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MECHANICAL-ELECTRICAL TRANSDUCER

Filed April 10, 1969

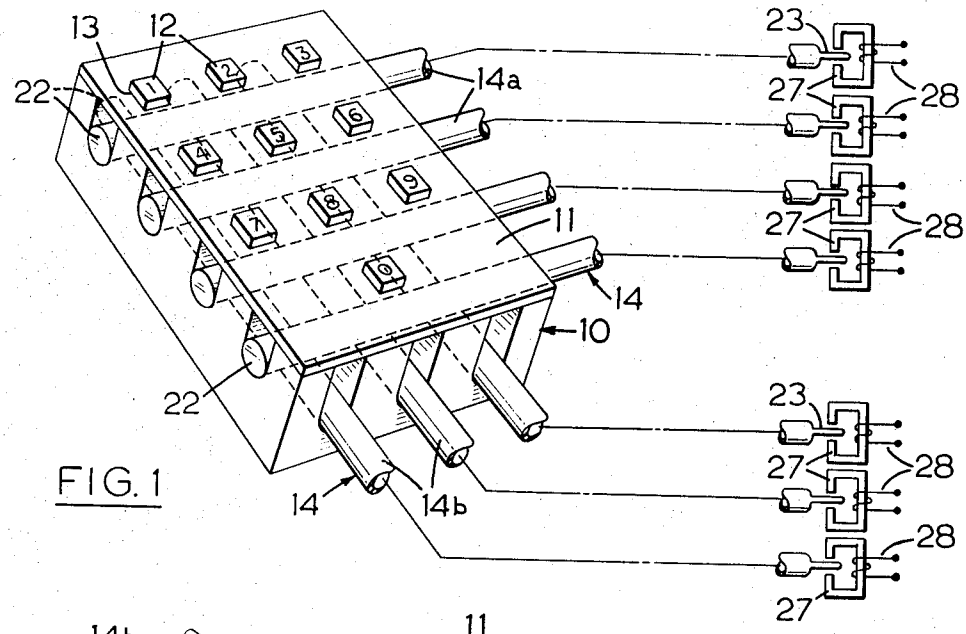


FIG. 1

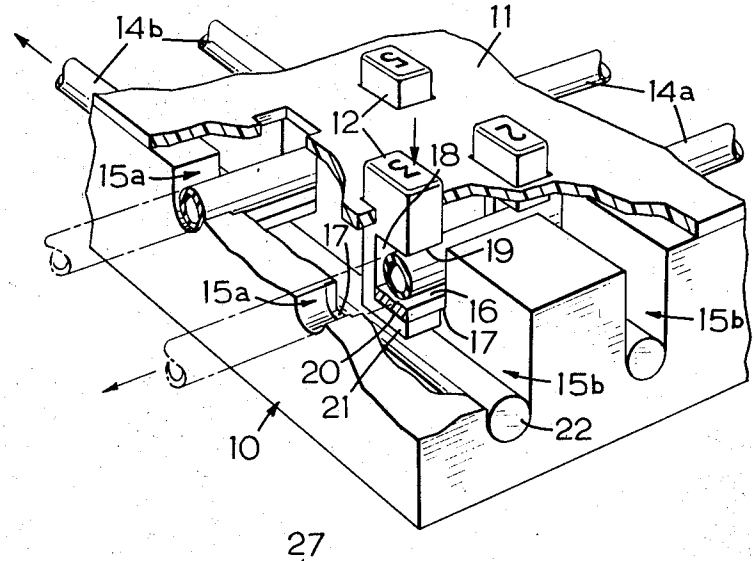


FIG. 2

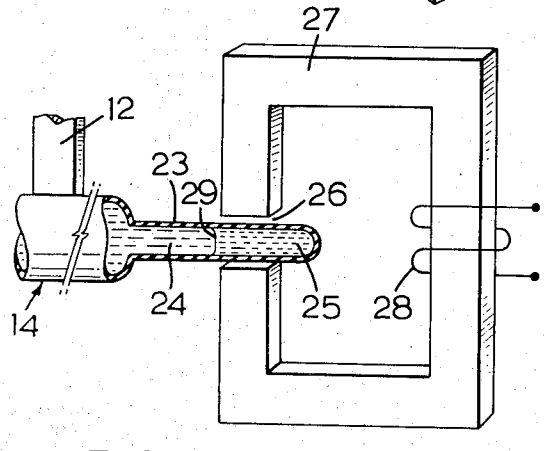


FIG. 3

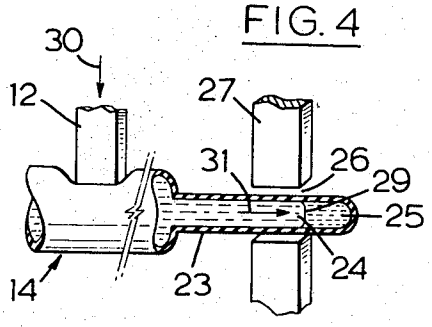


FIG. 4

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MECHANICAL-ELECTRICAL TRANSDUCER

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ABSTRACT OF THE DISCLOSURE

A mechanical-electrical transducer employing a flexible, closed tube carrying displaceable ferromagnetic means and traversing a magnetic field. When pressure is applied to the tube, the ferromagnetic means is displaced across the magnetic field to induce a signal in an electrical circuit coupled with the field. A lattice of such tubes in a switching matrix provides an *xy* encoding device.

The present invention relates to the mechanical-electrical transduction of energy using fluid pressure and more particularly to a fluid pressure switching matrix and switch.

In push-button telephone dials using tone dialling, each "dialled" number, selected by pushing a dial button, is converted into two different electrical impulses which are identified by the station apparatus to which the telephone is connected. The modulating impulse which identifies the selected number has been produced by an electronic circuit derived by a plurality of spring contacts. Certain disadvantages arise from this type of mechanical system, such as the problem backlash which is expensive to reduce, the low reliability of the spring contacts, and the brief duration of the modulating impulse compared with the push button contact time, which reduces the reliability of identification of the signal.

It is an object of the present invention to provide a switching matrix employing fluid pressure to convert mechanical energy, imparted to a key or push button, into electrical signals identifying the particular button which is pushed.

Another object of the invention is to provide an *xy* encoding system of digital signalling using a mechanical-hydraulic-electrical transduction of energy.

Another object of the invention is to provide an improved electrical switch employing fluid pressure to convert mechanical pressure into an electrical signal.

An example embodiment of the invention is shown in the accompanying drawings in which:

FIG. 1 is a view in perspective, partly schematic, of a push-button array and its associated fluid pressure conversion elements;

FIG. 2 is a view in perspective of a portion of the housing and push-button array of FIG. 1, partly broken away (and viewed from the side opposite that presented in FIG. 1), showing the arrangement of the tubes within the housing and the manner in which each key interacts with the tubes.

FIG. 3 is a view in perspective, partly broken away, showing the inter-relationship between each tube and a magnetic circuit; and

FIG. 4 is a view similar to FIG. 3 showing the movement of fluid in the tube, in relation to the magnetic circuit, when the tube is compressed by its associated push-button.

In the drawings, FIG. 1 shows a housing block **10** carrying on its upper face a dial plate **11** which has an array of push-buttons **12**, of the type lately introduced in telephones using tone dialling systems, forming rows and columns. Each button **12** is loosely retained in an aperture **13** in dial plate **11** and projects both above and below the dial plate, the upper projecting portion carrying indicia.

Underlying dial plate **11** and within housing **10** are two groups of spaced apart tubes **14** in parallel planes, forming a grid with crosspoints of the tubes lying directly beneath buttons **12**. Thus a plurality of parallel "row" tubes **14***a* and a plurality of "column" tubes **14***b* are provided, corresponding to the rows and columns of buttons **12**.

To arrange tubes **14** in this manner, a plurality of channels **15** are located in housing **10** to form a grid corresponding to that formed by tubes **14**. As seen in the drawings, channels **15***a* accommodating row tubes **14***a* are shallower than channels **15***b* accommodating column tubes **14***b*, the difference in depth being equivalent at least to the sum of the diameter of tube **14***b*, the thickness of a pressure lip on button **12** (to be described) and the thickness of a bridging strip **16** which interconnects separated portions of the trough of each channel **15***a*. Bridging strip **16** is slightly longer than the width of channel **15***b* and rests at each of its ends on a ledge **17** cut out of the end of adjacent portions of channel **15***a*.

To provide contact with both tube **14***a* and tube **14***b* simultaneously at their intersections, each button **12** is formed with a rectangular recess **18** in the shaft of the button lying below dial plate **11**. Recess **18** accommodates tube **14**a and strip **16**, its width from upper wall **19** to lower wall **20** being at least the sum of the diameter of tube **14***a* and the thickness of interconnecting strip **16**. Recess **18** provides a lower lip **21** for the shaft of button **12** which is accommodated between strip **16** and tube **14***b*, and touches tube **14***b* when face **19** of recess **18** touches tube **14***a*. Each button **12** may of course be urged upwardly by spring means, not shown, urging lip **21** against strip **16**.

As seen in FIG. 1 of the drawings, one end **22** of each tube **14** is sealed while the other end of each tube extends out from the housing and terminates in a sealed end portion or extension **23** of constricted diameter. Tube **14**, including constriction **23**, is filled with a non-compressible ferro-magnetic liquid **24** with a compressible cushion of gas **25** separating liquid **24** from the sealed end of constriction **23**, as shown more particularly in FIG. 3 of the drawings. That portion of constriction **23** holding gas cushion **25** is located within a gap **26** of a continuous permanent magnet **27** which has coupled with it an output coil or winding **28** forming part of an electrical circuit (not shown) in which an electrical signal may be induced. Meniscus **29** of liquid **24** in constriction **23** lies adjacent gap **26**, the proportions of tube **14**, constriction **23** and gas cushion **25** being such that on compression of the tube by button **12**, meniscus **29** will pass through gap **26** of magnet **27** to cut across a maximum number of flux lines of force in the magnetic field provided by magnet **27**. For this reason the sealed end portion of constriction **23** will lie outside gap **26** to accommodate gas cushion **25** in a compressed state, as shown in FIG. 4 of the drawings. As will be seen in FIG. 1, each tube **14** has an individual magnet **26** associated with it together with an individual coil **27** and electrical circuit in

which a signal is induced. Of course magnets **27** may be arranged in any suitable manner in relation to housing **10** and tubes **14** may be coupled with constrictions **23** in any suitable manner to carry the operation of the device into effect.

It will be seen that pairs of magnets **27** and their associated coils **28** serve to identify, through tubes **14**, individual crosspoints and push-buttons **12**, different combinations of magnets identifying different crosspoints, thus froming an *xy* encoding system.

The ferromagnetic fluid used in tubes **14** is preferably a colloidal suspension of submicron-sized ferrite particles in a carrier fluid, with a dispersing agent added to prevent flocculation. The suitable fluid is made up as follows:

Particles size—100 A.
Particles concentration—10^7 per cm.^{3}
Carrier fluid—kerosene
Dispersing agent—oleic acid

This fluid has a magnetic permeability of $1\mu 3$ and a magnetic induction greater than 70 gauss.

Tubes **14** may be formed of any suitable resilient material such as a rubber compound, which will retain fluid **24** and the gas of cushion **25** without deterioration.

In the opeartion of the described embodiment, any button **12** when pushed downward in the direction of arrow **30** will bear simultaneously against the crosspoints of two tubes **14***a* and **14***b* where they intersect the axis of the button, face **19** of recess **18** pressing against tube **14***a* and lip **21** pressing against tube **14***b* to compress each tube. The force imparted by button **12** to compress each tube **14** displaces non-compressible fluid **24** in that tube, which acts against compressible gas cushion **25**, causing the fluid to move across gap **26** of magnet **27** as the gas in compressed by the force transposed by the fluid from the button, as shown by arrow **31** in FIG. 4 of the drawings. The movement of ferromagnetic fluid **24** through gap **26** will vary the reluctance of the magnetic circuit in magnet **27** to produce an electromotive force in output coil **28**. Since the electromotive force generated in coil **28** is proportional to the change in reluctance of the magnetic circuit and hence to the rate of movement of fluid **24** through gap **26** of permanent magnet **27**, constriction of tube **14** in that portion of the tube lying within the gap increases the rate of movement of the fluid and hence the strength of the signal induced into the electrical circuit of coil **28**.

As mentioned above, coil **28** forms part of an electrical circuit (not shown) which carries the signal, induced in the coil by magnet **27**, by suitable circuitry (normally an amplifying circuit and a delay circuit) to an oscillator. A pair of such signals, induced by a pair of magnets **27** identifying a particular push-button **12**, generates a tone signal in the oscillator identifying the digitally selected number.

It will be appreciated that the magnetic field, to which the electrical circuit is coupled, may be produced electromagnetically by providing an exciting current in coil **28** or in a separate coil using a core equivalent to magnet **27**. If desired, extension **23** could be used as the core of a solenoid acting both as a magnetizing coil and as a signal output coil. Again, the hydraulic pressure exerted by any non-compressible fluid **24**, not necessarily ferromagnetic, could be exerted on a solid piston of ferromagnetic material located within constriction **23** and movable into gap **26** of magnet **27** (or into a solenoid) with a cushion of gas **25** being present for compressibility and to return the piston to its original position of rest when pressure on button **12** is released.

I claim:

1. A mechanical-electrical energy transducer comprising:

at least two groups of flexible, closed tubes disposed in contiguous planes, with the longitudinal axes of the tubes of one group crossing those of the other group to form a grid, each of the tubes carrying a non-compressible fluid therein;

means responsive to a change of pressure of the fluid in each of the tubes to produce, for each tube, an electrical signal; and

actuating means located adjacent the tubes at each crosspoint thereof selectively adapted to compress the tubes adjacent thereto whereby the pressure responsive means is actuated.

2. A transducer as claimed in claim **1** in which at least a portion of each tube is located in an individual magnetic field and an individual electrical circuit is coupled with each magnetic field, the fluid in each tube being adapted to be displaced on compression of the tube to move magnetically conducting material across the field whereby a signal is induced in the electrical circuit.

3. A transducer as claimed in claim **2** in which a permanent magnet, having an air gap therein, provides a closed magnetic circuit, the tube portion being located in the air gap, and the electrical circuit having a winding on the magnet.

4. A transducer as claimed in claim **2** including a ferromagnetic core having an air gap therein, the electrical circuit having a first winding on the core, the tube portion being located in the air gap, and a second winding of a further electrical circuit providing an exciting current to produce a magnetic circuit in the core.

5. A transducer as claimed in claim **2** in which a ferromagnetic core, having an air gap therein, carries a winding of said electrical circuit providing an exciting current to produce a magnetic circuit in the core, the tube portion being located in the air gap.

6. A transducer as claimed in claim **2** in which the magnetic field is produced by a solenoid in the electrical circuit, the tube portion constituting the solenoid core.

7. A transducer as claimed in claim **2** in which the magnetically conducting material is ferromagnetic fluid, and a compressible fluid contained in the tube discrete from the ferromagnetic fluid whereby the ferromagnetic fluid is movable longitudinally in the tube across the magnetic field.

8. A transducer as claimed in claim **2** in which one end portion of the tube lies in the magnetic field, said end portion comprising an extension of restricted diameter.

9. An *xy* encoding device comprising:

a housing;

two groups of transversely flexible, closed tubes disposed in contiguous planes to form a grid in the housing, each of the tubes carrying ferromagnetic fluid therein;

one end portion of each tube terminating in an individual magnetic field having an electrical circuit coupled therewith, said tube end portion carrying a discrete compressible fluid;

a shaft located at each crosspoint of the tubes transversely thereto and projecting from the housing, each shaft being constructed and arranged, on an axial force being applied thereto, to compress the pair of tubes at the crosspoint, the displaced fluid in each of said pair of tubes moving along the tube and across the magnetic field to induce a signal in the electrical circuit, the two signals induced by said tubes identifying said crosspoint.

10. A device as claimed in claim **9** in which each of said tube end portions lies in an air gap of a permanent magnet providing a closed magnetic circuit, the electrical circuit having a series winding on said magnet.

11. A device as claimed in claim **9** in which each of said tube end portions lies in an air gap of an electromagnet providing a closed magnetic circuit, the electrical circuit having a series winding on the electromagnet and supplying the exciting current therefor.

12. A device as claimed in claim 9 in which each of said tube end portions lies in the core of a solenoid in series with the electrical circuit, the exciting current for said solenoid being supplied by said circuit.

13. A device as claimed in claim 9 in which the end portion of each tube terminating in the magnetic field is reduced in diameter to provide a constricted extension of the tube.

14. A device as claimed in claim 13 in which the discrete compressible fluid is located in the extension of the tube contiguous with the colsed end thereof and with but outside the magnetic field.

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