with a core removably insertable. With a single winding there is an unbalance in the winding circuit with or without the core (although of different magnitude). There is a difficult and sensitive problem of distinguishing between the two states in the output circuit. No such problem exists with applicant's circuit which have a balanced effect and produce an approximately null output in one state, an unbalanced condition in the other state. Thirdly, it will be noted that the winding circuit is essentially of a low impedance. Thus, in a particular application a plurality of pairs of windings (each pair operated by a different ferromagnetic core) may be connected in series (as well as the windings in a pair being connected in series with each other). The potential produced in an unbalanced pair of such series arrangement is therefore little affected by the connection, in series therewith, of a plurality of balanced pairs.

Although it will be a less advantageous arrangement in a number of applications, applicant's invention includes an alternative arrangement to that already discussed. In the alternative all of the windings connected in a series circuit are, in one switching state, provided with cores and when so provided have a balanced (i.e. substantially null) output. In the other switching state the cores are withdrawn from some but not all of the windings in the electric circuit, and the windings are arranged to provide a material net output from the series circuit during such withdrawal. This alternative arrangement has all the advantages of the arrangement previously discussed.

The first-described arrangement of having the balanced (null output condition with the movable core withdrawn) has however a number of distinct advantages over the last-described arrangement where the null output condition occurs with the movable core inserted.

These advantages are:

(1) The total impedance will be less when several pairs of windings are used in series thus requiring the lowest input impedance of the attached sensing device.

(2) Since the movable core will frequently be moved by a push button or equivalent mechanical device, the simplest mechanical arrangement will result when the button and core are biased upwardly and where this defines the "core-out" balance position with unbalance occurring on depression of the button and core.

(3) With balance in the "core-out" position, the power requirements of the exciting source are lessened since the minimum of flux loss will result.

In the drawings which illustrate a preferred embodiment of the invention:

FIG. 1 shows a broken view of a ten-digit keyboard incorporating the invention;

FIGS. 2A and 2B are sections taken along the line 2—2 of FIG. 1.

FIG. 3 is a view along the line 3—3 of FIG. 2B;

FIG. 4 shows a variant of the embodiment shown in FIGS. 1–3; and

FIG. 5 shows relative magnitudes of input and alternative output signals obtained with the circuit of FIG. 5.

In the drawings FIG. 1 shows a magnetic circuit formed by a pair of substantially parallel magnetizable members **10** joined adjacent one end by magnetizable material **12**. An air gap **16** is therefore formed between unjoined portions of members **10**. About some part of the magnetic circuit is an energizing winding **14** powered by a source (not shown) of variable current to produce a varying magnetic field in air gap **16**. The length, spacing, and cross-sectional area of the ferromagnetic members is selected to provide an air gap **16** where a plurality of windings may be located and wherein ferromagnetic rods wholly or partially bridging the air gap **16** are selectively applicable to form cores for selected ones of the windings.

Ten pairs of windings **18** are, in the preferred embodiment, located between the members **10**. The members **10** and corresponding apparatus are however broken to indicate the positions of only the first, second, ninth and tenth of such windings. The two windings **18A** and **18B** of each pair are connected in a series circuit and are wound in opposite senses relative to a magnetic field created by and between member **10** and the number of turns and other parameters of the winding are designed so that for varying fields produced, in the air gap **16**, by energizing winding **14** the potentials created in the pairs of windings **18A** and **18B** with no core in either are substantially equal and opposite and the resulting output is substantially zero. Aligned with one winding **18A** of each pair, is a ferromagnetic rod **24** slidably mounted in an aperture in the upper of the two spaced members **10** with the aperture and the slidable mounting aligned so that when a rod is depressed it passes winding **18A** only and approaches the other member **10** as closely as possible. Means are schematically shown for mounting each rod and for biasing it to retracted position (i.e. out of coil **18A**). The biasing means here is shown as a compression spring **26** bearing at one end on the member **10** and at the other end on a key on the rod **24**. At the upper end of the rod **24** is provided a key **28** for digital manipulation similar to the key provided for a typewriter. Actuating means for the rod **24** may however take any manual or digital form. The upper member **10**, through which the rod slides is preferably relatively thick to give relatively good magnetic coupling with the rod **24**. If desired the lower member **10** may be apertured to received the rod during its lowermost depression to give better magnetic coupling at the lower end also. The rod **24** for the largest potential output will be designed to substantially bridge the air gap when inserted in the winding. In the preferred form shown, the buttons are numbered 1, 2, 3 . . . 0. The buttons and rods instead of being biased by spring **26** may in actual practice be interlocked and/or moved from upper to lower location in any other desired manner. Thus the arrangement may be a normal decimal keyboard of the type that when any key is pressed, all others are raised. This is frequently combined with a clearing key for raising all lowered buttons. Naturally any number of buttons and rods with corresponding rods **24** and pairs of windings **18A** and **18B** may be used. Pairs of windings are preferably located close to one another relative to other pairs to minimize distortion when the key is depressed.

In any event so far as this invention is concerned, the means of actuation of the ferromagnetic rods has no direct relationship to the invention as long as the actuation means allows the reciprocal movement of a ferromagnetic rod into and out of one winding of a selected group.

In FIG. 5 is shown schematic indications of an A.C. input signal and the net output signal in a series circuit containing a pair of opposed windings **18A** and **18B** (as shown in FIGS. 2A and 2B) from an opposed pair of windings with (FIG. 2A) and without (FIG. 2B) the rod inserted in winding **18A**. The values of the input and alternative output signals are of no relevance except for the relation of the net output signal from the series windings **18A** and **18B**, with and without the rod core in one. The ratios of input to output signal strength will obviously depend on the turns ratio, the permeability and the geometry and physical properties of the magnetic circuit and cores. The difference in output signal with and without the rod **24** in winding **18A** is however clearly demonstrated by comparing the approximately null output with the rod withdrawn and the material output with the rod forming a core for the winding **18A**. It will be appreciated that the null may be made as small as desired by precise design of the opposed windings but that even without precise design the difference in output with and without the rod **24** in winding **18A** may be made sufficient for most discriminatory circuits. With the rod out of the winding, the net output signal is substantially negligible, while with the rod **24** in the winding the net output signal is substantial. It will be noted that instead of an alternating current input, a pulse or any other varying level input may be used.

The use of the output which is selectively switched between levels which are easily discriminated from one another may be an actuating circuit, a memory, a transistor switch or any other circuit for energization.

If desired a three or more series connected windings may be provided with some in opposed relationship to others and with the rod passing through selected ones of such windings so selected to provide an unbalance potential and hence an output when the rod is inserted in the selected windings.

It will be seen that the invention provides, means for performing a switching function without the necessity of opening and/or closing contacts. The suggested decimal keyboard with ten such switching circuits is only one of many alternatives. One or any plurality of such circuits may be connected. The opposed series windings may be of any suitable arrangement as long as their effects are substantially balanced in output potential when neither winding has a core and materially unbalanced in output potential when a selected one of the windings has a core. It will be noted that it is immaterial what the geometric arrangement of a plurality of winding pairs is as long as the signal obtained in the unbalance condition is of measurable proportion with the apparatus used and hence easily distinguished from the small signal received in the balanced condition. It will be noted that since only two intended conditions of the output are desired it is immaterial whether the unbalance condition of the one pair of output windings is larger or smaller than the unbalance condition of another set of output windings as long as the unbalance conditions are distinguishable from balance conditions in the same series circuit.

Either or both of the opposed windings may be split into more than one as long as the substantially null and unbalanced conditions in the pair of windings are maintained without and with the core respectively.

The opposed windings may have any number of turns conducive to substantial null and unbalanced output signals, the latter of sufficient magnitude. Thus with sufficient energization, a single turn may be used for each winding in a pair.

Moreover more than one pair of windings may be used corresponding to one reciprocal rod with each pair of windings operating to supply signals of one of two states.

An example of this is shown in FIG. 4 wherein a re-

ciprocable ferromagnetic rod **124** is shown as connected to form (or not) the core for one of each of three pairs of opposed series connected windings **118A**, **118B** each pair arranged to provide substantially null output potential with the core withdrawn and each pair arranged to provide a material potential with the core in the respective windings **118A**.

It is assumed that this is the **7** key of the 10 key decimal input where it is desired to obtain an output in binary code. Thus the three winding pairs associated with the **7** key will form with the core in one each of the three windings, respectively, the **4**, **2**, and **1** outputs for a binary code input to another device. The other keys will be supplied with suitably valued windings to provide the required binary code output in accord with one of the well known decimal to binary code conversion systems.

It will be noted that the three windings aligned with the rod **24** in FIG. 4 may be concentrically or multifilar wound and the other three likewise and later connected in their series opposed circuits.

As previously noted the circuit may be designed alternatively to those above discussed by providing that all windings in a series connected circuit shall be provided to produce a null output when all windings in the circuit have cores and a material output when some but not all cores are withdrawn.

As an alternative to the energization means shown in FIG. 1, the magnetic circuit comprising members **10** joined by member **12** at one end, may be completed by providing a bridging member at the opposite end to give a complete ferromagnetic loop. The added bridging member is provided with a winding similar to winding **14** but providing flux in the opposite sense. Thus the opposing fluxes both extend across the air gap where the windings are located and both supply flux to effect a potential output from the windings.

A number of expedients are available for the provision of windings in accord with the invention. It will be noted that the two windings of opposed sense may be made by winding a winding in one sense of double the desired length for one winding in a pair and the two windings formed by bending the winding 180° on itself in the middle to provide two equal series connected oppositely wound windings side by side. Alternatively two windings may both be wound in the same helix and the opposite potential sense obtained by reversing their connections. Thirdly, where a number of opposed pairs of windings are provided, the same number of ones of said windings arranged to contemporaneously receive the core may be simultaneously bifilar or multifilar wound, the windings not receiving the core similarly treated and the connections in series opposed pairs made thereafter.

I claim:

1. Means for performing a switching function comprising:

means defining a magnetic circuit composed of ferromagnetic material having an air gap;

means for supplying a varying magnetic energization to said magnetic circuit to produce a correspondingly varying field in said air gap;

a plurality of electrical windings connected in series in a circuit, located in said air gap;

said windings being wound, oriented and connected to provide from said series circuit, when no winding has a magnetic core, approximately a null potential in response to said varying magnetic field;

means for selectively inserting or withdrawing a ferromagnetic core through some but not all of said windings, said windings receiving said core selected to give a substantial potential output from said circuit in said varying field.

2. A device as claimed in claim **1** wherein said core is arranged when so inserted to substantially bridge said air gap.

3. Switch actuating means as claimed in claim **1** wherein said plurality of windings comprises a pair of windings wound to produce opposed and substantially equal potentials in said varying field.

4. A device as claimed in claim **3** wherein said rod is arranged when inserted to substantially bridge said air gap.

5. Means for performing a switching function comprising:

means defining a magnetic circuit composed of ferromagnetic material having an air gap;

means for supplying a varying magnetic energization to said magnetic circuit to produce a correspondingly varying field in said air gap;

a pair of electrical windings, connected in series in a circuit and in opposite senses, located in said air gap;

means for selectively locating or not locating a ferromagnetic core in one of said windings to selectively produce in a varying magnetic field two potential states corresponding respectively to the presence or absence of a ferromagnetic core in said winding;

said other of said windings being designed, wound and oriented to provide a potential approximately equal to and opposing the potential of said one of said windings in one of said potential states and to be materially unequal to the potential of said one of said windings in the other of said potential states.

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U.S. Cl. X.R.

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