

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
6 April 2006 (06.04.2006)

PCT

(10) International Publication Number
WO 2006/036414 A1

(51) International Patent Classification:
G02B 26/00 (2006.01)

(74) Agent: DELANEY, Karoline, A.; KNOBBE,
MARTENS, OLSON & BEAR, LLP, 2040 Main Street,
Fourteenth Floor, Irvine, CA 92614 (US).

(21) International Application Number:
PCT/US2005/030418

(81) Designated States (unless otherwise indicated, for every
kind of national protection available): AE, AG, AL, AM,
AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN,
CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI,
GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE,
KG, KM, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA,
MD, MG, MK, MN, MW, MX, MZ, NA, NG, NI, NO, NZ,
OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL,
SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC,
VN, YU, ZA, ZM, ZW.

(22) International Filing Date: 25 August 2005 (25.08.2005)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/613,298 27 September 2004 (27.09.2004) US
11/194,046 29 July 2005 (29.07.2005) US

(84) Designated States (unless otherwise indicated, for every
kind of regional protection available): ARIPO (BW, GH,
GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM,
ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM),
European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI,
FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT,
RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA,
GN, GQ, GW, ML, MR, NE, SN, TD, TG).

(71) Applicant (for all designated States except US): IDC,
LLC [US/US]; 2415 Third Street, San Francisco, Califor-
nia 94107 (US).

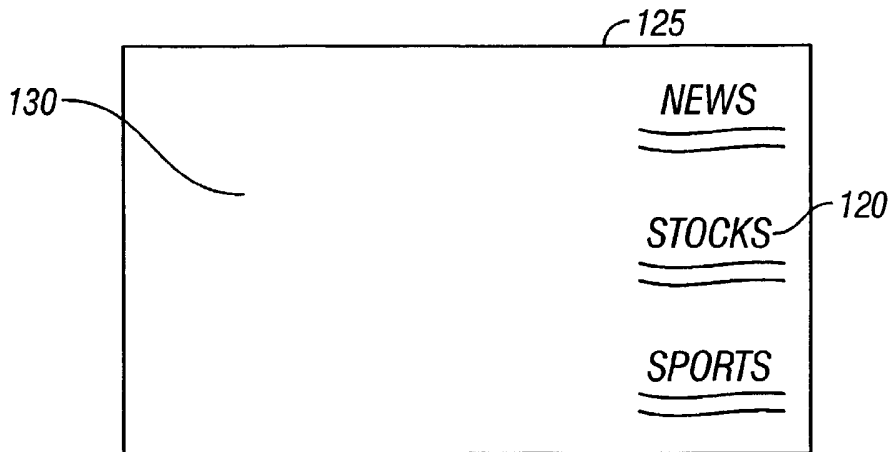
(72) Inventors; and

(75) Inventors/Applicants (for US only): GALLY, Brian, J.
[US/US]; 346 Bella Vista Avenue, Los Gatos, California
95032 (US). CUMMINGS, William, J. [US/US]; 149
Ashton Avenue, Millbrae, California 94030 (US).

Published:
— with international search report

[Continued on next page]

(54) Title: SYSTEM AND METHOD OF IMPLEMENTATION OF INTERFEROMETRIC MODULATORS FOR DISPLAY MIRRORS



(57) Abstract: A specular interferometric modulator array is configured to be at least partially selectively reflective. As such, the array forms a mirror surface having the capability of displaying information to the user while simultaneously being used as a specular mirror. The displayed information may be based on information from an external source, may be programmable, and may be based on user input.

WO 2006/036414 A1



For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

SYSTEM AND METHOD OF IMPLEMENTATION OF INTERFEROMETRIC MODULATORS FOR DISPLAY MIRRORS

5 Cross reference To Related Applications

This application claims priority to U.S. Provisional Application No. 60/613,298, titled "System and Method for Implementation of Interferometric Modulator Displays," filed September 27, 2004, which is incorporated by reference, in its entirety.

10 Background

Field of the Invention

The field of the invention relates to microelectromechanical systems (MEMS).

Description of the Related Technology

15 Microelectromechanical systems (MEMS) include micro mechanical elements, actuators, and electronics. Micromechanical elements may be created using deposition, etching, and or other micromachining processes that etch away parts of substrates and/or deposited material layers or that add layers to form electrical and electromechanical devices. One type of MEMS device is called an interferometric modulator. As used
20 herein, the term interferometric modulator or interferometric light modulator refers to a device that selectively absorbs and/or reflects light using the principles of optical interference. In certain embodiments, an interferometric modulator may comprise a pair of conductive plates, one or both of which may be transparent and/or reflective in whole or part and capable of relative motion upon application of an appropriate electrical signal. In
25 a particular embodiment, one plate may comprise a stationary layer deposited on a substrate and the other plate may comprise a metallic membrane separated from the stationary layer by an air gap. As described herein in more detail, the position of one plate in relation to another can change the optical interference of light on the interferometric modulator. Such devices have a wide range of applications, and it would be beneficial in the art to utilize
30 and/or modify the characteristics of these types of devices so that their features can be exploited in improving existing products and creating new products that have not yet been developed.

Summary of Certain Embodiments

The system, method, and devices of the invention each have several aspects, no single one of which is solely responsible for its desirable attributes. Without limiting the scope of this invention, its more prominent features will now be discussed briefly. After
5 considering this discussion, and particularly after reading the section entitled "Detailed Description of Certain Embodiments" one will understand how the features of this invention provide advantages over other display devices.

One embodiment includes a device including a substrate, and an array of reflective elements arranged on the substrate to form at least a portion of a mirror surface that
10 specularly and interferometrically reflects light in at least one wavelength band. One or more of the elements are configured to be selectably reflective.

Another embodiment includes a device including means for conducting light, and means for specularly and interferometrically reflecting light in at least one wavelength band. The specularly and interferometrically light reflecting means is arranged on the
15 conducting means and at least a portion of the specularly interferometrically light reflecting means is configured to be selectively reflective.

Another embodiment includes a vehicle including a steering mechanism, and a mirror configured to be positioned such that light coming from behind the vehicle is reflected to a location for an operator to see when the operator is positioned to use the
20 steering mechanism. The mirror includes a substrate, and an array of reflective elements arranged on the substrate to form a mirror surface that specularly and interferometrically reflects light in at least one wavelength band.

Another embodiment includes a vehicle including means for steering, and means for reflecting light from behind the vehicle to a location for an operator to see when the
25 operator is positioned to use the steering means. The reflecting means includes means for conducting light, and means for specularly and interferometrically reflecting light in at least one wavelength band. The specularly interferometrically light reflecting means is arranged on the conducting means and at least a portion of the specularly interferometrically light reflecting means is configured to be selectively reflective. The specularly and
30 interferometrically light reflecting means is arranged on the conducting means and at least a portion of the specularly interferometrically light reflecting means is configured to be selectively reflective.

Another embodiment includes a device including a mirror including a substrate and an array of reflective elements arranged on the substrate to form a mirror surface that specularly and interferometrically reflects light in at least one wavelength band, and a mount configured to attach the mirror to a vehicle, a wall, an article of furniture, an ornamental object, an article of clothing, or a person.

Another embodiment includes a device including means for reflecting light including means for conducting light, and means for specularly and interferometrically reflecting light in at least one wavelength band, and means for attaching the reflecting means to a vehicle, a wall, an article of furniture, an ornamental object, an article of clothing, or a person.

Another embodiment includes a method of using a display device including establishing a communication link between the device and an information source. The device includes a mirror including elements configured to selectably, specularly and interferometrically reflect light, and a mount configured to attach the mirror to a vehicle, a wall, an article of furniture, an ornamental object, an article of clothing, or a person. The method also includes receiving information from the source, and displaying the information on the array.

Another embodiment includes a method of manufacturing a device. The method includes forming a substrate, and forming an array of reflective elements arranged on the substrate so as to produce a mirror surface that specularly and interferometrically reflects light in at least one wavelength band. One or more of the elements are configured to be selectably reflective.

Brief Description of the Drawings

FIG. 1 is an isometric view depicting a portion of one embodiment of an interferometric modulator display in which a movable reflective layer of a first interferometric modulator is in a relaxed position and a movable reflective layer of a second interferometric modulator is in an actuated position.

FIG. 2 is a system block diagram illustrating one embodiment of an electronic device incorporating a 3x3 interferometric modulator display.

FIG. 3 is a diagram of movable mirror position versus applied voltage for one exemplary embodiment of an interferometric modulator of FIG. 1.

FIG. 4 is an illustration of a set of row and column voltages that may be used to drive an interferometric modulator display.

FIGS. 5A and 5B illustrate one exemplary timing diagram for row and column signals that may be used to write a frame of display data to the 3x3 interferometric modulator display of FIG. 2.

FIGS. 6A and 6B are system block diagrams illustrating an embodiment of a visual display device comprising a plurality of interferometric modulators.

FIG. 7A is a cross section of the device of FIG. 1.

FIG. 7B is a cross section of an alternative embodiment of an interferometric modulator.

FIG. 7C is a cross section of another alternative embodiment of an interferometric modulator.

FIG. 7D is a cross section of yet another alternative embodiment of an interferometric modulator.

FIG. 7E is a cross section of an additional alternative embodiment of an interferometric modulator.

Figure 8 is a front view of an interferometric device configured as a specular reflective display that can provide information to a viewer.

Figure 9 is a front view of a rear-view mirror embodiment.

20

Detailed Description of Certain Embodiments

The following detailed description is directed to certain specific embodiments of the invention. However, the invention can be embodied in a multitude of different ways. In this description, reference is made to the drawings wherein like parts are designated with like numerals throughout. As will be apparent from the following description, the embodiments may be implemented in any device that is configured to display an image, whether in motion (e.g., video) or stationary (e.g., still image), and whether textual or pictorial. More particularly, it is contemplated that the embodiments may be implemented in or associated with a variety of electronic devices such as, but not limited to, mobile telephones, wireless devices, personal data assistants (PDAs), hand-held or portable computers, GPS receivers/navigators, cameras, MP3 players, camcorders, game consoles, wrist watches, clocks, calculators, television monitors, flat panel displays, computer

monitors, auto displays (e.g., odometer display, etc.), cockpit controls and/or displays, display of camera views (e.g., display of a rear view camera in a vehicle), electronic photographs, electronic billboards or signs, projectors, architectural structures, packaging, and aesthetic structures (e.g., display of images on a piece of jewelry). MEMS devices of
5 similar structure to those described herein can also be used in non-display applications such as in electronic switching devices.

One interferometric modulator display embodiment comprises an array of MEMS display elements, at least a portion of which are substantially specular, and at least a portion of which are selectably reflective. The portion of the display which is specular may
10 be used as a mirror, and the selectably reflective portion may be used to display information. This allows for information to be displayed on the device while it is simultaneously being used as a mirror, for example, while driving, combing one's hair or applying make-up.

One interferometric modulator display embodiment comprising an interferometric
15 MEMS display element is illustrated in Figure 1. In these devices, the pixels are in either a bright or dark state. In the bright ("on" or "open") state, the display element reflects a large portion of incident visible light to a user. When in the dark ("off" or "closed") state, the display element reflects little incident visible light to the user. Depending on the embodiment, the light reflectance properties of the "on" and "off" states may be reversed.
20 MEMS pixels can be configured to reflect predominantly at selected colors, allowing for a color display in addition to black and white.

Figure 1 is an isometric view depicting two adjacent pixels in a series of pixels of a visual display, wherein each pixel comprises a MEMS interferometric modulator. In some embodiments, an interferometric modulator display comprises a row/column array of these
25 interferometric modulators. Each interferometric modulator includes a pair of reflective layers positioned at a variable and controllable distance from each other to form a resonant optical cavity with at least one variable dimension. In one embodiment, one of the reflective layers may be moved between two positions. In the first position, referred to herein as the relaxed position, the movable reflective layer is positioned at a relatively large
30 distance from a fixed partially reflective layer. In the second position, referred to herein as the actuated position, the movable reflective layer is positioned more closely adjacent to the partially reflective layer. Incident light that reflects from the two layers interferes

constructively or destructively depending on the position of the movable reflective layer, producing either an overall reflective or non-reflective state for each pixel.

The depicted portion of the pixel array in Figure 1 includes two adjacent interferometric modulators 12a and 12b. In the interferometric modulator 12a on the left, a
5 movable reflective layer 14a is illustrated in a relaxed position at a predetermined distance from an optical stack 16a, which includes a partially reflective layer. In the interferometric modulator 12b on the right, the movable reflective layer 14b is illustrated in an actuated position adjacent to the optical stack 16b.

The optical stacks 16a and 16b (collectively referred to as optical stack 16), as
10 referenced herein, typically comprise of several fused layers, which can include an electrode layer, such as indium tin oxide (ITO), a partially reflective layer, such as chromium, and a transparent dielectric. The optical stack 16 is thus electrically conductive, partially transparent and partially reflective, and may be fabricated, for example, by
15 depositing one or more of the above layers onto a transparent substrate 20. In some embodiments, the layers are patterned into parallel strips, and may form row electrodes in a display device as described further below. The movable reflective layers 14a, 14b may be
20 formed as a series of parallel strips of a deposited metal layer or layers (orthogonal to the row electrodes of 16a, 16b) deposited on top of posts 18 and an intervening sacrificial material deposited between the posts 18. When the sacrificial material is etched away, the
movable reflective layers 14a, 14b are separated from the optical stacks 16a, 16b by a
defined gap 19. A highly conductive and reflective material such as aluminum may be
used for the reflective layers 14, and these strips may form column electrodes in a display
device.

With no applied voltage, the cavity 19 remains between the movable reflective layer
25 14a and optical stack 16a, with the movable reflective layer 14a in a mechanically relaxed state, as illustrated by the pixel 12a in Figure 1. However, when a potential difference is applied to a selected row and column, the capacitor formed at the intersection of the row and column electrodes at the corresponding pixel becomes charged, and electrostatic forces
pull the electrodes together. If the voltage is high enough, the movable reflective layer 14
30 is deformed and is forced against the optical stack 16. A dielectric layer (not illustrated in this Figure) within the optical stack 16 may prevent shorting and control the separation distance between layers 14 and 16, as illustrated by pixel 12b on the right in Figure 1. The behavior is the same regardless of the polarity of the applied potential difference. In this

way, row/column actuation that can control the reflective vs. non-reflective pixel states is analogous in many ways to that used in conventional LCD and other display technologies.

Figures 2 through 5 illustrate one exemplary process and system for using an array of interferometric modulators in a display application.

5 Figure 2 is a system block diagram illustrating one embodiment of an electronic device that may incorporate aspects of the invention. In the exemplary embodiment, the electronic device includes a processor 21 which may be any general purpose single- or multi-chip microprocessor such as an ARM, Pentium[®], Pentium II[®], Pentium III[®], Pentium IV[®], Pentium[®] Pro, an 8051, a MIPS[®], a Power PC[®], an ALPHA[®], or any special purpose
10 microprocessor such as a digital signal processor, microcontroller, or a programmable gate array. As is conventional in the art, the processor 21 may be configured to execute one or more software modules. In addition to executing an operating system, the processor may be configured to execute one or more software applications, including a web browser, a telephone application, an email program, or any other software application.

15 In one embodiment, the processor 21 is also configured to communicate with an array driver 22. In one embodiment, the array driver 22 includes a row driver circuit 24 and a column driver circuit 26 that provide signals to a panel or display array (display) 30. The cross section of the array illustrated in Figure 1 is shown by the lines 1-1 in Figure 2. For MEMS interferometric modulators, the row/column actuation protocol may take
20 advantage of a hysteresis property of these devices illustrated in Figure 3. It may require, for example, a 10 volt potential difference to cause a movable layer to deform from the relaxed state to the actuated state. However, when the voltage is reduced from that value, the movable layer maintains its state as the voltage drops back below 10 volts. In the exemplary embodiment of Figure 3, the movable layer does not relax completely until the
25 voltage drops below 2 volts. There is thus a range of voltage, about 3 to 7 V in the example illustrated in Figure 3, where there exists a window of applied voltage within which the device is stable in either the relaxed or actuated state. This is referred to herein as the "hysteresis window" or "stability window." For a display array having the hysteresis characteristics of Figure 3, the row/column actuation protocol can be designed such that
30 during row strobing, pixels in the strobed row that are to be actuated are exposed to a voltage difference of about 10 volts, and pixels that are to be relaxed are exposed to a voltage difference of close to zero volts. After the strobe, the pixels are exposed to a steady state voltage difference of about 5 volts such that they remain in whatever state the row

strobe put them in. After being written, each pixel sees a potential difference within the “stability window” of 3-7 volts in this example. This feature makes the pixel design illustrated in Figure 1 stable under the same applied voltage conditions in either an actuated or relaxed pre-existing state. Since each pixel of the interferometric modulator, whether in
5 the actuated or relaxed state, is essentially a capacitor formed by the fixed and moving reflective layers, this stable state can be held at a voltage within the hysteresis window with almost no power dissipation. Essentially no current flows into the pixel if the applied potential is fixed.

In typical applications, a display frame may be created by asserting the set of
10 column electrodes in accordance with the desired set of actuated pixels in the first row. A row pulse is then applied to the row 1 electrode, actuating the pixels corresponding to the asserted column lines. The asserted set of column electrodes is then changed to correspond to the desired set of actuated pixels in the second row. A pulse is then applied to the row 2
15 electrode, actuating the appropriate pixels in row 2 in accordance with the asserted column electrodes. The row 1 pixels are unaffected by the row 2 pulse, and remain in the state they were set to during the row 1 pulse. This may be repeated for the entire series of rows in a sequential fashion to produce the frame. Generally, the frames are refreshed and/or updated with new display data by continually repeating this process at some desired number of frames per second. A wide variety of protocols for driving row and column
20 electrodes of pixel arrays to produce display frames are also well known and may be used in conjunction with the present invention.

Figures 4 and 5 illustrate one possible actuation protocol for creating a display frame on the 3x3 array of Figure 2. Figure 4 illustrates a possible set of column and row voltage levels that may be used for pixels exhibiting the hysteresis curves of Figure 3. In
25 the Figure 4 embodiment, actuating a pixel involves setting the appropriate column to $-V_{\text{bias}}$, and the appropriate row to $+\Delta V$, which may correspond to -5 volts and +5 volts respectively. Relaxing the pixel is accomplished by setting the appropriate column to $+V_{\text{bias}}$, and the appropriate row to the same $+\Delta V$, producing a zero volt potential difference across the pixel. In those rows where the row voltage is held at zero volts, the pixels are
30 stable in whatever state they were originally in, regardless of whether the column is at $+V_{\text{bias}}$, or $-V_{\text{bias}}$. As is also illustrated in Figure 4, it will be appreciated that voltages of opposite polarity than those described above can be used, e.g., actuating a pixel can involve setting the appropriate column to $+V_{\text{bias}}$, and the appropriate row to $-\Delta V$. In this

embodiment, releasing the pixel is accomplished by setting the appropriate column to $-V_{bias}$, and the appropriate row to the same $-\Delta V$, producing a zero volt potential difference across the pixel.

Figure 5B is a timing diagram showing a series of row and column signals applied to the 3x3 array of Figure 2 which will result in the display arrangement illustrated in Figure 5A, where actuated pixels are non-reflective. Prior to writing the frame illustrated in Figure 5A, the pixels can be in any state, and in this example, all the rows are at 0 volts, and all the columns are at +5 volts. With these applied voltages, all pixels are stable in their existing actuated or relaxed states.

In the Figure 5A frame, pixels (1,1), (1,2), (2,2), (3,2) and (3,3) are actuated. To accomplish this, during a "line time" for row 1, columns 1 and 2 are set to -5 volts, and column 3 is set to +5 volts. This does not change the state of any pixels, because all the pixels remain in the 3-7 volt stability window. Row 1 is then strobed with a pulse that goes from 0, up to 5 volts, and back to zero. This actuates the (1,1) and (1,2) pixels and relaxes the (1,3) pixel. No other pixels in the array are affected. To set row 2 as desired, column 2 is set to -5 volts, and columns 1 and 3 are set to +5 volts. The same strobe applied to row 2 will then actuate pixel (2,2) and relax pixels (2,1) and (2,3). Again, no other pixels of the array are affected. Row 3 is similarly set by setting columns 2 and 3 to -5 volts, and column 1 to +5 volts. The row 3 strobe sets the row 3 pixels as shown in Figure 5A. After writing the frame, the row potentials are zero, and the column potentials can remain at either +5 or -5 volts, and the display is then stable in the arrangement of Figure 5A. It will be appreciated that the same procedure can be employed for arrays of dozens or hundreds of rows and columns. It will also be appreciated that the timing, sequence, and levels of voltages used to perform row and column actuation can be varied widely within the general principles outlined above, and the above example is exemplary only, and any actuation voltage method can be used with the systems and methods described herein.

Figures 6A and 6B are system block diagrams illustrating an embodiment of a display device 40. The display device 40 can be, for example, a cellular or mobile telephone. However, the same components of display device 40 or slight variations thereof are also illustrative of various types of display devices such as televisions and portable media players.

The display device 40 includes a housing 41, a display 30, an antenna 43, a speaker 45, an input device 48, and a microphone 46. The housing 41 is generally formed from any

of a variety of manufacturing processes as are well known to those of skill in the art, including injection molding, and vacuum forming. In addition, the housing 41 may be made from any of a variety of materials, including but not limited to plastic, metal, glass, rubber, and ceramic, or a combination thereof. In one embodiment the housing 41 includes
5 removable portions (not shown) that may be interchanged with other removable portions of different color, or containing different logos, pictures, or symbols.

The display 30 of exemplary display device 40 may be any of a variety of displays, including a bi-stable display, as described herein. In other embodiments, the display 30 includes a flat-panel display, such as plasma, EL, OLED, STN LCD, or TFT LCD as
10 described above, or a non-flat-panel display, such as a CRT or other tube device, as is well known to those of skill in the art. However, for purposes of describing the present embodiment, the display 30 includes an interferometric modulator display, as described herein.

The components of one embodiment of exemplary display device 40 are
15 schematically illustrated in Figure 6B. The illustrated exemplary display device 40 includes a housing 41 and can include additional components at least partially enclosed therein. For example, in one embodiment, the exemplary display device 40 includes a network interface 27 that includes an antenna 43 which is coupled to a transceiver 47. The transceiver 47 is connected to the processor 21, which is connected to conditioning
20 hardware 52. The conditioning hardware 52 may be configured to condition a signal (e.g. filter a signal). The conditioning hardware 52 is connected to a speaker 45 and a microphone 46. The processor 21 is also connected to an input device 48 and a driver controller 29. The driver controller 29 is coupled to a frame buffer 28 and to the array driver 22, which in turn is coupled to a display array 30. A power supply 50 provides
25 power to all components as required by the particular exemplary display device 40 design.

The network interface 27 includes the antenna 43 and the transceiver 47 so that the exemplary display device 40 can communicate with one ore more devices over a network. In one embodiment the network interface 27 may also have some processing capabilities to relieve requirements of the processor 21. The antenna 43 is any antenna known to those of
30 skill in the art for transmitting and receiving signals. In one embodiment, the antenna transmits and receives RF signals according to the IEEE 802.11 standard, including IEEE 802.11(a), (b), or (g). In another embodiment, the antenna transmits and receives RF signals according to the BLUETOOTH standard. In the case of a cellular telephone, the

antenna is designed to receive CDMA, GSM, AMPS or other known signals that are used to communicate within a wireless cell phone network. The transceiver 47 pre-processes the signals received from the antenna 43 so that they may be received by and further manipulated by the processor 21. The transceiver 47 also processes signals received from the processor 21 so that they may be transmitted from the exemplary display device 40 via the antenna 43.

In an alternative embodiment, the transceiver 47 can be replaced by a receiver. In yet another alternative embodiment, network interface 27 can be replaced by an image source, which can store or generate image data to be sent to the processor 21. For example, the image source can be a digital video disc (DVD) or a hard-disc drive that contains image data, or a software module that generates image data.

Processor 21 generally controls the overall operation of the exemplary display device 40. The processor 21 receives data, such as compressed image data from the network interface 27 or an image source, and processes the data into raw image data or into a format that is readily processed into raw image data. The processor 21 then sends the processed data to the driver controller 29 or to frame buffer 28 for storage. Raw data typically refers to the information that identifies the image characteristics at each location within an image. For example, such image characteristics can include color, saturation, and gray-scale level.

In one embodiment, the processor 21 includes a microcontroller, CPU, or logic unit to control operation of the exemplary display device 40. Conditioning hardware 52 generally includes amplifiers and filters for transmitting signals to the speaker 45, and for receiving signals from the microphone 46. Conditioning hardware 52 may be discrete components within the exemplary display device 40, or may be incorporated within the processor 21 or other components.

The driver controller 29 takes the raw image data generated by the processor 21 either directly from the processor 21 or from the frame buffer 28 and reformats the raw image data appropriately for high speed transmission to the array driver 22. Specifically, the driver controller 29 reformats the raw image data into a data flow having a raster-like format, such that it has a time order suitable for scanning across the display array 30. Then the driver controller 29 sends the formatted information to the array driver 22. Although a driver controller 29, such as a LCD controller, is often associated with the system processor 21 as a stand-alone Integrated Circuit (IC), such controllers may be implemented in many

ways. They may be embedded in the processor 21 as hardware, embedded in the processor 21 as software, or fully integrated in hardware with the array driver 22.

Typically, the array driver 22 receives the formatted information from the driver controller 29 and reformats the video data into a parallel set of waveforms that are applied
5 many times per second to the hundreds and sometimes thousands of leads coming from the display's x-y matrix of pixels.

In one embodiment, the driver controller 29, array driver 22, and display array 30 are appropriate for any of the types of displays described herein. For example, in one embodiment, driver controller 29 is a conventional display controller or a bi-stable display
10 controller (e.g., an interferometric modulator controller). In another embodiment, array driver 22 is a conventional driver or a bi-stable display driver (e.g., an interferometric modulator display). In one embodiment, a driver controller 29 is integrated with the array driver 22. Such an embodiment is common in highly integrated systems such as cellular phones, watches, and other small area displays. In yet another embodiment, display array
15 30 is a typical display array or a bi-stable display array (e.g., a display including an array of interferometric modulators).

The input device 48 allows a user to control the operation of the exemplary display device 40. In one embodiment, input device 48 includes a keypad, such as a QWERTY keyboard or a telephone keypad, a button, a switch, a touch-sensitive screen, a pressure- or
20 heat-sensitive membrane. In one embodiment, the microphone 46 is an input device for the exemplary display device 40. When the microphone 46 is used to input data to the device, voice commands may be provided by a user for controlling operations of the exemplary display device 40.

Power supply 50 can include a variety of energy storage devices as are well known
25 in the art. For example, in one embodiment, power supply 50 is a rechargeable battery, such as a nickel-cadmium battery or a lithium ion battery. In another embodiment, power supply 50 is a renewable energy source, a capacitor, or a solar cell, including a plastic solar cell, and solar-cell paint. In another embodiment, power supply 50 is configured to receive power from a wall outlet.

30 In some implementations control programmability resides, as described above, in a driver controller which can be located in several places in the electronic display system. In some cases control programmability resides in the array driver 22. Those of skill in the art

will recognize that the above-described optimization may be implemented in any number of hardware and/or software components and in various configurations.

The details of the structure of interferometric modulators that operate in accordance with the principles set forth above may vary widely. For example, Figures 7A-7E illustrate five different embodiments of the movable reflective layer 14 and its supporting structures. Figure 7A is a cross section of the embodiment of Figure 1, where a strip of metal material 14 is deposited on orthogonally extending supports 18. In Figure 7B, the moveable reflective layer 14 is attached to supports at the corners only, on tethers 32. In Figure 7C, the moveable reflective layer 14 is suspended from a deformable layer 34, which may comprise a flexible metal. The deformable layer 34 connects, directly or indirectly, to the substrate 20 around the perimeter of the deformable layer 34. These connections are herein referred to as support posts. The embodiment illustrated in Figure 7D has support post plugs 42 upon which the deformable layer 34 rests. The movable reflective layer 14 remains suspended over the cavity, as in Figures 7A-7C, but the deformable layer 34 does not form the support posts by filling holes between the deformable layer 34 and the optical stack 16. Rather, the support posts are formed of a planarization material, which is used to form support post plugs 42. The embodiment illustrated in Figure 7E is based on the embodiment shown in Figure 7D, but may also be adapted to work with any of the embodiments illustrated in Figures 7A-7C as well as additional embodiments not shown. In the embodiment shown in Figure 7E, an extra layer of metal or other conductive material has been used to form a bus structure 44. This allows signal routing along the back of the interferometric modulators, eliminating a number of electrodes that may otherwise have had to be formed on the substrate 20.

In embodiments such as those shown in Figure 7, the interferometric modulators function as direct-view devices, in which images are viewed from the front side of the transparent substrate 20, the side opposite to that upon which the modulator is arranged. In these embodiments, the reflective layer 14 optically shields some portions of the interferometric modulator on the side of the reflective layer opposite the substrate 20, including the deformable layer 34 and the bus structure 44. This allows the shielded areas to be configured and operated upon without negatively affecting the image quality. This separable modulator architecture allows the structural design and materials used for the electromechanical aspects and the optical aspects of the modulator to be selected and to function independently of each other. Moreover, the embodiments shown in Figures 7C-7E

have additional benefits deriving from the decoupling of the optical properties of the reflective layer 14 from its mechanical properties, which are carried out by the deformable layer 34. This allows the structural design and materials used for the reflective layer 14 to be optimized with respect to the optical properties, and the structural design and materials used for the deformable layer 34 to be optimized with respect to desired mechanical properties.

Figure 8 shows an embodiment of a display device 125 comprising an array of interferometric modulators configured to perform substantially as a specular mirror in addition to displaying information. At least a portion of the array may be configured to be specular, e.g., mirror-like, instead of diffuse as is the case for many embodiments of interferometric modulators. Generally an interferometric modulator is a specular device. In one modulator embodiment the interferometric modulator appears diffuse only if a diffusion material is used to modify the incident and reflected light. When a diffusion material is not used the array appears substantially specular. The reflective layer within the interferometric modulator is substantially specular and the interferometric properties of the cavity and the optical stack may be configured so that the entire interferometric modulator is also specular. At least a portion of the array may be configured to be white (e.g. reflective of light across the visible spectrum), instead of colored (e.g. reflective of light within a narrow or wide band of visible wavelengths or reflective of light within multiple narrow or wide bands of visible wavelengths, but not across the entire visible spectrum), as is the case for many embodiments of interferometric modulators. In addition to being substantially specular, the reflective layer within the interferometric modulator is also substantially white, and the interferometric properties of the cavity and the optical stack may be configured so that the entire interferometric modulator is also white. Techniques for accomplishing whiteness and specularity include, but are not limited to those briefly discussed herein. In general, if the optical stack is sufficiently thin, it will not significantly alter the whiteness of the device. Specifics will depend at least on materials used. Some embodiments of interferometric modulators with thin optical stacks have the electronic control and the mechanical structure on opposite side of the deflectable mirror than the optical stack. This allows the thickness of the optical stack to be controlled independent of constraints incurred when the electrode is embedded within the optical stack. Another option to whiten the device is to create the interferometric cavities with gaps large enough to allow multiple frequencies of light to constructively interfere.

In some embodiments at least a portion of the display device 125 may be configured to display information. The interferometric modulators in such a portion can be configured to selectably change between at least two optical states according to an input, as described above. The optical characteristics of the at least two states differ enough so that a contrast
5 between the states can be perceived by a viewer. When the optical characteristics of individual interferometric modulators are properly selected, the information can be displayed. The optical characteristics which may be selectably altered include reflectivity, and color. For example, to display information certain interferometric modulators may be selected to have higher reflectivity than other interferometric modulators, or certain
10 interferometric modulators may be selected to have blue color and others green color, where the difference between the higher and lower reflectivity, and the blue and green color is at least enough to be perceived by a viewer. Combinations of optical characteristics may be used. For example, combinations of colors and reflectivity may be altered to create perceptible contrast. Other contrasting optical characteristic states are
15 possible and are not disfavored. Thus, the ability to selectably alter the interferometric modulators contrasting optical states allows for text or an image to be displayed.

In some embodiments at least a portion of the display portion 120 may be configured to change between first and second optical states, while a second portion may be configured to change between third and fourth optical states. In some embodiments
20 these portions are continuous and large enough to be seen by a viewer as being distinct areas where the each area is perceived as having a distinct optical characteristic. For example, a region may have the shape of a sun, and the interferometric modulators in the region may have a color characteristic of reflecting yellow light. Some of the interferometric modulators in the region may also selectably change between reflecting
25 yellow light and reflecting white light. The selectably changeable interferometric modulators may be used to, for example, display a current temperature.

In some embodiments the interferometric modulators may operate over a range of optical states, such as a continuous range of colors or grey-scale or reflectivity. The display portion 120 may also be a color display wherein each pixel can selectively display a
30 range of colors. The display portion 120 may also display in a grey scale mode where the interferometric modulators are configured to be white, and how much reflectivity in each pixel varies according to the information to be displayed. The display device 125 may have various display portions 120 which may each have different operating configurations as

described above. In some embodiments the operating configuration of the display portions may change.

As discussed above, in some embodiments the information is displayed by the contrast of two optical states both being reflective. In such embodiments it should be noted
5 that the display portion 120 in addition to displaying information is specularly reflective and will still function as a mirror. For example if a portion of the display portion is displaying information using interferometric modulators configured to change between orange and green reflective states that portion of the display device 125 will still show the image of objects seen in the mirror. The objects, however, will appear as if they are orange
10 and/or green.

In some embodiments the display portion 120 may have interferometric modulators which are formed in a specific shape corresponding to the information or a portion of the information to be displayed. For example the display portion 120 may have an interferometric modulator in the shape of a vehicle with a door open. Such an
15 interferometric modulator may be used on a rear-view mirror in a vehicle. A door not being completely closed may be indicated by actuating the interferometric modulator such as to have a contrasting appearance to the immediately surrounding area of the mirror. Some interferometric modulators may be in the shape of numeral segments, so as to be configured to, in combination, display various numerals.

20 In some embodiments a diffusion material is applied to at least a portion of the array to render that portion of the display more diffuse than other portions. For example, one or more portions of the device may be dedicated as display-only portions, where better display appearance may be attained with a diffusion material.

Alternatively, one or more portions may be dedicated as mirror-only portions. In
25 mirror-only portions the interferometric modulators may be configured to be in a single non-selectable state of having white color as perceived by a viewer and/or having high reflectivity (i.e. being reflective enough to effectively useable as a mirror). The regions between interferometric modulators may also be configured to have high reflectivity. In some embodiments the mirror-only portions may comprise reflective layers only and may
30 not comprise interferometric modulators. In some embodiments the mirror-only portion may have optical stack properties customized for high reflectivity.

Referring to Figure 8, a mirror surface 130 of a display device 125 may be used for any purpose for which mirrors are used, such as shaving or applying makeup.

Simultaneously, a display portion 120 of the display device 125 may be used to provide information to a viewer. The display portion 120 may be of any shape, may be located at any position of the display device 125, and may be moved from position to position. Such manipulation of the display portion 120 may be controlled, for example dynamically by user input, or through programming, or another external device. Although shown in Figure 8 as being rectangular the display device 125 may be of arbitrary shape.

The information may include any type of desired information including but not limited to news, stock quotations, sports scores etc. For example, while combing ones hair, information about the weather forecast may be displayed to help in deciding what clothing to wear for the day. The information may be communicated to the display device 125 from an external source, such as, but not limited to a telecommunications or display device over a wired or wireless connection. For example, the display device 125 may comprise or have a wired or wireless connection to a device with a television tuner, and the display may show the morning news or a sporting event. The display device 125 may also comprise or have an electrical connection to a PC, or a device for displaying video images, such as a video player, or a DVD player. In some embodiments the PC may be connected to an internet site showing live images of, for example, traffic conditions or a place of interest in natural setting such as a waterfall.

One or more aspects of the information may be programmable. The display device 125 may, for example, sequentially display current outside temperature, expected high temperature and expected low temperature for the day. The user may program the display device 125 to display one or more types of information from a set of optional information types, such as sports scores, news headlines, or driving conditions. The information may be primarily aesthetic, such as an ornamental design or a picture of ones family. The information may be user defined, such as a "to do" list, or a reminder of a friends birthday. The display device 125 may be configured to have various modes of operation from which the user chooses. For example, the user may select a mode to display aesthetic images or to display traffic information or to display combinations of information types.

The user programmability may be managed in various ways. There may be a wireless or wired connection to a PC with software to program the display device 125. The display device 125 may comprise local processing capabilities with software to enable the user to interface graphically with the associated programming software. There may be an interface for the user to connect a keyboard and/or a mouse to the display device 125 at

least for programming. In some embodiments the display device 125 may comprise touch screen technology, which may at least be used for programming. In some embodiments the display device 125 may comprise buttons and/or knobs for programming and/or for controlling display characteristics, such as location or brightness.

5 In some embodiments, the display device 125 is configured as a rear-view or side mirror on a vehicle. Such an embodiment is shown as rear-view mirror 150 in Figure 9. Using interferometric modulator technology, the mirror can display information to the driver. The information may include environmental information, such as temperature, wind speed and wind direction. Location data, such as position, speed, and direction of travel
10 may also be shown. Route information may be given, such as a map, turn by turn driving directions, and direction of and distance to the next turn. Vehicle status data, such as speed, temperature, engine RPM, the distance to objects behind the car, an image of what is behind the car may also be displayed. Radio information, such as volume, channel, CD title, song title, and program title may also be displayed. Various warnings, such as low
15 fuel, high speed, high engine temperature, passenger without a seatbelt, low tire pressure, and external object proximity. Various sensors throughout the vehicle may be configured to communicate to the display device 125 to provide the information to be displayed. The information may also be communicated from external sources using wireless connections.

The mirror may also be configured with a mount to attach the mirror to a vehicle, a
20 wall, an article of furniture, an ornamental object, an article of clothing, or a person.

While the above detailed description has shown, described, and pointed out novel features as applied to various embodiments, it will be understood that various omissions, substitutions, and changes in the form and details of the device or process illustrated may be made by those skilled in the art without departing from the spirit of the invention. As
25 will be recognized, the present invention may be embodied within a form that does not provide all of the features and benefits set forth herein, as some features may be used or practiced separately from others.

WHAT IS CLAIMED IS:

1. A device, comprising:
a substrate; and
5 an array of reflective elements arranged on the substrate to form at least a portion of a mirror surface that specularly and interferometrically reflects light in at least one wavelength band, wherein one or more of the elements are configured to be selectably reflective.
- 10 2. The device of Claim 1, wherein one or more of the selectably reflective elements is configured to selectably be in one of first and second optical states.
3. The device of Claim 2, wherein the first optical state differs from second optical state in at least one of reflectivity and color so that the contrast between the two
15 states is perceptible to a viewer.
4. The device of Claim 1, wherein one or more of the elements are configured to be in a single non-selectable state of being highly reflective.
- 20 5. The device of Claim 4, wherein at least a portion of the area between the elements configured to be in a single non-selectable state of high reflectivity is configured to be specularly reflective.
6. The device of Claim 1, wherein at least a portion of the reflective surface of
25 the mirror comprises a highly reflective layer configured to reflect non-interferometrically.
7. The device of Claim 1, wherein at least one of the reflective elements of the array is formed in a shape corresponding to at least a portion of the information to be displayed by the at least one element.
- 30 8. The device of Claim 1, wherein at least a portion of the area between the elements of the array is configured to be specularly reflective.
9. The device of Claim 1, wherein at least a first portion of the array comprises
35 adjacent elements configured to be perceived by a viewer as displaying an optical characteristic different from an optical characteristic displayed by another portion of the array.

10. The device of Claim 1, wherein at least at least one of the selectably reflective elements is configured to be perceived as:

5 displaying information; and
being highly reflective.

11. The device of Claim 1, wherein the optical characteristics of one or more of the elements is based upon at least one of input from an external source, user input, and programming.

10

12. The device of Claim 1, wherein one or more of the elements are configured to be reflective across the visible spectrum.

13. The device of Claim 1, wherein one or more of the elements are configured to reflect light substantially of a different wavelength band than one or more other elements.

15

14. The device of Claim 1, further comprising:
a processor that is in electrical communication with the array, the processor being
20 configured to process image data; and
a memory device in electrical communication with the processor.

15. The device of Claim 14, further comprising a driver circuit configured to send at least one signal to the array.

25

16. The device of Claim 15, further comprising a controller configured to send at least a portion of the image data to the driver circuit.

17. The device of Claim 14, further comprising an image source module
30 configured to send the image data to the processor.

18. The device of Claim 17, wherein the image source module comprises at least one of a receiver, transceiver, and transmitter.

19. The device of Claim 14, further comprising an input device configured to receive input data and to communicate the input data to the processor.

20. A device, comprising:

5

means for conducting light; and

means for specularly and interferometrically reflecting light in at least one wavelength band, wherein the specularly and interferometrically light reflecting means is arranged on the conducting means and at least a portion of the specularly interferometrically light reflecting means is configured to be selectively reflective.

10

21. The device of Claim 20, wherein the conducting means comprises a substrate.

22. The device of Claim 20 or 21, wherein the specularly and interferometrically reflecting means comprises an array of reflective elements forming at least a portion of a mirror surface.

23. The device of Claim 20, wherein at least a portion of the specularly and interferometrically reflecting means is configured to be in a single non-selectable state of being highly reflective.

20

24. The device of Claim 20, further comprising means for selecting the optical characteristics of a portion of the selectably and interferometrically reflecting means based upon at least one of input from an external source, user input, and programming..

25

25. The device of Claim 24, wherein the selecting means for selecting comprises a driving circuit.

26. The device of Claim 20, wherein a first portion of the selectably and interferometrically reflecting means is configured to reflect light substantially of a different wavelength band than a second portion of the selectably reflecting means.

30

27. A vehicle comprising:
a steering mechanism; and

a mirror configured to be positioned such that light coming from behind the vehicle is reflected to a location for an operator to see when the operator is positioned to use the steering mechanism, the mirror comprising:

a substrate; and

5 an array of reflective elements arranged on the substrate to form a mirror surface that specularly and interferometrically reflects light in at least one wavelength band.

10 28. The vehicle of Claim 27, wherein the mirror is configured to display warnings, radio information, vehicle status data, route information, location data, or environmental information.

15 29. The vehicle of Claim 27, wherein one or more of the reflective elements is configured to selectably be in one of first and second optical states.

30 30. The vehicle of Claim 27, wherein one or more of the reflective elements are configured to be in a single non-selectable state of being highly reflective.

20 31. The vehicle of Claim 27, wherein at least a portion of the reflective surface of the mirror comprises a highly reflective layer configured to reflect non-interferometrically.

25 32. The vehicle of Claim 27, wherein at least one of the reflective elements is formed in a shape corresponding to at least a portion of the information to be displayed by the at least one element.

30 33. The vehicle of Claim 27, wherein the optical characteristics of one or more of the reflective elements is based upon at least one of input from an external source, user input, and programming.

35 34. The vehicle of Claim 27, further comprising:
a processor that is in electrical communication with the array, the processor being configured to process image data; and
a memory device in electrical communication with the processor.

35 35. The vehicle of Claim 34, further comprising a driver circuit configured to send at least one signal to the array.

36. The vehicle of Claim 35, further comprising a controller configured to send at least a portion of the image data to the driver circuit.

5 37. The vehicle of Claim 34, further comprising an image source module configured to send the image data to the processor.

38. The vehicle of Claim 37, wherein the image source module comprises at least one of a receiver, transceiver, and transmitter.

10

39. The vehicle of Claim 34, further comprising an input device configured to receive input data and to communicate the input data to the processor.

40. A vehicle comprising:

15

means for steering; and

means for reflecting light from behind the vehicle to a location for an operator to see when the operator is positioned to use the steering means, the reflecting means comprising:

means for conducting light; and

20

means for specularly and interferometrically reflecting light in at least one wavelength band, wherein the specularly interferometrically light reflecting means is arranged on the conducting means and at least a portion of the specularly interferometrically light reflecting means is configured to be selectively reflective, wherein the specularly and interferometrically light reflecting means is arranged on the conducting means and at least a portion of the specularly interferometrically light reflecting means is configured to be selectively reflective.

25

41. The vehicle of Claim 40, wherein the steering means comprises a steering mechanism.

30

42. The vehicle of Claim 40 or 41, wherein the means for reflecting light from behind the vehicle comprises a mirror.

43. The Vehicle of Claim 40, 41, or 42 wherein the conducting means comprises a substrate.

44. The vehicle of Claim 40, 41, 42, or 43, wherein the specularly and interferometrically reflecting means comprises an array of reflective elements forming at least a portion of a mirror surface.

45. A device comprising:
a mirror comprising:
10 a substrate; and
an array of reflective elements arranged on the substrate to form a mirror surface that specularly and interferometrically reflects light in at least one wavelength band; and
a mount configured to attach the mirror to a vehicle, a wall, an article of
15 furniture, an ornamental object, an article of clothing, or a person.

46. The device of Claim 45, wherein one or more of the elements are configured to be in a single non-selectable state of being highly reflective.

20 47. The device of Claim 45, wherein at least a first portion of the array comprises adjacent elements configured to be perceived by a viewer as displaying an optical characteristic different from an optical characteristic displayed by another portion of the array.

25 48. The device of Claim 45, wherein optical characteristics of one or more of the elements is based upon at least one of input from an external source, user input, and programming.

49. The device of Claim 45, wherein one or more of the elements are configured to
30 be reflective across the visible spectrum.

50. The device of Claim 45, wherein one or more of the elements are configured to reflect light substantially of a different wavelength band than one or more other elements.

35 51. The device of Claim 45, further comprising:

a processor that is in electrical communication with the array, the processor being configured to process image data; and

a memory device in electrical communication with the processor.

5 52. The device of Claim 51, further comprising a driver circuit configured to send at least one signal to the array.

 53. The device of Claim 52, further comprising a controller configured to send at least a portion of the image data to the driver circuit.

10

 54. The device of Claim 51, further comprising an image source module configured to send the image data to the processor.

 55. The device of Claim 54, wherein the image source module comprises at least one of a receiver, transceiver, and transmitter.

15

 56. The device of Claim 51, further comprising an input device configured to receive input data and to communicate the input data to the processor.

20

 57. A device comprising:

 means for reflecting light comprising:

 means for conducting light; and

 means for specularly and interferometrically reflecting light in at least one wavelength band; and

25

 means for attaching the reflecting means to a vehicle, a wall, an article of furniture, an ornamental object, an article of clothing, or a person.

 58. The device of Claim 57, wherein the reflecting means comprises a mirror

30

 59. The device of Claim 57 or 58, wherein the conducting means comprises a substrate.

60. The device of Claim 57, 58, or 59, wherein the specularly and interferometrically reflecting means comprises an array of reflective elements forming at least a portion of a mirror surface.
- 5 61. The device of Claim 57, 58, 59, or 60, wherein the attaching means comprises a mount.
62. A method of using a display device comprising:
establishing a communication link between the device and an information
10 source, the device comprising:
a mirror comprising elements configured to selectably, specularly and interferometrically reflect light; and
a mount configured to attach the mirror to a vehicle, a wall, an article of furniture, an ornamental object, an article of clothing, or a person;
15 receiving information from the source; and
displaying the information on the array.
63. The method of 62, wherein displaying the information comprises displaying the information based upon at least one of input from an external source, user input, and
20 programming.
64. The method of Claim 62, wherein displaying the information comprises selecting states for the elements, wherein the elements are configured to selectably be in one of first and second optical states.
- 25 65. The method of Claim 64, wherein at least one of the elements for which a state is selected has a shape corresponding to at least a portion of the information to be displayed by the at least one element.
- 30 66. The method of Claim 62, wherein displaying the information comprises:
displaying a first optical characteristic on a first portion of the array; and
displaying a second optical characteristic on a second portion of the array.
- 35 67. A method of manufacturing a device, the method comprising:
forming a substrate; and

forming an array of reflective elements arranged on the substrate so as to produce a mirror surface that specularly and interferometrically reflects light in at least one wavelength band, wherein one or more of the elements are configured to be selectably reflective.

5

68. The method of Claim 67, wherein forming the array comprises configuring the elements to be selectably reflective based upon at least one of input from an external source, programming, and user input.

10

69. The method of Claim 67, wherein forming the array comprises configuring one or more of the elements to be reflective across the visible spectrum.

15

70. The method of Claim 67, wherein forming the array comprises configuring one or more of the elements to reflect light substantially of a different wavelength band than one or more other elements.

15

71. A device manufactured by the method of Claim 67

20

1/8

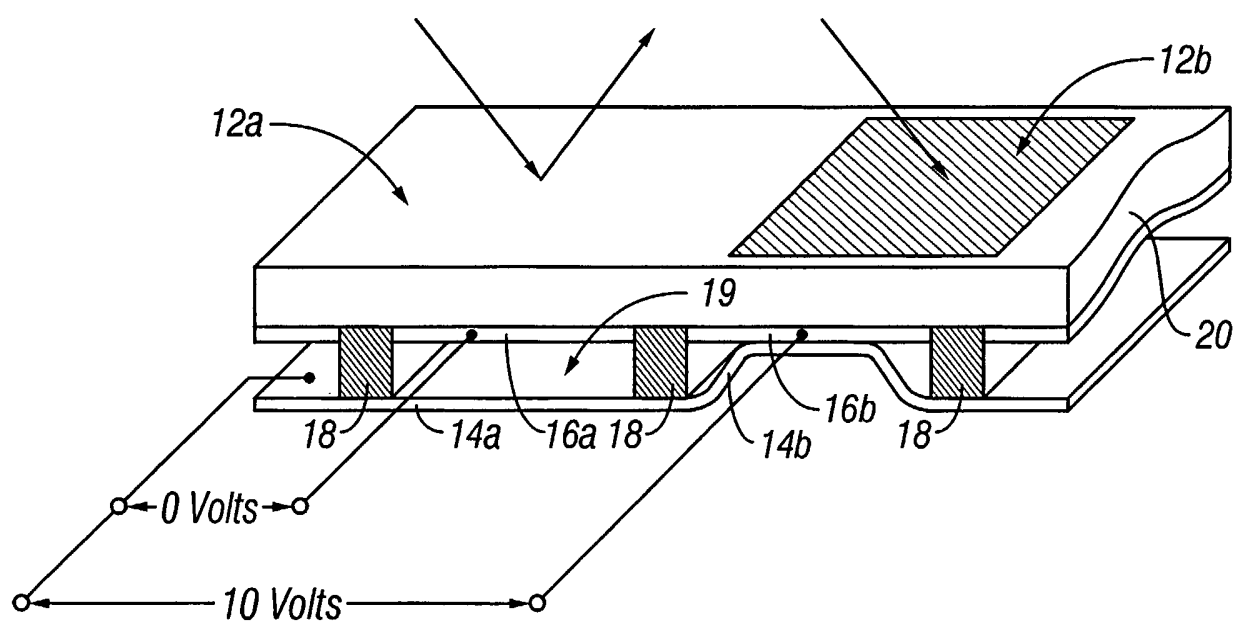


FIG. 1

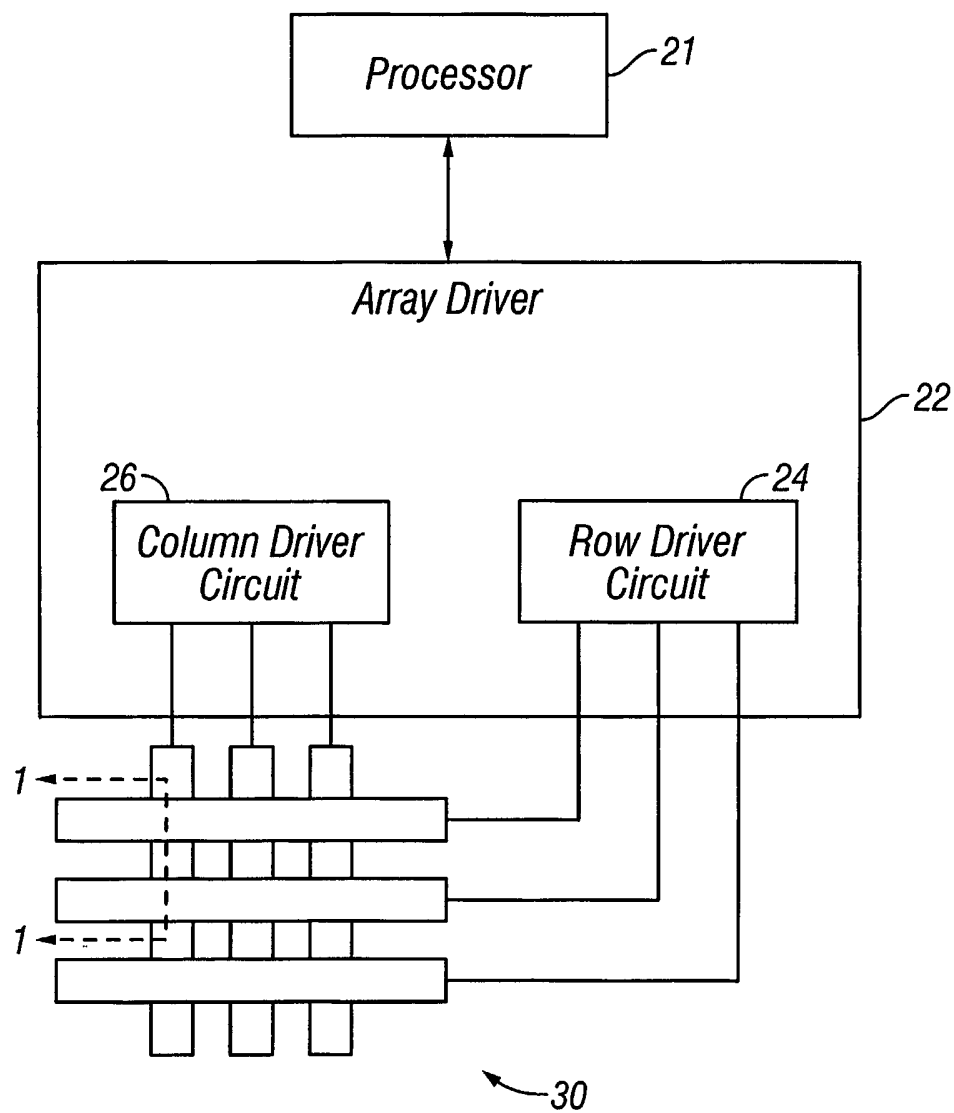


FIG. 2

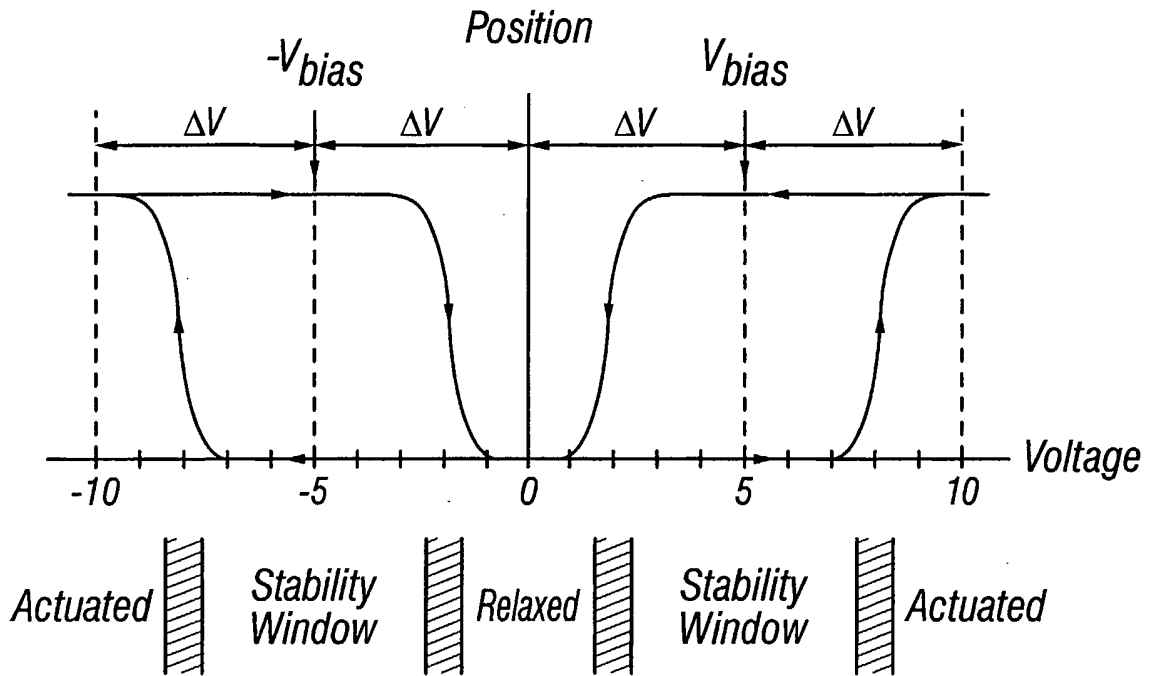


FIG. 3

		Column Output Signals	
		$+V_{bias}$	$-V_{bias}$
Row Output Signals	0	Stable	Stable
	$+\Delta V$	Relax	Actuate
	$-\Delta V$	Actuate	Relax

FIG. 4

4/8

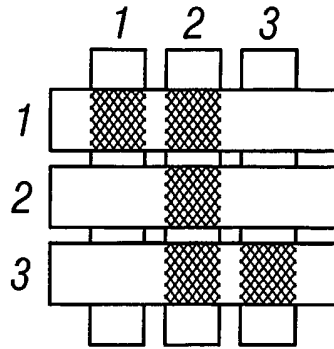


FIG. 5A

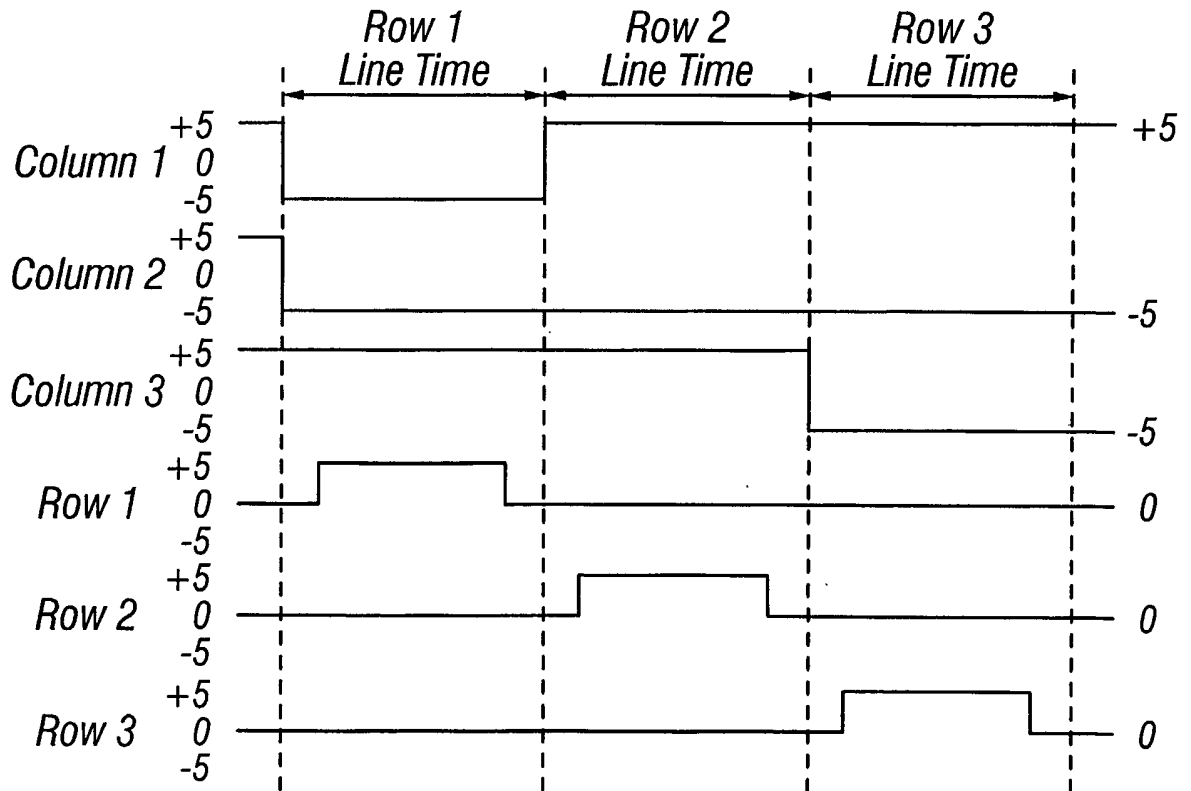


FIG. 5B

5/8

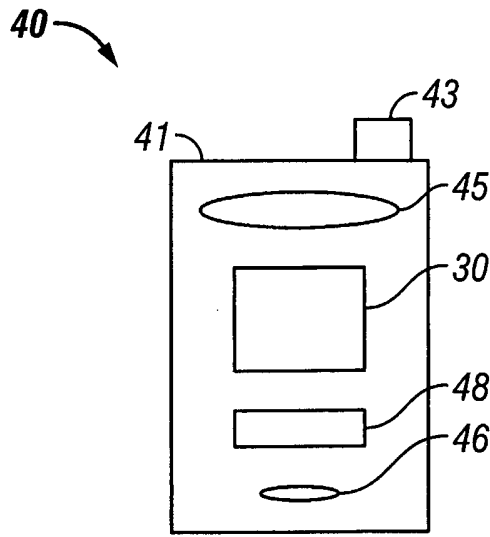


FIG. 6A

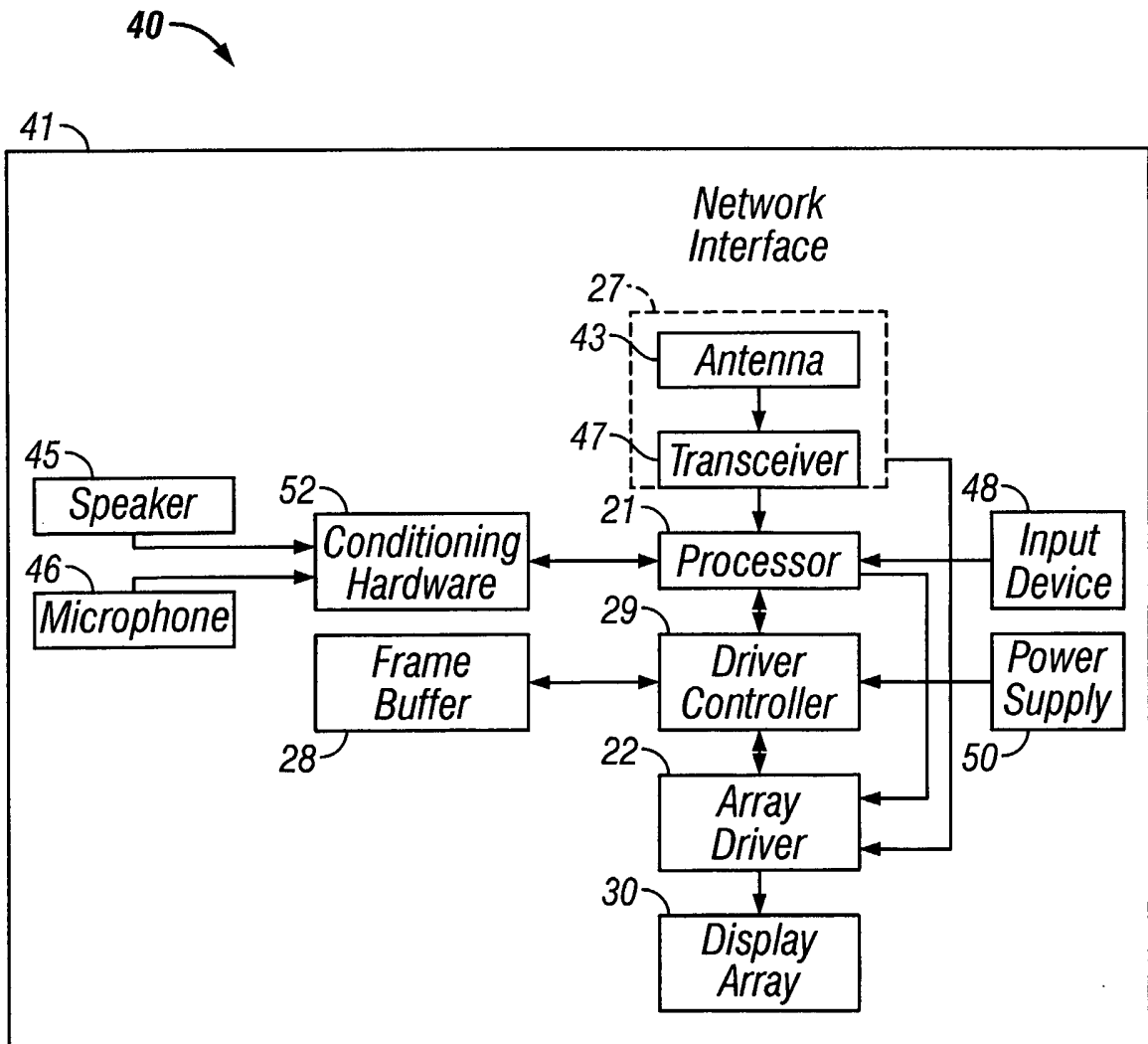


FIG. 6B

6/8

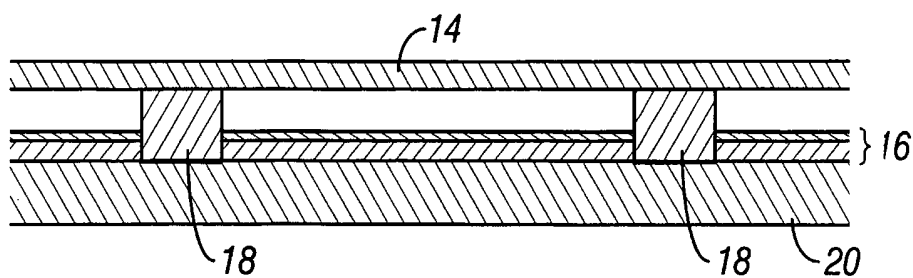


FIG. 7A

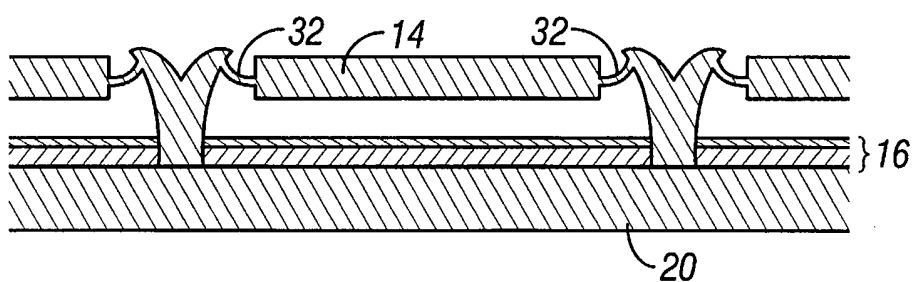


FIG. 7B

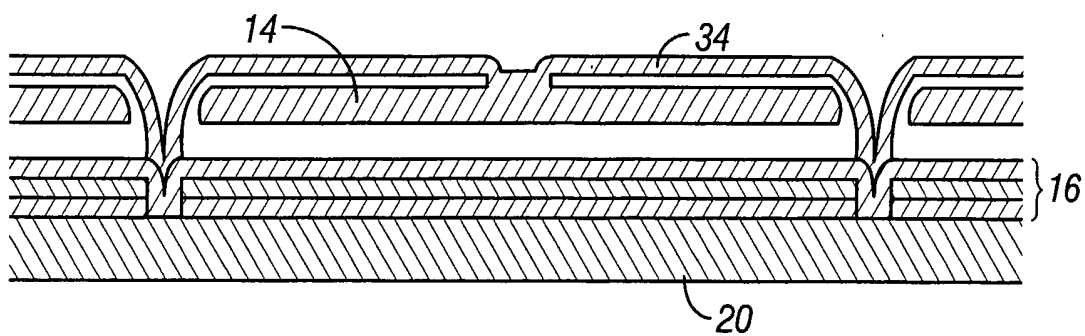


FIG. 7C

7/8

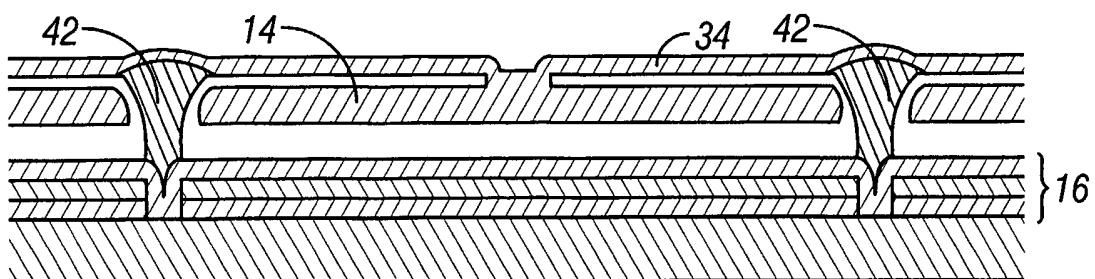


FIG. 7D

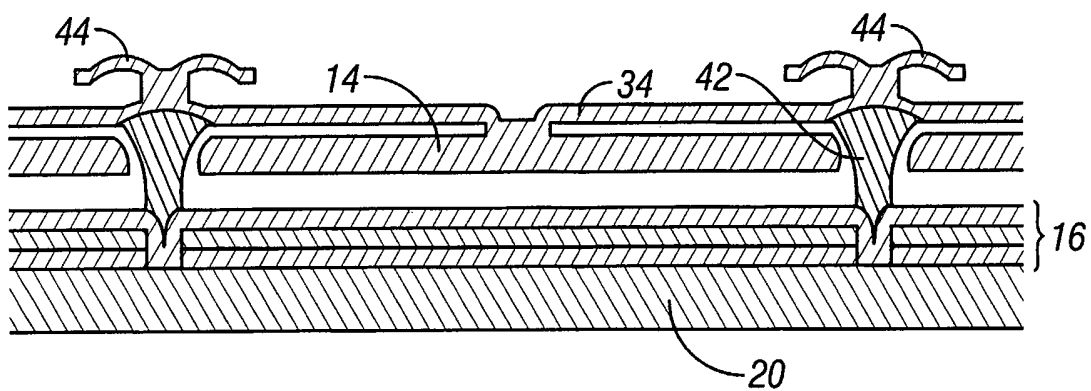


FIG. 7E

8/8

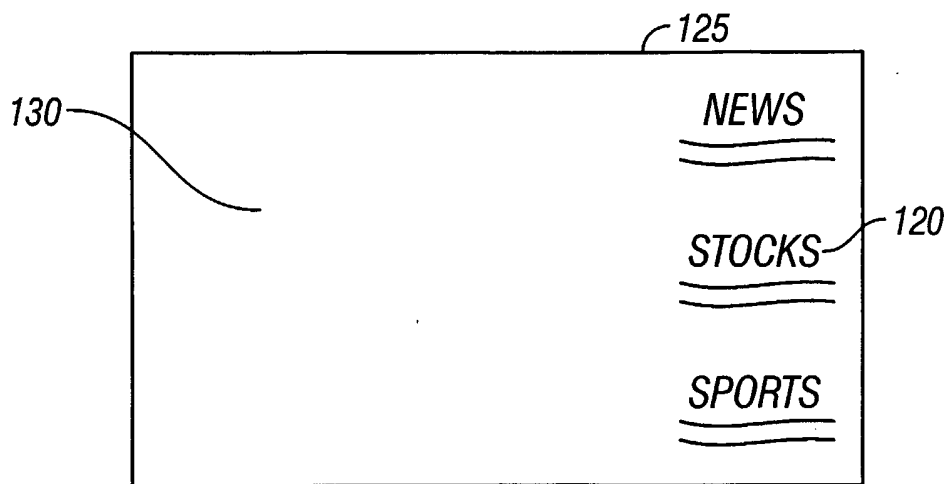


FIG. 8

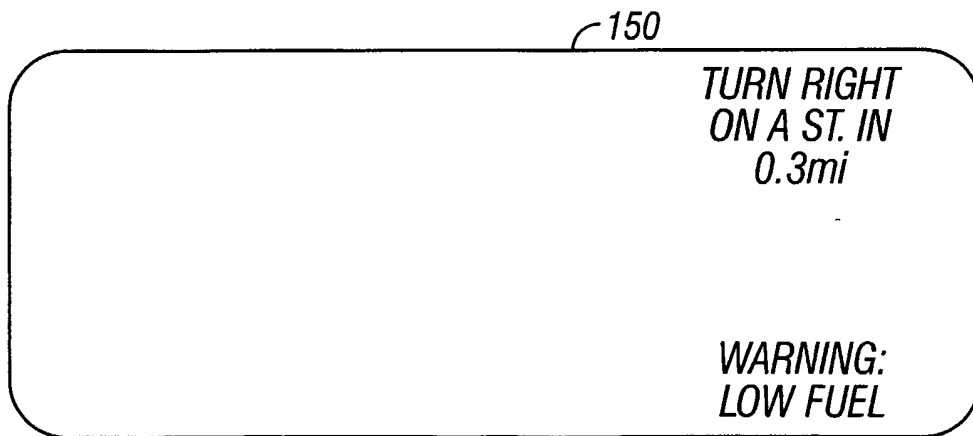


FIG. 9

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US2005/030418

A. CLASSIFICATION OF SUBJECT MATTER
G02B26/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G02B B60R A44C G09F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, INSPEC, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2002/126364 A1 (MILES MARK W) 12 September 2002 (2002-09-12) paragraph '0122! - paragraph '0128!; figures 1-4 paragraph '0164! - paragraph '0166! paragraph '0173!; figure 24 paragraph '0175!; figure 26c paragraph '0179!; figure 30 paragraph '0184!; figure 34	1-27, 29-71
X	PATENT ABSTRACTS OF JAPAN vol. 2003, no. 02, 5 February 2003 (2003-02-05) -& JP 2002 287047 A (SEIKO EPSON CORP), 3 October 2002 (2002-10-03) abstract; figure 7	1-71

Further documents are listed in the continuation of box C. Patent family members are listed in annex.

* Special categories of cited documents :

A document defining the general state of the art which is not considered to be of particular relevance	*T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
E earlier document but published on or after the international filing date	*X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
L document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	*Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
O document referring to an oral disclosure, use, exhibition or other means	*&* document member of the same patent family
P document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search 22 December 2005	Date of mailing of the international search report 03/01/2006
---	--

Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Authorized officer Ciarrocca, M
--	--

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US2005/030418

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 03/056367 A (NOKIA CORPORATION; KIMMEL, JYRKI) 10 July 2003 (2003-07-10) abstract; figure 4 page 13, line 25 - line 32 -----	1-71
X	US 2003/072070 A1 (MILES MARK W) 17 April 2003 (2003-04-17) claim 22 -----	1-71
A	US 6 412 962 B1 (KASPAR RUDOLF) 2 July 2002 (2002-07-02) column 1, line 59 - line 60 column 2, line 14 - line 15 column 2, line 26 - line 28 column 2, line 44 - line 46 figure 1 -----	4-6,8, 23,27, 29-31, 40-45, 57,61,62
A	US 5 530 240 A (LARSON ET AL) 25 June 1996 (1996-06-25) column 3, line 50 - column 4, line 8; figures 1,2 -----	4-6,8, 23,27, 29-31, 40-45, 57,61,62

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2005/030418

Box II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. Claims Nos.: 28
because they relate to subject matter not required to be searched by this Authority, namely:
Rule 39.1(v) PCT - Presentation of information
2. Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
3. Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
2. As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
4. No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- The additional search fees were accompanied by the applicant's protest.
- No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/JP2005/030418

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2002126364 A1	12-09-2002	NONE	
JP 2002287047 A	03-10-2002	NONE	
WO 03056367 A	10-07-2003	AU 2002225061 A1	15-07-2003
US 2003072070 A1	17-04-2003	NONE	
US 6412962 B1	02-07-2002	DE 19933879 A1 EP 1070637 A2	15-02-2001 24-01-2001
US 5530240 A	25-06-1996	NONE	