United States Patent [19]

Goodrich

[11] **3,812,490**

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[54] **FLEXIBLE MEMBRANE DISPLAY PANEL FOR GENERATING CHARACTERS VISIBLE IN AMBIENT LIGHT**

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[52] **U.S. Cl.** ..... **340/324 R,** 340/336, 350/267

[51] **Int. Cl.** **G02f 1/34**

[58] **Field of Search** ..... 340/324 R, 324 M, 378 R, 340/336, 334; 350/161, 267, 266, 269, 278, 280; 40/28 C, 130

[56] **References Cited**

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Assistant Examiner—Marshall M. Curtis
Attorney, Agent, or Firm—John S. Bell

[57] **ABSTRACT**

A digitally addressed magnetically actuated ambient light display panel is disclosed which incorporates a thin flexible magnetic membrane suspended between a ferromagnetic member and a transparent window in a fluid of a contrasting color. A plurality of small electromagnetic elements are disposed along the face of the ferromagnetic member adjacent to the magnetic membrane, which are capable of selectively magnetizing the ferromagnetic member at discrete locations. The magnetized ferromagnetic member attracts or repels the magnetic membrane in accordance with the magnetic polarity induced in the ferromagnetic member by the electromagnetic elements. Repelling the membrane against the face of the window at predetermined locations displaces the fluid between the membrane and the window and permits the contrasting color of the flexible membrane to become visible. A selectively repelled membrane generates characters or patterns visible under ambient light conditions.

17 Claims, 7 Drawing Figures

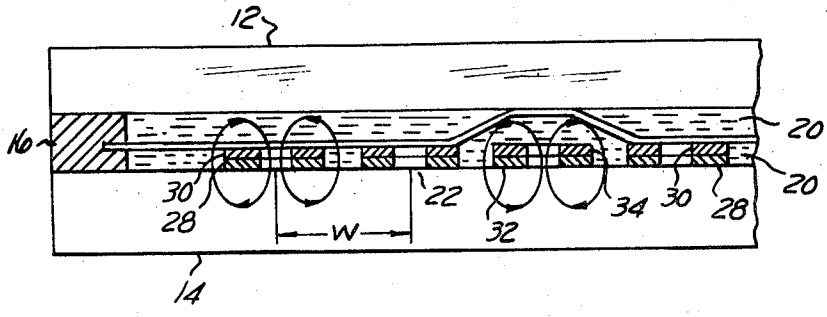


FIG. 1

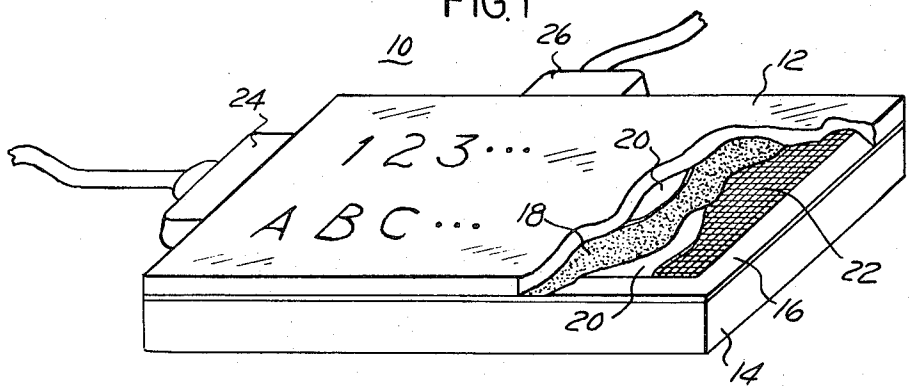


FIG. 2

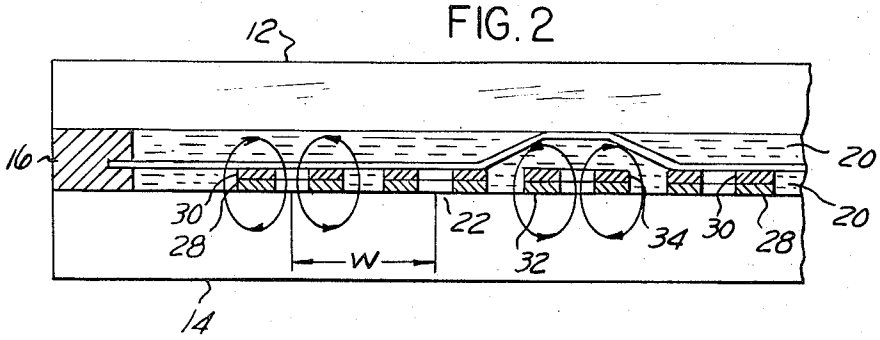


FIG. 5

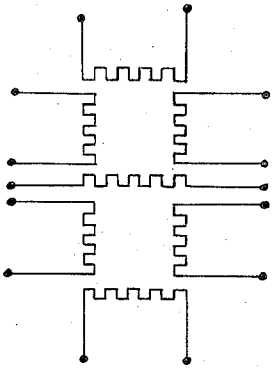


FIG. 3

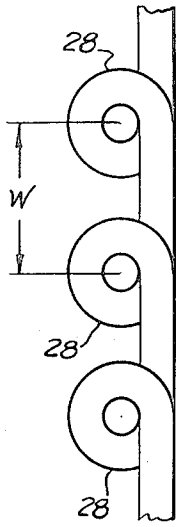


FIG. 4

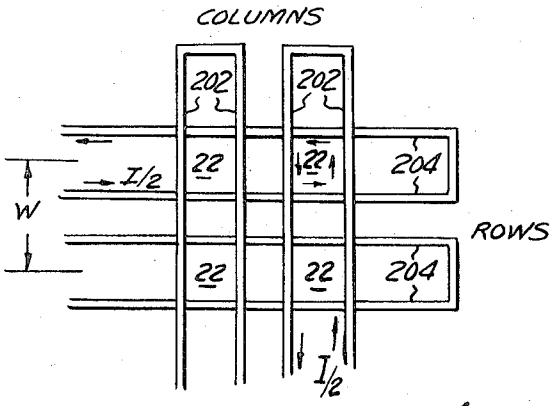
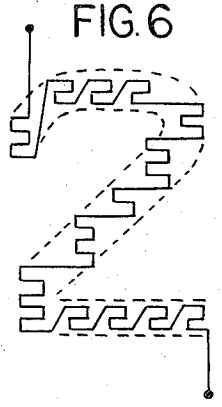


FIG. 6



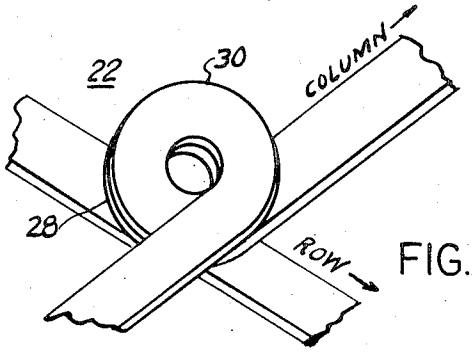


FIG. 7

FLEXIBLE MEMBRANE DISPLAY PANEL FOR GENERATING CHARACTERS VISIBLE IN AMBIENT LIGHT

BACKGROUND OF THE INVENTION

This invention relates to the field of ambient light display panels, and in particular, to digitally addressed electromagnetically activated ambient light display panels. The invention is similar with liquid crystal displays because both types of displays possess the desirable property of visibility under conditions of both intense and weak ambient illumination.

The use of display panels to display information in remote locations is increasing rapidly. Display panels may be categorized by the method in which the information is communicated to the recipient. Luminous display panels communicate information to the recipient by the self-generation of light. Luminous displays may have luminous characters on a black background, or black characters on a luminous background. Typical examples of luminous displays are cathode ray tubes, light emitting diode panels and plasma panels. The primary deficiency of luminous panels is the tendency of the information displayed to be lost or washed out under intense ambient lumination. The second category of display panels is the class of ambient light panels in which the information written on the display panel and transmitted to the recipient by means of reflected ambient light. Ambient light display panels are not self-luminous and are advantageous because the visibility of the displayed image increases with increasing ambient illumination conditions. Ambient light display panels have practical application in a variety of displays where ambient illumination may vary from intense daylight to subdued conditions such as those found in a home, an office, an aircraft, or automotive vehicle.

Various types of ambient light display panels are in existence. Recent developments in liquid crystals have resulted in ambient light displays which have the desirable property of visibility under conditions of both intense and weak ambient lumination. However, the inventive display panel offers several distinct advantages over presently existing liquid crystal displays. First, the inventive display panel diffusely reflects ambient light arriving from all directions, thus the display will not disappear at any angle of illumination or viewing. Second, the inventive display panel operates over a wide range of temperatures. Third, the inventive display panel is easy to digitally address on a point-for-point basis.

Magnetically activated ambient light display panels of various types are in existence, however none of the known systems are capable of meeting today's needs of high density information transfer. The existing magnetically activated display panels may be classified as simple on-off systems or character generating systems. U.S. Pat. No. 3,162,849 describes an on-off display panel in which a disc, upon which the desired message is printed, is suspended in a colored liquid a short distance from a transparent window. An electrically activated solenoid moves the disc against the transparent window, displacing the liquid, and rendering the printed message visible. This method is distinguished from the present invention in several ways: (1) it is basically an on-off device not readily capable of digital addressing or character formation; (2) the movable member is rigid, not flexible and therefore unable to display different patterns within a given area; (3) the movable member is made from magnetically susceptible material (soft iron) not from permanent magnetic material having a fixed magnetic polarity; (4) the display does not have a memory in the absence of power; and (5) the display requires the continuous application of electrical power in the off state.

Another type of magnetically activated ambient light display panel, which is disclosed in U.S. Pat. Nos. 3,444,551 and 3,469,258, include a plurality of cylindrical or spherical members which are rotated by small electromagnets located proximate to each member. The individual members have contrasting colors on their opposite sides, and the direction of the field of the electromagnets determines which side of the rotatable member and therefore which color is presented to the observer. These displays come in various sizes and number of rotatable members, and may be digitally addressed. However, they are structurally complex, containing a relatively large number of individual moving parts, and therefore are difficult to manufacture and maintain.

Still another type of magnetically actuated ambient light display, described in U.S. Pat. No. 3,292,171, uses a magnetic tape and magnetically susceptible particles suspended in a transparent fluid. The information to be displayed is magnetically written on the tape and the transparent fluid containing magnetically susceptible particles of a contrasting color is circulated across the tape. The particles separate from the fluid and form images on the tape corresponding to the information written thereupon. This and other concepts based upon magnetic particles suspended in a fluid face various difficulties and have not found wide acceptance.

SUMMARY OF THE INVENTION

The present invention is a digitally addressed magnetically activated ambient light display panel. The inventive display panel includes a ferromagnetic member which can be selectively magnetized to form local magnetic fields. Spaced apart from the ferromagnetic member is a transparent window and interposed between the window and the ferromagnetic member is a thin magnetized flexible membrane suspended in a colored fluid. When the ferromagnetic member is locally magnetized to a predetermined polarity, the magnetic fields repel the flexible membrane against the window. The membrane displaces the fluid between the window and the membrane permitting the contrasting color of the membrane to be visible. Reversing the local magnetic field in the ferromagnetic member attracts the flexible membrane away from the window and the colored fluid once more fills the space between the membrane and the window obscurring the membrane from visibility. Thus the selective attracting and repelling of the membrane at predetermined points over the face of the ferromagnetic member causes the display panel to display characters visible under ambient light conditions. The advantages of the inventive display panel are compact size, low power consumption, and memory in the absence of power. Additionally, a wide range of contrasting colors including highly visible fluorescent figures can be used in the inventive display panel. The inventive display is basically binary although gray scales may be introduced by combining multiple active cells into each resolution element. A further advantage of the in-

ventive display is that it may be extended to incorporate variable colors by associating two or three cells, each carrying a primary color within each resolution element thus permitting the generation of images or characters of different color. This technique of color imaging is similar to the color printing techniques used in magazines and newspapers as well as that used in the present day color television. Another advantage of the disclosed display panel is the fact that it can be produced at reasonable costs and includes no parts which are inordinately difficult to manufacture using standard manufacturing techniques. Further, the system contains a limited number of discrete parts or members, this is in contrast to the other prior art magnetically activated ambient light display panels which comprise a large number of individual components.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of the inventive ambient light panel with a section cut away to show the component parts

FIG. **2** is an exaggerated cross sectional view of the inventive display panel.

FIG. **3** is an enlarged plan view of one of the preferred configurations of the electromagnetic coils.

FIG. **4** is an enlarged view of an alternate preferred configuration of the electromagnetic coils.

FIG. **5** is an enlarged view showing an alternate coil configuration to form block arabic numerals.

FIG. **6** is an enlarged view showing a stylized numeral **2** using the inventive display panel.

FIG. **7** is a perspective view showing two electromagnetic coils superimposed.

DETAILED DESCRIPTION

Referring to FIG. **1**, a perspective view of a preferred embodiment of the ambient light display panel **10** is shown with sections cut away to show the major component parts. The display panel comprises a transparent window **12** supported a short distance from a ferromagnetic base **14** by a thin rim **16** approximately .01 centimeters thick. The assembly is sealed to form a fluid tight chamber between the window **12** and the base **14.** Internally supported between the window **12** and the base **14** is a permanently magnetized, semipermeable flexible membrane **18** suspended in a fluid **20** having color which contrasts with the color of the membrane **18.** The space between window **12** and membrane **18** is filled with the fluid **20** so that when the flexible membrane is attracted away from the window **12,** the color of the fluid is visible. The internal face of the ferromagnetic member is overlayed with a plurality of serially connected electromagnetic elements **22** in rows and columns. The magnetic elements **22** are capable of locally magnetizing the ferromagnetic base **14** in small discrete areas surrounding each magnetic element **22.** Connectors **24** and **26** are provided to distribute electrical signals to the individual rows and columns of electromagnets.

FIG. **2** is a partial cross section of the display panel in which the size of the individual electromagnets and the spacing between window **12** and ferromagnetic base **14** have been exaggerated for illustrative purposes. The flexible membrane **18** is made from a stainproof material, such as vinyl or neoprene rubber, and is much thinner than the center-to-center distance between adjacent electromagnetic elements **22.** For adequate flexibility the thickness of the membrane should be less than about 1/50 the center-to-center spacing between adjacent electromagnetic elements. The color of the flexible membrane is contrasting to the color of the fluid **20** between the ferromagnetic base and the window.

The individual electromagnetic elements **22** of the rows and columns may be superimposed electrically isolated electromagnet coils **28** and **30,** as shown. The distance "W" represents the physical center-to-center spacing between adjacent rows and columns and defines the size of a resolution element. In the simplest case a column may be formed by a plurality of series connected single turn coils **28** as shown in FIG. **3** and a row formed by a similar plurality of series connected single turn coils **30.** At each intersection of a row and column the serially connected electromagnetic coils **28** and **30** are superimposed forming an electromagnetic element **22,** as shown in FIG. **7.** An alternate configuration of the electromagnetic element is shown in FIG. **4.** In this configuration, crossed parallel conductors **202** and **204** form the columns and rows respectively. The electromagnetic elements **22** are the rectangular section formed at the intersection of electrically connected pairs of adjacent conductors as shown. The electromagnetic elements may be formed on the ferromagnetic base **14** by well-known vacuum deposition or printed circuit techniques. Other well-known methods for forming electromagnetic elements are equally applicable. If the ferromagnetic base is electrically conductive, the elements may be deposited on a thin layer of insulating material separating them from the base.

The material of the ferromagnetic base is selected to have a square hysteresis loop so that it operates similar to the ferromagnetic materials widely used magnetic memories. The electrical current flowing through the rows and columns of coils is controlled so that the magnetic field generated by each individual coil element **28** or **30** is less than that required to cause reversal of the direction of the magnetization of the ferromagnetic base in the immediate vicinity of the coil. It is only when the magnetic fields generated by magnet elements **22** consisting of a column electromagnetic coil element **28** and its associated new electromagnetic coil element **30,** combine that a reversal of magnetization in the ferromagnetic base **14** occurs in the immediate vicinity of the electromagnetic element **22.**

The flexible membrane is made magnetic by impregnating the membrane with particles of permanent magnet material or by any other suitable method of attaching permanent magnet particles to the membrane. After or during attachment, the particles are magnetized in a direction generally perpendicular to the plane of the membrane. However, the polarity of the magnetization of the membrane over each electromagnetic elements **22** is opposite the polarity in the interstitial spaces between the elements. The reason for the polarity pattern of the membrane is more clearly understood by referring to FIG. **2.** Consider the electromagnet elements **22,** wherein the magnet fields of the coils **28** and **30** combine to produce the flux pattern shown by the arrows. The direction of the flux lines immediately above the electromagnetic elements **22** are in a direction going from the base **14** towards the window **12** while in the space between the electromagnetic elements **22,** the flux lines flow in the opposite direction. For high efficiency, it is desirable to have the magneti-

zation of the permanent magnet particles in the membrane aligned with the magnetic field generated by the electromagnet elements and the field imparted to the ferromagnetic base. This alternating magnetic polarity may be accomplished in practice by magnetizing the membrane in a fixture configured like the ferromagnetic base with electromagnetic elements arranged in the identical pattern. The magnetizing fixture is desired to provide the much higher magnetic field needed to magnetically orient the permanent magnetic particles in the flexible membrane. The alternating magnetic polarity of the membrane may also be accomplished in the inventive display panel by having the electromagnet elements **22** themselves generate the required higher magnetic field to magnetize the particles after the panel has been assembled.

For illustrative purposes the direction of current flowing through electromagnetic coils designed **32** and **34** in FIG. **2** is opposite to the direction of current flowing through the remaining electromagnetic coils designated as **28** and **30** respectively. Coils **32** and **34** produce a magnetic field in which the magnetic flux lines flow in the opposite directions as shown. The magnetization pattern of the membrane remains fixed while the direction of the magnetization of the ferromagnetic base is changed to either attract or repel the magnetized membrane.

The operation of the display panel is described with reference to FIG. **2.** Initially the display panel is in the erased condition which is achieved by electrically energizing all the rows and columns of electromagnetic elements so that the magnetic polarity of the ferromagnetic material is aligned with the polarity of the magnetic field in the membrane. This causes the flexible membrane **18** to be attracted to the ferromagnetic base **14** away from the window **12.** Since the membrane is porous, the fluid flows through the membrane and fills the space between the membrane **18** and the window **12** occluding the visibility of the membrane. The strength of the magnetic field generated by the electromagnetic elements **22** is sufficient to establish the polarity over the entire surface of the ferromagnetic base **14,** therefore the membrane will remain attracted to the base even after the erase signal to the electromagnetic coil elements **22** is terminated.

As previously described, applying an electrical signal to either a row or column alone will not produce a magnetic field of adequate strength along the row or column to cause a reversal of the polarity of the ferromagnetic base in the immediate vicinity of the individual electromagnetic elements. It is only when an electrical signal is simultaneously applied to a given row and a given column that a polarity reversal can take place, and this polarity reversal will only take place at the intersection of the given row and the given column, where the magnetic fields of the row electromagnetic coil **30** and the column electromagnetic coil **28** combine.

The magnetic field in the ferromagnetic base is then selectively reversed at predeterminable points by digitally addressing the rows and columns of electromagnetic elements in a sequential manner well known in the art. The electrical polarity of the addressing signals are opposite the polarity of the erase signals and cause the magnetic polarity of the ferromagnetic base to be reversed at the addressed locations. The reversed magnetic polarity repels the flexible membrane, causing it to press against the window as illustrated in FIG. **2** showing the membrane repelled above electromagnetic elements **32** and **34.** As stated previously, the electrical current flowing through elements **32** and **34** are opposite the current flowing through the remaining elements shown. The fluid **20** is displaced from between the membrane **18** and window **12** permitting the contrasting color of the membrane to be visible.

Only a small physical displacement is required to yield a high contrast between the attracted and repelled section of the flexible membrane. Displacements as small as .005 centimeters are capable of providing adequate contrast for visual perception. The opacity of the fluid **20** is selected to maximize the contrast between the attracted and repelled positions of the membrane.

The inventive display panel is also adaptive to the alphanumerical type of display shown in FIGS. **5** and **6.** FIG. **5** illustrates one of many possible arrangements for the well known seven nonoverlapping bar system that adequately depicts the arabic numerals. The illustrated dovetailed configured windings enclose small regions of magnetic fields of alternating polarity having adequate attractive and repelling forces to deflect the membrane as required. The alphanumerical display panel illustrated in FIG. **5** does not require a ferromagnetic material having a square hysteresis loop because the magnetic polarity of the ferromagnetic base is switched by a single electromagnet winding as compared to the digitally addressed panel discussed above.

FIG. **6** shows an electromagnetic element pattern for generating a stylized numeral, in particular, the numeral **2.** It is possible to envision several overlays, i.e., one for each numeral or character desired, stacked together and affixed over the ferromagnetic base. Each overlay carries its own winding, photoetched or vacuum evaporated on an insulating film. The stylized display panel is limited to the number of characters that may be overlayed, and if many characters are desired, the digitally addressed system may be more appropriate.

Although the invention is shown embodied in a preferred configuration with several alternate methods of electromagnet element construction to form the desired character, the invention is not limited to the embodiments illustrated and changes can be made in materials and configuration without departing from the spirit of the invention.

What is claimed is:

1. A character generating ambient light display panel comprising:

an enclosure having at least one transparent window;

an opaque colored fluid filling said enclosure;

a flexible membrane, having a color contrasting to the color of said fluid and porous to said fluid, said membrane supported in said enclosure proximate to and spaced from said transparent window; and

means disposed in said enclosure for selectively deflecting said membrane at a plurality of predeterminable locations indicative of at least one character to contact said transparent window, thereby displacing said fluid from between said transparent window and said membrane at said predetermined locations, permitting the contrasting color of said

membrane and therefore said at least one character to be visible through said window.

2. The display panel of claim 1 wherein said flexible membrane further includes a plurality of isolated permanent magnet particles at least partially polarized normal to the surface of said membrane.

3. The display panel of claim 2 wherein said means for selectively deflecting said membrane is a plurality of electromagnetic elements systematically arranged with respect to the surface of said membrane.

4. The display panel of claim 3 wherein said plurality of electromagnetic elements are equally spaced along orthogonal axes forming rows and columns of electromagnetic elements.

5. The display panel of claim 4 wherein said magnetic elements comprise at least two electrically isolated superimposed electromagnets, one of said two electromagnets being associated with one of said rows, and the second of said two electromagnets being associated with one of said columns.

6. The display panel of claim 5 wherein said means for selectively deflecting said membrane further includes a ferromagnetic member having a planar surface, the planar surface of said ferromagnetic member being located proximate the surface of said flexible membrane opposite said window and said electromagnetic elements being disposed along the planar surface of said ferromagnetic member.

7. The display panel of claim 6 wherein said ferromagnetic member has a square hysteresis loop, and wherein the combined magnetic fields of two of said electromagnets comprising said electromagnetic elements is required to locally change the magnetic polarity of said ferromagnetic member.

8. The display panel of claim 7 wherein said ferromagnetic member is a part of said enclosure.

9. The display panel of claim 3 wherein said electromagnetic elements are arranged in at least seven electrically isolated linear segments forming a block numeral eight.

10. The display panel of claim 9 wherein said means for deflecting said membrane further comprises ferromagnetic member having a substantially planar surface, said planar surface located proximate the surface of said membrane and said electromagnetic elements are disposed along said planar surface.

11. The display panel of claim 3 wherein said electromagnetic elements are serially arranged to form a predetermined character.

12. The display panel of claim 11 wherein a plurality of character forming serially arranged electromagnetic elements are overlayed one on top of the other

13. The display panel of claim 12 wherein said means for selectively deflecting said flexible membrane further includes a ferrite member having a substantially planar surface and said electromagnetic elements are disposed along said planar surface.

14. A magnetically actuated ambient light display panel comprising:

an enclosure having at least one transparent window;

an opaque colored liquid filling said enclosure;

a magnetically responsive flexible membrane having a color contrasting to the color of said fluid and porous to said fluid, said membrane supported in said enclosure a short distance from said transparent window; and

means disposed in said enclosure proximate said membrane for generating localized magnetic fields at a plurality of predeterminable locations indicative of at least one character, said localized magnetic field operative to deflect said membrane to contact said transparent window whereby the contrasting color of said membrane and therefore said at least one character becomes visible through said window.

15. The display panel of claim 14 wherein said magnetically responsive deflectible membrane includes a plurality of isolated permanent magnetic particles systematically polarized normal to the plane of said membrane.

16. The display panel of claim 14 wherein said means for generating localized magnetic fields comprise:

a ferrite member having a square hysteresis loop, and at least one substantially planar surface, said one substantially planar surface located proximate the surface of said membrane;

a plurality of equally spaced rows of equally spaced and serially connected electromagnets disposed along the one substantially planar surface of said ferrite member; and

a plurality of equally spaced columns of equally spaced and serially connected electromagnets disposed along the one plane surface of said ferrite member, one of said serially connected electromagnets of said equally spaced columns being coincident with one of said serially connected electromagnets of said equally spaced rows at each intersections of said rows and columns.

17. The display panel of claim 16 wherein said rows and said columns of serially connected electromagnets are electrically isolated, and wherein the combined magnetic fields generated by a coincident row electromagnet and a coincident column electromagnet is required to change the magnetic polarity of said ferrite member at the intersection of a row and a column.

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