Dec. 31, 1968 D. WHEABLE ETAL 3,419,731

SWITCHING DEVICES

Filed Jan. 4, 1966 Sheet 1 of 3

FIG.1

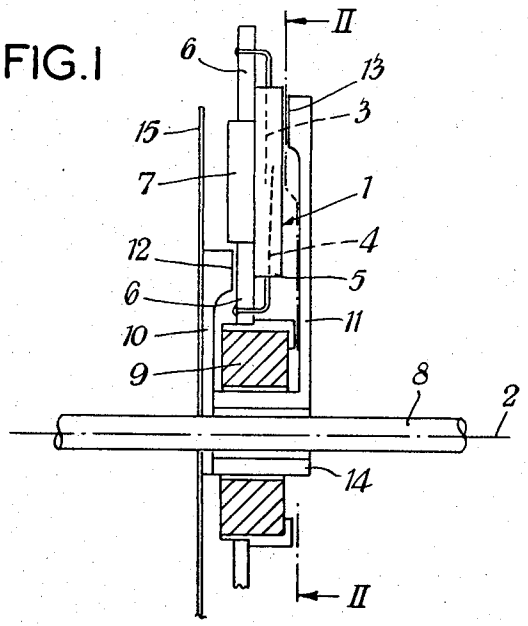
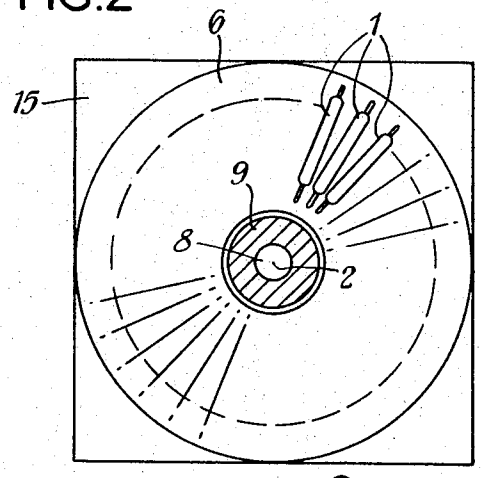


FIG.2



Inventors
Desmond Wheable
Edward Barrymore Stuttard
By Kaiser W. Flocks
attorney

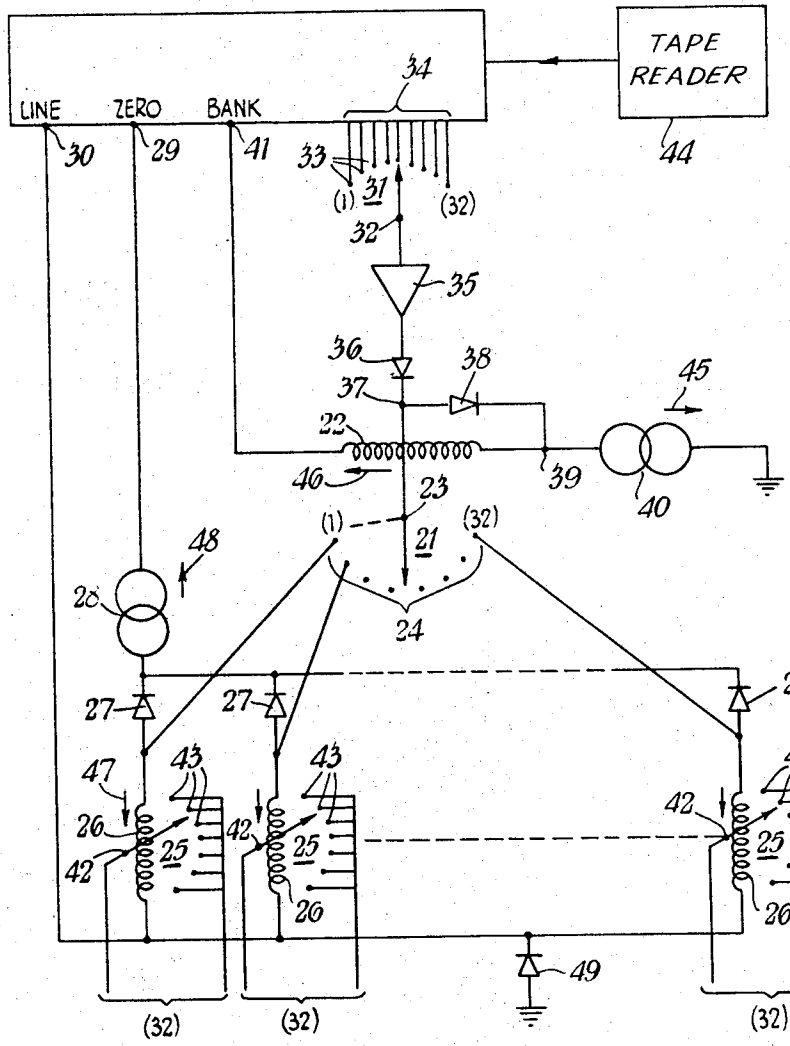
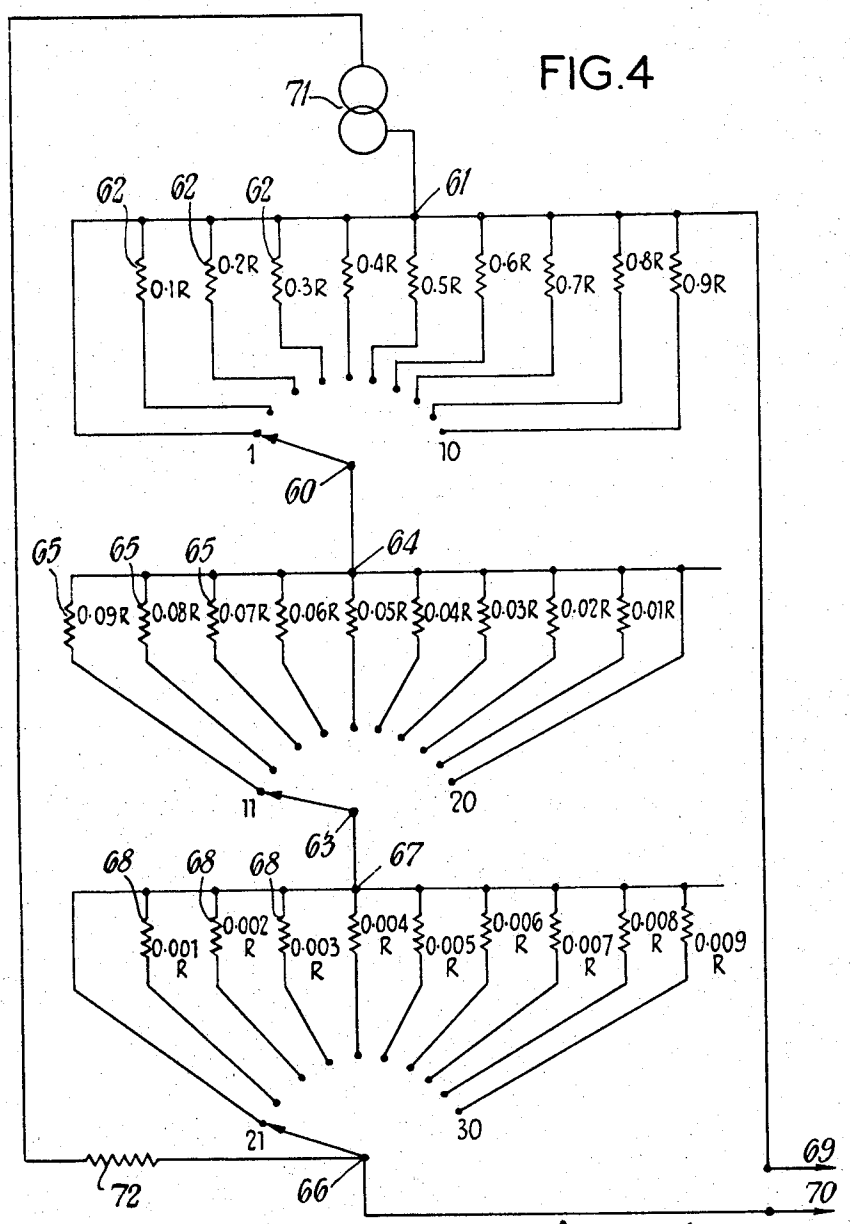


FIG.3

Inventors
Desmond Wheable
Edward Barrymore Stuttard
By Ladas W. Hocks
Attorney

FIG.4



Inventors
Desmond Wheable
Edward Barrymore Stuttard
By
Kenneth W. Flocks
Attorney

United States Patent Office 3,419,731 Patented Dec. 31, 1968

3,419,731

SWITCHING DEVICES

Desmond Wheable, Camberley, and Edward B. Stuttard, Wheathampstead, England, assignors to Hawker Siddeley Dynamics Limited, Hatfield, England, a company of Great Britain

Filed Jan. 4, 1966, Ser. No. 518,722
Claims priority, application Great Britain, Jan. 5, 1965, 423/65
9 Claims. (Cl. 307—115)

This invention relates to improved switching devices, and apparatus formed therefrom.

According to the present invention, a switching device comprises a plurality of reed switches angularly disposed about an axis and each operable by means of a magnetic field to assume either one of a first and a second condition, means associated with each switch to hold the associated switch in the second condition when so operated, and an electromagnet having an armature rotatable about said axis in proximity to said switches and energisable to change the condition of any one reed switch in proximity thereto.

According to one specific embodiment of the invention, there is provided a switching device comprising a plurality of reed switches angularly disposed about and extending radially of an axis and each operable by means of a magnetic field to assume either one of an open and closed condition, a separate permanent magnet associated with each switch to hold the associated switch in the closed condition when so operated, and an electromagnet having a fixed coil and an armature rotatable about said axis in proximity to said switches and energisable to change the condition of any one reed switch in proximity thereto.

The invention also extends to a switching device according to either of the two immediately preceding paragraphs in combination with means for applying to the electromagnet, in synchronism with the rotation of the armature, energising pulses to change the conditions of the switches.

The term "reed switch" is used herein to denote a switch comprising at least two electrical contacts disposed within an envelope and operable between a first and a second condition by means of an applied magnetic field. The envelope may be evacuated, or may contain a gas inert to the material of the contacts, for example, nitrogen.

According to one aspect of the invention, there is provided an electrical selector formed from switching devices according to the invention, the electrical selector comprising first electrical pulsing means for selectively closing any one of at least two of the reed switches of a primary switching device according to the invention and thereby selecting an electrical connection to a corresponding one of at least two secondary switching devices each according to the invention, and second electrical pulsing means, operable through said selected electrical connection, for selectively closing any one of at least two of the reed switches of the secondary switching device and thereby making a required electrical connection.

According to a specific embodiment of this one aspect of the invention, there is provided an electrical selector comprising a primary swtiching device according to the invention operable by an electromagnet and having at least two of its reed switches respectively connected to the electromagnets of a corresponding number of secondary switching devices each according to the invention, all of the switching devices having their armatures arranged for synchronous angular rotation, first electrical pulsing means operable upon the electromagnet of the primary switching device at a first angular position of the armature to close one of the reed switches of the primary switching device and thereby select an electrical connection to the electromagnet of the corresponding one of the secondary switching devices, and second electrical pulsing means operable through said selected electrical connection upon the electromagnet of the selected secondary switching device at a second angular position of the armature to close one of the reed switches of the selected secondary switching device and thereby make a required electrical connection.

The electrical selector of the two immediately preceding paragraphs may include neutralising means, for example at least one constant-current generator, arranged to be capable of passing an electric current through the electromagnet of the primary switching device, and/or through the electromagnets of the secondary switching devices, in a relatively opposite direction to the first and second electrical pulsing means respectively, so as to restore at least one of the reed switches of the relevant switching device to the open condition.

According to a second aspect of the invention, there is provided a discontinuously variable resistor formed from a switching device according to the invention, the discontinuously variable resistor comprising a switching device according to the invention and an array of at least two fixed-value resistors each of which has one of its terminals connected to a corresponding one of the reed switches of the switching devices.

According to a specific embodiment of the second aspect of the invention, a discontinuously variable resistor comprises a switching device according to the invention and at least two arrays of fixed-value resistors, each array of fixed-value resistors including a plurality of such resistors arranged in graduated order of resistance and each respectively and uniquely associated with a corresponding one of the reed switches of the switching device, each of the fixed-value resistors of each array having one of its terminals connected to a first common point of that array and having the other one of its terminals connected to one terminal of the corresponding reed switch, the other terminals of the reed switches associated with each array of fixed-value resistors being connected to a second common point of that array, and the first or the second common points of each array being so connected to the first or the second common points of the next array, that operation of the switching device permits any fixed-value resistor of one array to be connected in series with any one fixed-value resistor of the next array.

The invention also extends to a digital-to-analogue converter which includes electrical pulsing means for operating the switching device of a discontinuously variable resistor according to either one of the two immediately preceding paragraphs at at least one angular position of its armature and according to preselected information in digital form, the fixed-value resistors being so chosen that their effective resistance represent in analogue form the preselected information in digital form.

Furthermore, the invention also extends to a generator of a staircase-type waveform, the generator including a discontinuously variable resistor according to the invention, means for temporarily closing each of the reed switches of the switching device in a suitable sequence, and means for passing an electrical current through the discontinuously variable resistor, whereby the potential difference developed across the discontinuously variable resistor is of the required form.

Several embodiments of the invention will now be described by way of example, reference being made to the accompanying drawings in which:

FIGURE 1 is a fragmentary sectional view of a switching device according to the invention;

FIGURE 2 is a sectional view taken along the line II—II of FIGURE 1, with parts omitted;

FIGURE 3 is a circuit diagram of an electrical selector according to the invention, and

FIGURE 4 is a circuit diagram of a discontinuously variable resistor according to the invention.

Referring to FIGURES 1 and 2, the switching device includes a plurality of reed switches **1**, for example thirty-two in number, disposed equiangularly about and extending radially of an axis **2**. Each switch **1** is an ON-OFF switch having two normally open contacts **3** and **4** within an envelope **5**, the contacts being operable to the closed condition by an applied magnetic field. The switches **1** are carried upon a ring-shaped board **6** which conveniently also carries a number of printed-circuit elements.

Separate means is associated with each switch **1** to hold that switch in the closed condition when it has been caused to assume that condition by an applied magnetic field. In this example, such means is a permanent magnet **7** retained in a corresponding slot in the board **6**.

In a modification of the invention (not illustrated), each switch **1** is a changeover switch having two side contacts and one changeover contact. The arrangement is then such that, in a first condition of the switch **1**, the changeover contact touches one of the side contacts; upon the application of an applied magnetic field, the changeover contact changes over, to touch the other of the side contacts, the switch **1** being held in this second condition by means such as a permanent magnet **7**.

A shaft **8** is provided concentrically with the axis **2** for rotation about that axis and carries for rotation therewith the armature of an electromagnet the coil **9** of which is stationary, being arranged within the central aperture of the board **6**.

The armature includes two radially extending arms **10** and **11** disposed one on either side of the board **6** and having respective pole faces **12** and **13** so disposed relatively to the switches **1** as to close or open that particular switch **1** which is disposed between the arms **10** and **11** when the coil **9** is energised by an electrical pulse appropriate to the condition which it is desired to cause that switch to assume.

The magnetic circuit of the armature is completed by a sleeve **14** forming one end of the arm **11**, the sleeve **14** being arranged to coaxially surround the shaft **8**, and to extend through the coil **9** to the arm **10**.

In the operation of the device, the shaft **8** with the arms **10** and **11** and the sleeve **14** is rotated. At appropriate instants in time, when any given one of the switches **1** is required to be operated and lies between the arms **10** and **11**, an electrical pulse of appropriate polarity is applied to the coil **9** so as to produce, between the pole faces **12** **13**, a resultant magnetic field sufficient to close the contacts **3** and **4** of that switch **1**. When the electrical pulse has ended, the magnet **7** associated with that switch **1** will retain that switch in the closed condition.

Similarly, any one of the switches **1** which is in the closed condition may be caused to assume the open condition by energising the coil **9** with a pulse of relatively opposite porality, when that particular switch lies between the arms **10** and **11**, the magnetic field so generated being sufficiently strong to overcome the effect of the associated magnet **7**.

If desired, two or more switching devices may be axially spaced along a shaft **8** common to all of the devices, so that the armatures of the devices can be rotated in synchronism. Magnetic screens **15** may be located between adjacent switching devices, to localise the magnetic fields associated with each device.

The switches **1** need not extend radially of the axis **2** as described, but may extend parallel to that axis. Thus, the switches **1** of one or more switching devices may be carried on the wall of a cylinder coaxial with the axis **2**.

It will be appreciated that the switching device described may be operated by applying electrical energising pulses to the coil **9** in synchronism with rotation of the shaft **2** to operate the switches **1** in a selected sequence or in a predetermined pattern.

Referring to FIGURE 3, the electrical selector there shown includes an array of switching devices of the type provided according to the invention, these switching devices being arranged upon, and axially spaced along, a shaft (not shown) similar to the shaft **8**, whereby the armatures (not shown) of all of the switching devices can be rotated in synchronism and in phase.

Of the array of switching devices, a first one, the primary switching device, is indicated at **21**, its electromagnet coil being indicated at **22**. The switching device **21** has one contact of each of its thirty-two reed switches connected to a common point **23**, the other contacts of the reed switches being indicated at **24**: because of this, the operation of the switching device is similar to that of a single-pole thirty-two-way rotary switch, and the switching device **21** is symbolically indicated as such in FIGURE 3. The array of switching devices also includes thirty-two secondary switching devices **25** each having its reed-switch contacts connected similarly to those of the switching device **21**, and each therefore similarly symbolically indicated.

Each of the non-commoned contacts **24** of the primary switching device is connected to one terminal of the electromagnet coil **26** of a corresponding one of the secondary switching devices **25**, each of these electromagnetic coil terminals being also similarly connected, by way of a corresponding rectifier **27** of the polarity indicated, to one terminal of a constant-current generator **28** the other terminal of which is connected to a "zero" terminal **29**. The remaining terminals of the electromagnet coils **26** are all connected to a common "line" terminal **30** and are also all connected to earth, via a rectifier **49** of the polarity indicated.

The electrical selector also includes an auxiliary switching mechanism indicated at **31**. This mechanism is generally similar in form to the switching devices according to the invention, but differs in that the permanent magnet **7** associated with the reed switches are omitted; furthermore, the electromagnet coil **9** is replaced by a permanent magnet. During operation of the auxiliary switching mechanism, its armature rotates in synchronism and in phase with the armatures of the array of switching devices, all of the armatures being mounted upon the common shaft referred to above; it will be clear that, in this case, each of the reed switches of the auxiliary switching mechanism will be temporarily operated to the closed condition in sequence and during the periods when the pole-faces of the armature of the mechanism sweep past the reed switch in question. The thirty-two reed switches of the auxiliary switching mechanism have each one contact connected to a common point **32**; the remaining contacts of the reed switches are indicated at **33**, and are respectively connected to thirty-two "selection" terminals **34**. The common point **32** is connected to the input of a direct-current amplifier **35** the output of which is connected, by way of a rectifier **36** of the polarity indicated, to a common point **37** which is connected, on the one hand, to the common point **23** and, on the other hand, by way of a rectifier **38** of the polarity indicated, to a common point **39**. The common point **39** is connected to one terminal of a constant-current generator **40** the other terminal of which is connected to earth, and is also connected, by way of the electromagnet coil **22**, to a "bank" terminal **41**.

In the case of each of the secondary switching devices **25**, each having thirty-two reed switches, one contact of each of the reed switches is connected to a common point **42**. The remaining contacts **43** can be individually connected to any desired electrical circuit or circuits to which electrical connections are required to be made by means of the electrical selector.

The electrical selector being described is designed to be employed to operate certain ones or groups of the reed

switches of the secondary switching devices in sequences, according to instructions pre-recorded upon tape which, when it has been suitably coded, is fed into a tape reader **44**. This part of the apparatus forms no part of the invention; briefly, however, each instruction character upon the tape comprises a permutation based upon the perforation or non-perforation of the tape into holes at eight positions spaced laterally of the tape. The state of the first five of these hole-positions, giving thirty-two permutations, is detected by the tape reader **44** and, according to a pre-arranged code and by means of known apparatus (not shown), an electrical connection is made to a predetermined one of the thirty-two "section" terminals **34**, making that contact live, this electrical connection being to the positive terminal of a direct-current source (not shown) the other terminal of which is connected to earth. Two of the remaining hole-positions are similarly tested by the tape reader **44** and, according to a pre-arranged code and by means of known apparatus (not shown), one of three types of electrical connection is arranged to be made; either (i) the "bank" terminal **41** is connected to earth, or (ii) the "line" terminal **30** is connected to earth, or (iii) both the "line" terminal **30** and the "zero" terminal **29** are connected to earth. The remaining hole-position upon the tape is employed for checking purposes.

The operation of the electrical selector of FIGURE 3 will now be described, supposing that all of the reed switches of the primary and secondary switching devices **21** and **25** are initially in the open condition, and that the common shaft of the switching devices **21** and **25** and the switching mechanism **31** is rotated continuously by a motor (not shown).

Suppose that it is required to first close the second reed switch of the first of the secondary switching devices, and then to close the second reed switch of the thirty-second and last of the secondary switching devices. Four information characters upon the tape will be required for this sequence: thus, the first information character is employed to choose the first of the thirty-two secondary switching devices, the second information character to choose the second reed switch of that device, the third character to choose the last of the secondary switching devices, and the fourth character to choose the second reed switch of that device.

Thus, when the first information character is read, the first of the terminals **34** will be automatically made live as described above; in addition, the "bank" terminal **41** will be automatically earthed. Consequently, as the armature of the auxiliary switching mechanism **31** rotates, firstly, the constant-current generator **40** will cause a constant current to flow, in the direction indicated by the arrow **45**, through the electromagnet coil **22**, the direction and magnitude of this current being arranged to be such that the reed switches of the primary switching device **21** are restored to the open condition; secondly, when, simultaneously, the first reed switches of both the switching mechanism **31** and the switching device **21** are embraced by their respective armatures, an electric current will flow from the first "selection" terminal **34** to the input of the amplifier **35**, resulting in an electrical current pulse flowing from the output of the amplifier **35** to the common point **37** and thence via the common point **39** and through the electromagnet coil **22** in the direction of the arrow **46**, to earth at the "bank" terminal **41**, this current being arranged to be sufficient to overcome the constant current flowing oppositely through the coil **22** and to cause the electromagnet to operate the first of the reed switches of the primary switching device to the closed condition; this creates a semi-permanent circuit connection between the common point **23** and the electromagnet coil of the first (left-hand-end in FIGURE 3) secondary switching device.

This operation being complete, the tape reader **44** is directed to read the second information character which will be such that the second of the terminals **34** will now be made live as described above and, in addition, the "line" terminal **30** will be connected to earth. As all of the armatures (not shown) rotate in phase, an instant will occur when they all embrace the second reed switch of the relevent switching device, **21** or **25**, or switching mechanism **31**. At this instant, as before, an electric current will flow from the second of the terminals **34** and will again result in an electrical current pulse flowing from the amplifier **35** to the common point **37**; thence, this current flows, via the semi-permament circuit connection described above, to the electromagnet coil **26** of the first secondary switching device, and then to the earthed "line" terminal **30**. This current is arranged to flow in the direction of the arrow **47** through the electromagnet coil concerned, so as to operate the second of the reed switches of the first secondary switching device. A further semipermanent circuit connection is thus established within that secondary switching device.

This operation completed, the tape reader **44** is then directed to read the third information character which will be such that the last of the terminals **34** will be made live as described above, and, in addition, the "bank" terminal **41** will be earthed. The further operation of the arrangement will now be clear, it being only remarked that the semi-permanent circuit connection previously created within the primary switching device **21** will be automatically removed by the action of the constant current from the generator **40**, and replaced by a different semi-permanent circuit connection within that switching device.

In the manner described, then, any required number of the total of **32** times **32** reed switches of the secondary switching devices can be operated to the closed condition in sequence, each operation requiring two information characters and a minimum of two rotations of the common shaft of the armatures.

All of these reed switches can thereafter be restored together to their open condition, if the tape reader is arranged to read an information character which is such that the "zero" terminal **29** is connected to earth. In this case, the constant-current generator **28** causes current to flow, in the direction of the arrow **48**, through all of the parallel-connected electromagnet coils **26**, by way of the rectifiers **27**, the terminal **29** and the rectifier **49**, this current being arranged to be sufficient to cause the electromagnets to restore all of the reed switches of the secondary switching devices to their open conditions in sequence, as the armatures of those devices rotate.

Thereafter, the tape reader **44** may be arranged to cause another one, or another group, of the reed switches of the secondary switching devices to be operated to their closed conditions.

It is to be understood that the primary and the secondary switching devices, **21** and **25**, and the auxiliary switching mechanism **31**, need not have thirty-two reed switches each, but may have any other suitable number. Furthermore, it is to be understood that the reed switches of each of the secondary switching devices **25** need not have common points **42** as shown in FIGURE 3, but may, if preferred, be employed as individual switches which are not interconnected.

Referring to FIGURE 4, the discontinuously variable resistor there shown is formed from a switching device according to the invention, and employs thirty of the thirty-two reed switches of the switching device described with reference to FIGURES 1 and 2. In the case of the first ten reed switches, one contact of each reed switch is connected to a common point **60** so that the arrangement can be represented, similarly to the case of FIGURE 3, as a single-pole ten-way rotary switch, while, of the remaining contacts of the reed switches, that of the first is directly connected to a common point **61** to which the remainder, each via an appropriate corresponding one of an array of fixed-value resistors **62** in graduated order of resistance, are also connected.

The next ten reed switches are similarly connected, one

contact of each reed switch being connected to a common point **63** and, of the remaining contacts, the last one is directly connected to a common point **64** to which the remainder, each via an appropriate corresponding one of an array of fixed-value resistors **65** in graduated order of resistance, are also connected.

Finally, the last ten reed switches have one contact of each reed switch connected to a common point **66** and, of the remaining contacts, the first one is directly connected to a common point **67** to which the remainder, each via an appropriate one of an array of fixed-value resistors **68** in graduated order of resistance, are also connected.

The common points **60** and **64** are connected together, as are the common points **63** and **67**. The common points **61** and **66** are respectively connected to the output terminals **69** and **70** of the device, and a constant-current generator **71** has one of its terminals connected to the common point **61** and the other terminal connected, via a fixed resistor **72**, to the common point **66**.

The resistors **62** have resistances which range, as indicated in FIGURE 4, from 0.1 to 0.9 of a preselected resistance R, by intervals of 0.1 R. The resistors **65** have resistances which range from 0.09 R to 0.01 R, by intervals of 0.01 R. The resistors **68** have resistances which range from 0.001 R to 0.009 R, by intervals of 0.001 R.

It will thus be appreciated that, if the switching device is so operated that, at any one time, not more than one of the ten reed switches of each series of then is operated, then the device will behave essentially, as regards the total resistance presented between the common points **61** and **66**, as a three-decade resistance box capable of presenting any required resistance from zero to 0.999 R, with a resolution of one part in a thousand. Due to the presence of the constant-current generator **71**, the potential difference presented between the output terminals **69** and **70** will vary in proportion to the total resistance presented between the terminals **61** and **66**.

Such a device can be employed as a digital-to-analogue converter. Thus if a digital code is arranged to cause operation to the closed condition of a trio of reed switches of the switching device, one reed switch being selected from each of the three decades according to the digital information, then the potential difference appearing between the output terminals **69** and **70** will represent the digital information in analogue form. In particular, the present device may form one of the secondary switching devices **25** described with reference to FIGURE 3, the electrical selector there described serving to supply the requisite digital information; however, any other suitable electrical pulsing means may be employed to operate the switching device of the digital-to-analogue converter.

The device described with reference to FIGURE 4 can also be arranged to act as a generator of a staircase-type waveform. It will be basically clear that the potential difference appearing between the output terminals **69** and **70** will vary step-wise, if the connections made to the resistors **62**, **65** and **68** by the reed switches are varied stepwise. To obtain a staircase-type waveform at the terminals **69** and **70**, the waveform consisting of ascending and/or descending steps of potential difference, all that is required is suitable means for temporarily closing the reed switches of the switching device concerned in a suitable sequence; such means may be an electrical selector of the general form described with reference to FIGURE 3, but may have any other suitable form. If, for example, the device of FIGURE 4, commences, as shown, with the first, eleventh and twenty-first reed switches closed, and if the first reed switch is opened and thereafter the second to the tenth reed switches are first closed and then opened in sequence, then it will be seen that the total resistance presented between the common points **61** and **66** will vary, in steps of 0.1 R, from 0.09 R to 0.99 R, causing a corresponding staircase-type waveform to appear between the output terminals **69** and **70**.

We claim:

1. A switching device comprising a plurality of reed switches angularly disposed about an axis and each operable by means of a magnetic field to assume either one of a first and second condition, means associated with each switch to hold the associated switch in the second condition when so operated, and an electromagnet having an armature rotatable about said axis in proximity to said reed switches and energisable to change the condition of any one reed switch in proximity thereto.

2. A switching device according to claim **1** wherein said reed switches extend radially of said axis.

3. A switching device according to claim **1** wherein said means for holding the associated switch in said second condition comprises a permanent magnet.

4. A switching device according to claim **3** including means for applying to the electromagnet, in synchronism with the rotation of the armature, energizing pulses to change the conditions of the switches.

5. A switching device according to claim **3** wherein the armature comprises two radially extending arms having respective pole faces so disposed relatively to the switches as to close or open that switch which is disposed between the pole faces when the coil of the electromagnet is energised by an electrical pulse appropriate to the condition which the switch is to be caused to assume.

6. A switching device according to claim **5** wherein the magnetic circuit of the armature is completed by a sleeve forming one end of one of the two arms and arranged coaxially around a shaft coaxial with said axis, said sleeve extending through the coil of the electromagnet to the other of said two arms.

7. A discontinuously variable resistor comprising a switching device according to claim **3** and an array of at least two fixed-value resistors each of which has one of its terminals connected to a corresponding one of the reed switches of the switching device.

8. A discontinuously variable resistor comprising a switching device according to claim **1** and at least two arrays of fixed-value resistors, each array of fixed-value resistors including a plurality of such resistors arranged in graduated order of resistance and each respectively and uniquely associated with a corresponding one of the reed switches of the switching device, each of the fixed-value resistors of each array having one of its terminals connected to a first common point of that array and having the other one of its terminals connected to one terminal of the corresponding reed switches, the other terminals connected to one terminal of the corresponding reed switch, the other terminals of the reed switches associated with each array of fixed-value resistors being connected to a second common point of each array being so connected to the first or the second common points of the next array, that operation of the switching device permits any fixed-value resistor of one array to be connected in series with any one fixed-value resistor of the next array.

9. A switching device according to claim **1** wherein said electromagnet has a fixed coil.

References Cited

UNITED STATES PATENTS

3,038,976	6/1962	Koda	335—154 X
3,053,951	9/1962	Poinsot et al.	335—154 X
3,056,868	10/1962	Jacobson et al.	335—154 X
3,359,463	12/1967	Jones	335—152 X

ROBERT K. SCHAEFER, *Primary Examiner.*

T. B. JOIKE, *Assistant Examiner.*

U.S. Cl. X.R.

335—206, 207; 338—12, 190; 307—40, 41; 200—19