April 5, 1960 T. HENSE 2,932,007

MATRIX STORAGE REGISTER

Filed Oct. 14, 1958 2 Sheets-Sheet 1

FIG. 3

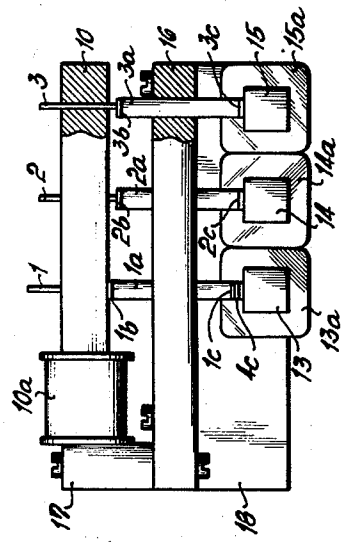


FIG. 5

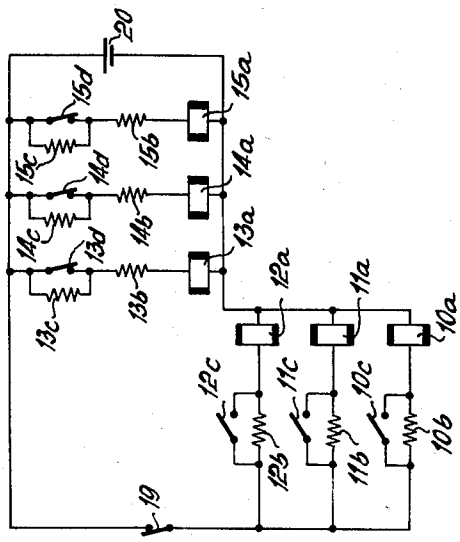


FIG. 2

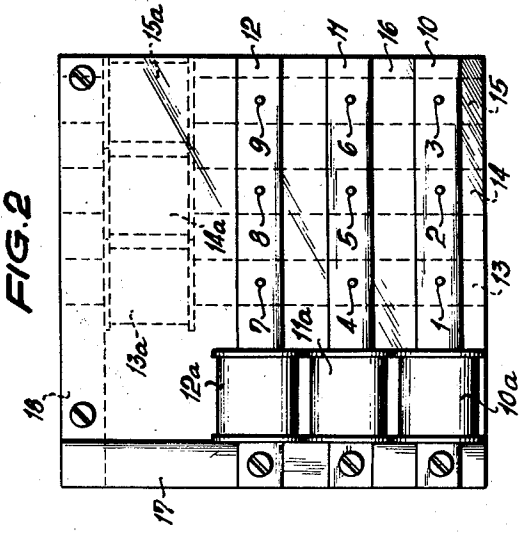


FIG. 4

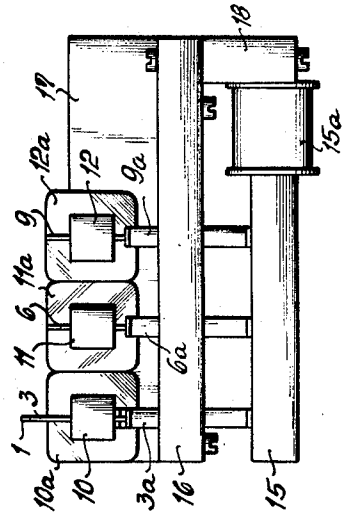
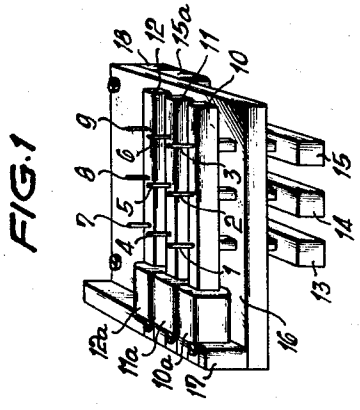


FIG. 1



INVENTOR
THEO HENSE

BY Toulmin & Toulmin

ATTORNEYS

April 5, 1960 T. HENSE 2,932,007

MATRIX STORAGE REGISTER

Filed Oct. 14, 1958 2 Sheets-Sheet 2

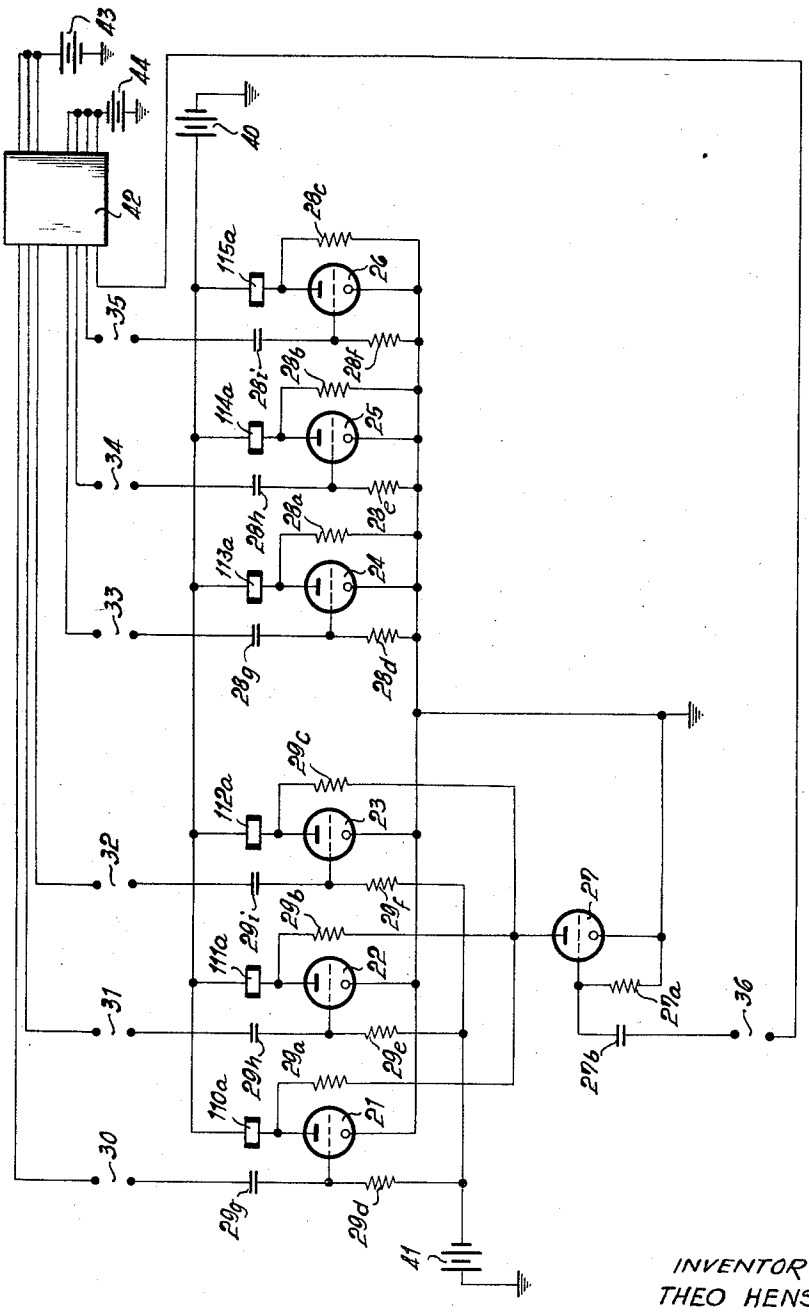



FIG. 6

INVENTOR
THEO HENSE

BY Toulmin & Toulmin

ATTORNEYS

United States Patent Office 2,932,007 Patented Apr. 5, 1960



2,932,007

# MATRIX STORAGE REGISTER

Theo Hense, Wilhelmshaven, Germany, assignor to Olympia Werke A.G., Wilhelmshaven, Germany

Application October 14, 1958, Serial No. 767,155

Claims priority, application Germany November 2, 1957

9 Claims. (Cl. 340—166)

The present invention relates to a matrix storage register, and, more particularly, to an electromagnetic matrix storage register in which stored information is represented by the position of movable pins.

There exists electromagnetic storage registers which include relays from which the stored information can be extracted electrically without being cancelled. Such registers require a large number of individual relays; also, they are generally of bulky construction and are expensive to produce.

It is, therefore, an object of the present invention to overcome the above disadvantages, and, with this object in view, the present invention consists mainly in that improvement in a storage register which comprises a plurality of first and second electromagnetic means arranged, respectively, in rows and columns so as to form a matrix, and a plurality of pin means arranged, respectively, at the intersections of the rows and columns. These pin means are mounted for movement between rest and actuated positions, and each pin means has armature means which are part of the magnetic circuit of each of the two electromagnetic means which intersect at the particular intersection at which each respective pin means is arranged. Thus, the movement of each pin means between its two positions may be controlled through the intermediary of the two electromagnetic means which intersect at the particular intersection at which each respective pin means is arranged.

Thus, electromagnetic matrix storage registers according to the present invention, which may be used in calculators, office machines, bookkeeping machines and other machines in which input data must be temporarily stored, are registers in which electromagnetic forces are applied directly to the pin means the position of which represents the stored information. As a result, registers according to the present invention may be made substantially smaller than existing registers, and therefore require considerably less material.

The present invention also makes use of the fact that the force exerted by a magnet upon a piece of soft iron and the work done by the magnet during movement of the piece, is taken from the energy contents of the magnetic field. When the air gap is not too great, i.e., when the magnetic field in the air gap is practically a homogeneous one, the attractive force F which the magnetic field exerts upon a piece of iron, assuming that the permeability of the iron is substantially different from a value of 1, may be expressed approximately by the following simplified formula:

$$F=\frac{AB^2}{2}$$

wherein A is the area of cross-section normal to the direction of the flux and B is the induction in the iron. Accordingly, the attractive force in the magnetic field varies as the square of the magnetic induction.

The above principle is applied in a matrix storage register according to the present invention by incorporating



therein first energizing means associated, respectively, with the first electromagnetic means for energizing the same, and second energizing means associated, respectively, with the second electromagnetic means for energizing the same. The first energizing means which are normally in activated condition, and the second energizing means which are normally in deactivated condition, are of such strengths that whenever any one of the first energizing means is activated, the pin means which form part of the magnetic circuit of the corresponding first electromagnetic means are held in their respective rest positions and that upon activation of any one of the second energizing means, one of the pin means forming part of the magnetic circuit of the corresponding second electromagnetic means will move to its actuated position only if the first energizing means of the corresponding first electromagnetic means of such pin means is deactivated. Furthermore, control means are provided for simultaneously deactivating any selected one of the first energizing means and activating any selected one of the second energizing means. Thus, any one of the pin means may be moved from its rest position to its actuated position by deactivating the first energizing means and activating the second energizing means of the first and second electromagnetic means which intersect at the particular intersection of rows and columns at which the pin means desired to be moved is arranged.

It will be seen from the above that one of the electromagnetic means serves to hold each pin means in its rest position whereas the other electromagnetic means serves to move each pin means into its actuated position. In this way, the armature is always attracted by that electro magnet the induction of which produces the greater flux density at the entering cross-section of the armature, it thus being a feature of the present invention that the induction of the electromagnetic means is changed upon the input of information, such as by de-energizing the holding magnet and simultaneously energizing the pulling magnet of the pin means which is to be moved from rest to actuated position.

Additional objects and advantages of the present invention will become apparent upon consideration of the following description of the accompanying drawings, in which:

Fig. 1 is a simplified perspective view of a matrix storage register according to the present invention, which includes nine pin means;

Fig. 2 is a plan view of the register shown in Fig. 1;

Fig. 3 is a front elevational view, partly in section, of the register shown in Fig. 1;

Fig. 4 is a side elevational view of the register shown in Fig. 1;

Fig. 5 is a wiring diagram of an energizing circuit incorporating mechanical switch means which may be used in conjunction with the register shown in Figs. 1 to 4; and

Fig. 6 is a wiring diagram of an energizing circuit incorporating electronic switch means which may be used in conjunction with the register shown in Figs. 1–4.

Referring now to the drawings, and to Figs. 1 to 4 thereof in particular, there is shown a register comprising a base plate **16** on which two supports **17** and **18** are mounted, the support **17** carrying electromagnet cores **10, 11** and **12** and the support **18** carrying electromagnet cores **13, 14** and **15**, with all of the elements **10** to **18** being made of ferromagnetic material. The cores **10, 11, 12** are arranged in rows and the cores **13, 14, 15** are arranged in columns, and all of the cores **10** to **15** have associated with them energizing coils **10***a* to **15***a*, respectively, so that the register incorporates six electromagnetic means each constituted by one of the cores and its coil, the support to which the core is attached, and the base plate.

A plurality of pins 1 to 9 of non-magnetical material, such as brass, are arranged, respectively, at the intersections of the rows and columns. Each pin carries an armature 1*a*, 2*a*, 3*a*, etc. of ferromagnetic material, and each pin together with its armature constitutes a pin means which passes through aligned openings in the corresponding cores and the base plate 16 and is movable in a direction transverse to the base plate between a rest position, as exemplified by pin means 2, 2*a* through 9, 9*a*, and an actuated position, as exemplified by pin means 1, 1*a*. The arrangement of the parts is such that the armature of each pin means forms part of the magnetic circuits of the two electromagnetic means at whose intersection it is arranged, e.g., the armature 1*a* of the pin means 1, 1*a* is part of the magnetic circuit of the electromagnetic means 10, 10*a*, 17, 16 as well as of the electromagnetic means 13, 13*a*, 18, 16; the armature 6*a* of the pin means 6, 6*a* is part of the magnetic circuit of the electromagnetic means 11, 11*a*, 17, 16 as well as of the electromagnetic means 15, 15*a*, 18, 16.

The coils 10*a* to 15*a* are connected to suitable energizing means, as will be more fully described below, so that the movement of each pin means may be controlled through the intermediary of the electromagnetic means which intersect at the particular intersection at which each respective pin means is arranged.

According to the present invention the electromagnetic means incorporating the cores 13, 14 and 15 act as holding magnets for holding the pin means in their respective rest positions, whereas the electromagnetic means incorporating the cores 10, 11 and 12 act as moving magnets for moving the pin means into their actuated position, and the energizing means associated with the coils are of such strength that whenever one of the holding magnets is energized, the three pin means forming part of the magnetic circuits of this holding magnet will be retained in their rest positions irrespective of whether the coils of any of the moving magnets are energized, so that energization of the coils of one of the moving magnets will cause a pin means to move to its actuated position only if the coil of the holding magnet associated with such pin means is de-energized.

Normally, coils of the holding magnets are energized whereas the coils of the moving magnets are not, so that each pin means will be in its rest position. A matrix storage register according to the present invention therefore includes control means for simultaneously de-energizing the coil of one of the holding magnets and energizing the coil of one of the moving magnets, so that any one of the pin means may be moved from its rest to its actuated position by de-energizing and energizing, respectively, the coils of the holding and moving magnets located at the intersection of rows and columns at which the pin means desired to be moved is arranged.

In order to prevent sticking of the armatures to any of the cores upon de-energization of the corresponding coil under the influence of residual magnetism, and thereby to facilitate movement of each pin means between its two positions, suitable end plates 1*b*, 1*c*, 2*b*, 2*c*, etc. of non-magnetic material are provided.

Fig. 5 shows a wiring diagram of an energizing circuit which may be used in conjunction with the matrix storage register shown in Figs. 1 to 4. This circuit includes suitable energizing means associated with the various coils, as well as means for controlling these energizing means. Thus, each coil lies in its own control branch, with all branches being in parallel with a source of electrical energy 20, a switch 19 being provided for disconnecting the branches of the coils 10*a*, 11*a*, 12*a* from the source 20.

Each of the coils 10*a*, 11*a*, 12*a*, is in series with a resistor 10*b*, 11*b*, 12*b* which can be short-circuited by closing a switch 10*c*, 11*c*, 12*c*. Each of these switches is normally open, so that the current flowing through the coils is small.



Each of the coils 13*a*, 14*a*, 15*a*, is in series with two resistors 13*b*, 13*c*; 14*b*, 14*c*; 15*b*, 15*c*, with switches 13*d*, 14*d*, 15*d* being provided for short-circuiting the resistors 13*c*, 14*c*, 15*c*. Each of these switches is normally closed, so that the resistors 13*c*, 14*c*, 15*c* are short-circuited, thereby allowing a relatively large current to flow through the coils.

The values of the resistors 13*b*, 14*b*, 15*b* are so selected that when the switch 19 is open, sufficient current flows through the coils 13*a*, 14*a*, 15*a* to cause the pin means to be attracted into and held in their rest positions. Upon closing of the switch 19, a certain current will flow through the coils 10*a*, 11*a*, 12*a*, and the values of the resistors 10*b*, 11*b*, 12*b* are so selected that the coils will be sufficiently energized to hold the pin means in actuated position, but will be insufficient to move the pin means into such position so long as they are being held in their rest position under the influence of the coils 13*a*, 14*a*, 15*a*. In other words, the values of the resistors are so selected that a pin means will be moved from its rest position to its actuated position only if the corresponding moving magnet is energized (by short-circuiting the resistor which lies in the same branch as the coil of the particular moving magnet) and the corresponding holding magnet is de-energized (by adding a resistor into the branch in which the coil of the particular holding magnet lies).

Once a pin means is in its actuated position, it will be held in it by the moving magnet until the branch incorporating such moving magnet is disconnected from the source 20. Thus, opening of the switch 19 will cause any pin means in actuated position to return to its rest position.

Thus, any selected pin means may be moved between its two positions. Assuming, for example, that it is desired to move the pin means 1, 1*a* from its rest to its actuated position. To accomplish this, the switch 10*c* is closed and the switch 13*d* is simultaneously opened. This may be effected by incorporating the switches in any suitable keyboard which is so constructed that upon actuation of the key marked "1," the switches 10*c* and 13*d* are closed and opened, respectively. Such a keyboard is shown, by way of example, in U.S. Patent 2,742,228. This switching operation increases the current flow through the coil 10*a* and simultaneously decreases the current flow through the coil 13*a*. This combined action is such that the attractive force exerted by the electromagnet means 10, 10*a*, is greater than that exerted by the electromagnetic means 13, 13*a*, so that the pin means 1, 1*a* is caused to move from its rest position to its actuated position.

It will be noted that insofar as the pin means 2, 2*a* and 3, 3*a* are concerned, the increase in the current flow through the coil 10*a* will in and of itself not be sufficient to move these two pin means out of their rest positions against the action of the still activated electromagnetic holding magnets 14, 14*a* and 15, 15*a*. Similarly, the decrease in the current flow through the coil 13*a* will not cause the pin means 4, 4*a* and 7, 7*a* to move into their respective actuated positions inasmuch as their respective moving magnets are not energized.

A number of pin means may be moved successively from rest to actuated position, and each will remain in such position until the switch 19 is opened, which causes all of the coils 10*a*, 11*a* and 12*a* to be disconnected from the source 20 so that all pin means which were moved to actuated position will be retracted into their respective rest positions under the influence of the coils 13*a*, 14*a* and 15*a*.

It will be noted that unless the switch 19 is opened, once a pin means has been moved to its actuated position, it will remain in such position. Thus, in the above example involving pin means 1, 1*a*, this pin means will remain in actuated position even when the key "1" of the keyboard is released, i.e., even after the switch 10*c*

is opened and the switch 13*d* closed. This is so inasmuch as so long as the control branch incorporating the coil 10*a* is connected across the source 20, it will act as a holding magnet of sufficient strength to prevent movement of the pin means 1, 1*a* from actuated position to rest position under the action of the coil 13*a*, notwithstanding the fact that the resistor 10*b* is no longer short-circuited.

The information stored in the register may be sensed by suitable mechanical feeler means, of the type shown in United States Patents Nos. 1,957,617, 2,034,345 and 2,742,228. Alternatively, the register may have associated with it switch means which are adapted to be actuated by the pin means and electrically convey the information stored in the register. Such an arrangement is shown in Fig. 4 of co-pending application Serial No. 719,092, filed March 3, 1958.

A matrix storage register according to the present invention may be built in accordance with the following data, it being understood, however, that these figures are given by way of example and are, therefore, illustrative and not limitative of the invention: The plate 16 and the supports 17 and 18 each have a thickness of 6 mm., the cores 10 to 15 have a substantially square cross-section of 5 x 5 mm., and the armatures 1*a* to 9*a* are of substantially circular cross-section of 3 mm. diameter. Each of the coils has 500 turns and a resistance of 100 ohms, each of the resistors 10*b*, 11*b* and 12*b* has a resistance of 200 ohms, each of the resistors 13*b*, 14*b* and 15*b* has a resistance of 20 ohms, and each of the resistors 13*c*, 14*c* and 15*c* has a resistance of 500 ohms. The source of electrical energy has an electric potential of 60 volts.

Instead of mechanical switch means for controlling the energizing means, the circuit may be one incorporating electronic means, such as tubes or thyratrons or the like. Fig. 6 shows such a circuit, in which the coils of the moving magnets are indicated at 110*a*, 111*a* and 112*a*, with the coils of the holding magnets being indicated at 113*a*, 114*a* and 115*a*. Each of the coils 113*a*, 114*a* and 115*a* lies in a branch which incorporates one of the resistors 28*a*, 28*b*, 28*c*, and the branches are connected in parallel with a source of electric energy 40. The tubes 24, 25 and 26 are connected across the resistors 28*a*, 28*b* and 28*c*, and with the grids of these tubes being connected to ground by way of grid resistors 28*d*, 28*e* and 28*f*, these tubes are conductive so that the resistors 28*a*, 28*b* and 28*c* are short-circuited. Thus, a relatively large current normally flows through the coils 113*a*, 114*a* and 115*a*. However, each of these tubes may be rendered non-conductive by applying a negative pulse to the grid inputs 33, 34 or 35, suitable capacitors being arranged at 28*g*, 28*h* and 28*i*.

Each of the coils 110*a*, 111*a* and 112*a* lies in a branch which incorporates one of the resistors 29*a*, 29*b* and 29*c*, and these branches are connected in parallel, by way of a tube 27, with the above-mentioned source 40. This tube, the grid resistors 27*a* of which is also connected to ground, is normally conductive, but may be rendered non-conductive whenever a negative pulse is applied to the grid input 36, a suitable capacitor 27*b* being arranged in the grid circuit.

The tubes 21, 22 and 23 are connected across the resistors 29*a*, 29*b* and 29*c*, and are normally biased negatively from a source of electrical energy 41 by way of resistors 29*d*, 29*e* and 29*f*. The tubes are therefore non-conductive, unless and until a positive pulse is applied at grid inputs 30, 31 or 32 by way of capacitors 29*g*, 29*h* and 29*i*.

As in the circuit shown in Fig. 5, the values of the various resistors are so selected that a pin means will be moved from rest to actuated position only if the corresponding moving magnet is energized (by rendering conductive the tube which lies in the same branch as the coil of the particular moving magnet) and the corresponding holding magnet is de-energized (by rendering non-conductive the tube which lies in the same branch as the coil of the particular holding magnet, thereby adding a resistor into the branch of such coil).

The grid inputs 30 to 36 may be connected to a common keyboard 42 by means of which the sources of electrical energy 43 and 44 may be connected to the grid inputs 30 to 32 and 33 to 36, respectively, for applying a pulse of the requisite polarity to each grid. This keyboard may be of conventional construction, and may be of the type shown in U.S. Patent 2,742,228.

Thus, if it is desired to store the value "1" in the register, the appropriate key on the keyboard 42 is depressed, and this causes the simultaneous application of a positive pulse to the grid input 30 and a negative pulse to the grid input 33. Tube 24 is thereby rendered non-conductive so that the resistor 28*a* is no longer short-circuited, thereby causing a reduced current to flow through the coil 113*a*. At the same time, tube 21 is rendered conductive, thereby short-circuiting resistor 29*a* so as to increase the current flow through soil 110*a*. It is through this combined action that the pin means 1, 1*a*, and only this pin means will be moved to its actuated position.

As in the circuit of Fig. 5, a number of pins may thus successively be moved into actuated position, and each will be held in such position until a negative pulse is applied to the grid input 36, which causes all of the coils 110*a*, 111*a* and 112*a* to be disconnected from the source 40 so that all pin means are retracted into their respective rest positions under the influence of the coils 113*a*, 114*a* and 115*a*.

The energizing circuit shown in Fig. 6 may be built in accordance with the following data, it again being understood that this data is given by way of example and is not intended to be limitative of the present invention: Each of the tubes is a 6AQ5 connected as a triode, and each of the coils has 5,000 turns and a resistance of 1 kilo-ohm. Each of the resistors 28*a*, 28*b* and 28*c* has a resistance of 3 kilo-ohms, each of the resistors 29*a*, 29*b* and 29*c* has a resistance of 2 kilo-ohms, each of the grid resistors 27*a*, 28*d*, 28*e*, 28*f*, 29*d*, 29*e* and 29*f* has a resistance of 500 ohms, each of the capacitors 27*b*, 28*g*, 28*h*, 28*i*, 29*g*, 29*h* and 29*i* has a capacitance of .001 microfarad, the source 40 has a voltage of +150 V., the source 41 has a voltage of −40 v., the source 43 has a voltage of +40 v., and the source 44 has a voltage of −40 v.

It will be understood that this invention is susceptible to modification in order to adapt it to different usages and conditions, and, accordingly, it is desired to comprehend such modifications within this invention as fall within the scope of the appended claims.

What is claimed is:

1. In a matrix storage register in which stored information is represented by the position of movable pin means, the combination which comprises a plurality of electromagnetic means arranged in rows and columns so as to form a matrix, and a plurality of pin means arranged, respectively, at the intersections of said rows and columns and being mounted for movement between two positions, each pin means having armature means which are part of the magnetic circuit of each of the two electromagnetic means which intersect at the particular intersection at which each respective pin means is arranged, whereby movement of each pin means between its two positions may be controlled through the intermediary of the two electromagnetic means which intersect at the particular intersection at which each respective pin means is arranged.

2. In a matrix storage register in which stored information is represented by the position of movable pin means, the combination which comprises a plurality of electromagnetic means arranged in rows and columns so as to form a matrix; a plurality of pin means arranged, respectively, at the intersections of said rows and columns and being mounted for movement between two positions, each pin means having armature means which are part

of the magnetic circuit of each of the two electromagnetic means which intersect at the particular intersection at which each respective pin means is arranged; and control means for simultaneously controlling any selected one of the electromagnetic means which are arranged in said rows as well as any selected one of the electromagnetic means which are arranged in said columns in such a manner that the pin means located at the intersection of the thus controlled electromagnetic means is moved from one of its positions to the other.

3. In a matrix storage register in which stored information is represented by the position of movable pin means, the combination which comprises a plurality of first electromagnetic means and a plurality of second electromagnetic means, said first electromagnetic means being arranged in rows and said second electromagnetic means being arranged in columns so as to form a matrix; a plurality of pin means arranged, respectively, at the intersections of said rows and columns and being mounted for movement between two positions, each pin means having armature means which are part of the magnetic circuits of the first and second electromagnetic means which intersect at the particular intersection at which each respective pin means is arranged; a plurality of first energizing means associated, respectively, with said first electromagnetic means for energizing the same, each of said first energizing means being normally in activated condition; a plurality of second energizing means associated, respectively, with said second electromagnetic means for energizing the same, each of said second energizing means being normally in deactivated condition and being of such strength that when it is activated, it will cause its respective second electromagnetic means to move one of the pin means forming part of the magnetic circuit of the respective second electromagnetic means out of the position such pin means occupies when the first electromagnetic means, which is located at that intersection of rows and columns at which said one pin means is arranged, is energized by its respective first energizing means, only when such first energizing means is deactivated; and control means for simultaneously deactivating any selected one of said first energizing means and activating any selected one of said second energizing means, whereby any one of said pin means may be moved from one of its positions to the other by deactivating the first electromagnetic means and activating the second electromagnetic means which intersect at the particular intersection of rows and columns at which the pin means desired to be moved is arranged.

4. In a matrix storage register in which stored information is represented by the position of movable pin means, the combination which comprises of a plurality of first electromagnetic means and a plurality of second electromagnetic means, said first electromagnetic means being arranged in rows and said second electromagnetic means being arranged in columns so as to form a matrix; a plurality of first energizing means associated, respectively, with said first electromagnetic means for energizing the same, said first energizing means being normally in activated condition; a plurality of second energizing means associated, respectively, with said second electromagnetic means for energizing the same, said second energizing means being normally in deactivated condition; a plurality of pin means arranged, respectively, at the intersection of said rows and columns, each pin means having armature means which are part of the magnetic circuits of the first and second electromagnetic means which intersect at the particular intersection at which each respective pin means is arranged and being so mounted as to be movable between actuated and rest positions, said first and second energizing means being of such strengths that whenever any one of said first energizing means is activated, the pin means forming part of the magnetic circuit of the corresponding first electromagnetic means are held in their respective rest positions and that upon activation of any one of said second energizing means, one of the pin means forming part of the magnetic circuit of the corresponding second electromagnetic means will move to its actuated position only if the first energizing means of the corresponding first electromagnetic means of such pin means is deactivated; and control means for simultaneously deactivating any selected one of said first energizing means and activating any selected one of said second energizing means, whereby any one of said pin means may be moved from its rest position to its actuated position by deactivating the first energizing means and activating the second energizing means of the first and second electromagnetic means which intersect at the particular intersection of rows and columns at which the pin means desired to be moved is arranged.

5. In a matrix storage register in which stored information is represented by the position of movable pin means, the combination which comprises a plurality of electromagnetic holding means and a plurality of electromagnetic moving means, said holding means being arranged in rows and said moving means being arranged in columns so as to form a matrix; a plurality of normally activated energizing means associated, respectively, with said holding means and a plurality of normally deactivated energizing means associated with said moving means; a plurality of pin means arranged, respectively, at the intersection of said rows and columns, each pin means having armature means which are part of the magnetic circuits of the holding and moving means which intersect at the particular intersection at which each respective pin means is arranged and being so mounted as to be movable between actuated and rest positions, said energizing means being of such strengths that whenever the energizing means of any one of said holding means is activated, the pin means forming part of the magnetic circuit of such holding means are held in their respective rest positions irrespective of whether the energizing means of any of the moving means are activated so that activation of the energizing means of one of said moving means will cause a pin means to move to its actuated position only if the energizing means of the holding means associated with such pin means is deactivated; and control means for simultaneously deactivating any selected one of the energizing means associated with said holding means and activating any selected one of the energizing means associated with said moving means, whereby any one of said pin means may be moved from its rest position to its actuated position.

6. The combination defined in claim 5 wherein said control means include switch means for controlling the energization of said energizing means.

7. The combination defined in claim 5 wherein said control means include mechanical switch means for controlling the energization of said energizing means.

8. The combination defined in claim 5 wherein said control means include electronic switch means for controlling the energization of said energizing means.

9. The combination defined in claim 5 wherein each of said electromagnetic means comprises a coil and each of said energizing means comprises resistor means in circuit with the coil of its respective electromagnetic means, and wherein said control means include switch means for short-circuiting said resistor means.

No references cited.